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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% 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% are repeat CASIS customers who see merit in continuing to utilize the ISS National Laboratory for their R&D activities. 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% 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
- 1000's 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 parlays 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 platform 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 American, 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 applications 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.