A REVIEW OF NASA'S PLANS FOR THE INTERNATIONAL SPACE STATION AND FUTURE ACTIVITIES IN LOW EARTH ORBIT

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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C O N T E N T S

July 10, 2019

A REVIEW OF NASA'S PLANS FOR THE INTERNATIONAL SPACE STATION AND FUTURE ACTIVITIES IN LOW EARTH ORBIT

WEDNESDAY, JULY 10, 2019

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

The Subcommittee met, pursuant to notice, at 10:03 a.m., in room 2318 of the Rayburn House Office Building, Hon. Kendra Horn [Chairwoman of the Subcommittee] presiding.

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

HEARING CHARTER

"A Review of NASA's Plans for the International Space Station and Future Activities in Low Earth Orbit"

July 10, 2019
10:00 A.M.
2318 Rayburn House Office Building

PURPOSE

The purpose of the hearing is to examine NASA's plans for the International Space Station and future activities in low Earth orbit, and associated issues.

WITNESSES

- **Mr. William Gerstenmaier,** Associate Administrator, Human Exploration and Operations Mission Directorate, National Aeronautics and Space Administration
- **The Honorable Paul Martin,** Inspector General, National Aeronautics and Space Administration
- **Mr. Eric Stallmer,** President, Commercial Spaceflight Federation
- **Professor Joanne Irene Gabrynowicz,** Emerita, University of Mississippi, Editor-in-Chief, Emerita, Journal of Space Law

OVERARCHING QUESTIONS

- *What are the key challenges for the current and near-term operations and utilization of the International Space Station?*
- *What are the options for transition of the International Space Station and its activities to an alternative model of operation or to a commercial space station, and to what extent is NASA exploring those options?*
- *What are the key questions and issues regarding NASA's low Earth orbit development plan?*
- *What are the implications of NASA's plans for the International Space Station and low Earth orbit for enabling the human exploration of deep space?*

BACKGROUND

The International Space Station (ISS) is the world's only crewed orbiting space laboratory. The U.S.-led ISS partnership is governed by an intergovernmental agreement and includes Japan,

Canada, Russia, and several countries in the European Space Agency. The first module of the ISS, the Russian-built, but NASA-owned, Functional Cargo Block node (Zarya), was launched in 1998 to provide power, storage, propulsion, and station keeping for the ISS. That same year, the U.S. launched the Unity module, providing environmental control, life support, and docking ports allowing other modules to be added. Russia launched the Zveda Service Module in 2000, which provided crew living quarters. Human occupation of the ISS began in 2000. Crew have occupied the ISS continuously since then, allowing the U.S. and Russia to acquire nearly 20 years of continuous human operations in low Earth orbit (LEO). Other ISS partners, including Europe and Japan, have launched additional modules and facilities to support the ISS and to carry out research. Assembly of the ISS was completed in July 2011.

Since 2011, NASA's focus has been on utilization of the ISS for research and technology demonstrations. Congress designated the U.S. segment of the ISS as a national laboratory in the NASA Authorization Act of 2005.[1] The ISS National Laboratory has access to 50 percent of ISS resources (e.g., crew time, power, and cargo transportation) and encourages utilization of the ISS by private entities and other Federal government agencies. Congress authorized extensions of ISS operations in 2010 and 2017 through at least 2024. U.S. taxpayers have invested approximately $87 billion in the development, assembly, and operations of the ISS.[2]

International Space Station Transition Report

The NASA Transition Authorization Act of 2017 directed NASA to work with its partners and stakeholders to *"develop a plan to transition in a step-wise approach from the current regime that relies heavily on NASA sponsorship to a regime where NASA could be one of many customers of a low Earth orbit non-governmental human space flight enterprise."*[3]

In March 2018, NASA issued an International Space Station Transition report detailing its plans for low-Earth orbit beyond 2024, including the potential for ending direct U.S. financial support for the ISS in 2025 and for transitioning NASA's low-Earth orbit activities to commercial platforms.[4] The report states that the ISS is expected to be structurally sound until at least 2028.

The ISS Transition report states that *"[a]n on-orbit platform like the ISS is necessary to mitigate 22 of the 33 human health risks in the portfolio identified by NASA's Human Research Program in support of current and future deep space missions. NASA is also using the ISS as a testbed to fill critical gaps in technologies that will be needed for long-duration deep space missions."*

The Transition report further states that "*NASA's vision for LEO is a sustained commercial LEO human space flight marketplace where NASA is one of many customers*." That vision is one in which privately-owned or operated platforms and associated crew and cargo transportation capabilities to low Earth orbit are supported by commercial revenue. The ISS Transition report

[1] Pub. L. No. 109-155, "National Aeronautics and Space Administration Authorization Act of 2005," December 30, 2005.
[2] NASA OIG, "Nasa's Management of the Center for the Advancement of Science in Space", IG-18-010, January 11, 2018.
[3] Pub. L. No. 115-10, "National Aeronautics and Space Administration Transition Authorization Act of 2017," March 21, 2017.
[4] NASA, "International Space Station Transition Report", March 30, 2018.

notes that NASA's Commercial Resupply Services, Commercial Crew Program, and the ISS National Laboratory are helping enable this vision.

The report laid out the following principles to ensure access to LEO:

- *"Continuity among NASA's LEO, deep space exploration, and development and research activities and missions toward expanding human presence into the solar system;*
- *Expanding U.S. human spaceflight leadership in LEO and deep space exploration, including continuity of the relationship with our current ISS international partners;*
- *Increase platform options in LEO to enable more ISS transition pathways, security through redundant capabilities, and industrial capability that can support NASA's deep space exploration needs;*
- *Spur vibrant commercial activity in LEO;*
- *Maintaining critical human spaceflight knowledge and expertise within the Government in areas such as astronaut health and performance, life support, safety, and critical operational ground and crew experience;*
- *Continuing to return benefits to humanity through Government-sponsored basic and applied on-orbit research;*
- *Continuing Government-sponsored access to LEO research facilities that enable other Government agencies, academia, and private industry to increase U.S. industrial competitiveness and provide goods and services to U.S. citizens; and*
- *Continuing to reduce the Government's long-term costs through private industry partnerships and competitive acquisition strategies."*

The plan identified that the options for the eventual future of the ISS include *"transitioning the operations of the ISS platform to private industry, augmenting it with privately developed modules, combining portions of the ISS with a new private platform, or deploying a new free-flying platform and de-orbiting the ISS."*

In trying to project the future landscape of LEO, NASA's ISS Transition Plan notes a low degree of certainty that private industry will have sufficient capabilities *"to satisfy NASA's needs and requirements"* and *"whether or not a viable commercial market [will have] matured in LEO that is not dependent on Government support."*

In June 2019, as part of its plans for transition of the ISS and its activities to low Earth orbit market in which NASA is one of many customers, NASA released three documents:

- NASA Plan for Commercial LEO Development "*to achieve a robust low-Earth orbit economy from which NASA can purchase services as one of many customers*";
- NASA Interim Directive: Use of International Space Station (ISS) for Commercial and Marketing Activities, which describes the activities that will be allowed by private entities on the ISS; and

- A pricing policy, which sets the cost for ISS resource utilization, including, for example, power, trash disposal, crew time, stowage, and crew supplies, by private companies.

FY 2020 President's Budget Request for LEO and Spaceflight Operations

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
International Space Station	1493.0	–	**1458.2**	1448.5	1449.4	1352.6	1315.7
Space Transportation	2345.8	–	**1828.6**	1854.1	1814.5	1746.2	1727.2
Space and Flight Support (SFS)	910.3	–	**848.9**	891.9	905.7	911.8	914.5
Commercial LEO Development	0.0	–	**150.0**	175.0	200.0	225.0	225.0
Total Budget	**4749.2**	**4639.1**	**4285.7**	**4369.5**	**4369.5**	**4235.5**	**4182.3**
Change from FY 2019			**-353.4**				
Percentage change from FY 2019			**-7.6%**				

In the Administration's Fiscal Year (FY) 2019 budget request, NASA proposed *"to end direct Federal funding for the ISS in 2025."* The FY 2020 budget request no longer specifies a date, though it continues to support the goal where NASA is one of many customers of a commercial LEO marketplace. The Administration's FY 2020 budget proposal requests nearly $4.3 billion for LEO and Spaceflight Operations. The budget lines for the International Space Station and Space Transportation comprise the proposed budget ISS-related operations, maintenance, research, and crew and cargo transportation.

- **International Space Station** includes the Systems Operations and Maintenance and ISS Research, including funding for the ISS National Lab and NASA's research programs.
- **Space Transportation** contains the cost of both the Commercial Crew Program and the Crew and Cargo Program to the ISS and includes crew seats bought from Russian Roscosmos State Corporation.
- The **Space and Flight Support (SFS)** budget line funds Space Communications Networks and Support.
- The **Commercial LEO Development** line funds NASA's efforts to transition its presence in LEO to that of one customer among many in commercially owned and operated regime.

NASA Inspector General Report on the Management of Utilization of the ISS

In July 2018, NASA's Office of the Inspector General (OIG) released the results of an audit of the ISS to assess NASA's progress in maximizing the utilization of the ISS.[5] The audit focused on NASA's use of the ISS to accomplish its human exploration objectives and evaluated options and challenges associated with transitioning the ISS to commercial operation. The audit found that *"each year the Station remains operational costs NASA roughly half of the Agency's annual human spaceflight budget--an outlay that may limit funding for development of systems needed to visit the Moon and other destinations beyond low Earth orbit."*

[5] NASA OIG, "Nasa's Management and Utilization of the International Space Station", IG-18-021, July 30, 2018.

In order to ensure that NASA is positioned to complete its critical human health research and technology demonstration projects and to provide a safe transition and disposition of the ISS, the report had the following recommendations:

1. *"To the extent practicable, establish plans for additional one-year missions to the ISS;*
2. *Ensure development of a contingency plan for each human health risk not scheduled to be mitigated prior to 2024, such as identification of alternate testing platforms, impact of health risks for astronauts, and impact to the mitigation schedule;*
3. *Develop a contingency plan for each exploration-enabling technology demonstration not scheduled to be fully tested by 2024, such as identification of alternate testing platforms, impact to technical risk of exploration systems, and impact to the technology demonstration schedule;*
4. *Complete all end-of-mission critical systems and open work related to nominal and contingency deorbit operations;*
5. *Develop options for obtaining supplemental emergency deorbit propellant support from U.S. commercial vehicles."*

NASA agreed with the recommendations and described planned corrective actions to the OIG.

NASA Inspector General reports on the Management of Non-NASA Research on the ISS

Pursuant to the NASA Authorization Act of 2010, in 2011, NASA awarded a 10-year Cooperative Research and Development Agreement (CRADA) to the Center for the Advancement of Science in Space (CASIS), a non-profit organization, to manage non-NASA research on the ISS.[6] In 2017, NASA extended the CRADA to September 2024. The agreement is worth a total of $196 million over the 2011-2024 period.

According to the FY 2018 ISS National Lab Annual Report *"185 new-to-space users in the areas of life sciences, physical sciences, technology development, and remote sensing have been awarded the opportunity to conduct investigations onboard the ISS National Lab. In total, 241 projects have been directly sourced by the ISS National Lab (135 of which represent commercial users), and dozens of other projects sourced by commercial partners and education programs have also been added to the ISS National Lab manifest."*[7] Additionally, CASIS attracted more than $150 million in non-NASA funding from FY 2012 through FY 2018.

NASA OIG audits have found that CASIS has experienced challenges in expanding non-NASA users of the ISS. A 2018 OIG report[2] found that CASIS *"has underperformed on tasks important to achieving NASA's goal of building a commercial space economy in low Earth orbit."* As a result, *"CASIS has not fully met a majority of the goals and expectations set out by NASA. Of the nine performance categories we assessed, CASIS met expectations in only two: research pathways and science, technology, engineering, and mathematics (STEM) education."* CASIS also *"failed to ensure a balanced portfolio of research projects from theoretical to basic to*

[6] Pub. L. No. 111-267, "National Aeronautics and Space Administration Authorization Act of 2010," October 11, 2010.
[7] "ISS National Lab: FY18 Annual Report", https://ar2018.issnationallab.org/

applied research as required by the cooperative agreement. CASIS failed to meet expectations in ... utilization of crew time for National Lab research and outreach."

Additionally, the OIG found that *"NASA failed to actively oversee CASIS's technical performance and ... has not developed an overall strategy identifying the achievements or outcomes expected from CASIS through the end of its cooperative agreement nor has the Agency provided guidance or set expectations for CASIS's performance."*

The OIG made seven recommendations to the Associate Administrator for Human Exploration and Operations (HEO) to improve the effectiveness of the CRADA with CASIS. They also recommended that the Associate Administrator of HEO develop a performance plan for CASIS, evaluate them semiannually, and ensure that the plans include metrics and targets for each category. NASA concurred or partially concurred on all recommendations, but took exception with the OIG's methodology to assess CASIS's performance and with the OIG's assessment being partially based off CASIS's ability to attract external funding. While NASA concurred with the OIG's recommendation to "establish goals for CASIS raising non-NASA funds to offset operating expenses", the OIG says that NASA's comments are unresponsive. Therefore, this recommendation remained unresolved.

Commercialization of the ISS and LEO

In 2017, the Institute for Defense Analyses Science and Technology Policy Institute (STPI) published a NASA-sponsored study, "Market Analysis of a Privately Owned and Operated Space Station".[8] In the report, STPI identified 21 activities that could generate revenue on a commercial space station in LEO. These activities fell into five categories:

- *"Human habitat or destination for private space flight participants or government astronauts*
- *Activities supporting the satellite sector, especially on-orbit assembly of satellites*
- *Manufacturing products and services for use in space and on Earth, specifically high-grade silicon carbide and exotic fiber optic cable*
- *Research and development (R&D), testing, and Earth observation*
- *Media, advertising, and education"*

The report found that *"[t]he low estimate for total annualized revenues from activities conducted on a space station is $528 million; and the high estimate is $1,255 million"*, but with the caveat that "*[t]hese revenues are highly uncertain and based on extrapolations of current views since they are for revenues 10 years from 2016.*" However, according to the report, "*Venture capitalists whom [STPI] interviewed noted that the projections of revenues and costs are so uncertain that they would have no interest in financing a space station until projected revenues from these activities show signs of materializing.*"

[8] Institute for Defense Analyses Science and Technology Policy Institute, "Market Analysis of a Privately Owned and Operated Space Station", March 2017.

STPI found that *"it is unlikely that a commercially owned and operated space station will be economically viable by 2025."* It then identified three ways that the federal government might participate in an at least partially commercialized space station:

- **Public-private partnership:** The federal government acts as an investor to a space station owner and operator, which may or may not be a commercial entity.
- **Advance purchase or lease agreements:** The federal government purchases services before the station is fully ready at prices below the future market rate.
- **Direct purchases:** The federal government purchases services after the space station is ready at market rate.

Spacesuits

NASA astronauts use spacesuits, officially called Extravehicular Mobility Units (EMUs), to carry out space walks. The EMUs currently in use to support U.S. crew on ISS space walks were developed more than 40 years ago and are well past their 15-year design life.[9]

In 2017, the NASA OIG conducted an audit of NASA's management of current spacesuits and development of the next generation of spacesuits.[9] As of 2017, NASA had spent more than $200 million on developing new spacesuits despite remaining *"years away from having a flight-ready spacesuit capable of replacing the EMU or suitable for use on future exploration missions."* The OIG found that *"only 11 of the 18 original EMU Primary Life Support System units – a backpack-like structure that performs a variety of functions required to keep an astronaut alive during a spacewalk – are still in use, raising concerns that the inventory may not be adequate to last through the planned retirement of the ISS. Given these issues, NASA will be challenged to continue to support ISS needs with the current fleet of EMUs through 2024, a challenge that will escalate significantly if Station operations are extended to 2028."* A major impediment to NASA's spacesuit development that is cited in the OIG report is the lack of a formal plan and specific destinations for future NASA missions. Different mission profiles (e.g., low Earth orbit, the Moon, and Mars) require different spacesuits.

The OIG recommended that NASA:

"(1) develop and implement a formal plan for design, production, and testing of the next-generation extravehicular activity (EVA) spacesuits in accordance with the exploration goals of the Agency, crew needs, and the planned retirement of the ISS in 2024;
(2) conduct a trade study comparing the cost of maintaining the current EMU spacesuit and developing and testing a next-generation spacesuit; and
(3) apply lessons learned from operations of existing EVA and launch, entry, and abort spacesuit systems to the design of future exploration spacesuit systems to ensure mitigation of non-life-threatening health risks or other injuries that could impair mission objectives."

NASA concurred with the IG's recommendations and described corrective actions it would take to the OIG.

[9] NASA OIG, "Nasa's Management and Development of Spacesuits", IG-17-018, April 26, 2017.

Chairwoman HORN. This hearing will come to order.

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

Good morning, everyone, and welcome to our panel of distinguished witnesses. I appreciate you being here, and I look forward to our discussion today.

And before I begin with my opening statement, I do want to acknowledge the panel and say thank you for your testimony, but to express, just to be clear, that we didn't receive the testimony from NASA (National Aeronautics and Space Administration) and from Mr. Stallmer until late yesterday evening, which, in the future—I understand we all have a lot going on, but it really makes it easier for us to—or helpful for us to prepare for this if we're able to review the testimony further in advance. So I'll just make a request to all of you that hopefully we can expedite that more in the future so we're not cramming the night before. And as a lifelong procrastinator, I understand, but if you all could help us out with that, it would be very, very much appreciated because we've got some very important issues to tackle here today.

So to begin, beginning our hearing on "A Review of NASA's Plans for the International Space Station and the Future of Activities in Low Earth Orbit."

For nearly 20 years, the International Space Station (ISS) has expanded our understanding of what it means to live and work in space. Our investment in the ISS has enabled scientific research, development, and technology demonstrations from DNA sequencing to advanced technology for water purification worldwide, and much more. More importantly, we haven't done this alone. The ISS is a shining example of international cooperation, as well as innovative relationships for transportation services and expanded partner use of the ISS National Laboratory.

I want to acknowledge the NASA, international, and commercial partners who continue to ensure the safe and productive operation of the ISS. As the Aerospace Safety Advisory Panel noted, the ISS program deals with "the challenges of operating in the space environment in such a way to make it seem normal business." That's quite an accomplishment. However, there is nothing normal about operating in human spaceflight. I know you all are aware of that. And aging spacesuits and delays in the availability of U.S. commercial crew transportation services are just a few of the risks that need to be addressed looking forward at ISS.

In addition to dealing with these and other near-term challenges involved in sustaining the ISS, we also need to look at what lies ahead. While NASA has affirmed the integrity of the ISS structure through at least 2028, the lifetime of the laboratory is finite. What will come next? How will NASA and the Nation ensure that the objectives for ISS are sustained following the end of ISS operations, whenever that occurs? And what are the steps that are needed to occur such that we can have confidence in avoiding the gap between the ISS and a future low-Earth orbit (LEO) facility?

NASA's International Space Station Transition Report identifies options, including "transitioning the ISS platform to private industry, augmenting it with privately developed modules, combining portions of the ISS with a new private platform, or deploying a new

free-flying platform and deorbiting the ISS." I'm looking forward to learning more about these and other approaches because when and how we transition NASA's activities in low-Earth orbit from the ISS to an alternative platform or operating module is critical.

NASA has made clear its plans to transition from a government-owned and operated ISS "to a regime where NASA is one of many customers purchasing services from a LEO nongovernmental human space flight enterprise." This leaves a number of important and urgent questions that must be addressed: Who are those other customers? What does NASA's vision mean? In terms of NASA's commercial LEO development plan, what is the value proposition for the U.S. taxpayer? What level of investment is the private sector willing to make? Are NASA's planned investments in stimulating a commercial market demand and supply in LEO going to ensure a smooth transition and prevent a gap in NASA's ISS and low-Earth orbit activities?

The challenge here is in the balance of risk and reward. Under this plan, the commercial entities aren't the ones assuming the bulk of the risk; that falls to NASA. And yet the potential benefits to the government and taxpayer are uncertain at best.

The question then is what the U.S. taxpayer will be on the hook to fund. With no near-term market other than NASA, there is a real question about the cost to the taxpayer. NASA currently pays more than $3 billion a year to operate the International Space Station, a worthwhile investment. But on top of that, NASA's plans to fund the development of one or more commercial space stations, subsidize commercial activity on the ISS, and purchase services from future commercial space stations call into question whether this plan will save NASA money that it can apply to the moon program or if it will end up costing us more, not less, over the next decade. I look forward to getting more into the details.

NASA's plan may result in impacts to ISS research and technology development that is needed to enable human exploration of the moon, Mars, and more, which is why these issues are so critical. We also need to understand the potential implications of the plan for ISS and international partnership on which NASA intends to build its future human space exploration.

In closing, the low-Earth orbit and microgravity environment may in time support a commercially viable market. NASA has already taken initiatives to support commercial space through its development of commercial cargo services, commercial crew capabilities, and enabling research and development in low-Earth orbit. While NASA's interest in finding innovative approaches and stimulating a commercial market in low-Earth orbit are well-intended, we need to be responsible with the taxpayers' investment in the ISS as a national and international asset, and we need to carefully consider how we ensure a successful transition of our ISS activities going forward.

[The prepared statement of Chairwoman Horn follows:]

Good morning, and welcome to our distinguished panel of witnesses. I appreciate your being here, and I look forward to our discussion.

For nearly twenty years, the International Space Station has expanded our understanding of what it means to live and work in space. Our investments in the ISS have enabled scientific research, development, and technology demonstrations from DNA sequencing to advanced technology for water purification, now used worldwide.

More importantly, we haven't done it alone. The ISS is a shining example of international cooperation as well as innovative relationships for transportation services and expanded partner users of the ISS National laboratory.

I want to acknowledge the NASA, international, and commercial partners who continue to ensure the safe and productive operation of the ISS. As the Aerospace Safety Advisory Panel noted, the ISS Program deals with "the challenges of operating in the space environment in such a way as to make it seem 'normal' business."

However, there is nothing normal about human spaceflight. Aging spacesuits and delays in the availability of U.S. commercial crew transportation services are just a few of the risks that need to be addressed.

In addition to dealing with these and other near term challenges involved in sustaining the ISS, we must also look to what lies ahead.

While NASA has affirmed the integrity of the ISS structure through at least 2028, the lifetime of the laboratory is finite. What will come next? How will NASA and the nation ensure that the objectives for the ISS are sustained following the end of ISS operations, whenever that occurs? What are the steps that need to occur such that we can have confidence in avoiding a gap between the ISS and a future low Earth orbit facility?

NASA's International Space Station Transition Report identifies options, including "transitioning the ISS platform to private industry, augmenting it with privately developed modules, combining portions of the ISS with a new private platform, or deploying a new free-flying platform and de-orbiting the ISS."

I'm looking forward to learning more about these, and any other approaches, because when and how we transition NASA's activities in low Earth orbit from the ISS to an alternative platform or operating model is critical.

NASA has made clear its plans to transition from a government-owned and operated ISS "to a regime where NASA is one of many customers purchasing services from a LEO non-governmental human space flight enterprise."

This leaves a number of important and urgent questions that must be addressed.

- Who are those other customers? What does NASA's vision mean?
- In terms of NASA's commercial LEO development plan, what is the value proposition for the U.S. taxpayer?
- What level of investment is the private sector willing to make?
- Are NASA's planned investments in stimulating commercial market demand and supply in LEO going to ensure a smooth transition and prevent a gap in NASA's ISS and low Earth orbit activities?

The challenge here is the balance of risk and reward. Under this plan the commercial entities aren't the ones assuming the bulk of the risk, that falls to NASA yet the potential benefits to the Government and taxpayer are uncertain at best. The question is what the U.S. taxpayer will be on the hook to fund. With no near-term market other than NASA, there is a real question about the cost to the U.S. taxpayer.

NASA currently pays more than $3 billion a year to operate the ISS. On top of that, NASA plans to fund the development of one or more commercial space stations, subsidize commercial activity on the ISS, and purchase services from future commercial space stations.

Will this plan save NASA money that it can apply to its Moon program, or will it end up costing NASA more, not less, over the next decade? I look forward to getting the details.

NASA's plan, may result in impacts on the ISS research and technology development that is needed to enable human exploration of the Moon and Mars and more.

We also need to understand the potential implications of the plan for the ISS international partnership on which NASA intends to build its future human exploration plans?

In closing, the low-Earth orbit and microgravity environment may in time support a viable commercial market. NASA has already taken initiatives to support commercial space through its development of commercial cargo services, commercial crew capabilities, and enabling research and development in low Earth orbit. While NASA's interest in finding innovative approaches to stimulating a commercial market in low Earth orbit are well intended, we need to be responsible with the taxpayers' investment in the ISS as a national and international asset, and we need to carefully consider how we ensure a successful transition of our ISS activities going forward.

Chairwoman HORN. And now I will turn to Ranking Member Mr. Babin for your opening statement.

Mr. BABIN. Thank you, Madam Chair. I appreciate it. I want to say thank you to our distinguished witnesses here today. And also, I'd like to extend a welcome to several folks that are up here from my district from Johnson Space Center (JSC). If you would stand if you're out there from Johnson Space Center. Oh, man, we've got half the room. OK. I knew there were some familiar faces out there, but I wanted to say welcome. I hope you're learning a lot up here about legislation and some of the activities that we're going to talk about today are right in their bailiwick is some of their responsibilities, so thank you for being up here.

But anyway, thank you, Chairwoman Horn, for holding this hearing. The International Space Station is one of humanity's highest technological achievements. As an internationally built and operated orbiting laboratory, the ISS conducts critical research that helps us both on Earth and in space. As a multinational project, this engineering marvel illustrates the power of U.S. leadership on the frontiers of this exploration.

NASA has worked very hard to conquer the challenges of low-Earth orbit. We have learned how the human body reacts to the microgravity environment, and we're still learning, I might say. And we have grown food, crystalized proteins, we've launched satellites, we've conducted scientific observations of the Earth and the stars above.

During the 115th Congress, I introduced the *Leading Human Spaceflight Act*, which, among other provisions, would extend the authorization of the ISS from 2024 to 2030. And I would note that this extension would not simply swap out dates. Rather, my bill would also call for an earlier termination of Federal support for the ISS if a commercial alternative is in place prior to 2030. It is vital to not only our leadership in space but also our national security that America maintain a continual, uninterrupted human presence in low-Earth orbit.

I look forward to working with my colleagues on both sides of the aisle to ensure that we prevent another damaging capability gap like the one we experienced at the conclusion of our Space Shuttle program.

All of that being said, it is very important to note that our financial resources for space activities are limited, and any decision on ISS extension will result in some tradeoffs. NASA has previously estimated that the ISS will cost taxpayers between $3 and $4 billion annually through 2024, roughly half of NASA's total human spaceflight budget. Each dollar spent on transportation to, and maintenance of, the ISS is a dollar that is not being spent on exploration beyond low-Earth orbit, whether it is to the moon, to Mars, or other destinations. Numerous reports from the National Academies and the NASA Inspector General have concluded that an extension of the ISS could result in a multiyear delay to future deep-space missions.

So I proudly represent the Johnson Space Center, which manages both the ISS and the Orion programs, so I am especially aware of the trades that we have to make between low-Earth orbit and deep space exploration.

Aside from today's discussion of the ISS, we will also hear from our witnesses about ongoing efforts to increase commercial activi-

ties in low-Earth orbit. NASA has engaged in a lot of work over the last 3 years to examine potential markets and the capacity for them. They've commissioned think-tank studies, sought input from industry, and researched the various architectures at length. This work informed their recent announcement on ISS commercialization last month. Our witnesses today will share their thoughts on how NASA can continue to work with industry to find opportunities to develop more commercial markets in low-Earth orbit.

Section 303 of the *2017 NASA Transition Authorization Act* directed NASA to conduct a transition report for ISS where NASA would be "one of many customers of a low-Earth orbit commercial human space flight enterprise." A future where NASA is able to act as a customer and purchase a variety of services will allow the agency to focus on more ambitious deep-space missions, and I look very much forward to hearing from our witnesses how this Committee can help make this step happen. And allowing NASA to serve as a customer rather than a developer of basic services is a very fiscally responsible move that will benefit the taxpayer and industry alike.

I want to thank today's witnesses for being with us, and I look forward to your discussion. And with that, I yield back, Madam Chair.

[The prepared statement of Mr. Babin follows:]

Thank you for holding this hearing, Chairwoman Horn.

The International Space Station is one of humanity's highest technological achievements. As an internationally built and operated orbiting laboratory, the ISS conducts critical research that helps us both on Earth and in space. As a multi-national project, this engineering marvel illustrates the power of U.S. leadership on the frontiers of exploration.

NASA has worked hard to conquer the challenges of low-Earth orbit. We have learned how the human body reacts to the microgravity environment. We have grown food, crystalized proteins, launched satellites, and conducted scientific observations of the Earth and stars above.

