THE ISS AFTER 2024: OPTIONS AND IMPACTS

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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March 22, 2017

THE ISS AFTER 2024: OPTIONS AND IMPACTS

WEDNESDAY, MARCH 22, 2017

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

The Subcommittee met, pursuant to call, at 10:06 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Babin [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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The ISS after 2024: Options and Impacts

Wednesday, March 22, 2017
10:00 a.m.
2318 Rayburn House Office Building

Witnesses

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

Dr. Mary Lynne Dittmar, Executive Director, Coalition for Deep Space Exploration

Mr. Eric Stallmer, President, Commercial Spaceflight Federation

Dr. Robert Ferl, Distinguished Professor and Director of the Interdisciplinary Center for Biotechnology Research, University of Florida

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

Charter

TO: Members, Committee on Science, Space, and Technology
FROM: Majority Staff, Committee on Science, Space, and Technology
DATE: March 15th, 2017
SUBJECT: Space Subcommittee Hearing: "The ISS After 2024: Options and Impacts"

On Wednesday, March 22nd, 2017 at 10:00 a.m. in Room 2318 of the Rayburn House Office Building, the Committee on Science, Space, and Technology, Subcommittee on Space, will hold a hearing titled, "The International Space Station After 2024: Options and Impacts."

Hearing Purpose

It is the policy of the United States to support full and complete utilization of the International Space Station through at least 2024. What happens to the ISS after that date remains an open question. The hearing will examine the range of choices facing our nation and the impacts of those various options.

Witnesses

- **Mr. William Gerstenmaier**, Associate Administrator for Human Exploration and Operations, NASA
- **Dr. Mary Lynne Dittmar**, Executive Director, Coalition for Deep Space Exploration
- **Mr. Eric Stallmer**, President, Commercial Spaceflight Federation
- **Dr. Robert Ferl**, Distinguished Professor and Director of the Interdisciplinary Center for Biotechnology Research, University of Florida

Staff Contact

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

Chairman BABIN. Good morning. The Subcommittee on Space will come to order.

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

Welcome to today's hearing titled "The International Space Station after 2024: Options and Impacts." I'd like to recognize myself for five minutes for an opening statement.

The International Space Station ranks among humanity's highest scientific, technological, and political 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 exploration.

However, frontiers are not static. NASA has worked hard to conquer the challenges of low-Earth orbit. We have learned how the human body reacts to a microgravity environment. We have grown food, crystalized proteins, launched satellites, and conducted scientific observations of the Earth and stars above. What was once the height of technological daring nearly two decades ago has become almost ordinary.

Once such pioneering challenges are overcome, it is time to reexamine where the frontier really lies. In 2015, Congress extended ISS operations until 2024. Congress recently passed and the President just yesterday enacted the NASA Transition Authorization Act of 2017, which requires NASA to develop a transition plan for the ISS after 2024. NASA has estimated that the ISS will cost taxpayers between $3 and $4 Billion annually through 2024—roughly half of NASA's total human spaceflight budget. A 2014 report from the NASA Inspector General calls this figure optimistic. That report also noted several hardware concerns, including the degradation of the station's solar power arrays. If NASA stays on the ISS beyond 2024, we ought to be aware that remaining on the ISS will come at a cost.

That cost means tradeoffs with other NASA priorities. Tax dollars spent on the ISS will not be spent on destinations beyond low-Earth orbit, including the Moon and Mars. What opportunities will we miss if we maintain the status quo? In its report, Pathways to Exploration, the National Academies stated that a continuation of flat budgets for human spaceflight is insufficient for NASA to execute any pathway to Mars and limits human spaceflight to LEO until after the end of the ISS program. And if you would put this slide up, please? As you can see on the screen, the longer we operate the ISS, the longer it will take to get to Mars. The ISS is there in the purple. You can see that.

Subsequent reports, particularly by the Planetary Society in their Humans Orbit Mars report, evaluated different architectures, and found that Mars exploration could be conducted with flat budgets, but that transitioning from the ISS in 2024 would be considerably better.

Many private sector stakeholders currently rely on the ISS and would need to seek out other options if they can should the ISS be unavailable. While I believe it is in the Nation's interest to encourage a thriving economy in space, we must balance our support for private-sector efforts while also prioritizing NASA's role as an exploration agency. Can commercial use generate sufficient revenue by 2024 to cover the full cost of U.S. participation on the ISS? Could public-private partnerships or other novel approaches allow the U.S. to continue involvement in the ISS without tying up NASA funding? Will there be a sufficiently robust market that the U.S. will be able to procure service in low-Earth orbit commercially, or will the government need to continue to subsidize these activities in order to maintain access?

Aside from private sector impacts, the international aspect is also a critical part of the puzzle. The European Space Agency has already shifted its focus from the ISS, changing its contribution from ISS resupply to collaborating with NASA on the Orion Crew Vehicle. Meanwhile, China will be putting their first space station into operation just as the presence of NASA and its international partners on the ISS could be ending, effectively turning over human presence in low-Earth orbit to China.

Continuing NASA's involvement on the ISS could arbitrarily limit or delay human exploration of deep space by the U.S. Let us not forget that China also plans to launch a crewed mission to the Moon in the 2030s. What we do in low-Earth orbit will dramatically influence global efforts in our space exploration.

I want to thank today's witnesses for being here, and we look forward to our discussions and having your answers to our questions.

[The prepared statement of Chairman Babin follows:]

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

For Immediate Release
March 22, 2017

Media Contact: Kristina Baum
(202) 225-6371

Statement of Space Subcommittee Chairman Brian Babin (R-Texas)
The ISS after 2024: Options and Impacts

Chairman Babin: The International Space Station ranks among humanity's highest scientific, technological, and political 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.

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That cost means trade-offs with other NASA priorities. Tax-dollars spent on the ISS will not be spent on destinations beyond low-Earth orbit, including the Moon and Mars. What opportunities will we miss if we maintain the status quo? In its report, *Pathways to Exploration*, the National Academies stated that a "continuation of flat budgets for human spaceflight is insufficient for NASA to execute any pathway to Mars and limits human spaceflight to LEO until after the end of the ISS program." As you can see on the screen, the longer we operate the ISS, the longer it will take to get to Mars.

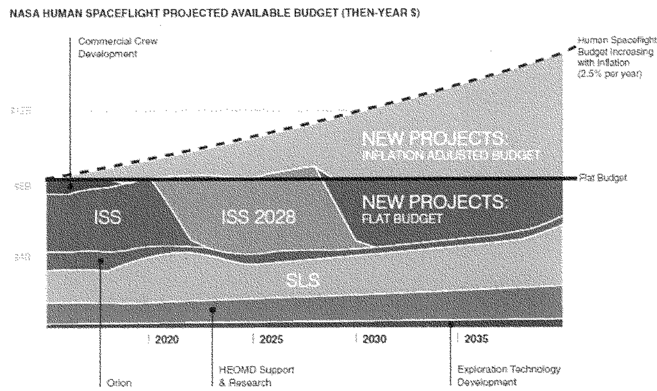

FIGURE 4.29 Projected available budget and costs of the currently planned human spaceflight program.

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Many private sector stakeholders currently rely on the ISS and would need to seek out other options — if they can — should the ISS be unavailable. While I believe it is in the nation's interest to encourage a thriving economy in space, we must balance our support for private-sector efforts while also prioritizing NASA's role as an exploration agency. Can commercial use generate sufficient revenue by 2024 to cover the full cost of U.S. participation on the ISS? Could public-private partnerships or other novel approaches allow the U.S. to continue involvement in the ISS without tying up NASA funding? Will there be a sufficiently robust market that the U.S. will be able to procure service in low Earth orbit commercially, or will the government need to continue to subsidize these activities in order to maintain access?

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Continuing NASA's involvement on the ISS could arbitrarily limit or delay human exploration of deep space by the US. Let us not forget that China also plans to launch a crewed mission to the Moon in the 2030s. What we do in low-Earth orbit will dramatically influence global efforts in space exploration.

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

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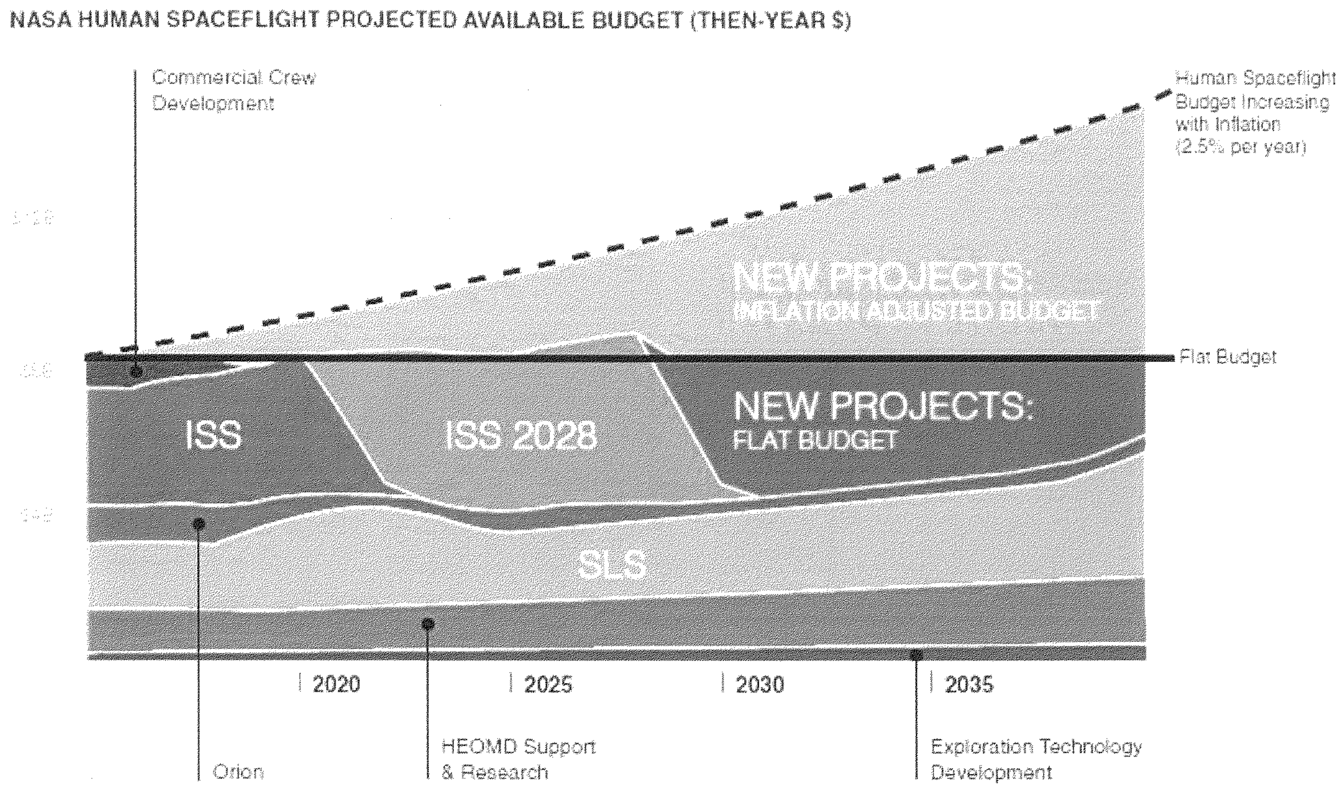

FIGURE 4.29 Projected available budget and costs of the currently planned human spaceflight program.

Chairman BABIN. And let's see. Now I want to recognize the Ranking Member, the gentleman from California, Mr. Bera, for an opening statement.

Mr. BERA. Good morning, Mr. Chairman, and thank you for holding this obviously very timely hearing, The ISS After 2024: Options and Impacts.

I'd also like to welcome our witnesses and I look forward to hearing your testimony.

Two hundred and twenty miles above the Earth, the International Space Station, a complex assembly of interconnected nodes and modules, weighing almost a million pounds and spanning the length of a football field, orbits our Earth 16 times a day.

NASA and its international and commercial partners have overcome many challenges during the many years of design, development and assembly to ensure the continued safe and productive operations of the Space Station, and I want to thank NASA's employees, supporting contractors, researchers, and partners for their continued dedication and commitment. This is a marvel of what we can do when we put our minds to a challenge.

That said, the current mission, ISS Expedition 50, is testing lighting effects to improve crew health and investigating changes in tissue regeneration while in space, adding to a growing array of scientific, biomedical, and technology research being carried out on the ISS.

As NASA's focus has turned to a vibrant research program, supported by a frequent schedule of visiting vehicles for crew transfer and cargo delivery, it is sometimes easy to forget how hard human spaceflight really is. Aboard the ISS, NASA is enabling the research, skills and capabilities that our astronauts need for taking the next step: moving out into exploring deep space.

Taking these next steps is something this Committee and Congress have supported through multiple NASA Authorizations, most recently the NASA Transition Authorization Act of 2017 that is now law. Again, as we start to set our sights on sending humans beyond low-Earth orbit, we also face some difficult funding decisions. Several independent panels have concluded that if we want to both extend the ISS past 2024 and undertake a meaningful human exploration program, we need to provide the required funding. Otherwise, we have to choose between NASA's extending the role of ISS past 2024 or reconsider our goals and expectations for human exploration beyond low-Earth orbit.

The ISS is currently authorized to operate through at least 2024. Within the next few years, Congress will need to decide whether to extend the ISS beyond 2024, and what role NASA should have in low-Earth orbit once ISS operations cease.

So, Mr. Chairman, this obviously is a very timely discussion that we're having as we look at the broader NASA mission, and again, our stated goal of trying to get to human exploration and human travel to Mars by 2023—2033. We could bump it up, though, Mr. Trump. I look forward to this discussion this morning, and thank you, and I yield back.

[The prepared statement of Mr. Bera follows:]

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

House Committee on Science, Space, and Technology
Subcommittee on Space
"The ISS after 2024: Options and Impacts"
March 22, 2017

Good morning, and thank you, Mr. Chairman, for holding this hearing on "*The ISS After 2024: Options and Impacts*".

I'd also like to welcome our witnesses and I look forward to your testimony.

220 miles above our earth, the International Space Station, a complex assembly of interconnected nodes and modules weighing almost a million pounds and spanning the length of a football field, orbits our Earth more than 16 times a day.

NASA and its international and commercial partners have overcome many challenges during the many years of design, development and assembly to ensure the continued safe and productive operations of the Space Station, and I want to thank NASA's employees, supporting contractors, researchers, and partners for their continued dedication and commitment.

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However, as we set our sights on sending humans beyond low Earth orbit, we also face difficult funding decisions.

Several independent panels have concluded that if we want to both extend the ISS past 2024 and undertake a meaningful human exploration program, we need to provide the required funding.

Otherwise, we need to choose between ending NASA's role in ISS in 2024 or reconsider our goals and expectations for human exploration beyond low Earth orbit.

The ISS is currently authorized to operate through at least 2024. Within the next few years, Congress will need to decide whether to extend the ISS beyond 2024, and what role NASA should have in low Earth orbit once ISS operations cease.

So, I'm pleased we have the opportunity today, Mr. Chairman, to hear from our witnesses on a number of questions:

What is the status of the critical ISS research tasks needed to enable long-duration human space flight?

What would be the impact of another ISS extension on NASA's deep space exploration program?

What is the status of NASA's plans for low Earth Orbit following the end of ISS operations, whenever that happens?

Will there be sufficient demand to support commercial activity in low Earth orbit as NASA shifts its focus to deep space exploration?

I look forward to our discussion this morning.

Thank you, and I yield back.

Chairman BABIN. Thank you, Mr. Bera.

Seeing that our full Committee Chair nor the Ranking Member are present, I'd like to go ahead and introduce our witnesses today.

Our first witness is Mr. Bill Gerstenmaier, Associate Administrator for Human Exploration and Operations at NASA. Mr. Gerstenmaier provides strategic direction for all aspects of NASA's human exploration of space and cross-agency space support functions including programmatic direction for the operation and utilization of the International Space Station. He holds a bachelor of science in aeronautical engineering from Purdue University, and a master of science in mechanical engineering from the University of Toledo. He also earned his Ph.D.—so I apologize for not saying "doctor," Dr. Gerstenmaier—he earned his Ph.D. in dynamics and control with emphasis on propulsion at Purdue University. So we're glad to have you here.

Dr. Mary Lynne Dittmar, our second witness today, Executive Director of the Coalition for Deep Space Exploration. We appreciate you being here. The Coalition for Deep Space Exploration is an industry trade group supporting human exploration, development in science and deep space. Dr. Dittmar has worked for the Boeing Company, where she coordinated research and development, and managed the Flight Operations Group for the International Space Station program. She has also served as a Senior Policy Advisor for the Center for the Advancement of Science in Space, or CASIS, which manages the ISS National Laboratory. Dr. Dittmar is also a Fellow of the National Research Society and an Associate Fellow for AIAA and a Board Member of AAS, and was a co-author of the Pathways to Exploration report produced by the NRC in 2014. Glad to have you here.

And our third witness today is Mr. Eric Stallmer, President of Commercial Spaceflight Federation. Mr. Stallmer has worked at the Space Transportation Association, a nonprofit industry trade organization providing government representation to companies interested in the U.S. space launch industry. Glad to have you here this morning. Mr. Stallmer has also served as an officer in the United States Army Reserves and was awarded the Bronze Star Medal for Meritorious Service while engaged in combat operations during Operation Iraqi Freedom. He earned a master of arts in public administration from George Mason University and a bachelor of arts in political science and history from the Mount St. Mary College. Glad to have you here.

Our fourth witness today is Dr. Robert Ferl. He is a Distinguished Professor and Director of the Interdisciplinary Center for Biotechnology Research at the University of Florida. Dr. Ferl cochairs the Committee on Biological and Physical Sciences in Space for the National Academies of Science and is the past President of the American Society for Gravitational and Space Research. Dr. Ferl and his lab have studied the aspects of microgravity environment as well as develop flight hardware for understanding biological effects of spaceflight.

I now recognize Dr. Gerstenmaier for five minutes to present his testimony.

TESTIMONY OF MR. WILLIAM GERSTENMAIER, ASSOCIATE ADMINISTRATOR FOR HUMAN EXPLORATION AND OPERATIONS, NASA

Mr. GERSTENMAIER. Thank you, Chairman, and thank you to the Committee for having me here. You were correct originally. I completed coursework for my Ph.D. but I never received my Ph.D. So "Mister" is good and it works well.

The International——

Chairman BABIN. You can have an honorary doctorate.

Mr. GERSTENMAIER. I don't know about that.

So the International Space Station is about humanity's future in space. It also tells us about the roles major players participated in helping us to get there.

ISS is the most complex engineering complex ever constructed. As an engineer, I'm tempted to quote numbers: 37 space shuttle flights, 1,000 hours of EVAs, or space walks, 197 space walks, both U.S. and Russian, 12 years to build, $67 Billion including the shuttle launch costs, and a mass of 925,000 pounds.

The scale of what we've accomplished is enormous. Like the interstate highway system, it was designed to move our Nation forward, and it could not have been done without public investment.

As a high-tech spaceflight endeavor, ISS has changed the way the Nation thinks about space. We've shown that humans can life off the Earth for extended periods of time. There's been a continuous human presence off the Earth for over 16 years. We can assemble large structures in space via humans in spacesuits. We've changed the way that robotics can be used for assembly in space. All of the recent SpaceX external payloads were installed on the ISS via ground-controlled robotics, and the three external payloads were removed from the Space Station and installed in the SpaceX trunk for disposal, all again through ground robotics. SpaceX was even berthed at the Space Station via ground control and not by astronauts on board.

ISS created the need for NASA to accept alternate engineering standards from a variety of grounds. This allowed NASA to build techniques to accept alternate commercial standards for commercial vehicles. Today ISS represents 13 percent of the total global launches to space.

The relaxed reliability requirements for ISS cargo allowed for disruption of the U.S. launch industry and resulted in lower launch costs for all users and return of commercial satellite launches to the United States.

One of the most enduring outcomes from the ISS is the ability for the governments of the U.S., Japan, Russia, Europe and Canada to work together peacefully in space. ISS has paved the way for international operations with 225 people from 18 countries having visited the International Space Station. This cooperation is much more than simply working together. We are dependent on each other for successful operations.

The intergovernmental agreements developed to make this happen are phenomenal in their simplicity and ability to facilitate real-time operations of this incredibly complex facility. These arrangements paved the way for future exploration and allowed for the European Service Module to become part of Orion. Although the cost and effort—although the cost, effort and resources to build this facility was high, this is precisely the role of large government activities. The diversity of benefits from a single activity are enormous. The private sector could have done some of the individual items in part but not the entire suite of accomplishments and not with such broad national benefit. The role of government is to do things that the private sector cannot so both commerce and the broader society will have more opportunities in the future.

As we go forward, how do we build off of the ISS achievement and utilize the International Space Station to strengthen the role of the United States as a leader in space and technology. The focus needs to be on using the ISS for the full range of national purposes both of those predicted in advance and those that we discovered through its use.

It's great to have this hearing today and discuss better uses of the ISS. How we utilize the ISS through 2024 can influence the options and impacts for ISS after 2024. The promise of ISS to continue to yield national benefits is high. We are exploring today with the ISS by using it to test out systems, both human and machine, and understand how those systems will work when applied to deep space exploration missions. ISS is perfect for that role.

