

**EXAMINING THE FUTURE OF THE INTERNATIONAL
SPACE STATION: STAKEHOLDER PERSPECTIVES**

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE, SCIENCE,
AND COMPETITIVENESS

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

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JUNE 6, 2018
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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

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**EXAMINING THE FUTURE
OF THE INTERNATIONAL SPACE STATION:
STAKEHOLDER PERSPECTIVES**

WEDNESDAY, JUNE 6, 2018

U.S. SENATE,
SUBCOMMITTEE ON SPACE, SCIENCE, AND COMPETITIVENESS,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:17 p.m., in room SR-253, Russell Senate Office Building, Hon. Ted Cruz, Chairman of the Subcommittee, presiding.

Present: Senators Cruz [presiding], Gardner, Markey, Nelson, and Hassan.

**OPENING STATEMENT OF HON. TED CRUZ,
U.S. SENATOR FROM TEXAS**

Senator CRUZ. Good afternoon. This hearing is called to order. Welcome to all the witnesses. Thank you for being here.

Today's hearing is the second in a series of hearings focused on the future of the International Space Station. During the previous hearing, this subcommittee received testimony from government witnesses who cast considerable doubt on the administration's proposal to end Federal support of the International Space Station in 2025. In our hearing, not only did NASA confirm that the International Space Station has operational life through at least 2028, if not longer, but NASA's Inspector General raised significant concerns that it is not only quite unlikely that a private entity or entities would assume the Station's annual operating costs, but also, quote, "Any assumption that ending direct Federal funding would free up \$3 billion to \$4 billion in 2025 for use on other NASA initiatives is wishful thinking." I agree with the concerns that NASA's Inspector General has raised to this Subcommittee.

The concerns and the confirmation from NASA that the ISS has operational life well beyond 2025 should not be taken lightly by members of this Committee or by the National Space Council.

American taxpayers have invested roughly \$100 billion in the International Space Station, and it is my firm belief that it would be irresponsible for the United States Government to prematurely end the life of the International Space Station before maximizing American taxpayer investment. We should not throw away that very significant investment of resources from the taxpayers and also from our allies.

It is concerning that some have argued during this debate that the rationale for ending direct funding of the ISS is that the United States cannot afford both continued ISS operations and deep space exploration at the same time. I disagree that this is an either/or decision. And Congress has demonstrated a strong bipartisan commitment to NASA and to our human spaceflight programs through significant increases in appropriations over the last several fiscal years to ensure both a healthy low-Earth orbit and deep-space exploration program.

What's clear is, we cannot afford to continue to pursue policies that have the consequences of creating gaps in capability or that send three and a half billion dollars in taxpayer money to the Russian government because we failed to plan to have adequate tools to reach low-Earth orbit, nor can we create a leadership vacuum in low-Earth orbit that provides a window of opportunity for the Chinese to capitalize upon as they look to have an operational space station in low-Earth orbit in 2022.

As long as I am Chairman of the Space Subcommittee, the ISS will continue to have strong and bipartisan support in the U.S. Senate. The past several years, we have passed two major pieces of space legislation, working cooperatively, Republicans and Democrats, in support of space, one that was signed by President Obama, one that was signed by President Trump. The purpose of today's hearing is to receive testimony from nongovernmental ISS stakeholders who can provide Congress with their firsthand experience interacting with the ISS and what the impact would be for commercial stakeholders, even those looking at building a successor to the ISS, which we will need one day, but we should not prematurely disregard the investment we have made into it.

I look forward to our witnesses' testimony and will now recognize our Subcommittee's Ranking Member, Senator Markey, for his opening statement.

**STATEMENT OF HON. EDWARD MARKEY,
U.S. SENATOR FROM MASSACHUSETTS**

Senator MARKEY. Thank you, Mr. Chairman, very much.

Today, a trio of astronauts from the United States, Russia, and Europe blasted off for the International Space Station. But, if the Trump administration has its way, in just a few short years, that sort of mission might not be possible. The International Space Station is the lone platform in low-Earth orbit on which our astronauts can undertake fundamental research for humankind's health, well-being, and prosperity in space. We continue to push deeper into our solar system, but the Space Station remains of paramount importance.

Construction of the Space Station began in 1998, in cooperation with the Russian, Canadian, European, and Japanese space industries. Continuously occupied for almost two decades, the scientific research executed onboard the Space Station has given us unique insights from many stakeholders, and produced countless valuable results. Because of the International Space Station, we better understand the basic physics of our planet, have developed antimicrobial vaccines, and are improving cancer-fighting drugs. Yet, in February, the Trump administration announced that it would end

direct funding to the International Space Station after 2024, turning it into a privately run entity. Although many stakeholders have voiced support for a long-term transition to a privately run Space Station, they are fearful of the lights going out as a result of the Trump administration's proposal. We simply cannot pull the plug on the International Space Station without a plan in place for what comes next.

As we work to put humankind back on the Moon and onto the Martian surface for the first time, as well as to open up new commercial and telecommunications opportunities in space, it is crucial to understand the many dangers which we face. The International Space Station is the only platform in existence on which we can research how the harsh conditions of space affect the human body and mind. In fact, NASA has declared that an on-orbit platform like the Space Station is absolutely necessary to research the impacts of the majority of risks to human health that exist as we venture deeper into space.

If we really want to go where no one has gone before, we need the International Space Station to not go away. Outstanding universities, like MIT, the University of Florida, Texas A&M, in partnership with the National Science Foundation and the National Institutes of Health and companies across the Nation, are all undertaking fundamental scientific research through the Center for the Advancement of Science in Space. This research can only be done in a microgravity environment like the International Space Station. Putting an end to direct funding for the Space Station after 2024 would seriously interrupt, if not completely end, the scientific research that is critical for building a commercial market in space. It would spell serious trouble for both NASA and the commercial space industry. We cannot afford to allow funding for the Space Station to crater in 2025.

What we need is a nuanced transition plan for the next great space age that carefully reflects the commercial market and the space community's needs. But, that is not what this administration has put forward. The International Space Station is an irreplaceable facility for science and human exploration in space. It is an interplanetary incubator fostering discovery, focusing imagination, and supporting achievement. It builds goodwill and good discoveries at the same time.

I look forward to continuing to work with the Chairman and my colleagues, led by Senator Nelson on a bipartisan basis, to ensure that the International Space Station can continue to house the research that inspires the world and promotes progress.

And we thank the witnesses for being here, and we look forward to your testimony.

Thank you, Mr. Chairman.

Senator CRUZ. Thank you, Senator Markey.

We'd now like to recognize Senator Nelson, the Ranking Member of the Full Committee, if he would care to make an opening statement.

**STATEMENT OF HON. BILL NELSON,
U.S. SENATOR FROM FLORIDA**

Senator NELSON. Thank you.

Just to undergird the remarks already made by the Chairman and the Ranking Member of the Subcommittee, I might note that this November marks 20 years since the Russians launched the Zarya module, and then NASA launched the Unity module two weeks later, and so began the assembly of the International Space Station.

Now we're on a new age, golden age, for this incredible structure in space, the ISS, because Boeing and SpaceX are set to begin launching crew from the Cape. That's going to allow us to increase the number of astronauts aboard the Station and dramatically increase the amount of research conducted. And, of course, all of NASA's centers have come together too, from the astronauts trained at Johnson that launched at Kennedy to the experiments prepared and assembled in final form at Kennedy, to ensure that the ISS is performing well. The ISS ought to keep going to 2030, because now is the time to reap the benefits of all the effort and all the expense that we have to build the ISS. And now let's do the research on it. There's a broad bipartisan consensus to keep it going and not to have this arbitrary date that's going to cutoff after 2024.

Why in the world would you want to take a large, multiyear investment of \$100 billion and suddenly de-orbit it and let it burn up on reentry? What about the commercial crew and the cargo capabilities that we've been investing so heavily in? What would happen to them if there's no certainty that they're going to have a destination, even though we have other space stations that are in the planning stage?

I can tell you one group of people that understand this, and that's the Chinese. It's no accident that, within a few months of the administration's proposal to end the Space Station in 2025, the Chinese announced that their space station will soon be open for business. And just last week, they invited countries from around the world to conduct research aboard their space station. And they advertise a lot of capabilities—medical sample analysis, combustion science, freezers, a science glove box—all of which are very similar to what we have on the ISS. So, at one point in the future, we may have low-Earth orbit filled with commercial space stations serving NASA and other government and private-sector customers. And then NASA is going to be doing what it needs to do, which is, get out beyond low-Earth orbit and explore the heavens. But, the ISS is not an obstacle to that. It can be complementary.

Thank you all for holding this hearing. I appreciate it. We are very fortunate to have a panel of experts, as we do today.

Thank you.

Senator CRUZ. Thank you, Senator Nelson.

And I'll make a point to observers that one of the things that I think is striking across the opening statements—there are many issues on which Senator Markey, Senator Nelson, and I might disagree, but when you have unanimity across the partisan spectrum, across the ideological spectrum, when you're hearing the exact same thing from conservative Republicans and liberal Democrats, that the ISS—

Senator MARKEY. And moderate Democrats. Moderate Democrats.

[Laughter.]

Senator CRUZ. I will let folks self-identify as they choose.

[Laughter.]

Senator CRUZ. I didn't say "nutcase lefties." I kept it—everyone can self-identify on that spectrum.

[Laughter.]

Senator CRUZ. And even our friendly Libertarians in Colorado.

[Laughter.]

Senator CRUZ. I mean, we've got a full spectrum. And yet, what there's agreement across that spectrum is that the ISS is a critical asset to the United States of America. It is a tremendous asset for scientific research, for innovation, for discovery. The American taxpayers have invested \$100 billion into it. Our allies have invested billions and billions of dollars into it. And it would be foolish to waste that investment, to cut it short, to invent an arbitrary deadline like 2025 and say, "Never mind that we have additional good, productive use out of it. We're going to plunge our head in the sand and throw away that asset." That is the height of foolishness. And this is a message that should be heard. It should be heard by every contractor, everyone doing business with the ISS, by every researcher who has an idea for a new innovation on the ISS, and by our allies, our partners in the ISS, that, whatever might be put in an OMB proposal, it remains the Congress of the United States that authorizes programs and that appropriates programs. When you see bipartisan unanimity in support of the ISS, the position of the United States Government should be clear and unambiguous. Part of the reason why you see that unanimity is because of what we're hearing from the leaders at NASA, from the stakeholders, about the science and the potential future.

This panel is an excellent representation of those, with deep expertise and knowledge. And so, with that, I'm going to introduce each of the four witnesses.

Mr. Michael Suffredini is the President and CEO of Axiom Space. Axiom plans to launch two commercial modules in 2021, setting the stage for the first commercial space station in low-Earth orbit. Prior to Axiom, Mr. Suffredini served for 10 years at NASA as the Manager of the International Space Station. In that role, Mr. Suffredini spearheaded the transition of ISS from development and assembly to research and commercial utilization. He managed a 15-nation team and a \$3 billion budget, which was the largest international peacetime project in the history of humanity.

Mr. Bob Mitchell, a longtime friend, is the President of the Bay Area Houston Economic Partnership. He has served in this role since 2008. When he first joined the Partnership in 2000, Mr. Mitchell oversaw the statewide implementation of the State—Space Alliance Technology Outreach Program. Prior to that, Mr. Mitchell gained extensive experience during his 15 years at Grumman Aerospace Corporation, now known as Northrop Grumman. As an executive at Grumman, Mr. Mitchell directed all production, engineering, and material operations for the Houston facility.

Mr. Jim Chilton is Senior Vice President of the Space and Launch Division of Boeing Defense, Space, and Security. His portfolio includes the International Space Station, the CST-100 Starliner Commercial Crew Vehicle, NASA's space-launch system,

government and commercial satellite systems, and Boeing's participation in United Launch Alliance. Previously, Mr. Chilton served as Vice President and Program Manager for Exploration Launch Systems and led SLS, Boeing's Heavy-Lift Launch Vehicle Program.

And finally, Ms. Cynthia Bouthot, who is Director of the Commercial Innovation and Sponsored Programs at the Center for the Advancement of Science in Space, also known as CASIS. Ms. Bouthot heads a team of business development professionals that focus on generating flight projects for the ISS National Lab in the life science, energy, chemicals, materials, clean tech, and IT sectors. Prior to her current position, Ms. Bouthot was President of the Collaborative Innovation Group, an organization focused on providing the tools and methodologies to establish successful product offerings, developing efficient routes to market, and building image and brand.

With that, we'll start the testimony. We'll begin with you, Mr. Suffredini.

STATEMENT OF MICHAEL T. SUFFREDINI, CHIEF EXECUTIVE OFFICER AND PRESIDENT, AXIOM SPACE, INC.

Mr. SUFFREDINI. Ranking Member Nelson, Chairman Cruz, Ranking Member Markey, and members of the Subcommittee, thank you for inviting me to give my perspective on the future of the International Space Station, and specifically the transition to a vibrant, robust marketplace in low-Earth orbit.

From 2005 to 2015, as NASA's ISS Program Manager, I oversaw the development, assembly, operation, utilization of the International Space Station for the United States Government and the 14 other countries who participated in the program. I retired after 27 years of government service, and later cofounded Axiom Space, whose goal is to build, launch, and operate the world's first commercial space station. With decades of engineering, operations, and management experience in human spaceflight, we are uniquely equipped to take the baton from the remarkably successful ISS to continue its legacy in LEO and facilitate the extension of America's leadership among spacefaring nations, but the handoff must be accomplished carefully.

I see several key elements of a successful transition strategy. First, as NASA begins its human spaceflight focus and budget from LEO to deeper space exploration, one concept must remain inviolable. The United States must not relinquish uninterrupted access to LEO for its astronauts. I have detailed in my written testimony the work that is either underway or planned for the ISS that will need to be continued indefinitely in LEO to support sustained human deep-space exploration. But, as important as those activities are, the principal argument for the U.S. to maintain uninterrupted access to, and a destination in, LEO is intangible to safeguard our position as the world's preeminent spacefaring nation. We hold that position today, thanks, in no small part, to our leadership of the ISS partnership. But, other countries, like Russia, China, and even Europe, are taking leadership steps, in the absence of a strong American commitment to exploration, and the end of the ISS represents an opportunity for them to fill the void. Send-

ing astronauts to a LEO platform will always appeal to nation-states. It is, therefore, imperative that there be no gap in access between the platform of today, the ISS, and its American commercial successor.

Second, NASA must allow companies to compete for the right to attach one or more modules to the ISS as soon as possible. While it's certainly possible to develop and launch a free-flying commercial space station, there are numerous advantages, both for the commercial provider and the government, to starting one or more modules mated to a port on the ISS. These advantages are also outlined in my written testimony.

A NASA Request for Information in the summer of 2016 solicited information on the commercialization of LEO, the potential business case, and the criteria to grant access to an ISS port. This RFI was intended to inform a follow-on announcement opportunity which, itself, would result in granting access to an ISS port to a commercial entity. Now, almost two years later, a NASA research announcement was released, soliciting proposals to study commercialization of LEO. These studies are not due until the end of the calendar year. If the resultant studies are used only to inform a competitive port-reward process, it is unlikely that access to a port will be granted before 2020. The award of a birthing port is the first dominant must-follow in a chain of events, each of which relying on the previous, that will lead to a viable commercial platform in LEO and confidence that the Nation is ready to transition its human LEO activities from ISS to commercial operators. Therefore, NASA should announce a fair and open competition for the right to use an ISS birthing port in parallel with, rather than following, the NRA studies.