During the 115th Congress, I introduced the Leading Human Spaceflight Act which, among other provisions, would extend the authorization of ISS from 2024 to 2030. I would note that this extension would not simply swap out dates. Rather, my bill would also call for an earlier termination of federal support for ISS if a commercial alternative is in place prior to 2030. It is vital to—not only our leadership in space—but also our national security that America maintain a continual, uninterrupted human presence in low Earth orbit. I look forward to working with my colleagues on both sides of the dais to ensure we prevent another damaging capability gap like the one we experienced at the conclusion of the Space Shuttle program.

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Aside from today's discussion of ISS, we will also hear from our witnesses about ongoing efforts to increase commercial activities in low-Earth orbit. NASA has engaged in a lot of work over the last three years to examine potential markets and the capacity for. They've commissioned think-tank studies, sought input from industry, and researched the various architectures at length. This work informed their recent announcement on ISS Commercialization last month. Our witnesses today

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I want to thank today's witnesses for being with us, and I look forward to our discussion.

I yield back.

Chairwoman HORN. Thank you, Ranking Member.

And the Chair now recognizes the Chairwoman of the Full Committee, Ms. Johnson, for her opening statement.

Chairwoman JOHNSON. Thank you very much, Chairwoman Horn and Ranking Member Babin, for holding this hearing to consider NASA's plans for the International Space Station and future activities in low-Earth orbit.

As I have noted in the past, the International Space Station is the largest and most complex science and engineering project ever carried out in space. It plays a critical role in carrying out human health and technological research that is essential if we are to successfully send astronauts to Mars and back. The ISS also serves as a laboratory for fundamental and applied science, as well as an observation platform for astronomical, environmental, and heliophysics research. It has been an enduring example of international cooperation in space, and it continues to inspire young people to excel and to provide opportunities for classrooms across our Nation to interact with our astronauts through live communication downlinks.

Yet the ISS is a limited resource with a limited lifetime, and we need to make sure that we make the best use of it while we have it. And to me, that means making sure that its highest priority is carrying out the research and engineering testbed activities that can only be done in ISS. That is the lens through which I will be looking at NASA's proposals for ISS commercial activities.

I support efforts to create a vibrant commercial space economy in low-Earth orbit, but ultimately it is the private sector that will determine whether or not that will happen. Private investment will be needed, not government subsidies, if LEO commercialization is to be sustainable over the long term. I believe that the jury is still out as to whether that will happen.

In the meantime, the International Space Station has a limited lifetime, limited crew size, and limited research capabilities. As I said earlier, we need to ensure that those resources are focused on those tasks that can only be done by ISS and that are a high priority. As a result, we will be taking a close look at NASA's proposed commercialization initiative to see whether it meets that standard. At this point, I'm not convinced that it does. For example, I'm skeptical that sending wealthy space tourists to ISS is the best or even a good use of taxpayers-funded facility.

NASA keeps saying that there are unanswered human health research questions that can only be addressed on the ISS; questions that need to be answered if we are to reduce the risk of sending

humans to Mars. If that is the case, our focus should be on sending additional crew members or researchers to the station, not well-heeled individuals seeking an exotic vacation.

We have much to discuss today, and I look forward to hearing from our witnesses. I welcome our witnesses. Thank you, and I yield back.

[The prepared statement of Chairwoman Johnson follows:]

Thank you, Chairwoman Horn, for holding this hearing to consider NASA's plans for the International Space Station and future activities in low Earth orbit.

As I have noted in the past, the International Space Station is the largest and most complex science and engineering project ever carried out in space. It plays a critical role in carrying out the human health and technological research that is essential if we are to successfully send our astronauts to Mars and back. The ISS also serves as a laboratory for fundamental and applied science as well as an observation platform for astronomical, environmental, and heliophysics research. It has been an enduring example of international cooperation in space, and it continues to inspire our young people to excel and to provide opportunities for classrooms across our nation to interact with our astronauts through live communication downlinks.

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Well, we have much to discuss today, and I look forward to hearing from our witnesses. Thank you, and I yield back.

Chairwoman HORN. Thank you, Madam Chairwoman.

And if there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

And let me extend my warm welcome as well again to the witnesses. We have a distinguished panel today, and clearly we have a lot to discuss as we're moving into this next phase to address concerns as we move forward to prevent, as my colleague said, a capability gap in this important endeavor.

I'll begin by introducing our witnesses today. Our first witness, Mr. William Gerstenmaier, is no stranger to appearing before this Committee, and we're glad to have you here today—Associate Administrator for the Human Exploration and Operations Mission Directorate at NASA. Prior to his current position, Mr. Gerstenmaier served as the Manager for the International Space Station program. He also served as the Associate Administrator for the Space Operations Mission Directorate during the completion of the space station. Mr. Gerstenmaier holds a bachelor of science in aero-

nautical engineering from Purdue University and a master of science degree in mechanical engineering from the University of Toledo. He is becoming a regular when it comes to testifying before us and clearly has expertise related to ISS. And we are glad to see you again, and we appreciate you being here as we consider these important issues. So welcome, Mr. Gerstenmaier.

Our next witness, Mr. Paul Martin, Inspector General for the National Aeronautics and Space Administration. Mr. Martin has been NASA Inspector General since Senate confirmation in 2009. Prior to his appointment at NASA, he served as the Deputy Inspector General in the Department of Justice. He also spent 13 years at the U.S. Sentencing Commission, including 6 years as the Commission's Deputy Staff Director. Mr. Martin received a B.A. in journalism from Pennsylvania State University and a juris doctorate from Georgetown University Law Center. We look forward to your testimony today, Mr. Martin, and we're glad that you're here, so welcome.

Our next witness is Mr. Eric Stallmer. Mr. Stallmer is the President of the Commercial Spaceflight Federation, CSF, and has much experience in the commercial space sector. CSF is a trade organization dedicated to promoting the development of commercial spaceflight and was recently appointed to the National Space Council User Advisory Group. Before working at the Commercial Spaceflight Federation, Mr. Stallmer served as the Vice President of Government Relations for Analytical Graphics, Incorporated. Mr. Stallmer has a bachelor's degree in political science and history from Mount Saint Mary College and a master's in Public administration from George Mason University.

Mr. Stallmer also testified yesterday before our colleagues in the Senate, and so you've had a long 2 days but we're glad you're joining us today and appreciate your willingness to do back-to-back hearings in 24 hours, so welcome. Glad to have you here.

And our last witness is Professor Joanne Irene Gabrynowicz. Did I get it right? Excellent. I know Gerst. I just want to make sure I get it right. So Professor Gabrynowicz is a Professor Emerita of Space Law and Director of the National Center for Remote Sensing, Air, and Space Law at the University of Mississippi Law Center. Professor Gabrynowicz is also the Editor-in-Chief Emerita of the Journal of Space Law. In addition, she is the Director of the International Institute of Space Law (IISL) and is an official observer for the IISL to the U.N. Committee on the Peaceful Uses of Outer Space. She received her bachelor's from City University of New York and earned her juris doctorate from the Cardozo School of Law. Welcome, Professor Gabrynowicz.

As our witnesses, you should all know that each of you will have 5 minutes for your spoken testimony, and your written testimony will be included in the record for this hearing. When you've completed your spoken testimony, we'll begin with questions, and each Member will have 5 minutes of questions.

And since you've been through this drill many times before, Mr. Gerstenmaier, we'll start with you.

TESTIMONY OF MR. WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, HUMAN EXPLORATION AND OPERATIONS MISSION DIRECTORATE, NASA

Mr. GERSTENMAIER. Thank you very much.

ISS is the most amazing and productive space research facility ever constructed by humankind. ISS is accomplishing more than previously envisioned. For example, ISS' role in CubeSat, CubeSatellite deployment and development, was unanticipated. Who would've thought that ISS and its relatively low altitude would be seen as the go-to CubeSat deployment platform. The CubeSat lifetime is on the order of months at the altitude of the space station. The lifetime constraint would seem to reduce CubeSat developers' desire to use the space station.

The cost of access to ISS and the ability of crews to interact with the satellites prior to deployment made ISS a great research platform for CubeSats. As of today, 250 CubeSats have been deployed from the ISS. ISS has played a pivotal role in the development of the CubeSat market.

ISS also played a strong role in lowering launch costs. Cargo transportation to allow—to ISS allowed for new competition to enter the launch market. ISS cargo with relaxed launch reliability requirements allowed new competition in launch vehicles and helped bring commercial satellite launch back to the U.S. soil. Clearly, this role for ISS was not envisioned at the beginning of ISS.

Last, the ISS international partnership has allowed the ISS team to set interoperability standards for the rest of the world to follow. The international docking standards allow anyone building to the standard to dock with the ISS. The standard does not dictate design but allows for docking. There are now standards for life support, power, data, and avionics. The ISS team is setting standards for the rest of the world to follow in human spaceflight. These standards will be used for our lunar activity.

Today's hearing discussing future plans for the ISS is very timely. Just as the activities that I mentioned have surprised us and the benefits from ISS, I think the upcoming years of ISS operations offer the chance to see ISS contribute in ways not yet envisioned or imagined.

The area that I would like to discuss in my opening remarks is the ISS activity associated with creating a commercial market for low-Earth orbit activities. Several weeks ago, NASA announced a plan to utilize ISS to explore market development in low-Earth orbit. Previously, NASA asked commercial industry for their ideas to commercialize low-Earth orbit, and, based on the input from 12 studies and 12 companies, NASA developed a plan. That plan comprises five key areas.

First, to establish ISS commercial use and pricing policy. That allows the commercial companies to understand where they can use ISS and how much it will cost.

The second point was to enable private astronaut missions to the ISS.

The third point was to initiate a process of commercial development of low-Earth orbit destinations. This means allowing the

docking port to be used on ISS for commercial activities and also investing—investigating new free-flying platforms.

Fourth, we were seeking out and pursuing opportunities to stimulate demand.

And fifth, we've been quantifying NASA's long-term needs for activities in low-Earth orbit. With this data, commercial companies should be able to build a business plan and determine ways to generate revenue from low-Earth orbit.

NASA can enable U.S. industry to see the benefits and opportunities in low-Earth orbit spaceflight. However, the results will only come from the private sector investing and taking risk. All companies investing in low-Earth orbit will not be successful. It is critical that NASA create the right environment for these potential low-Earth orbit entrepreneurs. The ultimate goal is for NASA to become one of many customers for activities in low-Earth orbit. Being one of many customers will lower cost for NASA and allow us to more effectively use the dollars that we have been provided. I stress that the burden of creating this new market will be on the private sector and not on NASA.

Again, thank you for the opportunity to be here today, and I look forward to your questions.

[The prepared statement of Mr. Gerstenmaier follows:]

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UNTIL PRESENTED
BY WITNESS
July 10, 2019

Statement of

William H. Gerstenmaier
Associate Administrator for Human Exploration and Operations
National Aeronautics and Space Administration

before the

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

Chairwoman Horn and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the future of the International Space Station (ISS) and NASA's long-term vision for use of low-Earth orbit (LEO).

NASA will send the first woman and the next man to the South Pole of the Moon by 2024 and develop a sustainable human presence on the Moon by 2028. We have designated this program "Artemis" – Apollo's twin sister and goddess of the Moon in Greek mythology.

NASA's Artemis program will build a sustainable, open architecture that returns humanity to our nearest neighbor. We are building for the long term, and this time are going to the Moon to stay. We are designing an open, durable, reusable architecture that will support deep space exploration for decades to come. Sustainability requires reusable systems and partnerships from across the commercial sector and around the world.

The Agency is incentivizing speed and drawing on commercial and international partners as it looks to land humans on the Moon within five years. NASA is completing development of both the Orion spacecraft that will carry humans to lunar orbit, and the Space Launch System (SLS) rocket that will launch Orion. We are pressing forward toward the Artemis 1 mission, an uncrewed test flight of Orion and SLS as an integrated system around the Moon. This will be followed by the Artemis 2 mission that will be the first test flight with human crew to the lunar vicinity aboard SLS and Orion. Then, the Artemis 3 mission will send the first crew to the lunar surface.

Critical to this sustainable strategy are the Gateway, an outpost that will orbit the Moon and support missions to the lunar surface, commercial human lander services, and reusable infrastructure on the lunar surface. Artemis 3 will utilize on the Gateway and use commercial human landing services that depart from this outpost. On May 23, 2019, NASA awarded a contract for the first element of the Gateway, the power and propulsion element (PPE). The PPE will use solar-electric propulsion to give us access to more of the lunar surface than ever before. On May 16, 2019, NASA announced the selection of 11 companies to conduct studies and produce prototypes of human landers for its Artemis lunar exploration program. These studies and prototypes will provide critical data needed to inform requirements for the Artemis 3 hardware.

As the Artemis program develops this sustainable deep space exploration architecture, we will continue to draw on ISS capabilities to develop the knowledge and technology required to support missions to the Moon and ultimately to Mars. ISS is supporting development of more efficient life support systems, approaches to managing the health risks of deep space travel, and enhanced understanding of other critical systems for human spaceflight. At the same time, the transition to a vibrant, sustainable LEO economy has the potential to make increasing contributions to exploration by engaging the broader economy.

The ISS currently serves as a unique platform to prepare for human exploration beyond LEO, promotes U.S. economic activity in space, and accelerates innovative research and technology development. Equally important, under the leadership of the United States, the ISS contributes to America's preeminence around the world in space and technological innovation. Since its inception over 30 years ago, the ISS partnership has been a model of peaceful international cooperation. The ISS partnership has developed interoperability standards for human spaceflight that the rest of the world will follow as human presence is expanded into the solar system. ISS has accomplished many things that were never envisioned, such as helping to establish a cube satellite market and creating a market for commercial cargo resupply services that helped underpin the return of commercial satellite launches to the U.S. through reduced launch costs. NASA and the U.S. recognize the huge investments that have been made in ISS and are needed to continue operating it and are looking new ways to leverage the ISS in order to continue U.S. leadership in LEO; we are transitioning NASA's LEO activities to a model where the Agency 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 with U.S. industry in ensuring American preeminence as the world's leading spacefaring nation. We will continue to transition from a Government-led presence in LEO to a private sector model where the Government is one of many users. The ISS has been and will continue to be a key enabler for that new dynamic enterprise.

NASA seeks to achieve a continuous U.S. human presence in LEO – both with Government astronauts and with private citizens – in order to support the utilization of space by U.S. citizens, companies, academia, and international partners, and to maintain a permanent American foothold on the nearest part of the space frontier.

Principles for Transitioning LEO

Several key principles are reflected in NASA's strategy regarding the ISS and the future of LEO, as well as NASA's role as one of many customers of services or capabilities that are provided by private industry as part of a broader commercial market. The following principles will ensure uninterrupted access to LEO capabilities and long-term national interests in human space exploration, while supporting national security objectives, such as a competitive industrial base and U.S. leadership:

- Expanding U.S. human spaceflight leadership in LEO and deep space exploration, including continuity of the relationships with our ISS international partners;
- Increasing platform options in LEO to enable more ISS transition pathways, security through redundant capabilities, and industrial capability that can support NASA's deep space exploration needs;
- Spurring vibrant commercial activity in LEO;
- Continuing to return benefits to humanity through Government-sponsored basic and applied on-orbit research;

- Providing continuity among NASA's LEO, deep space exploration, and development and research activities and missions toward expanding human presence into the solar system;
- Maintaining critical human spaceflight knowledge and expertise within the Government in areas such as astronaut health and performance, life support, safety, and critical operational ground and crew experience;
- Continuing Government-sponsored access to LEO research facilities that enable other Government agencies, academia, and private industry to increase U.S. industrial competitiveness and provide goods and services to U.S. citizens; and
- Continuing to reduce the Government's long-term costs through private industry partnerships and competitive acquisition strategies.

NASA's vision for LEO is a sustained U.S. commercial human spaceflight marketplace with multiple privately-owned/operated platforms – human-tended, permanently-crewed, and/or robotic – together with transportation capabilities for crew and cargo that enable a variety of activities in LEO, where those platforms and capabilities are sustained to a greater degree than today by commercial revenue. The path to these future platforms may either initially leverage ISS or be free-flying, or potentially both. This flexibility allows the private sector to determine how best to meet the market demand rather than have the Government dictate how to meet this demand.

A robust and competitive LEO economy is vital to continued progress in space. The United States is committed to encouraging and facilitating the growth of the U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the next generation of new markets and innovation-driven entrepreneurship. NASA has developed a long-term plan to achieve this goal where NASA will become one of many customers in LEO. This plan builds on, uses the capabilities of, and applies the lessons learned from over a decade of work and experience with commercial companies.

In the future, NASA will be able to share the cost of LEO platforms and commercial transportation with other commercial, Government, and international users. Allowing the Agency to maximize its resources toward missions beyond LEO, while still utilizing LEO for research, training, and technology development.

For nearly two decades, NASA has been moving from the purchase of hardware and vehicles to purchasing services to support the government's needs in LEO. Initially, NASA experimented with the purchase of non-essential services for ISS, such as the acquisition of water production capabilities through United Technologies Corporation. NASA moved on to stimulate the development of critical cargo delivery systems through the Commercial Orbital Transportation Services Program, which led to the development and purchase of commercial capabilities to provide Commercial Resupply Services for the ISS. This highly successful program resulted in the development of two U.S. cargo delivery capabilities which have delivered over 70 tons of cargo to ISS over the past seven years, and a third system is in development. This partnership changed the way NASA does business and strengthened the American commercial space industry while restoring America's capability to deliver and return ISS cargo.

NASA's Commercial Crew Program (CCP) was formed to facilitate the development of a U.S. commercial crew space transportation capability with the goal of achieving safe, reliable, and cost-effective access to and from the ISS and LEO. CCP has invested in American companies that are designing and developing these transportation capabilities, and will soon be launching astronauts to the ISS for the first time from U.S. soil since the end of the Space Shuttle Program.

NASA has applied this approach not only to commercial space transportation, but also to purchasing research capabilities as they became commercially available from companies with their own hardware on the ISS. There are currently 14 commercial facilities on the ISS developed by 11 U.S. companies. These research capabilities provide NASA a cost-effective means to expand the research pipeline at reduced costs, without needing to develop new facilities and capabilities in house. Additional companies are working to develop more new hardware and state-of-the-art research capabilities.

NASA is preparing to secure the Nation's long-term presence in LEO by partnering with industry to continue developing commercial enterprises and capabilities that will stimulate and utilize private demand while supporting NASA's long-term needs in LEO. To enable this future, building on the progress made over the last two decades, NASA has developed and is now implementing a Plan for Commercial LEO Development.

NASA's Plan for Commercial LEO Development

NASA is undertaking the Commercial LEO Development program as a focused effort to enable and foster a commercial space economy in LEO. This effort is intended to stimulate both the supply side of the economy – the development of commercially-owned and -operated LEO destinations from which NASA can purchase services, as well as the demand side of the economy – the continued growth of commercial activities in LEO such that NASA is but one of many users purchasing those services.

NASA entered into agreements with 12 industry partners in FY 2018 to study the commercialization of LEO and to gain better insight and help inform recommendations for how the program will move forward with both policy and acquisition efforts. These studies were designed to solicit industry's commercialization concepts, business plans and viability for habitable platforms in LEO, whether using ISS or free-flying, that would enable a commercial marketplace in LEO. The studies also sought to understand the role of Government and the evolution of ISS in the roadmap to the commercialization of LEO, including how private demand for commercial LEO services could be stimulated in order to sustain a long-term LEO marketplace with primarily non-NASA commercial revenue. Insights from the studies were very helpful in refining NASA's plan for commercial LEO development.

NASA publicly released its five-part plan for Commercial LEO Development during a press event at NASDAQ in New York on June 7, 2019, to communicate the exciting potential of the new LEO economy to new and non-traditional entrants.

The plan includes five near-term activities, detailed below:

1) Establish ISS commercial use and pricing policy;
2) Enable private astronaut missions to ISS;
3) Initiate a process for commercial development of LEO destinations;
4) Seek out and pursue opportunities to stimulate demand;
5) Quantify NASA's long-term needs for activities in LEO.

It is important to note that NASA released these activities as a package rather than individually. From the industry studies, we received a variety of ideas. This prompted us to put together a complete package so that companies could understand the breadth of NASA's plans and policies for LEO and tailor their work with a better sense of the overall direction that NASA intends to take. NASA will not be able to ensure success for all of these companies. Some may start and fail. These companies will be forced to be innovative and creative and their success will depend on their own strengths. NASA is attempting to remove enough risk and create opportunities that allow that some companies to be successful. NASA is

also mindful of the need to not compete with private companies for limited markets by providing free or subsidized services that erode their addressable markets.

Establish ISS commercial use and pricing policy. The ISS is a unique orbiting platform that enables researchers from all over the world to put their talents to work on innovative experiments that can only be conducted in the space environment. Having proven its capability as a platform for a broad array of research disciplines as well as technology development, the ISS also provides an opportunity to test new business relationships. This allows an opportunity to shift from a paradigm of Government-owned and – operated equipment provided by contractors to commercially provided goods and services, with Government as a customer.

More than 50 companies already are conducting commercial research and development on the space station and their results are yielding great promise. This builds on the 14 commercial facilities already supporting research and development (R&D) on ISS. To go beyond R&D and open new opportunities in areas such as manufacturing, marketing and tourism, NASA needs to expand the scope of allowable activities aboard the ISS.

Therefore, NASA has opened the ISS to expanded commercial and marketing opportunities that will continue the Agency's efforts to develop a sustainable economy in LEO. This is being done through a *NASA Interim Directive on Use of International Space Station (ISS) for Commercial and Marketing Activities*. The new policy enables commercial manufacturing and production, allows both NASA and private astronauts to conduct new commercial activities aboard the orbiting laboratory, and sets commercial prices for the use of U.S. Government resources in pursuit of commercial and marketing activities aboard the ISS. NASA has set aside five percent of the Agency's ISS utilization resources to serve commercial and promotional activities – with no impact to the 50 percent allocation to the ISS National Laboratory.

With this new policy, U.S. entities will have the ability to pursue the following:

- Manufacturing, production, transportation, or marketing of commercial resources and goods, including products intended for commercial sale on Earth;
- Inclusion of private astronauts on U.S. Government or commercial missions to the ISS and associated on-orbit activities, including commercial and marketing activities;
- U.S. Government astronauts conducting coordinated and scheduled activities in support of commercial and marketing activities;
- Purchase resources available for use on the ISS for commercial and marketing activities.

U.S. entities may pursue these activities if they meet any of the following: require the unique microgravity environment, have a nexus to the NASA mission, or support the development of a sustainable LEO economy.

NASA has also developed a pricing policy that will be updated approximately every six months. This allows industry to understand the cost of obtaining services from NASA. Just establishing prices has created an awareness within NASA of the impact of price on corporate strategy. Learning how the Agency can more effectively incentivize development of a LEO economy will be critical to the successful transition to the private sector.

Enable private astronaut missions to ISS. Building a robust economy in LEO will depend on routine and affordable access to space for humans and cargo. NASA has partnered with Boeing and SpaceX through the Commercial Crew Program to develop the U.S. capability for human access to space.

NASA's accommodation of private astronaut missions to the ISS enables an expanded market opportunity for these commercial service providers. Such missions also expand the scope and amount of commercial activities that private astronauts can accomplish while their missions are at the ISS. The first private astronaut mission, using the U.S.-developed spacecraft, could come as early as 2020.

Market studies identified private astronaut missions to ISS as a key element to demonstrate demand and reduce risk for future commercial destinations in LEO. NASA can accommodate up to two short-duration private astronaut missions per year to the ISS, if supported by the market.

The commercial entity developing the mission will determine the crew composition and ensure private astronauts meet NASA's medical standards, training, and certification procedures to be a member of the ISS crew. A private astronaut assigned to a mission on the space station will have the ability to fulfill duties that fall into the approved commercial and marketing activities outlined in the new commercial use policy.

Initiate a process for commercial development of LEO destinations. In order to meet its long-term research and technology development needs in LEO in a cost-effective manner, NASA must enable the development of a robust commercial human spaceflight economy and facilitate new markets in order to be one of many customers of a broad portfolio of commercial products and services. To enable industry to catalyze new markets, NASA will partner with U.S. industry for the development of commercial destinations in LEO, either using the ISS or by going directly to a free-flying platform.

NASA is offering commercial use of the ISS Node 2 (Harmony) forward port and associated ISS services to enable development, launch, and operations of one or more commercial destination elements. On June 21, 2019, NASA released Appendix I to the Next Space Technologies for Exploration Partnerships (NextSTEP-2) Broad Agency Announcement (BAA) to request proposals from U.S. commercial entities to enter into a public-private partnership with NASA. The goal is to develop commercial markets in one or more habitable commercial elements attached to the space station. Successful ventures will leverage the capabilities of the ISS to stimulate demand and catalyze new markets, leading to a transition to a long-term, sustainable, commercial, human spaceflight enterprise in LEO where NASA is one of many customers. NASA seeks commercial destinations that provide a diverse portfolio of products and services that meet both NASA and non-NASA needs, but do not rely heavily on continued NASA purchase of services in the long term.

In July, NASA plans to release a synopsis for Appendix K to the NextSTEP-2 BAA to enable additional partnerships for development and spaceflight demonstrations of free-flying commercial destinations in LEO. NASA intends to acquire services from the commercial destinations that are produced through Appendix I and K partnerships through a future competitive solicitation. NASA expects that it will remain a major customer of commercial space stations until the Agency's goal of being one of many customers is realized.

Seek out and pursue opportunities to stimulate demand. If NASA is to achieve its goal of becoming one of many customers of future commercial destinations in a robust LEO economy, the Agency must partner with industry to catalyze and nurture the development of sustainable, scalable, and profitable non-NASA demand for services in LEO. NASA is taking a multi-pronged approach, including using NASA Research Announcements (NRA) and the NextSTEP-2 BAA.

NASA has expanded the ISS Utilization NRA to request proposals from U.S. industry for commercial concepts with a focus on the areas of in-space manufacturing and regenerative medicine/bioengineering, and will also consider other fields that may lead to a scalable, financially self-sustaining demand for LEO capabilities. Successful ventures will further mature concepts with potential for scalability, such as

returning high-value items for terrestrial use, capturing sizeable markets or creating new markets, and disrupting existing technologies by taking advantage of the ISS, and eventually follow-on human-rated destinations in LEO.

NASA has released Appendix J to the NextSTEP-2 BAA to request proposals from U.S. entities. NASA seeks proposals that, if successful, will: strengthen NASA's insights into opportunities for reducing cost and technical barriers to enable space market growth; identify actionable recommendations, and lead to a strong LEO economy with NASA as one of many customers of commercial transportation and destinations in LEO.

Quantify NASA's long-term needs for activities in LEO. On October 26, 2018, NASA released the white paper *Forecasting Future NASA Demand in Low-Earth Orbit*. It provided a qualitative description forecasting the types of research- and exploration-related activities NASA will conduct in the future in LEO. As the fifth part of NASA's Plan for Commercial LEO Development, the Agency has updated this white paper to include a quantification of the demand forecast, representing the type and amount of services that NASA intends to purchase in the future when those services become available on one or more commercial destinations. NASA is planning to continue with the following LEO needs and objectives beyond the life of ISS:

- Maintaining the ISS international partnership and developing new relationships with other international and domestic participants;
- Conducting regular LEO crewed operations, including short- and long-duration missions:
  - Enabling operational space proficiency;
  - Shifting from human health and performance countermeasures development (the ISS portion of which is expected to be complete by 2024) to validations of integrated long-duration systems, habitation, operations, and crew isolation;
- Developing and demonstrating long-term technology/systems (e.g., life support);
- Conducting space life and physical sciences basic and applied research at current level and capabilities;
- Conducting National-Laboratory-based research and technology development; and
- Providing opportunities for astrophysics, space, and Earth science research.

These long-term requirements, while similar to those of the current ISS Program, could be met with various types of modules or platforms that do not necessitate a vehicle (or vehicles) as complex as the ISS. Many of the research activities could be conducted on shorter-duration platforms, similar to the Space Shuttle, or crew-tended platforms.

Commercial LEO Development will advance the Nation's goals in LEO and exploration by furthering the development and maturity of the commercial space market. This will enable private industry to assume roles that have been traditionally Government-only, by creating new opportunities for economic growth through new markets and industries in LEO, and potentially yielding long-term cost savings to the Government by leveraging private industry innovation and commercial market incentives.

Future of the ISS Platform

In recent years, the space station's retirement date has become a very important topic of discussion. Although it is likely technically feasible to continue to operate the ISS in the short term with continued maintenance, there is a very real potential that critical systems could fail or the ISS could suffer a major damaging impact from orbital debris, bringing the lifetime of the facility to an end. New commercial

systems or approaches to managing the ISS could potentially significantly reduce the costs of operating in LEO. These approaches will need to look at creative ways to lower transportation costs, but they will ultimately make ending direct Government funding for ISS possible. The Administration has challenged NASA to accomplish this goal by 2025 and we are seeking to do so. We recognize the numerous difficulties inherent in this challenge, but also the importance of starting along this path. In all circumstances, NASA is committed that there will be no gap of a U.S. human presence in LEO. As the private sector develops capability, ISS use will need to be moderated to not compete with the private sector. This transition will be challenging and require close Government and private sector interaction. The LEO economy will not reach its full potential if the Federal Government is the sole supplier of, or demand for, LEO research capabilities. One key will be the private sector creating demand beyond the needs of the U.S. Government.