The use of ISS as our national laboratory in space to help develop the private sector demand and revenue for space-based activities as NASA prepares for deep space exploration will be critical to U.S. leadership in science and technology. We are today formulating plans to make available a port on the ISS for private sector use. We are looking at legislative proposals to help facilitate commercial uses of ISS. All of these activities are just starting and will be critical to advancing U.S. leadership.

The external world is not static, and China's plans for human space exploration are also likely to influence the options for the ISS. China is planning for a government space station in 2023.

As NASA progresses towards moving human spaceflight into the solar system, the rate of this expansion will also be an influence on the operations and options for ISS. The continuity of human spaceflight from ISS in low-Earth orbit to regular missions of SLS and Orion to cislunar space is a critical requirement feature for U.S. leadership in space. A continuous U.S. national astronaut program is part of this leadership.

The decision to extend the ISS to 2024 showed great leadership by the Administration and Congress. This decision was made without full knowledge of the future but is proving to keep the United States in a leadership role for space technology development and to benefit—to the benefit of both U.S. commerce and broader national goals. Likewise, the decisions for ISS after 2024 will be made without all of the data on future benefits required for a perfect decision, but we can today utilize ISS in ways that influence that decision towards a greater national benefit.

Global leadership requires decisions with less-than-perfect data or foresight but that's what leadership is all about. Where the United States leads, others will follow, and the future will be shaped by American values.

I look forward to your questions and discussions in the hearing today, and I thank you for the timely discussion on this topic.

[The prepared statement of Mr. Gerstenmaier follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
March 22, 2017

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

before the

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

Mr. Chairman 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). As you know, the ISS serves as a unique platform to prepare for human exploration beyond low-Earth orbit (LEO), promote U.S. economic activity in space, and conduct 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 international partnership has been a model of peaceful cooperation through difficult times.

The ISS represents an unparalleled capability in human spaceflight that is increasing our knowledge of fundamental physics, biology, the Earth, and the universe. This knowledge is benefiting our lives here on Earth and enhancing the competitiveness of U.S. private industry. The research and technology demonstrations onboard the ISS are not only providing the basis for extending human presence beyond the bounds of LEO and taking our next steps into the proving ground of cislunar space, but also advancing the competitiveness of U.S. private industry.

We appreciate the action Congress took in 2015, reaffirmed in this year's legislation, regarding continued Station operations through at least 2024, and are pleased to note that all of the International Partners have agreed to participate through at least 2024, as well. NASA has the opportunity to continue to utilize ISS for research, commercial, and international partnerships to ensure that the U.S. continues to be the world leader in human spaceflight and to enable U.S. industry to realize the commercial benefits of space. As we consider the future of ISS and U.S. leadership in space, it is helpful to review the benefits provided by Station to exploration, space commercialization, and terrestrial applications.

Preparing for Human Deep Space Missions

The ISS is vital to NASA's mission to extend human presence into the solar system. In order to prepare for human expeditions into deep space, we must first use the ISS to conduct breakthrough research and test the advanced technology necessary to keep our crews safe and productive on long duration space exploration missions. The ISS – which has been home to a continuous human presence on orbit for over 16 years – is NASA's only long-duration flight analog for future human deep-space missions. It is an invaluable space laboratory for exploration research that addresses human health and performance risks associated with future deep-space missions.

Work in support of exploration missions includes biomedical research and the development of new human health capabilities. NASA's Human Research Program (HRP) continues to develop biomedical science, technologies, countermeasures, diagnostics, and tools to keep crews safe and productive on long-duration space missions. An on-orbit platform like the ISS is necessary to mitigate 22 of the 33 human health risks in the HRP portfolio. With the certainty of an ISS lifetime through at least 2024, HRP will have the tools necessary to make great progress toward mitigating the majority of exploration health and performance risks. In the event that not all risk areas have been mitigated by the end of ISS' operational life, NASA will assess the potential impacts and the best way to address them, given the available knowledge. The progress in science and technology driven by this research could have broad impacts on Earth as it advances our ability to support long-duration human exploration. 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. For example, elements of the ISS life support and other habitation systems, along with contributions from private sector firms, will evolve into the systems that will be used for deep space exploration missions. It is NASA's plan to first develop and demonstrate many critical technology capabilities using the ISS as a permanently-crewed testbed prior to deploying these capabilities beyond LEO. This approach is much more cost-effective and faster than conducting this research in cislunar space because of the higher costs inherent in operating so far from the Earth.

The strength of the international partnership created through the ISS Program is a testament to U.S. leadership in space and to the aerospace expertise of all the nations involved. It serves as a robust example of how many countries can work together to design, build, operate, and maintain large, complex human space assets. As we consider the future of ISS and prepare for human missions of exploration into deep space, it is important to reflect on the practical value of the proven partnership that has made the ISS possible, and to consider how we may build on these relationships as we proceed into cislunar space.

Supporting LEO Commercialization

Through public-private partnerships centered around the ISS platform, NASA is supporting the development of a commercial space economy in LEO.

The Center for the Advancement of Science In Space (CASIS) manages the activities of the ISS National Laboratory to increase the utilization of the ISS by other Federal entities and the private sector. CASIS works to ensure that the Station's unique capabilities are available to the broadest possible cross-section of U.S. scientific, technological, and industrial communities. The goal is to support, promote and accelerate innovations and new discoveries in science, engineering, and technology that will improve life on Earth and expand commercial activities and markets in space. ISS National Laboratory partners can use the unique microgravity environment of space and the advanced research facilities aboard Station to enable investigations that may give them the edge in the global competition to develop valuable, high technology products and services. The ISS National Laboratory is helping to establish and demonstrate the market for research, technology demonstration, and other activities in LEO beyond the requirements of NASA.

NASA is collaborating with CASIS to enable sustained investment and research activities onboard the ISS across industry and other Government agencies that will transcend the life of the Station. The extension of ISS operations to at least 2024 was very important to commercial sector planning for the use of the ISS National Laboratory. The timeliness of this decision by the Administration and Congress was extremely important. Industry required the planning stability provided by the extension in order to consider further investment in microgravity research and transportation services. This timely decision allowed time to begin enabling and maturing emerging commercial LEO markets.

Under the Commercial Resupply Services (CRS) contracts, NASA's two commercial cargo partners, Space Exploration Technologies (SpaceX) and Orbital ATK, have demonstrated not only the ability to provide cargo deliveries to ISS, but also the flexibility to recover effectively from mishaps. In January 2016, through CRS-2, NASA contracted with SpaceX, Orbital ATK, and Sierra Nevada Corporation to ensure that critical science, research, and technology demonstrations will be delivered to the ISS from 2019 through 2024.

NASA's commercial crew partners, SpaceX and the Boeing Company, are developing the Crew Dragon and CST-100 Starliner spacecraft, respectively. These companies have made significant progress toward returning crew launches to the U.S., and NASA anticipates having these capabilities in place by 2019 to regularly fly astronauts safely to and from ISS. The crew and cargo vehicles, as well as the launch vehicles developed by these providers, have the potential to support future commercial enterprises as well.

The Administration views public-private partnerships as the foundation of future U.S. civilian space efforts. NASA is continuing to develop cooperation on use of the Station to enable increased commercial investment and to transition to more public-private partnership models. For example, NanoRacks and Boeing have partnered to provide a commercial airlock on the ISS, and NASA is studying how to implement other commercial capabilities such as private modules or external facilities. In addition, NASA has begun to transition from a model where NASA provides payload integration and other services to one where those services can be purchased from one of many commercial partners. For example, the Made In Space, Inc. commercial Additive Manufacturing Facility (AMF) aboard ISS enables NASA and National Laboratory users to obtain 3D printing services on orbit. The ability to print on orbit has the potential in NASA's exploration activity to reduce the quantity of parts and tools carried as supplies – needed parts could simply be printed. Printing in space in microgravity has the potential to enable commercial companies to manufacture parts with higher purity or even to print biological material without the need to counteract gravity during printing. The ISS has also played a role in the development of CubeSats, which are small satellites measuring about four inches on a side that can be combined and configured to support a variety of research objectives for commercial companies, educational institutions, and non-profit organizations. CubeSats offer opportunities to conduct scientific investigations and technology demonstrations in space in such a way that is cost-effective, timely, and relatively easy to accomplish. Approximately 150 CubeSats have been deployed from ISS. As stated in the President's FY 2018 Budget Blueprint, NASA will also be working to create new opportunities for collaboration with industry on space station activities.

Benefitting Humanity

Across a range of disciplines and applications, ISS research ultimately benefits people on Earth. In the physical and biological sciences arena, the ISS allows researchers to use microgravity conditions to understand the effect of the microgravity environment on microbial systems, fluid physics, combustion science, and materials processing, as well as environmental control and fire safety technologies. In the areas of human health, telemedicine, education, and Earth observations from space (including those anticipated from the recently delivered Stratospheric Aerosol and Gas Experiment III [SAGE III]), there are benefits that have already been demonstrated, such as robotic microsurgery techniques and water purification technologies used in developing regions. Pharmaceutical studies and Station-generated images that assist with disaster relief and farming are just two of the many examples of Station activities that can benefit humanity.

ISS crews are conducting human medical research to develop knowledge in the areas of: clinical medicine, human physiology, cardiovascular research, bone and muscle health, neurovestibular effects, diagnostic instruments such as advanced ultrasound, exercise and pharmacological countermeasures, food and nutrition, immunology and infection, exercise systems, human behavior and performance, and visual impairment intracranial pressure. Many investigations conducted aboard ISS will have application to terrestrial medicine. For example, the growing senior population may benefit from experiments in the areas of bone and muscle health, immunology, vestibular response and balance, and from the development of telemedicine techniques used to monitor and treat ISS crews. These telemedicine capabilities can be used on Earth to improve medical care to patients without requiring travel to a hospital or doctor.

The ISS also plays an important role in promoting education in the science, technology, engineering, and mathematics (STEM) fields, inspiring students to pursue scientific and technical careers. In addition to research- and technology-related educational opportunities, astronauts aboard ISS participate in educational downlinks with schools, engage in communicating with people around the world using "ham" radio, and conduct experiments that involve student participation.

Options for the Future

The ISS continues to be a healthy system that is operating well within prudent technical margins while consistently demonstrating outstanding steady-state performance that meets or exceeds prior engineering estimates. U.S.-built Station modules were designed for a 30-year on-orbit lifetime, and the lifetime extension data that NASA and the ISS Partnership have reviewed to date indicates that extension to 2028 is technically feasible. Further, as NASA has moved into Station's intensive utilization phase, we have become more cost-efficient in ISS operations and continue to look for further efficiencies.

It is timely to begin discussions on the future of ISS. In the NASA Transition Authorization Act of 2017, Congress requests a plan from NASA to transition ISS from the current regime that relies heavily on NASA sponsorship to a regime where NASA could be one of many customers of a LEO non-governmental human space flight enterprise. NASA has been building a strategy and assessing options that supports this vision for the future of human spaceflight in LEO. These options include: extension of ISS beyond 2024 as-is, revising the current ISS operating model to shift to a more commercial model, maintaining and transitioning pieces of the ISS to a commercial platform, and de-orbiting portions of the ISS or the entire spacecraft.

Some of the key considerations in assessing these options are: whether critical deep-space technologies and systems have been demonstrated; whether human health risks for deep space missions have been mitigated; whether NASA is executing human missions beyond LEO; whether alternative platforms for conducting necessary research and technology development are becoming available; the interest among NASA's international partners either to extend or terminate the existing ISS financial and operational arrangements; changes to the current assessment of the technical feasibility of extending the platform beyond 2024; the demand outside of NASA in private industry and other government agencies for ISS capabilities; and the amount of time required for ISS maintenance vs. research time. Whichever option is ultimately chosen, in consultation with the ISS partnership, it is critical that we maintain continuity in U.S. human spaceflight and America's leadership in space and technology innovation.

NASA is engaged with several commercial partners to advance and test a variety of habitation technologies. This Next Space Technologies for Exploration Partnerships (NextSTEP) activity, plus related technology developments and partnerships, will enable deployment of a deep space habitation capability in the mid-2020s, which in turn will validate systems needed for more challenging human future deep space activities. NASA and industry will identify commercial capability development for LEO that intersects with the Agency's long duration, deep space habitation requirements, along with any options to leverage commercial LEO advancements towards meeting NASA long duration, deep space habitation needs while promoting commercial activity in LEO. The Agency is working with industry to define common interests between LEO and deep space habitation systems, architectures, requirements, common interfaces and standards, and invest in technology maturation efforts. NASA is conferring with industry to inform deep space habitation requirements while maximizing commercial capabilities for LEO.

NASA is investigating concepts for habitats that can keep astronauts healthy during space exploration. Expandable habitats are one such concept under consideration – they require less payload volume on a rocket than traditional rigid structures, and expand after being deployed in space to provide additional room for astronauts to live and work inside. The Bigelow Expandable Activity Module (BEAM) is the first test of such a module attached to the ISS. It will allow investigators to gauge how well it performs overall, and how it protects against space radiation, space debris and the temperature extremes of space. BEAM was filled with air and expanded in May 2016. Astronauts are entering BEAM on an occasional basis to conduct tests to validate the module's overall performance and the capability of expandable habitats.

NASA is actively developing transition strategies for the concurrent- and post-ISS LEO era and is engaged with the private sector to foster both private demand and supply for LEO services. It is NASA's intention to continue to foster the development of private industry capabilities and private demand. Once these private capabilities are available, NASA intends to be one of many customers, including both private and other Government agencies, for LEO platforms. The Agency welcomes input from other stakeholders on how best to enable future private LEO platforms and the development of a commercial market in LEO.

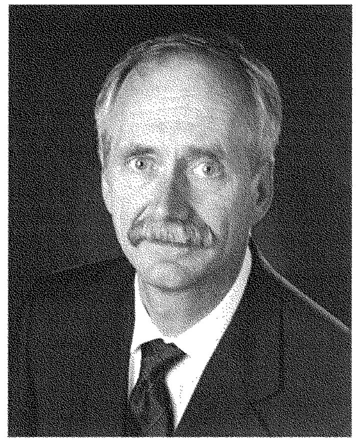
Conclusion

The ISS has now entered its intensive research and technology demonstration phase and is enabling a maturing commercial market. The maturity and stability of the ISS Partnership allows the U.S. to demonstrate global leadership in human spaceflight and technology development and is already providing the foundation for continuing human spaceflight beyond LEO. Closer to home, NASA's ISS National Laboratory partners can use the unique capabilities aboard Station to enable investigations that may give them the edge in developing valuable, high technology products and services for the global market. Furthermore, the demand for access to the ISS enables the establishment of robust U.S. commercial crew and cargo capabilities. Both of these aspects of the ISS National Laboratory will help establish the U.S. market for research in LEO beyond the current NASA requirements.

While the future of ISS will require both careful consideration and advance planning, we have a few years yet to allow the Program to continue to produce results, and for potential markets for commercial facilities in LEO – which will take time to develop – to evolve before committing to a specific course of action, in consultation with the ISS partners. In the coming years, we will be able to make a well-grounded assessment, but for now, the crews aboard ISS will continue paving the way for future deep space missions, supporting the growth of commercial activities in LEO, and providing benefits to people on Earth.

NASA appreciates this Committee's ongoing support of the ISS as we work together to support this amazing facility which yields remarkable results and benefits for the world.

Mr. Chairman, I would be happy to respond to any questions you or the other Members of the Subcommittee may have.



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

Chairman BABIN. Thank you, Mr. Gerstenmaier.

I now recognize Dr. Dittmar for five minutes to present her testimony.

**TESTIMONY OF DR. MARY LYNNE DITTMAR,
EXECUTIVE DIRECTOR,
COALITION FOR DEEP SPACE EXPLORATION**

Dr. DITTMAR. Chairman Babin, Ranking Member Bera, and Members of the Subcommittee, thank you for the opportunity to speak with you today on a subject of great importance to our national leadership in space: the future of the International Space Station after 2024.

It is indeed an honor to appear before you and particularly in the company of this distinguished panel.

Before I begin, I would like to congratulate you and the Committee staff on passage of the NASA Transition Authorization Act signed into yesterday by the President. On behalf of the Coalition for Deep Space Exploration and its 67 member companies, I want to thank you personally for your diligence and your ongoing support of the Nation's space program.

In 2014, in response to a request from Congress, the Committee for Human Spaceflight of the National Research Council produced the Pathways to Exploration report, which contained observations and recommendations supporting a robust program of human space exploration. Among other findings, the report described the funding constraints facing NASA should the ISS continue to operate after 2024, namely, that if NASA is to continue making progress in deep space, it could not maintain the ISS without significant cost reduction. The committee discussed the role of ISS research and reducing risk in deep space exploration and understood that termination of the program would end opportunities for continued research in these areas as well as potentially cut short the research benefiting Earth going on at the ISS National Lab.

Fortunately, thanks to Congress, in the three years since the report was published, NASA's human spaceflight program funding has improved, and in my written testimony, I provide a moderation—a modification of the chart that you showed earlier, Chairman, that showed that line inching up a little bit there.

However, the larger point remains: one political avenue for reducing the government's investment in the ISS is by generating alternate sources of revenue. However, at present, there is no compelling economic driver apparent in LEO that can bridge the gap between current commercial activity and the revenues that are necessary to significantly offload ISS operations costs. Given that markets frequently take decades to develop, this is not surprising.

The best answer for now is to create the optimal conditions for market breakthroughs, reducing barriers through the use of the ISS while working hard to enable innovation with economic value to occur and recognizing that this will take time and ongoing investment, and indeed, this is what NASA and CASIS have been doing.

In my written statement, I noted the significant progress being made in this regard. The growing number of applications and paying customers in space combined with an increased diversification of research objectives, funding sources and actors improves the odds that one or more of these efforts will lead to sustained economic activity, and indeed, applications with strong market political are emerging, which in turn are leading to increased interest in the development of commercial modules and follow-on platforms.

These efforts will not guarantee development of a market or establishment of sufficient revenues or investment to offload the government and reduce costs. However, abandoning the ISS too soon will most certainly guarantee failure.

I would like to briefly turn to the importance of ISS to deep space exploration. First, the international partnership already mentioned at the heart of the ISS is a major building block for an international program to move humans off the Earth toward Mars. The ISS has demonstrated that a great multilateral enterprise such as this one brings to the table intellectual capital, scientific abilities, research, engineering, funding, and interest in peaceful technology development on the part of many nations. We have come to trust each other, to learn from each other, and to depend on each other for our very lives in low-Earth orbit. It will be the same in deep space. Continuing engagement with partners old and new through the ISS is required at least until such time as a robust international program is also established beyond low-Earth orbit.

Secondly, innovation on the ISS has the potential to create breakthroughs that will inform deep space exploration and reduce costs there as well. A company called Made in Space is experimenting with 3D printing in LEO but wants to extend this work into deep space including on the surface of the Moon and Mars. The ability to manufacture tools and other equipment from native materials can reduce mass requirements and therefore cost for deep space missions. Other innovations are likely to follow.

Third, NASA is now putting in place the exploration architecture that will take us out into the solar system. The next steps will help inform the uses of the ISS in helping that architecture to progress, doubtless in some ways that we cannot now anticipate. A good example of this is using the ISS as a testbed for systems that don't always work the way we think they're going to once they're put into space. The Environmental Life Control System, or ECLSS, is very high on that list but as we move into deep space, there will be others.

Finally, the next two years or so will see the return of Americans on American launch vehicles to the ISS and will see the return of Americans to deep space on American systems built for that purpose for the first time in almost 50 years.

The ISS is the heartbeat of human spaceflight 24 hours a day, 365 days a year. American leadership in space requires a constant and vigilant presence, one that the ISS has provided during the gap in our own flight access. Learning from history, we should not step away from the ISS until a robust human spaceflight program has been established in cislunar space.

Thank you for your attention. I look forward to your questions.

[The prepared statement of Dr. Dittmar follows:]

Statement of
Mary Lynne Dittmar
Executive Director
Coalition for Deep Space Exploration

before the

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

SUMMARY OF KEY POINTS

1. The International Space Station is the cornerstone of NASA's human spaceflight program, both through operations in low Earth orbit (LEO) and by providing the foundation of the nation's development of a deep space human exploration program.

2. The 2014 "Pathways to Exploration" report published by the National Academies identified continued funding of the ISS past 2024 as a limiting factor on the development of a deep space exploration program; however, the continuing use of the ISS also benefits that program and will be the most cost-effective way for ongoing research both for Earth benefit and deep space exploration for many years to come.

3. The international partnership at the heart of the ISS is also critical for deep space human exploration and the process of extending human presence into the solar system. Continued engagement with partners old and new through the ISS is required at least until such time as a robust international program is established beyond LEO.

4. Economic development of low Earth orbit offers an opportunity to reduce government investment in LEO potentially offloading some of the operating costs of the ISS and/or providing sufficient revenues for new LEO platforms operating commercially after the ISS has ended. While early progress is being made, the timeline for such development is uncertain. Some conclusions can already be made regarding transition, however.

5. In addition to the international implications, there are several interdependencies between the ISS and deep space exploration that were not sufficiently addressed in the Pathways report; these should be better understood and taken into account before any decisions about the disposition of the ISS are made.

6. Additional time is needed to better define the conditions under which ISS transition should occur, with particular attention to avoiding any "gap" in ongoing human space exploration activities.