Finally, the FY 2019 President's budget includes \$150 million for LEO commercial development. As the head of a commercial space-station company might reasonably expect, I would like to receive some of that money to put toward module development. I do not. These resources should be utilized to foster increased LEO demand, to award contracts for development of hardwares, to put NASA funding and its extensive development requirements in the critical path for success and threatens to hold the agency hostage in the event the awardee would need more money to complete their design. NASA should give priority to companies who raise their own capital. These firms will be incentivized to help grow LEO demand beyond merely the government customer. Their survival will depend on it.

The only way for NASA to eventually divert much of the almost \$3.5 billion that it's spending today on ISS to deep-space exploration is by not owning a LEO infrastructure or becoming an anchored tenant. A truly commercial platform will succeed only if it has multiple customers, both private and government. Public-private partnership in this case work best when the public promotes expansion of the demand and the private spends its own capital to satisfy it.

In summary, we cannot afford for the transition, the United States human presence in LEO, from the ISS to one or more U.S. commercial platforms to be unsuccessful. Ensuring continued access to a LEO platform for our astronauts will maintain our posi-

tion as the world's leading spacefaring nation. To achieve this in a manner that will allow the most timely transition, NASA must issue an opportunity for companies to compete for the ISS port as soon as possible. Finally, any funding made available to NASA to help develop commercial capability in LEO should be spent on building demand.

I look forward to answering questions.

[The prepared statement of Mr. Suffredini follows:]

PREPARED STATEMENT OF MICHAEL T. SUFFREDINI, CHIEF EXECUTIVE OFFICE
AND PRESIDENT, AXIOM SPACE, INC.

Dear Chairman Cruz, Ranking Member Markey and Members of the Subcommittee,

From 2005 to 2015, as NASA's International Space Station (ISS) program manager, I oversaw the development, assembly, operation and utilization of the International Space Station (ISS), for the United States government and the other 14 nations invested in the program. I retired after 27 years of government service, and later co-founded Axiom Space, whose goal is to build, launch and operate the world's first commercial space station. We are dedicated to making living and working in Earth orbit commonplace, as a means to sustained human deep space exploration. We plan to build a commercial successor to the ISS, first attaching our modules to it, and then ultimately separating from it when ISS is retired. We have an extraordinary team of seasoned space and business professionals. With decades of engineering, operations and management experience in human spaceflight, we are uniquely equipped to take the baton from the remarkably successful ISS, continue its legacy in low Earth orbit (LEO) and facilitate the extension of America's leadership among spacefaring nations.

Throughout the course of modern history, it has been the role of governments to open new frontiers. The Catholic Kings financed the voyage of Christopher Columbus that ultimately discovered the New World. President Thomas Jefferson commissioned the expedition of Lewis and Clark that began the westward expansion in the United States. When the risk—personal or financial—is high, and the reward uncertain and/or many years into the future, it is appropriate for governments to expend state resources in the interest of their citizens. Once security is established, a market is identified and revenue appears nearer term, it is likewise appropriate for state actors to step aside in favor of entrepreneurs, and to allow commerce to develop. Human presence in LEO is ripe for such a transition; adhering to the following strategic elements will provide the highest likelihood of a successful evolution to a vibrant and robust commercial marketplace in LEO.

Ensure Continuous Access to LEO

As NASA begins to shift its human spaceflight focus—and, by necessary consequence, its budget—from LEO to exploration of cis-lunar space, one concept must remain inviolable: *In order to preserve our leadership in space, the United States must not relinquish uninterrupted access to LEO for its astronauts.* Needless to say, this includes both a way to get there, and an orbiting platform on which to continue the important activities underway today aboard the ISS.

Human deep space exploration will require the continuation of several tasks that are either already underway or planned for execution aboard the ISS. One is continued research into understanding the responses of the human body to the space environment. NASA's Human Research Program has been very successful in retiring many risks toward a notional Mars flyby mission, but one set of investigations that is not scheduled to be complete before ISS retirement, even assuming a retirement of 2028, is on the effects of space radiation exposure.¹ Secondly, microgravity can negatively affect machines as well as man. The ISS has suffered the unexpected failure on-orbit of systems that were thoroughly tested on the ground. Some broke down in the first few hours of operation; others after months of successful run time. With these systems in LEO, while neither simple nor inexpensive, the logistics involved with repairing them were relatively straightforward. Ultimately, the crew was always a short flight back to Earth if the repairs were not successful. However, in a distant lunar retrograde orbit—or, worse, on the way to Mars—such logistics

¹NASA Advisory Council Human Operations and Exploration Committee, March 2018, *ISS Status and Transition*, p. 13

would be orders of magnitude more complex, if not impossible. For this reason, it is imperative that critical hardware be thoroughly tested in LEO before such systems are deployed to deep space, and a platform on which to do so is crucial. The need for this capability in LEO will be continuous for a sustainable human exploration program because as new technologies are developed to better serve exploration, the technology and the resultant systems will need to be thoroughly tested in LEO before being deployed on missions further from our planet. Finally, current plans for NASA's Lunar Orbiter Platform-Gateway reflect no more than annual crewed missions of 30-day duration with astronauts from several participating countries. This cadence will severely strain NASA's ability to maintain an experienced and proficient astronaut corps. A readily accessible LEO destination will be a vital proving ground where astronauts can gain valuable spaceflight experience in preparation for more challenging deep space missions.

As important as the considerations of human research, critical systems hardware testing and astronaut proficiency are, the principal argument for the U.S. to maintain uninterrupted access to and a destination in LEO is intangible—to safeguard our position as the world's preeminent spacefaring nation. We are clearly in that position today, thanks to our leadership of the ISS partnership. But with Europe having expressed its pivot toward the Moon before us, and the impending launch of China's Tiangong-2 space station, our place at the head of the class may be in jeopardy. The mission sequence planned today for human deep space exploration—which may not begin for close to a decade—may not be of sufficient frequency or duration to maintain the interest of other nations. But there will always be useful work to do aboard a LEO platform that will appeal to nation states with astronauts. It is therefore imperative that there be no gap in access between the platform of today—the ISS—and its American commercial successor.

Award the Port

While it is certainly possible to develop and launch a free-flying commercial space station, there are numerous advantages to starting with one or more modules attached to the ISS, and then to separate them prior to the lowering of the ISS altitude in preparation for its deorbit. With modules attached to the ISS, a company can use revenue generated from their utilization to offset capital requirements and consequent investment needs. More importantly, such an arrangement would allow a commercial operator more time to establish a viable customer base, and would permit NASA to transition not only research that is underway on ISS, along with attendant hardware, but also that of National Lab customers. Being able to transfer useful research and manufacturing hardware from ISS to a new platform on orbit when ISS is retired will save significant costs (avoiding having to rebuild and launch new hardware), ensure the ISS is utilized to the maximum extent possible even as it nears retirement, and perhaps most importantly, protect the LEO marketplace that will have developed at that point. Finally, NASA will have less insight into the design and development of commercially provided modules; having them attached to ISS for a period of time will give NASA and other ISS partner government space agencies an opportunity to gain experience not only with the modules but with how their commercial provider operates and protects the crew and spacecraft. There is clear benefit to both the government and to the commercial space station developer to attach one or modules to the ISS via one of its berthing ports.

In the summer of 2016, NASA issued the Sources Sought solicitation “Advancing Economic Development in Low Earth Orbit via Commercial Use of Limited Availability, Unique International Space Station Capabilities.” In it, NASA stated:

NASA will use the results of this RFI to guide development of a possible future announcement of opportunity appropriate to the Agency's objective of fostering a self-sustaining commercial marketplace in LEO. NASA is seeking industry ideas to stimulate economic development through the use of unique ISS capabilities such as unused common berthing mechanism (CBM) attachment ports, non-standard attachment sites or any other capability which can be used in a way not previously envisioned.²

Responders were given six weeks to respond. Now, almost two years later, industry is still waiting for the “announcement of opportunity.” In the meantime, in its FY 2019 President's Budget, the Administration has expressed a desire to defund the ISS as early as 2025, rather than the date presumed by many of 2028. These two events combine to reduce the time available for developing a robust, commercial market in LEO by up to five years. And the clock is still ticking. NASA recently

²Federal Business Opportunities, *Advancing Economic Development in Low Earth Orbit via Commercial Use of Limited Availability, Unique International Space Station Capabilities*

released a Research Announcement (NRA) for the “Study for the Commercialization of Low Earth Orbit.” This solicitation “. . . grants no rights for use of or guarantee of any ISS port obligation.”³ With the NRA schedule showing awardees being selected in June or July, contracts to be finalized in August, and study products due in December 2018,⁴ if these studies will be used only to *inform* the aforementioned announcement of opportunity to compete for the berthing port, it is reasonable to expect the awarding of the port will occur no earlier than 2020.

It is difficult to imagine that an investor would commit a significant outlay—the kind necessary to build one or more space station modules—to a commercial company that doesn’t have access to an ISS berthing port. The start of construction, which will take several years to complete, depends on this investment, which in turn depends on the award of a berthing port. Once the module(s) is complete, it must be launched, berthed and integrated with the ISS. And, of course, all of this must occur before any customer could utilize the module. So, the award of a berthing port to a company is the first domino that must fall in a chain of events, each of which relying on the previous, that will lead to a sound decision that the Nation is ready to transition its human LEO activities from the ISS to one or more commercial operators. Each day NASA delays this port award, it correspondingly postpones the moment when it can reasonably shift its ISS operations budget to that of deep space exploration.

A much more efficient course of action would be for NASA to announce a fair and open competition for the right to use the ISS Node 2 forward berthing port *in parallel with*, rather than following, the NRA studies. NASA could establish criteria for the port solicitation utilizing the considerable information provided in response to the summer 2016 “Advancing Economic Development in Low Earth Orbit via Commercial Use of Limited Availability, Unique International Space Station Capabilities” RFI, which reportedly resulted in responses from 19 industry partners. When the reports awarded through the “Study for the Commercialization of Low Earth Orbit” NRA are submitted at the end of this calendar year, NASA would verify the consistency between those studies and their competitive process, make any adjustments necessary as a result, and could be ready to award use of the berthing port to a company within a month or two, rather than only *then* commencing to develop a process to award the port. The parallel approach could save up to a year, accelerating by the same amount the investment necessary to build the successor to the ISS, and ultimately advancing the moment when a viable commercial platform would allow NASA to shift its focus from LEO infrastructure sustainment and operation to deep space exploration.

Build Demand

The FY 2019 President’s Budget includes \$150M for LEO Commercial Development. As a commercial space station company, you might reasonably expect that Axiom would like to receive some of that money to put toward design and building of one or more modules. We do not. To award contracts for development of hardware is to put NASA funding and extensive development requirements in the critical path for success, and threatens to hold the Agency hostage in the event the awardee would need more money to complete their design and build. Although the Commercial Orbital Transportation System agreements and follow-on Commercial Resupply Services contracts were both innovative and successful, NASA is the only customer for those services, and without its funding, the companies would surely discontinue manufacture of the Dragon and Cygnus spacecraft. To avoid being put in the same posture when it comes to a commercial orbital platform, NASA should give priority to companies who raise their own capital, instead of asking for government funding. These firms will be more incentivized to succeed and therefore to grow LEO demand beyond merely the government customer; their survival will depend on it. The only way for NASA to eventually divert much of the almost \$3.5B that it’s spending today on ISS to deep space exploration is by NOT being the anchor tenant. A truly commercial platform will succeed only if it has multiple customers—both private and government. In the short term, NASA’s role should be limited to making unique ISS resources available for potential commercial partners, and to stimulating demand for on-orbit services. When NASA is the only customer, there is no driver to create demand. Public-private partnerships in this case work best when the public promotes expansion of the demand, and the private spends its own capital to satisfy it.

³NASA Solicitation and Proposal Integrated Review and Evaluation System, Study for Commercialization of Low Earth Orbit, *Announcement*, p. 8

⁴NASA Solicitation and Proposal Integrated Review and Evaluation System, Study for Commercialization of Low Earth Orbit, *Industry Day Charts*, p. 15

It is important for NASA to be judicious in selecting its partners for commercial development of LEO. Since the ISS cannot support more than one large commercial station provider, NASA should pick the one that has the best chance of success, based on the technical merit of their design, the soundness of their business case, and the pedigree of their team. It should also acknowledge that demand will be, at least in the beginning, limited. Picking more partners than there is demand to satisfy will result in the failure of the market for LEO services to develop. This further highlights the imperative that NASA use whatever funding it receives for LEO commercial development to stimulate demand, and limit supply side help to the right to use unique ISS capabilities, such as a berthing port.

Don't Compete with Industry

Finally, one of the principal revenue streams that commercial space station companies are pursuing is human spaceflight for astronauts from other nations. The ISS partnership distributes flight opportunities based on each partner's contribution to the project. Outside of these allocations, NASA should not also offer flights to other nations either inside or outside the ISS partnership, as this directly competes with the offerings of commercial companies and would severely diminish the addressable market available to them today. This would not only be in violation of National Space Policy,⁵ it would be counterproductive to the development of a sustainable commercial market for LEO services.

In summary, we cannot afford for the transition of the United States' human presence in LEO from the ISS to one or more U.S. commercial platforms to be unsuccessful. Ensuring *continued access* to a LEO platform for our astronauts will maintain our position as the world's leading spacefaring nation. Second, to achieve this transition in a manner that allows the resources currently being allocated to ISS to be eventually diverted toward human deep space exploration, NASA must issue an opportunity for companies to compete for the ISS berthing port *as soon as possible*. Third, any funding made available to NASA to help develop a commercial capability in LEO should be spent on *building demand*. Finally, NASA should be mindful of *not competing with industry*.

Senator CRUZ. Thank you, sir.
Mr. Mitchell.

STATEMENT OF BOB MITCHELL, PRESIDENT, BAY AREA HOUSTON ECONOMIC PARTNERSHIP

Mr. MITCHELL. Thank you. Chairman Cruz, Ranking Member Nelson, and Ranking Member Markey, thank you for the opportunity today to be here to testify on the important topic of the International Space Station.

I serve as the President of the Bay Area Houston Economic Partnership, the member-driven 501(c)(6) nonprofit economic development organization located just outside the gates of the Johnson Space Center. We have over 268 members, which include a diverse mix of businesses in aerospace, medical, life sciences, petrochemicals, and maritime. We also are proud to work on initiatives that contribute to the economic growth of the 13 cities and two counties in and around the Johnson Space Center. Although aerospace companies make up a fraction of our membership, the entire business community understands and values the contributions of NASA and the space community in making all of our lives better.

The ISS is a critical element of the work performance in Houston at the Johnson Space Center and the backbone to maintaining a number of key elements of our success in human spaceflight—the astronaut corps, Mission Control, countless technical resources, and world class researchers. The Johnson Space Center offers unparalleled national capability that has been built over decades of experi-

⁵National Space Policy of the United States of America, June 28, 2010, p. 10

ence. The loss of, or weakening of, its capabilities would have dramatic implications to our outcomes in deep-space exploration.

The return on investment of the ISS can be calculated many ways. It's difficult to quantify the exact dollar value of many of these returns, but the overall impact is undeniable. The International Space Station, by its design has established the foundation for sustained generation of technology that improves life on Earth. Each year, spinoffs, like new drugs, materials, scientific technology, become licensed and begin generating new revenue streams for companies, large and small.

Beyond the abilities show the ROI, ISS positions us to tackle the challenge of deep space, buying down cost and risk now and to give missions to the Moon and Mars a headstart. The Station is a critical, inexpensive testbed for exploration and hardware that needs to work perfectly on its first live mission. It allows us to test, tweak, and perfect life-support systems, radiation abatement methods, and other advanced materials. These breakthroughs will eventually make it from launch pad into our homes and businesses across America.