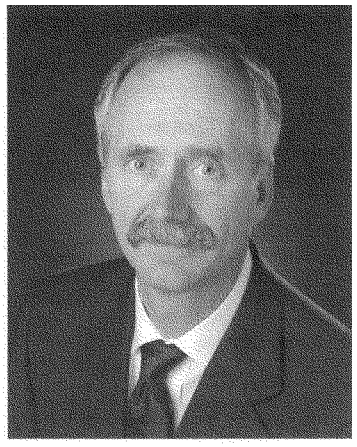
The future of the ISS platform will be evaluated using the *ISS Transition Principles* previously described, to ensure there is no gap in the availability of a LEO destination to meet NASA's needs. NASA will pursue an orderly transition to new commercial destinations in LEO as they become available and demonstrate their capabilities and ability to meet NASA's needs. We will continue to discuss decisions about the future of the ISS across the ISS international partnership.

Conclusion

NASA will continue its mission in LEO with the ISS to enable exploration, while performing research that benefits humanity, supporting National Laboratory research by private industry and other organizations, and working towards reducing operations and maintenance costs. The Agency will create new opportunities for collaboration with industry on the ISS and develop public-private partnerships for exploration systems that will extend human presence into the solar system. NASA is working to leverage commercially-provided services that help enable deep space exploration and private sector expansion in LEO. These services will continue and accelerate the transition of human spaceflight operations in LEO to commercial partners in support of NASA and non-NASA needs. To support this transition, NASA will focus on partnerships with commercial industry to develop future commercial destinations and stimulate growth of demand for services from those destinations, as well as meeting Government requirements in LEO.

NASA looks forward to working with Congressional stakeholders, researchers, private industry, and our ISS international partners on the future of the ISS and LEO, to ensure that the U.S. maintains its human spaceflight leadership.

WILLIAM H. GERSTENMAIER
ASSOCIATE ADMINISTRATOR FOR
HUMAN EXPLORATION AND OPERATIONS



William H. Gerstenmaier is the associate administrator for the Human Exploration and Operations Mission Directorate at NASA Headquarters in Washington, DC. In this position, Mr. Gerstenmaier provides strategic direction for all aspects of NASA's human exploration of space and cross-agency space support functions of space communications and space launch vehicles. He provides programmatic direction for the continued operation and utilization of the International Space Station, development of the Space Launch System and Orion spacecraft, and is providing strategic guidance and direction for the commercial crew and cargo programs that will provide logistics and crew transportation for the International Space Station.

Mr. Gerstenmaier began his NASA career in 1977 at the then Lewis Research Center in Cleveland, Ohio, performing aeronautical research. He was involved with the wind tunnel tests that were used to develop the calibration curves for the air data probes used during entry on the Space Shuttle.

Beginning in 1988, Mr. Gerstenmaier headed the Orbital Maneuvering Vehicle (OMV) Operations Office, Systems Division at the Johnson Space Center. He was responsible for all aspects of OMV operations at Johnson, including development of a ground control center and training facility for OMV, operations support to vehicle development, and personnel and procedures development to support OMV operations. Subsequently he headed the Space Shuttle/Space Station Freedom Assembly Operations Office, Operations Division. He was responsible for resolving technical assembly issues and developing assembly strategies.

Mr. Gerstenmaier also served as Shuttle/Mir Program operations manager. In this role, he was the primary interface to the Russian Space Agency for operational issues, negotiating all protocols used in support of operations during the Shuttle/Mir missions. In addition, he supported NASA 2 operations in Russia, from January through September 1996 including responsibility for daily activities, as well as the health and safety of the NASA crewmember on space station Mir. He scheduled science activities, public affairs activities, monitored Mir systems, and communicated with the NASA astronaut on Mir.

In 1998, Mr. Gerstenmaier was named manager, Space Shuttle Program Integration, responsible for the overall management, integration, and operations of the Space Shuttle Program. This included development and operations of all Space Shuttle elements, including the orbiter, external tank, solid rocket boosters, and Space Shuttle main engines, as well as the facilities required to support ground processing and flight operations.

In December 2000, Mr. Gerstenmaier was named deputy manager, International Space Station Program and two years later became manager. He was responsible for the day-to-day management, development, integration, and operation of the International Space Station. This included the design, manufacture, testing, and delivery of complex space flight hardware and software, and for its integration with the elements from the International Partners into a fully functional and operating International Space Station.

Named associate administrator for the Space Operations Mission Directorate in 2005, Mr. Gerstenmaier directed the safe completion of the last 21 Space Shuttle missions that witnessed assembly complete of the International Space Station. During this time, he provided programmatic direction for the integration and operation of the International Space Station, space communications, and space launch vehicles.

In 2011, Mr. Gerstenmaier was named to his current position as associate administrator for the Human Exploration and Operations Mission Directorate.

Mr. Gerstenmaier received a bachelor of science in aeronautical engineering from Purdue University in 1977 and a master of science degree in mechanical engineering from the University of Toledo in 1981. In 1992 and 1993, he completed course work for a doctorate in dynamics and control with emphasis in propulsion at Purdue University.

Mr. Gerstenmaier is the recipient of numerous awards, including three NASA Certificates of Commendation, two NASA Exceptional Service Medals, a Senior NASA Outstanding Leadership Medal, the Meritorious Executive Presidential Rank Award, and Distinguished Executive Presidential Rank Award. He also was honored with an Outstanding Aerospace Engineer Award from Purdue University. Additionally, he was twice honored by Aviation Week and Space Technology for outstanding achievement in the field of space. His other awards include: the AIAA International Cooperation Award; the National Space Club Astronautics Engineer Award; National Space Club Von Braun Award; the Federation of Galaxy Explorers Space Leadership Award; AIAA International Award; the AIAA Fellow; Purdue University Distinguished Alumni Award; and honored at Purdue as an Old Master in the Old Masters Program; recipient of the Rotary National Award for Space Achievement's National Space Trophy; Space Transportation Leadership Award; the AIAA von Braun Award for Excellence in Space Program Management; and the AIAA von Karman Lectureship in Astronautics.

He is married to the former Marsha Ann Johnson. They have two children.

October 2015

Chairwoman HORN. Thank you, Mr. Gerstenmaier. Mr. Martin.

TESTIMONY OF THE HON. PAUL K. MARTIN, INSPECTOR GENERAL, NASA

Mr. MARTIN. Chairwoman Horn, Ranking Member Babin, and Members of the Subcommittee, over the past 5 years, the Office of Inspector General has issued 13 reports related to the International Space Station, including reviews of NASA's efforts to maximize onboard research, manage the $17 billion in contracts with private companies to fly cargo and crew, and maintain international partnerships that fund almost one-quarter of the station's annual expenses. My testimony today is informed by these past reviews, in particular, an audit we issued last July that assessed NASA's utilization of the ISS.

For the past 21 years, the ISS has served as a unique platform for humans to experience living in space while conducting research in a microgravity environment. But while a unique platform, it's also an expensive platform that costs NASA between $3 to $4 billion annually or about half its human space flight budget.

In my remarks this morning, I offer three observations based on our oversight work. Observation one: NASA's current plans for a more incremental approach to ISS commercialization appear more realistic than its previous approach that set a hard deadline of October 2025 to end direct Federal funding for the station. That said, we continue to question whether a sufficient business case exists under which private companies can create a self-sustaining and profit-making business using the ISS independent of significant government funding in the short or midterm. From our perspective, it is unlikely that a private entity would assume the station's operating cost, currently $1.2 billion annually, to enable NASA to achieve its stated goal of, quote, "becoming one of many customers of a commercial LEO platform."

Observation two: Structurally, it appears the service life of the ISS could safely be extended to at least 2028 if not beyond. However, the larger challenge may be the yearly expense of operating the station past 2024, an expense that may impact NASA's ability to fund other priorities. Unless the agency receives a substantial and sustained appropriations increase, it will be hard-pressed to continue supporting ISS operations under its current model while also funding initiatives such as the Gateway, lunar landers, new spacesuits, and other technologies required for a moon landing.

Observation three: Last month, NASA announced an interim directive outlining use of the ISS for commercial and marketing activities. To help companies develop business plans, NASA also published a pricing policy under which it plans to charge private astronauts around $1 million for a month-long stay on the ISS or about $35,000 per day. While NASA acknowledges these prices are substantially subsidized and represent only a small portion of the agency's actual cost, the initiative is one approach NASA is undertaking to foster a commercial market in low-Earth orbit. The likelihood of success of this effort remains unclear for a variety of reasons, not the least of which is uncertainty about when routine commercial crew flights to the ISS will begin and how much a seat will cost a private astronaut.

In conclusion, one positive benefit of the Administration's FY 2019 plan to end direct Federal funding of the ISS after 2024 was that it helped focus the conversation about the station's future. Whether the final decision is extension, increased commercialization, retirement, or some combination of these options, the sooner the Administration and Congress agree on a definitive path forward for the ISS, the better NASA will be able to maximize use of the station and make additional plans to commercialize low-Earth orbit. Thank you.

[The prepared statement of Mr. Martin follows:]

NASA
National Aeronautics and Space Administration

Office of Inspector General

Testimony before the House of Representatives
Subcommittee on Space and Aeronautics,
Committee on Science, Space, and Technology

EXAMINING NASA'S PLANS FOR THE INTERNATIONAL SPACE STATION AND FUTURE ACTIVITIES IN LOW EARTH ORBIT

Statement of Paul K. Martin
Inspector General
National Aeronautics and Space Administration

For Release on Delivery (expected at 10 a.m.)
July 10, 2019

Chairwoman Horn, Ranking Member Babin, and Members of the Subcommittee:

The Office of Inspector General (OIG) is committed to providing independent, aggressive, and objective oversight of NASA. We welcome this opportunity to discuss the Agency's challenges and opportunities for fully utilizing the International Space Station (ISS or Station) at least through 2024 while spurring commercialization activities in low Earth orbit.[1]

Over the past 5 years, the OIG has issued 13 reports related to the ISS, including reviews on NASA's efforts to maximize research, extend its operations, manage contracts with private companies to fly cargo and crew to the Station, and maintain international partnerships that fund close to one-quarter of the Station's annual expenses. My testimony today is informed by each of these past reports, but primarily draws on our July 2018 audit examining NASA's plans for maximizing ISS utilization, including extension of ISS operations beyond the end of fiscal year (FY) 2024 and the necessity to safely dispose of the Station once it is no longer in use.[2] In that report, we also touched on the Administration's stated goal of transitioning the ISS to private operation beginning in FY 2025 and raised concerns about the significant challenges NASA faced in stimulating adequate private sector interest in this endeavor.

For the past 21 years, the ISS has served as a platform for humans to learn about living and working in space. NASA's original vision was that astronauts living on the Station would conduct biological and materials research, demonstrate American leadership in space, forge international cooperation, and lead efforts to commercialize low Earth orbit. To its credit, the Agency has accomplished many of these goals over the past two decades. NASA has sponsored research aboard the ISS in the areas of life and physical sciences; human health; astrophysics; Earth sciences; space science; and commercial research and development for pharmaceuticals, materials, manufacturing, and consumer products. The ISS has also been used in disaster response on Earth by providing near real-time mapping support for recovery and humanitarian aid efforts. However, all of these achievements have come at a cost of $3 to $4 billion annually or about half of the Agency's human space flight budget.[3] Moreover, any decision regarding extending NASA's activities in low Earth orbit needs to be considered in tandem with the Agency's efforts to achieve a lunar landing mission by 2024.[4]

Against this backdrop, the President's FY 2020 budget request for NASA envisions new commercial capabilities on the ISS by 2025 as well as new commercial facilities and platforms in low Earth orbit. Further, NASA recently announced plans to host private astronauts on the ISS and provide a range of capabilities for private researchers beginning as soon as 2020. These developments are a marked change from the proposal in NASA's FY 2019 budget request to end direct federal funding for the ISS beginning in 2025 and provide a more incremental approach to commercializing ISS operations. In our July 2018 report, we found the Station will require significant federal funding beyond 2025 to continue

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[1] The ISS is currently authorized to continue operations through September 30, 2024. Legislation introduced in the Senate would extend that authorization through 2030.

[2] NASA OIG, *NASA's Management and Utilization of the International Space Station* (IG-18-021, July 30, 2018).

[3] In the President's FY 2020 budget request, the ISS budget included approximately $1.8 billion for crew and cargo transportation, $1.1 billion for systems operations and maintenance, and $353 million for research.

[4] In March 2019, the Vice President stated that the Administration was committed to landing humans on the Moon by 2024, 4 years sooner than planned in the President's FY 2020 budget request. In May 2019, NASA submitted a budget amendment requesting an increase of $1.6 billion above the President's initial $21 billion FY 2020 budget request for the Agency as a "down payment" to meet that goal. Designated the Artemis Program, in June 2019 the Administrator said NASA would need $20 to $30 billion in addition to current Agency appropriations over the next 5 years—an average of an additional $4 to $6 billion per year—to put the first woman and next man on the Moon by 2024.

operations and maintenance given the current limited commercial market interested in assuming the ISS's operational costs. Although we have yet to review in-depth the Agency's new plans, the approach appears more realistic by seeking to maximize utilization of the ISS under the current government-funded model while providing incremental opportunities for commercialization. We plan to examine NASA's evolving strategies for ISS commercialization as the Agency further develops its plans.

Continuing Utilization of the ISS

In March 2017, Congress directed NASA to submit an ISS Transition Report detailing the impact that extending the service life of the ISS beyond 2024 would have on its deep space exploration capabilities.[5] Although the ISS is currently authorized to operate through September 2024, several legislative proposals would extend Station operations through at least 2030.[6] NASA is close to completing its evaluation of the feasibility of extending the Station's service life through at least 2028 with The Boeing Company (Boeing), NASA's prime ISS contractor, certifying to date all major U.S. structural elements to 2028 with the exception of an external stowage platform and six truss segments, which the Agency expects to be completed by late December 2019. In addition, Boeing assessed and cleared to 2028 critical operational capabilities including electrical power, environmental control and life support, and thermal control. As NASA noted in its Transition Report, based on structural integrity analyses the ISS platform has significant structural life well beyond 2028 and many of its modules, particularly those launched in the latter years of ISS assembly, are likely to have structural life well into the 2030s.

Our July 2018 audit highlighted the significant funding required to operate and maintain the Station as one of the biggest challenges to continuing ISS operations past 2024, at least under the current funding model.[7] Congress directed the Agency to include in its ISS Transition Report "the impact on deep space exploration capabilities, including a crewed mission to Mars in the 2030s, if the preferred service life of the ISS is extended beyond 2024 and NASA maintains a flat budget profile."[8] Despite this directive, the ISS Transition Report is silent on this issue. Nonetheless, in previous work we have found that extension of the Station's service life beyond 2024 will continue to require $3 to $4 billion per year. This amount is currently about half of NASA's annual human space flight budget and therefore directly impacts the Agency's ability to fund components NASA has deemed necessary for its deep space exploration goals including the Space Launch System, Orion Multi-Purpose Crew Vehicle, Lunar Gateway, lunar landers, and spacesuit development unless NASA receives a marked and sustained increase in funding.[9]

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[5] National Aeronautics and Space Administration Transition Authorization Act of 2017, Pub. L. No. 115-10, 131 Stat. 28 (2017).

[6] 51 U.S.C. § 70907(a)(3). In February 2019, the Senate Committee on Commerce, Science, and Transportation introduced S. 584, Advancing Human Spaceflight Act, which would authorize the ISS through 2030, direct NASA to develop a next-generation spacesuit to enable human exploration beyond low Earth orbit, and establish the goal of a permanent human presence beyond Earth as national policy. In March 2019, the Committee also introduced S. 919, Space Frontier Act of 2019, which would also authorize the ISS through 2030 and includes a provision to streamline and update regulation of commercial space launch services and commercial satellite remote sensing.

[7] IG-18-021.

[8] Pub. L. No. 115-10 § 303 (c), 131 Stat. 28.

[9] The Lunar Gateway is envisioned as a small space station in orbit around the Moon that will contain living quarters for astronauts, a laboratory for science and research, and ports for visiting spacecraft in support of both human and robotic missions. NASA sees the Gateway as the home base for astronaut expeditions on the Moon and future human missions to Mars. NASA plans to build a scaled-down version of the Gateway in time for a 2024 Moon landing consisting of a Power and Propulsion Element (scheduled to launch in 2022) and a small living space with science and operational capabilities.

Balanced against the expense, an extension to 2028 or beyond would enable NASA to continue critical on-orbit research into human health risks and demonstrate the technologies that will be required for future missions to the Moon and Mars. At this time, NASA forecasts that research for at least 6 of 20 human health risks requiring the ISS for testing and 2 of 37 technology gaps will not be completed by the end of September 2024 when the Station's current authorization to operate expires. In addition, research into 2 other human health risks and 2 additional technology gaps is not scheduled to be completed until sometime in 2024, meaning that even minor schedule slippage could push completion past the end of that fiscal year.

While NASA may be able to find alternative, ground-based or Lunar Gateway testing options for certain health risks and technology demonstrations, Agency officials have stressed that research into other areas will continue to require the Station's unique, long-duration microgravity environment. In July 2018, we reported that although NASA has generally met or exceeded its goal of 35 hours per week dedicated to research aboard the ISS, the amount of crew time available for research continues to be a major factor limiting greater utilization on-orbit given that many investigations require participation by the crew in some capacity, particularly human health research.[10] If the remaining health risks and technology demonstrations cannot be fully tested on the ISS, NASA may have to accept higher levels of risk than planned for future exploration missions.

Delays in commencement of commercial crew transportation capabilities likely will result in significant decreases in research conducted on the ISS.[11] If commercial transportation is delayed beyond February 2020, there is a risk the U.S. portion of the ISS could be forced to operate with only 2 crew members or possibly just a single crew member beginning in April. This reduction in crew will significantly decrease the amount of on-board scientific research because Station crew will need to focus mainly on visiting spacecraft operations and ISS maintenance. NASA has several key technology demonstrations planned for 2020 required for deep space exploration including water processing and fire containment, research that could be compromised by a reduction in crew. To help mitigate the risk of limited crew availability, the Agency is implementing a recommendation from our July 2018 report to develop plans for additional one-year astronaut missions to the ISS.

In April 2017, we reported on NASA's development of new spacesuits, another key technology demonstration project that will utilize the Station's microgravity environment.[12] The Shuttle-era spacesuits NASA astronauts currently use on the Station need to be replaced due to aging and attrition, and the Agency expects a demonstration unit of the replacement suits to be delivered to the ISS for testing in 2023. Our 2017 report highlighted a number of current spacesuit design inadequacies and

[10] IG-18-021.

[11] Since NASA's Space Shuttle was retired in 2011, the Russian Soyuz spacecraft has been the only vehicle capable of transporting crew to the ISS. NASA's contract for seats on the Soyuz to transport U.S. astronauts to the ISS ensures access to the Station through early 2020. As the Government Accountability Office (GAO) reported in January 2018, delays in the development and certification of commercial crew vehicles could result in these vehicles not being available to ferry crew to the ISS before NASA's current contract for Soyuz seats ends. Therefore, if commercial crew providers are not ready by that time and NASA is unable to purchase additional Soyuz seats, NASA could face a gap in its access to the ISS thereby limiting crew availability. GAO, *NASA Commercial Crew Program: Continued Delays Pose Risks for Uninterrupted Access to the International Space Station* (GAO-18-317T, January 17, 2018).

[12] NASA OIG, *NASA's Management and Development of Spacesuits* (IG-17-018, April 26, 2017).

health risks that NASA continues to manage, including the limited number of sizes available.[13] This issue was brought to the forefront 4 months ago when NASA planned, but was not able to execute, its first all-female spacewalk because both women required the same size hard upper torso but only one such unit was available. The replacement spacesuits are designed to address many of the inadequacies and health risks posed by the current spacesuit and are planned for use on the ISS, Lunar Gateway, and ultimately in support of a Moon landing.

Research managed by the Center for the Advancement of Science in Space (CASIS) also contributes to NASA's ability to fully utilize the ISS. Since August 2011, CASIS has managed non-NASA research activities—those performed by commercial companies, academia, and other government and non-government entities—on the U.S. portion of the ISS known as the National Laboratory (National Lab). NASA initially awarded CASIS a 10-year, $136 million cooperative agreement to manage, develop, and stimulate interest and use of the National Lab. In July 2017, the Agency extended the CASIS cooperative agreement to September 2024, increasing its total cost to $196 million.

However, since 2013 we have raised concerns about CASIS's performance and its ability to spur ISS research; specifically, we found that fostering a commercial interest in ISS-based research and recruiting users for the National Lab has proven to be a significant challenge for CASIS.[14] In particular, CASIS had difficulty attracting commercial companies because ISS research costs were significantly higher than ground-based research. In January 2018, we reported that CASIS had not met a majority of the expectations set out in its cooperative agreement with NASA and the organization had underperformed on tasks important to achieving NASA's goal of building a commercial space economy in low Earth orbit.[15] In that report, we also found that NASA shared responsibility for CASIS's failure to meet expectations because the Agency did not actively oversee the organization's technical performance and generally allowed CASIS to operate independently.

In the 18 months since we issued our January 2018 report, NASA and CASIS have reported improvement in both oversight and performance. Specifically, in support of closing six of the seven recommendations from that audit, CASIS increased staffing in areas critical to business development; implemented an on-line Implementation Partner Portal; and made improvements to the implementations partner selection process to improve transparency, fair and open competition, and protection of partner proprietary data. NASA also has established measurable metrics in the CASIS annual program plan and provided CASIS management with constructive, regular feedback. In its FY 2018 Annual Report, CASIS reported a record year including $150 million in external, non-NASA funding to support its portfolio, a 50-percent increase over FY 2017, and the strongest year for growing its research and development portfolio by selecting 50 new projects. However, as NASA reiterated in its June 2019 feedback to CASIS, sustained focus on exceeding metrics, increasing available seed funds, managing administrative costs, finding and developing new users for the National Lab, and improving mechanisms to foster business-to-business relationships are required to expand commercialization in low Earth orbit and maximize utility of the ISS.

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[13] Developed beginning in 1974 and first flown in 1981, the spacesuits currently aboard the ISS were originally designed for the Space Shuttle Program during a time when the astronaut corps was not as diverse in size as they are now. Over the last 40 years, each suit has been partially redesigned and completely refurbished multiple times, but the sizes available include only medium, large, and extra-large.

[14] NASA OIG, *NASA's Efforts to Maximize Research on the International Space Station* (IG-13-019, July 8, 2013).

[15] NASA OIG, *NASA's Management of the Center for the Advancement of Science in Space* (IG-18-010, January 11, 2018).

Commercialization Efforts on the ISS and in Low Earth Orbit

In addition to its work with CASIS, NASA has taken several concrete steps over the past decade to meet its goal of increasing commercialization of the ISS and low Earth orbit, the largest of which is supporting the commercial launch market by introducing competition and developing new domestic capabilities. In April 2018, we reported that through 2017 NASA had awarded $17.8 billion towards development of commercial launch vehicles and spacecraft to deliver cargo and crew to and from the ISS through 2024.[16] This funding—more than $9 billion for cargo delivery and over $8 billion for development of a crew transportation capability to deliver astronauts to the ISS—helped pay for development of two launch vehicles, four spacecraft for cargo deliveries, and two spacecraft for crew transportation. These cargo and crew transportation efforts represent NASA's most significant investment in the commercialization of low Earth orbit.

As part of NASA's vision to commercialize ISS activities and low Earth orbit, the Agency is considering a range of options to subsidize commercial partners to foster development of a private market while maintaining funding to the ISS. These options include augmenting the Station with privately developed modules, combining portions of the current platform with a new private platform, and deploying an entirely new free-flying platform that will allow NASA to retire and deorbit the ISS. NASA also recently announced a commercialization policy to allow private astronauts and commercial and marketing activities on the ISS.[17] In addition, NASA is assessing whether its long-term research requirements, which are similar to those of the current ISS Program, could be met with platforms or modules that do not require a vehicle as complex and expensive to maintain as the ISS. In this way, NASA's vision presents a more measured and incremental approach to commercialization that matches the responses the Agency received from private companies to last year's request for commercialization studies, all of which indicated the commercial market needed substantial government support to be viable in the short-term.

In May 2018, before the Senate Subcommittee on Space, Science, and Competitiveness, I testified that NASA's then-plan to privatize the ISS by the beginning of FY 2025 remained a controversial and highly debatable proposition, particularly with regard to the feasibility of fostering increased commercial activity in low Earth orbit by that time.[18] Specifically, we questioned whether a sufficient business case exists under which private companies can create a self-sustaining and profit-making business independent of significant government funding. In particular, I stated that it is unlikely a private entity or entities would assume the Station's annual operating costs, which was projected at $1.2 billion in 2024.[19] Such a business case requires robust demand for commercial market activities like space tourism, satellite servicing, manufacturing of goods, and research and development, all of which have yet to materialize.

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[16] This does not include all cargo transportation costs through 2024. As of December 2017, NASA had to purchase at least 10 more missions to meet minimum order requirements, which in turn will increase the Agency's funding beyond $20 billion when those task orders are awarded. NASA OIG, *Audit of Commercial Resupply Services to the International Space Station* (IG-18-016, April 26, 2018).

[17] See Introduction to ISS Commercial Use Policy, https://www.nasa.gov/leo-economy/commercial-use/introduction-to-policy (accessed July 3, 2019).

[18] Examining the Future of the International Space Station. Before the Senate Subcommittee on Space, Science, and Competitiveness, 115th Congress (2018) (statement of NASA Inspector General Paul Martin).

[19] NASA's FY 2020 budget forecasts $983.1 million will be needed in 2024 for Station operations.

Last month, NASA announced a new interim directive outlining use of the ISS for commercial and marketing activities.[20] The directive addresses manufacturing of goods on the ISS for commercial sale on Earth, hosting private astronauts on the Station, and allowing NASA astronauts to support commercial activities on the Station by allocating up to 5 percent of Station resources for these commercialization efforts. To reduce uncertainty and allow companies to develop business plans, NASA also published a pricing policy for delivery of cargo to and from the Station and the cost of resources available to private astronauts while on the ISS. For example, cargo prices range between $6,000 and $18,000 per kilogram round trip while NASA plans to charge around $1 million for a one-month stay or about $35,000 per day to host a private astronaut. This hosting cost does not include the expense of transporting the private astronaut to and from the ISS on a commercial launch vehicle. NASA acknowledges these prices are substantially subsidized—representing a small portion of NASA's actual costs—but are another effort to foster a commercial market in low Earth orbit.

While all of these actions are positive steps, the effectiveness of NASA's current plan to commercialize ISS operations while continuing to provide substantial Agency funding remains to be seen, particularly with regard to the feasibility of fostering increased commercial activity in low Earth orbit. Specifically, the new commercialization policy does not have performance metrics to evaluate how effectively NASA is nurturing commercial markets, although the Agency did agree with a recommendation we submitted during our review of the interim directive to add language establishing future metrics. Further, additional clarity may be needed on how to manage commercial mission and private astronaut requests and how their activities could impact commercial crew and cargo missions and crew capacity on the ISS. For example, the policy does not address pricing for commercial enterprises that may require shorter or longer timeframes than a 30-day mission. While the policy represents a more realistic and incremental approach than the original plan envisioned by the Agency's FY 2019 budget request, the bottom line remains that NASA has struggled over the past 20 years to stimulate commercial interest on the ISS. Moreover, commercial entities have not developed a successful business case for manufacturing and other commercial activities in low Earth orbit, at least in the short or mid-term.

ISS International Partnerships Beyond 2024

Lastly, any discussion of the future of the ISS needs to consider the level of support from NASA's current international partners—Russia's Roscosmos space agency, the European Space Agency (ESA), the Canadian Space Agency, and Japan Aerospace Exploration Agency—whose continued participation hinges on issues ranging from international politics to differing space exploration goals. For example, the outlook for Russia's continued involvement with the ISS is uncertain given the current state of relations between the two countries. Russia's role is critical to sustaining ISS operations because it controls the Station's propulsion system and propellant and is currently the only partner capable of providing crew transportation to and from the ISS. In addition, NASA's exemption from the Iran, North Korea, Syria Nonproliferation Act (INKSNA) for ISS efforts expires on December 31, 2020, and failure to extend the Agency's waiver would prohibit NASA from paying Roscosmos for services

[20] NASA Interim Directive 8600.121, *Use of International Space Station (ISS) for Commercial and Marketing Activities* (June 6, 2019).

performed on the Station after that point.[21] Consequently, approval from Congress to further extend the exemption is required in order to maintain ISS operations as currently structured into the future.

The participation of NASA's other current international partners is also unsettled at this time given their desire to consider exploration missions beyond the ISS. For example, ESA has announced its intent to partner with NASA on the Lunar Gateway and other lunar activities. However, ESA and several other space agencies have also expressed interest in working with the Chinese Space Agency aboard its space station planned for operation in 2022.[22] Given that NASA's current international partners are responsible for 23 percent of the Station's shared annual costs, the loss of one or more of these space agencies could have a significant impact on NASA's ability to sustain ISS operations past 2024.