Statement of
Mary Lynne Dittmar
Executive Director
Coalition for Deep Space Exploration

before the

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

Mr. Chairman 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). The ISS is the cornerstone of human spaceflight and near-Earth research and technology development for NASA, the United States, the ISS international partners, and dozens of countries who have participated in the program to date. Currently authorized to continue operations through 2024, the ISS can last until at least 2028. Given the central role currently played by the ISS national consideration of its future after 2024 is of critical importance. Such consideration should take into account the full range of functions played by the platform in LEO and implications of ISS activities and costs upon the human exploration of deep space.

Funding Constraints: The "Pathways to Exploration" Report

In the 2010 NASA Authorization Act, NASA was directed to ask the National Academies to perform a study to review "the goals, core capabilities, and direction of human spaceflight." In 2012, the National Research Council convened a Committee on Human Spaceflight charged with a wide-ranging statement of work intended to address Congressional interests described in the request. The resulting reported, entitled "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration" was published in 2014 by the National Academies.[1]

Notional projections of annual costs and available funding for human spaceflight as a function of time were plotted in "sand charts" presented in Chapter 4 of the report. One of these, Figure 4.29, shows current and planned programs of record as of early 2015. Near term costs were based on the FY 2014 budget request with run out to 2018, at which point both the Space Launch System and Commercial Crew would reach their operational capability. The Orion spacecraft would continue development, ramping down until 2022. Two bounds of the NASA human spaceflight budget were presented; one in which the budget remained flat at 2015 levels and an upper bound where the budget began at 2015 levels and increased with inflation, at roughly 2.5% per year. Under these assumptions, extension of the ISS to 2028 was not possible under flat funding. Had this scenario prevailed, NASA would have to terminate ISS sometime after 2020 but well before 2028, unless funds were transferred from one of development programs to the ISS account.

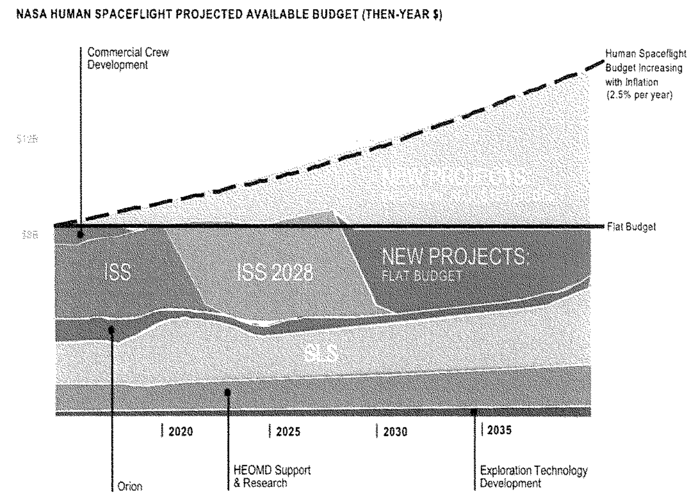


FIGURE 4.29. Projected available budget and costs of the currently planned human space flight program. Used by permission.

In 2016, after the report was published, Congress appropriated almost 10% more for human exploration than in 2015. Figure 4.29m, below (modified and used by permission) includes a new function representing the increase from 2015 to 2016, with a new lower bound (aka "flat budget") running out beyond 2016. Under this scenario, which represents the enacted budget in that year, extension of the ISS to 2028 is possible.

Although the ISS *can* be extended past 2024, doing so while completing and operating the Space Launch System, the Orion spacecraft, the exploration ground systems upgrades at the Kennedy Space Center and undertaking development of a cislunar hab (not pictured) beyond 2024 could constrain NASA to a limited program in cislunar space. On the other hand, ramping down the ISS after 2024 would increase the funding available for deep space development and missions, depending upon the extent to which NASA continues to invest in LEO. In other words, unless options for cost reduction emerge in LEO, cislunar space, or both, the committee felt that at approximately $3B/year to operate the ISS (including transportation costs), NASA could not afford both an ongoing program in LEO (the ISS) and a deep space human exploration program much beyond 2024.

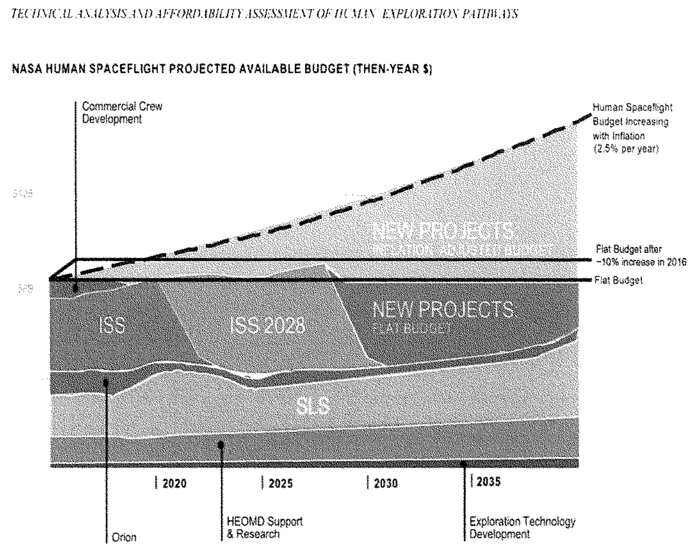


Figure 4.29m, with enacted levels in 2016 (modified by M. L. Dittmar) Used by permission.

International Collaboration and Diplomacy

Given the importance of the ISS for both current and future human space exploration, it is important to understand the roles played by the program, beginning with its international nature. The ISS is the focus of a strong international partnership. NASA's work side-by-side with international counterparts, through changing political climates, has demonstrated the stabilizing effect of international collaboration and an ability to bridge the gaps and tensions that inevitably emerge within global politics. The ISS is also the means for emerging space nations such as India, UAE, Singapore and South Korea to establish their own human spaceflight programs, forming the basis for an international, collaborative architecture in space that begins in Low Earth Orbit (LEO). To date, over 100 countries have participated in some way in the International Space Station program.

The international relationships, operational and diplomatic protocols, commitments and cooperation established over the past decades in support of the ISS are important as NASA prepares to return to deep space for the first time in 50 years. Indeed, a central finding of the Pathways report was the NASA's deep space exploration program – particularly one focused on Mars – must be international in nature. Continued engagement is critical to maintaining this successful partnership. The ISS should continue at least until such time as international projects beyond LEO are better defined.

Economic Development in LEO

One avenue for reducing the government's investment in LEO is by developing alternate sources of revenue. Accordingly, NASA's commercial activities have changed over the past several years, migrating from mission-directed innovation and development - projects sponsored by NASA for the benefit of its missions - to distributed innovation and development. New projects are initiated by a variety of different actors with varied objectives. This increasing diversification of projects and actors maximizes the likelihood of identifying breakthrough technologies or research outcomes that might spur sustained economic activity in LEO, given sufficient time and funding.

There are some signs of progress. The Center for the Advancement of Science in Space (CASIS), which manages the National Lab, has helped to engage investors willing to invest $100,000's of dollars. High-potential applications include manufacturing of advanced optical fiber (ZBLAN) under the auspices of a company called Made in Space. NanoRacks, another commercial company, has raised private capital and has a range of customers including NASA, other governments, biopharmaceutical companies, space companies including Urthecast and Planet Labs, schools and other private customers – all of whom pay for services on a commercial basis.

Generating enough revenue to transition economic activity off the ISS to a commercial LEO platform with reduced government involvement sometime after 2024 requires two things to occur. First, public investment must lead to private sector revenues or investment via subsidized use of the ISS that are in turn invested into space infrastructure. These investments could include enhancements of the ISS, offloading of some portion of transportation costs from the government to ISS customers, or the development of commercial modules attached to the ISS. The first of these is already underway, with NanoRacks, Made in Space, BioServe, TechShot, and a new platform launched in 2016, SpaceTango, each operating commercial facilities onboard the ISS. NASA is also assessing the viability of attaching one or more commercial modules to the ISS in the near future.

The second step would involve closing the gap between public investment (NASA/CASIS), private sector gain, and enough revenues to lead private investors to fund new orbital facilities that would be available for both private and public use. This outcome is much more uncertain, and will probably require additional investment on the part of the government above current levels in order to speed up diversification, target promising development efforts, and encourage private investment. A definitive date for termination of the ISS could reduce some uncertainty for investors and developers. However, it is also apparent that there is currently a large gap between commercial activity and the revenues that would be needed to significantly offload ISS operations costs or to cover operating costs of a new LEO platform. Long-term stability of the ISS past 2024 may enable commercial markets to develop, although there is no guarantee. However, it is an absolute certainty that abandoning the ISS too soon will cause economic development to fail. Such an outcome would impact commercial transportation partners, discourage private sector investment in LEO-based ventures, and cut short promising research and technology development.

Continuing access to a LEO research platform will remain the most cost effective means of testing systems and other capabilities for deep space for many years to come. Assuming that the United States wishes to remain in LEO in some capacity beyond 2024, several conclusions can be stated regarding the transition from ISS to commercial LEO platforms:

- We should avoid a gap in LEO capability and access, which would not be in the best interests of the United States ("lesson learned" from Shuttle);
- Transitioning the ISS to more and more commercial use would enable commercial entities to make a smoother transition to another platform;
- Alternate LEO destinations are essential to sustain the business model for commercial crew and cargo as well as other commercial entities such as those now providing facilities onboard the ISS; and
- To justify a business model for commercial entities to invest in another platform there has to be a plan, funding, and the continued development of economic activity in LEO for several years

From Earth to LEO to Deep Space and Back Again

The ISS supports scientific research and systems development and testing, including research and development with benefits to the people of the Earth as well as technologies needed by NASA to pursue the nation's deep space aspirations. For example, the environmental control and life support system (ECLSS) currently operating onboard the ISS is not sufficiently robust to transfer to vehicles or habitats intended for long-duration operations in deep space, as it requires significant maintenance and replenishment. Development of an advanced ECLSS will probably require continuance of the ISS until at least 2024.

There are other interdependencies between ISS utilization in LEO and NASA's activities in deep space. In addition to human research and research in the biological and physical sciences, commercial utilization encourages the private sector to advance technologies with applications not only to Earth but in space. 3D printing projects such as those conducted by Made In Space are themselves pathfinders for utilization of native materials on the Moon or Mars. Meanwhile, NASA is pursuing public private partnerships as a mechanism for driving technology by means of the Next Space Technologies for Exploration Partnerships (NextSTEP) programs, wherein companies invest in habitat architectures for crews traveling from cislunar space to Mars. As mentioned, technologies developed in LEO can be leveraged for deep space; however, research and technology underway for deep space could also be leveraged to the development of platforms in LEO.

Finally, the ISS is the heartbeat of human spaceflight - 24 hours a day, 365 days a year – not just for NASA and its international partners but for the industrial base that supports the ISS community across the globe. Once underway, flights of the Space Launch System and the Orion spacecraft into cislunar space are anticipated once or twice a year, in comparison to 16 missions (crew and cargo) to the ISS anticipated for 2017 alone. The steady rhythm of human spaceflight operations provided by the ISS is important to providing a continuous presence in space, which should continue until a robust program has been established in cislunar space.

Conclusion

The ISS is at the center of U.S. human spaceflight, with ongoing research across a range of disciplines and technology applications for Earth and in space. It is also the basis for economic development in low Earth orbit and provides a destination for transportation systems developed under the auspices of NASA's commercial cargo and crew programs. The ISS is a also critical asset for development of systems needed for human deep space exploration. Ongoing utilization beyond 2024 without significant cost reductions will limit NASA's deep space exploration programs; however, too-early termination could also have deleterious effects by slowing technology development with applications to deep space, cutting short economic development in low Earth orbit, and limiting or terminating U.S. presence in LEO. Prior to making a decision about the ISS, additional time is needed to better define the nature of international collaboration in deep space, to seed economic development and broaden both the range of actors and the nature of research and technology development with the goal of stimulating economic demand in LEO, and to ensure that a human spaceflight program to cislunar space is well underway, avoiding any "gap" in human activities in space as the United States charts a course into the future of human space exploration.

Thank you for the opportunity to appear before you, Mr. Chairman. I would be happy to respond to any questions you or the other Members of the Subcommittee may have.

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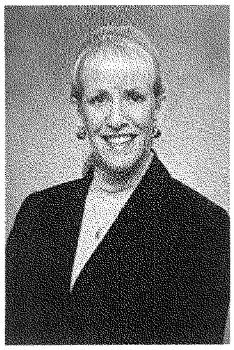
[1] National Research Council of the National Academies Human Spaceflight Committee (2014). Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration. Washington, D.C., National Academies Press.

Mary Lynne Dittmar, Ph.D.



Dr. Mary Lynne Dittmar is Executive Director of the Coalition for Deep Space Exploration, an industry trade group supporting human exploration, development, and science in deep space. Under her leadership the Coalition has grown from 5 companies to more than 60 over the past year and is an active advocate for the aerospace industry. She is also President and CEO of Dittmar Associates, a consulting firm that she founded in 2004.

Prior to starting Dittmar Associates, Mary Lynne worked for The Boeing Company where she coordinated payload interface development, operations development, and technology development projects destined for the International Space Station. Beginning in 1999, she managed the Flight Operations Group, overseeing systems integration and procedural development for assembly, activation and checkout of roughly 1/3 of the ISS assembly fights. Later, she acted as a special advisor to the NASA Astronaut Office before her appointment as Boeing's first Chief Scientist for Commercial Utilization of the ISS. During this time she consulted to NASA on international training development and contributed to NASA's early commercialization roadmap for low Earth orbit. Her technical contributions and inventions earned her the NASA Silver Snoopy and Boeing's Chief Technology Officer's Award for Technical Excellence.

Upon leaving Boeing Dr. Dittmar established a thriving consulting practice, working in human factors engineering, strategic planning, artificial intelligence, business development, and strategic communications. As principal and senior consultant she worked with most major aerospace companies, the DoD, the FAA, and extensively with NASA for many years. More recently she engaged in strategic planning and then became Senior Policy Advisor for the Center for the Advancement of Science in Space (CASIS), which manages the International Space Station National Laboratory. She left CASIS to accept the position of Executive Director for the Coalition in late 2015.

Dr. Dittmar is a Fellow of the National Research Society, an Associate Fellow of the American Institute for Astronautics and Aeronautics, and is a member of the Board of Directors of the American Astronautical Society. From 2012-2014 she served as a member of the National Research Council Committee on Human Spaceflight and is a co-author of the "Pathways to Exploration" report produced by the NRC in 2014 and is beginning her second term as a member of the Executive Committee of the Space Studies Board of the National Academies of Sciences, Engineering and Medicine. She resides in Washington, D.C.

Chairman BABIN. Thank you, Dr. Dittmar.

Now I recognize Mr. Stallmer for five minutes to present his testimony.

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

Mr. STALLMER. Thank you, Mr. Chairman.

Chairman BABIN. Yes, sir.

Mr. STALLMER. I want to thank you and Ranking Member Bera and Members of the Subcommittee. I'm pleased to have this opportunity to present the Commercial Spaceflight Federation's views on the ISS after 2024.

CSF represents 70-plus companies and tens of thousands of employees dedicated to America's future in space. In my testimony, I will lay out a sustainable vision not just for human spaceflight in low-Earth orbit but for America's broader and deeper space ambitions. This discussion is not just about the value of ISS in and of itself or even NASA's exploration agenda for the Moon, Mars and beyond. The right yardstick is America's future economic development and settlement of space starting with LEO but expanding outward. Clearly, want our first long-term international space station to be a firm steppingstone to that grander future.

By next year, for the first time in U.S. history, our space program will have multiple means of safely and affordably getting science experiments, other cargo, and crew to space. The ISS is currently expected to be utilized through at least 2024, but this Committee is posing the question of what should occur after. My testimony will focus on three of these areas.

First, the ISS should be sustained beyond 2024 to the extent that the space station is technically capable and safe to remain in orbit. In addition, rather than abruptly ending such a major program without a functional successor, any ISS transition plan should prepare an evolutionary path in order to avoid disrupting science and operations on orbit, and any unnecessary economic upheaval to local economies.

Second, to maximize return on investment for the Nation, commercial utilization of the ISS should be expanded, and NASA should take full advantage of these opportunities to offset some of the costs to maintain the space station.NASA should use public-private partnerships to develop commercial space capabilities and services to support its cislunar activities, and should use commercial launch systems to support and augment these activities.

The International Space Station is one of the greatest is one of the greatest achievements of our time. It's an engineering marvel, built and operated in concert with our partners around the world. It's a treasured national lab, contributing to key scientific breakthroughs in science and research, and it represents the longest ever sustained human presence in space. It's the foundation of humanity's voyage to the stars, and the commercial spaceflight industry is proud to play a key role in its continued success.

Given this incredible investment, we need to ensure that we are maximizing our scientific and economic return from this unique asset. We are grateful for the Committee and the Congress's recognition of the value of Space Act Agreements, which has helped further along the transportation goals for the ISS, and for your support of this important tool in the recent NASA Authorization bill.

SpaceX as well as a growing number of new American commercial launch companies are recapturing a majority of the world's multiBillion dollar commercial launch market after years in which the United States was simply not competitive, and the same Space Act Agreement partner with NASA has also helped restore getting American astronauts on American vehicles from American soil.

The private sector has jumped at the opportunity to support research on the ISS. Companies like Bigelow Aerospace, Planet, and NanoRacks are testing new technologies like inflatable habitats to help us go deep into space, developing new generations of advanced satellites, and opening up opportunities to a broader utilization community to fly thousands of experiments.

Understandably, in this era of fiscal constraints, it's prudent to review opportunities that exist to introduce additional efficiency. But, to be very clear, the ISS and NASA's deep space exploration programs are not in competition, but, rather, are complementary.

Opening the ISS to private businesses now and continuing this agenda past 2024 will deliver an assured transition to a sustained private American presence in low-Earth orbit that can untether NASA from the fixed costs of the future space stations while continuing to make capabilities available whenever needed. The same technologies being developed for use traveling to and operating on ISS today, as well as other commercial capabilities, will enable us to sustainably go deeper in space than ever before. We must leverage the commercial capabilities, both those being proven out on ISS, as well as these others under development.

Blue Origin right now has announced it's developing its own deep space exploration architecture and has proposed to conduct what it's calling Blue Moon by 2020, a lunar lander that will touch down on the resource-rich crater on the Moon's south pole. This program would augment and enable NASA's lunar activities. We've also heard that SpaceX which has recently announced a privately funded mission to Mars in 2020 on the Red Dragon spacecraft, a derivative of the Crew Dragon spacecraft they will be using to fly NASA astronauts. Made In Space, as Mary Lynne has mentioned, already manufacturing on ISS and is developing advanced commercial on-orbit manufacturing services producing products for use in space and on Earth. And Moon Express has announced that it has the resources it needs to ensure that the company can attempt to launch a small robotic lander to the Moon as soon as the end of this year.

In conclusion, how should Congress enable a sustainable, robust American space enterprise, one that will continue to foster the burgeoning commercial activity in low-Earth orbit but also enable the United States to make meaningful progress in deep space? The answer is short. It's to expand the use of public-private partnerships with American commercial space companies. Through private-sector competition, investment, and innovation, the commercial space industry has proven it can deliver reliable and affordable goods and services that support U.S. government civil space missions and initiatives, as well as recapture global market share.

Thank you so much, and I look forward to your questions.

[The prepared statement of Mr. Stallmer follows:]

THE ISS AFTER 2024: OPTIONS AND IMPACTS

STATEMENT OF
ERIC W. STALLMER
PRESIDENT, COMMERCIAL SPACEFLIGHT FEDERATION

BEFORE THE
COMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE
SUBCOMMITTEE ON SPACE
UNITED STATES HOUSE OF REPRESENTATIVES

March 22, 2017

Chairman Babin, Ranking Member Bera, and Members of the Subcommittee, I am pleased to have the opportunity to present the Commercial Spaceflight Federation's views on "The ISS after 2024: Options and Impacts." I'm Eric Stallmer, President of the Commercial Spaceflight Federation, which represents 70-plus companies and tens of thousands of employees dedicated to America's future in space.

In my testimony, I will lay out a sustainable vision, not just for human space flight in low Earth orbit (LEO), but for America's broader and deeper space ambitions. This discussion is not just about the value of ISS in and of itself, or even to NASA's exploration agenda for the Moon, Mars, and beyond. The right yardstick is America's future economic development and settlement of space, starting with LEO but expanding outward. Clearly we want our first long-term international space station to be a firm steppingstone to that grander future.

By next year, for the first time in U.S. history, our space program will have multiple means of safely and affordably getting science experiments, other cargo, and crew to space. The ISS is currently expected to be utilized through at least 2024, but this Committee is posing the question of what should occur after. My testimony will focus on the following areas:

1. The ISS should be sustained beyond 2024 to the extent that the space station is technically capable and safe to remain in orbit. In addition, rather than abruptly ending such a major program without a functional successor, any ISS transition plan should

prepare an evolutionary path in order to avoid disrupting science and operations on orbit, and unnecessary economic upheaval to local economies.

2. To maximize return on investment for the Nation, commercial utilization of the ISS should be expanded, and NASA should take advantage of opportunities to offset some of the costs to maintain the space station.

3. NASA should use public-private partnerships to develop commercial space capabilities and services to support its cis-lunar activities, and should use commercial launch systems to support and augment these activities.