Through engagement with the Russian Space Agency and 13 other ISS partners, the U.S. has led an era of peaceful collaboration and exploration that has provided stability in space leading to the current level of space commercialization. The commitment to the ISS, uninterrupted for the last 25 years, has provided more than just a destination to space. The ISS has cultivated a cultural learning lab for diplomacy, education, and inspiration, a learning lab for technology applications, testing performance machines, materials, and humans in space, a science lab for comparing terrestrial knowledge in a new frontier in weightlessness, a lab for exploring both on Earth and outer space in preparation for the next exploration endeavors.

I think it's important to take a detailed look at the overall ISS budget, which is often cited at around 3 and a half to 4 billion dollars per year. What is misleading about this statement is that the commercial crew and cargo programs are funded out of those funds along with overhead cost at the centers housing the programs. The real ISS budget is a fraction of that total cost, ranging from 1 to 1.5 billion dollars per year. Saving this much each year will have minimal impact on overall exploration efforts, in terms of funds transfer. Commercial alternatives would likely cost significantly more than sustaining the ISS, essentially creating an entirely new development program while providing a fraction of the existing capabilities.

If the U.S. Government terminates its support of the ISS in 2025 and we step away from the ISS before an equivalent long-term engagement is created, there will be a disruption in the space program in an emerging commercial industry. Not very long ago, NASA's Constellation Program was canceled at the same time we retired the Space Shuttle Program, which profoundly had a negative impact on America's leadership in space. I sincerely hope that we all learned a valuable lesson from this and trust that you will not allow history to repeat itself.

My position is that the U.S. Government should commit to the ISS for as long as it safely feasible to do so. However, as we suc-

ceed, others look to follow. As you probably have seen, just last week, China invited other nations to partner with them on their space station. They realize, as we do, the power of these partnerships and the leadership and the technology that can be gained from them. As we question our commitment to the future of the ISS, the Chinese space program is actively seeking to leverage this moment in time to provide an alternative path and platform for our traditional international space partners. This has very serious implications for our national security, trade, technology partnerships, and leadership if this is not managed carefully.

At the end of the day, the ISS program is the culmination of all the reasons we are so passionate about the entire space program. It represents America's future in global leaderships, education, innovation, healthcare, and the quality of life.

Thank you for the invitation to speak on this topic, and I look forward to questions.

[The prepared statement of Mr. Mitchell follows:]

PREPARED STATEMENT OF BOB MITCHELL, PRESIDENT,
BAY AREA HOUSTON ECONOMIC PARTNERSHIP

Introduction

Chairman Cruz, Ranking Member Nelson, distinguished members of the Committee:

Thank you for the opportunity to be here today and to testify on the important topic of the International Space Station.

I serve as the president of the Bay Area Houston Economic Partnership, a member-driven, 501(c)(6) nonprofit economic development organization located just outside the gates of the Johnson Space Center in Bay Area Houston. We have over 268 members, which include a diverse mix of businesses in aerospace, medical, life sciences, petrochemicals, and maritime. We also are proud to work on initiatives that contribute to the economic growth of the 13 cities and two counties in the area around the Johnson Space Center. Although aerospace companies make up a fraction of our membership, the entire business community understands and values the contributions of NASA and the space community in making all of our lives better.

The International Space Station (ISS) is a critical element of the work performed in Houston at the NASA Johnson Space Center and the backbone to maintaining a number of key elements of our success in human spaceflight: the astronaut corps, mission control, countless technical resources, and world-class researchers. The Johnson Space Center offers an unparalleled national capability that has been built over decades of experience. The loss of or weakening of its capabilities would have dramatic implications to our outcomes in deep space exploration.

I would like to note our strong appreciation for this committee's careful review of any discussion about transitions on the ISS, which must be done carefully and thoughtfully as a matter of national policy objectives and priorities rather than as a response to short term political or budget pressures. As was noted in the hearing with NASA last month, going about this transition too quickly could result in the loss of these key capabilities and lead to critical gaps in U.S. capabilities in space, allowing international competitors to seize such moments to usurp American leadership.

The ISS has achieved remarkable goals in science, diplomacy and commercial space market advances, but its work is far from complete. It remains as vital a resource today as it has since crews first started manning it in November of 2000. There are multitudes of productive initiatives left that can only be explored on the station.

Economic Impact

The technology generated out of ISS research continues to improve the quality of human life. NASA literally publishes a book on all of the spinoffs each year. New innovations boost our economy and create jobs in our communities.

The ROI on the ISS can be calculated in many ways. It is difficult to quantify the exact dollar value of many of these returns, but the overall impact is undeniable. The International Space Station—by its design and enactment—has estab-

lished the foundation for sustained generation of technology that improves life on earth. Each year, spinoffs like new drugs, materials, and scientific technology become licensed and begin generating new revenue streams for companies large and small.

Beyond the ability to show an ROI, ISS positions us to tackle the challenge of deep space by buying down cost and risk now to give missions to the Moon and Mars a head start. The station is a critical, inexpensive test bed for exploration hardware that needs to work perfectly on its first live mission. It allows us to test, tweak, and perfect life support systems, radiation abatement methods, and other advanced materials. These breakthroughs will eventually make it from the launch pad into our homes and businesses across America.

Through engagement with the Russian space agency and 13 other ISS partners, the U.S. has led an era of peaceful collaboration and exploration that has provided stability in space leading to the current level of space commercialization. This commitment to ISS—uninterrupted for the last 25 years—has provided more than just a destination in space. The ISS has cultivated:

- A cultural learning lab for diplomacy, education, and inspiration
- A learning lab for technology applications—testing performance machines, materials, and humans in space
- A science lab for comparing terrestrial knowledge in a new frontier of weightlessness
- A lab for exploring both our earth and outer space in preparation for the next exploration endeavors

I think it is important to take a detailed look at the overall ISS budget, which is often cited at \$3B per year. What is misleading about that estimate is that the Commercial Crew and Cargo programs are funded out of those funds along with overhead costs at the centers housing the programs and other expenses. The real ISS budget is a fraction of that total cost, ranging from \$1B—\$1.5B/year. Saving this much each year will have a minimal impact on our overall exploration efforts in terms of a funds transfer. Commercial alternatives would likely cost significantly more than sustaining the ISS, essentially creating an entirely new development program, while providing a fraction of the existing capabilities.

Leadership

History will look back at the ISS as the first time the world joined together, under American leadership, to build an outpost in space. The ISS partner relationships have fostered an invaluable boost to diplomacy and global peace and a powerful tool to leverage resources for necessary basic research. It remains the most visible symbol of NASA and our human spaceflight program, and it is a unique asset that should be used to its full extent by the U.S. and its partners.

However, as we succeed, others look to follow. As you have probably seen, just last week China invited other nations to partner with them on their space station. They realize, as we do, the power of these partnerships and the leadership and the technology that can be gained from them. As we question our commitment to the future of ISS, the Chinese space program is actively seeking to leverage this moment in time to provide an alternative path and platform for our traditional international partners in space. This has very serious implications for our national security, trade and technology partnerships, and leadership if this is not managed carefully.

If the U.S. Government terminates its support of the ISS in 2025, and we step away from ISS before an equivalent long-term engagement is created, there will be a disruption in the space program and the emerging commercial space industry. Not very long ago, NASA's Constellation Program was cancelled at the same time as the retirement of the Space Shuttle Program, which had a profoundly negative impact on America's leadership position in space. I sincerely hope that we all learned a valuable lesson from this and trust that you will not allow history to repeat itself! My position is that the U.S. Government should commit to the ISS for as long as it is safely feasible to do so.

Conclusion

Although counter-intuitive, the mere discussion of the end of life to the ISS dries up the commercial investments that may one day provide a viable revenue alternative. Scientists begin to worry about investing time and resources if the endgame is uncertain bringing significant challenges to future experiments, and international partners look in other directions for leadership to advance their aspirations in space.

At the end of the day, the ISS program is the culmination of all of the reasons we are so passionate about the entire space program—it represents America’s future in global leadership, education, innovation, healthcare, and our quality of life.

Thank you for the invitation to speak on this topic, and I look forward to your questions.

Senator CRUZ. Thank you, Mr. Mitchell.
Mr. Chilton.

**STATEMENT OF JIM CHILTON, SENIOR VICE PRESIDENT,
SPACE AND LAUNCH, BOEING DEFENSE, SPACE AND
SECURITY, THE BOEING COMPANY**

Mr. CHILTON. Thank you, Chairman Cruz, Ranking Member Nelson, Ranking Member Markey. I’m very grateful for the chance to speak here, and also for your leadership over a long period on space.

I’m here representing Boeing, and with great pride, as I was once Mike Suffredini’s contractor, building and supporting a space station. Something I’d like to point out that’s been said is, humans have been living on orbit for 18 years, which means that today’s high school students, the kids graduating this month, have never had a day in school without people living and working aloft. And I support all previous witnesses and the Senators who have said we ought to keep permanent human presence in low-Earth orbit and for all of humanity.

Let me talk about Boeing’s role. We were the prime system developer of the Station from the U.S. operating-segment standpoint. That meant we integrated all the international partners, as well, because that was fundamentally an American-led enterprise. That means we created a bunch of industrial relationships with international partners. That was good for American business, and I think it set a new model.

It does put us in a role to opine about ISS longevity.

Some of you may know that we recently conducted a study for NASA and concluded, with NASA’s approval, that the ISS could live, structurally, through 2028. I’d like to point out that it’s not unusual for a Boeing product to go a lot longer than her initial design life. Think about B-52s, where the grandsons and daughters of the original pilots are now flying them. They’re actually better airplanes than they were before. And today, the Space Station is a better vehicle than when the first modules were hooked together.

But, the question of longevity is very important for anyone who wants to close a business case. Think about buying an airplane, where the airworthiness certificate expires in 3 years. So, it will be important for people to develop opinions with facts and data around the long-term life of the Station. Ours is that the mid-2030s are eminently reasonable, given the history of our product lines.

Given that, if we assume that, let me talk about a first-order commercial assessment as an industrial partner to NASA. The U.S. operating segment costs the U.S. Government about \$3.2 billion a year. These numbers are approximate. \$1.8 billion of that, over half, is launch—launch for resupply; \$1.1 billion, approximately, is ops and sustaining. That’s keeping the lights on. Boeing addresses about half of that market, a little less than half. And, by the way, our cost of doing the same work has come down about 30 percent

in 10 years, so there has been progress, in partnership with NASA. \$300 million of this is the research and science money, which my colleague and fellow witness will address. But, if you add all that up, our assessment is, the U.S. operating segment is funded by the government at about \$3.2 billion a year, and there's about \$100 million of revenue that we've now been able to get across all parties on Space Station. And that's a big gap. So, just as an industrialist, please consider that some incremental capability-based approach may make more market sense than absolutely cutting it on a date.

There are global—well, let me add one more thing. Historically, none of the people who generate revenue on the Station today pay for launch, raising questions like, Does the commercial entity—if this ever happened, if one commercial entity operated the Station, do they control the launchers, or does the government continue to provide those? I offer that question because there are many things to be considered as we go forward. But, the difference between \$3.2 billion and \$100 million is a lot, commercially. That's a big gap.

Global considerations have been mentioned, but I would argue that ISS paved the way for true interdependency on space projects. It is a false choice, in my view, that you have to choose between going further into deep space and staying in low-Earth orbit. We wouldn't know how to go further into deep space if we hadn't learned how to build the Space Station. If you believe that humanity is best served doing something collaboratively with other nations for deep space, ISS is our only model.

So, we should consider that government funding in the U.S. is something that other nations look at. Their governments will continue to fund their segments. Capital in their countries doesn't flow in the same way that it flows in our country, in the way Mr. Suffredini has referenced. So, we should all be mindful that we have to harmonize that operating model if we would like to retain the option to have international partners under our leadership for deep space. So, we shouldn't fall for the choice of station or BO. We need Station to prove out BO, not just technically, but as an operating model across industry and governments.

So, I'll leave you with—you now know our view, that LEO and deeper space are compatible, and we shouldn't be lulled into anyone trying to choose that we must do only one or the other. So, I would offer a recommendation to use your authorities and powers that we should avoid uncertainty for the science community. Some of these long-cycle science projects take 6 to 8 years lead time. If those researchers who currently haven't been paying—some pay, some don't—believe that they might get a bill, and they—or they believe that the model won't be sound, we could see science dry up soon—this year, next year—people on these long-cycle experiments. And we should be mindful to signal certainty and incrementalism. We should be very careful to, whatever we do, keep a permanent human presence in space. We have had times in the U.S. where we couldn't get access to space, between Apollo and Shuttle, and we're going through one now, between Shuttle—let's not—I respectfully suggest we try not to do that with our presence in low-Earth orbit.

And so, when I wrap all that up, the uncertainty could be around just picking a time and say everything must change by one year.

A more incremental capabilities-based approach seems more appropriate, from Boeing's perspective.

Thank you for your time and attention.

[The prepared statement of Mr. Chilton follows:]

PREPARED STATEMENT OF JIM CHILTON, SENIOR VICE PRESIDENT, SPACE AND LAUNCH, BOEING DEFENSE, SPACE AND SECURITY, THE BOEING COMPANY

Chairman Cruz, Ranking Member Nelson, Ranking Member Markey and members of the Subcommittee, on behalf of The Boeing Company, thank you for the opportunity to testify today to provide Boeing's perspective on the future of the International Space Station and pathways to increase commercial use of low Earth orbit (LEO). I appreciate your holding last month's hearing with NASA and today's hearing with industry and other stakeholders to understand the implications of important policy decisions before Congress and the Administration that will determine the future of American leadership in LEO.

Mr. Chairman, as you know Boeing is proud to work closely with the Johnson Space Center and Mission Operations in Houston where about 1,000 Boeing employees collaborate with NASA teams to support the astronauts, ISS operations and research on a daily basis. And Senator Nelson, our Boeing team of more than 400 employees in and around the Kennedy Space Center is preparing for launch of the CST-100 Starliner later this year and supporting ISS, Space Launch System and the X-37B spacecraft.

On November 2 the world will celebrate 18 years of a continuous human presence in space. That means that students graduating high school this month with aspirations of one day being part of human exploration of deep space . . . will have lived their entire life on Earth while men and women continuously orbited above . . . living, working and expanding the realm of what's possible in space. In other words, they were helping to make those students' dreams a reality.

The question the subcommittee is considering today has profound implications for whether we will continue to have a continuous human presence in space for decades to come, if not indefinitely. If we as a country make strategic policy decisions at this juncture, future generations may celebrate November 2, 2000 as the beginning of mankind's permanent presence off Earth.

The men and women of Boeing are rightfully proud of our company's role as NASA's prime contractor for the International Space Station. In that capacity, we designed, developed, integrated, tested and delivered all U.S.-built elements of the station. We also ensured these elements integrated seamlessly with those built by our international partners, a tough task given these elements were developed half way across the world and only met for the first time on orbit.

Having created this unique home and laboratory in space, Boeing maintains this continued orbital presence as NASA's contractor for sustaining engineering for the ISS. We are responsible for maintaining the station at peak performance levels to ensure that this invaluable and inspirational engineering marvel remains available to NASA, its international partners, other U.S. government agencies and private companies.