Ultimately at some point, whether in an emergency or because its useful life has ended, NASA will need to decommission and deorbit the Station. Ideally, this will occur via a controlled, destructive reentry into the Earth's atmosphere. NASA estimates a controlled reentry of the ISS will take up to 3 years to execute and cost approximately $950 million. However, the Agency has not completed the necessary tasks to execute such a deorbit. In January 2017, NASA completed a draft plan to address various deorbit scenarios and received and dispositioned comments from Roscosmos. As of July 2019, the Agency has received technical concurrence from all partners and is awaiting final Russian space agency programmatic concurrence. Although NASA engineers continue to work on the technical details of deorbit scenarios, the Agency presently does not have the capability to ensure a controlled deorbit of the ISS in the event of an emergency.

Conclusion

As NASA turns its attention to returning humans to the Moon by 2024, concrete plans for the future of the ISS need to be resolved. Whether it be extension, increased commercialization, or retirement, the timing of each of these decisions has a cascading effect on the funding NASA will be able to dedicate for space flight operations in low Earth orbit, its ambitions for establishing a permanent presence on the Moon, and ultimately sending humans to Mars. The sooner NASA, the Administration, and Congress agree on a definitive path forward for the future of the ISS, the better NASA will be able to plan the future of on-board research and commercialization in low Earth orbit.

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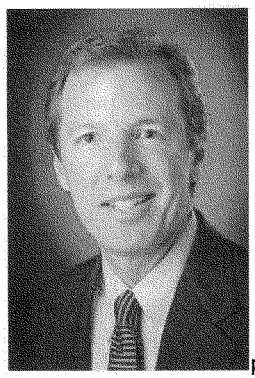
[21] The Iran Nonproliferation Act of 2000, Pub. L. No. 106-178, 114 Stat. 38 (2000) discouraged U.S. dealings with states that would proliferate nuclear materials to Iran and required the President to report payments made to Russia in connection with the ISS. The Iran Nonproliferation Amendments Act of 2005, Pub. L. No. 109-112, 119 Stat. 2366 (2005) amended the Iran Nonproliferation Act of 2000 to allow for unreported payments to Russia until 2016 for obligations under the Agreement Concerning Cooperation on the Civil International Space Station, signed on January 29, 1998, and entered into force March 27, 2001. The 2005 Act was also amended to apply to Syria as well as Iran. The North Korea Nonproliferation Act of 2006, Pub. L. No. 109-353, 120 Stat. 2015 (2006) amended this legislation to include North Korea and renamed the statute accordingly [hereinafter INKSNA]. The Space Exploration Sustainability Act, Pub. L. No. 112-273 (2013) amended INKSNA to extend NASA's exemption from reporting payments to Russia in connection with the ISS until 2020.

[22] In March 2019, China announced it would begin construction of a new space station able to host up to three astronauts. In June 2019, the United Nations Office for Outer Space Affairs announced that 9 experiments had been selected for implementation aboard the Chinese space station representing work from 17 member states.

Paul K. Martin
NASA Inspector General



Paul K. Martin was confirmed by the United States Senate as NASA Inspector General on Nov. 20, 2009.

Prior to his NASA appointment, Martin served as the Deputy Inspector General at the U.S. Department of Justice, Office of the Inspector General (OIG). In that capacity, he assisted the Inspector General in managing the audit, inspection and investigative activities of the office's 425 employees. From 2001 to 2003, he served as Counselor to the Inspector General, and from 1998 to 2001 he served as Special Counsel to the Inspector General.

Before joining the Department of Justice OIG, Martin spent 13 years at the U.S. Sentencing Commission in a variety of positions, including 6 years as the Commission's Deputy Staff Director. Martin was one of the Sentencing Commission's first employees when the agency was created in 1985, and helped develop the first set of federal sentencing guidelines.

Martin began his professional career as a reporter with The Greenville News, a daily newspaper in Greenville, SC. He holds a B.A. in Journalism from The Pennsylvania State University and a Juris Doctor from The Georgetown University Law Center.

Martin is married to Rebekah Liu, an attorney working in Washington, DC. A native of Pittsburgh, PA, he and his wife have three daughters.

Chairwoman HORN. Thank you, Mr. Martin. Mr. Stallmer, you're recognized for 5 minutes.

TESTIMONY OF MR. ERIC W. STALLMER, PRESIDENT, COMMERCIAL SPACEFLIGHT FEDERATION

Mr. STALLMER. Thank you so much.

Chairwoman Horn, Ranking Member Babin, and distinguished Members of the Subcommittee, thank you for inviting the Commercial Spaceflight Federation to discuss our members' views on the state of the U.S. commercial space industry. We also appreciate the opportunity to review NASA's plans for the International Space Station and examine future activities in low-Earth orbit.

In addition to NASA's utilization of the ISS, the United States now has a vibrant, highly capable commercial space sector that is beginning to maximize the utility of the ISS and is demonstrating a growing LEO economy. As we look to the future in which the government is one of many customers, it needs to be reduced—it needs to reduce the burdens on the system and moves at the speed of business.

Because of NASA's foresight and cultivation of this industry, American companies support space exploration and national security needs today in addition to the commercial marketplace. Unlike when the first pieces of the ISS were being launched into LEO, we now have an exciting and diverse commercial marketplace, one which NASA can partner to achieve its goals. Twenty years after Americans launched the first module of ISS, the current Administration, NASA, and Congress have established a national commitment to ensure American leadership in low-Earth orbit to establish a permanent human presence in low-Earth orbit and enable the development of a commercial and industrial ecosystem.

Long-term, sustainable human presence and commercial activity in LEO requires an integrated effort. This includes stimulating greater demand for space-based industrial R&D and spaceflight products and services to LEO, the development of commercial space stations and space habitats, and routine transportation of astronauts and cargo to and from LEO. Public-private partnerships with commercial companies are fundamental to developing these capabilities.

As you look to ensure America's leadership in space, you must ensure we—this includes rapid innovation. Last month, NASA released guidance for its LEO economy initiative. CSF commends Administrator Bridenstine and the entire NASA team for recognizing the success of the commercial industry, incorporating best practices, and updating objectives to accelerate the development of these important capabilities.

As NASA works to implement this initiative, we recommend the following few ideas:

- Encourage NASA to adopt the best elements of its successful efforts to commercialize space such as the Commercial Orbital Transportation Services, COTS, program and the Commercial Crew Program.
- Maintain competition throughout the life of a program to encourage innovation and cost reduction. Multiple providers offer redundant capabilities in the event of delays or challenges.

- Support of a complete utilization of the ISS through at least 2028 in a timely, seamless transition process toward commercial space stations to ensure that the U.S. maintains a continuous human presence in low-Earth orbit.
- Provide certainty and predictability by communicating a clear plan for the transition to commercial systems. That means that if NASA is going to charge for ISS-related services, those prices should change infrequently and with substantive advance notice.
- And resist the temptation to try to make money now at the expense of future LEO market expansion. This would be the very definition of killing the goose that lays the golden eggs.

Regularly engage with industry, which NASA does a great job with, to understand and incorporate new commercial capabilities as they evolve as opposed to requesting the business—requesting that business fit within NASA's plans.

Grant users complete control over intellectual property developed on ISS and avoid competing with private industry.

We are ready to take the next step with NASA, and we look forward to continuing to work with this Committee to establish a permanent human presence in low-Earth orbit and enable the development of strong commercial ecosystem.

Chairwoman Horn, Ranking Member Babin, I really—and Members of the Committee, I really appreciate the invitation to testify before you today, and I thank you for your attention. I look forward to all your questions.

[The prepared statement of Mr. Stallmer follows:]

Testimony of Eric Stallmer
President,
Commercial Spaceflight Federation

Before the Committee on Science, Space, & Technology
Subcommittee on Space and Aeronautics
United States House of Representatives
Wednesday, July 10, 2019

Chairwoman Horn, Ranking Member Babin, and distinguished members of the Subcommittee—thank you for inviting the Commercial Spaceflight Federation (CSF) to discuss our members' views on the state of the U.S. commercial space industry. We also appreciate the opportunity to review NASA's plans for the International Space Station (ISS) and and examine future activities in low-Earth orbit (LEO). In addition to NASA's utilization of the ISS, the United States now has a vibrant, highly capable commercial space sector that is beginning to maximize the utility of ISS and demonstrating a growing LEO economy and demand for operations in LEO, and ultimately closing more business cases. As we look to the future, and transition to a new paradigm in which the Government is one of many customers, the Government needs to reduce burdens on the system by moving at the speed of business.

CSF is the leading national trade association for the commercial space industry, with more than 85 member companies and organizations across the United States. Founded in 2006, CSF is focused on laying the foundation for a sustainable space economy and democratizing access to space for scientists, students, civilians, and businesses. CSF members are responsible for the creation of thousands of high-tech U.S. jobs driven by billions of dollars in investment. Through the promotion of technology innovation, CSF members are guiding the expansion of Earth's economic sphere, bolstering U.S. leadership in aerospace, and inspiring America's next generation of engineers, scientists, and explorers.

NASA has embarked on an ambitious effort to commercialize low-Earth orbit (LEO), to establish a long-term presence on the surface of the Moon, and to send astronauts to Mars. These bold commitments should be commended. Over the last two decades, NASA has fostered a nascent domestic spaceflight industry into becoming a highly diverse and capable portfolio of companies. NASA has invested in private development, used its purchasing power to serve as an anchor customer, and enabled private companies to develop, own, and operate their own human spaceflight hardware to serve both public and private needs. Because of the agency's foresight and meticulous cultivation of this industry, American companies support the critical space exploration and national security needs today, in addition to the commercial marketplace. Unlike when the first modules of the ISS were being launched and assembled in low-Earth orbit, NASA now has a vibrant and diverse commercial marketplace with which it can partner with to achieve its objectives.

Policymakers have recognized the benefits of these kinds of partnerships since the earliest days of the space program. The National Aeronautics and Space Act of 1958 outlines one of NASA's core missions is: "[t]o seek and encourage, to the maximum extent possible, the fullest commercial use of space." National Space Policies from both Democratic and Republican administrations have stressed the importance of the commercial space sector. And Space Policy Directives 1, 2, and 3, each issued over the past two years, take further steps to strengthen the partnership between Government and industry and to

remove barriers to industry growth. And, under your leadership, this Subcommittee has taken important steps to facilitate commercial space industry development.

Today, I will outline CSF's perspectives as to how we all can collectively advance our Nation's space goals through innovative, strategic partnerships with American industry.

I. The ISS Today: A Vibrant, Highly Capable Commercial Space Sector

The International Space Station (ISS) is one of the greatest achievements of our time and an unqualified success by any measure. It is an engineering marvel, built and operated in concert with our partners around the world. It is a treasured national laboratory, contributing to key research breakthroughs in science, and it represents the longest ever sustained human presence in space. It is the foundation of humanity's voyage to the stars, and increasingly, a port for commercial activity. In the more than 18 years of crewed operation on the ISS, thousands of researchers on the ground in more than 100 countries have conducted more than 2,500 experiments in microgravity, and with operational cargo flights and, soon, crew flights achieving a steady flight cadence that number will continue to grow.[1]

Thanks in large part to NASA's leadership, pathfinding, and partnerships with the private sector in the decades since, a broad and dynamic space industry has emerged. Since 2000, investors have supported 375 private space companies with nearly $19 billion of private capital.[2] As NASA continues to drive the frontier outward with groundbreaking research in space, the commercial sector is making space affordable and accessible to everyone.

Today, the United States is enjoying a renaissance in space, with commercial space enterprises playing a leading role. American companies continue to make significant progress driving commercial and industrial use from ISS and LEO. Allow me to update the Subcommittee on the commercial space industry's recent major milestones:

- A growing number of companies are restoring and expanding America's human spaceflight capabilities. This year SpaceX—in close partnership with NASA—will launch American astronauts to space in an all-American system, ending the country's drought on orbital human spaceflight capability left by the retirement of the Space Shuttle in 2011. Already, SpaceX and NASA conducted a successful flight qualification mission of the Crew Dragon spacecraft in March. Virgin Galactic and Blue Origin have flown over two dozen NASA Flight Opportunities Program technology development payloads across these test flights, affording researchers robust and cost-effective access to the valuable microgravity environment. Meanwhile, both companies plan to fly spaceflight participants to space for revenue by the end of the year.
- Sierra Nevada Corporation's (SNC) Dream Chaser spacecraft—in an uncrewed cargo configuration—passed a key milestone in its development to be the third commercial cargo vehicle for the International Space Station.
- Maxar Technologies is looking at feasibility of habitable space platforms for building commercial satellites and how they might unlock new capabilities and business paradigms.
- NanoRacks is the single largest private investor on the International Space Station. The company has invested $40 million of private capital and its investments continue to grow. Most recently NanoRacks made significant strides in building a new airlock to attach to the ISS, which will be the first permanent commercial structure on the ISS since its construction. The airlock is slated to launch to the ISS in 2020 and NanoRacks has already signed commercial contracts for its use. A couple quick numbers. NanoRacks has launched nearly 800 payloads to the ISS, including 243

[1] NASA. Available at: https://spacenews.com/international-experiments-selected-to-fly-on-chinese-space-station/

[2] Proprietary Data, Space Angels, September 30, 2018.

satellites. Those numbers include payloads from 34 countries over 35 total launches and over $50 million of revenue.

- The ISS National Lab is a key driver of private activity on board the ISS. Acting as a space integrator, ISS National Lab has more than tripled direct NASA funding through external, non-NASA funding to support a robust industrial R&D portfolio that benefits life on earth. Private sector projects accounted for more than 70 percent of the 74 payloads delivered to the ISS National Lab in FY18. ISS National Lab has directly funded commercial implementation partners, such as NanoRacks and Made In Space, to the tune of over $30 million in order to support users' R&D work. 15 of the 16 commercial facilities on board the ISS were launched by the ISS National Lab. Finally, the ISS National Lab has launched over 360 R&D payloads to the ISS.
- Axiom and Bigelow are developing commercial space habitats, and each has made major technical progress over the past year.
- Made In Space has developed and demonstrated the ability to manufacture a wide variety of materials and objects in microgravity. These include spaceworthy 3D printable materials, exotic, low loss, high bandwidth optical fiber. These technologies have the potential to disrupt billion dollar industries in telecommunications and satellite manufacturing. Made In Space is also developing several other payloads that will demonstrate the proof of potential of manufacturing high strength, high value metal objects in microgravity, ceramics, industrial crystals, and other materials. Made In Space has more than ten manufacturing payloads in operation or in development for the ISS.
- TechShot will launch the first-ever 3D printer capable of manufacturing human tissue in the microgravity condition of space. These innovations will also provide improved models of disease that could help scientists uncover the mechanisms behind a wide range of conditions affecting people on Earth.
- Space Tango designs, builds and operates facilities on the ISS to support R&D and manufacturing of technology and biomedical applications in microgravity. Space Tango's first platform, TangoLab-1, was installed on the ISS in August of 2016 with a second facility installed on the SpaceX CRS-12 mission in August of 2017. In November 2018, Space Tango unveiled plans for its ST-42 scalable manufacturing platform which is envisioned as an autonomous free-flying facility for on-orbit manufacturing of technology and biomedical products with flights beginning in the mid-2020s.
- Arizona State University has worked closely with NASA over the life of the International Space Station (ISS) to study the effect of the microgravity environment of spaceflight on microbial responses, especially those that are important for causing infectious disease in astronauts and biofouling spacecraft environmental life support systems. These critical factors will not only enable NASA to send humans beyond low Earth orbit (LEO) and travel to deep space, they also provide innovative concepts with potential for translation back to Earth to benefit the general public.

These recent achievements are just a few of many by the commercial industry, and they set the stage for even greater accomplishments the rest of this year and beyond for a broad set of stakeholders.

II. Maximizing use of the International Space Station and Transitioning to Commercialization and Industrialization

20 years after Americans launched *Unity*, the first of three node modules of the ISS, President Trump, NASA and Congress have established a national commitment to ensure American leadership in low-Earth orbit—not just as a quick pass-through to cislunar space and the Moon, but to establish a permanent human presence in low-Earth orbit and enable the development of a sustainable commercial and industrial

ecosystem. This will foundation provide the spaceflight community a valuable proving ground for NASA's goal of being one of many customers for commercial services and capabilities in LEO.

This ambitious objective should be applauded and, if executed appropriately, will serve to reinforce American leadership in space as international competitors like China focus their own efforts in low-Earth orbit. In June 2019, China announced that 17 nations will fly nine experiments on the Chinese Space Station.[3] The Chinese Space Station will provide external platforms for experimental payloads and 16 experiment racks that can support 11 disciplines such as space medicine, life science, and microgravity physics and material science. Opening up the Chinese Space Station to international participation is part of a wider effort by China to demonstrate its own technological growth while diminishing the perception of American superiority. It seeks to strengthen its own diplomatic ties with various nations by offering new opportunities to stimulate their space technology and science sectors without the United States.[4] To retain its leadership in space exploration, the United States must ensure it remains the premiere spacefaring nation in low-Earth orbit—and American private industry is here to help.

Long-term, sustainable human presence and commercial activity in LEO requires an integrated effort that includes stimulating greater demand for space-based industrial R&D, and spaceflight products and services in LEO; the development of commercial space stations and space habitats, and routine transportation of astronauts and cargo to and from LEO. Public-private partnerships with commercial companies are fundamental to developing these capabilities. NASA's fiscal year 2020 budget request and Low Earth Orbit Economy initiative prudently highlight partnerships with commercial providers as a key tenet of this strategy.

Undeniably, NASA and its partners have conducted incredible, groundbreaking work aboard the International Space Station, and the Nation now proudly has the longest continuous human presence in space in history. As we consider our options for the future, we should look to build upon these achievements by leveraging the capabilities provided by a new commercial revolution in space. CSF companies are proud to be playing a role in this new era.

III. The Future of Low-Earth Orbit

As this Subcommittee looks to how best ensure the country's ongoing leadership in space, it must carefully review commercial LEO efforts to ensure responsible use of finite taxpayer dollars and to encourage, rather than hamper, rapid innovation.

Last month, NASA released guidance for its Low Earth Orbit Economy initiative. These plans and policies include pricing for facilities and resources that may be accessed on a reimbursable basis by commercial entities onboard the ISS; an announcement of opportunity and associated costs to fly private astronauts; calling for proposals on opportunities to stimulate demand, a commercial use policy for the ISS, and other initiatives. CSF commends Administrator Jim Bridenstine and the entire NASA team for recognizing the success of the commercial industry, incorporating best practices learned from the agency's years of partnership with private companies, and updating its strategic objectives to accelerate additional development of these important capabilities.

As NASA works to implement its Low Earth Orbit Economy initiative and expand human presence in space, CSF recommends the following:

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[3] China Daily, "17 nations to join China's space station," June 2019. Available at: http://www.china.org.cn/china/2019-06/13/content_74883265.htm

[4] Space News, "International experiments selected to fly on Chinese space station," June 2019. Available at: https://spacenews.com/international-experiments-selected-to-fly-on-chinese-space-station/

- Encourage NASA to adopt the best elements of its successful efforts to commercialize space, such as the Commercial Orbital Transportation Services (COTS) program and the Commercial Crew program. Whereas traditional cost-plus contracts can perversely incentivize companies to run over budget and behind schedule, NASA properly structured its commercial partnerships to develop new space capabilities at a rapid pace by implementing milestone-based agreements for development and firm-fixed-price contracting for services.
    - The COTS Program to develop uncrewed cargo resupply capabilities has been a clear success for NASA. A 2017 NASA Cost Analysis review of the program was direct in its assessment of the benefits of true public-private partnerships: "the COTS development and later the operational Commercial Resupply Services (CRS) are significant advances in affordability by any measure."[5]
    - NASA's Aerospace Safety Advisory Panel (ASAP), the most conservative and safety-focused group within the agency, identified the commercial, competitive structure used under the Commercial Crew program as a preferred model for NASA's future development activities for human spaceflight systems, particularly in NASA's return to the Moon.[6]
- Maintain competition throughout a program's life, instead of just during the bidding process, to encourage ongoing innovation and cost-reduction. Multiple operational providers also offer redundant capabilities to assure NASA's access to space in the event of delays or technical challenges with one system.
- Support the full and complete utilization of the ISS through at least 2028, and a timely, seamless transition process towards commercial space stations to ensure that the United States maintains a continuous crewed presence in LEO. Continued industrial research and development activities on the ISS in the immediate term will identify new markets or new applications in space and inform future platform development.
- One of the most important things that the Government can do for the LEO economy is to provide certainty and predictability in the LEO marketplace by developing and communicating a clear plan for the transition to commercial systems. It also means that if NASA is going to charge for ISS-related services, those prices should change infrequently and with substantial advance notice. Above all, NASA must resist the temptation to try to make money now, at the expense of future LEO market expansion: this would be the very definition of "killing the goose that lays the golden eggs." The ISS was created for non-economic reasons, and it should not now have to be justified entirely on its near-term economic value.
- Regularly engage with industry to understand and continually incorporate new commercial capabilities as they evolve, as opposed to requesting that business fit into solely within NASA's plans.
- Support uses of the ISS that are based on scalable business models, and then support the scale-up of those models with consistent and plentiful access to upmass, operations, and downmass.
- Invest in "proof of potential" payloads and business models to identify potential markets for LEO commercialization.
- Grant users complete control over intellectual property developed on the ISS.
- Avoid competition with private industry. Simply put, the domestic commercial industry will not mature if the world's largest and best funded space agency is competing with it. As a key example, NASA should not provide "free" space transportation to countries that are not already participants in the ISS program. These countries would otherwise commercially procure seats to space for their astronauts on American suborbital and orbital spaceflight systems.

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[5] Zapata, Edgar. An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions. American Institute of Aeronautics and Astronautics, 23 Oct. 2017, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf, pp. 1.

[6] https://spacenews.com/safety-panel-calls-on-nasa-to-apply-commercial-crew-lessons-for-artemis/.

- Support the increased use of ISS as a destination for private astronauts, as well as support for new commercial LEO platforms.
- Stress the importance of short-duration, "sortie" missions to the ISS. These missions, lasting one to two weeks in length, offer NASA the opportunity to conduct more frequent missions to space, promising greater scientific discovery and more opportunities for the astronaut corps to go to space than the current six month rotation missions allow. To reduce costs to the taxpayer, NASA should purchase seats on commercial missions to ISS to allow for a mixed NASA / commercial crew on these missions. Not only would this mission architecture better support NASA's objectives, it would also support the development of a marketplace for private passenger transportation to space.
- Establish a national microgravity policy initiative, informed by a Microgravity Decadal Survey. Microgravity research will stimulate the next technological and economic changes for the United States. As policy has recognized the importance of investment in artificial intelligence, similar policy needs to be established should foster the pursuit of innovation, technology development, and discovery where public.
- Microgravity Decadal Survey – microgravity research and development is critical to American leadership, discovery, exploration, and the development of the space economy. NASA, the National Science Foundation (NSF), and the National Institute of Health (NIH), should jointly fund the National Academies of Sciences, Engineering, and Medicine to carry out a microgravity decadal survey.
- Enhance utilization of the Flight Opportunities Program (FOP) for suborbital microgravity research. The Flight Opportunities Program enables low-cost access to environments where cutting edge research and development can be conducted. The Flight Opportunities Program is a key component of a microgravity R&D pipeline that contributes to the development of a robust low Earth orbit ecosystem. This pipeline can be strengthened by broadening the Flight Opportunities Program user community to include universities and academia, by allowing basic and applied science payloads to fly in addition to technology development payloads, and by enabling principal investigators (PIs) to fly alongside and tend to their payloads during flight.
- Assume a long-term view of LEO commercialization and avoid "taxing" early commercial efforts as a means to fund ISS operations or deep space in the short term.

IV. Conclusion

With the technological advancements and increased knowledge achieved through decades of work by NASA in deep space, including Mars, the United States is now well-positioned to build upon and surpass our past achievements in space. With NASA resources and expertise, coupled with American ingenuity, the principles of free enterprise, and the benefits of competition, the United States can do more in space than has ever been accomplished previously. We just need to appropriately recognize and leverage our advantages.

At long last, as we approach the half-century mark of the Apollo 11 mission, we are seeing the commercial sector investing in a broad swath of activities in partnership with NASA, from LEO to the Moon and beyond. We must further and accelerate this momentum, and CSF members know that anything is possible when you unleash the full innovative capacity of American industry.

We are ready to take the next step with NASA, and we look forward to continuing to work with this Committee to establish a permanent human presence in low-Earth orbit and enable the development of a strong commercial ecosystem. Chairwoman Horn, Ranking Member Babin, I appreciate your invitation to testify before the Committee today. Thank you for your attention, and I look forward to your questions.

Eric W. Stallmer

Eric Stallmer is the President of the Commercial Spaceflight Federation. CSF is the largest trade organization dedicated to promoting the development of commercial spaceflight, pursuing ever-higher levels of safety and sharing best practices and expertise throughout the industry. Under Stallmer's leadership, CSF has worked tirelessly to craft the modern Commercial Space Launch Act, as well as to promote innovation as a national policy to spur the economy and create high technology jobs. In addition, CSF works to develop industry standards and encourages further growth in the commercial spaceflight industry.

Stallmer has been recently appointed to the National Space Council Users' Advisory Group (UAG), where he has provided testimony at the 2nd National Space Council meeting. He serves as co-chair of the Federal Aviation Administration (FAA) Airspace Integration Aviation Rulemaking Committee (ARC) and is a member of the Space Launch and Reentry ARC and the Spaceport ARC. Stallmer is also a member of the FAA's Commercial Space Transportation Advisory Committee (COMSTAC).

Stallmer constantly promotes the industry and CSF member companies through his outreach to high-ranking government officials and high-profile media outlets. His professional comments have been featured in The Washington Post, Wall Street Journal, Bloomberg, NBC Today Show, ABC News, CBS News Radio, Fox News, The BBC, CNBC, SpaceNews and many more. Stallmer also promotes the mission of CSF through participation at multiple industry conferences throughout the year.

Stallmer has testified before both the House Committee on Science, Space, and Technology as well as the Senate Commerce committee. He recently testified at a hearing titled, "The Commercial Space Launch Industry: Small Satellite

Opportunities and Challenges." There he encouraged Congress to support policies that will facilitate growth and innovation in the industry, and maintain the American space sector's competitive leadership. He has served on numerous industry affiliated boards including
the Future Space Leaders Foundation and is the former Chairman of the Washington Space Business Roundtable.

Before working at CSF, Stallmer served as the Vice President of Government Relations at Analytical Graphics Inc. (AGI). Stallmer joined AGI in 2002. While there, Stallmer oversaw all Washington Operations and represented AGI's commercial off-the-shelf products and technology to defense, intelligence, Congress and civil government sectors within the aerospace industry.

Stallmer came to AGI from The Space Transportation Association (STA), a non-profit, industry trade organization providing government representation to companies with a vested interest in the U.S space launch industry. Prior to that, Stallmer worked on Capitol Hill in the office of then Congressman Tom Coburn.

For more than two and half decades, Stallmer has served as an Officer in the United States Army and Army Reserves. He was awarded the Bronze Star Medal for meritorious service while engaged in combat operations during Operation Iraqi Freedom. He has served as an Adjunct Professor of Military Science at Georgetown University and is currently assigned to the Pentagon in the Office of the Deputy Chief of Staff Army for Logistics, G-4.

Stallmer earned a Master of Arts Degree in Public Administration from George Mason University and a Bachelor of Arts Degree in Political Science and History from Mount Saint Mary College. He and his wife Amy live in McLean, Virginia with their three children, Charlie, Billy and Catherine.

Chairwoman HORN. Thank you very much, Mr. Stallmer. Professor Gabrynowicz.

TESTIMONY OF DR. JOANNE IRENE GABRYNOWICZ, EMERITA UNIVERSITY OF MISSISSIPPI, EDITOR-IN-CHIEF EMERITA, JOURNAL OF SPACE LAW

Dr. GABRYNOWICZ. Thank you. Chairwoman Horn, Ranking Member Babin, Members of the Subcommittee, thank you for giving me the opportunity to address NASA's Plans for the International Space Station and Future Activities in low-Earth orbit. I am delighted to respond. My full statement has been submitted for the record.

This statement addresses two points of space law that are particularly germane to plans to develop low-Earth orbit and the station. They speak directly to U.S. national interests, and there is a brief conclusion.

The first point is that the U.S. Government is internationally responsible for the activities of its nongovernmental space actors in perpetuity. The second point is that the legal obligations of the U.S. Government continue in force even after the transfer of station elements to nongovernmental commercial activities.

Regarding the first point that the United States has international responsibility for its nongovernmental space actors, Article 6 of the Outer Space Treaty provides that states, parties shall bear international responsibility for activities carried on by nongovernmental entities. It is crucial that article 6 of the Outer Space Treaty become central to the plans for commercial LEO development.

What constitutes responsibility is part of a growing body of law that has strengthened and matured in recent years. The United States Government and, through it, the United States taxpayer, will ultimately be responsible if it is deemed necessary because of events—will ultimately be deemed responsible for reparation if it is deemed necessary because of events arising from U.S. nongovernmental activities.