The ISS Today

The International Space Station (ISS) is one of the greatest achievements of our time. It is an engineering marvel, built and operated in concert with our partners around the world at a cost of over $100 billion. It is a treasured national lab, which is being managed by CASIS, contributing to key scientific 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 the commercial spaceflight industry is proud to play a key role in its continued success.

CSF represents 70-plus companies and tens of thousands of employees dedicated to America's future in space.

Given this incredible investment, we need to ensure that we are maximizing our scientific and economic return from this unique asset. As the Space Shuttle program was winding down, NASA recognized that new partnerships with the private sector would best allow the agency to serve the needs of ISS while also significantly reducing costs. So, in 2006 during the Bush administration, NASA started the Commercial Orbital Transportation Services (COTS) program. This effort has been an undeniable success. By partnering with private industry under efficient fixed price Space Act Agreements (SAAs) that required co-investment for development, NASA now has two new launch systems and two new spacecraft for routine resupply to and from the ISS, with a third system from Sierra Nevada Corporation on the way

We are grateful for the Committee's and the Congress' recognition of the value of SAAs and for your support of this important tool in the recent NASA Authorization bill.

In addition to supporting NASA's logistical needs, one of the goals of the Commercial Cargo program was to stimulate what had been a declining U.S. spaceflight industry. It's clear that was achieved. Following the introduction of the Falcon 9 launch vehicle and the certainty provided by ISS as an anchor customer, SpaceX, as well as a growing number of new American commercial launch companies, are recapturing a majority of the world's multi-billion dollar commercial launch market after years in which the U.S. was simply not competitive. That means thousands of high-tech jobs and billions of dollars flowing back into the U.S. economy that otherwise would have gone overseas.

Building on that success, NASA has pressed ahead, partnering with the U.S. commercial space industry, to restore America's human spaceflight capability in 2018, once again sending American astronauts to space from American soil aboard American rockets and spacecraft. Here, too, ISS remains a valuable component of the economics for ongoing commercial development of innovative space systems, new technologies, and scientific research.

We are learning how to make flying to and from space, and living in space, safe and routine. These developments are valuable for missions beyond Earth.

Maximizing the Use of ISS

The goal of our space program has always been to achieve both significant scientific progress and a sustainable human presence in space. The ISS has been successful in each of these by any measure. With operational cargo flights and, soon, crew flights achieving a steady flight cadence, the value of the ISS as a national asset has grown. There are more opportunities than ever to perform the key science and engineering experiments for which the station was designed.

In addition, the private sector has jumped at the opportunity to support important research on ISS. Companies like Bigelow Aerospace, Planet, and NanoRacks are testing exciting new technologies like inflatable habitats to help us go to deep space, developing new generations of advanced satellites, and opening up opportunities to a broader utilization community to fly thousands of experiments. This is precisely the kind of response that this Committee had envisioned when it challenged NASA in the Commercial Space Act of 1998 to open ISS' airlocks to commercial industry. We are grateful to both Congress and NASA for having that vision and for the resultant opportunities today.

The Commercial Spaceflight Federation is concerned that a premature termination of the ISS would harm the scientific community, American industry, and, most importantly, the Nation's ambitions to be the world's leader in deep space exploration. Only now are we finally reaching the full operational level for which ISS had been designed. An early retirement of the station prior to 2028 would not allow sufficient time to leverage the asset appropriately. It would be folly to deorbit ISS in 2024 on the promise of future space capabilities; the ISS should fly throughout a transition period until such time as we have a sustainable orbital economy, more likely to be in place by 2028.

Understandably, in this era of fiscal constraint, it is prudent to review opportunities that exist to introduce additional efficiency. But, to be very clear, the ISS and NASA's deep space exploration programs are not in competition, but, rather, are complementary.

Certainly, there exist numerous opportunities to streamline ISS operations and reduce costs, all the while increasing utilization. These should be explored and pursued. Specifically, it is our perspective that continued and increased partnerships with industry offer this opportunity. NASA should continue to encourage competition and contract on a firm fixed price basis for crew and cargo transportation services. This keeps costs low and incentivizes continuous innovation. NASA should continue to partner with industry under SAAs for development activities and under firm fixed price contracts to acquire services. This model has been repeatedly proven to be successful.

One potential opportunity for partnership might be to privatize portions of the station or to even expand the station with the addition of new habitats. Last year, SpaceX delivered Bigelow Aerospace's Expandable Activity Module, or BEAM, to ISS, in a partnership with NASA's Advanced Exploration Systems division.

This partnership depicts a successful venture between NASA and the private sector, providing important technologies that increase the value of ISS and provide a critical proving ground for technologies that will be needed once the ISS is retired. Commercial habitats, such as BEAM, present NASA with increased capabilities and cost savings for future missions to the Moon and to Mars. This is merely one example of multiple opportunities. To that end, we would advocate strongly for a node to be placed on the ISS as soon as possible to support the addition of multiple private sector modules.

Other opportunities could include adding a NanoRacks docking port or even the commercial lease of entire modules. Together with commercial cargo and commercial crew transportation systems, the next step is commercial space destinations. A Commercial Space Destinations Program, modeled after COTS and CCP, is technologically achievable, has a high likelihood for attracting non-government customers, and could be implemented for a moderate government investment.

Continued ISS operation beyond 2024 provides certainty to industry and the scientific community, opening the door for even greater investments by the private sector.

An "ecosystem of space commerce" could be created – one that is sustainable, cost effective, and safe. It would cement the transition of LEO space activity from a primarily government-directed activity to more of a commercially-directed activity. In addition, it would provide essentially the same capability to NASA for microgravity research for significantly less money, as well as expand the United States commercial industrial capacity to help meet national security space needs.

It is also critical that NASA require private industry to invest its own capital in order to secure any NASA partnerships. Under the COTS program, SpaceX and Orbital ATK, and now Sierra Nevada Corporation, invested hundreds of millions of dollars of their own money to develop their systems. Bigelow also invested millions of dollars developing the BEAM. Traditionally, NASA would have had to bear those costs.

Next Space Technology Exploration Partnerships (NextSTEP), a NASA initiative to develop better technologies for application beyond LEO, has chosen several commercial companies as awardees for the program's phase II. Currently, two CSF member firms, NanoRacks and Space Systems Loral, are working together to convert the used upper stages of United Launch Alliance rockets into habitats. These habitats will then be attached to the ISS, allowing a new incubator for commercial launch innovation. NASA chose this Ixion Team, as well as Bigelow and several others, to participate in NextSTEP.

Private companies are now developing the technologies required for a fully private low Earth orbit economy, complete with space stations and routine transportation. But, this is far more likely to be ready by 2028, rather than 2024. In the intervening period, a reliable commercial crew marketplace to fully grow and demonstrate the sustainability of the marketplace for private passengers is necessary. Opening the ISS to private businesses now, and continuing this agenda past 2024, will deliver an assured transition to a sustained private American presence in LEO that can untether NASA from the fixed costs of future space stations while continuing to make capabilities available whenever needed.

Commercial industry is already gearing up to train the next generation of private astronauts. For example, companies like ETC/NASTAR, ZeroG, and David Clark provide equipment, training services, life support, suits/gear, and various support for NASA and commercial human spaceflight missions to ISS and beyond.

A Sustainable Deep Space Exploration Program

The same technologies being developed for use traveling to and operating on ISS today, as well as other commercial capabilities, will enable us to sustainably go deeper in space than ever before.

This Committee and NASA have discussed the goals of sustained human presence in lunar orbit, on the lunar surface, and on Mars. In order for that goal to be achieved, we must leverage the commercial capabilities, both those being proven out with ISS, as well as others under development.

Again, these capabilities would act in concert with NASA's other deep space exploration efforts. The SLS and Orion system is planned to launch once or twice a year at most, with a range of competing missions not just to the Moon, but to Europa and Mars. In order to ensure a sustained human presence, and assured access, we need a far more frequent and regular flight cadence, and we should leverage US commercial launch systems to support and augment NASA cis-Lunar activities.

Blue Origin has also announced it is now developing its own deep space exploration architecture, and it has proposed to conduct what it is calling Blue Moon by 2020. Blue Moon, which would be done in partnership with NASA, is a lunar spacecraft with a lander that would touch down near a resource-rich crater at the Moon's south pole. This program would augment and enable NASA's lunar activities. The Blue Moon spacecraft could carry as much as 10,000 pounds of cargo to the lunar surface, leveraging their liquid hydrogen expertise and experience with precision vertical landing to offer one of the fastest paths to a lunar lander mission.

Already, we are seeing efforts to go to deep space as a direct result of the ISS program. SpaceX has announced a privately funded mission to Mars in 2020 on the Red Dragon spacecraft, a derivative of the Crew Dragon spacecraft they will be using to fly NASA astronauts. NASA has said publicly this effort is saving the agency millions of dollars.

Made In Space, which is already manufacturing on ISS, is developing advanced commercial on-orbit manufacturing services producing products for use in space and on Earth. The company is scheduled to send a new manufacturing product to the ISS in the first quarter of 2017. If initial tests are successful, the company will begin producing ultra-high-quality optical fiber for applications here on Earth, like fiber-based internet, medical devices and sensors for the aerospace and defense industry. We are confident that in-space manufacturing of goods valuable to people on Earth will soon drive significant commercial activity in space, perhaps one day creating a space-based economic boom.

Moon Express has announced that it has all the resources it needs to ensure the company can attempt to launch a small robotic lander to the Moon as soon as the end of this year. Last year, Moon Express became the first commercial company to win U.S. government approval to fly a commercial deep space mission.

Conclusion

How should Congress enable a sustainable, robust American space enterprise, one that will continue to foster the burgeoning commercial activity in low-Earth orbit (LEO), but also enable the United States to make meaningful progress in deep space?

The answer, in short, is to expand the use of public-private partnerships with American commercial space companies. Through private-sector competition, investment, and innovation, the commercial space industry has proven it can deliver reliable and affordable goods and services that support U.S. government civil space missions and initiatives, as well as recapture global market share.

Eric W. Stallmer

President, Commercial Spaceflight Federation

Eric Stallmer is the President of the Commercial Spaceflight Federation. The CSF is the largest trade organization representing over 75 organizations, dedicated to promoting the development of commercial spaceflight, pursue ever-higher levels of safety, and share best practices and expertise throughout the industry. As CSF President, Stallmer develops the strategy, plans and communications for the organization and works closely with CSF member companies to advocate for the commercial space industry.

Prior to joining CSF, Stallmer served as the Vice President of Government Relations at Analytical Graphics Inc. (AGI). Stallmer joined AGI in 2002, during his time at AGI, Stallmer represented AGI's commercial off-the-shelf (COTS) 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 over two 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 is currently assigned to the Pentagon in the office of the Deputy Chief of Staff Army for Logistics, G-4.

Stallmer earned a Masters 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.

Chairman BABIN. Thank you, Mr. Stallmer.

Now I recognize Dr. Ferl for five minutes to present his testimony.

TESTIMONY OF DR. ROBERT FERL, DISTINGUISHED PROFESSOR AND DIRECTOR OF THE INTERDISCIPLINARY CENTER FOR BIOTECHNOLOGY RESEARCH, UNIVERSITY OF FLORIDA

Dr. FERL. Mr. Chairman, Mr. Ranking Member, and Members of the Subcommittee, thank you for the opportunity to talk to you this morning from the scientist's perspective of life and physical sciences as they both enable deep space exploration and are enabled by the unique opportunities of understanding physical and life processes in the absence of gravity.

I speak to you today as a scientist with more than 25 years of experience in the broader areas of spaceflight research using many of the platforms, flights and tools that have been available to spaceflight over this time. My research is dedicated to understanding the molecular and physiological effects of spaceflight on terrestrial life forms in order to develop safer deep space capabilities for human exploration.

My comments today are also informed by my roles with the National Academies. I was a member of the writing committee for the NRC study that ended up being called Recapturing Space for—Recapturing a Future for Space Exploration, Life and Physical Sciences for a New Era. That was published in 2011. And I wish to share with you a very positive regard—positive view regarding the current status and activities on the ISS, a view in fact enriched by experiments over the last few weeks conducted on the Space Station, monitored in real time from Kennedy Space Center 3 weeks ago with Peggy Woodson doing our stuff on orbit. We spent last week at Glenn Research Center downloading in real time information from the light microscopy module on orbit, and our samples landed in the Pacific this weekend. I can tell you there's essentially no better time to be a spaceflight researcher than right now given the capabilities of the International Space Station.

The demonstration and the evolution of the quality of experiments as they've moved from the early days in the space shuttle era into the space station era is dramatic, and the kinds and difficulties and opportunities of science in the Space Station are remarkable.

The space life and physical sciences are governed, enabled by, and monitored and managed by the Space Life and Physical Sciences Research and Applications Division of NASA. I wish to give my thanks to NASA for standing up that division. That division was stood up in alignment with the Decadal Study and has reinvigorated the scientific community such that we can indeed talk about the science of space and spaceflight now in ways that were not available in years past. They've done a great job getting our community back up and running and doing the science in support of the exploration agenda.

The ISS is currently the only space-based platform that provides extended access to the spaceflight environment, and as such, provides the only means to assess the long-term effects of this environment on terrestrial organisms and the physical systems that would be used to support them. Such data are crucial to inform—more fully inform the deep space exploration ideas such as missions to Mars.

I wish to stress that the ISS is now a fully functional laboratory with trained personnel that are interested in science and that are doing the business of science on a daily basis in space. A shift to private sector platform providers as part of the increasingly privatized LEO ecosystem could be a part of a successful microgravity program provided that NASA's stewardship of this portfolio of research is maintained. They've been great stewards of the science that it takes to move humans into deep space and they've been doing that on the International Space Station and any movement away from the International Space Station would be enhanced greatly but mostly only if NASA and Space Life and Physical Sciences within NASA remain stewards of this portfolio of research.

There are important things for Congress to look at as we move forward towards the dates such as 2024 as crew time on orbit. As I mentioned, the access to the special laboratories that are represented in the International Space Station are enabled by a highly active and highly integrated, interested and capable crew there. So crew time on orbit is something that the Committee and Congress should be very much aware of, and in any notions of projecting whether we'll be "ready" to enter deep space will be sort of deeply affected by how much crew time is dedicated to science between now and that time.

So I wish to thank you again for the opportunity to present. I look forward to your questions.

[The prepared statement of Dr. Ferl follows:]

The International Space Station after 2024: Options and Impacts

Statement by

Robert J Ferl, Ph.D.
Distinguished Professor and Director
Interdisciplinary Center for Biotechnology Research
The University of Florida

Before the

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

March 22, 2017

Abstract

The past several years have seen the maturation of the International Space Station as a functioning research platform, a platform that provides unique science capabilities that serve both to enable exploration and to advance fundamental life and physical sciences. Concomitantly, the recent evolution and expansion of the private-sector spaceflight community brings an added dimension to the utilization of ISS in Low Earth Orbit as well as additional potential platforms for microgravity research. As NASA prepares to move out of LEO and into the exploration of deep space, understanding the pace of results from microgravity and spaceflight-related research to enable deep space exploration is imperative. The unique environment of microgravity must be available to complete needed research that delivers results across the continuum of science from discovery through exploration applications, drawing innovation from all segments of this research into NASA's future needs. This complex set of considerations is especially important during discussion of options after this current era where ISS operations still dominate the research opportunities in space, and as we discuss the ISS as an integral element of NASA's exploration of deep space. The variables having the largest impact on being able to assess what science will be able to deliver by 2024 are availability of crew time on the ISS, the stability of grant support for the science, and the prioritization of microgravity science and exploration needs within ISS operations.

Mr. Chairman, Ranking Member, and Members of the Subcommittee:

Good morning. Thank you for the opportunity to submit testimony and participate in the discussion surrounding the options for and impacts of microgravity space science after 2024. This is a very important subject and the discussion is timely, due to the rapid evolution and diversification of spaceflight capabilities available to our nation, as well as the functional maturation of the International Space Station.

I speak to you today as a scientist with more than 25 years of spaceflight related research, largely funded by grants from NASA and having made use of many spaceflight and spaceflight-related platforms. My research is dedicated to the intertwined goals of 1) understanding the impacts spaceflight has upon terrestrial life to better develop safer deep space capabilities for human exploration, and 2) expanding what we know about the limits of terrestrial biology as we consider both human expansion in the solar system and by extension our place in the universe.

My comments today are informed not only by the research I have carried out but also by consultative roles I have played associated with NASA program development for many years. I was a member of a writing committee for National Research Council[1] decadal survey recommendations contained in "Recapturing a Future for Space Exploration: Life and Physical Sciences Research for a New Era," published by the National Academies in 2011[2] (referred to hereafter as the Decadal or Decadal Survey). This Decadal Survey lays out a comprehensive portfolio of life and physical sciences research that is enabled by spaceflight and that enables further spaceflight exploration. I am currently the Co-Chair (with Dr. Elizabeth Cantwell of Arizona State University) of the National Academies' Standing Committee on Biological and Physical Sciences in Space (CBPSS). In addition, I Co-Chair (with Mr. Daniel Dumbacher of Purdue University and formerly of NASA) the National Academies' Committee on A Midterm Assessment of Implementation of the Decadal Survey on Life and Physical Sciences Research at NASA[3], which will be completed by the end of 2017. I am a recent past President of the American Society for Gravitational and Space Research (ASGSR), the society of research scientists most closely aligned with the science portfolio under discussion today.

It should be noted that I speak to you today in my capacity as an academic scientist. While my comments are informed by and deeply influenced by my experience and association with the committees of the National Academies and by my association with the ASGSR, I speak solely from my personal perspective—and I should add that nothing I say today should be construed as previewing any findings of the Academies midterm assessment study.

My comments are guided by overarching questions which are stated here then expanded in the narrative to follow. The answers to these questions emphasize space life and physical sciences as they

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[1] Now more commonly referred to as The National Academies of Sciences, Engineering and Medicine.
[2] https://www.nap.edu/catalog/13048/recapturing-a-future-for-space-exploration-life-and-physical-sciences
[3] http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_174910

enable exploration, as moving into deep space is a major part of the discussion at this hearing. Yet the microgravity research that benefits Earth is an equally important part of this area of science.

1. What is the status of space life and physical sciences research and how is this status affected by NASA deep space exploration goals and timetables?
2. Is the ISS uniquely required for space life and physical sciences research?
3. How would privatized low earth orbit systems influence space life and physical science?
4. What are the opportunities and challenges that Congress should consider as it decides whether or not to extend ISS beyond 2024?

I will be sharing a positive view regarding the current status and activities on the ISS, a view richly informed by very recent experiments conducted on the ISS. These experiments draw directly upon the ISS as a critical, unique and extraordinarily capable research platform. These experiments also emanate from NASA programs that have been designed to further the science of the Decadal Survey. My comments are also informed by past experiments on the ISS and Space Shuttle, as well as experiments on spaceflight analog platforms, and ground-based experiments in extreme terrestrial environments as planetary exploration analogs. Most of my direct experience and expertise is in the life sciences. However the operations and practical discussions, as well as the community status, are applicable to the physical sciences. The challenges that need to be met to move us towards deep space exploration are complex and multi-disciplinary. The integration of life and physical sciences in ISS research is part of what my community believes will be necessary to solve the issues of deep space exploration.

1. *What is the status of critical ISS research in space life and physical sciences that is needed to enable deep space exploration and produce fundamental research that is enabled by microgravity? Can sufficient progress be expected to be made by 2024 on the enabling research, or is additional time on the ISS needed? What will be required to complete the enabling research by 2024?*

For the purposes of today's discussion, I offer the following observations. The Space Life and Physical Sciences Research and Applications Division (SLPSRA) within NASA was formed only six years ago, in 2011, in alignment with Decadal Survey. It should be noted that space life and physical sciences has always been a program within NASA, though over the years it has been its own enterprise directorate or in the science directorate, and is now a division within the Human Exploration and Mission Operations Directorate. SLPSRA initially sought to revive and invigorate NASA's microgravity space life and physical sciences portfolio and reestablish the community of science needed to conduct these areas of research described in the Decadal Survey. It has been very successful in this regard. There again exists a vibrant science community that is engaged in SLPSRA research projects and programs, and is ready for more growth. SLPSRA is closely associated with the Human Research Program and SLPSRA integrates science activities across many disciplines in support of microgravity research, making progress in a wide range of science that supports NASA's needs while creating STEM excitement and recruiting new scientists. The ISS maturation as a laboratory has moved beyond facility management to include a strong effort to track its science impacts. A simple perusal of the ISS science website[4], for example, reveals a regular outpouring of science happenings in space, and results and scientific publications are noted and measured as major output metrics, similar to the metrics used by other national research agencies.

[4] https://www.nasa.gov/mission_pages/station/research/index.html

SLPSRA has also engaged with the National Academies to monitor progress of Decadal recommended science. SLPSRA has activated its programs, fueled the community and is now producing major science discoveries, all in what is essentially a few short years. It is my personal assessment that the status of the overall Decadal portfolio is in a healthy state of growth and accomplishment, and becoming more so as the access to ISS increases.