But today, I am pleased to be here with this distinguished panel to talk about ISS sustainment of a different sort. We ask you to use your authority to preserve the long-term viability of this vital national laboratory, this icon of aerospace engineering, this symbol of an international vision for space, for as long as the Station is able to operate safely and reliably; even as we work together to return to the moon and press beyond into deep space.

And we believe that ISS mission goes well beyond 2028, ensuring that the investment taxpayers and international partners made in building the station continue to provide value for many years ahead.

As you may know, at NASA's request, Boeing performed a study on the life of major space station hardware components. Our study shows the primary structure can reach 2028 and found no technical showstoppers to continued flight beyond 2028. The ISS was designed and built in Boeing's robust tradition which has seen spacecraft and aircraft far exceed their initial design life. Working with NASA we routinely upgrade systems and capabilities. The fact is, the ISS is far more capable now than it was even seven years ago. And with the NASA-Boeing team focused on operations 24-7-365 we are able to operate in a mindset of continuous improvement for safety and reliability.

It's important to add that Boeing continues to work with NASA to reduce the costs of sustaining the International Space Station. In fact, over the past 10 years, we have reduced the costs to our sustaining role by more than 30 percent.

Notice that I said “technical showstoppers.” Unfortunately, we do see that this potential extended life could be compromised due to premature discussions about terminating the program or withdrawing U.S. funding and support.

Like you, we are concerned by consideration of ending direct government funding of ISS in 2025, creating an uncertain future for this valuable space asset. Uncertainty due to the risk of subjecting the station and all that it represents to the hope of a commercial space market that may not have a chance to take shape in seven years—risking reduction or elimination of research and science, and even America’s leadership role in LEO should viable commercial alternatives not materialize.

Before considering this policy question, let’s take a look at what the ISS represents. . . .

The ISS is—by far—the largest spacecraft in history and represents the investment of hundreds of billions of dollars from 15 nations around the world. It operates 24/7.

ISS Provides a Unique Geopolitical Benefit

We believe that deep space exploration will only be possible through international cooperation, and ISS proved this is best done under American leadership. It will require global investment and infusion of ideas from a coalition of space-faring nations. The International Space Station has proven and will continue to prove that it is possible, and it should be our model for our future in LEO as well as in deep space as we prepare to launch the Space Launch System with NASA and international astronauts on Exploration Missions to the Moon in the 2020s. In fact, through current intergovernmental agreements, our international partnerships on ISS are directly contributing to cost-sharing for exploration, and can be further leveraged as we build out the Lunar Orbiting Platform-Gateway and build systems for the Moon and Mars.

It is a model of geopolitical efficiency and tenacity that is far from finished in its work to demonstrate the benefits of cooperative space exploration. Abandoning the ISS at this time not only risks U.S. leadership in space, but also imperils our ability to forge essential collaborative political, engineering and scientific relationships around the world.

NASA currently leads the world’s space agencies, and is positioned to lead a deep-space exploration campaign including international and industry partners. Those other space agencies, space-faring nations and emerging aspirants like Australia and the United Arab Emirates will not abandon their plans if we abdicate our responsibility to lead and inspire. Continued operations in low-Earth orbit will be essential for them to realize their aspirations in space and provide them the incentive and experience to make future contributions as we explore deep space.

If the ISS program is terminated in 2025, then our international partners and commercial businesses will look for alternative low Earth orbit opportunities. Russia has talked about separating from ISS and offering their capabilities to our international partners. China is currently building and plans to operate their own space station starting in 2022 and is engaging the international community to use it. Ending American government support for ISS will have significant impacts on our Nation’s standing in the world, and weaken U.S. influence of the international and commercial communities needed for deep space exploration.

No nation alone can sustainably return humans to the moon and send them to Mars—it will take the collective capacity and funding of our global partners. If we end our human presence in LEO prior to having a steady cadence of human spaceflight missions to deep space, we put at risk not only U.S. funding but the support of international partners. Also, if the U.S. is not the leader in human spaceflight, other nations will assume that leadership role.

ISS Provides Significant Scientific Benefit

The ISS provides a unique, micro-gravity research capability unlike anything else in the world. More than 2,000 experiments have been conducted on orbit with the participation of 103 countries. And this has contributed to significant breakthrough science. To cite just a few:

- The development of osteoporosis drugs available now to treat bone loss
- Clinical trials for treating Duchenne muscular dystrophy
- A vaccine for salmonella

And currently in work:

- Cancer therapy targeting tumor cells
- Fiber production
- Human organ and tissue manufacturing

- The development of robotic arms to treat inoperable tumors

If the research and science community sees the ISS future as uncertain, planning for future experiments could begin to slow or stop as early as this year. These are long cycle endeavors, and not commercial in nature. More than 300 experiments are performed every month aboard the ISS. These experiments not only contribute to down-to-earth scientific breakthroughs, but also develop understanding and human health and environmental support systems to support future deep space missions. It is for these reasons and more that with great wisdom and an eye to the long-term future, Congress enacted the 2005 NASA Authorization Act that designated the U.S segment of the ISS as a national laboratory. National Laboratories, like the ISS, are important to delivering world-class research and strengthening the overall contribution of the laboratories to the Nation's research enterprise. The ISS provides significant benefits here on Earth, and holds the potential to expand our economic sphere beyond the Earth's surface.

It's also important to note that the work being done on ISS inspires the next generation of researchers and visionaries. Boeing is proud to sponsor the "Genes in Space" contest that offers an opportunity for middle-school and high school students—future researchers and explorers—in the U.S. and around the world, to propose actual, meaningful experiments to be performed on orbit, and then allows them to see their ideas in action.

Cutting short this government-supported research in 2025, or causing future researchers to wonder whether the ISS will be viable in its current science model, risks putting the brakes to much of the breakthrough discoveries that could be possible. Even the uncertainty of future government involvement puts new science at risk. With average lead-time of six to seven years to plan, propose, fund and initiate meaningful research projects, scientists and researchers will have little choice but to abandon their ideas and look elsewhere. We must ensure the science community that their future contributions to life on Earth—and in space—will find a lasting home on orbit.

ISS provides significant economic opportunity

Our advocacy for continued government support for operation of the Station does not dismiss the prospects of viable commercial utilization of the ISS. We believe there is opportunity on orbit, but that it is unlikely to happen with the turn of a switch on a certain date. Total ISS reliance on private funding is unlikely to be economically viable by 2025 absent significant, if not exclusive, NASA investment and anchor tenancy. There will simply not be enough of a space economy in place for market forces to drive robust commercial behavior in low-Earth orbit in that timeframe. There is a good chance that a premature termination of ISS could ultimately result in a U.S.-government funded LEO platform with less capability, fewer international partners and comparable costs. Such a plan could even inhibit the commercial development of LEO, without ISS as an anchor without which bigger business arrangements would not be viable.

We don't lack capacity for commercial opportunities with the ISS, but the likelihood that those opportunities can fund the entire ISS by 2025 is very low. Currently NASA funds the U.S. Operating segment of the ISS at ~\$3B annually. Commercial revenue is \$100M or less. This is a big gap. The problem we really need to solve is growing the private sector demand for services in space. We are already seeing signs of what could be possible where commercialization and investment in the ISS capability can seed and foster a sustainable economy in LEO. From our vantage point, the Boeing/Nanoracks commercial airlock will enable Cubesat and other small satellite deployment from ISS by way of the national laboratory. Boeing investment in innovation targets an untapped user community of start-ups through business accelerators like MassChallenge.

But the fundamental fact remains and has been pointed out as recently as last month's Science and Technology Policy Institute study, "it is unlikely that a commercially owned and operated space station will be economically viable by 2025." Indeed, today, there is less than \$100 million of revenue generated by commercial companies for services aboard the ISS . . . at an annual cost to operate the Station of \$3.2 billion. Today's commercial LEO destination business case relies on continued government funding while other markets around non-US governments, manufacturing, and private spaceflight participants continue to develop. This is unlikely to evolve much more toward a viable commercial market by 2025.

Furthermore, uncertainty about that near-term future discourages venture capitalists from substantial investment that leverages the ISS as a platform. The U.S. government must continue serve as the anchor customer in LEO and, to the greatest extent possible, maintain our current international partners to drive global investment to U.S. commercial providers serving and using the ISS. With continued

government support the Station can serve as an incubator to define these future commercial opportunities, but the government must still be able to rely on the Station for basic scientific research and more understanding of what is needed to support deep space missions.

ISS continues to provide significant down-to-Earth economic opportunity

If economic opportunity is to be the driver of the Space Station's future, let's not dismiss the real economic opportunity that has been at the heart of development, assembly and operation of the Station for over two decades. It's opportunity that continues well into the future.

Over the past 18 years of human presence on orbit, approximately 400 suppliers from at least 35 states have supported the Station. Last year alone, 227 suppliers have been part of robust economic activity of approximately \$165 million. With approximately \$300 million in annual contract expenditures, at least \$50 million has been awarded to small businesses.

The ISS program, along with its crew and cargo transportation programs, help ensure that NASA maintains critical leadership in mission operations, human spaceflight and other competencies that will be necessary as we launch upcoming Exploration Missions to the Moon and beyond.

Long-term viability of the Station is essential to sustaining that earthbound economic vitality.

All of these arguments—international collaboration, breakthrough science and research, a nascent yet promising commercial space economy, earthbound economic vitality, and deep space exploration needs—point to a compelling rationale to keep the International Space Station operating in a government-funded model through 2025 and on into the future.

Recommendation

While it is very important for the Administration and Congress to consider the future of ISS beyond 2024 and how to make greater commercial use of this unprecedented platform, we believe that proposing a termination date at this time will result in confusion, missed opportunities and potentially compromise our permanent human presence in space—just at a time when the commercial space ecosystem in LEO is starting to develop. It also may compromise planned scientific research and result in international partners losing confidence in America's commitment to LEO.

Some have argued that the rationale for ending direct funding of the ISS is that the United States cannot afford both continued ISS operations and deep space exploration at the same time. We disagree that this is an "either-or" decision, and Congress has demonstrated its commitment to NASA and our human spaceflight programs through significant increases in appropriations over the last several Fiscal Years to ensure both a healthy LEO and deep space exploration program.

The retirement of the world-recognized Space Shuttle created a misperception in some quarters that NASA was going out of business and America was ceding space leadership. It is easy to see how that perception could arise. Premature retirement of the Shuttle created a seven-year gap in U.S. spaceflight and brought about a \$3 billion reliance on Russia to carry our astronauts to the ISS, effectively leaving control of this vital asset in their hands. At the same time, NASA only saw about \$500 million shifted to exploration.

The ISS remains as the foundation for U.S. leadership in the international space community, and premature retirement before we have established follow-on capabilities and platforms could be even more problematic than the void left after Shuttle retirement. As such, NASA should develop a plan founded on transition criteria and objectives as guidelines rather than an arbitrary decommission date to avoid future unintended consequences which could undermine U.S. leadership and recent investments in low-Earth orbit. Elements of the plan should include, but not be limited to:

- Continued U.S. human presence in LEO to sustain crew and cargo transportation
- Completion of exploration-related research and technology development requiring ISS
- Availability of alternate capability to conduct NASA microgravity research
- Establishment of a human exploration habitation capability in deep space.
- Considerations of "industrialization" vs pure commercialization.

To ensure U.S. leadership in space we need a criteria-based approach to the future of the International Space Station, not an arbitrary end date. ISS serves an important role for deeper space exploration, as a test bed and example of coopera-

tion. The science community needs to know ISS will be viable outside a pure commercial model, or the science pipeline could begin to dry up soon. Moving toward a more efficient industrial model on ISS makes sense if these risks can be managed on a criteria based timeline.

Our generation—soon to include those high-school graduates (Generation ISS, if you will)—are demonstrating how we will be able to live in space for a half-century.

Thank you.

Senator CRUZ. Thank you, Mr. Chilton.

Ms. Bouthot.

STATEMENT OF CYNTHIA BOUTHOT, DIRECTOR, COMMERCIAL INNOVATION AND SPONSORED PROGRAMS, CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE (CASIS)

Ms. BOUTHOT. Chairman Cruz, Ranking Member Markey, Ranking Member Nelson, thank you for the opportunity to share with you my views on the International Space Station.

Today, I plan on discussing the success we've achieved in driving new demand for the ISS National Lab. CASIS is the manager of the National Lab and is serving as a bridge from a government-driven operation to a commercially sustainable marketplace. In this short time, I will describe why demand is important to a sustainable LEO marketplace, what has that—what is the state of that demand, and how have we been able to build it, and, basically, why we need more time.

An end date was suggested for the ISS National Lab that would fully commercialize operations by 2025. We understand that commercialization is imminent, and we are fully supporting this process. However, to achieve this goal, enough time must be given, both for a smooth transition and for the Nation, to realize the return on investment to the American taxpayer.

So, let me start with, Why is building demand important? It's the foundation for a sustainable and self-funded LEO marketplace. It's the source of revenue for the transportation on-orbit providers and services markets, some of my colleagues here on the panel. Demand is providing a tangible return on investment to the American taxpayer. And finally, the demand we're generating right now with research and development is the underpinning for eventual manufacturing in space.

So, what is the state of this demand? Today, more than 55 percent of our payloads are commercial customers and include large programs from iconic Fortune 500 companies as well as innovative startups. We have flown more than 175 payloads, and have 88 in queue. A majority are new to space, and 20 percent are repeat users.

Work on the ISS is providing tangible return on investment to the American taxpayer. We have looked at a value impact process where our project sponsors, validated by external experts, project incremental revenue of more than \$900 million, a total addressable market of \$110 billion, an acceleration in time to market, on average, of 1.5 years, and thousands of new direct and indirect jobs. These are just a few of the economic metrics tied directly to the projects executed on the International Space Station National Lab.

Some examples of these projects are Houston Methodist Research Institute, working with Novartis in Cambridge, on an implantable drug delivery system for muscle atrophy; Nalco Champion, an

Ecolab company in Sugar Land, working on biofilms related to corruptions in piping; and Honeywell, out of Clearwater, Florida, looking at remote sensing applications to detect oil and gas leaks in remote parts of the world.

So, let's step back. How were we able to build this demand? CASIS has funding of \$15 million per year from NASA, which does not allow us to act like a big funding agency like the NIH. Therefore, we had to find creative ways to build demand, which admittedly has not been easy. When we first stood up CASIS, there were no customers banging down our doors, and there was generally a lack of awareness of the ISS. In my testimony, I describe, over the past 6 years, what we did to actually build this demand and how we evolved from an organization that initially had to pay researchers, who were mostly academic, to an organization that attracts commercial companies that are paying their way. To date, over \$140 million of skin in the game which is non-CASIS, non-NASA funding has directly paid for flight projects. This excludes transportation cost. And this trend is increasing as more and more commercial companies are seeing the value of space-based research.

Per our cooperative agreement with NASA, CASIS cannot accept royalties or fees for services, so we had to be creative when attempting to generate additional non-NASA funding to support new demand. We created a sponsored program model that has generated over \$33 million of committed third-party funding for XPRIZE-type competitions like Target's \$1 million cotton sustainability challenge and our partnership with Boeing on the MassChallenge Accelerator and Genes in Space STEM Program.

So, finally, why do we need more time? First of all, we believe the perceived cliff with a hard cut-off date of 2025 or unknown path forward dampens long-term prospects for demand. Companies will simply stop investing if they don't see a runway that matches their R&D roadmap.

Second, any abrupt change in which the private sector is asked to assume the role of managing the ISS without its best and most profitable uses defined may stunt the return on the investment to the American taxpayer.