The government's responsibility exists in perpetuity. Withdrawing from or altering the Outer Space Treaty can change this, but that is an option that is not favored either by the space industry itself or by the United States Department of State.

A risk-sharing regime has been established for launching and reentry services. An analogous risk-sharing regime should be developed for all stages of the planned U.S. exploration roadmap in which nongovernmental actors will be part of the roadmap space activities.

The second legal point is that the United States' space station obligations remain in force even after transfer of station elements to nongovernmental commercial entities. The IGA, the International Space Station Intergovernmental Agreement, is a remarkable space law achievement. It has governed space station cooperation for 15 states over 3 decades, and it is described in more depth in my statement.

An essential feature of the International Space Station Agreement is that the transfer of ownership shall—and I quote, "The transfer of ownership shall not affect the rights and obligations of the parties," end quote. Therefore, if the space station transition

will include, quote, "transfer of all or parts of the station itself to commercial entities, including exercise of ownership or equipment," end quote, then the United States will still have the same rights and obligations that were in force prior to the transfer.

Changing post-transfer obligations will require at a minimum renegotiating post-transfer rights and obligations among space station partners. This moves the issue of U.S. post-transfer obligations more into the realm of politics than law, increasing uncertainty regarding the degree, the nature, and the duration of U.S. obligations.

In conclusion, there are legal and economic forces at play that can expose the United States Government and the U.S. taxpayer to substantial, recurring, long-term obligations that can result in hard-to-quantify financial obligations. Development of low-Earth orbit and the station is beginning at a time when the current value of the space economy is being questioned, when recent U.S. national space law increasingly places more of the cost of industry risk-taking onto the U.S. taxpayer, and when recently enacted U.S. national space law has created an uncertain legal environment by the use of illusory language that is mostly aspirational and repetitive and creates little black-letter law. It is in the U.S. national interest for the Subcommittee to consider these forces going forward.

Thank you for your work to develop the law of space.

[The prepared statement of Dr. Gabrynowicz follows:]

Written Testimony of

Joanne Irene Gabrynowicz

Before the

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

July 10, 2019

Chairwoman Horn, Ranking Member Babin, Members of the Committee: Thank you for giving me the opportunity to *address A Review of NASA's Plans for the International Space Station and Future Activities In Low Earth Orbit.* I am delighted to respond. I thank the Subcommittee for giving me this opportunity.

This statement addresses two points of space law that are particularly germane to plans to develop commercial low Earth orbit (LEO), including the *International Space Station (ISS)*. They speak directly to U.S. national interests. There is a brief conclusion.

The first point is that the US Government is internationally responsible for the activities of its nongovernmental space actors in perpetuity.[1]

The second point is that the legal obligations of the U.S. Government continue in force even after the transfer of its *ISS* elements to nongovernmental commercial entities.[2]

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[1] Treaty on Principles Governing the Activities of States in the Exploration and Outer Space Treaty]. Art. VI

[2] Agreement Among the Government of Canada, Governments of the Member States of the European Space Agency, the Government of Japan, the Government of the Russian Federation, and the Government of The United States of America Concerning Cooperation on the Civil International Space Station, Jan. 29, 1998, T.I.A.S. No. 12927, State Dep't No. 01-52, 2001 WL 679938 [hereinafter IGA].

I. The United States is Internationally Responsible for Its Nongovernmental Space Actors.

1. Art. VI of the Outer Space Treaty

Article VI states that the "activities of non-governmental entities in outer space...shall require authorization and continuing supervision."[3]

Art. VI is the legal source for recognizing nongovernmental actors as legitimate space actors. During Outer Space Treaty negotiations, it was the position of the Soviet Union that only States could be legitimate space actors. The U.S., of course, did not agree and took the position that private entities were also legitimate space actors. The compromise between the two positions was "to require authorization and continuing supervision" of nongovernmental space actors. To assure that nongovernmental space entities acted in accord with the law, Art. VI also provides that "States Parties...shall bear international responsibility for...activities...carried on...by non-governmental entities."[4]

It is crucial that Art. VI of the Outer Space Treaty is central to plans for commercial LEO development. What constitutes "responsibility" is part of a growing body of law that has strengthened and matured in recent years.[5] The United States Government—and through it—the U.S. taxpayer—will ultimately be responsible for reparation if it is deemed necessary because of events arising from U.S. nongovernmental space activities.

The Government's responsibility exists in perpetuity. Withdrawing from, or altering the terms of, the Outer Space Treaty can change this but that is an option not favored by the space industry[6] or the U.S. State Department.[7]

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[3] Outer Space Treaty, *supra* note 1.
[4] *Id.*
[5] James Crawford, Jacqueline Peel, Simon Olleson, *The ILC's Articles on Responsibility of States for Internationally Wrongful Acts: Completion of the Second Reading*, 12 EJIL 963 (2001).
[6] *Reopening the American Frontier: Exploring How the Outer Space Treaty Will Impact American Commerce and Settlement in Space, Before the S. Comm. on Commerce, Science and Transportation Subcommittee on Space, Science, and*

A risk sharing regime has been established for launch and reentry services. In it, a provider "shall obtain liability insurance or demonstrate financial responsibility in amounts to compensate for the maximum probable loss from claims" and the NASA Administrator "...shall prescribe taking into account the availability, cost, and terms of liability insurance, any contract between [NASA] and a provider may provide that the United States will indemnify the provider against successful claims". [8] An analogous risk sharing regime should be developed for all stages of the planned human exploration roadmap in which nongovernmental actors will be part of the roadmap's space activities.[9]

II. United States *ISS* Obligations Remain in Force Even After Transfer of Its *ISS* Elements to Nongovernmental Commercial Entities.

1. The International Space Station Intergovernmental Agreement

The *IGA* is a remarkable space law achievement. It has governed *ISS* cooperation for 15 States over three decades. It has undergone three iterations, first serving Cold War relationships, then meeting the opportunities presented by the fall of the Soviet Bloc, and now in the globalization era. It also facilitates some of Congress' most important policies and purposes for the U.S. space

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Competiveness, 115 Cong., (2017); Marcia Smith, *Congress Looking at Additional Measures to Facilitate Commercial Space,* (May 30, 2017, 12:00 AM), "the Senate hearing...focused on...has the 50-year-old OST been so overtaken by events that the United States should withdraw from or seek to renegotiate it. None of the witnesses supported either of those courses of action." https://spacepolicyonline.com/news/congress-looking-at-additional-measures-to-facilitate-commercial-space/

[7] *The Next Fifty Years of the Outer Space Treaty*, Remarks by Brian J. Eagan, Legal Advisor, U.S. State Department, (Dec. 7, 2016), "the Outer Space Treaty serves a constitutional role in the international legal framework for outer space...If the preparations for future space activities underway in the United States and other nations are any indication, the Treaty will serve this function well into its second half century and beyond." https://2009-2017.state.gov/s/l/releases/remarks/264963.htm

[8] National Aeronautics and Space Administration Transition Authorization Act of 2017, 51 USC § 20148; and Commercial Space Launch Activities § 50915

[9] 51 USC § 20302

program, that activities in space should be devoted to: peaceful purposes for the benefit of all humankind; the expansion of human knowledge; and, cooperation by the U.S. with nations and groups of nations[10]

The *IGA* is part of a three-tier legal framework that includes memoranda of understanding (MOUs), implementing arrangements and, other formal arrangements. It is based on and incorporates the space treaties and addresses 4 bodies of law: jurisdiction, torts, intellectual property, and criminal jurisdiction.

An essential feature of the *IGA* is that "[t]he transfer of ownership...shall not affect the rights and obligations of the Partners." This is equally applicable to the MOUs and implementing agreements.[11] Therefore, if the *ISS* transition will include "transfer of all or parts of the ISS itself to commercial entities"[12] including ownership, or "exercise of ownership or equipment"[13] then the United States will still have the same rights and obligations that were in force prior to the transfer. Changing post-transfer obligations will require, at a minimum, renegotiating post-transfer rights and obligations among the *ISS* Partners. This moves the issue of U.S. post-transfer obligations more into to the realm of politics than law, increasing uncertainty regarding the degree, the nature, and duration of U.S. obligations.

III. Conclusion

There are legal and economic forces at play that can expose the U.S. Government and the U.S. taxpayer to substantial, reoccurring, long-term obligations that can result in hard to quantify financial obligations. Development of LEO and the *ISS* is beginning at a time when the current value of the space economy is being questioned;[14] when recent U.S. national space law increasingly

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[10] P.L. 111-314 § 20102 (Dec. 18 2010)
[11] IGA, *supra* note 2, Article 6.3.
[12] Forecasting Future NASA Demand in Low-Earth Orbit: Revision Two – Quantifying Demand, pg. 1.
[13] IGA, *supra* note 2, Article 6.7.
[14] *Examining the Future of the International Space Station: Hearing Before the S. Subcomm. on Space, Science, and Competitiveness*, 115th Cong. 2 (2018)

places more of the cost of industry risk-taking onto the U.S. taxpayer;[15] and, when recently enacted U.S. national space law has created an uncertain legal environment by the use of illusory language that is mostly aspirational and repetitive and creates little black-letter law.[16] It is in the U.S. national interest for

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(statement of Pail K. Martin, Inspector General National Aeronautics and Space Administration). "[I]t is questionable whether a sufficient business case exists under which private companies can create a self-sustaining and profit-making business independent of significant Government funding...Candidly, the scant commercial interest shown in the Station over its nearly 20 years of operation gives us pause about the Agency's current plan." at 2 https://oig.nasa.gov/docs/CT-18-001.pdf , and,

STPI Questions $1 Trillion Space Economy Claims, By Marcia Smith, June 5, 2019 11:19 pm https://spacepolicyonline.com/news/stpi-questions-1-trillion-space-economy-claims/ ; and,

How Big is the Space Economy?, https://www.nesdis.noaa.gov/CRSRA/pdf/ACCRES_Lal_June_2019_Final.pdf, a

[15]Amanda Robert, *Commercial Spaceflight Industry Faces uncertain legal, regulatory environment*, Legal Newsline, (June 5, 2017) http://legalnewsline.com/stories/511121527-commercial-spaceflight-industry-faces-uncertain-legal-regulatory-environment "Linda Lipsen, chief executive officer of the American Association for Justice, [said] in a statement before the bill's passage that it would force victims and taxpayers to pay the costs of any private space travel crash or disaster. 'The bill jeopardizes both civilians on the ground and the passengers, whose right to hold anyone accountable would be eliminated,' quoting Linda Lipsen, regarding the *Commercial Space Launch Competitiveness Act* which "extends the indemnification regime and learning period".

[16] Together, the U.S. national space law statutes enacted since 2015 contain few provisions that actually authorize, require, or prohibit action. They do contain numerous findings, reaffirmations, and Sense of Congress provisions, none of which make law.

Regarding Sense of Congress resolutions, "A 'sense of' resolution is not legally binding because it is not presented to the President for his signature. Even if a 'sense of provision' is incorporated into a bill that becomes law, such provisions merely express the opinion of Congress or of the relevant chamber. **They have no formal effect on public policy and have no force of law**." (emphasis added). Christopher M. Davis, Cong. Research Serv. 98-825, "Sense of" Resolutions and Provisions", (2016).

For example, The National Aeronautics and Space Administration Transition Authorization Act of 2017 contains approximately 33 Sense of Congress provisions; 16 findings; and, 4 reaffirmations. The use of these non-law making provisions is a subject well worth its own paper.

places more of the cost of industry risk-taking onto the U.S. taxpayer;[15] and, when recently enacted U.S. national space law has created an uncertain legal environment by the use of illusory language that is mostly aspirational and repetitive and creates little black-letter law.[16] It is in the U.S. national interest for the Subcommittee to consider these forces going forward. Thank you for your work to develop the law of space.

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STPI Questions $1 Trillion Space Economy Claims, By Marcia Smith, June 5, 2019 11:19 pm https://spacepolicyonline.com/news/stpi-questions-1-trillion-space-economy-claims/ ; and,

How Big is the Space Economy?, https://www.nesdis.noaa.gov/CRSRA/pdf/ACCRES_Lal_June_2019_Final.pdf, a

[15]Amanda Robert, *Commercial Spaceflight Industry Faces uncertain legal, regulatory environment*, Legal Newsline, (June 5, 2017) http://legalnewsline.com/stories/511121527-commercial-spaceflight-industry-faces-uncertain-legal-regulatory-environment "Linda Lipsen, chief executive officer of the American Association for Justice, [said] in a statement before the bill's passage that it would force victims and taxpayers to pay the costs of any private space travel crash or disaster. 'The bill jeopardizes both civilians on the ground and the passengers, whose right to hold anyone accountable would be eliminated,' quoting Linda Lipsen, regarding the *Commercial Space Launch Competitiveness Act* which "extends the indemnification regime and learning period".

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For example, The National Aeronautics and Space Administration Transition Authorization Act of 2017 contains approximately 33 Sense of Congress provisions; 16 findings; and, 4 reaffirmations. The use of these non-law making provisions is a subject well worth its own paper.

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Prof. Gabrynowicz is Professor Emerita of space law, Director Emerita of the National Center for Remote Sensing, Air, and Space Law, Univ. of the Mississippi Law Center and the Editor-in-Chief Emerita, Journal of Space Law. She managed a faculty and staff off 6 - 8 people, 10 - 15 student workers, and a multi-million dollar budget.

Prof. Gabrynowicz has taught space law since 1987 and currently lectures at various universities including the University of Vienna, the Univ. of Warsaw, the Univ. of Copenhagen, and the Beijing Institute of Technology School of Law. She has lectured at the Harbin Institute of Technology School of Law, the China University of Political Science and Law, and the Beihang University (Beijing University of Aeronautics and Astronautics). In 2014 and 2015 she was invited by the Subcommittee on Space of the U.S. House Committee on Science, Space, and Technology to testify regarding the legality of asteroid mining and remote sensing law. She is currently a member of a Dept. of Interior Federal Advisory Committees and recently served on advisory committees for the National Academy of Science and the Commerce Dept.

Prof. Gabrynowicz briefed former U.S. Secretary of the Interior Gayle Norton as part of the Secretary's preparation for the Earth Observation Summit. Prof. Gabrynowicz briefed Frank A. Rose, Deputy Assistant Secretary for Space and Defense Policy, U.S. Department of State on legal aspects of orbital debris. She was the organizer and chair of the U.S. Federal Advisory Committee for the National Satellite Land Remote Sensing Data Archive.

Prof. Gabrynowicz was a founding faculty member of the Space Studies Department at the University of North Dakota, where she also served as its Director of Graduate Studies. From 1992-94, Prof. Gabrynowicz was a member of The Congress of the United States Office of Technology Assessment Earth Observations Advisory Panel. From 1994-96, she was a member of the National Research Council Committee that produced Bits of Power: Issues in Global Access to Scientific Data. In 1994-95, Prof. Gabrynowicz was awarded a NASA/American Society of Engineering Education Summer Faculty Fellowship from Goddard Space Flight Center where she also served as the 1997 Dean of the NASA Space Academy. Prof. Gabrynowicz has been invited by the U.S. Dept. of Commerce/NOAA, the U.S. National Research Council, the NASA Public Health Applications Program on Confidentiality and Geospatial Data, the Univ. of Cologne Institute of Air and Space Law to participate in a number of studies. Prof. Gabrynowicz was the managing attorney of a NYC law firm. She is a member of the American Bar Association Forum on Aviation and Space Law.

Prof. Gabrynowicz is a Director of the International Institute of Space Law (IISL) and is an official observer for the IISL to the UNCOPUOS Legal Subcommittee and has made a number of presentations to that group on space law issues. She was a member of the Advisory Board for the Permanent Court of Arbitration for the Draft Arbitration Rules on Disputes Relating to Outer Space Activities and has presented to the UN Institute for Disarmament Research. The UN Office of Outer Space Affairs (UNOOSA) invited Prof. Gabrynowicz to lecture on space law at all of its space law capacity building workshops for government officials and policymakers and she is the lead author for UNOOSA's remote sensing law curriculum. In 1999, the IISL invited Prof. Gabrynowicz to write and present the remote sensing law position paper at UNISPACE III. In 2001 she was awarded the Women in Aerospace *Outstanding International Award*. In 2011 she was awarded the IISL *Distinguished Service Award*. In 2014, Prof. Gabrynowicz received the China Institute of Space Law 1st *International Service Award*. In 2016, she was awarded the IISL *Lifetime Achievement Award*. In 2017, her work was recognized by the International Astronomical Union by naming an asteroid "(9002) Gabrynowicz"

Chairwoman HORN. Thank you, Dr. Gabrynowicz.

And before we move into questions, I'm going to take a moment of personal privilege to recognize two young women that are here today who I think are attending their second hearing in 2 days. And as we talk about these important issues, we have Elsa and Phaedra Curry, who I know have grown up in this area, that we talk about the importance of investing in the future and inspiring future generations, so I just want to take a moment—go ahead and stand up and say hello. Yes. This could be our next generation of scientists.

OK. Now at this point we'll begin our first round of questions.

So clearly there are many issues that we have to tackle, and it's important that as we're looking forward, we take all of these things into account about how we do this in a way that is sustainable, that is fiscally responsible, that encourages economic development, that allows NASA to move to a new iteration of what it means for us to explore and do science in space. So I'm going to try and get through a number of questions as quickly as possible because I think we've got a lot of important issues to tackle.

So, Mr. Gerstenmaier, I would like to start with you because when we're considering this transition and how we're going to ensure that our national interests and activities in low-Earth orbit can continue without, as Ranking Member Babin put it, a capabilities gap, I think that's one of the major questions that we have to face, as well as the legal issues in how we make that transition. There are many questions that need to be answered. I'm going to run through a few of them and I will submit some for the record but highlight a couple just to set the stage.

One, what are the costs to NASA and international partners of NASA's proposal to transition its ISS activities to potential commercial space station?

Two, have you carried out a cost-benefit analysis of all of the potential options for an ISS transition, including a NASA-developed smaller follow-on platform to handle NASA and international partner research?

Three, did you carry out a market analysis of commercial activity in low-Earth orbit?

Four, what is the value proposition for the U.S. taxpayer of NASA's planned investments in stimulating commercial LEO market supply and demand?

Five, how much is the commercial sector willing to invest? Who would own a commercial platform and who would own the data from NASA research conducted on a commercial space station? How much money would the commercial plan save as compared to NASA's current ISS expenditures, and when would those savings be realized?

And finally, what is the plan B if commercial platforms or alternative models of ISS operations don't prove feasible either technically or financially? So those are the stage setting.

I'd ask, Mr. Gerstenmaier, if you would address if you've carried out a cost-benefit analysis and if you know how much the commercial sector is willing to invest.

And, Mr. Stallmer, I'd ask that second question of you to follow on.

Mr. GERSTENMAIER. So the way we're kind of approaching this is last month we've—first of all, we spent 1 year asking the commercial sector what their interests were in low-Earth orbit and what they needed from NASA to understand the environment. And what we got clearly from those 12 studies was there was lots of uncertainty about what was available, what the constructs were, what they could do on station, how much it would cost, those kind of things. So what we did a month ago is we tried to define for them all these key parameters that they said they needed through these studies. So we gave them the five things I described to you that they have available. Now it's up to them to see if they can put together a business plan, generate revenue from that, where they see the market potential.

We define what NASA's long-term needs are, what NASA needs to spend annually for space station activities in the future. So we believe we've given the private sector now all the parameters they need to give us back a business plan, and then we can start to begin to answer that series of questions that you asked us about cost-benefit and analysis, et cetera.

So we've done our part. We've identified what's available, what we need, how much it will cost to find the constraints. It's now up to the private sector to give us back business plans that we can then start evaluating to turn that back around into cost-benefit analysis type of activities you described.

Chairwoman HORN. Thank you. Mr. Stallmer?

Mr. STALLMER. From a commercial perspective since 2000, right around the time that the space station was—became functional, the private sector has invested $20 billion, and much of that investment has gone to low-Earth orbit. As we're projecting on what the rate of return will be for the shuttle given NASA's investment cost, the global space community right now, the worldwide figures I think are—range anywhere from $360 to $380 billion of the global space economy.

Within the next decade, several major institutions, Goldman Sachs, J.P. Morgan—or, I'm sorry, Morgan Stanley and others have projected that the commercial marketplace or the global space marketplace, which is all of space, to be a $1 trillion business. So, you know, short of the business plans that—I don't have them in hand to present to NASA right now, but the companies that are working with the International Space Station on the International Space Station are projecting this I think into the future.

But I think the most important thing is the stability of knowing that the station will be there, beyond—it's hard to do a business plan for something that may not exist and how do you project out? So if we're talking about, you know, the space station going away in 2024, well, that's 4 1/2 years from now. If we can do 2028 or beyond I think makes for a better case for investment.

Chairwoman HORN. Thank you very much. Professor Gabrynowicz, I think you've hit on a couple of very important points, and I just want to reiterate and ask a question about your observation regarding the legal challenges in the next generation of what we're looking at and that the development of LEO and ISS is beginning at a time when the current value of the space economy is being questioned. But to get to the last part of it right at the

heart where the risk and reward and the liability lies, that the space law has created and the movement has created an uncertain legal environment that there's very little black-letter law.

And so my question to you is, what do you see as an effective pathway to addressing those issues and creating an effective and enforceable body of law?

Dr. GABRYNOWICZ. Well, to begin with, if we have black-letter law, it is law that actually authorizes, requires, or prohibits action. What we have had since about 2014, 2015 are a number of statutes that rely on reaffirmations and sense-of-Congress provisions. None of these create law. There's a pattern in these statutes where there's a congressional finding or the sense of Congress, and then the requirement is to produce a study and to bring it back to the relevant committee, and so there's a lot of activity going back-and-forth—regarding studies that are intended for future action, but most of these statutes don't actually authorize, prohibit, or source action. And if one were to go over these statutes, you'd see large chunks of numbered pages that are simply opinions and not law. Even a sense-of-Congress provision, even if it's incorporated into a bill, it does not create law. And I don't remember the numbers now, but I've gone through these statutes, and a number of them have 15, 20 sense-of-Congress provisions in one bill.

Chairwoman HORN. Thank you very much. I have many more questions, but we're going to pass the time, so turn it over to Ranking Member Babin for his.

Mr. BABIN. NASA just released details highlighting its plans for the low-Earth orbit commercialization. The intent of the plan is to facilitate private-sector use of low-Earth orbit to offset the government's costs on LEO so that NASA can focus on deep space exploration. And the focus of the plan appears to be focused on selling access to the ISS.

And, Mr. Gerstenmaier, will this offset NASA's costs for ISS transportation and operations, and if so, by how much? And if not, then why decrease NASA's utilization?

Mr. GERSTENMAIER. Yes, so the intent is not to lower NASA's cost for this activity. The idea is to essentially allow the commercial sector to experiment with revenue-generating activities on board station. And for that we want to recoup some of the cost associated with the activities for which they're using on station, and that was the pricing policy that we placed for them. It's not an absolute pricing policy, but gives them an idea of how to build a plan. And the idea is then can they then look at—from that determine were there a private station on their own that they built could be used, and then that's something NASA could then acquire services from in the future.

Mr. BABIN. OK.

Mr. GERSTENMAIER. So the purpose of that was to allow them to essentially experiment with revenue-generating options and concepts moving forward, and we didn't take things away. We made available to them 5 percent of the available time on ISS, and that 5 percent we can remove from our other activities and move forward so we still protect our basic research, we still protect the fundamental research needed for exploration and human health and other aspects.

Mr. BABIN. OK. Will revenue derived from the ISS commercialization plan go back to the Treasury or will it stay with NASA? And what oversight will Congress and the taxpayer have on funds derived from the taxpayers' significant investment in the ISS?

Mr. GERSTENMAIER. Again, our focus really isn't on capturing revenue.

Mr. BABIN. OK.

Mr. GERSTENMAIER. The intent is to allow them to experiment——

Mr. BABIN. Sure.

Mr. GERSTENMAIER [continuing]. And then later in the future where they now have their space station to serve other purposes other than the government's purpose, then we're one user of many. Then we're buying from a larger service, and that lowers our cost for future activities. But the intent is not to generate revenue from ISS.

Mr. BABIN. I understand. And, Mr. Martin, recent reports from your office have highlighted the need to develop new spacesuits both for future use in the microgravity environment of LEO for extravehicular operations and for future deep space missions and surface operations. Our current extravehicular mobility units were designed in the late 1970s, but astronauts have nearly drowned from water leaking into their helmets, and the current astronaut corps would very much benefit from a larger variety of suit sizes.

Future spacesuits for surface operations were postponed years ago after a contract protest and deferments under the previous Administration. How important is the ISS for NASA's testing of the next generation of spacesuits?

Mr. MARTIN. It's critical. It's critical for testing the EMUs (Extravehicular Mobility Units)——

Mr. BABIN. OK.

Mr. MARTIN [continuing]. And I think NASA has a plan to get the next—it's called the xEMU suit up on station by 2023.

Mr. BABIN. OK. Great, thank you. Good news.

And then, Mr. Stallmer, recent IG (Inspector General) reports and a report from the Science and Technology Policy Institute were pessimistic about the potential of the private sector offsetting government's funding in LEO. Can you comment on the private sector's perspective of LEO commercialization, and is this something that the private sector could provide private capital for or does the private sector see this as another opportunity for more government money?

Mr. STALLMER. Yes, I saw that report, and I somewhat disagree with the assessment, the pessimism of what markets are there. As we were talking about offsets, I don't think the station was designed as this economic engine, you know, for—in low-Earth orbit. It started off as a scientific platform. But I do see the investment that the private-sector community is making.

For instance, the Space Angels network, which is—started off as a small group of small investors into space making minimal—smaller investments is now over 200 individual investors that are investing in these companies that are going to be doing work on the International Space Station.

So I don't see a trend of companies coming up to the Hill to ask for more and more money for the station. I think it's what we're looking for is stable policies that we know that we can work within the boundaries of the space station. So——

Mr. BABIN. Excellent. Thank you. Thank you very much.

And, Dr. Gabrynowicz, NASA's plans allow for private astronauts on the ISS. Current law allows for government astronauts under the current statute. What is a private astronaut under the current statute, and what are the differences in these names from a practical perspective and also from a legal perspective?

Dr. GABRYNOWICZ. Thank you. Well, as the designations indicate, a government astronaut is an employee of the Federal Government, and as such, there are legal rights and privileges that astronauts have as well as restrictions. It's roughly analogous to being a member of the military. You have certain rights and obligations that a civilian does not have. A private astronaut would not be a government employee. Their relationship would be based on for whom they work or if they work for themselves, at whose direction are they taking instruction. Are they acting as an agent for an entity? And therefore that person's rights and obligations are going to arise from that relationship.

But then there's the additional overlay that if you have a private-sector astronaut who is a nongovernmental actor, then ultimately the United States is responsible for that astronaut anyway. There's that additional overlay.

And I just want to give you a little background as to why that responsibility exists because it's very important to the United States' values. When the Outer Space Treaty was being negotiated, it was the position of the Soviet Union that only nation-states were legitimate space actors. And of course the United States couldn't agree to that and said no, private entities are also legitimate state actors.

Well, a compromise was made between the Soviet and the American position, and that compromise was that nongovernmental space actors will be authorized and continually supervised by the Nation that is party to the treaty. So that supervision, that authorization is the source of the right of the private sector to be in space.

And the flipside of that coin is because they have to be authorized and continually supervised, they are—the United States is internationally responsible for them. So that responsibility goes hand-in-hand with American values of private activity.

Mr. BABIN. Absolutely. Thank you. Very fascinating. I appreciate it. I yield back.

Chairwoman HORN. Thank you very much. And thank you, Dr. Babin. I think one of the things that is clear from the questions from me is that you ask many of the remaining questions I had that are very important, although there are more that—these are clearly very much a bipartisan issue in the best interest of NASA.

And the Chair recognizes Chairwoman Johnson for 5 minutes.

Chairwoman JOHNSON. Thank you very much.

In line with the questioning that just happened, Professor——

Dr. GABRYNOWICZ. Joanne.

Chairwoman JOHNSON [continuing]. Gabrynowicz, as we consider the Administration's proposal for the ISS commercialization, I was

struck by your statement that there are legal and economic forces at play that can expose the U.S. Government and the U.S. taxpayer to substantial recurring and long-term obligations that can result in hard-to-quantify financial obligations. What do you think are the most significant potential financial obligations that need to be considered before we sign off on NASA's commercialization proposals? And what legal risk are we should be concerned that the U.S. Government might be assuming?

Dr. GABRYNOWICZ. OK. The—I cannot speak to what are the most significant risks. Those are engineering and science questions. And I would have to direct you to speak to the engineers and the scientists who would tell you where the risk is, what can go wrong in terms of science and engineering.

In terms of what the United States would be responsible for, again, this is why it's unknown. This is all going to be very fact-dependent on what happens when, where, and what the results are. As I'm sure you're aware, the elements in—of the space station are registered by the nations who put them in there, so if you're in the American—one of the American modules and you go to the Japanese module, you're going from a place where U.S. national law applies to a place where Japanese law applies. They're like little tiny embassies. Well, not so tiny; they're pretty big.