Space life and physical sciences contribute effectively to NASA research and technology needs. While the time between now and 2024 will see tremendous progress in science in support of exploration, NASA's need for exploration-related science will neither cease nor be fully met. NASA works to enhance and enable exploration by undertaking research to improve our understanding of and reduce the risk associated with putting humans in extreme extraterrestrial environments. Meeting this challenge is not a simple matter of identifying risks and establishing tolerance thresholds for future astronauts. It is a matter of continual evaluation and discovery of principles that enhance the overall exploration endeavor. The resulting portfolio of science activity is built upon the dual notions of research *enabling* space exploration and research that *is enabled by* space exploration—in a manner that actually breaks down the traditional notions of fundamental research versus applied research. Exploration life and physical sciences research is a body of work that is a continuum, and critical advances can and do arise from across the entire continuum. Exploration research recognizes there is seldom a direct connection between experiment intent and practical outcome. The future development of the most important exploration-related research therefore transcends the ISS question, and the need for the kinds of research supported by SLPSRA will continue throughout the evolution of spaceflight exploration, well beyond LEO and ISS.

As space exploration and utilization expands, research ahead of that exploration will be needed. As in all major technology endeavors, such as terrestrial transportation and aviation, continual research improves safety and enhances efficiency. One particularly relevant spaceflight example involves our increasing understanding of radiation effects on biology. Although we have accumulated data on the effects of radiation on biological tissues for more than 70 years, only in the past 15 have we had the ability to explore how this information translates to the spaceflight environment, and even more recently have we been able to observe the effects on the cardiovascular system and brain, and how these systems might be affected by more chronic exposure. In this and in many other areas we will continue to learn how spaceflight effects create unanticipated interactions between risks, and develop more effective solutions that mitigate those risks.

2. *Is the ISS uniquely required for space life and physical sciences research or could other space-based platforms be suitable for carrying out such research? What other types of platforms could be used?*

The short answer to whether the ISS is *uniquely required* for space life and physical sciences research, is yes. The ISS is currently the only space-based platform that provides extended access to the spaceflight environment, and as such, provides the only means to assess the long-term effects of this environment on terrestrial organisms, on physical systems, and on how physics and engineering principles can be utilized to mitigate the long term effects of spaceflight on biological organisms, structures and physical processes. To reiterate, the key word phrases are *extended access* and *long-term*. Extended and long-term data are crucial to inform more fully the preparations for and the future execution of successful deep space exploration activities such as crewed transit missions to the moon or Mars, as well as for private-sector endeavors such as asteroid mining, and any missions that would involve crewed vehicles and stations.

While other platforms, such as suborbital vehicles and sortie missions in orbital vehicles, can fulfill important research niches (such as the evaluation of biological and physical responses to the initial transition from unit gravity to microgravity) none, at present, can maintain the sustained spaceflight environment over long periods of time such as is required to fully support an exploration initiative. It is, however, possible that these other platforms could be employed to lower the pressure on ISS resources. These possibilities and their challenges are discussed below.

It is also important to note that the ISS is now a fully functioning laboratory. It has a well-trained crew that appreciates science. It has well equipped science bays. NASA has processes and procedures for getting samples up, sample processing on orbit, and bringing samples down. It has increasingly sophisticated onboard analytic capabilities, such as the recently demonstrated DNA sequencing. The ISS is equipped with many unique science facilities, launched at great expense but providing considerable payback. Keeping them on orbit lets those facilities serve multiple investigations over many years. But relaunching those facilities for sortie flights or to other platforms would reiterate the costs. So while it is possible to argue that other platforms may provide microgravity research capabilities, the costs would need to be compared to the current model of simply launching samples to existing facilities that are maintained on orbit on the ISS.

The current model relies heavily on international partnerships and the US commercial launch sector for access to and from the ISS. Some of these partnerships are only a few years old and have not had the time to be a well measured part of the discussion. Yet it is likely these partnerships need to continue, and perhaps be enhanced in order for research science to fully exploit the capabilities of the ISS.

Moreover, successful science in space is more than just a well-appointed platform. A trained and trainable crew is required. A steady cadence of launch opportunities that keeps pace with science advancement is critical, a cadence that enables and supports the cycle wherein hypotheses are tested and answered, leading to new insights and the next cycle of question and answer. In addition, strong, regular, grant program management at the agency level is necessary to keep the science community vibrant and engaged. Currently the ISS, with some notable exceptions listed below, together with SLPSRA, does this. Any transition to other platforms would have to keep these points in clear focus.

3. *What would be the impact on research if NASA were to turn low Earth orbit over to the private sector?*

The potential transition of LEO to the private sector is a compelling notion. However the notion is complex and nuanced when considering the spectrum of microgravity science under discussion. Without careful consideration of this notion, we risk assurance that the nation's exploration goals could be met.

Could a private space laboratory serve the needs of space life and physical sciences? Fundamentally, yes. Essentially it does not matter to the science community who the operator of the laboratory is, whether private or government. What matters on the practical level is the cost and reliability of research access. Government laboratory facilities are dedicated to providing access at reasonable costs to all research. Private sector laboratory facilities seek a more immediate return on investment, which affects costs and priority of access. What matters on a strategic level is continued stewardship of the space life and physical sciences portfolio by the United States in general and by NASA in particular. Similar to the Decadal Studies that guide the science in the Science Mission Directorate of NASA, the "Recapturing a Future for Space Exploration" Decadal Survey guides SLPSRA as the primary steward of space life and physical sciences. Our exploration of space will constantly pull innovation from this area of science and NASA stewardship of space life and physical sciences must, I believe, be maintained. The goals of the private sector are driven by fundamentally different outcomes than those which service the exploration needs of NASA. In order for a private or commercial LEO operation to serve the microgravity life and physical sciences, agreements would have to be in place that ensure that NASA's needs receive the priority and access necessary to ensure science success. This is especially true for "long-range studies of the potential benefits to be gained from, the Opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes.[5]" Transition to a private-sector, commercial platform provider would therefore require care and attention to assure that the space life and physical sciences research necessary to meet NASA exploration initiatives remain as clear priorities.

Could private research supplant NASA stewardship of the portfolio of science covered by the Decadal? Not likely. While the goals of the private sector may overlap with exploration science on occasion, the time-scales and risks of research are not typically embraced by the private sector. It is likely that there would be a tendency toward prioritizing profit-directed investigations, as is entirely appropriate for the shareholders of a company, but which would be inconsistent with the needs of NASA. Similarly, it seems unlikely that expansion of the northwestern United States enabled by the Lewis and Clark expedition would have been so remarkably successful without government sponsorship.

Is commercial research a part of the research portfolio covered by the Decadal Survey on space life and physical sciences? Yes, most likely. In point of fact, that type of collaboration is already occurring today. The research enterprise consists of science carried out by industry researchers, federal researchers, and academic researchers. Any of these scientists that comprise the community as a whole may conduct science in support of NASA goals. And certainly we have seen an increase in the research scientists of private companies doing microgravity research, suggesting that scientist participation across the range of government and private activities can contribute to and compete to provide research in support of SLPSRA and NASA's exploration research goals.

Therefore a shift to private-sector platform providers as part of an increasingly privatized LEO ecosystem could be part of a successful microgravity sciences program. However, I am convinced NASA will need to maintain stewardship of space life and physical sciences, in order to ensure that our national scientific enterprise continues to meet NASA needs, priorities and timeframes - regardless of the academic, industrial or governmental location of the scientists conducting the work.

4. *What, in your view, are the opportunities and challenges for the future of space life and physical sciences, and what issues should Congress consider regarding those opportunities and challenge as it decides whether or not to extend ISS beyond 2024?*

The strategic science challenges and opportunities for the space life and physical sciences largely remain as articulated in the Decadal Survey. While tremendous progress has been made in some areas over

[5] NATIONAL AERONAUTICS AND SPACE ACT OF 1958, Pub. L. No. 85-568, 72 Stat. 426-438 (Jul. 29, 1958)

these last six years, there is plenty of work that remains undone, particularly in the physical sciences and larger-scale biological systems such as mammalian studies. Generally stated, the biological and physical systems work on the ISS is just reaching an acceptable rate of progress. The physics and chemistry of the manufacturing revolution that is underway are just beginning to be explored for adaptation to space. The integration of biological and physical systems that feed forward to exploration scenarios is in its infancy. The high fidelity evaluations of the molecular, genetic, and epigenetic responses of biological organisms and systems to long-term spaceflight (primarily humans, human pathogens, and plants) is just now close to fully underway.

The primary questions regarding the movement toward those strategic science goals can, in my opinion, be reduced to several essential tactical and operational issues. Any serious projections of science accomplishments and science remaining by 2024 must come to grips with these issues.

The first issue is crew time. At present, crew time available to science is often cited as the single biggest limitation to the conduct of science on the ISS. This is the one area where the ISS itself has yet to reach its envisioned science potential. All too often, space life and physical science waits near the bottom of a queue for crew time. Some experiments that are highly important to the pursuit of Decadal-recommended science need crew time beyond what the SLPSRA program is allotted. The result is that some funded science can be situated such that it never makes it out of the queue, and may be dropped altogether. So, I believe the first issue that Congress may wish to consider is the mechanisms for getting more crew on the ISS. The importance of this cannot be overstated – in my opinion the amount of crew time available for space life and physical science is the single biggest factor in evaluating the possibility of accomplishing the science needed before heading to deep space.

A closely related issue is competing program priorities in the allocation of ISS resources. Additional crew on the ISS would create the potential for more space life and physical sciences, but only if science priorities are kept in balance with other programs. The establishment of the ISS National Laboratory effectively brings non-NASA science to the ISS, which greatly increases the reach of microgravity science toward Earth-directed goals and extends the value of the ISS investments. Yet the National Lab, too, draws upon the limited ISS resources. It is my personal view that Congress should examine the prioritization of resources across the spectrum of ISS users when considering the prospects of getting enough science accomplished out of the space life and physical sciences to effectively reach for deep space by 2024.

The "Recapturing a Future for Space Exploration" Decadal Survey provides a comprehensive set of research priorities for the space life and physical sciences. While an entire chapter (Chapter 11) is dedicated to the capabilities of the ISS, it should be noted that the Decadal recognizes that ground-based experiments are necessary in some areas. In addition, some microgravity and spaceflight related studies are well suited for platforms other than the ISS. A robust consideration of ground studies and all available microgravity platforms would ensure that the entire portfolio moves forward, targeting to ISS those experiments that actually require its unique capabilities. Congress should examine and be mindful of the full range of platforms, analogs and ground based facilities currently and potentially available to Decadal research and should seek to enhance access to those platforms and facilities especially when such access meets the dual goals of supporting exploration research while relieving throughput stress on the ISS itself.

Lastly I also believe that Congress may wish to consider all current limitations on travel of materials and crew to and from the ISS. While additional crew members would greatly accelerate the progress of the Decadal science portfolio, other factors affects science as well. Greater access to up-mass and down-mass, especially in environmentally conditioned compartments, would clearly accelerate science. Repeatability, quicker access to space, accessible laboratory equipment that parallels ground laboratory equipment, the ability to get samples back to Earth and to the research team, all improve science on the ISS and increase our readiness for deep space science and exploration.

Dealing with each of these tactical issues, together with providing a level of strategic funding for the space life and physical sciences, has the potential to demonstrate a possibly dramatic impact on any evaluation of the amount of science to be accomplished on the ISS by 2024.

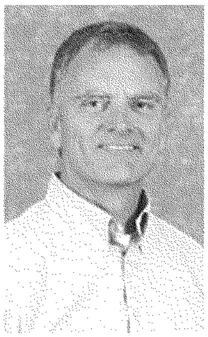
Summary and conclusions:

We are approaching a very appropriate time to consider space life and physical sciences within the context of the operational life of the International Space Station. The increasing success of ISS research is now well documented and available for evaluation, while the SLPSRA Division has years of productivity to be measured and evaluated. Over the course of this calendar year the National Academies will conduct and release its Mid Term Assessment of the Decadal Survey. This Assessment should provide deep insights that inform the questions raised in this testimony.

From a personal perspective I believe that there are key unknowns that potentially have a dramatic impact on these considerations:

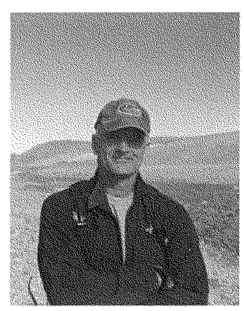
- The trajectory of crew time available for research on the ISS could significantly influence any evaluation of science attainable by 2024.
- The development of commercial spaceflight outside of NASA sponsorship remains an intangible but important factor in considering the pace of microgravity science in support of deep space exploration.

And the largest unknown is the unknowable discovery that will inevitably occur as this body of space life and physical science progresses. The unique qualities of spaceflight must be deeply understood and continually explored across the spectrum of space life and physical science to extract the innovation required to best enable and enhance deep space exploration, and to return benefits to the Earth.



DR. ROBERT FERL
UNIVERSITY OF FLORIDA
DISTINGUISHED PROFESSOR AND DIRECTOR OF ICBR

Rob is a Distinguished Professor the Director of the Interdisciplinary Center for Biotechnology Research. His experimental heritage is the study of plant gene expression in response to environmental change, and recently that environment has been spaceflight and extraterrestrial habitats. Rob Co-Chairs the Committee on Biological and Physical Sciences in Space for the National Academies of Science and is a past president of the American Society for Gravitational and Space Research. Among his honors are the 2016 NASA Medal of Honor for Exceptional Scientific Achievement and the 2016 AIAA Jeffries Aerospace Medicine and Life Sciences Research Award. While a dedicated lab geek, he enjoys and advocates for the field experiential side of science – he and his lab have flown with their experiments on many parabolic flight and other research aircraft to study aspects of the microgravity environment and develop flight hardware for understanding biological effects of spaceflight. Rob also conducts ground based science on space-related environmental effects on terrestrial biology and works within planetary exploration analogs including the Haughton Mars Project in the Arctic and in Antarctic venues.



He has designed and flown several spaceflight experiments and conducted numerous experiments in spaceflight and planetary analog environments studying the effects of spaceflight and planetary habitats on plant molecular biology. His lab has had experiments on multiple Space Shuttle missions and International Space Station segments including recent launches and recoveries on with NASA and CASIS that emphasize cross and multi discipline approaches to space research. He is currently in the preparation stages for ISS experiments next year and technology development for suborbital research flights. His lab has also flown with their experiments on several parabolic flight and other research aircraft to mimic aspects of the microgravity environment and develop flight hardware for understanding biological effects of space vehicles and space flights. Ferl also conducts ground based science on space-related environmental effects on terrestrial biology and works within planetary exploration analogs including the Haughton Mars Project in the Arctic. He has published extensively on the subject of spaceflight biology and extraterrestrial plant growth - and on the fundamentals of moving life off the surface of the earth.

Chairman BABIN. Thank you, Dr. Ferl.

I want to thank all the witnesses for their testimony. The Chair now recognizes himself for five minutes.

This first one is to Dr. Dittmar. China plans to send a crewed mission to the Moon in the 2030s. The European Space Agency has discussed a Moon village. Assuming flat budgets, how is America's leadership in space impacted by continuing the ISS into 2028 or even into 2030? For every year we extend the ISS, are we delaying the development of new deep space projects by year?

Dr. DITTMAR. Mr. Chairman, first of all, I don't know about the one-to-one relationship that you described which is that for every year that station continues to fly, there's a delay by a year. I would not really know how to go about answering that question.

What I would say is that there is no question that under a flat budget you're basically in a zero-sum game unless you're able to find ways to offset that game with either significant cost reductions or the influx of additional revenue from some source, whether that source is coming from commercial ventures or whether it's coming by contributions of international partners or in some other way.

So with regard to continuing to fly the ISS and while still planning to move into cislunar space and beginning to generate activities there, what's going to have to happen, okay, is that there—the things I've already started talking about in testimony, in order for the station to continue, you're going to have to find ways to reduce cost. The clearest way that we see that happening right now is through the advent of things like public-private partnerships, which Eric mentioned, as a way of sort of doing acquisition that's a little bit different. We need acquisition reform in general, and so that's one path to being able to reduce costs. Continuing to encourage the existing partners who are develop corporate partners with NASA who are developing deep space exploration activities to find ways to reduce costs in production as well as in operations is another way to reduce cost, trying to get costs down on that end as opposed to the ISS end.

I think the thing that's most important is to look at the entire portfolio of activities that NASA's considering, to try and find opportunities for cost reduction everywhere along the way. I think we make a bit of a mistake, we're not thinking about things systematically if we're just focusing on reducing costs associated with ISS. I think we have to look at it across the board: Where can we find cost reductions in the entire human spaceflight enterprise and/or opportunities to bring in additional revenues across that entire spaceflight enterprise, and I think that's what we really have to focus on and NASA has to focus on very carefully.

Chairman BABIN. Thank you very much.

And Mr. Stallmer, NASA has invested a lot of money in the United States commercial space companies in the hopes of developing a self-sustaining space infrastructure. Could the ISS be self-sustaining without NASA subsidizing transportation or operations costs? Do any of your members have plans to offer low-Earth orbit Space Station Services in the near term absent NASA development funding?

Mr. STALLMER. Thank you very much, Mr. Chairman. That's a great question. I appreciate that.

I think as Mary Lynne had said earlier, echoing the public-private partnerships that NASA has engaged in with the commercial sector, I think we are already seeing the NASA investment in these partnerships are already paying huge dividends. We're seeing this in the cost to access to space, with the Commercial Crew program, the tremendous reduction in costs that has afforded NASA, as well as coming online next year the Commercial Crew program that will be returning astronauts to the Space Station. Those are already yielding great benefits for NASA.

I see also the value of what a lot of the commercial companies are doing currently on the Space Station, most recently the investment that Bigelow Aerospace has made with the module that they attached to the Space Station. I think that—you're going to see commercial benefits yielded from that, not just on the Space Station but for future missions outside and off the Space Station. And also the manufacturing that we'll see, the potential there, a very, very small investment that NASA made years ago, just a few years ago on 3D printing with Made in Space and the benefits that that is reaping right now.

So I'm very excited about the returns that NASA will see from the investment in the commercial community.

Chairman BABIN. Thank you very much.

And then finally, Mr. Gerstenmaier, at a 2015 NASA Advisory Council meeting, you were quoted as saying "we're going to get out of ISS as quickly as we can whether it gets filled in by the private sector or not. NASA's vision is, we're trying to move out." Is this statement still accurate?

Mr. GERSTENMAIER. I think the accuracy in the statement or the discussion is really, we have a—we need to do a transition. It was described in some of the earlier testimony, it's not good to end Space Station and then try to start exploration. There needs to be a smooth handoff from the one activity on Space Station to the exploration activity moving forward.

I think it's also wrong to assume that exploration and ISS are competing with each other. They're really helping each other. We're working today on Space Station to understand the physiological problems of being in microgravity on the human body. Those are not fully resolved yet. We just recently discovered several years ago the intracranial pressure problem that causes vision problems on station. If that was not discovered on Space Station, we would have carried that potentially with us into Moon, Mars activities and it could have been detrimental to our crews. So that work and that research is absolutely critical to what we're doing going forward.

We're also testing Orion life support systems today on station, so I think there's a transition, but I think NASA's predominant role should be to move to deep space, take the private sector along with us to deep space, and continue that activity moving forward, and to do that, we need to relinquish the NASA role in low-Earth orbit, so it's a natural transition. It's not quite as stark as maybe it was described in the quotes that you previously read to me.

Chairman BABIN. Thank you very much, Mr. Gerstenmaier.

I now recognize Mr. Bera.

Mr. BERA. Thank you, Mr. Chairman.

I think, Mr. Gerstenmaier, and actually all of you talked about the remarkable engineering accomplishment of the International Space Station. In addition, it was a remarkable accomplishment of different governments working together, you know, finding that cooperation. That's going to be necessary as we go on to our next mission into deep space, so I think that's as equally a remarkable achievement.

In your comments, this is not an abrupt let's stop in 2024. This should be a transition as we move from one mission to the next mission, and if we've got a workable asset that still is safe and can be used, we clearly—there's clear scientific value in continuing to use that asset, and I have to imagine there's commercial interest in how you use that asset. So I think for this body as we start to think about this transition, it shouldn't be an either/or, it should be how do we broaden and bring in other partners.

I think, Dr. Dittmar, you talked a little bit about this, you know, you can either lower costs or increase revenue, or do both simultaneously, which is what you do in the private sector and what we ought to be thinking about doing here. In your view, or Mr. Stallmer, is there sufficient commercial or academic interest that could start raising revenue or even international interest, other companies that have growing interest in space like India and others who may want to bring in additional partners. Dr. Dittmar?

Dr. DITTMAR. One of the things that's really interesting when you take a look at the ISS in terms of utilization of it is the growth curve, which is astonishing over the last ten years. I started a few companies, and if I had gone from four, five, well, 15 originally countries who were eventually—originally engaged in the ISS to over 100 given all the barriers that are involved in flying to the ISS and actually doing operations in space, and these are really significant. They're not—it's not the same as doing work here on Earth.

When I was preparing for this testimony, I went and looked at—one interest I have is the amount of time that it takes for technology once it's introduced to basically kick off a market, and those numbers sort of average around 15 to 20 years, but they can be even longer. So for example, the interval between the integrated circuit and the iPhone is about 49 years. We think about these things as they occurred very closely in time but they didn't. Twenty-seven years ago, we began the Human Genome Project, and despite the fact that we basically have unraveled the genome and are now doing a lot of research in that area, we still don't have the cure for cancer. However, we've grown a lot of markets that have developed off of that research, a lot of which couldn't originally been predicted when you looked at the original definition of trying to define the genome.