And finally, the demand I've just described is nascent and growing, and it's also on a trajectory to manufacturing in space. Two big examples are advanced materials, which could revolutionize the communications and semiconductors industry. The second example is the regenerative medicine work we're doing, which could ultimately lead to manufacturing new organs, like heart and lung, in space.

In conclusion, we are creating demand, we have a model that's working, we see a trajectory to a sustainable marketplace, but we need time to ensure smooth transition and to fully realize the benefits and fulfill this vital mission.

Thank you very much.

[The prepared statement of Ms. Bouthot follows:]

PREPARED STATEMENT OF CYNTHIA BOUTHOT, DIRECTOR, COMMERCIAL INNOVATION AND SPONSORED PROGRAMS, CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE

Chairman Cruz, Senator Markey, and Members of the Committee, thank you for the opportunity to discuss with you my thoughts on *Examining the Future of the*

International Space Station: Stakeholder Perspectives. I am pleased to share with you my perspectives in my capacity as the director of Commercial Innovation & Sponsored Programs, Center for the Advancement of Science in Space. In this role, I work directly with the private sector, nonprofits, and other government agencies to bring awareness to U.S. organizations that the International Space Station (ISS) U.S. National Laboratory is open for business, ultimately driving new demand. We work with organizations to analyze what projects would benefit from using the ISS National Laboratory platform and have Earth and U.S. taxpayer benefit. *The Center for the Advancement of Science in Space (CASIS), the manager of the International Space Station U.S. National Laboratory, is creating a brand-new marketplace in low Earth orbit (LEO) and generating demand with new-to-space users. My team works with companies such as Target and Novartis as well as nonprofits such as Houston Methodist Research Hospital and the Michael J. Fox Foundation to introduce them to the National Laboratory on the ISS and assist them in realizing the benefits of utilizing this low Earth orbiting platform in a way that provides value to them and value to the Nation.*

I want to acknowledge the foresight Congress had back in 2005 when it designated the U.S. operating segment of the ISS as the Nation's newest National Laboratory. The NASA authorization Act of 2005 was sponsored by Senator Kay Bailey Hutchison from Texas and Senator Bill Nelson from Florida. The NASA Authorization Act of 2010 directed NASA to engage in a cooperative agreement with a not-for-profit entity to manage non-NASA utilization of the ISS National Laboratory. The nonprofit was guaranteed allocation of not less than 50 percent of the U.S. research capacity in order to implement these non-NASA research and development (R&D) projects.

Through a competitive process, CASIS was selected as the nonprofit to manage the ISS National Laboratory in late 2011. Between 2010 and 2015, a series of bipartisan legislation was passed to ensure continuation of support and utilization of the ISS through 2024, including support for exploration, development of commercial capabilities, and international cooperation. I would like to express our appreciation to past congressional leaders and yourselves for setting forth a national vision for U.S. leadership in low Earth orbit using the ISS National Laboratory as a pathfinder—essentially creating CASIS to open the ISS National Laboratory to recruit the research community from all sectors (commercial, academic, and other government agencies), focusing on driving utilization of the ISS with a broad range of new and non-traditional users. While NASA's ISS activities are focused on exploration, technology development, and living and working in space, CASIS was created to provide a pathway for disruptive non-exploration R&D, commercial activities, and STEM education initiatives with Earth-based applications that directly benefit the American public and the Nation's economy. The ISS National Laboratory is working, and CASIS has come a long way in implementing Section 504 of the NASA Authorization Act of 2010.

My testimony is focused on the success and challenges we've experienced in driving and attracting new private and public-sector demand to utilize the ISS National Laboratory. This comes at a propitious time when Congress is engaged in discussions of an ISS transition. The ISS National Laboratory model serves as a bridge from a government-driven operation to a commercially sustainable marketplace. Our efforts will lay the foundation for a future commercial LEO platform ecosystem and the attraction of private sector investment to grow and sustain the program.

While we and our partners at NASA and in industry are making strong progress in building interest and demand in space R&D, we do have concerns about the impact of prematurely halting government support of the ISS and its impact on this nascent market. The FY19 President's budget request recommends a termination of direct funding of the ISS with a transition to fully commercialize operations by 2025. We understand that attraction of the commercial sector is a critical element of a successful transition, and we at CASIS are working diligently to inform this process. However, it is important that sufficient time be dedicated to ensuring not only a smooth transition but also a return on investment be realized for the American taxpayer with regards to the ISS National Laboratory. We are truly still in the early stage phase of the process of building a sustainable LEO marketplace, with the creation of demand for access to the facility, supply, and investment.

Today, more than 55 percent of our payloads are private sector customers and include projects from iconic Fortune 500 companies and innovative startups. We have flown more than 175 payloads and we have 88 in queue ready to go to the ISS National Laboratory. We have placed emphasis on projects that benefit by using the unique ISS platform. A majority of the ISS National Laboratory projects managed by CASIS are new-to-space users and 20 percent are repeat CASIS customers who see merit in continuing to utilize the ISS National Laboratory for their R&D activi-

ties. These initial activities are key to building a sustainable market. We are working with key R&D markets that we believe could lead to sustainable demand for access to LEO, such as manufacturing in microgravity.

Results and Impacts:

Over the past several years, we developed a value assessment process that quantifies the value and impact back to the American taxpayer. The methodology we adopted is based on best practice analogs from industry, government research agencies, and other National Laboratories and is directly applied to the R&D projects accomplished on the ISS National Laboratory. To date, the following is the projected value of these projects (conducted on approximately 75 percent of the CASIS portfolio), validated by the project sponsors and external experts:

- Incremental revenue of more than \$900M directly tied to ISS National Laboratory projects
- Total estimated addressable market of more than \$110B
- Accelerated time to market, on average between 1 and 3 years
- 1000s of new direct and indirect jobs
- 25+ new solution pathways of innovation (a measure of innovation that can lead to a major advance in knowledge or new intellectual property)

In this section we present examples of new ISS National Laboratory users that are now conducting R&D projects using the benefits of microgravity, the extreme conditions of space, and the LEO vantage point for development of data and products that are subsequently returned to the project sponsor on Earth:

- Houston Methodist Research Institute (Texas): This team is collaborating with Novartis (Massachusetts) on the development of an implantable drug delivery device, using microgravity to understand the capability of the small nanofluidic instrument to deliver a drug. The end goal is to achieve efficacy in combating muscle atrophy without the requirement of daily injections.
- Nalco Champion (a subsidiary of the Fortune 500 company EcoLab) (Texas): This project is directed toward the mitigation of bacterial biofilm-related corrosion in oil and gas lines. In today's world, microbiologically influenced corrosion causes an estimated \$0.5B–1.5T in damages and lost revenue annually, mostly in the oil and gas industries. The conditions produced by microgravity are being exploited to better understand the mechanisms of biofilm formation, their corrosive effect, and methods to mitigate physical damage to metal surfaces—which may potentially have tremendous economic benefit for this industry.
- Honeywell (Florida): This project is using remote sensing applications to detect oil and gas leaks which, if successful, would have major economic and environmental benefit for the energy sector.
- Sanofi (Florida): This project is directed toward improving vaccine production, with microgravity enabling an understanding of cell-based vaccine production compared to older models using chicken eggs. Results could substantially reduce manufacturing cost and time to production while improving both the quality and efficiency of vaccine development.
- Merck (New Jersey): This project is directed toward an improved drug delivery formulation for a major new cancer therapy using a monoclonal antibody, Keytruda®. The goal is to reduce the requirement for the administration of large monoclonal antibody drugs in hospital settings, thereby reducing hospital stays and costs.
- Delta Faucet (Indiana): This project seeks to improve water droplet formation technology in shower heads designed to make the user feel wetter using less water. This technology can improve water sustainability and water use efficiency.
- Eli Lilly (Indiana): The company is undertaking four projects—two focused on drug development and two focused on drug delivery, including one to reduce the need for refrigeration of some drugs. The latter, if achieved, would facilitate worldwide distribution of biologics to parts of the world that do not have refrigeration.
- Business Integra (Texas): Demonstrate higher processing speeds and less costly single-board computers available for the aerospace market.
- Goodyear (Ohio): Using microgravity to better understand silica morphology for manufacturing tires with low rolling-resistance that are more fuel efficient and safer.

- Procter and Gamble (Ohio): Using microgravity to understand complex fluid behavior and improve the functionality and shelf life of consumer personal care products.
- Anheuser-Busch International (Missouri): Barley is the 4th most cultivated grain in the world. This project examines barley seed germination to provide valuable information on the production of barley for the agricultural community on Earth.
- Target (Minnesota): This Challenge is focused on solutions for more sustainable cotton production. A broad range of solutions to improve cotton cultivation are to be explored including plant genetics, plant root systems, and remote sensing applications.
- Mass Challenge (Massachusetts): 2D Nanomaterials initially focused on radiation detection technology for homeland security.

ISS National Laboratory—Early Challenges in Developing Demand:

CASIS receives \$15M per year from NASA within the ISS Research budget. Within the parameters defined in our cooperative agreement, CASIS strives to identify creative ways to build demand and create a sustainable business model to allow a future transition of the facility to the private sector.

Our experience suggests that building sustainable demand is not a trivial task. When we created CASIS, there were no customers banging down our doors. There was generally a lack of awareness of the ISS National Laboratory or demand for access to LEO for the conduct of research that would benefit from the conditions on the ISS.

Thus, our first step was defining the intersection between phenomena and advantages that LEO offers with propositions that are interesting and beneficial to organizations here on the ground. As noted with the company examples, there are three big reasons why R&D takes place on the ISS National Laboratory:

- Microgravity—the near absence of gravity has a fundamentally unique effect on many biological and physical systems that cannot be investigated for any duration of time on Earth. Understanding how gravity acts upon the biological and physical systems parlay into improving terrestrial R&D areas such as human health, agriculture, and materials design.
- Extreme Conditions of Space—accelerated degradation testing using external platforms takes advantage of heat and cold cycling, atomic oxygen, radiation, and debris impact.
- Vantage Point—the ISS is big satellite bus providing a platform for remote sensing applications from the unique orbital altitude and path.

Because the commercial sector was not initially enthusiastic about being on the “bleeding edge” of ISS use, we had to first focus on generating proof-of-concept evidence. To introduce the research community to the concept of LEO-based research, we issued solicitations in key areas with a higher probability of success, such as stem cells, advanced materials, and remote sensing. These were fully-funded solicitations from CASIS that mainly engaged the academic research community.

Once we had “proof-of-concept” evidence from this early work, combined with the body of basic research that was done prior to CASIS, we were able to talk with private sector customers about benefit to their respective research areas. We have continued to refine our approach by defining a commercial go-to-market strategy that focuses on four main areas: life science, physical science, technology, and remote sensing. We further delineated propositions that overlap with R&D portfolio areas here on the ground. We can also conclude that much of the publicly funded and even CASIS-funded basic research activities leads to creation of research pathways and reduced risks for possible downstream applications.

We evolved from an organization that initially had to PAY for projects to an organization that attracts private-sector companies that are paying their way. To date, more than \$140M of non-CASIS/non-NASA funding has directly paid for ISS National Laboratory projects. This trend is increasing as more and more private-sector customers are seeing the value of space-based R&D. While these funding trends are positive, we are not yet at the point where organizations are willing to pay for full project costs including transportation.

Per our cooperative agreement with NASA, CASIS cannot accept royalties or fees for service—so again, we’ve had to be creative in generating new non-NASA funding. We developed a new “product” called a sponsored program, which is a pivot from our early unsuccessful fundraising model. Sponsored programs leverage third-party funding to support use of the ISS National Laboratory as an innovation plat-

form focused on solving big challenges through a competition or solicitation model. They are also a great public-private partnership framework.

Demonstrating an upward trend in leveraged funding, in the last three years, we have generated more than \$33M of committed funding for sponsored programs, with examples including:

- Target Corporation’s \$1M cotton sustainability challenge is funding three pathways from diverse sectors to investigate water conservation.
- The National Institutes of Health (NIH) has supported multiple competitions related to “Tissue Chip” R&D in space, committing up to \$19M+ in support of multiple experiments related to drug development and regenerative medicine.
- The National Science Foundation has supported multiple competitions related to tissue engineering, fluid physics, and combustion, committing up to \$5M+ in support of multiple space-based experiments.

In addition to the economic value and impact delivered to the U.S. taxpayer as a result of our R&D programs, we are also addressing another critical national need—improvements in science, technology, engineering, and mathematics (STEM) education, so our youth are better prepared to participate and compete in our increasingly technology-driven world. As defined in the enabling legislation that created CASIS, our efforts in education constitute approximately 10 percent of our total effort and are directed toward the creation of a national STEM program using the “bright shiny object” of the ISS to attract, motivate, and retain student interest. To achieve a national reach, we have entered into a partnership with many leading institutions with similar interests forming a consortium that includes the Boys and Girls Clubs of America, Girls Inc., the Boys Scouts of America, and several science museums and foundations, to create afterschool and summer programs that augment the basic science exposures provided by our public schools. We estimate that with programs such as our Space Station Explorers Consortium effort, we are leveraging the ISS National Laboratory to reach an estimated 800,000 students throughout the U.S. yearly, a number that is expected to grow to approximately 2 million during 2019. Space Station Explorers connects students and educators with the astronauts on the ISS to discuss science programs, and even design projects that can be flown to the station for execution in the ISS National Laboratory (see: <https://www.spacestationexplorers.org/>).

What Does the Future look like?

One of our goals per the cooperative agreement is to stimulate, develop and manage the uses of the ISS National Laboratory by commercial, not-for-profit enterprises, other U.S. government agencies (besides NASA) and academic institutions. This goal will contribute to the building of a sustainable LEO marketplace that starts with private-sector demand for access to the ISS. We believe the efforts of CASIS in managing the ISS National Laboratory will encourage private-sector participation and inform the Nation regarding how a smooth transition can be made from near-total government sponsorship to a commercially sustainable model. We believe that demand is in a formative stage for this evolutionary process.

CASIS operations provide a critical element for a national effort to support a smooth transition to a sustainable LEO marketplace. The majority of private-sector companies positioning themselves for a possible transition are engaged in preparing transportation services or facilities (e.g., platforms, modules, and in-orbit laboratory R&D facilities) required to carry out activities in LEO, whereas CASIS is engaged in identification of the applications in LEO that will make use of these facilities and services to establish the market.

Our current CASIS strategy, which is R&D based, includes a pathway to in-orbit manufacturing in advanced materials and organ-on-chip technologies. We believe in-orbit manufacturing could represent a critical element of a new commercially driven and sustainable LEO marketplace.

Conclusion:

A space-based National Laboratory is vital in supporting the emergence of a sustainable LEO marketplace, and it is an important construct not only for the existing ISS but also as model and testing ground for a future space station or stations. The ISS National Laboratory has been a pathfinder for examining and encouraging demand for access to the unique ISS platform for R&D activities undertaken by the private and non-NASA public sector. While the growth in numbers and quality of project work suggests that we are making progress, we have not reached the threshold for a sustained market. It is well understood that Research and Development, and the translation of data into a market, is a long and risk-laden process. More time is required to ensure the early success in the identification of research applica-

tions for LEO and sponsors prepared to pursue these initiatives. These elements must be translated into a sustainable source of revenue for the transportation, in-orbit provider, and services market.

The FY19PBR calls for the end of ISS direct funding by NASA by 2025. This perceived cliff, or unknown path forward for the continuation of a platform in LEO, dampens long-term prospects for demand from industries—companies will stop investing if they don't see a runway that matches their own R&D roadmap. Also, any abrupt change in which the private sector is asked to assume the role of managing the ISS without its best and most profitable uses defined may stunt the return on investment to the U.S. taxpayer.