But it's going to be very—they make great hypothetical questions on my exams because it's very fact-dependent as to what the U.S. has to be prepared for. But the bottom line is there must be the awareness that under the Outer Space Treaty the United States is internationally responsible for whatever that fact pattern may arise to be. And under the International Space Station Agreement, the obligations will continue after transfer unless there is a new agreement reached with the partners that supersedes the current International Space Station Agreement.

Chairwoman JOHNSON. Thank you very much. Mr. Gerstenmaier, reducing the risk of human missions to Mars and other destinations have long been a prime justification for continuing operations for the ISS. Mr. Martin's prepared testimony notes that there are a series of human health risks and technology gaps required for future missions to the moon and to Mars that will not be completed on the ISS by the mid-2020s. At the same time, NASA's low-Earth orbit commercial development plans propose providing commercial entities access to NASA's available crew time, power, and other resources that otherwise could be used to make progress on the human health and technology research.

Given the limited life of the ISS, how do you justify using NASA's constrained ISS resources to try to stimulate commercial activities such as space tourism and marketing rather than using these resources to reduce the risk of human missions to Mars?

Mr. GERSTENMAIER. We are very focused on reducing the risk associated with Mars both technically and also from a human physiology standpoint. That is our primary focus. We're spending a lot of research time on both of those activities. But what we've done is we've created this 5 percent piece beyond that of which we can allow this experimentation and commercialization. We think that's important because then at some point this station will wear out. We've identified a long-term need for us to do this technology de-

velopment and research in the future. We're going to need some other facility to do that. What we'd like to do is not be in the position where NASA and the U.S. Government have to build that facility. We would like to be able to use a private facility. So we think this small portion at a the time being available to prepare for that future allows us to ensure that we can keep a research facility in low-Earth orbit to investigate the technology into human factors we need to get ready to go to Mars.

Chairwoman JOHNSON. Thank you very much. My time is expired.

Chairwoman HORN. Thank you, Madam Chairwoman. The Chair now recognizes the Full Committee Ranking Member Lucas for 5 minutes of questions.

Mr. LUCAS. Thank you, Madam Chair.

Mr. Gerstenmaier, let's step back and look at a broader perspective. NASA recently released summaries of the private sector's low-Earth orbit commercialization plans. Did NASA learn anything from these studies that it did not expect? Were you surprised by anything?

Mr. GERSTENMAIER. Yes. I think the takeaway that we saw from the plans was the diversity and the options of what the companies thought. For revenue generation, what they thought the cost would be associated, there were a lot of differing opinions from their perspective of what they saw the benefits of space research were. So I think the diversity of the responses we got surprised us. We thought they would be more aligned in one specific area, so that's why we pursued this five-point plan——

Mr. LUCAS. So I assume that was a pleasant surprise then?

Mr. GERSTENMAIER. It's interesting because—but it's hard for us now to pick then a concrete path to go forward from those studies.

Mr. LUCAS. Along that line, Mr. Gerstenmaier, in 2015 we saw reports that the Russians intended to detach their modules in 2024 to form their own habitat in low-Earth orbit. If in the event this were to happen, how should the U.S. engage its international partners? And along with that, would a Russian departure from the ISS require further U.S. investment in ISS to keep it running without a Russian segment?

Mr. GERSTENMAIER. I think that's an interesting hypothetical discussion. There's lots of dependencies between the Russian segment and the U.S. segment. We provide power to them, we provide—approximately 1,000 commands a day to go through USS—U.S. assets, and those are Russian commands going to their side. So I think in reality we're going to have to stay together as an international partnership whether we really want to or not. And we can talk about things hypothetically, but in reality we're part of the international partnership that needs to work together, and we'll continue to work together in the future.

Mr. LUCAS. So we're hooked at the hip then? That makes sense.

Mr. Stallmer, does maintaining a presence in low-Earth orbit necessarily mean the presence must be a NASA presence or could American companies maintain that presence? And along that line, does maintaining any sort of crew presence in low-Earth orbit necessarily mean maintaining a presence on the ISS in particular?

Mr. STALLMER. Sir, I think it's both. I think that NASA should retain a permanent presence in low-Earth orbit, but I think there's also a commercial element as we're seeing private-sector habitats being developed and potentially private space stations being developed. I think you can't have it both ways. I think the commercial sector will provide services, and I think NASA eventually will be a customer of those services. So I think it's a good balance that we have to look forward to.

Mr. LUCAS. Thank you. And, Madam Chair, using my precious time precisely, I now yield back the balance.

Chairwoman HORN. Thank you, Mr. Ranking Member. The Chair now recognizes Mr. Crist for 5 minutes.

Mr. CRIST. Thank you, Madam Chair. And thank you, panelists, for being with us today.

I think we can all agree that performing research in microgravity is critical to achieving scientific and technological advances, which is why I support an extension of space station operations beyond 2024. However, there will eventually come a time when the station is no longer usable simply because it has reached its operational lifespan.

Mr. Gerstenmaier—and I apologize if I mispronounced it—when this occurs, what do you envision for the future of microgravity research? Specifically, do you see the need for some sort of national space-based lab to support research and development beyond the useful life of the space station?

Mr. GERSTENMAIER. Yes, in the plans we provided to commercial industry, we identify what we believe is NASA's long-term needs for space research. And included in that is a continuation of doing research for NASA's needs, both technology development and also microgravity research.

Mr. CRIST. Thank you. Again to you if you don't mind, I assume that increased commercialization of low-Earth orbit will result in additional traffic to and from the station. Can you discuss NASA's plan for space traffic management under a commercialized low-Earth orbit situation?

Mr. GERSTENMAIER. Even today, we have a visiting vehicle specification that essentially defines the operating environment around space station. So we have certain zones where vehicles can transit and come into, but they need authority to come into those, so there's a very methodical approach of how we do vehicle traffic management in a way almost similar to an airport here terrestrially but it's around space station. I propose we would use that same kind of thing in the future for another space station or the space station as it moves forward. But it's becoming a very busy environment for us, and the monitoring and activities of the folks at the Johnson Space Center are critical for those——

Mr. CRIST. Thank you, sir. Mr. Stallmer, as you know, NASA announced last month that it will allow two flights to the space station each year for private astronauts. Do you believe it's feasible to begin these flights with an all-commercial astronaut crew, or would it be better to start with missions that include both NASA and private astronauts to help build and establish this market?

Mr. STALLMER. I think it would be the latter. I think using NASA astronauts as well as commercial astronauts is a prudent

approach. I think we're seeing in many different markets—later this year, we're going to see Virgin Galactic and Blue Origin large commercial astronauts in a suborbital fashion. And of course with the Commercial Crew Program coming online I think it's going to increase the access to utilization of the space station. I think it's a great way of NASA leaning forward to try to greater utilize the International Space Station for commercial astronauts and the science they can do.

I think if you look at it from a research perspective, if the private company pays for that astronaut to go up to the International Space Station and conduct studies, I think that's part of the economic engine that we're looking to develop from generating more revenue from the space station. So I think it's a very prudent approach by NASA.

Mr. CRIST. Thank you. And then my last question for any of the panelists, what in your opinion can NASA do to help encourage a commercial astronaut transportation market? If you have an opinion.

Mr. STALLMER. For NASA to encourage the greater utilization of commercial astronauts?

Mr. CRIST. Yes, sir.

Mr. STALLMER. I think it's—to highlight the opportunities for the science that is up there. I think when we see some of the breakthrough technologies—and NASA has done a great job of showcasing the breakthrough technologies that have been developed on the International Space Station. But if companies can see this as a platform for research, whether it be pharmaceutical research or, as the Australians were talking about, having—to be able to consume beer in space, you know, and they're working on that diligently, or if it's just the technology to hit a golf ball 10 yards further I think, you know, understanding the technology that microgravity offers, it's limitless on what we can do. So I think as NASA and the partnership with commercial sector I think working together to promote that and the possibilities, I think that's what's going to really encourage this market to grow.

Mr. MARTIN. I guess a note of caution just to point out that any—at least the initial steps of commercialization of low-Earth orbit is heavily subsidized by NASA, so the figures, the cost figures that NASA put out, the $35,000 a day for an astronaut or $1 million for a 1-month stay, that's extremely heavily subsidized almost as a loss leader to get—to entice and encourage the market.

Mr. GERSTENMAIER. There's a few interesting biological things that we've seen on station I think that have tremendous benefit. One is a lab—it's called essentially lab on a chip or biology on a chip. It turns out that, for whatever reason, some functions happen faster in space like immune system degradation, et cetera, so there's an idea that you can actually take liver cells, which are used to determine whether a pharmaceutical product will be toxic to you or not, in the microgravity environment because those processes are speeded up, it would typically take a year to get results on the Earth, can occur in several months on station. So we think there's a huge benefit potentially for pharmaceutical companies to bring drugs to market faster by doing this lab-on-a-chip kind of technology on station.

We're also looking at 3-D printing of organs in space. Because there's no gravity, you don't have to have any material to make the organs actually resist gravity, so now you could actually print essentially organs of much larger size. So the idea is for us to expose the private sector to these interesting innovative ideas that are transformative and then let them take that through their ingenuity and innovativeness and then turn that into a marketable product to move forward. But those are some of the aspects that are very intriguing.

Mr. CRIST. Thank you. I yield back, Madam Chair. Thank you.

Chairwoman HORN. Thank you, Mr. Crist. The Chair now recognizes Mr. Brooks for 5 minutes.

Mr. BROOKS. Mr. Stallmer, the national lab is a key driver of private activity on board the International Space Station. What setbacks have you seen or experienced that have held back the commercialization of low-Earth orbit, ISS activities?

Mr. STALLMER. I wouldn't say setbacks per se, and I'm sure others can speak to technical setbacks that they may have had. I see more of opportunities. I think from a timeline perspective certainly the funding questions and the timeline with the extension, streamlining some of the policies that we're looking at in some of the space policy directives on streamlining policies, that's been slower than we would hope for.

But from a more optimistic perspective, I see the progress that commercial industry has made. When I—one of the reports was cited that were pessimistic of the growth of, you know, on commercial industry. I also read a report about 10 years ago that was pessimistic about reusable launch vehicles, and 5 years later we had reusable launch vehicles. And now we have over 22 vehicles that were launched and reentered the Earth's atmosphere, and we're reusing them again, reducing the cost to access to space.

I see the growth in industry from what companies do—startup companies, whether it be electric propulsion, you know, for satellite—small satellite boost or the things, you know, that are going on in the space station, companies like Techshot and Space Tango about this manufacturing human cells and things of that nature.

So will there be setbacks and have there been? Absolutely, and there's different timetables. And I think we're moving at an aggressive pace, but I think we need to as a Nation. I think we—for 50 years, as we celebrate Apollo, you know, next week and what we've done over the past 50—what we did 50 years ago, I think it's a little disappointing what we've done in the last 50 years, not—the space station is a remarkable modern marvel, and I'm not knocking that at all, but I think as a Nation we can do better. I think we can do a lot better. And I think—and I know the commercial sector will be helping do that.

Mr. BROOKS. This is a question for any who wish to opine on it. In your judgment, either in percentage terms or dollar terms, how much of a taxpayer subsidy is there for commercialization at the International Space Station?

Mr. MARTIN. Over the past 12 to 14 years NASA has invested approximately $17 billion to help the commercialization of both cargo transportation and crew transportation. That does not mean that the companies involved in both of those enterprises also don't have

skin in the game. They have significant resources but $17 billion investment in that. As we've all indicated, it costs upwards of $3 to $4 billion per year to maintain and operate the station, so, as you can see, significant subsidies.

Mr. BROOKS. My hometown is Huntsville, Alabama. We like to call ourselves the birthplace of the American space program. And, as such, I've heard projections but rather optimistic on occasion that we're just around the corner from having commercialization of space that does not involve much in the way of taxpayer subsidies either by our country or others as the case may be with a joint facility like the International Space Station. What needs to be done to truly make commercialization a solely private venture? Is there anything Congress can do where we can eliminate these taxpayer subsidies of these private efforts?

Mr. STALLMER. I think when you categorize it as subsidies I'd like to look at more of the advancements that the government assistance has created. And, as we see, you know, for instance, on the commercial cargo program, with the government—you know, the investment that the government has made on that program coupled with the investment of these private companies, we now have two fully capable launch vehicles that are providing routine access and routine, you know, resupply to the International Space Station.

So to put a price tag on that investment, well, now we have, you know, these two vibrant companies that are providing services, as well as a—that we're going to see cargo with Boeing and SpaceX later—I'm sorry, crew with Boeing and SpaceX later this year. The U.S. dominates the global commercial marketplace now. You could not say that 10 years ago where we had less than 10 percent of the global market.

So now the U.S. industry, on launch, on small sat, on spacecraft, we are the dominant leader. So whatever that number of investment that the government has made I think it has paid, you know, tremendous dividends to the American public, and I think it will continue to pay that with the investment that we have in the International Space Station.

Mr. BROOKS. Thank you, Madam Chair. I yield back.

Chairwoman HORN. Thank you, Mr. Brooks. The Chair now recognizes Congresswoman Hill for 5 minutes.

Ms. HILL. Thank you so much, Madam Chair.

Mr. Gerstenmaier, earlier this year, NASA and partners work to upgrade the batteries on the International Space Station to provide greater efficiency and power to the growing number of users on the station, as well as to prepare for continued upgrades in the years ahead. This is just the latest example of ongoing efforts that have been made to continue to improve ISS based on new technologies and grow its capabilities. What other efforts is NASA taking to improve power, life support systems, and other elements to ensure that ISS continues to support astronauts and science needs for the years ahead?

Mr. GERSTENMAIER. Today, we're actually testing the next generation of life support systems that will be used potentially on journeys to Mars, so they're much more efficient from a water-use standpoint, recycling carbon dioxide. We've also just recently increased the bandwidth coming down from space station to 600

megabits per second. That is now the standard every day, and we've increased the number of video channels coming down so we can do more interactive and virtual-reality activities with space station. So those are some of the examples of the improvements. And we have more battery upgrades coming this fall.

Ms. HILL. Great, thank you. Also, Mr. Gerstenmaier, as you know, the Senate has voted repeatedly to extend the ISS through at least 2030, and the majority of the House voted for a similar provision last year. As this issue comes up again in the new Congress, how important is certainty of ISS extension to you, our international partners, and other users as they plan for crewed missions and experiments in the years ahead?

Mr. GERSTENMAIER. We just had a discussion on how we could help commercial industry transfer or take over more of the role in low-Earth orbit. I think that's very difficult to predict exactly when that's going to occur. I think that timeframe is going to be hard. It's going to take longer to create a new economy than I think we've envisioned, so I think we need to be careful we don't set an arbitrary or artificial deadline. We need to essentially provide some certainty so industry and the commercial sector can understand what's coming in the future, they can plan for that, and then they can move forward. So I think getting a plan of how that moves forward and when that occurs, then we have a chance of envisioning this world where the commercial sector is taking a larger portion of the cost associated with low-Earth orbit.

Ms. HILL. And right now, we don't have that certainty or that plan of transition?

Mr. GERSTENMAIER. No, we have varying numbers depending on where we talk, between what Congress says, the Administration says, what NASA's plans are, et cetera, I think some certainty about that. But again, not setting an arbitrary deadline but maybe more setting criteria such that we don't create this gap that was talked about earlier.

Ms. HILL. Right.

Mr. GERSTENMAIER. The gap would be unacceptable, but we need some plan to do that.

Ms. HILL. Right. And, Mr. Martin and Mr. Gerstenmaier, I understand that NASA and partners have already worked to certify the ISS for use through at least 2028, and these studies indicated that its lifespan could extend well into the 2030s. Can you talk about the status of these studies and what other steps NASA is taking to ensure that ISS can be extended and healthy for many years?

Mr. GERSTENMAIER. We've done the structural studies through 2028. We've done other studies. These improvements I talked to you about earlier, those are all part of essentially allowing us to do more with station. These life support systems we're checking for the future, actually allows us to have more crew on board station.

The thing that we've got to weigh again is, you know, we are spending money in low-Earth orbit that we could be spending in deep space, so we need to make sure that we have the right balance between those two moving forward.

Mr. MARTIN. And I guess I would emphasize that these are opportunity costs. If you continue the station for any number of years

past 2024, that is approximately $3 to $4 billion you don't have available to pursue other exploration goals such as lander developments, such as Gateway, such as preparing and bending metal for moving to Mars, so it is a—it's a choice. No one disputes that the ISS is just a critical element up there, but it's a question—again, absent substantial and sustained funding increase for NASA.

Ms. HILL. Got it. Well, thank you all so much. I really appreciate it, and I yield back.

Ms. HORN. Thank you. Thank you, Congresswoman Hill. The Chair now recognizes Mr. Posey for 5 minutes.

Mr. POSEY. Thank you, Madam Chair.

Mr. Gerstenmaier, what are the main cost drivers for the $3 to $4 billion operational cost of the ISS?

Mr. GERSTENMAIER. The major cost driver is crew and cargo transportation to and from ISS, and it's about the $1.8 billion of the $3 billion that——

Mr. POSEY. OK. Which factors affect the shelf life of the ISS?

Mr. GERSTENMAIER. Again, I think we've been doing a pretty remarkable job of maintaining station and upgrading systems and components through use of our crews and astronauts and engineering expertise. There are some components structurally that may wear out over time, and we need to watch those and monitor those, but we're actively tracking those and then looking on a——

Mr. POSEY. What kind of components would they be?

Mr. GERSTENMAIER. They'd be some of the truss elements, some of the large structural pieces. Solar rays will need to be replaced at some point and augmented, and we have plans to do that.

Mr. POSEY. OK. Could the ISS be mothballed?

Mr. GERSTENMAIER. Space station is designed to be crew operated, and so a lot of the systems really require a crew presence on board station, so essentially shutting station down and removing crew for an extended period of time would make it very difficult to ensure that we could bring the station back up when crew came forward or crew were available in the future. So it's not easy to essentially stop operations without the crew. We need to keep the crew presence on board station to keep the vehicle maintained.

Mr. POSEY. Would it be feasible even remotely to relocate the ISS, say, to an orbit around the moon?

Mr. GERSTENMAIER. We've looked at that. It's attractive but physically it just doesn't seem practical. The amount of energy to do that isn't there. The number of orbits if you even have low propulsion, you'd have to circle through the Van Allen belts multiple times over multiple months. And then by the time you get there, it's not physically possible to maneuver large pieces of station. You might be able to deconstruct and use small pieces of station, but generally, you're probably going to want to use those small pieces in the same roughly inclination orbit that space station is in today.

Mr. POSEY. OK. Mr. Martin, you mentioned that we've invested about $17 billion in the ISS.

Mr. MARTIN. Seventeen billion in commercial cargo and crew transportation.

Mr. POSEY. OK.

Mr. MARTIN. Significantly more in the ISS, upwards—the number is—what you're counting, but it could be $80 to $100 billion over the 21-year life of the station.

Mr. POSEY. OK. What kind of investments have our partners made?

Mr. MARTIN. The international partners pay for approximately 23 percent of annual station costs.

Mr. POSEY. OK. Mr. Stallmer, from an industry perspective, how has the public-private partnership benefited the ISS and LEO missions?

Mr. STALLMER. I think it's greatly contributed. Companies like NanoRacks has invested $40 million. I think they're one of the larger investors on the International Space Station creating—they will be developing their own airlock for the International Space Station. I think that's going to be delivered in 2020, in that timeframe. So I think they're—you know, again, when you talk about—the numbers that Mr. Martin is talking about, yes, it is a large contribution, but I think it's what the vision of NASA is. Was NASA designed to be, you know, an economic driver or was it designed to be an agency for exploration? And I think we've got to look at what our priorities are and what NASA's priorities are in working with the commercial sector on this. And I think the partnership with—that NASA has had over the past 2 decades working with the commercial industry, the information sharing and the service sharing that we've had, I think it's only going to grow, so I'm very optimistic about that.

Mr. POSEY. How do you think the relationship could be improved?

Mr. STALLMER. The—I think just the communication on the pricing, the stability on pricing, as they've recently released. I think—I think greater access—I think once we're able to launch American astronauts from American soil on American vehicles, I think that that type of partnership that's going to open up of having routine access to space I think we're going to see a lot more opportunities.

I was inspired by Scott Kelly's book Endurance and what it took for a year on the space station and the challenges that they had and routine challenges, just regular preventive maintenance they need to do. And I think having this commercial access and not being dependent on a foreign nation to provide our astronauts access to space at, you know, rather large rates and the cost savings that will have, I think is going to greatly enhance the capabilities that the commercial sector and NASA can greater partner with. But I think we have a very good partnership, and I think Mr. Gerstenmaier's leadership has been outstanding on that front.

Mr. POSEY. Thank you. Thank you, Madam Chair.

Chairwoman HORN. Thank you. Thank you. The Chair recognizes Mr. Olson.

Mr. OLSON. I thank the Chair, and welcome to our four expert witnesses.

One thing we all agree upon, the activities of the ISS must keep going and expand in the future. We can't go back one step back. We can't do that. The question is without its future be the ISS, some expansion, some new experiment platform, maybe something here on the moon or something based on the moon? We avoid

human debris fields for sure, but that's very expensive. And so, regardless, the International Space Station has been a great asset.

I want to remind everybody what this space station has done. Every single day since November 2, 2000, we've had a human being in orbit on the International Space Station 230 miles above our planet. And in fact our two honored guests over there, these two amazing ladies weren't born when the station went into orbit and became active, but we're here to make sure you have a space station or something like that to go to when you walk on the moon or walk on Mars and wave to us and say, hey, Energy Committee there, Science, Space, and Technology Committee, I'm on Mars, I'm on the moon.

We all know, too, the ISS has done great wonders, great experiments we can't do here on Earth. A couple of examples, the Alpha Magnetic Spectrometer, AMS, it's been up there since 2013, and it may have discovered the start of dark matter. As you all know, most of our universe is dark matter, and that's a huge benefit for human life.

Also, as you guys talked about, the benefits for human health that we've learned through the International Space Station, for example, learning how to deal with muscle atrophy, also bone density loss and fluid shifts and just what we've learned, we've learned that Scott Kelly can now call his twin or could call his twin Mark shrimp for a few weeks because Scott was 2 weeks taller than Mark when he came back home after almost 1 year in space.

I want to talk about going forward and making sure we keep this in International Space Station. That means we have a plan to stop fly or something by 2024 right now that could be extended. I want to ask the question of all of you starting with you, Gerst. How are our international partners engaged in this—do they want us to extend it, how long, what will they pay? I mean, again, we've got Japan, China, Russia, America, including the Republic of Texas, European Space Agency, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, all these nations are involved right now in the Space Station. How are they going forward with our plans? Do they want to go to 2024, longer, and what will they put up to help us go make those things happen?

Mr. GERSTENMAIER. I think in general the international partnership wants to continue using station. They see it still as a resource that has plenty of life in the future, and they want to continue to use it.

There's a European ministerial at the end of this year, in November of this year, and at that time we should see a formal position from the European Space Agency (ESA) about their position of using station beyond 2024.

Mr. OLSON. Mr. Martin?

Mr. MARTIN. Again, just a caution, every space agency, like every government, has a limited budget, so ESA's budget, while significant and important to maintenance of the International Space Station, is much, much smaller than NASA's. I've—from what I've read, they've shown some interest in being part of a Chinese—a planned Chinese space station set to launch and begin construction in 2022. I just don't know that their budget is large enough to con-

tinue their current commitment to the ISS past 2024, as well as partake in perhaps the Artemis mission with the U.S. or the Chinese space station activities.

Mr. OLSON. Mr. Stallmer?

Mr. STALLMER. The United States is the global leader in space, and I think we need to continue to be that way. I think the international partnerships that we have on the space station are critical and most necessary, and I think we should continue to engage our global partners. But do keep in mind when you walk around the United States, the Republic of Texas, all over the world you see people wearing NASA T-shirts. It's a brand. You don't see people wearing other space agency—the Polish Space Agency or anything else, T-shirts. So I think that's critical to keep in mind. The leadership that NASA provides the world is imperative.

Mr. OLSON. And not to butcher your name, but Dr. G, any comments on——

Dr. GABRYNOWICZ. That's what my students call me. Please feel free.

And as a Gabrynowicz, I do not like you dissing the Polish Space Agency.

Mr. STALLMER. I only do that because they're one of the newest space agencies around, and I don't know——

Dr. GABRYNOWICZ. OK.

Mr. STALLMER [continuing]. What their logo is, but I'm fully supportive of the Polish Space Agency and all global space agencies, except for two.

Dr. GABRYNOWICZ. OK. Coming from a space law perspective, the reason why we have the Outer Space Treaty and other treaties is because the world faced its worst fears at the time, placing nuclear weapons in space. And people forget that the Outer Space Treaty prohibits putting nuclear weapons in space, which makes it one of the most important treaties of the 20th century.

But the treaty also provides for our highest aspirations—that space is dedicated to peaceful purposes for all humankind. When the space station was first proposed by President Reagan, it was the height of the cold war. The Soviet Union was our enemy, and then a funny thing happened on the way to the space station. The cold war came to an end and the Soviet Union became the Russians and the Russians became a partner, and now here we are in the era of globalization. And we've had a space station for 30 years in which we have learned how to work together with one another. And each country that is in that station is making a commitment—financially, technologically, and otherwise—that, relative to their assets, is just as great as what the United States provides.

And I would point out that Canadarm is a fantastic example of that. The Canadarm in terms of dollars is a relatively smaller contribution than some of the other bigger elements, but we would not have a space station without the Canadarm. So I think we need to think of the space station in terms of quality as well as quantity, and the quality of the relationships we have with 15 other nations through the International Space Station Agreement is not to be understated.

Mr. OLSON. I'm aware of my time, Chairwoman. I thank you so much. I want to remind you, though, there's a special countdown

happening right now around Johnson Space Center in Houston, Texas. It's T minus 94 days and counting until the Texas Longhorns repeat and beat the Oklahoma Sooners. They boom them in Dallas, Texas. I yield back.

Chairwoman HORN. I think you're being overly optimistic. And let's just be clear, it's OU-Texas, not Texas-OU for all of the Texans in the room.

See what you started, Mr. Stallmer, you know, Polish Space Agency. Of course, Mr. Olson, thank you. Thank you very much.

The Chair recognizes Mr. Waltz. Hopefully, the Floridian won't cause quite as many problems as our Texan over here.

Mr. WALTZ. Well, I do have to say thank you, Madam Chair. And we've heard a lot about Alabama is the home of space and the Republic of Texas, but I think we all know where space DNA really resides, which is in Florida and excited to celebrate the 50th anniversary of Apollo 11 coming up.

So a lot of discussion today around the international aspects of the ISS. I am very focused also as a Member of the Armed Services Committee on what the Chinese in particular are doing in space. I think it is always worth remembering and reminding that the Chinese military is behind every major component of what the Chinese are doing in space, whether that's in their new space station or if they have manned research station on the moon. I put research in air quotes—on the moon. And that basically everything that NASA has done going forward or looking backward has not been in the same type of competitive and potentially hostile environment that we will look at going forward.

So I think we all agree that American and NASA leadership in space must continue. We must maintain a low-Earth orbit. And please interject if you disagree that we must maintain LEO and we must maintain a presence and particularly if it's a competitive space going forward.

But the disconnect seems like the white elephant in the room is whether this plan will actually work with commercialization and whether it will work in the timeline. And I'm hearing from the Inspector General some skepticism. Is that fair to say, that the plan will actually work to be able to take on that O&M budget of operating the space station in the timeline proposed?

Mr. MARTIN. Skepticism is in an Inspector General's job description.

Mr. WALTZ. Sure. I know it's built-in.

Mr. MARTIN. It is. It's a real concern. The $1.2 billion operation and maintenance annual cost of maintaining station.

Mr. WALTZ. Right.

Mr. MARTIN. Correct.

Mr. WALTZ. So President Reagan put forward a plan approximately 10 years in advance. What is NASA's plan B? I've heard you ask when are we going to see that plan B that if the figures don't work and the private sector can't take it on, what's the decision point to extend beyond 2024, and then what's the decision point to extend beyond 2028 or to have a new platform in place? Mr. Gerstenmaier?

Mr. GERSTENMAIER. We have some time to decide for the new platform in place. That's not an immediate problem. I think we need to——

Mr. WALTZ. What is the time, is it 6 years then? If it's not 10, then is it 5 years, 6 years? In the military we forecast, right? What's that decision point?

Mr. GERSTENMAIER. It's probably about 6 years out or so, so that would probably be 2030 kind of lifetime and then back that up 6 years.

Mr. WALTZ. Assuming the 4-year extension?

Mr. GERSTENMAIER. Yes.

Mr. WALTZ. OK.

Mr. GERSTENMAIER. Yes. And so—but I think the more important thing is we need some stability and understanding for the commercial sector so they can plan. I think it's also probably not appropriate to assume that the private sector is going to take over all the cost of the capability we have in low-Earth orbit, but we can reduce that cost by using the private sector where we're now—we're not the only agency taking people to space. The private sector is doing that on their own through private astronaut missions, et cetera. So we're one of many customers. That reduces our cost some amount. How much we reduce that cost is important to us. We don't—I don't think we can predict that, but we need to try to drive to that situation.