So the point I'm basically trying to make is, I think that it's impossible to predict commercial activity that's based on research and innovation. What we do know are the kinds of conditions that you can create to help bring that about, and I think that NASA and CASIS and other entities have done—and international partners have done a fantastic job in trying to lower the barriers to the use of ISS and create that sort of environment.

So I think there are a growing number of commercial companies—right now there's six companies flying onboard the station with their own commercial facilities with paying customers. That's a huge change from ten years ago. And there's certainly a lot of companies that are interested in developing a commercial module. Eric mentioned Bigelow. There's Axion, there's some other companies that are trying to do it, and then there's international—as I mentioned, international participation which has grown to over 100. So I think that what we really have to do is look at the trend lines, which are all very positive, but if you're going to ask me to predict a date and a time when that would happen, I'm not able to do that.

Mr. BERA. And we certainly shouldn't predict that day and time. It may happen sooner than 2024, which allows us to free up additional resources to do other missions.

Mr. Stallmer, you know, just playing off of Dr. Dittmar, it does seem like there's that interest if we created that space for the commercial sector. You know, again, they may not know exactly what they're going to do but there's an interest in using this asset and the potential for generating revenue to offset the costs of operating ISS. Is that an accurate statement?

Mr. STALLMER. I think that's a very accurate statement. I think you're seeing work being developed on the ISS by companies, some that didn't exist a decade ago, and the technologies that they are doing and the research that they're learning from the microgravity experience that they have. We touched on a few of them, but I see the manufacturing that is going to go on in the Space Station. It really is a tremendous building block of what we're going to do and it's just critical that any deep space exploration that we're going to do down in the future that we're developing that technology and research now on the station.

Mr. BERA. So we don't know what 2024 looks like but we do know there's a curiosity and a desire, and we ought to create that space for other international partners or commercial partners to explore that space.

Mr. STALLMER. And there's investment.

There's commercial investment. That's, I think, the most important takeaway.

Mr. BERA. Great. I'll yield back.

Chairman BABIN. Thank you.

I now recognize other members for questions, and we'll start with the gentleman from Louisiana, Mr. Higgins.

Mr. HIGGINS. Thank you, Mr. Chairman.

Ladies, ma'am, gentlemen, thank you for appearing before the Committee. Thank you for the work that you do for our Nation and indeed our world.

This Committee is certainly committed to the revitalization of NASA's manned space program. Keeping that in mind, we're also committed and indeed bound in our duty to protect and be careful stewards of the people's treasure.

So considering the fact that new technologies are developed every day, technologies like carbon nanotubes, which have the diameter of 10,000 times less than that of a human hair, they're stronger than steel, and have the stiffness properties of diamond; 3D printers, which are developing quite remarkable products every day with new technologies across the world; it leads one to wonder, considering although the unbelievably successful service that existing International Space Station has rendered to America and the world, leads one to wonder whether or not the continued investment beyond 2024 in the ISS is reasonable.

On the other hand, the same technologies that are being developed which could ultimately lead to perhaps a next-generation International Space Station will also present us new opportunities to extend the life of the existing Space Station.

So my question, first, to Mr. Gerstenmaier, specifically regarding manned spaceflight and deep space exploration for the American space program led by NASA, do you envision beyond 2024 the existing ISS to be in any way useful for that manned space exploration or does it have a role, do you envision that role, and if so, please explain, and if not, please expound.

Mr. GERSTENMAIER. I believe the station has a critical role in exploration as we have technical challenges that we have to conquer or overcome as we go beyond low-Earth orbit. The requirements to keep technology highly reliable with low resources to essentially break the tie back to the planet Earth—Space Station is resupplied all the time today by cargo vehicles to and from the Earth, but as we move human presence deeper into the solar system, we need to break that tie back with Earth, and the Space Station is a great testbed to test that technology, to understand the next generation of life support systems. You know, we tested the systems for many years on the ground terrestrially before we took them to the Space Station. They did not work nearly as well in space as we had anticipated because of the loss of gravity. The carbon dioxide removal system is still a problematic system for us on board Space Station. We can operate it and keep it working well but it's not easy. We need to use the unique properties of Space Station to actually test that next generation of life support systems. Understanding how the human performs in space is important, and understanding even how we break that tie and we keep sensors like oxygen measurement devices calibrated for years without returning to the ground for recalibration. So I think station plays a pretty critical role. I don't think we'll have all those technology challenges done. We're going to need some facility in space beyond 2024 to keep working as we break the tie of the planet and move human presence further into the solar system.

Mr. HIGGINS. Dr. Dittmar, would you comment on that question, please?

Dr. DITTMAR. I don't think there's any disagreement that we have to move off station. I think the only issue is when and how and what needs to happen between now and then. So it's already been talked about that there has to be a transition plan of some type. I don't know about you but I really like a certain amount of certainty, as a business owner in particular. I like it when I can predict outcomes. I don't like it when I can't predict outcomes. This is one of those circumstances where you just can't really predict the outcomes.

We do know that there are certain things that have to happen, right? We have to meet as many of the research objectives that are involved in going to deep space as we possibly can, and NASA in fact has a risk matrix that it's been burning down, okay, doing that kind of research. We know that we want to enable researchers like Dr. Ferl to be able to do as much research as they can, and we want to establish some mechanism to be able to continue to do that research after we're finished with ISS. We know that for all the reasons that Bill just talked about and Eric just talked about, we want to be able to continue to have facilities available for people to do commercial development as well as to be able to test systems that we need to go into deep space. So the only real question is how do we get from here to there, right? I mean, that's the question. That's the one that's sort of facing everybody.

The kinds of things that we know we want to allow for more time for have to do with commercial development, the kinds of things that we've already been discussing here, learning what kinds of systems work we may need to do as we go forward into deep space. So do I think that this is a value to the Nation to continue doing this? I certainly do. The unique properties of microgravity are things that we're just still starting to—I mean, we're really just early in trying to figure those out. Think about when radiation was discovered and all the things that we've learned about what to do with that in the years since, right? We had no idea when we first started. That was a unique physical property, right? What we've learned to do with that in the decades and decades since is extraordinary. It's actually in most aspects of our lives. So I think that it's just—I hate to counsel patience but I'm going to counsel patience. We need a little bit more time, I think, to allow these things to develop before we can get a real clear view of what that transition looks like.

Mr. HIGGINS. Those are very helpful responses. Thank you both, ma'am, gentlemen, for appearing today.

Mr. Chairman, I yield back.

Chairman BABIN. Thank you, Mr. Higgins.

I now recognize the gentleman from Illinois, Mr. Lipinski.

Mr. LIPINSKI. Thank you, Mr. Chairman. Thank you for holding this hearing. I want to thank our witnesses for their testimony today.

I want to ask Mr. Stallmer and Dr. Dittmar, can you speak to the readiness of the private sector to fly its own modules in low-Earth orbit without NASA assistance or physical attachment to the ISS? And then can you talk about what roles that NASA and ISS played thus far and what role can it should it play in the future for this? Mr. Stallmer?

Mr. STALLMER. I think what you're seeing right now with the flying of modules and the role of NASA in commercial is a tremendous partnership. It's a partnership that I think can't have one without the other, and I think what the assistance that NASA is providing is the technical assistance and some of the resources that are enabling these technologies to kind of crawl, walk, run. As I mentioned earlier, we saw this with Bigelow and we're seeing this with the possibilities of Axion and what they're looking to do.

You know, time is going to be the best indicator of how we can move away to, you know, purely commercial space stations. I feel that the steppingstone that what is ISS and what they're doing is critical, and I think that partnership with NASA and the technology transfer and the investment that they're making intellectually is really critical.

Mr. LIPINSKI. Thank you.

Dr. Dittmar?

Dr. DITTMAR. I don't have much to add to that except to say that there are things about learning how to operate in space that you can only learn by operating in space. It sounds ridiculous but it's true. So when it comes to the development of commercial modules, I think that there are folks that are doing some really good work in thinking about how it is that they want to develop those, but a steppingstone approach where you have attachment to the station, for example, and you've got essentially the station resources available to you, knowledge available to you, that's a reasonable approach. If you had a commercial provider that really wanted to go try and do it all, I'd be a little concerned about that, only because I think that really, there's a unique knowledge set that just has to do with operations. It's different than launch, it's different than landing. All these things are a little bit different.

So the partnership that NASA affords, I think, in developing those kinds of capabilities and sort of handing over that knowledge that's been developed over all these years I think is critical to commercial success, really important to those people who were wanting to go in that direction, and it's wonderful that NASA makes that available.

Mr. LIPINSKI. So will the ISS or a replacement and NASA work in cooperation with commercial operations, will it always be necessary in order for this to be viable, or do we not know?

Mr. STALLMER. "Always" is such a tricky word, and as I said, you know, it's a timetable——

Mr. LIPINSKI. That's why I said we probably don't really know.

Mr. STALLMER. Yeah. I do see the greater role that commercial is going to play, and I think, as we say these steppingstones, as we are making these technological breakthroughs at the ISS through microgravity, I see a greater interest in the investment community of enabling more commercial companies to do this and whether it's on medical research or just technologies that will be applicable here on the ground, I think that you'll only see that growing and with time you'll see the commercial impact on the station grow.

Mr. LIPINSKI. Anyone else want to add anything on that?

All right. Thank you very much. I yield back.

Chairman BABIN. Thank you, Mr. Lipinski.

I now recognize the gentleman from Florida, Dr. Dunn.

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

I spent the last few years on the board of Space Florida, very much a commercial sort of focused entity, and with some pride we like to say we actually ran that thing in the black, so I know there is a commercial niche for space. I'd like to sort of focus on the commercial niches of the ISS specifically so let me start with Mr. Stallmer. Can you quantify for me the likelihood that the ISS would be supported entirely by commercial partners by 2024 or at any other time frame?

Mr. STALLMER. I think it would be hard to speculate by 2024. I think the commercial sector is moving in the right direction with

NASA to fully privatize the station. It would be difficult but—because I think you do need that expertise that NASA offers. But I see more and more breakthroughs, you know, with—and it's going on in your state with the onset of the Commercial Crew program and the doubling of the crew that it would be able to work, more and more work on the station. I think that'll move the ball in the right direction to a greater and greater commercial percentage to allow NASA to do those——

Mr. DUNN. Can you quantify, give me a percentage you think we can get to? Is it 50/50, 70 percent?

Mr. STALLMER. I would love to see 50/50. I think that would be a great starting-off point and move in a higher direction.

Mr. DUNN. Dr. Dittmar, same question, likelihood or, commercial balance versus NASA in the ISS?

Dr. DITTMAR. Very difficult to quantify. What I would point out——

Mr. DUNN. That's what we have to do, though. You're going to help us.

Dr. DITTMAR. I understand. One of the things I would point out is that the cost of ISS, when we talk about the operations, we're talking about transportation as well as the actual operation of the vehicle, right? So let's assume for a moment, let's do a thought experiment, and let's just say that you're able to generate commercial revenues sufficient to support the entire operating cost of the vehicle itself, the M&O of the vehicle itself, that still leaves you right now—I know Bill's probably going to correct me if I'm wrong here—about 1.7 Billion of transportation costs, roughly, which I would assume would go up over time. So one of the questions really is, is when are you generating enough business that you can start shifting the transportation costs back to the people who are actually generating the business. In other words, pay for your ride, right?

Mr. DUNN. Yes.

Dr. DITTMAR. And that's for me actually even a more important question than the actual operations and the M&O part of the station. I think that's a difficult one to call because it's not just the United States, right? There's an international component to that. I think it's around half a Billion is being contributed right now by the international partners. So I'm much more interested in when you can start getting payback on the transportation end.

Mr. DUNN. Good point. Thank you very much.

Again, Mr. Stallmer, so how disrupting would it be to the commercial space industry to lose the ISS, if you just lost it entirely?

Mr. STALLMER. I think it would be tremendously disruptive.

Mr. DUNN. Can you quantify that?

Mr. STALLMER. A hundred percent? We would lose——

Mr. DUNN. That's what we're talking about here at the end, right?

Mr. STALLMER. That's a number. We would lose our outpost in space where, you know, we're doing all the low-Earth orbit experimentation, all the advance sciences. I mean, to lose the ISS would be critical, you know, in part on the transportation sector of where we're going in space. It would, I think, infringe tremendously on our ambitions as a Nation for deep space exploration.

Mr. DUNN. Okay. Dr. Ferl, are you doing any commercial research or is it pure science? By the way, very near my district and home. So nice to have you here. Any commercial-based research?

Dr. FERL. The simple answer to that question is yes. We've seen as——

Mr. DUNN. Well, I only have a minute so keep it simple.

Dr. FERL. We've seen from the community over time increased interest in the industrial private commercial sector in doing experiments on station. By nature, those experiments involve scientists. Some of those scientists are within the company and some of those scientists are contracted by the company from——

Mr. DUNN. Are you working on the commercialization of a product by any chance?

Dr. FERL. People are, yes. Am I? No.

Mr. DUNN. Okay. That's good. Thank you very much.

I yield back, Mr. Chairman. Thank you. And thank you all for your work.

Chairman BABIN. Thank you, Mr. Dunn.

I now recognize the gentleman from Colorado, Mr. Perlmutter.

Mr. PERLMUTTER. [audio malfunction in the hearing room.]

Chairman BABIN. No, we can't wait. I'm sorry.

Then I recognize the gentleman from Florida, Mr. Crist.

Mr. CRIST. Thank you, Mr. Chairman, very much, and I have—actually I have a question for Dr. Ferl, my fellow Floridian. I was curious, there's a lot of discussion obviously today about the International Space Station. There's also a lot of discussion about a potential mission to Mars, and I noticed that in some of you work you've looked into—let me get my eyes back on—the Haughton Mars Project in the Arctic is some of your body in work, and I was just curious if you had to prioritize between continuing the International Space Station beyond 2024 or pursuing getting to Mars sooner, how would you prioritize those two if you would, or do you think it's just as important to simultaneously pursue both?

Dr. FERL. I would agree with my compatriot from the other end of the table here who says there has to be a transition and basically a dual-use appreciation for all the science that occurs in space. The notion that the station stands sort of alone as the way in which we derive scientific benefit for the trip to Mars is too simplistic. And by the way, touching the commercial sector are all the other vehicles that also currently inform scientific research for that mission to Mars—suborbital space, parabolic flight. Commercial providers now are giving science the opportunity to develop the processes, experiences and data that it takes to get us to Mars. So the long way around to answering to your question is, I wouldn't prioritize as a scientist one or the other but I would say that maximal use of every opportunity from ground-based studies that do analog environments through suborbital projects and on-station projects all richly inform that mission when we do decide to go to Mars.

Mr. CRIST. Thank you very much. To pursue that a little bit because getting to Mars is fascinating obviously, and what we might glean or be able to learn by, you know, that opportunity to explore it in greater detail fascinates me, but I can't help but recognize the fact that this week I read in the press about the potential additional discovery of significant amount of planets. Are you familiar with what I'm referring to?

Dr. FERL. I am, yes.

Mr. CRIST. I bet you are. And if you could elaborate on that, I would just be very grateful for your insight into what you think is happening, why they may have been missed prior or just—I'm a lawyer so I don't—my dad's a doctor and my sister's a doctor but I don't have your expertise and that's why we appreciate you all being here today, or I do, for sure.

Dr. FERL. From my perspective, the discovery of additional planets and additional Earth-like planets is simply going to continue and continue at a very rapid rate. We're going to continue to find that there are more and more planets like ours and like Mars the better our observation opportunities progress. I would not be surprised at all if we find that planets like ours are quite common in the universe, and don't be surprised the next time another handful of rocky Earth-like planets is discovered.

Mr. CRIST. Well, if I could take it a bit further, we're on a line of questioning, what do you think the possibilities or probabilities are that those planets that are similar to Earth would have any kind of life similar to ours?

Dr. FERL. One hundred percent.

Mr. CRIST. I would agree. I've always thought that it was almost arrogant to think that we're like the only thing moving around the entire universe.

Dr. FERL. Well, and again, I'd like to expand on that just a little bit, drawing back to——

Mr. CRIST. But that's just a gut feel for me. For you, it's a scientific conclusion.

Dr. FERL. And drawing back to the matter at hand, as we take our biology, ourselves, the creatures that go with us as we go into space, we learn an awful lot about what it takes for life to move around the solar system and therefore life moving around the universe. So the human exploration mission that NASA currently provides also richly informs a lot of our information on where we are in the universe and tells us how easy, hard, difficult it is to move life around. So it does reach out to your question about, you know, what's out in the universe in terms of other planets as well.

Mr. CRIST. Thank you very much.

Thank you, Mr. Chairman.

Chairman BABIN. Yes, sir, good questions. Thank you.

Now I recognize the gentleman from California, Mr. Rohrabacher.

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

I think I may be the only one on the panel that was here when we approved the Space Station, and I think I was sitting way over there at that time, and I listened to all the arguments, and it was not a certainty that the Space Station would be approved because I remember that we were also trying to balance the budget at the time, and we had to take some budget considerations and put them into the debate. Can you tell us, can anyone on the panel tell us how much has already been spent now on Space Station from the time we voted to move forward with the project?

Mr. GERSTENMAIER. As I said in my opening remarks, the number we have is $67 Billion, and that includes the shuttle transportation costs is our current estimate.

Mr. ROHRABACHER. Fifty-seven Billion dollars?

Mr. GERSTENMAIER. No, 67.

Mr. ROHRABACHER. Oh, 67? All right. Sorry, I came in about 15 minutes late here for the hearing today.

Okay. And if we maintain the Space Station, we decide to keep it in service, how much more will we be spending? Does anyone know that?

Mr. GERSTENMAIER. We're spending about $3 Billion per year on Space Station. That's made up of about $1.7 Billion of transportation costs. Those are the 13 percent of the global launch market, 700 to 800 million for research, and then roughly about a Billion dollars for just operation costs on station. That's U.S. costs. The international partners are also contributing to that overall.

Mr. ROHRABACHER. I was going to ask, how much do our partners contribute?

Mr. GERSTENMAIER. They're probably contributing, the other three, probably roughly about a Billion dollars per year.

Mr. ROHRABACHER. All of them together?

Mr. GERSTENMAIER. All of them together.

Mr. ROHRABACHER. Okay. And how many partners do we have?

Mr. GERSTENMAIER. We have the Canadians, Japanese and Russians, and Europeans.

Mr. ROHRABACHER. Okay. Now, when we were being—and by the way, I voted for it. It won by one vote, and it was my vote, just so you know.

There is one element here that people don't realize. I'm not sure if the scientific research that has been done on the International Space Station has justified the expense of the $67 Billion that we're talking about, and I'm not sure that's the case, but there are other factors rather than just scientific research that come into play, and Space Station certainly renewed our national self-assuredness that we could do great things, and I think it's hard to put a price tag on that, and when people are demoralized and they don't think they can do great things, they don't do great things, and that costs a certain amount of money.

Let me also note that Space Station played and continues to play an important role in creating an image of peaceful cooperation between the two countries that were willing to destroy each other and destroy the planet for the 40 years prior to building the Space Station, mainly the Soviet Union, which now has devolved away and is now Russia, but the example of Russian-American cooperation in space, there had been an attempt at earlier on at a much smaller level, Skylab, but I think that the—Mr. Chairman, we have to make sure that we understand that especially in Russia but in the United States as well, we have examples of now even at this time intentions are very on the upswing now between Russia and the United States, that we have an example of cooperation of what we can do technologically rather than just building better technology of how to destroy one another. And so I would think that even though the promises—and I will add there were many promises that cancer would be cured. I mean, I sat and listened to them.

While I never did buy that, I hoped it would be true but I never really counted on that, but I do think that we can say that when we write our history of what was accomplished in the last century, Space Station will be up there on the list of great accomplishments and of things that showed there is a better way for mankind.

So thank you very much, Mr. Chairman.

Chairman BABIN. Yes, sir. Thank you, Mr. Rohrabacher.

I now recognize the gentleman from Colorado, Mr. Perlmutter.

Mr. PERLMUTTER. Thank you, and I agree with Mr. Rohrabacher. I think that the accomplishments of the Space Station are tremendous, and both scientifically as well as in connection with international relations. The ability of so many countries to work together, to cooperate, to face challenges together I think bodes well for us as humans, and hopefully we will continue to do that.

Now, where I don't agree with him and oftentimes that happens, is on the funding side of all of this, and I don't—I mean, he was here during the budget discussions for the lab. I was here during the budget discussions for the banks, and we were somehow able to come up with $800 Billion over a weekend to save the financial system, and so when there is a priority, when there is a will, we can do a lot of things whether it's an emergency or in a planned sort of setting, and I think we can maintain the laboratory and transition it to commercial operations and use over time and go to Mars.

And so I would like to start with you, Dr. Dittmar, and just have you respond to sort of what I think we can do, and oh, by the way, I've always got to put my commercial up, which is to get to Mars by 2033. It says "We can do this."

Mr. ROHRABACHER. I would—would the gentleman yield for 15 seconds?

Mr. PERLMUTTER. To my friend from California, sure.

Mr. ROHRABACHER. Just to remind you, I voted against the bailout of the banks.

Mr. PERLMUTTER. Okay. Doctor?

Dr. DITTMAR. I was going to be very disappointed if you didn't flash that bumper sticker, so thanks for doing that.