In conclusion, we have been creating demand, we have a model that's working, and we see a trajectory to a new sustainable marketplace—but we need more time to fully realize the benefits and fulfill this vital mission!

Mr. Chairman and Senator Markey, thank you again for opportunity to address the committee on this important topic today. Thank you for your time and attention. I look forward to your questions.

Senator CRUZ. Thank you very much, Ms. Bouthot.

Let's start with questioning.

Mr. Chilton, based on the technical study in the report that Boeing produced for NASA on the life span of the International Space Station, what's your assessment of the real life span of the Station? And how can we fully leverage this investment to get the maximum return on the platform?

Mr. CHILTON. Our assessment of life span of Station with all the calculations complete is to 2028. In the course of doing that, we saw no technical showstoppers to extend her life significantly. I mentioned previously that 2030 seemed very reasonable.

I'd like to point out that, as we've improved, in partnership with NASA, the capability of the Station, I mentioned it's a better platform today than 10 years ago. The natural upgrade and improvement process in the course of maintenance is—should take all the subsystems that are not structure just as reasonably.

Senator CRUZ. So, from a scientific and technical perspective, you don't see any significant barriers to going to at least 2028 and potentially 2030 or beyond. Is that right?

Mr. CHILTON. That's correct, Senator.

Senator CRUZ. OK, thank you.

Let me ask a question to all the witnesses. What do you think could be the unintended consequences of terminating Federal funding for ISS in 2025, 5 years, potentially, before the end of its usable life?

I'll open that up to anyone.

Mr. CHILTON. I don't mind starting. I think we could signal to the science community some uncertainty, and we could see science dry up. I think we could signal to the entrepreneurial community, who may need more time, and we could see capital dry up. I think we could—you know, I'll use the term "head fake"—we could have some people start something and, as we go down this path, they've invested some capital, and they find it's not going to work out because we're not certifying the life extension using government dollars. And, frankly, I think the transportation costs are a bit of an elephant in the room. Everybody who's able to generate revenue on ISS today is having government-sponsored transportation back and forth. So, that's got to be solved.

Ms. BOUTHOT. I would just add that the entrepreneurial community, the commercial community, when they look at doing research

on Station, they're not looking at a one-shot deal. They're looking at a research roadmap, especially when we're talking about our pharmaceutical companies that are doing work. We're talking about a 10-year timeframe. They do not want to see a trajectory that does not meet their research roadmap. We've already had anecdotal evidence of companies that we're working with to try to get to Station hesitate once that 2025 date was announced.

Senator CRUZ. And if we get to 2025 and the only Space Station in low-Earth orbit is being operated by China, is that good for the United States of America?

Mr. MITCHELL. You know, Congressman, that is exactly what I was going to add to the conversation, is that our biggest concern, as well, needs to be the international relationships that we've developed all these years, developed the collaboration. Look at the relationship that we continue to have today with Russia. Even though we know what's going on in the world, this is the one thing that has really pulled us all together, kept us focused and working together. To give that up to China would be devastating to—in my opinion.

Mr. SUFFREDINI. So, I'd like to add, you know, I lived through ISS for many, many years, since the beginning. During that process, I was involved in the decision process from the outside of watching us decide that we would retire Shuttle and have commercial crew. It didn't really turn out the way we had all talked about, which really was, you had to have—bring on a commercial crew provider and then let Shuttle retire. And we are seriously suffering the consequences today. That we are relying on another country to get us to orbit, get our crews to orbit and back, is a travesty. If we are going to lead, which this country only should be doing, we need to do it by making the right commitments and making sure our transitions are sound. We need to stay in space. We have to be there. That's the high ground. That's where we need to be. And we need to do it with other countries, as well. That's critically important for us, as well. So, to lose the ISS without having some other capability orbit that is American-made, I think it would be a huge mistake.

Senator CRUZ. So, if I understand your testimony, you're saying, before we wind down any platform, that history has taught us we need to have a reliable alternative in place first so that we're not left with nothing and a lack of capability and a vulnerability to other nations.

Mr. SUFFREDINI. That is of critical importance. Yes, sir.

Senator CRUZ. Mr. Mitchell, you and I are both Houstonians. What impact does the Johnson Space Center have on economic development and jobs in and around Houston? And what would happen if NASA were to prematurely cancel a large program like ISS or to reduce Mission Control at JSC?

Mr. MITCHELL. Well, NASA has a tremendous impact from an economic development standpoint. Today, there's currently \$1.4 billion in salaries that go to the Johnson Space Center. But, more importantly, I need to set up the answer to that question by stating a few facts. And that is that, in 2012, the Johnson Space Center had 18,294 employees. Today, we have less than 11,000 employees. Today, currently, there are a little over 4,700 that are working on

the International Space Station. I hate to use the same term that I used a few minutes ago, but it would be devastating to the community and to the space program to cut our number of people working for NASA, supporting the International Space Station. That would put us down to less than 5,000 people. So, we'd be devastating to the community.

Senator CRUZ. OK, thank you.

My final question, Ms. Bouthot, is directed to you. Your written testimony highlights that more than 55 percent of payloads to the National Lab are private-sector customers, and that includes projects from iconic Fortune 500 companies and also from innovative startups. Some of the examples of research that have been conducted on the ISS include: Goodyear is using microgravity to better understand silica morphology for the manufacturing of new tires with low rolling resistance that are more fuel efficient and safer. CASIS material states that, quote, "Research could give Goodyear a competitive advantage in the tire industry by developing superior rubber materials." Likewise, Procter & Gamble is using microgravity to understand complex fluid behavior and to improve the functionality and shelf life of consumer personal care products, such as shampoo, shaving cream, and gelatin. Merck is using microgravity to grow a crystalline suspension of millions of tiny uniform crystals to improve the formulation of the company's cancer immunotherapy drug, Keytruda. Keytruda is the drug that helped former President Jimmy Carter's cancer go into remission. And Forbes has reported that some analysts predict that Keytruda may be Merck's next \$10 billion drug.

Now, Ms. Bouthot, tell me, to what extent do American taxpayers receive direct payments or benefits from the research that's being conducted by Fortune 500 companies that may give them a competitive advantage in their respective industries?

Ms. BOUTHOT. That's an excellent question. And I—we were just with Paul Reichert, the researcher from Merck, yesterday talking about the Keytruda drug at the Bio Conference, and I have to say that Merck is one of the biggest spokes companies and advocates for doing research in space. I would step back and point to the work that we have done to quantify value and impact back to the American taxpayer. We have looked at best-practice analogs around, What are the economic, the innovation, and the human-kind social benefits? Those were the numbers I was quoting, around the \$900 million of incremental revenue, the \$110 billion of total addressable market, the acceleration in time to market. These are some examples of those broader economic impacts that are coming back to the American taxpayer.

When you mentioned Goodyear, with the tires, not only are there going to be return on investments to Goodyear from tire sales and being a leader in their industry, but those tires are going to result in lower emissions. I've got another—which is a humankind benefit—we've got other examples, like Delta Faucet, which is looking at showerheads. And again, their project may result to Delta Faucet and their product, but the point is, How do you make a better water-efficient tool that, again, can look at these broader human-kind benefits?

So, we've done a lot of work looking at best-practice analogs to understand how we can best communicate that overall value of economic, innovation, and humankind benefit back to the country, in addition to what the individual organizations are doing in terms of benefiting from that work on Station.

Senator CRUZ. Well, thank you for your testimony. I think that was helpful. If I understood you right, though, you said that there would be benefits to humanity from new technologies, and those are certainly real and cognizable. At the same time, there's not currently a revenue stream coming to the taxpayers if a \$10 billion drug is developed on the ISS, that that revenue, that profit is not going back to the taxpayers. I know I and, I think, other members of this committee are interested in working with stakeholders in thinking about whether it makes sense for the taxpayers to enjoy some of the upside. We see many of our large research universities that innovate in science and enjoying the upside from the innovations they receive. And I think that has the potential, over the long term, to help provide additional funding streams for deep-space exploration and for continued American leadership in space. So, that will be a continued topic of discussion among members of this committee and stakeholders throughout the industry.

I will note, at this point, that I am, unfortunately, going to a meeting at the White House right now. And so, Senator Markey is—or Senator Nelson has very kindly agreed to chair the remainder of—

Senator MARKEY. I'm going to chair the remainder.

Senator CRUZ. OK. So, they're—

[Laughter.]

Senator CRUZ. One or the other will chair, and I'll let them fight it out as to who gets the gavel. But, I appreciate both of their willingness to chair. And I apologize that this conflict arose just a couple of hours ago. And so, being unable to be in two places at once—

Senator NELSON. Mr. Chairman, you might not want me to chair, because we might, by the time you got back, already have passed a NASA bill.

[Laughter.]

Senator CRUZ. I have faith we will continue to work together in a bipartisan manner to get that done.

And I want to thank each of the witnesses. I think this hearing has already been productive, and I'm sure there will be continued and very positive discussion, going forward. So, thank you for being here.

And, with that, I'll turn it over to Senator Markey.

Senator MARKEY [presiding]. And I will recognize the Ranking Member, Senator Nelson.

Senator NELSON. I have a quick question to follow up on the question of products and medicines.

I'm curious. Do you happen to know what it is about the properties of zero G that are allowing Keytruda to become more effective, even more so than it already is?

Ms. BOUTHOT. So, Merck is actually doing protein crystallization work on Station. And what they're doing is, they're looking at the ability to deliver the biologic in a less painful way. So, it's all about

the protein crystallization effects of larger, more formed proteins on Station within microgravity. The big, sort of, end result for Keytruda is, right now those biologics are very painful to deliver into the body. They have to be administered in the hospital. And the work that Merck is doing with Keytruda using protein crystallization in microgravity is allowing that biologic to be delivered less painfully into the body and also let it be delivered in a doctor's office or even the homecare setting, which dramatically will reduce the healthcare-type costs associated with it.

Senator NELSON. Well, I'm curious to hear more about that. If you want to see the original apparatus on protein crystallization on orbit, I invite you to stop by the office, over here at the Hart Building. But, what I can't understand is, from what you just said, what it is about zero G and the growing of crystals in zero G, which we've been doing now for 32 years, that is making the Keytruda drug less painful, as you indicated. I'd just like to follow up with that.

Ms. BOUTHOT. I'm happy to—I will take that offline, and we will bring back information to you, detailed information, on that.

Senator NELSON. I'll just say this in passing. We've given all these kinds of reasons of why you want to extend the ISS beyond 2024, but this one is an example of something that the American people can immediately understand. If you are developing products and medicines unique to the properties of zero gravity of orbit, then, when the American people see that being developed for applications here on Earth, that's going to be pretty dramatic. So, keep those examples coming, and in the course of your testimony, if you might give other examples, that would be very good.

Mr. MITCHELL. Senator, I could give you an example right now.

Senator NELSON. Please.

Mr. MITCHELL. OK. Osteoporosis and low bone mass are estimated to affect 44 million U.S. men and women over the age of 50 every year. A pharmaceutical company named Amgen decided to fly mice on the ISS and study the impacts of certain drugs on the mice's bone mass while in orbit. It was discovered that the drug named Osteoprotegerin, OPG, decreased bone reabsorption in compared to untreated mice. So, their first year of sales in 2011 was \$554 million. This year, their sales will reach \$3.3 billion. So, there's another example.

Senator NELSON. And so, what you're saying is, by the properties of zero G, of which we already know, besides this experiment with mice, we know that that's affecting our astronauts. And that's why they have such a vigorous physical regimen onboard the Space Station, because when you don't have the effects of gravity, and you don't have that stress on the skeletal structure, then there is a lessening of bone mass. We've seen this by the annual physicals that are occurring over time, what they call a longitudinal study of astronaut health. So, what you're saying is, by growing mice, they see lessened bone mass and then this drug is directly helping that?

Mr. MITCHELL. Yes, sir. In fact, there are two drugs that they've created now. It's Prolia and Xgeva. Those are the two drugs that they were able to develop from that experiment on the ISS with the mice.

Senator NELSON. OK. Thank you very much.

Senator MARKEY. Thank you.

So, the—this hearing, I think, is fascinating to everyone who is watching it, because it's talking about this potential to have real benefits that flow to corporations and, through corporations, to individuals all across our country and all across the world. And that storyline is really the 21st story—21st-century storyline. You know, people know that Tang was developed because of the original 1960s NASA program. But, it has been harder for people to step back and look at the constellation of possibilities, you know, for our country and for the world from the next generation of NASA investment, of space exploration, of the recombinant private-sector/public-sector DNA combinations that can make a tremendous difference in the future.

I know that, just on the International Space Station from Massachusetts, we have 1Drop Diagnostics U.S. From Boston—we have Guardian Technologies, from Boston. We have radiation monitoring devices, from Watertown. We have Emulate, Incorporated, from Cambridge. But, as you said, Ms. Bouthot, the public still doesn't grasp that Novartis has an interest in this. That is that it's not just the companies that are providing the equipment for the Space Station who are now interested in it, it's companies who don't provide equipment, who are trying to find ways in which they can use these technologies to improve their ability to create products, create jobs, create wealth in our society.

So, can you expand upon that a little bit more, what the vision is of the private-sector companies?

Ms. BOUTHOT. I think that it's important to note that these examples that we're giving on the demand side are from nontraditional space companies that would not normally think about diverting their research goals to do something in low-Earth orbit, even though they are starting to see the benefit. So, the more that we have this proof of concept, the more results that we're getting, the more value that we're projecting, the more that we see this demand increasing. But, I would just like to mention that, yesterday, General Abramson, who is our CASIS Interim Chief Executive Officer, and I were at the Bio Conference in Boston. General Abe came up with this idea to give Pioneer Awards to four of the major pharmaceutical companies that we're working with: Merck, Novartis, Lilly, and Amgen. And I actually was very skeptical, saying, "You know, we're already working with these companies. Why do we need to give them an award?" And, as it turned out, it was fabulous. We got senior-level, real excitement about receiving this Pioneer Award. And I think we have to recognize, when we're working with this nontraditional demand, that, yes, they may be, you know, producing their own research and benefiting from it, there may be the knock-on benefits to the value and return on investment to the American taxpayer, but these nontraditional space companies are truly pioneers in doing this type of research on Station. And we should really acknowledge that and celebrate that. So, I'd just like to—

Senator MARKEY. So, again, you're—so, you're saying that—perhaps not Novartis itself, but companies like Novartis, who now look

at the Space Station, see real potential for research that leads to development—

Ms. BOUTHOT. That's right.

Senator MARKEY.—of new products, are now looking at a 2024–2025 cliff—and again, not necessarily Novartis, but companies like that, dozens of them, maybe hundreds of them, if they felt that there was a runway here—start to say, “Well, with that cliff, why should I take the risk”—

Ms. BOUTHOT. That's exactly—

Senator MARKEY. —“of making the investment now, in this new way of looking at the Space Station, which actually starts to create products back on Earth, that create jobs?” So, what percent of these companies would you say are in that category? Is it pervasive across our economy that companies that historically have been looking at this are now a little bit more hesitant to engage?

Ms. BOUTHOT. I only have anecdotal evidence, but what I would say is this. In every case, when we talk with a commercial company about the research they're doing on Station, these are strategic discussions about a broad portfolio of the work they're doing. It's never a one-shot deal. They would not divert resources for that. So, they do need to see that runway that matches their development timeline. For drug companies, that development timeline is 10-plus years. So, we already have anecdotal evidence of companies that we've initiated discussions with about doing research on Station. Once they heard that 2025 date, they really started pulling back and questioning.