What we need to avoid is we need to avoid the gap, as we discussed here, especially in light of the Chinese space station, which could be in orbit, a portion of it even as early as this year or next year. We need to make sure that we don't create a gap where we the U.S. don't have a facility in low-Earth orbit——

Mr. WALTZ. Absolutely.

Mr. GERSTENMAIER [continuing]. And there's only the Chinese.

Mr. WALTZ. Absolutely. Hundred percent agree.

Mr. Stallmer, in the time I have remaining, the FAA (Federal Aviation Administration)—switching tracks here. The FAA recently released a notice of proposed rulemaking regarding regulatory reform for launch and reentry of commercial vehicles. Obviously, launch is critical to everything we've discussed today with projections of getting up to 50-plus flights by 2021. What are your thoughts on how industry views the draft rules that are out? What needs to be addressed moving forward to enable American companies and private sectors to operate efficiently?

Mr. STALLMER. That's a great question. In short, we have concerns. We have concerns. There is a directive put out that we're going to streamline, you know, the regulatory burden that a lot of the industry is facing. And I say burden. It's a burden because it hasn't been updated. The—what the launch industry was back in the mid-'80s is different from what the launch industry is today in 2019. There's more commercial launch vehicles than ever. We have, just for NASA alone, four vehicles, you know, that will be servicing the space station with reusability.

So these issues need to be addressed, and I think with this rulemaking process I think the FAA really needs to hear—especially the Office of Commercial Space Transportation really needs to hear what industry has to say on how their industry is being regulated.

It has to—it can be so—it has to be performance-based rather than so prescriptive-based. And I think the FAA needs to work more with industry in understanding what their needs are. And we're trying to get there. We're trying to get there. We do have a deadline of July 30, which is closing in on us.

Mr. WALTZ. Madam Chair, if you'll indulge me, could you submit a more fulsome response for the record?

Mr. STALLMER. I certainly can.

Mr. WALTZ. Thank you.

Mr. STALLMER. I certainly can. Thank you.

Chairwoman HORN. Thank you, Mr. Waltz. Mr. Weber.

Mr. WEBER. Thank you, Madam Chair. And as a card-carrying member of the Republic of Texas, regarding the Texas and Johnson's Space Center's preeminence, let me just say that my colleagues can feel free to express their confusion and lack of understanding anytime they want to.

And, Madam Chair, without objection, I'd like that read into the record. I'm just saying.

Mr. Gerstenmaier, when we partner with industry, how do we ensure that we don't take jobs away from our NASA facilities? Let me qualify that. My district, half a mile south of the Johnson Space Center has thousands of people that work in my district. It's huge for us as a country and national security, and I'll talk about that more. But how do we ensure that we don't take jobs away from NASA? And I like to think about the NASA T-shirt by the way. All you see is NASA T-shirts. Who was that other smaller space agency?

Mr. STALLMER. I don't recall.

Mr. WEBER. Oh, you don't recall? OK. All right. For example, Boeing is subcontracting back to JSC to handle mission control for the Starliner missions. My district is home to many of those great NASA employees who work there, and some 50 percent of the JSC jobs are tied to ISS. So I think it's critical that we ensure that the commercialization of ISS will still model that of the Space Shuttle and ISS programs where integration, operations, and other activities are still done. Did I mention Johnson Space Center is close to me?

So Mr. Gerstenmaier, how do we ensure that that happens, that we don't want those jobs to go away?

Mr. GERSTENMAIER. You know, again, I think the right role for NASA is to do the long-term research, technology, and exploration, so the activities around the moon, those kind of things that we don't really know how to do, to build the next generation of rocket engines, to build the next-generation of flight control strategies, those kind of things of how we operate independently from the Earth, those are the roles of the government to do that, to establish that first where doesn't make sense. We're building the heavy lift launch vehicle, as you know, the Space Launch System. There's not really a market for that if you look at that. That's really unique to what we need to do around the moon and other activities. But then once that market then comes behind it, then we can use the private sector.

So I think the role of the civil servants are to do these really hard research, cutting-edge technology development that don't

make sense at all for industry. It's good for the government to own that because then we can distribute that to industry as a whole and they can use that moving forward. So I think there's a strong role for the civil servants in the government to continue to do those research activities.

Mr. WEBER. Well, thank you for that. And, Mr. Martin, you said the Chinese space station is set to be operable 2022? Was that the year you said?

Mr. MARTIN. I believe it's going to be—portions will be in orbit by 2020, Bill?

Mr. WEBER. Is it 2020?

Mr. MARTIN. Yes.

Mr. WEBER. OK. Mr. Stallmer, I want to fix one thing that you said in your comments. You said that you think the U.S. needs to be the leader in space. The USA——

Mr. STALLMER. We—yes, sir.

Mr. WEBER [continuing]. Needs to be the leader in space.

Mr. STALLMER. We are and we need to continue to be——

Mr. WEBER. Yes.

Mr. STALLMER [continuing]. Our leadership.

Mr. WEBER. Yes, thank you. I just wanted to point out. And then, Dr. G, discussing his dissing of the Polish Space Agency——

Mr. STALLMER. It was just noting another space agency——

Mr. WEBER. OK.

Mr. STALLMER [continuing]. That does not have T-shirts.

Mr. WEBER. It's no big deal, Mr. Stallmer. It's just something people are going to remember about you for a long time.

Mr. STALLMER. I get hate mail. I get hate mail, I got to tell you.

Mr. WEBER. Yes, welcome to the club.

Mr. STALLMER. Can you strike that from the record, Madam Chairwoman?

Mr. WEBER. And I appreciate you talking about the international agreement, no nukes in space, but I do want to point out military experts know that in any military conflict, whoever occupies the high ground has the upper hand. There is no higher ground than space. And so while I appreciate that in the words of nuclear nonproliferation or in terms of nuclear nonproliferation, I still want the United States of America to have preeminence in space. I absolutely do.

And I remember a great one-liner from Senator Graham who said that if the lamb is going to lie down with the lion, we want America to be the lion. So space is important to us, we want to have that preeminence and make sure that we maintain that.

A couple of small questions I have in my time left over. Mr. Gerstenmaier, you said that we had increased the bandwidth some 600 percent did you say?

Mr. GERSTENMAIER. The bandwidth is 600 megabits.

Mr. WEBER. Six hundred megabits. What was it?

Mr. GERSTENMAIER. It was I think about 100 megabits per second.

Mr. WEBER. So that's a substantial increase, so we're making progress. OK. Well, I appreciate all of you all being here to testify, and I will close by saying, Madam Chairwoman, let me wish you a happy belated birthday yesterday.

Chairwoman HORN. Thank you. It was actually June, but thank you.

Mr. WEBER. OK. Madam Chairwoman, would you strike the comments from the record?

Chairwoman HORN. I will be happy to.

Mr. WEBER. OK.

Chairwoman HORN. You got the date right——

Mr. WEBER. OK.

Chairwoman HORN [continuing]. But so very close, and thank you very much.

Mr. WEBER. Thank you.

Chairwoman HORN. I think we can all point to Mr. Stallmer as having started the trouble with his comments about the Polish Space Agency.

I've got a couple more questions. I want to sincerely thank all of the Members on this Committee and all of the panelists. As you can tell, this is an issue that is critical. I know it's not news to any of you, but it's also an issue that is critical to all of us, that we are attempting to ask and frame these important questions about how we move forward, about how we avoid capability gaps in the future and in absence of a space station, in the absence of the ability to do research and exploration in low-Earth orbit.

The issues surrounding certainty and the investment of our taxpayer dollars and how we get there, where is the role of an emerging commercial sector and how much we subsidize these priorities that are critical to all of us, as well as, Dr. Gabrynowicz, the legal structure and the legal questions that will inevitably face us because, Mr. Weber, I agree with you, absolutely, we absolutely have to invest and be intentional about maintaining our investment and our preeminence in space. It is important for our scientific advancement. It is important for our national security and for our commercial sector and our ability to move forward.

So having said that, I've got just a couple more very quick questions before we close out this hearing that have been raised for me. Throughout the questions, I've seen a few themes from all of you and from all of us, the capability gap in the transition, how we navigate that and what the extension is, the need for certainty both from NASA and from the commercial sector for us to plan because space and complicated issues require ongoing planning, how we prioritize and where we have to make those hard choices about the pathway forward, and finally, the risk and the legal structure and the need to ask all those questions and for us to give authorization and put that into law on the legal side but also a framework.

So, Mr. Martin, there's a question that I wanted to ask you about, the cost and the subsidies for commercial. And so my question is what is the percentage of subsidy as a part of the commercial LEO development plan? We've talked about different aspects of it, but can you speak to the percentage of NASA subsidy?

Mr. MARTIN. You're talking about the newly released——

Chairwoman HORN. Yes.

Mr. MARTIN. Eighty-five percent.

Chairwoman HORN. Eighty-five percent, OK. And, Dr. Gabrynowicz, one additional question. When we're speaking about

the U.S. Government responsibilities and legal obligations under the Outer Space Treaty and looking forward with commercial astronauts and other commercial entities, what level of ownership does the U.S. Government need to have in order to ensure sufficient oversight of a commercial space station?

Dr. GABRYNOWICZ. That's not an answerable question at this point because the law doesn't speak in degrees. It speaks in principles at this point.

Chairwoman HORN. Could you speak to some of those principles that need to be taken into consideration or used to create that legal framework then?

Dr. GABRYNOWICZ. Well, regarding the Outer Space Treaty is the principle I raised about international responsibility. That is a principle that the United States Government is responsible for its nongovernmental space actors. The degree and kind of responsibility is going to be defined by what actually happens, and we don't—these would be cases of first impression, so we don't know what it's going to be.

Then the other principle is in the International Space Station Agreement, which says even with the transfer of elements, the obligation of the partners still remains. So, again, that hasn't been done yet, so we're going to figure that out as we do it. But the principle is already there. Responsibility will continue to be—I'm sorry, rights and obligations will continue to be in force even after the transfer of elements.

Chairwoman HORN. Thank you very much. Mr. Gerstenmaier, would you care to comment?

Mr. GERSTENMAIER. Again, I think her points are valid. I think it's—the rights and ownership responsibility of governments are important because it cuts the other way, too. If one of the other international partners want to remove, they can't remove themselves from their rights and responsibilities, so I think it's a good benefit both ways.

Another thing we should talk a little bit about at some point is also the potential and maybe the role of the Commerce Department in some of these activities as we talk about economic development. We're not really an economic development agency. We're doing cutting-edge research and exploration. We're doing our best to move forward, but there may be a role for Commerce in this activity that should be thought about, as well as potential funding sources. Maybe it's not the burden of NASA to fund all this stuff. Maybe some of these transportation costs and other things may come from other areas of the government, but those should be discussed as well.

Chairwoman HORN. Thank you for raising that point. Yes, there are very clearly issues surrounding commercial development in the Department of Commerce that this Committee and others will need to tackle moving forward.

So, Mr. Babin, do you have further questions?

Mr. BABIN. I have no other questions except to say this has been a great hearing. I've enjoyed listening to the expert answers. Thank you for having this.

I also want to say thank you to the Johnson Space Center folks that came up here to visit and get a little continuing education,

and I'm proud of you for being here and all the great work you do back home. Thank you. I yield back.

Chairwoman HORN. Thank you, Mr. Babin. And yes, thank you to all of our civil servants and the work that you've done. And thank you to our panelists. I agree; this is an important topic, and your insights were incredibly valuable as we tackle this critical issue about how we make the transition.

And I want to thank the Committee, as well as all of the witnesses, for your participation and note that the record will remain open for 2 weeks for additional statements from the Members and for any additional questions the Committee may ask of the witnesses.

And the witnesses are excused, and the hearing is now adjourned.

[Whereupon, at 11:55 a.m., the Subcommittee was adjourned.]

Appendix

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. William Gerstenmaier

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

A Review of NASA's Plans for the International Space Station and Future Activities in Low Earth Orbit

Questions for the Record to:

Mr. William Gerstenmaier

Submitted by Chairwoman Horn

1. **NASA recently released its plan for Commercial LEO Development.**
   a. **Currently, NASA uses its allocation of crew time for scientific research, exploration research and technology, and the human research program. If NASA plans to make 5% of its utilization available for commercial use, which of the above NASA activities will be reduced, and how does the decrease research time affect the timeline for mitigating human health risks and technology gaps for human exploration?**

A: NASA has opened the ISS to expanded commercial and marketing opportunities to develop a sustainable economy in low-Earth orbit (LEO), ultimately benefitting NASA by enabling the development of providers of services needed to accomplish Agency missions. As part of this effort, the Agency has set aside five percent of its ISS utilization resources to serve commercial and promotional activities – with no impact to the 50 percent allocation to the ISS National Laboratory. At the same time, NASA will continue its mission in LEO, conducting regular crewed operations; developing and demonstrating long-term technology/systems; conducting space life and physical sciences basic and applied research at current levels and capabilities; and providing opportunities for astrophysics, space, and Earth science research. NASA expects to be able to conduct these additional activities primarily through crew time efficiencies typically seen on orbit. In addition, it is not uncommon for actual crew hours available for research to exceed the number of hours planned over the course of a week, so making some utilization resources available for commercial use does not necessarily mean that other planned activities cannot be accomplished. NASA will plan the resource usage to minimize impacts on any ongoing research. NASA plans to continue research and technology development in support of deep space exploration using ISS and commercial LEO capabilities as they become available.

   b. **The commercial LEO development plan states that private astronauts must meet NASA's medical standards, training, and certification procedures to travel to the ISS. How will these requirements be fulfilled? Will companies reimburse NASA for the full cost of participating in its astronaut training program? Or if the private astronauts are independently trained, how would NASA verify that they meet the standards?**

A: These requirements will be fulfilled through agreements between NASA and the companies conducting the private astronaut missions. Wherever possible, the companies interested in private astronaut missions are contracting directly with the same companies that NASA uses for these activities. Since NASA owns the unique training facilities, and it is not cost effective nor in the Government's best interest to work with a commercial company to duplicate these facilities, NASA will support companies conducting private astronaut missions by making NASA-unique training facilities available to them on a reimbursable basis. NASA will require evidence that the private astronauts meet the NASA training requirements.

c. Who on the ISS would keep track of private sector use of purchased crew time, power usage, etc.? How is NASA planning to handle this accounting process?

A: The ISS Program will keep track of private sector activities done on orbit in the same way crew time is tracked and accounted for with the International Partners to allow for the reconciliation of the agreed-upon allocations. Private sector activities, which would use various Station resources, would be factored into and tracked through the standard scheduling process.

2. In March 2018, the NASA Advisory Council recommended that NASA formulate metrics to guide the transition from a NASA-owned and operated International Space Station to a commercial option. Has NASA developed such metrics, and if so, what are they?

A: In the ISS Transition Report, released March 30, 2018, NASA identified eight ISS Transition Principles intended to ensure uninterrupted access to LEO capabilities to enable NASA and the Nation's long-term interests in LEO and human spaceflight exploration. These principles are:

- Continuity among NASA's LEO, deep space exploration, and development and research activities and missions toward expanding human presence into the solar system;
- Expanding U.S. human spaceflight leadership in LEO and deep space exploration, including continuity of the relationship with our current ISS international partners;
- Increase platform options in LEO to enable more ISS transition pathways, security through redundant capabilities, and industrial capability that can support NASA's deep space exploration needs;
- Spur vibrant commercial activity in LEO;
- Maintaining critical human spaceflight knowledge and expertise within the Government in areas such as astronaut health and performance, life support, safety, and critical operational ground and crew experience;
- Continuing to return benefits to humanity through Government-sponsored basic and applied on-orbit research;
- Continuing Government-sponsored access to LEO research facilities that enable other Government agencies, academia, and private industry to increase U.S. industrial competitiveness and provide goods and services to U.S. citizens; and
- Continuing to reduce the Government's long-term costs through private industry partnerships and competitive acquisition strategies.

In addition, once U.S. entities are able to provide commercial activities or capabilities, NASA intends to adjust the recently released "NASA Interim Directive (NID) on Use of International Space Station (ISS) for Commercial and Marketing Activities," in whole or in part, as market conditions mature. Performance metrics for the success of this policy will be established and reported in accordance with criteria established by the Human Exploration and Operations Mission Directorate.

a. What are the criteria by which the transition would considered a success or a failure, and when would this determination of the transition be made?

A: Please see response to Question #2, above.

3. Were any international partners on the ISS consulted during the planning process for the commercial LEO development plans? If so, what were their reactions? Are any of them developing their own commercialization plans?

A: Yes. On August 9, 2017, NASA held a workshop in Washington, D.C., to engage ISS stakeholders in gathering information that may be used in the development of NASA's future planning activities. The workshop was attended by individuals from the commercial space sector, researchers, technology developers, transportation and habitation providers, other federal government agencies, international partner agencies, and other interested parties, providing a forum for dialogue with NASA on topics relevant to space station future planning. A complete summary of the workshop, including presentations, can be found here: https://www.nasa.gov/content/international-space-station-stakeholder-workshop

Consistent with the ISS Transition Principles, NASA has continued discussions with the ISS International Partners to help shape the long-term future of the ISS platform and LEO, and reviewed the five-part plan with the Partners prior to its rollout. Consultations with the ISS Partners and other stakeholders are essential to developing an implementation strategy that could result in the day-to-day execution of the ISS being performed by private industry. Recognizing that there are differences in each Partner's organization and approach to commercialization, all of the agencies are united in striving to be innovative in their industrial partnerships, and actively share information about emerging approaches.

4. Given the uncertainty that a privately owned and operated space station would be economically viable, is partnering with more countries on the ISS, such as South Korea or India, an option? What is the legal process for doing so?

A: The ISS partnership will continue enabling research opportunities for non-partner countries. Such participants are currently sponsored by an existing ISS partner. To date, over 100 countries have utilized the ISS for research or education activities. Any current ISS Partner may propose the participation of non-Partners in the ISS Program, either as users or as hardware providers, or both, in accordance with the provisions of the Intergovernmental Agreement (IGA) and the Memoranda of Understanding (MOUs).

Adding a new "Partner" to the ISS legal framework established among 15 countries would be, at best, complex and time consuming, as it would require conclusion of a new international agreement between the new countries joining the partnership and all the existing countries currently party to the IGA. The ISS partners have no plans to seek an expanded partnership at this time, given the success of incorporating non-partners in ISS activities.

Aside from expanding the ISS partnership, the results of the 12 LEO Commercialization studies on the future of the LEO economy consistently found that sovereign nations could be an important element of the customer base for a privately-owned and -operated destination in LEO. With users from over 100 countries completing educational or scientific activities on ISS, the existing partnership is flexible in allowing partners to sponsor and benefit from participation of non-partner entities. Thus, adding official partners is not a necessary step for broadening the international market for ISS access.

a. What are the costs and benefits of allowing other countries to join the ISS?

A: Please see response to Question #4, above.

5. **According to a presentation in May of 2019 to the NASA Advisory Council's Human Exploration and Operations committee, NASA has contracted with Russia to ensure US crew presence on the ISS through January of 2020. What is NASA's plan if the Commercial Crew Program is not operational by then? What would be the implications for NASA's LEO Commercial Development plans?**

A: The Agency will begin transporting astronauts to the ISS via its U.S. providers as soon as possible. Flight test dates for NASA commercial crew providers are currently under review. The last contracted U.S. On-orbit Segment (USOS) crewmember flying on a Russian Soyuz is currently scheduled to return from orbit in October 2020. NASA is continuing to monitor the progress of the commercial crew program and is working to protect options to maintain a U.S. presence on the ISS. NASA is in contract discussions with Roscosmos for services on a sole source basis for one Soyuz seat and associated services to the ISS. This transportation would be for one crewmember in the fall of 2020, with a return in the spring of 2021.

Although Private Astronaut Missions to the ISS are dependent on Commercial Crew becoming operational, the other facets of the LEO Commercial Plan are not dependent on this capability. These include purchase of other ISS resources for commercial use, development of commercial modules and platforms, and stimulating sustained non-NASA demand for LEO services.

   a. **In Mr. Martin's written testimony, he stated that if the commercial crew program is delayed beyond February 2020, the U.S. portion of the ISS could be forced to operate with two or even possibly one crew member. What is your response to this comment? To what extent could NASA carry out research activities with such a reduced crew?**

A: NASA continues to have confidence in the Commercial Crew partners, will continue to safely operate the ISS at an appropriate crew level. While NASA is making every effort to avoid reduced crew on ISS, should that eventuality occur, NASA will continue to maximize the amount of research that can be accomplished. However, a substantial impact on research and commercialization activities can be expected should the USOS crew size be limited to one crewmember. Having a single USOS crew member on orbit does not support operations required to conduct some exploration-critical science.

6. **The 2018 NASA ISS Transition Report listed four options for the future of the ISS: 1) transitioning the operation of the ISS to private industry through public-private partnerships, 2) augmenting the ISS with privately developed modules, 3) combining portions of the ISS with a new private platform, or 4) beginning anew with free-flying platforms. The 2019 NASA plan for commercialization focuses on developing free-flyers and decommissioning the ISS. How did NASA arrive at this conclusion?**

A: NASA's plans for transitioning LEO to the commercial sector are continuing to evolve. The recently released Commercial LEO Development Plan has been informed by inputs provided by industry via the 12 LEO Commercialization studies provided to the Agency in December of 2018. All four options identified by the ISS Transition Report are represented in the plan, and continue to be viable options. Over the last decade, NASA has begun to transition elements of ISS operation to private industry and will continue to do so. The port solicitation released as Appendix I to the Next Space Technologies for Exploration Partnerships-2 (NextSTEP-2) Broad Agency Announcement (BAA) envisions commercial module(s) attached to the Node 2 forward port of the ISS, with an evolution path to a free flyer. Appendix K of the NextSTEP-2 BAA envisions commercial destinations that begin directly as free-flyers.

Both paths, through the port and as free-flyers initially, could potentially use portions of the ISS as part of their concepts. NASA continues to be open to a variety of approaches to transitioning LEO operations.

a. **The 2018 ISS Transition Report stated that NASA wants to completely transition its LEO activities to commercial entities by 2025. However, the Commercial LEO Development Plan is proposing a commercial free-flyer or ISS port module starting around 2025 and is expecting the transition to be complete by 2030. Does the Commercial LEO Development Plan supersede the 2018 ISS Transition Report? When is NASA assuming ISS operations will cease?**

A: As noted in the response to Question #6, above, the Commercial LEO Development Plan represents the Agency's approach to LEO commercialization and is informed by data not available at the time the initial edition of the ISS Transition Plan was written (e.g., results of the 12 LEO Commercialization studies). The Commercial LEO Development Plan is consistent with the 2018 ISS Transition Report, and moves it forward with concrete actions and development activities. It should also be noted that the plan, directed in the NASA Transition Authorization Act of 2017, is a biennial requirement that will be updated to reflect the evolution of NASA's efforts.

7. **In the April 25 meeting of the Aerospace Safety Advisory Panel, the Panel recommended that NASA "immediately" transition to new space suits for space walks outside of the ISS. A 2017 NASA Inspector General report on spacesuits, "NASA's Management and Development of Spacesuits", states that NASA will be challenged to support the ISS with spacesuits through 2024. What are NASA's development plans for new ISS spacesuits?**

A: NASA is developing a flexible spacesuit architecture with common core subsystems that can be modified to support the needs of specific destinations from low-Earth orbit, to deep space, and to the lunar surface. NASA intends to demonstrate the core spacesuit technologies and subsystems applicable to both ISS-based operations and surface exploration through a series of subsystem demonstrations at ISS, culminating in delivery of a complete suit system for an on-orbit demonstration at ISS prior to the 2024 lunar mission.

a. **How are you ensuring that the next generation of spacesuits will support a diverse astronaut corps in terms of body height and shape, especially between women and men?**

A: For the exploration EVA suit, the pressure garment design has focused on improving fit and performance for the full range of astronaut sizes and is not uniquely driven by gender. The exploration pressure garment design and sizing scheme has been validated in over 30 test events with crew. The rear-entry adjustable upper torso design accommodates crew from the 1st percentile female shoulder breadth up to 99th percentile male, offering a significant improvement over all previous EVA suit systems and representing the smallest size ever built.

8. **According to a 2018 NASA Inspector General report, "NASA's Management and Utilization of the International Space Station", "at least 6 of 20 human health risks that require the ISS for testing and 4 of 40 technology gaps will not be completed by the end of FY 2024". What is the current plan to address these health risks and technology gaps, as part of an ISS transition?**

A: A number of the risks that can be addressed using ISS will have completed on-orbit activities in 2024, even though the testing and final recommendations from the research will not be complete. However, there are some risks that will not be fully addressed by the end of 2024. A major requirement of the current path to risk reduction is 10 additional ISS subjects that spend approximately one year each in space to reduce the health and performance risks for Mars missions. These one-year missions are dependent on commercial crew transportation, and will require about five years to complete from the date when the first one-year crewmember flies on a commercial vehicle. Government requirements for use of ISS during transition and on possible commercial LEO platforms were summarized in LEO demand studies that include the needs that the Human Research Program (HRP) and technology demonstration activities have for continued LEO testing. NASA's forecast for Government LEO demand details the Agency's future needs in LEO.[1]

NASA continues to prioritize utilization of ISS for testing of technologies critical for exploration of the Moon and Mars. In FY 2018 and FY 2019, NASA initiated eight in-space demonstrations of technology critical to enable human habitation in deep space. Research and technology development efforts that have not been completed by the end of 2024 will be conducted on LEO platforms – whether they be new commercial platforms or commercially-operated ISS elements – are available in 2025 and beyond.

a. If the human research risks are not sufficiently understood and mitigated by the time of the transition to a commercial space station occurs, how difficult would it be to complete the research on a commercial platform?

A: NASA intends to conduct needed R&D and technology demonstrations in LEO by competitively purchasing services from commercially-owned and -operated destinations in LEO. NASA's quantified market forecast for such services was released on June 7, 2019, with the rollout of the Commercial LEO Development Plan. Many currently identified Human Research Program (HRP) human health and performance risks for deep space missions should be sufficiently mitigated by the end of 2024. However, there will be some exploration risk areas requiring additional mitigation research, validation of countermeasures for efficacy, and optimization of exploration biomedical systems, that will require significant efforts and development. Some of these, such as validation of the autonomous exploration medical system and advanced space radiation environment observation system, can only be conducted in cislunar space with the Gateway, while others, such as behavioral health and radiation testing, will be able to use ground-based facilities such as those at Johnson Space Center and Brookhaven National Laboratory. For those areas requiring or substantially benefitting from LEO, such as operational testing in microgravity, NASA will need a commercial habitation service that supports a crew presence at a level sufficient to meet the objectives that are defined in the HRP path to risk reduction. A LEO destination intended to host NASA human research will likely need to support crew health and safety, access to and from LEO, and the research capabilities needed to enable the activities identified in HRP risk reduction plans.

9. A 2018 NASA Inspector General report, "NASA's Management of the Center for the Advancement of Science in Space (CASIS)", found that CASIS has only succeeded in meeting 2 of its 9 goals: 1) research pathways and science, and 2) STEM education. CASIS failed to meet expectations in both the utilization of crew time for research and outreach. In fact, between

[1] "Forecasting Future NASA Demand in Low-Earth Orbit: Revision Two – Quantifying Demand" available at: https://www.nasa.gov/sites/default/files/atoms/files/forecasting_future_nasa_demand_in_low-earth_orbit_revision_two-quantifying_demand_links_tagged.pdf

2013 and 2017, projects managed by CASIS only used 53% of the allocated crew time. The report noted that NASA failed to actively oversee CASIS. How has NASA responded to this management challenge?

A: Among NASA's comments in response to the Office of Inspector General report, "NASA's Management of the Center for the Advancement of Science in Space," (IG-18-010), the Agency noted that it would continually develop and modify criteria to measure CASIS' performance; provide formal feedback on a semiannual basis (along with NASA's ongoing evaluation of CASIS' performance and provision of routine feedback through discussions on a weekly and monthly basis); and identify annual metrics and targets that are quantifiable and track to the requirements of the Cooperative Agreement with CASIS. All of these efforts have been initiated and are ongoing. During the time period for which the 2018 report was written, ISS utilization was affected by the loss of two cargo flights which impacted the CASIS metrics

NASA has converted an independent review team (IRT) to provide assessment on the status of the cooperative agreement with the CASIS and its ability to meet NASA's needs over the next five years. The IRT will produce a final report with observations, findings, concerns, and recommendations.

10. During the question and answer session of the hearing, NASA Inspector General Paul Martin said that NASA has invested $17 billion in the Commercial Crew and Cargo programs over the last 12-14 years. Do you agree with this level of investment, and if so, what does it include? If not, why not? How much has NASA invested into the Commercial Crew and Cargo programs from their inception until today? How much more does NAS plan to invest?