I like your vision, of course. I've been at this for not as long as some people around the table but enough of my life that I'm deeply invested in forward progress in space. To echo something that you said, Congressman Rohrabacher, I believe that aspiration is absolutely critical to advancing society and advancing the human condition, and I also believe that aspiring to do great things—the Space Station is certainly one of them, moving into deep space is another one, going to Mars is an extension of that. Aspiring to great things, especially great, I mean truly great, daunting goals that we set ourselves to forces us to advance not only our technology and our science but the human condition.

The International Space Station, in my view, is an exemplar of this for the reasons that have already been discussed here. Having been involved in it when the transition was really occurring for the Russians coming on board, I can tell you that I used to sit in meetings where I had the Japanese on one side and the Russians on the other side and the Americans in the middle, and this represents a range of cultures in a whole lot of different ways, and the intensity and focus of the individuals that are in that room to learn how to transcend language boundaries, cultural boundaries, technical boundaries and figure out how to work together is the reason that the ISS has been nominated for the Nobel Peace Prize, and I hope will be again.

Going forward to Mars is that times 100. It's a truly exciting goal, a very challenging goal. It will bring out the best of us in this country. There is no question in my mind that the United States must lead that way forward, and I believe that it's worth the investment of our treasure and our resources and our commitment and our time over decades in order to be able to achieve that goal. I do believe it is achievable, and I think that we do have the resources to be able to reach it. We just have to choose to do it.

Mr. PERLMUTTER. Thank you.

Mr. Stallmer, go ahead.

Mr. STALLMER. I'd love to address that issue. I think at times when you look at cost, you have to look at intangibles and sometimes numbers aren't always black and white. With $3 Billion as in the $3 Billion of investment this Nation makes on the International Space Station per year, look at maybe where that $3 Billion gets you at the Department of Defense. I can say that firsthand working at the Pentagon. My colleague up there, who also works with me in the Reserves, how do we spend our dollars, and I think when you put it in that perspective, if it's a $3-Billion-a-year investment on what we're doing in space, I would tell you that today there's no place I'd rather be in this world than in front of you except for one other place: my daughter's first-grade class is doing a field trip to the Air and Space Museum today, and I was supposed to chaperone it, but again, I'm here with you guys by choice.

Mr. PERLMUTTER. What time do you got to be there?

Mr. STALLMER. It's too late. It's too late. They got there at 9:00.

However, that being said, I get to talk to them enough and I get to see the excitement in their space, and to take—to look up above sometimes and to see the International Space Station with young people and to talk about the things that they're doing up there and the vision that they have, that my daughter and my sons and this younger generation are going to have in space because of the investment, the $3 Billion a year that we're spending. You know, there's some things I don't think you can put a price tag on, and I think that might be one of them.

Now, in Congress, you've got to put a price tag on everything, and I certainly understand that challenge, but I think the benefit that we're getting from an international perspective from just a domestic perspective of our leadership in the world I think is well worth the cost.

Mr. PERLMUTTER. And I thank you. And we've got to be smart with the people's money, no ifs, ands or buts about it, but the intangible investments that we're making, it's hard to quantify it but we've got to consider that, so thank you for your testimony.

Mr. STALLMER. Thank you, sir.

Chairman BABIN. Thank you, Mr. Perlmutter.

Now I recognize the gentleman from Indiana, Mr. Banks.

Mr. BANKS. Thank you, Mr. Chairman, and thanks to each of you for your testimony.

I wonder if each of you could comment briefly on the impact of the Chinese station on commercial interests and low-Earth orbit and specifically what—in what ways might a Chinese station compete with commercial platforms?

Mr. GERSTENMAIER. Again, that's difficult to predict exactly how that comes about or what happens but we're also—you know, today as a national Space Station program, we have international agreements with all the countries I described earlier, and what works well there is we do a barter agreement where there's no exchange of funds between us and the other countries so, for example, if the Europeans want to build a module, they do that investment in Europe and then that module flies to Space Station and is attached and is used for all of us and it's to the benefit of all the partners. So that's the basic model that the Space Station, the U.S. Space Station operates under.

I could imagine the Chinese space station doing the same thing. I can see other countries interacting with China, and if we don't have a U.S. space station, then that would be the only space station available essentially to go to for these agreements, and that could pull away from America's leadership in space and technology towards China.

So I think it's important that we keep our focus, we use the private sector as we've been doing before to leverage the private sector as much as we can. That gives us a unique competitive advantage over other countries but I think there is a threat from the Chinese and their potential relationship with other governments and other countries that our international leadership role could be diminished unless we have a very strong human presence in space at that time.

Dr. DITTMAR. I don't have anything to add to that.

Mr. STALLMER. I would just add that it would—I think it'll push us harder as a Nation, as an industry, as a collective voice to work harder to achieve what we're looking to achieve in space from a commercial perspective. I think there's a laundry list of ambitions that we want to do in space, so it would be a challenge and a competitive nature, I think.

Mr. BURNETT. And I can't speak to the commercial impacts but I can tell you that leadership in science is an important thing for our science community, the role that the United States plays with regard to its current leadership. Its current ability to point science in the right direction is a very, very treasure that we would like to maintain.

Mr. BANKS. Okay. Thank you. I yield back.

Chairman BABIN. Thank you, Mr. Banks.

Now I recognize the gentleman from Texas, Mr. Veasey.

Mr. VEASEY. Mr. Chairman, thank you very much, and I appreciate everything today.

I wanted to ask about some of the key objectives in order of priority that argued for extending ISS operations until 2024 and what is the status of progress on meeting those objectives. Mr. Gerstenmaier?

Mr. GERSTENMAIER. One of the things that we need to do is, we need to understand how the human body performs or how the physiology works in microgravity environments so we can go further into space. We have 33 items that we track on a list of things such as bone loss, vestibular ability of the balance system, fluid shifts, those kind of things, tolerance to radiation. There's 33 items listed on that list of which 22 are being actively mitigated or being investigated on board Space Station so those 22 items are helping us with that activity. Then separate from that, we're testing life support systems. The Orion carbon dioxide removal system is on board the Space Station and has been operating, and we're testing that system that is needed.

And then also we're working with the commercial and private sector to expand the ability of commerce in space. We have awarded some new contracts for cargo resupply to the Space Station. Sierra Nevada Corporation out of Colorado is going to be one of the providers for cargo in the future. They have a different vehicle that comes back and can actually land on a runway. We think that has some advantages to us in returning samples from space, not landing in a capsule in the water and then picking the vehicle up, so that's another thing the station's doing. It's helping expand and help commerce get more experience.

We're also kind of teaching the private sector how to operate in space and build space stations and do those things, and then there's some very fundamental research activities on station that are very unique. There's the alpha magnetic spectrometer, which looks for dark matter, looks for kind of the high-energy particles traveling through space. That research is purely fundamental in nature. We're about ready to fly an experiment called the Cold Atom Lab, which will be the coldest location in the universe where we can essentially take a molecule and despin the molecule and look at basic physics principles. That can be done absolutely nowhere else in the world, and that's a pure fundamental research of basic physical science.

And I'm sure some of the other members on the panel here can add some more, but those are the things that we said we would do between now and 2024, and those things that we are actively working on today as we go through the operations on Space Station every day.

Mr. VEASEY. Thank you.

Dr. Dittmar, Mr. Stallmer, Dr. Ferl, anyone else want to comment?

Dr. FERL. I'd be happy to jump in there just a little bit on a couple of the notions that Mr. Gerstenmaier put forth. One is that the science behind some of the technology challenges that he mentioned, for example, the fluid shifts in biological systems and the management of life support systems involve physical and biological principles that are now being understood because of Space Station. In other words, the notion that you have to fix fluid shifts in humans is an interesting technological challenge. Understanding the reason behind them and how you might mitigate them before they occur is a scientific challenge. So too with the movement of fluids and particles in biological systems and in physical systems such as the ECLSS system that supports human respiration and function.

The additional notion is that the ecology within a closed environment such as the International Space Station is a unique environment to study what happens when humans and their microbes and their plants and their entire life system are kept in close quarters, and this informs a lot of clean building and other technologies here on Earth. But the other thing is that it is a scientific challenge to integrate across the biological and physical domains, not only to understand how to get into deep space but just to understand them better, period.

Mr. VEASEY. Thank you.

Mr. Chairman, I yield back.

Chairman BABIN. Yes, sir. Thank you.

Well, I thank the witnesses for their valuable testimony and the Members for their questions. The record will remain open for two weeks for additional comments and written questions from Members.

And so with that, this hearing is adjourned.

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

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. William Gerstenmaier

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"The ISS after 2024: Options and Impacts"

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

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

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

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

2. President Trump has released his budget blueprint for Fiscal Year 2018, and I understand that the request for NASA includes a cut of $272 million to the Space Operations account, which includes the ISS. What is the rationale for the cut and what impact will it have on ISS research and operations?
   Answer: The President's detailed FY 2018 Budget Request is slated to be released in May, at which point, specific information about the various accounts will be available. NASA is committed to ISS operations and utilization through at least 2024; Station is a key component of NASA's human exploration portfolio, and its requirements will be balanced with those of other elements in that portfolio.

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

   a. Could NASA sustain a safe cadence of Space Launch System (SLS) and Orion launches and acquire all the other needed systems as part of a deep space human exploration program, while also sustaining ISS operations, if it receives no increased funding?
      Answer: NASA is committed to the safe operation of the Space Launch System (SLS) and Orion. The specific balance of ISS operations and utilization (including whether to extend Station beyond 2024), SLS/Orion mission cadence, and pace of development and acquisition of future human space exploration systems will be reflected in future budget requests. The use of international contributions and value of public private partnerships will affect the funding needed.
   b. What would the flight rate be?
      Answer: The SLS is being designed to be capable of supporting a long-term flight rate of one per year with a surge capability to three per year. The actual cadence of missions beyond Exploration Mission-2 (EM-2) will be defined based on mission needs, available resources, and operational costs. NASA's current human exploration planning is consistent with an SLS/Orion flight rate of one per year augmented by commercial and/or international logistics flights.

c. Please provide any analysis to the Subcommittee to support your conclusions.
Answer: Please see response to Question #3a, above.

4. During the question and answer session of the hearing, Dr. Dittmar said that if Station is to continue, *"you're going to have to find ways to reduce costs."* She referred to acquisition reform as being *"one path to being able to reduce cost."* She also mentioned the need to reduce costs in production as well as in operations across the human spaceflight enterprise.
   a. What, if any, acquisition reforms is NASA considering and how would they affect ISS or human spaceflight costs?
   Answer: NASA continually assesses and, when prudent, makes changes to its acquisition approach. As the ISS operational lifetime policy is developed, NASA will address the implications of each of the ISS Program's contracts, agreements, and future acquisitions. We also continue to assess acquisition options across all of our human spaceflight programs. As part of the President's FY 2018 budget, NASA will support and expand public-private partnerships as the foundation of future U.S. civilian space efforts, to include ISS operations.
   b. Is NASA making or planning to make cost reductions in the Human Exploration and Operations Directorate that will be applied to the ISS program and operations? If so, where will those cost reductions be made and at what level?
   Answer: NASA continues to look for further opportunities to increase efficiencies, to allow us to productively operate and sustain the ISS, keep our crews healthy and safe, and support utilization at lower costs. Ongoing activities to decrease the operations and maintenance cost of the ISS include changes to our contracts to incentivize efficiency, lower overhead cost, and apply targeted enhancements in technology investments to reduce manpower-intensive processes.
   c. As the ISS ages, do you anticipate that maintenance costs will increase? If so, by how much? If not, why not?
   Answer: NASA's budget for ISS includes a balance of systems operations and maintenance; research; and cargo/crew transportation. U.S.-built Station modules were designed for a 30-year on-orbit lifetime. NASA is tracking Station maintenance needs; at this point, a number of Station components are lasting longer than originally anticipated. In addition, enhancements to the baseline ISS systems to increase reliability and thereby decrease crew maintenance time are underway. For example, improvements to some of the life support components that have been more prone to failure are in work. These improvements will not only save precious crew time on ISS, but fill capability gaps for missions beyond LEO. Most spares have already been purchased and maintenance costs are not likely to increase.

5. When does a decision need to be made on whether or not ISS operations are extended beyond 2024? If no other nation signs on to an extension of operations, could the U.S. go it alone?
   Answer: NASA, in consultation with its International Partners, will need to make a decision about whether to extend ISS beyond 2024 in the next couple of years. It is important to note that NASA and its International Partners are dependent on each other for the operations, resupply, and maintenance of the ISS.

   NASA and Roscosmos are mutually reliant on one another in the operation of the ISS. NASA will continue to need Russia-unique critical capabilities not currently available elsewhere, such as: propellant and propulsion systems for desaturation of the rate gyros, reboost, phasing burns and debris avoidance maneuvers; redundant life support for U.S. systems; sustaining engineering for the Russian-built, U.S.-owned Functional Cargo Block (FGB); goods and services related to Russian Segment systems training for on-orbit ISS operations; supplies and sustaining engineering on the Russian-built toilet in the non-Russian segment; and potential de-orbit assistance. Roscosmos will continue to need NASA capabilities including: electrical power for Russian core systems and payloads; redundant life support for Russian systems; attitude control; communications downlink telemetry and commanding to augment limited Russian ground site coverage; and training for non-Russian Segment operations. The other partners are not as critical as Russia to day-to-day ISS operations. Some of the dependencies on Russia can be mitigated. For example, U.S. cargo vehicles could supply reboost and control-moment-gyro desaturation capability. Life support system redundancy could come from the new exploration systems planned to be tested on ISS.

6. Does NASA need a sustained capability for research or human operations in low Earth orbit (LEO) beyond 2024? If so, what are the requirements for that research?
   Answer: NASA expects to have ongoing research and technology development requirements that will require financial support, but the nature and magnitude of these requirements has not yet been defined. NASA is currently assessing its long-term requirements for LEO research, technology development, and utilization beyond 2024. NASA plans to complete the majority of its research and technology development for deep space exploration around 2024. Research areas such as life sciences, physical science, astrophysics, and other areas are being assessed. NASA is actively working transition strategies for the 2020s that include the goals of U.S. leadership in space and the development of a viable commercial market in LEO, including the possibility of private platforms. In developing these transition strategies with our International Partners, domestic industry, academia, and Administration and Congressional stakeholders, NASA will take into account the Agency's plans for human deep space exploration.
   a. Are there Federal government agencies who have expressed a need for a human presence in LEO following the end of ISS operations? If so, which ones?

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

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

8. Your testimony talks about public-private partnerships being the "*foundation of future U.S. civilian space initiatives*." Partnerships imply that each party has "skin in the game." Currently, NASA pays for all the transportation costs to get commercial payloads to and from the ISS. When will that change, so that commercial ventures can get a realistic understanding of the costs of doing business in LEO?
   Answer: At this time, NASA plans to continue providing transportation services in support of research being conducted under the auspices of the ISS National Laboratory, as managed by the Center for the Advancement of Science in Space. NASA defers to commercial entities for information on their business plans for commercial facilities in LEO, including those related to transportation to and from such facilities. The Agency is actively developing transition strategies for the post-ISS era and is engaged with the private sector to foster both commercial demand and supply for LEO services, including transportation services. It is NASA's intention to transition LEO to private platforms and capabilities enabled by commercial markets, academia and government agencies, including NASA (should a requirement arise), with interest in LEO research and activities.

Responses by Dr. Mary Lynne Dittmar

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"The ISS after 2024: Options and Impacts"

Dr. Mary Lynne Dittmar, Executive Director, Coalition for Deep Space Exploration

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

1. Mr. Gerstenmaier's prepared statement talked about public-private partnerships being the "*foundation of future U.S. civilian space initiatives*." Partnerships imply that each party has "skin in the game". Currently, NASA pays for all the transportation costs to get commercial payloads to and from the International Space Station (ISS). What would it take for companies to be willing to pay the full transportation costs of getting their payloads into space?
Answer: Unless the payload is funded entirely by NASA as part of its own science program, all payloads – to a limited or significant degree - that fly to the ISS can be thought of as individual "public private partnerships", wherein the payload developer is leveraging extensive government funding of the transportation systems and full funding of all transportation services and of the U.S. segment of the ISS itself. Limiting our case to cargo for this initial discussion, let us say hypothetically that an individual company has a payload weighing 10 pounds. Cargo costs have not improved much since shuttle at approximately $10,000.00/pound at the least (and can be as much as $40,000.00.) Assuming that the payload requires little in the way of resources and flies on a fully loaded cargo vehicle, let us say that the company flying the payload is therefore benefitting from $150,000 carriage funded by NASA.

   If payload development is another $1M (a hypothetical figure referring to the development of equipment, procedures, training, cost of personnel and time to work through all flight requirements and reviews, and a method to capture results of an experiment or demonstration), then in the most simple terms a company would need to produce or test something on orbit that would net $1.150M plus profit in order to be able to assume all of the costs for transportation for a single payload. In such a case the company would be investing an amount much greater than NASA's "investment" to cover transportation. Only in the case where the payload is about the same mass but payload development was less than $150,000 (a very rare case) would NASA's investment for transportation be in line with that of the business.

   Of course, neither business nor science is a "single shot" proposition, nor are NASA's or the business's expenditures limited to flight preparations[1]. For example a business will expend funds on the ground developing the technology or product line and may be flying in space as a near-final step, to validate a method, approach or technology. Larger businesses can sometimes leverage other business units or Internal Research & Development funding (IRAD), while startups or younger businesses may have to use investor money or their own limited funds to underwrite development with the hope that it will eventually return value to the business and the investor. It may take multiple flights to determine whether the product is viable (or to determine if the ISS is a useful venue to advance the product's development). It is not unusual for companies to spend millions on development once all the costs are tallied.

As a matter of scale, large businesses may have more resources to devote to ISS projects, depending upon internal resources and how these are allocated. As a result, they may be able to pick up some or all of their transportation costs sooner in the product lifecycle. On the other hand, startups – often some of the most innovative entities around – are much more unlikely to be able to assume transportation costs until and unless they are able to develop a product, bring it to market, and achieve market success (e.g., profit) because they are usually heavily leveraged in the early years of business growth.

Given the challenges of developing, flying and operating payloads in low Earth orbit, however, it is to the government's advantage to reduce barriers to utilization of the ISS by providing transportation services to that facility – and possibly, to other platforms in low Earth orbit following the ISS – to help "bootstrap up" a sustainable economic system beyond the surface of the Earth. In-space technology and services, if proved viable in low Earth orbit, may help advance exploration and science beyond LEO, in deep space, where those capabilities could reduce costs for taxpayers over time or accelerate development that leads to greater access, affordability and opportunity for the U.S. – or it may not, depending on both the technological and market development over a period of time. These are important considerations that the government must consider as it weighs its level of investment and participation in existing or future public-private partnerships.

Flipping the normal argument for a moment – that companies are leveraging NASA's transportation services – NASA's carriage of flight costs may be seen as leveraging significant investment on the part of most entities with projects destined for the ISS to advance the larger goal of economic development of LEO. That said, development of a truly sustainable "market" (or markets) in LEO will eventually require market demand for goods and services developed there in whole or in part that is sufficiently great to cover all of the "cost of doing business" – including transportation – and to generate revenues sufficient to return profit to the entities involved. If this does not occur, it cannot be said that a truly "commercial" market exists in low Earth orbit.

As mentioned during the hearing, NASA funding that continues to go to transportation to and from LEO after 2024 will not be funds spent on deep space exploration. These trades are difficult and probably premature as at present, there has not been enough time to determine whether operations in LEO will generate robust market demand. Given the upcoming timeframe for making these decisions in the context of an ISS extension or industry-provided LEO station services, Congress and the Administration will almost certainly have imperfect information about the viability of shifting the cost of transportation in whole or in part from government funding to the private sector and determining the impacts of such a decision to U.S. non-government access to LEO.

1. NASA or CASIS also provides services for payload investigators and developers including payload integration at government cost.

a. To what extent will a viable non-ISS market exist that is sufficient to support commercial cargo and crew transportation services to low Earth orbit (LEO) by 2024?
Answer: As I mentioned in my testimony it is not possible to predict the growth curve of economic activity in low Earth orbit. If things go very well and business is able to find a way to exploit the ISS and the environment in low Earth orbit for profit, it is possible that cargo could be covered by 2024. Crew, however, is a much more expensive proposition. Both Boeing and SpaceX have offered the possibility of selling seats on crew vehicles to private entities – the so-called "commercial astronauts" – who would presumably then carry out some sort of activities either at the ISS or at a follow up platform. Along the same lines there are several entities that believe they are able to assemble a portfolio of customers – including the government, which would buy services and facility use on a "commercial" basis – to close a viable business case supporting the development and operation of such platforms. Without insight into the business cases of those entities (which are proprietary) or the ability to predict a timeline for economic development in LEO, it is impossible to answer this question at this time

b. What are potential destinations for crewed missions to LEO in the absence of the ISS?
Answer: At present there are at least three companies – Bigelow Aerospace, Axiom, and Ixion – the latter a joint venture of NanoRacks, Space Systems Loral and United Launch Alliance – seeking opportunities for development in LEO. All of them have expressed interest in NASA's efforts to make at least one port available on the ISS to which a private company could attach a "commercial module". The module – itself a public-private partnership as it would be leveraging government assets such as the ISS structure, power, and thermal and environmental control and government funding of transportation - would provide a test platform to teach a private company how to operate in space. At least as

importantly it would provide a destination for customers interested in doing business with a private entity as an intermediate step between a fully government owned and operated facility (ISS) and a fully private station. Should the business case be sufficiently robust, any one of these companies could develop such a private platform or station after ISS.