Senator MARKEY. So, you're saying that, if a drug company was trying to develop a new line of research, they'd give themselves 10 years—

Ms. BOUTHOT. At least.

Senator MARKEY.—in order to make the breakthrough.

Ms. BOUTHOT. Yes.

Senator MARKEY. And if all we're going to give them is another 7 years, that makes it more problematic for them—

Ms. BOUTHOT. Right.

Senator MARKEY.—in terms of taking tens of millions or hundreds of millions of dollars and putting it at risk. Is that what you're saying?

Ms. BOUTHOT. Yes.

Senator MARKEY. Yes.

Now, what other industries are like the drug industry, that are name industries that are looking at the Space Station in the future for dramatic increase in commercialization of products that would be developed up there?

Ms. BOUTHOT. So, a—so, drug companies within our life-science vertical are big. We have four big areas that we focus on. The second is physical sciences, which has a whole host of consumer product and industrial-type companies doing research.

Senator MARKEY. For example.

Ms. BOUTHOT. Goodyear. We've already talked about Goodyear. They are doing—looking at the morphology of the silica within their tires. NEMAC, it's a Wisconsin-based company looking at lighter, cheaper alloy in the production of engines. So, we've got whole—and we mentioned Procter & Gamble, where they were

looking at shelf life and those types of things. So, that's a big area that we're seeing interest. The third is technology. We're seeing technology companies looking at a whole host of project work on Station. And then, the fourth is the remote-sensing area. We gave the example of Honeywell looking at using remote-sensing applications to detect oil and gas leaks in parts of the world that—you know, that there's nobody there.

So, we're seeing a broad interest in all of those four categories. And, you know, the research portfolio discussions we have with each and every one of those companies is similar. Once they look at this sort of investment and shifting resources, they do not want to see a cliff.

Senator MARKEY. Right. So, we have a situation, here, where NASA is eager to move on to Moon—to the Moon and to Mars, and then to just say to the private sector, "Here, you take low-Earth orbit. Your job to figure this out now and to try to figure out how to commercialize it."

Mr. Chilton, do you think that the commercial market will be ready to take on the low-Earth orbit missions by 2025?

Mr. CHILTON. I think signaling that we have to do it by 2025 or there is no market will become a self-fulfilling prophecy for no market. There has to be an incremental approach. I would add to the previous answer the transportation industry. We've got a Starliner product, previously discussed. If I'm not sure that the commercial industry running the Station is going to buy resupply in its current form, I've got an uncertain market, and product upgrades and continued advances become problematic.

So, I think that, with the revenue gap of \$3.2 billion of cost to about \$100 million of revenue is probably unlikely to close and come together in 7 years, sir.

Senator MARKEY. And she did mention Goodyear tires, which is in the transportation sector, OK. So, what are the biggest challenges that the private sector—private space sector faces in terms of taking the helm from NASA? What are those top obstacles that will be hard for them to resolve?

Mr. CHILTON. I'll throw out a few and then wait for reaction from my colleagues.

We have to remember, the Space Station is a National Lab today, by law, and those typically don't have to generate revenue. The people who staff that National Lab are government employees, highly trained. The new commercial operators got a very small pool of applicants to staff their lab if they're operating it commercially. Currently, the U.S. Astronaut Corps and from—some from a few other nations.

Other obstacles are, that Station includes labs from Europe and Japan. And so, you have to get the export control and all the policy things right to be able to work with them up there. I think those are all long-cycle obstacles. And 7 years will be tough.

Senator MARKEY. Long cycle is, in your mind, not 5 to 7 years. It's longer than that.

Mr. CHILTON. With absolute certainty and knowing you could approach policy, 7 years seems like a long time. History suggests, commercial crew and otherwise, that this is a long-cycle endeavor. I respectfully offer that the answer to who might not show up in

7 years, how many of them are thinking about it, that would quit? It's 100 percent of those who haven't started. If you're in the pipeline to take something to Station commercially today, you may continue. If you're thinking about it, but haven't started, now you've got a new consideration.

Senator MARKEY. So, it's going to create a chilling effect, then, on anyone else that—although there are always other private-sector opportunities, which any company can look at, but this would be one that, in your opinion, would just be too risky if someone was starting now and thinking about trying to put something together for—before—that's completed before 2025.

Mr. CHILTON. In my view, the capital you could attract for this in the complete absence of a government backbone is not going to be as attractive as other options.

Senator MARKEY. OK. Thank you.

So, on average, NASA's budget for the Space Station is \$3.4 billion a year. The administration's central argument for its proposal to end direct funding of the Space Station in the mid-2020s is, "to reduce costs." Though funds for the Space Station could be used for other costly deep-space missions, I am skeptical those missions would be successful without the important research carried out on the Space Station.

To all of you, why is it important that the government continue to fund the Space Station at those levels into the mid-2020s and possibly after?

Mr. Suffredini.

Mr. SUFFREDINI. Yes. Thank you.

Well, I don't know if you're asking about the funding in general or just keeping the International Space Station around. But, in our view, and similar to the rest of the folks here with me, the idea that the ISS goes away without some other platform being available is not good, for a number of reasons, not the least of which is what you've heard here this afternoon. But, when you think about, as has been said here, the fact that we have users onboard today, many of who, particularly those trying to do manufacturing, they're—if you pick a date and don't have a sound plan, you're going to lose these people. And you'll see the utilization of ISS start to tail off. But, most critical, from our way of thinking about it, is, you're going to lose the LEO marketplace that is slowly building. So, we think the big push for the International Space Station, other than what it does today, starts with what's going on at CASIS, which is bringing commercial entities to the market, particularly right now in research, but also in studying manufacturing options, but then to continue that process, because, as you're saying—as you're seeing here today, a lot of these things are on a very long cycle, and so, we're just now starting to be able to give evidence of specific cases where it's useful. If we start talking about ending ISS without having another platform available to take over, what's going to happen is, we're going to have a big dip, which we may not recover from. It's—

Senator MARKEY. So, Mr. Mitchell, if you could give us your view on—on this argument—

Mr. MITCHELL. Right.

Senator MARKEY.—that they're saying, "We just have to reduce costs. And this just has to go," what's your answer to that?

Mr. MITCHELL. Well, it—to me, you can't do it. It's impossible. I like the term "backbone." The Federal Government has to be the backbone of the ISS. Even if you do commercialize it, there's no way you can make the business plan, in my opinion, for small commercial companies and our launch vehicles to support the ISS. So, in my opinion, you have to have a backbone to it. You go back and look at this year's budget. To operate the ISS itself is—1.4 is the proposal. The Space transportation is 2.5. There's your 3.5 to 4 billion dollars. 2.5 to launch. So, who's going to pay for that? To me, there's just not a business plan in the commercial industry to be able to maintain and launch at the same time.

Senator MARKEY. So, let me come back to you, then, Mr. Suffredini. Yesterday, the WASHINGTON POST reported that, "NASA is talking to several international companies about forming a consortium that would take over operation of the International Space Station and run it as a commercial space lab." NASA Administrator said, in an interview, "Axiom Space is one of a handful of companies looking at building the commercial successor to ISS." What would happen to Axiom Space if NASA establishes a consortium to operate ISS? Are you concerned that it could have a chilling effect on competition and innovation?

Mr. SUFFREDINI. Well, I think those are really two different things. Operating the ISS with a consortium theoretically would continue ISS as we know it till sometime the government decides it won't be spending money on it anymore. I think Jim's been very clear, and we see it the same way, you're not going to make money off the International Space Station as it is today. It is expensive to own and operate. However, new spacecraft built specifically based on later technology, we can build them much less expensive, operate them for less cost. And so, we actually can make a buck.

So, the answer to your question is, As long as there is a point at which we will ultimately transition to a fully commercial capability, having a transition period where industry does operate the ISS is certainly viable, in our way of thinking.

Senator MARKEY. Ms. Bouthot, you—NASA carries out vital research on the Space Station. A platform like the Space Station addresses 22 out of 33 human health risks identified by NASA for current and future deep-space missions, including the effects of a closed spacecraft design and what effect exposure to long-term radiation would have on cancer rates. Could you elaborate on the consequences of this administration's proposal about ISS and what would happen to all of this important research?

Ms. BOUTHOT. I think you've noted life science is a very rich area for research on Station, not just for the commercial and entrepreneurial community that are doing it, but also as a proof of concept and a proving ground for a lot of the work that NASA is doing. I think we see the ISS National Lab as this proof of concept that can eventually lead to the Moon, to exploration and beyond, but also as being on the cusp of a sustainable manufacturing, where some of the things that you've just noted, we eventually could be not just finding proof-of-concept solutions in the short term, but actually solving them in the longer term.

Senator MARKEY. OK. So—

Yes, Mr. Chilton.

Mr. CHILTON. Senator, I would offer that NASA—when we talk about eliminating cost versus reducing cost, NASA will—I predict NASA will want access to the Station in all scenarios. And, beyond 2025, they need to address those human health risks, they need to learn more about long-term life support. So, NASA and the government will spend money on the Station in some model. The desire to reduce that seems reasonable on some timescale, but the idea of just eliminating it on a date certain, less reasonable.

Senator MARKEY. OK. So, let me ask you this. When you say to them, “It’s not reasonable to completely reduce it, because there’s going to be a need for research for NASA,” what do they say to you?

Mr. CHILTON. In full disclosure, they’ve, in good faith, asked for studies and information from industry. We’ve all submitted those, and we don’t have our feedback yet.

Senator MARKEY. You don’t have feedback yet, OK. So, they’ve given you this opportunity to explain to them how you can’t just pull out, that NASA’s still going to need a substantial amount of information coming back from the Space Station in order to help all these already preceding initiatives that NASA has. Is that what you’re saying?

Mr. CHILTON. Yes. They’re giving us a chance to give them full feedback, and asking broadly, not just companies like Boeing.

Senator MARKEY. OK, beautiful.

OK. Here’s what I—how’s what I’d like to do. I’d like to give each one of you one minute to summarize what you want the Subcommittee, the Full Committee, to remember as we’re moving forward here. And again, understanding that Senator Cruz and I agree, Senator Nelson and I agree with Senator Cruz on these issues, in terms of the sequencing that should, in fact, take place. So, that’s no small moment in the history of this Committee. So, we’re—and congratulations on creating our consensus here, because we—it definitely helps to increase dramatically our likely success, our effectiveness in getting the right answer here.

So, I’m going to give each one of you one minute to tell us what you want the Committee to remember about your testimony, and about the future of NASA and the Space Station.

Mr. Suffredini.

Mr. SUFFREDINI. Well, first, I’d say we feel strongly that the United States should not allow a gap of access to LEO and a platform on which to operate. We would like to see the government and the agency work toward supporting commercial being able to be in a position, at some point, to take over for the International Space Station. And, to that end, we’d like to see port solicitation be put in place immediately, and that any money additional that NASA is given for commercial development be spent on helping develop demand.

Senator MARKEY. Thanks.

Mr. Mitchell.

Mr. MITCHELL. Thank you. I think—what I’d like to say is, to go back what I said a little bit earlier, and that’s for us to understand the importance of our leadership, America’s leadership in space and

to look at what China, what Russia, what are other countries trying to accomplish to get ahead of us on that. And the fact that—again, go back to China—China just, you know, recently, last week, asked our international partners to work with them on their ISS—or their space station. It’s something that we should be concerned about. To me, it’s a national security issue, it’s global leadership, and that’s where our focus should be, not to mention that we have to have this as a testbed for us to go on to Moon and Mars and beyond. But, first and foremost, in my mind, we have to maintain our leadership in space.

Senator MARKEY. Yes, beautiful.

Mr. Chilton.

Mr. CHILTON. First, I would say a strong recommendation that you consider a criteria- versus time-based way to reduce cost, just let the facts and data and the markets emerge as they do on the time they naturally do versus say it must be a certain time. That’s first. Second, as you do that, avoid uncertainty for the research and science communities. We need to keep that pipeline full, and we need to signal to them that we’re deliberately working through this, and that lab will be there. And the third thing I would ask you to do is remember those high school students who spend every day of their life with humans living and working aloft. I’ll call them Generation ISS. Let’s not have them talking, in 10 or 15 years, saying, “In my day, we had people in space, living continuously.” Let’s just keep it that way.

Senator MARKEY. Thank you—

Mr. CHILTON. Thank you.

Senator MARKEY.—Mr. Chilton.

Ms. Bouthot.

Ms. BOUTHOT. I’ll go back to the demand. And we believe demand is the underpinning for building a sustainable LEO marketplace. We believe that it is also the trajectory to eventual manufacturing in space. And when we can do that, we will truly have a viable market that can support supply as well as the nontraditional demand. We would hope that we continue to receive support around generating this demand and looking at the capabilities that these new users need. We’re working very closely with NASA now on identifying what those enabling capabilities are. So, understanding what the best—what can best meet the needs of these new users, and protecting them, and also really celebrating these new users, because they are pioneers in the creation of this new marketplace.

Senator MARKEY. OK, beautiful.

Well, this was an excellent, excellent hearing, excellent set of witnesses. We thank you.

And again, we’re trying to work as closely as we can together in order to come up with a common perspective that we can advocate for on a bipartisan basis in order to ensure that we get the right result here.

And the hearing record will remain open for two weeks. During this time, Senators are asked to submit any questions for the record to our witnesses. And, upon receipt, the witnesses are requested to submit their written answers to the Committee as soon as possible.

The Committee thanks the witnesses for appearing today.
And, with that—he took the gavel with him. No, no, no, no.
[Laughter.]
Senator MARKEY. And, with that, this hearing is adjourned.
[Whereupon, at 3:40 p.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO
MICHAEL T. SUFFREDINI

Question 1. What are the most important things NASA should and should not be doing in the near future to grow commercial activity aboard crewed platforms in low Earth orbit?

Answer. The most important thing NASA could be doing is to immediately make an ISS berthing port available for a company that is building a follow-on U.S. commercial space station. Since at the moment the ISS can provide only enough power for a single attached set of space station modules, and a station should be attached to ISS prior to its retirement to allow transfer of the existing commercial and government users, NASA must immediately create a competitive process that permits commercial entities to compete for an ISS berthing port to attach to (assuming said commercial entity intends to remain on orbit post ISS retirement). In addition, preference for the ISS port usage should be given to companies who request no money from NASA for the development, launch and operation of their space station.

Second, any additional money NASA is given for "LEO Commercialization" should be spent specifically on building demand. While some enhancement of the commercial research development effort by CASIS is necessary, an Administration-wide effort to educate and incentivize companies to manufacture products in LEO would result in the kind of growth not seen since the advent of the internet. With the proper growth of demand, U.S. commercial suppliers can gain private investment to address the demand.

NASA should NOT compete with commercial companies trying to establish a LEO marketplace for human spaceflight platform related services. There are a number of cases where NASA could end up competing with commercial LEO supplier entities; NASA should be very sensitive to making sure that whenever they are asked to provide a service to anyone, they point the requestor to U.S. commercial suppliers. A case in point is what is referred to as country customers. An early big market for commercial LEO providers are countries who want to build a human spaceflight program, or those who want more access to space for their existing programs. When these countries come to NASA for flight opportunities for their astronauts and related services, NASA should NOT barter to 1) provide those flight opportunities to ISS for these countries; 2) assist the countries in selecting their national astronauts; 3) train their crew; or 4) provide any other services relative to implementing a human spaceflight program. NASA can still have a partnership for ISS and exploration beyond LEO with such countries, but should point countries to U.S. commercial entities to supply these LEO operational capabilities.