A: NASA has allocated about $19 billion towards commercial crew and cargo to date. This has supported the completion of two cargo vehicles and the ongoing development of another, ongoing development of two crew vehicles, and 31 successful cargo flights to the ISS. Of that amount, NASA contributed $6 billion towards the development of the commercial crew and cargo systems. This is the amount NASA refers to as "investment" in the systems, and it includes NASA's share of the commercial cargo development costs, as well as all NASA Commercial Crew Program development costs (Commercial Crew Development [CCDev] phases 1 and 2, the Commercial Crew Integrated Capability [CCiCap] initiative, Certification Products Contract [CPC] and Commercial Crew Transportation Capability [CCtCap]). The remaining amount of $13 billion is the amount NASA has contracted for services, i.e., the transportation of cargo and crew to the ISS. This includes the current contract values for both Commercial Resupply Services (CRS)-1 and CRS-2 cargo contracts, as well as CCtCap crewed missions to the ISS. Within the current maximum contract value, NASA can still award another $10 billion under the CRS-2 contracts.

Of the $19 billion NASA has allocated to these programs, $14 billion has been paid to the companies to date.

Responses by the Honorable Paul Martin

Questions for the Record

A Review of NASA's Plans for the International Space Station and Future Activities in Low Earth Orbit

Submitted by Chairwoman Horn

1. Currently, NASA uses its allocation of crew time for scientific research, exploration research and technology, and the human research program. If NASA plans to make 5% of its utilization available for commercial use, other NASA activities will have to be reduced. How would this affect the timeline for mitigating human health risks and technology gaps for human exploration?
   While NASA's Plan for Commercial LEO Development references making available 5 percent of its allocation of utilization resources for commercial use, the plan is silent on any affects the allocation would have on completion of its human health and technology gap research. NASA expects research for at least 6 of 20 human health risks requiring the International Space Station (ISS or Station) for testing and 2 of 37 technology gaps will not be completed by the end of September 2024 when the Station's current authorization to operate expires. In addition, research into 2 other human health risks and 2 additional technology gaps is not scheduled to be completed until sometime in 2024, meaning that even minor schedule slippage could push completion past the end of that fiscal year.

   a. Would the revenues from selling 5% of ISS utilization go to NASA, or do they go to the U.S. Treasury?
      According to an Agency official, NASA plans to retain the funds because it would use a Reimbursable Space Act Agreements to conduct these activities.

2. The Aerospace Safety Advisory Panel recommended that NASA "immediately" transition to new space suits for space walks outside of the ISS. The 2017 NASA Inspector General report, "NASA's Management and Development of Spacesuits", states that NASA will be challenged to support the ISS with spacesuits through 2024. What are NASA's development plans for new ISS spacesuits?
   NASA has 11 functioning Extravehicular Mobility Units (EMUs – the "old suits") and will continue to use these to maintain EVA capability on the ISS for the next several years. The Agency plans to begin testing its next-generation suit, known as the Exploration EMU (xEMU), on the ISS in 2023.

3. According to a 2018 NASA Inspector General report, "NASA's Management and Utilization of the International Space Station", "at least 6 of 20 human health risks that require the ISS for testing and 4 of 40 technology gaps will not be completed by the end of FY 2024". What is the current plan to address these health risks and technology gaps as part of an ISS transition?
   NASA has established mitigation plans for addressing outstanding health risks and technology gaps if its research is not completed by 2024 that include a mix of ground-based tests. NASA also plans to perform some of this research aboard the Lunar Gateway currently scheduled for completion in 2026.

   a. If the human research risks are not sufficiently understood and mitigated by the time of the transition to a commercial space station occurs, how difficult would it be to complete the research on a commercial platform?

NASA's plans for ISS contingency operations and commercial LEO development currently do not reference the timing or capabilities of any future commercial platforms, thus making it difficult to assess their usefulness to the Agency to complete any remaining human health or technology demonstration research.

4. A 2018 NASA Inspector General report, "NASA's Management of the Center for the Advancement of Science in Space", found that CASIS has only succeeded in meeting 2 of its *9* goals: I) research pathways and science, and 2) STEM education. CASIS failed to meet expectations in both the utilization of crew time for research and outreach. In fact, between 2013 and 2017, projects managed by CASIS only used 53% of the allocated crew time. The report noted that NASA failed to actively oversee CASIS. How has NASA responded to this management challenge?
   NASA has responded positively to the report and the recommendations by implementing measurable goals and metrics and providing timely feedback to CASIS using those criterion. Agency actions in response to all but one of the recommendations have been implemented and the remaining action is expected to be completed later this year.

   a. The same report found that, between 2013 and 2016, CASIS "has underperformed on tasks important to achieving NASA's goal of building a commercial space economy in low Earth orbit." How has NASA responded?
      The 2018 CASIS annual report shows a growing portfolio of commercial entities and projects utilizing the National Laboratory. That said, in August 2019 NASA announced an independent review to evaluate CASIS's management of the ISS National Laboratory.

   b. How has CASIS's performance been since the 2018 IG report?
      Although we have not performed a detailed follow-up audit of their actions, the most recent CASIS annual report shows improved performance, with CASIS reporting $150 million in external, non-NASA funding to support its research portfolio, a 50 percent increase over FY 2017. The report also stated that the group's outreach efforts reached more than 2 million students, parents, and educators—nearly double all previous years combined.

5. In your written testimony, you stated that, if the commercial crew program is delayed beyond February 2020, the U.S. portion of the ISS could be forced to operate with two or even possibly one crew member. To what extent could NASA carry out research activities with such a reduced crew?
   On the U.S. portion of the ISS, a typical work week with a 3-person crew allows each astronaut to perform roughly 12 hours of scientific research, 6 hours of vehicle traffic operations, and 4 hours of maintenance, among a variety of other tasks and operations. However, if commercial crew transportation delays persist and the U.S. segment is left with a single crewmember, that astronaut will be forced to focus mainly on vehicle traffic operations and ISS maintenance rather than scientific research. We examine this issue in our forthcoming report on ISS crew transportation expected for public release in early fall 2019.

Responses by Dr. Joanne Irene Gabrynowicz

Answers to Questions Submitted for the Record by Chairwoman Kendra S. Horn

Submitted by

Prof. Joanne Irene Gabrynowicz, Emerita

1. *NASA has plans to transition the ISS from a government-owned and operated laboratory to a commercial model in which the ISS, or portions of it, may be commercially operated or commercially-owned and operated. What are the legal issues, both domestically and internationally, that this change may pose? What are the implications for the Intergovernmental Agreement that governs the ISS partnership?*

At the international level there are two major legal points:

1. The U.S. Government is internationally responsible for the activities of its nongovernmental space actors in perpetuity.[1] Article VI[2] of the Outer Space Treaty states that the "activities of non-governmental entities in outer space...shall require authorization and continuing supervision."[3] To assure that nongovernmental space entities act in accord with the law, Art. VI also provides that "States Parties...shall bear international responsibility for...activities...carried on...by non-governmental entities."[4]

It is crucial that Art. VI of the Outer Space Treaty is central to plans for commercial LEO development. What constitutes "responsibility" is part of a growing body of law that has strengthened and matured in recent years.[5] The United States Government—and through it—the U.S. taxpayer—will ultimately be responsible for reparation if it is deemed necessary because of events arising from U.S. nongovernmental space activities.

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[1] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, opened for signature Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter
Outer Space Treaty]. Art. VI

[2] Art. VI is the legal source for recognizing nongovernmental actors as legitimate space actors. During Outer Space Treaty negotiations, it was the position of the Soviet Union that only States could be legitimate space actors. The U.S., of course, did not agree and took the position that private entities were also legitimate space actors. The compromise between the two positions was "to require authorization and continuing supervision" of nongovernmental space actors.

[3] Outer Space Treaty, Art. VI.

[4] *Id.*

[5] James Crawford, Jacqueline Peel, Simon Olleson, *The ILC's Articles on Responsibility of States for Internationally Wrongful Acts: Completion of the Second Reading*, 12 EJIL 963 (2001).

The Government's responsibility exists in perpetuity. Withdrawing from, or altering the terms of, the Outer Space Treaty can change this but that is an option not favored by the space industry[6] or the U.S. State Department.[7]

2. Pursuant to the *International Space Station Intergovernmental Agreement* (*IGA*), United States *ISS* obligations will remain in force even after transfer of its *ISS* elements to nongovernmental commercial entities. The IGA provides that "[t]he transfer of ownership...shall not affect the rights and obligations of the Partners." This is equally applicable to the MOUs and implementing agreements.[8] Therefore, if the *ISS* transition will include "transfer of all or parts of the ISS itself to commercial entities"[9] including ownership, or "exercise of ownership or equipment"[10] then the United States will still have the same rights and obligations that were in force prior to the transfer.

Implications for the IGA

Implications include expecting negotiations among the *ISS* partners regarding the long-term effect of the transfers. Additionally, negotiations regarding United States transfers will have ramifications for analogous plans under consideration by the Partners. Together, these negotiations have the potential to change or modify some aspects of the IGA that are currently unanticipated.

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[6] *Reopening the American Frontier: Exploring How the Outer Space Treaty Will Impact American Commerce and Settlement in Space, Before the S. Comm. on Commerce, Science and Transportation Subcommittee on Space, Science, and Competiveness*, 115 Cong., (2017); Marcia Smith, *Congress Looking at Additional Measures to Facilitate Commercial Space,* (May 30, 2017, 12:00 AM),
"the Senate hearing...focused on...has the 50-year-old OST been so overtaken by events that the United States should withdraw from or seek to renegotiate it. None of the witnesses supported either of those courses of action." https://spacepolicyonline.com/news/congress-looking-at-additional-measures-to-facilitate-commercial-space/

[7] *The Next Fifty Years of the Outer Space Treaty*, Remarks by Brian J. Eagan, Legal Advisor, U.S. State Department, (Dec. 7, 2016), "the Outer Space Treaty serves a constitutional role in the international legal framework for outer space...If the preparations for future space activities underway in the United States and other nations are any indication, the Treaty will serve this function well into its second half century and beyond." https://2009-2017.state.gov/s/l/releases/remarks/264963.htm

[8] Agreement Among the Government of Canada, Governments of Member States of the European Space Agency, The Government of Japan, the Government of the Russian Federation, and the Government of the United States of America Concerning Cooperation on the Civil International Space Station, [Hereinafter, IGA], Article 6.3. https://www.state.gov/wp-content/uploads/2019/02/12927-Multilateral-Space-Space-Station-1.29.1998.pdf

[9] Forecasting Future NASA Demand in Low-Earth Orbit: Revision Two – Quantifying Demand, pg. 1.

[10] IGA, Article 6.7.

It must also be noted that The *IGA* is part of a three-tier legal framework that includes memoranda of understanding (MOUs), implementing arrangements and, other formal arrangements. All of these must be taken together to determine the implications for the IGA in any given situation.

At the domestic level there is one major, overarching legal point:

There currently is an uncertain national space law environment that includes a regulatory gap for on-orbit activities[11]. The role and responsibility of the private sector conducting on-orbit activities is unclear. Further, under the Outer Space Treaty,[12] the United States is internationally responsible for their activities. This issue is discussed further under questions 3 and 4.

2. *Given the uncertainty that a privately owns* [sic] *and operated space station would be economically viable, is partnering with more countries on the ISS, such as South Korea or India, an option? What are the legal processes for doing so?*

Whether or not it is an option for any given nation to become a Partner in the *ISS* is a political question, not a legal question. Therefore the answer would depend on a number of variables including the political will of the existing Partners and proposed Partners; the proposed contributions of the proposed Partner(s); and, the engineering and scientific aspects of integrating the proposed Partner(s) and contributions into the existing physical infrastructure.

The legal processes of partnering with more countries will depend on the diplomatic choices made. Possible processes include bilateral and multilateral negotiations. All diplomatic choices will require following relevant procedures contained in the *IGA*; the four bilateral Memoranda of Understanding between NASA and the other Cooperating Agencies; and, the Implementing Agreements that have arisen as needed. There is also the precedent of bringing the Russian Federation, then a non-Partner, into the *IGA* as a Partner.

In the first iteration of the IGA from 1988 to 1998, the Partners were Canada, Europe, Japan, and the United States. With the end of the former U.S.S.R, and the advent of the Russian Federation, the U.S. sought to bring the Russian Federation into the *ISS IGA*. In order to do so, the "prior concurrence"[13] of the other Partners was required. In order to facilitate acquiring the other

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[11] National Academies of Sciences, Engineering, and Medicine, *Review and Assessment of Planetary Protection Policy Development Processes*, Washington, DC: The National Academies Press. https://doi.org/10.17226/25172, at 86, (2018).
[12] Art. VI.
[13] IGA Art. 6.4.

Partners' concurrence, the U.S. and Russia entered into a bilateral Interim Agreement from 1994 to 1998.[14] In the Interim Agreement Russia agreed to fulfill U.S. obligations under the *IGA*. However, vis-à-vis the existing Partners, the U.S. was still legally responsible for its obligations under the IGA. The bilateral interim language was identical to the *IGA* multilateral language. This arrangement allowed the U.S. and Russia to demonstrate that Russia could be a viable *ISS* partner. It resulted in the 1998 iteration of the *ISS IGA* in which the Partners are now Canada, Europe, Japan, Russia, and the United States.

There is the option of bringing a nation into the *ISS* as a something other than a Partner. Brazil and Italy each participate in the *ISS* through an arrangement called a "Side Agreement". These agreements are ancillary to the *IGA* and supplement the broader agreement. Each were catalyzed by different political and technical motives and the Side Agreements appear to be *sui generis*.

3. **What are the most significant legal risks to NASA's commercial LEO development plans? What further questions regarding legal issues and liabilities need to be asked and answered?**

The most significant legal risk is an uncertain and illusory legal regime. This is explained below in answer 4.

4. **In your written testimony, you state, "Development of LEO and the *ISS* is beginning at a time...when recent U.S. national space law increasingly places more of the cost of industry risk-taking onto the U.S. taxpayer and, when recently enacted U.S. national space law has created an uncertain legal environment by the use of illusory language that is mostly aspirational and repetitive and creates little black-letter law." Can you expand on your comments? How has risk been shifted to the taxpayer? How has the "illusory language" created an "uncertain legal environment"?**

The Uncertain Legal Environment

From 2015 to the present numerous space bills have been introduced in Congress and a number of them have become Federal space laws. Together, the U.S. national space law statutes enacted since 2015 contain few provisions

[14]Interim Agreement Between the United States and Russia for the Conduct of Activities Leading to Russian Partnership in the Detailed Design, Development, Operation and Utilization of the Permanently Manned Civil Space Station (Signed at Washington June 23, 1994. Entered into force June 30, 1995).

This followed the Agreement between the United States of America and the Russian Federation Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes of June 17, 1992. https://www.princeton.edu/~ota/disk1/1995/9546/954610.PDF

that actually authorize, require, or prohibit action. There is little authentic law to define rights and obligations and to provide guidance in disputes. They do contain numerous findings, reaffirmations, and Sense of Congress provisions, none of which make law. This has resulted in a body of "law" that appears to provide stability and direction but which—in reality—contains precarious regulatory gaps[15] and creates legal uncertainty.

Congress has yet to authorize any Federal agency to exercise jurisdiction over the on-orbit activities addressed in these laws. They range from lunar missions to asteroid mining. This has caused a regulatory gap in which the role and responsibility of the private sector conducting on-orbit activities is unclear[16] and for which the United States is internationally responsible under the Outer Space Treaty.[17] The single payload review conducted for a planned lunar landing "does not extend to future missions by [the same company] or similar missions from other entities...[f]uture missions may require additional authority...**on a case-by-case basis when the law permits.**"[18]

Because these laws address so may commercial issues both old and new, some are characterizing these laws as a major breakthrough for U.S. commercial space law and activities. However, upon closer examination of the content of these laws, it is apparent that quantity does not mean quality. They contain a formula for action that, if all goes as designed, results in a political "machine" that serves political interests rather than the law.

The formula consists of the generous use of technical legal terms of art that do not create law; numerous calls for studies and reports on topics and issues rather than addressing the actual substance of the topics and issues; and the establishment of advisory committees whose work is to be integrated into the ongoing research and reporting. The reports are to be sent to specific Congressional committees for further action. Together this establishes an interconnected mechanism among agencies, advisory committees, and Congressional committees in which lobbying, advocacy, and the legislative process become interchangeable.

The Use of Illusory Language

The use of technical legal language that does not create law includes the use of Findings, Sense of Congress provisions, and Reaffirmations. These are

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[15] National Academies of Sciences, Engineering, and Medicine, *supra* note 11, at 86.
[16] National Academies of Sciences, Engineering, and Medicine, *supra* note 11, at 86.
[17] Art. VI.
[18] FAA, Fact Sheet—Moon Express Payload Review Determination, August 3, 2016, https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20595. Emphasis added.

legitimate legislative tools. However, in a number of recent space laws and bills, the cumulative amount of this language in a given law is more than the language that actually creates law. Some relevant laws and bills include the *U.S. Commercial Space Launch Competitiveness Act of 2015 (CSLCA)*[19], *the National Aeronautics and Space Administration Transition Authorization Act of 2017 (Transition Act)*[20], the *American Space Renaissance Act*[21](*Renaissance Act*) and a bill in process, the *Space Frontier Act of 2019*.[22]

"Findings" and "reaffirmations" in a public law state the problems and principles that the public law's operative sections attempt to address. They are not operative sections themselves. Courts consult the findings and reaffirmations of a public law to determine the law's meaning when the operative provisions of the law are capable of different interpretations. [23] Both "findings" and "reaffirmation" language have been liberally used in recent U.S. Federal space law.

However, "Sense of Congress" provisions have been the most used technical term of art that does not make law. As explained by the Library of Congress, "A 'sense of' resolution is not legally binding because it is not presented to the President for his signature. Even if a 'sense of provision' is incorporated into a bill that becomes law, such provisions merely express the opinion of Congress or of the relevant chamber. **They have no formal effect on public policy and have no force of law**."[24]

For example, Sense of Congress provisions appear in the *Transition Act* 34 times.[25] If all of these provisions were removed from the *Transition Act*, less than half of the Act would remain. There is even a provision in which "Congress reaffirms the sense of Congress..."[26], literally adding one non-substantive layer over another non-substantive layer. The Sense of Congress provisions apply to a wide range of important space issues including sustaining national space commitments; the use of low Earth orbit and the *International Space Station*; the

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[19] P.L. 114-90 (2015).
[20] P.L. 115-10 (2017).
[21] H.R. 4945, 114th Congress, (2015-2016).
[22] S. 919, 116th Congress, (2019-2020).
[23] William N. Eskridge, Jr. et al., Legislation and Statutory Interpretation (2nd Edition), (2006), pp. 280-281.
[24] Christopher M. Davis, Cong. Research Serv. 98-825, "Sense of" Resolutions and Provisions", (2016). (Emphasis added.)
[25] This count excludes the use of the term "Sense of Congress" in titles and prefatory language. Including these the count comes up to 66.
[26] *Transition Act*, *supra*, note 20 at Sec. 501 (a).

Commercial Crew Program; transparency; the Space Launch System; human space exploration; and, asteroids, among others.

There are nine Sense of Congress provisions in the *CSLCA*.[27] They apply to such important topics as launch competitiveness; space traffic management; government astronauts; and, U.S. sovereignty. The *CSLCA* is also a prime example of substituting studies and reports on issues rather than addressing the substance of the issues. It calls for 13 reports, 3 studies, 2 reviews, 2 plans, 1 evaluation, and 1 assessment.[28] Some are to be produced annually.[29] The majority address space transportation vehicles and services; one report is regarding asteroid mining; and, one annual report is regarding commercial remote sensing. Most of them are to be delivered to the Senate Committee on Commerce, Science, and Transportation and/or the House Committee on Science, Space, and Technology of the House of Representatives. None of the studies are funded.[30] Some of the studies have been completed and others have not.

There are 20 Sense of Congress provisions[31] in the unenacted bill, the *Renaissance Act*.[32] The issues they address include satellite architectures for the Dept. of Defense; strategy for positioning, navigation, and timing for GPS; the ability of the Space Based Infrared System to generate useful weather data; the National Geospatial-Intelligence Agency's use of open-source methods; and, reorganization of NASA, among others.

The *Space Frontier Act of 2019*[33] has five Sense of Congress provisions[34] and shows that the practice of using language that makes no law is continuing. The provisions address the existing authorities of the Secretary of Transportation; the terms of fair access to NASA assets and services by the commercial space industry; and, maintaining a human presence in low Earth orbit, among others.

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[27] This count excludes the use of the term "Sense of Congress" in titles and prefatory language. Including these the count comes up to 15.
[28] *Supra,* note 19, at Sec., 102, Sec. 105, Sec. 108, Sec. 109, Sec. 110, Sec. 111, Sec. 113, Sec. 115, Sec. 116, Sec. 201, Sec. 202, Sec. 302.
[29] *Supra,* note 19, at Sec. 113, Sec. 201, Sec. 202.
[30] H.R. Rep. No. 114-119, at 47 (2015).
[31] This count excludes the use of the term "Sense of Congress" in titles and prefatory language. Including these the count comes up to 36.
[32] *Supra*, note 21.
[33] *Supra*, note 22.
[34] This count excludes the use of the term "Sense of Congress" in titles and prefatory language. Including these the count comes up to 10.

Shifting Risk to the Taxpayer

Taken together, all of these statutes create an uncertain legal environment at the national level in which there is little or no legal authority or guidance over circumstances that have the potential to cause harm. The only real certainty is that the United States will be responsible for the activities of nongovernmental actors. If that responsibility is determined to include financial reparations, it will be the U.S. taxpayer who will pay them.

Recent laws and bills also include specific measures that shift the risk for nongovernmental activities to the taxpayer. The *CSLCA* "force[s] victims and taxpayers to pay the costs of any private space travel crash or disaster".[35] It also extends Government indemnification to the customers of commercial human spaceflight providers ("spaceflight participants") and prohibits regulating commercial space travel until 2025.[36]

The current proposed rule for remote sensing regulations will not require licensees to obtain insurance for what is called a "low risk category" of satellites.[37] In lieu of insurance, licensees must "comply with the latest version" of the still evolving space traffic management practices issued by the U.S. Government.[38] There is no specific mention of whether or not insurance is required for what is called the high-risk category.[39] Not requiring insurance at a time when evolving space traffic management practices are being "contemplated" and are in the process of being "updated', and when "a new approach" must be

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[35] Amanda Robert, *Commercial Spaceflight Industry Faces uncertain legal, regulatory environment*, Legal Newsline, (June 5, 2017) http://legalnewsline.com/stories/511121527-commercial-spaceflight-industry-faces-uncertain-legal-regulatory-environment "Linda Lipsen, chief executive officer of the American Association for Justice, [said] in a statement before the bill's passage that it would force victims and taxpayers to pay the costs of any private space travel crash or disaster. 'The bill jeopardizes both civilians on the ground and the passengers, whose right to hold anyone accountable would be eliminated,' quoting Linda Lipsen, regarding the *Commercial Space Launch Competitiveness Act* which "extends the indemnification regime and learning period".

[36] *Supra*, note 19, § 103.

[37] Licensing of Private Remote Sensing Systems, 84 Fed. Reg. 21282 (proposed) (May 14, 2019) (to be codified at 15 C.F.R. Part 960).

[38] Space Policy Directive-3, National Space Traffic Management Policy, 6(b)(ii), (June 18,2018), https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/ [Hereinafter SPD-3].

[39] Fed. Reg. *supra* note 34 at § 960.10, "If the Secretary makes an initial determination that an application is high-risk, the Secretary shall also make an initial determination of whether the application should be subject to specific license conditions under § 960.18. The Secretary shall presume that the standard license conditions are sufficient, unless the application presents a novel or not previously licensed capability with unforeseen risk to national security or compliance with international obligations and policies."

"developed"[40] means the U.S. Government and the U.S. taxpayer will pay for harm caused by the licensees.

Requiring no insurance and placing all risk on the U.S. Government and U.S. taxpayer creates fertile conditions for moral hazard. There is no incentive for a licensee to take action to reasonably decrease or mitigate risk because it will not bear the cost of the harm that is caused by its actions. This is particularly applicable in the proposed rule that relies on self-reporting[41] and volunteering[42].

It can be expected that a number of licensees will value good corporate citizenship and act appropriately. However, experience demonstrates that will not always be the case.[43]

5. In your written testimony, you stated that the United States Government would maintain its obligations over ISS elements even after transferring them to commercial industry. Would this also apply to ISS elements owned and operated by ISS international partners?

Yes. The *ISS IGA* provides that, "Canada, the European Partner, Russia, and the United States...and Japan"[44] have the same rights and obligations regarding "transfer of ownership of...elements"[45] as well as "[t]he exercise of ownership of elements and equipment."[46] Further, "[t]he addition of evolutionary

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[40] SPD-3 *supra* note 35.

[41] Fed. Reg. *supra* note 34 at § 960.15 (a), "the licensee will certify in writing to the Secretary that each material fact in the license remains accurate."

[42] Fed. Reg. *supra* note 34 at § 960.15 (b), (1) (2) (3), "If any material fact in the license is no longer accurate at the time the certification is due, the licensee must: (1) Provide all accurate material facts; (2) Explain the reason for any discrepancies between the terms in the license and the accurate material fact; and (3) Seek guidance from the Secretary on how to correct any errors, which may include requesting a license modification."

[43] Caleb Henry, *FCC Fines Swarm $900,000 for unauthorized smallsat launch, Space News*, (Dec. 20, 2018), "Swarm defied the FCC by launching the satellites after the agency dismissed its application for an experimental authorization to communicate with the spacecraft." https://spacenews.com/fcc-fines-swarm-900000-for-unauthorized-smallsat-launch/

[44] IGA Art. 6.1.

[45] IGA Art. 6.3. "The transfer of ownership of the elements listed in the Annex or of equipment in or on the Space Station shall not affect the rights and obligations of the Partners under this Agreement the MOUs, or implementing arrangements."

[46] IGA Art. 6.7. "The exercise of ownership of elements and equipment shall be subject to any relevant provisions of this Agreement, the MOUs, and implementing arrangements, including relevant procedural mechanisms established therein."

capability shall in no event modify the rights and obligations of any Partner State."[47]

a. If NASA transitions to being an anchor tenant on commercial, free flying modules in low Earth Orbit, to what extent could NASA transfer the *ISS* Intergovernmental Agreement to a commercial module? Or is the *ISS* Intergovernmental Agreement only applicable to government-owned elements and spacecraft?

To a degree. It will depend on the nature and purpose of the free flyer, the political will to have one, and the ensuing negotiations among the Partners. In general, only the *IGA* provisions for station evolution[48] and cross-waivers of liability[49] "shall apply to any additions of evolutionary capability".[50]

The Partners agree "to create an integrated international Space Station"[51] which has an "evolutionary character".[52] Further, "it shall be the object of each Partner to provide, where appropriate, the opportunity to the other Partners to cooperate in its proposals for additions of evolutionary capability.[53]

However, "[t]he addition of evolutionary capability shall in no event modify the rights and obligations of any Partner State."[54] The IGA "sets forth rights and obligations concerning only the elements listed in the Annex[55]...[the IGA] does not commit any Partner State to participate in, or otherwise grant any Partner rights in, the addition of evolutionary capability."[56]

The Cross-Waiver of Liability required by the *IGA* would apply to the free flyer's provider.[57] The Partners agreed that they, and their "related entities" that is,

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[47] IGA Art.14.7. "The addition of evolutionary capability shall in no event modify the rights and obligations of any Partner State under this Agreement and the MOUs concerning the elements listed in the Annex, unless the affected Partner State otherwise agrees."
[48] IGA Art.14.
[49] IGA Art. 16.
[50] IGA Art. 14.2
[51] IGA Art. 1.2.
[52] IGA Art. 1.4.
[53] IGA Art. 14.1
[54] IGA Art. 14.7.
[55] "The Government of the United States, through NASA, shall provide:
--Space Station infrastructure elements, including a habitation module;
--as user elements, laboratory modules (including basic functional outfitting), and attached payload accommodation equipment;
--other flight elements to supply the Space Station; and
--in addition to the flight elements above, Space Station-unique ground elements." IGA Annex 5.
[56] IGA Art. 14.
[57] IGA Art. 16.

the cooperating space agency; contractors; subcontractors; users and customers at any tier cannot sue the other Partners and their "related entities" for damage caused to "protected space operations." "Contractors" and "subcontractors" include suppliers of any kind.[58] Protected space operations "means all launch vehicle activities, Space Station activities, and payload activities on Earth, in outer space, or in transit between Earth and outer space in implementation of [the IGA], the MOUs, and implementing arrangements."[59]

U.S. national law governs the relationships between and among NASA and its U.S. contractors; subcontractors; suppliers; users and customers. Assuming the free flying module is provided by a U.S. nongovernmental commercial entity, U.S. law would govern the agreement between it and NASA. The free flyer would have to be registered as a U.S. space object and U.S. law would apply onboard. The U.S. would be "internationally responsible" for it.[60]

[58] IGA Art. 16.2 (b) (3).
[59] IGA Art. 16 (2) (f).
[60] Outer Space Treaty, Art. VI.