A second possibility – though a complex one given the realities of geopolitics – is commercial missions to the Chinese space station Tiangong, which will be completed in orbit and capable of sustaining a 3-person crew by 2024. The Chinese have expressed their willingness to collaborate with other nations as well as with commercial entities. It is certainly conceivable that U.S. companies may be willing to pay to utilize Tiangong, assuming export control regulations can be observed and that there is sufficient market demand to justify such missions – a condition that applies to U.S. commercial stations as well.

2. During the question and answer session, you commented that in order for the ISS to continue, acquisition reform and cost reductions (across the human spaceflight enterprise) would be needed. What type of acquisition reform and what level of cost reduction would be needed? Where in the human spaceflight program could costs be reduced? What impact would any cost reductions have on human exploration activities?
Answer: To clarify - my comment referred to continuation of the ISS past 2024 at the same time the agency is developing a robust deep space exploration program. I will attempt to answer the first two questions through discussion of 8 avenues for cost reductions below, and finish with a statement about the impacts of such cost reductions.

First, acquisition reform has been broadly recognized by successive Administrations and Congresses as a priority to address waste in government programs and to counter increasing costs and schedule growth (which contributes to increasing costs) – NASA included. Acquisition reform must be considered in the larger context, however, which unfortunately includes federal budget uncertainty and instability along with the use of continuing resolutions – which together have significant negative impacts upon planning and programs. One consequence of this is that program decisions have shifted away from program offices and into budget offices – including OMB – which in turn results in program decisions being made by budgetary fiat. This set of circumstances makes strategic planning and consistency of programmatic objectives nearly impossible, and it virtually guarantees cost and schedule growth as well as increased programmatic risk, across the board.

Second, the regulatory burden associated with procurements can hardly be overstated with regard to its negative impact. The Federal Acquisition Regulations (FAR) and its regulatory step-children (laws, processes, additional regulations, and reporting requirements) have grown over the years to a collection of individual fixes and charges intended to address specific circumstances but which, taken as a whole, add little value to the acquisition process, slowing procurements, and adding overhead costs to both the acquisition process and to program management. Meaningful reform will need to "scrub the FAR", streamlining processes and increasing flexibility, while preserving the necessary transparency, accountability and fairness in contracting decisions and oversight, for the government to manage acquisitions in line with agency objectives.

Third, cost-plus contracts are an important tool for procuring and managing development programs – especially large-scale programs such as the ISS or currently, the Space Launch System (SLS), Orion crew vehicle, and Exploration Ground Systems, or the James Webb Space Telescope. Such programs frequently push the limits of manufacturing and utilize novel applications of existing technologies to achieve great things in space, with the results that technical problems and challenges crop up that are not foreseen at program onset. However, a judicious approach to the use of cost-plus contracts is needed, wherein the ability to advance development programs is balanced with the ability to constrain cost growth.

Fourth, with regard to NASA, the agency has been forward-leaning in its use of Other Transactional Authority and public-private partnerships. NASA's immediate "ancestor", NACA, began use of PPP from inception almost 100 years ago, resulting in most of the major advances in aviation and aeronautics in the United States. More recently the agency has made use of Space Act Agreements (SAAs) – a specialized form of the DoD's Cooperative Research and Development Agreements (CRADA); Broad Agency Announcements (BAAs), Cooperative Agreements (CAs), and other contracting mechanisms to maximize flexibility and potentially reduce costs. One of the more successful of these has been the Cargo Orbital Transportation Systems (COTS) program, in which the government invested roughly 85% of the costs but left development in the hands of private enterprise to design and oversee. The resulting systems were developed at significantly less cost to the government than a traditional cost-plus contract with government oversight would have created though, as noted, the cost-per-pound to orbit has not been reduced as a result. The story is even less clear with the development of crewed systems, which have involved considerably more government investment, are behind schedule, and in which the risk v. government discretion and insight question continues to be hotly debated.

Looking beyond LEO, NASA is currently using a BAA – the NextSTEP program – to develop technologies on a cost-shared basis that may be deployed in cislunar space. Continued use of OTA in innovative partnering arrangements – which could include government-backed loans, use of existing government assets, leveraging private investment, the creation of industry consortia, etc – might lead to cost reductions in both LEO and beyond Earth exploration. However, this approach should only be considered in the case where there are business cases with revenues other than the federal government (though the government may also be a customer) at a foreseeable date in the future – otherwise, there is a potential for abuse, or for creating "programs" that are simply subsidies by another name. As with cost-plus contracts, judicious use of this contracting mechanism with transparency and insight is the appropriate approach.

Fifth, additional cost reductions may be had by encouraging a relatively rapid transition from cost-plus contracts to production and services contracts. In the case of SLS and Orion, for example, Lockheed Martin has recently announced that it plans a 50% reduction in production costs for Orion after the first two crewed vehicles are produced for Exploration Missions 1 and 2. Consolidating launch processing, vehicle and payload integration, and some operations into an end-to-end services contract – similar to that being used for Commercial Crew – would enable life-cycle costs to be projected and controlled. Incentives for cost reductions could be built into the contracts. In addition, synergies between government programs and costs and private industries utilization of government assets could be better scrutinized. As with the space station discussion above, a step-wise implementation of cost-sharing for launch facilities (for example) utilized by "commercial" providers could be folded into cost reductions across the board.

Sixth, with regard to the ISS itself, several "futures" have been discussed, including instituting a "Go-Co" model where a private company or joint venture takes control of the ISS after 2024, significantly reducing the government funding load. The advantage is this could keep the ISS viable longer; the disadvantage is that transportation costs would remain (unless they could be partially addressed by means of a step-wise approach such as described above) and the continued existence of the ISS could slow down or stop commercial stations from developing.

A Go-Co would also require development of market demand across several sectors in order to offset operating costs. In this way it is no different than a commercial station. However, the ISS is also aging, and maintenance costs will increase. Therefore a Go-Co should only be considered in the presence of (a) a partial business case with demonstrable cost reduction impacts to the government, and (b) a negotiated agreement as to how to handle increasing operating and maintenance costs. If the Go-Co represents simply an alternate contracting mechanism with no advantage to offloading government costs, it should not be considered if the sole objective is cost reduction. In the context of broader strategic interests, however, such as assuring that the United States retain an ongoing presence in low Earth orbit rather than cede it to foreign interests, a Go-Co may represent a viable path forward.

Seventh – some "tweaking" of the current ISS contracts may potentially reduce costs. Creating an integrated logistics contract, for example, where a private company or J/V assumes responsibility for all aspects of ISS provisioning – including cargo planning, manifesting, integration, and the terms and conditions for the transportation providers themselves, *may* hold some promise for reduction in costs – although how much or how sure is unknown. This "FedEx in space" model has been discussed for some years. The greatest barrier to implementation may be the impact to civil service jobs, which would be reduced in such a commercial enterprise. (This consideration also applies in the Go-Co model above.) It is unclear whether such an integrated contract would significantly impact costs, however.

Eighth – As mentioned when discussing transportation costs to the ISS, the government may consider charging fair market value for some of the payloads it currently subsidizes transportation costs for, both in human spaceflight and in other sectors, to include not only private experiments but satellites and secondary payloads that are flown at a significantly reduced rate or "for free" because the government is paying for much of the launch expense. This could have a negative impact in slowing opportunities for economic development in space, but it would generate more savings for the government in future transportation services contracts. As mentioned previously, this is a trade that would need to be carefully weighed against U.S. strategic and economic objectives.

Ninth and final – "rightsizing" NASA has been recommended in numerous reports from the National Academies and others[2]. The amount of oversight (in terms of FTE) assigned to development programs is inconsistent with cost-efficient program management. Combined with many of the factors described above – reporting requirements, procurement requirements, day-to-day operations – a reduction in force that retains or even improves critical skills while providing program managers and center directors with increased flexibility regarding personnel assignment and reduces overhead would reduce program costs significantly. A reduction in force is also key to several of the approaches described above, including the Go-Co model, integrated contracts, and reductions in cost for development and operational programs. As with the other approaches described here, reductions must be balanced in order to assure that the government retains sufficient technical, acquisition and program management expertise to remain a "smart buyer" and to assure good technical and program execution, but not so much as to burden programs with excessive oversight and needless processes.

In terms of magnitude of reductions that could be generated – well, at present the ISS costs approximately $3B/yr to operate. This includes transportation costs. Implementation of some of these approaches – particularly those that are nearer term and do not require legislative "fixes" – in an integrated fashion, could target as much as a 50% reduction in ISS costs, much of this in transportation. Whether this is achievable is unknown. Implications for the other NASA programs mentioned – notably those currently or about to go into development – should be encouraged to the maximum extent.

Finally, with regard to impacts of such reductions – to date the deep space exploration programs currently under development at NASA have been executed under a flat budget, which is inconsistent with such development and inevitably results in drawn out programs. The agency has also proceeded under conditions of significant budget instability across most of the last decade. Despite these challenges, tremendous progress has been made on the SLS, Orion and Exploration Ground Systems programs. Simply addressing budget stability and ensuring adequate funding would reduce costs going forward. In addition, the ideas above may or may not be viable in execution, but might be considered in part, whole or in combination to reduce overall costs. As mentioned under question #1, the introduction of new technologies that may be folded into exploration programs could also reduce costs, though this is not a certain outcome.

The specific impact of such reductions is a question better referred to NASA, as the agency would have much more insight. That said, any reductions that could result in funds being applied to either accelerate deep space exploration – speeding science returns, and contributing to the earlier development of a deep space infrastructure enabling international and commercial partnerships – or to developing technologies such as nuclear thermal propulsion, surface habitation, and/or entry, descent and landing (EDL) capabilities for the eventual human surface missions on Mars, would be to the advantage of the overall exploration enterprise.

2. In the interests of transparency, it should be noted that the author is one of the co-authors of the "Pathways to Exploration: Rationales and Approaches to a U.S. Program of Space Exploration" report published by the National Research Council in 2014, in which streamlining of the NASA workforce recommended.

Responses by Mr. Eric Stallmer

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"The ISS after 2024: Options and Impacts"

Mr. Eric Stallmer, President, Commercial Spaceflight Federation

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

1. To what extent will a viable non-ISS market exist that is sufficient to support commercial cargo and crew transportation services to low Earth orbit (LEO) by 2024? What is the basis for your answer?

   Answer: When assessing the viability of the market for commercial cargo and crew transportation services it is important, like with any product, to assess the entire market, not just a walled off portion of the market, like the non-ISS commercial market in LEO. For commercial cargo and crew transportation services there are:

   Low-Earth Orbit (LEO) market.

   (a) In order to perform deep space exploration, NASA will need to answer many questions and accumulate significant data regarding effects of microgravity on humans. Thus, NASA's need to perform microgravity research is not going to end in 2024, and the Agency will need a place in LEO in which to do it. In addition, NASA is using LEO (ISS for now) as a testbed to fill critical gaps in technologies that will be needed for long-duration deep space missions. NASA plans to first develop and demonstrate many critical technology capabilities using the ISS (and its follow-on/replacement) as a permanently-crewed testbed prior to deploying those capabilities beyond LEO because it is more cost-effective and faster.

   (b) The private sector has jumped at the opportunity to support important research and technology development on the ISS. Companies like Made In Space are developing commercial on-orbit manufacturing services producing products for use in space and on Earth. Companies like Made In Space are building demand for a growing non-ISS market that will continue to require access to commercial cargo and crew services. Together, companies like Made In Space, and those that follow their trailblazing path, are building an every increasingly larger portion of non-ISS demand. However, CSF is concerned that a premature termination of the ISS would harm companies like Made In Space, and others helping to build non-ISS demand. Only now are we finally reaching the full operational level for which ISS had been designed. Private companies are now developing the technologies required for a sustainable commercial low Earth orbit economy, but, it is far more likely to be ready by 2028, rather than 2024. In the intervening period, a reliable commercial cargo and crew marketplace to fully grow and demonstrate the sustainability of the marketplace is necessary. Opening the ISS to private businesses now, and expanding this agenda past 2024, with an overlap to transition to commercial habitable platforms, will enable companies like Made In Space the time and certainty they need to grow the non-ISS market demand for commercial cargo and crew services.

Beyond LEO Market

(a) A key component to the success of long-term sustainable space operations is affordable assured access to space; by that I mean reliable and redundant systems that enable continued operations in the case one launch system was sidelined. This is true for the commercial satellite telecommunications market, the national security space community, and for the International Space Station. For sustainable deep space operations this is even more so true. Reliable and redundant systems that can regularly access deep space for human operations will be critical for its success and safety. If relying on one launch system (the Space Shuttle) to access and resupply continuous human operations 250 miles above the Earth was a bad policy, then most certainly relying on one launch system to access and resupply continuous human operations 250,000 miles away from the Earth would be an even worse policy; not to mention an expensive one. Therefore, accessing and resupplying deep space exploration activities should be considered another viable piece of the non-ISS market that commercial cargo and crew services can meet. This is an idea that NASA and NASA's Inspector General have supported. For example, NASA's Inspector General, in its most report, IG-17-017, stated, "Given that costs associated with an SLS launch are expected to exceed $1 billion, private launch vehicles may provide a cost-effective means of transporting certain payloads to low-Earth and cislunar orbit as part of the Agency's Journey to Mars."

2. How important is NASA's role in helping to establish commercial space transportation services to LEO, and when can NASA transition out of that role?
   Answer: NASA has played a critical role in helping establish commercial space transportation services to LEO, and will continue to play an important role into the foreseeable future. As long as NASA has a need for commercial transportation services (science missions, microgravity research, human physiology research, technology development, etc.) then it will always play an important role in the commercial space transportation services market in LEO, as well as to other destinations. The size of that role, depending on NASA's needs, is likely to change over time, for example, the creation of more companies like Made In Space that will expand and increase the non-ISS demand for commercial space transportation services to LEO, potentially decreasing NASA's portion of

demand relative to other parts of the market. But as I mentioned previously, as long as NASA has a need for commercial space transportation services, including LEO, then it will never completely transition out of having an important decision-making role that impacts the market

Responses by Dr. Robert Ferl

Response to questions submitted by Ranking Member,

House Committee on Science, Space and Technology

04/21/2017

Robert J Ferl University of Florida

Thank you for the opportunity to respond further to the questions before the Committee. The attention of the Committee to these issues is very important toward enabling the exploration of deep space and the opportunity to contribute is much appreciated.

The major science set forth for the decade ending in 2021 is well outlined in the Decadal Study. However, from the deep space exploration perspective, the overriding remaining science issues would be to, as much as possible, understand the biological impacts of spaceflight and spaceflight radiation, along with the physical phenomena of microgravity that might actually limit spaceflight exploration safety or efficiency. So too, the effects of lunar and Martian gravities (and other partial gravities) are yet to be fully elucidated. To get to answers to those issues, the overall rate of science accomplishment is clearly limited by access to crew time and programmatic access to ISS. Determining how much of this science will be accomplished by 2024 is critically dependent upon crew time. Crew time is such an impactful issue that science accomplishments by 2024 could range from falling short of science needed for exploration to robust support for going beyond low earth orbit. So until crew time is well known, estimates of remaining science accomplishment will be vague at best.

A closely related issue is competing program priorities in the allocation of ISS resources, including but not limited to crew time. The establishment of the ISS National Laboratory has been effective in bringing non-exploration, non-NASA science to the ISS. While this greatly increases the reach of microgravity science toward Earth-directed goals and extends the value of the ISS investments overall, CASIS in support of those non-exploration activities, rightfully draws upon the limited ISS resources that might be available for exploration. It is my personal view that making exploration science a higher priority or at least keeping that priority in balance on the ISS is key to ensuring that this science is in the best position to support deep space exploration.

Commercial platforms could relieve some of the science pressure on the ISS now, or replace the ISS in the future. However, there is a rather simple fear that commercial spaceflight and/or space station providers would have an economic incentive, rather than an exploration incentive driving their pricing and priorities. Therefore, choices of what to fly and the charges for those flights would be market driven, rather than exploration driven. This could force NASA into cost structures that are higher than needed, simply to support profits. In markets where NASA exploration is not the major buyer, the costs could be driven up by competition from commercial concerns that might, say, wish to do manufacturing in orbit that is not at all related to exploration. So too, NASA exploration science could be bumped if a higher paying customer were to bid for access. The required agreements to alleviate this fear might be, at a minimum, guaranteed access riders that would reserve portions of a commercialized ISS for NASA science, paid for at a pre-negotiated government rates that reflect the taxpayer investment in the ISS. This could be particularly important if, for example, NASA were to turn over the existing ISS to a commercial enterprise and absorb all of the sunk costs of the original NASA investment into ISS. This would also apply to situations where any commercial platform were highly enabled by NASA before becoming profitable. Once a stable and viable commercial enterprise exists, one that is viable outside of NASA contracts, the stabilized market prices would present a simpler and fairer cost structure within which NASA could purchase capabilities. Until that viable commercial enterprise exists, NASA should retain favored status while underpinning the commercial sector.

The baseline biology and physical sciences facilities that will be needed in LEO are largely scoped by the ISS as it exists today. I believe that the ISS has reached a very functional state as an orbiting laboratory and therefore it represents a strong model within which to evaluate facilities and capabilities that will be needed in the future. While the entire ISS may not be needed by NASA, the specific core capabilities of the existing ISS could be identified and prioritized by careful study of current capabilities and therefore accommodated in future orbital space laboratories. The key concept is that the current ISS likely defines the largest grouping of facilities that will be needed, and a subset of those facilities can be identified as high priority facilities in future stations.

The 2011 Decadal Survey makes specific mention of ground based, suborbital and other platforms for conducting its portfolio of science. In my opinion, recent discussions have tended to conflate all of space life and physical sciences with ISS science. This is understandable, given the tremendous resource that the ISS presents to the research community and to the decadal portfolio. However, I believe that many of the research priorities of the 2011 Decadal Survey, even some of those associated with enabling deep space exploration, can indeed be met on other platforms, such as space-based, suborbital and ground facilities. One key thing to keep in mind is that the larger unknowns for deep space exploration involve durations of microgravity and biological impacts beyond the one year time horizon. Therefore, much of the research will continue to need longer duration orbital platforms.

Generally speaking, Space Life and Physical sciences has made marked progress in meeting the extensive set of priorities in the Decadal and will be, in my opinion, in a good state to support deep space missions by 2024. A detailed evaluation of science progress will be available when the National Academies releases its mid term assessment of the decadal later in 2017. While many of the space life and physical sciences decadal goals may well be met by 2024 depending on resource allocations such as crew time, it is likely that NASA will require some continued access to long-term exposure to space in LEO beyond 2024, simply because some level of continued research in microgravity spaceflight will better enable deep space exploration at all future phases, in much the same way that aeronautic science continues to support air travel.

Appendix II

ADDITIONAL MATERIAL FOR THE RECORD

STATEMENT SUBMITTED BY FULL COMMITTEE RANKING MEMBER EDDIE BERNICE JOHNSON

OPENING STATEMENT
Ranking Member Eddie Bernice Johnson (D-TX)

House Committee on Science, Space, and Technology
Subcommittee on Space
"The ISS after 2024: Options and Impacts"
March 22, 2017

Good morning, and welcome to our witnesses.

The International Space Station is the largest and most complex science and engineering project ever carried out in space. It serves as a laboratory for fundamental and applied science as well as an observation platform for astronomical, environmental, and heliophysics research.

The International Space Station is also a stepping stone for the human exploration of deep space, helping us to better understand the health risks of long-term human spaceflight and how to address them, as well as providing a testbed for some of the key technologies astronauts will need to safely explore deep space.

In addition, Mr. Chairman, the Space Station has had a broader value to our society and to our global relations. The success of the U.S.-led International Space Station partnership has been an important example to the rest of the world of our capacity to see past geopolitical differences to achieve challenging goals in space.

And of course, the Space Station has provided an entry point for emerging commercial ventures in low Earth orbit. Commercial cargo delivery, and soon, commercial crew transport are just two examples of the way in which the ISS has helped to stimulate commercial activity in space. Research carried out by companies on the ISS that could not be done in the same way back on Earth is another example.

While the Space Station's value for science, commerce, and exploration is clear, the time left to realize that value is limited. We need to understand what, if any, ISS-based research needs be sustained once ISS operations cease, and what the options and likely costs for doing such research are.

The International Space Station has demonstrated that productive research and development can be carried out in low Earth orbit. While I want to see a robust research program continue, I also want to see NASA achieve the challenging goal of returning humans to deep space.

Doing both will require significant resources, and I hope that we will provide NASA with sufficient resources to do both. Let me be clear—we should not fool ourselves that it will be possible to carry out a meaningful human exploration program and extend the operations of the ISS without providing NASA with additional resources. If we are unwilling do so, then we have some hard choices to make.

Finally, while the focus of today's hearing is 20<u>24</u>, I am also concerned about the health of the ISS program <u>today</u>. President Trump's recently released Fiscal Year 2018 budget would cut NASA's Space Operations account—an account that funds the International Space Station—by more than a quarter of a billion dollars. This Committee needs to understand the rationale for that proposed cut and its impact on the ISS, and I hope that our NASA witness will be able to shed some light on it today.

With that, Mr. Chairman, I want to again thank our witnesses for participating in today's hearing, and I yield back the balance of my time.

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