Question 2. Would an extension of the space station beyond 2025 be helpful to your company and ones like it? What would be the impact of deorbiting the ISS in 2025, or of NASA turning over the ISS to a "commercial operator" (who might then compete with other commercial space stations in LEO) as has also been suggested?

Answer. Axiom takes as a given that the United States must maintain a continuous presence in space to maintain its global leadership position in human spaceflight. This can be accomplished by ensuring a U.S. commercially developed ISS follow-on space station is available to utilize before ISS is retired. Axiom Space, Inc. is developing just a commercial space station to follow the ISS. In fact, we believe any ISS follow-on station should first attach to ISS to ensure continuity for all users, including National Lab, government and commercial entities. This is critical to fully utilizing ISS toward the end of its life and ensuring the LEO economy developed up to the point of ISS retirement isn't discarded when ISS is deorbited.

However, at this point, due to the lack of NASA making a berthing port on ISS available, it would be very difficult for a commercial company to build a station, attach it to ISS, transfer National Lab and other government and commercial users from ISS to the commercial station and separate to operate independently by 2025. The first step in the process is a solicitation to compete for the use of a berthing

port on ISS. Once the port is awarded to a company, then the company can secure the investment necessary to design, build, launch, assemble and operate the new space station. NASA is just now concluding the selection process for a *second* study on LEO commercialization that is not due to be complete until the end of this year. Assuming 3 months to review the study results and decide to create a solicitation for the port, NASA could not be ready to award a port before mid-2020. Investors have expressed the need to see the port awarded before significant investment will be available; no significant commercial space station development can take place until after use of the berthing port is awarded. At this point, therefore, it will be difficult to build a successful station that begins its life at ISS if ISS is retired in 2025.

Finally, turning over ISS to a “commercial” operator who would then be allowed to sell LEO services would effectively kill any truly commercial LEO effort. First, the “commercial operator” model is not commercial at all. It is a NASA contractor that will be paid about \$3B to operate ISS and make it available to NASA to meet its needs and commitments. The company that wins this contract (likely to be the large ISS contractors for NASA today on ISS) will easily be able to undercut any would-be commercial provider, since they can use their fee (and what is sure to be significant margin in their operation) to subsidize their cost, thus preventing real competition. Without competition, the ISS contractor will own any user market. Without any competition, the NASA contractor will not be incentivized to build a successor platform, since the U.S. government is subsidizing the one they use and paying significant fee to keep the ISS viable. No new platform means no creative cost reductions for users and very limited enhancements to ISS. Also, when ISS life does end (which is inevitable), it is highly likely that no U.S. commercial platform will be available to take over. Perhaps more disturbing, commercial startups like Axiom Space are incentivized to help build the LEO demand, but this NASA contractor will not be incentivized to build demand since it has NASA as an anchor tenant. The government should not underestimate the effort a truly commercial company will put into developing LEO demand . . . which the government will benefit from.

If the government wants to create a consolidated contractor to take over operations of ISS to perhaps save some money and/or for political reasons, this contractor must be forbidden from selling services commercially on orbit.

In summary, the most effective way to grow a commercial market in LEO, and the quickest/safest way ensure a U.S. capability for NASA astronauts in LEO, is to take steps today to incentivize commercial suppliers for LEO services. These include: immediately generating a solicitation for commercial space station companies to compete for use of an ISS berthing port; utilizing any additional “commercial LEO development” funds for developing LEO *demand*, in particular in-space manufacturing; ensuring NASA does not provide spaceflight opportunities to other countries that do not otherwise already have opportunities through the ISS partnership, or sell related astronaut or flight operation services that are commercially available to other nations; and, finally, if NASA creates a consolidated operations contract for ISS, ensuring the companies involved cannot sell ISS services or flight opportunities.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BILL NELSON TO
BOB MITCHELL

Question. What are the most important things NASA should and should not be doing in the near future to grow commercial activity aboard crewed platforms in low Earth orbit?

Answer. The most important thing NASA should be doing is continuing to provide access and services for research in LEO onboard the International Space Station (ISS). ISS is an excellent proving ground to foster the development of a commercial LEO economy. NASA should also communicate that ISS will continue to provide these services through 2028 and beyond—as long as this national and international asset can provide these services. Without a level of certainty, we will continue to lose critical research opportunities which will hinder economic growth. NASA should also continue to allow researchers to retain the rights to the information and discoveries. If NASA were to retain rights or put a royalty/tax on research, there is a high likelihood that the LEO commercial market would collapse. The government is already getting economic benefit in the form of taxes on new products developed based on ISS research. NASA should also continue to provide access to potential commercial capabilities on-board ISS, like Nanorack’s Airlock and the possibility of a future commercial habitat. In conclusion, any level of uncertainty with regards to ISS

availability will have a significant impact on the future of commercial LEO economy.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO
JIM CHILTON

Question 1. What are the most important things NASA should and should not be doing in the near future to grow commercial activity aboard crewed platforms in low Earth orbit?

Answer. NASA, industry and international partners should seek to fully leverage the ISS over the next decade to foster growth in commercial demand for services in LEO. The ISS provides an unparalleled platform and opportunity for commercial entities to explore different technologies and business models, while leveraging the ISS National Lab as well as the regular crew and cargo transportation funded by NASA.

Unfortunately, there is no “silver bullet” for rapid commercialization and growth. Currently, NASA and foreign governments remain the exclusive or primary funders of spaceflight in LEO and there is no comparable non-government market demand for these services. Today, there is a large gap between supply and demand in LEO with significantly more supply than market demand for these services. As I noted in my testimony, NASA currently funds the on-orbit U.S. operating segment of the ISS at approximately \$3 billion annually. \$1.8B of this is for crew and cargo resupply launches, \$1.1B for station operations and maintenance, and the balance for science. Commercial revenue is \$100 million or less. This is a significant gap to close, but commercial revenue can grow with a long-term commitment to ISS as a platform available to commercial users and time for this nascent market to grow. However, it would be premature to assume how long it will take for this market to grow and what the ultimate nature of this market may entail.

A key element to successful commercialization is allowing sufficient time and stability for market maturation. There are a number of new and growing businesses and commercial opportunities that have developed in recent years thanks to NASA encouragement and industry investment. For example, the Boeing/Nanoracks commercial airlock will enable Cubesat and other small satellite deployment from ISS by way of the national laboratory. Although some argue this is a launch service taking advantage of the no cost access NASA allows for science, it does show emerging demand. Additionally, Boeing investment in innovation targets an untapped user community of start-ups through business accelerators like MassChallenge. These efforts, among others on ISS, may foster the development of commercial demand, but it is too soon to know how and when this market may mature to provide sufficient demand independent of significant government support. At the present time, commercial activities on ISS are heavily subsidized and consistent with the laboratory environment, are primarily in the incubation phase of development. The larger question revolves around how to mature commercial concepts from the incubation phase into viable self-sustaining market opportunities? Continued ISS operations are needed to explore processes for economic maturation and reduce the dependence on government subsidies.

NASA has been very forward-leaning in supporting the development of commercial supply services and capabilities through significant investment and service purchases of cargo and crew transportation, support for CASIS and the ISS National Lab, as well as ongoing work with commercial service providers to help stimulate a market for cubesats, experiments and testing onboard the ISS. To fully leverage these investments and emerging markets, the ISS should be extended through at least 2030 to provide the necessary time to enable commercial demand in LEO. We applaud the leadership of this committee in the extension of ISS authorization through at least 2030 in the Space Frontier Act to provide the necessary time and stability to foster commercial growth.

Regulating In-Space Activities. The Trump administration has proposed establishing a new office at the Department of Commerce that would be responsible for overseeing commercial activities in space. This would be separate from the Department of Transportation’s responsibility to regulate launch and reentry. So, crewed commercial space vehicles such as Starliner would have to deal with Department of Transportation regulations during launch and reentry but with Department of Commerce for operations in space. A different idea would be to have one department—be it Commerce or Transportation—just take care of everything as a “one-stop-shop.”

The Boeing Company supports the principles of Space Policy Directive-3 (SPD-3), which transitions Space Situational Awareness (SSA) and Space Traffic Manage-

ment (STM) authorities to ensure that America's national security, civil, and commercial space assets are fully protected from space debris and other orbital threats. The Trump Administration has indicated that the Department of Commerce should be the lead agency for these functions and the House and Senate committees of jurisdiction are considering legislation in both chambers that address the implementation of these and other commercial space reforms, including those in your Space Frontier Act.

Above all, it is important that SSA and STM be implemented in a manner that establishes a positive example and precedent for the industry and the international community. With the anticipated growth in launches, satellites and orbital debris in the years ahead, we need an effective SSA and STM process and standards to prevent costly or even catastrophic impacts in orbit. Boeing is a longtime partner with the DoD, NASA, and other agencies on national security, human spaceflight, and commercial satellite programs and as the risk of space debris grows we are committed to astronaut safety and the protection of critical assets operating in space.

We look forward to working with the Administration, Congress and all of the appropriate entities involved in the licensing and management of commercial space launch and activities to ensure safe, responsible and transparent oversight of civil and commercial entities operating in space.

Question 2. What do you think is the best way for the government to provide oversight and supervision for new activities in space?

Answer. The best way for the government to provide oversight and supervision in space is to establish a clear regulatory regime and to ensure that all civil and commercial actors operating in space are conducting activities in compliance with these rules. We believe that the protection of national assets—including national security systems, GPS, the International Space Station, weather satellites, among other assets—should be at the center of any regulatory regime, and that there should be a clear process that ensures full compliance with these rules by all actors in space. Civil and commercial entities should be expected to share equally in these responsibilities and obligations to protect our national assets.

Question 3. If NASA's demand for commercial crew transportation goes down as a result of retiring the space station in 2025, what is the impact on commercial crew transportation? Will there be enough demand to keep multiple U.S. crew transportation providers in business?

Answer. Currently there is significantly more commercial transportation supply than commercial demand for LEO services. NASA is currently a monopsony buyer, able to compete multiple existing and emerging providers. Without more destinations or demand on ISS, there will be an upper limit to the number of launch resupply providers who can remain viable. NASA should carefully manage this supply and demand imbalance until a larger market emerges.

NASA investment and the continued operation of the ISS are central to the business case for the current cargo and crew transportation providers as nascent commercial demand continues to develop and grow. Without continued ISS operations, it is unlikely that NASA would need to sustain currently planned levels of cargo and crew transportation to LEO, which could result in higher prices to sustain less frequent transportation or fewer providers. The commercial space habitat market is still in its infancy and based on past development program schedules, it is unlikely that an alternative to ISS that would drive this level of demand and investment would be in place by the mid-2020s.

While Boeing is confident that there is commercial interest in Starliner transportation services to ISS for international and non-government astronauts, this market is mostly predicated on governments and companies seeking to conduct activities on the ISS using the platform's unique assets and facilities. It is not safe to assume that alternative U.S. platforms will materialize or will provide the same capabilities that attract potential commercial demand as the ISS.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO
CYNTHIA BOUTHOT

Question 1. What are the most important things NASA should and should not be doing in the near future to grow commercial activity aboard crewed platforms in low Earth orbit?

Answer. Since our partnership began in 2011, NASA has been an incredible partner, and it has been an honor to work together with this agency to support the ISS National Laboratory.

By continuing its commitment to space exploration, development of advanced technological capabilities, and international cooperation, NASA's success and reliability is at the foundation of our corporate partnerships and our ability to someday achieve the commercialization of low Earth orbit (LEO), particularly research and development (R&D) on the ISS National Lab.

Potential concerns that we are addressing together with NASA include the high cost of transportation and regulation that could hinder getting payloads to LEO, as well as the continued training and development of a U.S. workforce of scientists that will operate in LEO on the ISS National Lab and beyond. Transportation and talent are both invaluable resources in this endeavor. We work collaboratively with NASA to cultivate a wide range of potential ISS National Lab users to develop research projects and programs that will be impactful from an economic, innovation, or social perspective. We are growing a network of investors, and through that network, we are able to distribute information and investment opportunities to bring in people who have not yet made their first investments in space, thereby infusing more capital into this emerging ecosystem.

To summarize the important things NASA should and should not be doing in the near future:

- (1) Focus on transportation and providing low-cost and repeatable access to LEO.
- (2) Continue to use the ISS National Lab as a pathfinder for:
 - a. Commercial activities, including proof-of-concept activities aligned with strategic investments that will lead to larger sustainable activities such as in-orbit manufacturing.
 - b. Technology readiness level (TRL) maturation of commercial products that have Earth applications.
 - c. Public-sector basic research activities, which are the underpinning for future private-sector activities (*e.g.*, keep the seed corn, continue to cultivate the pipeline of the U.S. workforce, and advance U.S. innovation in areas such as tissue engineering activities by the National Institutes of Health and the National Science Foundation).
- (3) Create a balanced strategy for the development of alternative commercial platforms and capabilities and the development of demand by the private sector. It is important to now consider low-cost R&D platforms beyond the lifetime of the ISS to ensure a gapless transition by the time the ISS is decommissioned. In parallel, attention needs to be given to understanding, creating, and enabling demand by the private (and public) sector. The emerging commercial platform market needs to understand the nontraditional customers. Don't put the cart before the horse.
- (4) Don't put in place processes or policies that would detract demand interest, such as intellectual property (IP) and data rights. For example, the U.S. should create a broad exemption from the Federal government taking a stake in a company's IP and data rights. Companies that cover the cost of their projects in space (not including transportation costs) should be exempt from any stake the U.S. government would otherwise take. Establishing simple IP and data right expectations will help drive demand for commercialized space.
- (5) Retain an honest nonconflicted broker to manage the activities and evaluate the value of national laboratory platform(s). This construct is the same principle used for ground-based national laboratories and is effective for fair practices in getting ideas and products from lab to market.
- (6) Reduce the regulatory burden for companies looking to operate in space.
- (7) Focus on cost-sharing partnerships by attracting and enabling third-party investment opportunities in space research and technology development (*e.g.*, the ISS National Lab investor network).

Question 2. How does uncertainty about the future of the space station impact your efforts to grow commercial use of the space station? Have you noticed any hesitation from potential users or investors over the last few months?

Answer. The FY 19PBR calls for the end of ISS direct funding by NASA by 2025. This perceived cliff, or uncertainty of the path forward for the continuation of the ISS, negatively impacts the long-term prospects for demand from industries. Companies are no longer incentivized to invest if they don't see a runway that coincides with their R&D timeline. For example, the time required to develop and test a new medication or make meaningful advances in tissue engineering is quite long, spanning several years. If an end to the ISS National Lab is perceived, it will discourage long-term investment in the lab, which will destabilize prospects for further LEO

commercialization. Moreover, uncertainty about the future of the ISS National Lab could prevent the lab from being able to attract the top talent necessary to perform experiments and operate properly.

Therefore, we believe any abrupt change in which the private sector is asked to assume the risk of managing the ISS without its uses defined will stunt the return on investment that the ISS National Lab currently creates for tax payers. We instead recommend a managed, gapless transition to the commercialization of LEO, in which policymakers, NASA, CASIS, the Department of Commerce, and private industry work together to define a timeline that is based on measured, proven commercialization techniques.

When CASIS was created, we were an organization that literally had to pay for projects that would attract private-sector companies to participate in LEO R&D. Today, more than \$140 million of non-CASIS/non-NASA funding has directly paid for ISS National Lab projects. Although this trend is increasing, we are not yet at the point at which organizations are willing to pay for full project costs. We need more time and certainty in this market to achieve commercialization; however, we know that we can get there.

