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Chair Hickenlooper, Ranking Member Lummis, Chair Cantwell, Ranking Member Wicker, and members of the Subcommittee, thank you for the invitation to appear before you today with such an extraordinary and distinguished panel to discuss my thoughts on the topic of today's hearing: "International Collaboration and Competition in Space: Oversight of NASA's Role and Programs". My name is Dr. Mary Lynne Dittmar, and I am the former President and CEO of the Coalition for Deep Space Exploration – an industry trade group supporting NASA's programs of record in human exploration, science, and space commerce - and now, the Executive Vice President of Axiom Space, which is building the world's first commercial space station. The topic of this hearing is of intense interest to me, as it has guided most of my professional activities and service for more than 20 years. I wish to note that while I will be discussing some of Axiom's plans to illustrate my discussion, the positions presented here are my own and do not reflect the official opinion of my employer.

Axiom is the first (and so far, the only) company to develop a new station destined for low Earth orbit (LEO) without government funds for development, launch, and operations. Beginning by building modules that extend the functionality of the ISS, it will provide capabilities to a broad array of users – researchers, astronauts, manufacturing firms, scientists, artists – and will offer those capabilities to meet existing and emerging needs across the U.S. government, international customers, and the business community. Critically, for the purposes of this hearing, it is also best positioned to help challenge China's interests in LEO at the end of life of the International Space Station. Indeed, it was for that latter reason, more than any other, that I joined Axiom.

It's often said we're at an "inflection point" in space, and while that is true, the phrase glosses over the complexities, challenges and opportunities confronting us now and in the years to come. Regarding LEO, the term has been used to describe the transition from an exclusively government owned-and-operated domain to one utilizing public-private partnership. What is less frequently discussed is a more dangerous reality – namely, that if the U.S. does not act decisively and strategically, it risks squandering the competitive moat the U.S. has built in commercial space to national actors who continue to maintain laser focus on asserting their own national interests. In this testimony I will discuss this situation in both LEO and in deep space, with an emphasis on human spaceflight and exploration.

NASA's Efforts to Build Alliances

The National Aeronautics and Space Act of 1958 – the so-called "organic act" that created NASA – has as one of its nine objectives "Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and to the peaceful application of the results thereof."[1] In other words, cooperation with other nations is in the DNA of our nation's space agency. This part of NASA's mission has been ratified by Congresses since 1958 in a series of Authorization Acts that build upon the first.

NASA has demonstrated its commitment to that cooperation in the years since – in space science, in human spaceflight, in technology development, and in education and outreach. The most visible example – but certainly not the only one – of multilateral cooperation in space is the International Space Station (ISS). For the past 20 years the ISS has been the focus of a strong international partnership that has attracted over 100 countries as participants. NASA's daily engagement with the partnership has weathered changing political climates both at home and abroad,

[1] U.S. Congress (1958). National Space and Aeronautics Act of 1958, Pub. L. No. 85-568, as amended (29 July). Printed for NASA Use November 30, 2006. Accessed at: https://history.nasa.gov/spaceact-legishistory.pdf

demonstrating extraordinary stability, positive interdependence, and an ability to bridge the tensions and conflicts that inevitably surface in international relations.[2] This has been particularly true with Russia, which served to ensure the continuation of the ISS after the loss of the shuttle Columbia and in the long interval between 2011 and the end of the shuttle program until 2020 when the U.S. was again able to launch astronauts on American rockets from American soil. This partnership has been even more remarkable given the stresses that attended the Russian annexation of Crimea, and recent, sometimes contrary statements from Roscosmos regarding Russian intentions for future participation on the ISS.

Guiding this cooperation has been the Intergovernmental Agreement (IGA), a treaty-level multilateral agreement among the governments of Canada, governments of member states of the European Space Agency, the government of Japan, the government of the Russian Federation, and the government of the United States.[3] The 15 member nations who signed the IGA after years of negotiations have remained committed to its goals and principles and have created a strong foundation of multilateralism in human spaceflight. However, the IGA is specific to the ISS and does not extend to exploration of deep space. In addition, China was not included in the ISS partnership.

In 2010, Congress directed NASA to ask the National Academies to perform a study to review "the goals, core capabilities, and direction of human spaceflight." In 2012 NASA asked the National Research Council at the Academies to perform a wide-ranging study in accord with Congressional direction. The NRC in turn convened a Committee on Human Spaceflight, on which I served, to carry out the work. The resulting report, entitled "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration," was published in 2014.[4] Among many other recommendations, a central finding of the Committee was that NASA's deep space exploration program must be international in nature, and that continuing engagement is necessary to develop and maintain international partnerships. The report also recommended that China be engaged, arguing that exclusion of the Chinese space program could work against the interests of the United States, particularly given China's stated openness to working with other nations.[5]

In October of 2020, NASA announced the signing of the Artemis Accords by eight founding member countries including the United States. Announced earlier in May of that year, the Accords "reinforce and implement" the principles of the Outer Space Treaty, and are aimed at avoiding conflict, strengthening international relationships, and encouraging ongoing cooperation in a growing coalition dedicated to the peaceful uses of outer space. The Accords do not constitute a treaty, but rather a framework to encourage bilateral agreements developed under the umbrella of several principles that, it is hoped, will develop into international law through custom and practice. The Accords thus offer a significant step toward implementing the recommendation of the Pathways report that U.S. deep space exploration be international in nature, providing a framework of principles underpinning future exploration: Transparency, interoperability, emergency assistance, registration of space objects, release of scientific data, preservation of outer space heritage, extraction and utilization of space resources, deconfliction of space activities, and planning for the safe disposal of orbital debris.[6]

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[2] Dittmar, M. L. (2017). Statement before the Committee on Space, Science and Technology, U.S. House of Representatives, 22 March. "The ISS After 2024: Options and Impacts." https://docs.house.gov/meetings/SY/SY16/20170322/105737/HHRG-115-SY16-Wstate-DittmarM-20170322.pdf

[3] The U.S. State Department (1998). Space Station Agreement between the United States of America and Other Governments (signed 29 January 1998). https://www.state.gov/wp-content/uploads/2019/02/12927-Multilateral-Space-Space-Station-1.29.1998.pdf

[4] National Research Council of the National Academies Human Spaceflight Committee (2014). Pathways to exploration: Rationales and approaches for a U.S. program of human space exploration. Washington, D.C., National Academies Press.

[5] Ibid, p. 26

[6] National Aeronautics and Space Administration (2020). NASA, international partners advance cooperation with first signings of Artemis Accords. 13 October. https://www.nasa.gov/press-release/nasa-international-partners-advance-cooperation-with-first-signings-of-artemis-accords

Progress and Intentions of Other Nations in Space: Focus on China

It is worth noting that neither the People's Republic of China (PRC) nor Russia have announced an intention to sign the Artemis Accords, offering mixed responses to the initiative at various times.[7] [8]However, the two countries have signed an intergovernmental agreement to proceed with plans for an International Lunar Research Station (ILRS). In June they announced opportunities for additional partnerships and said that they were already in negotiations with several nations.[9] China, in particular, shares the U.S. determination to assert leadership in cislunar space, recognizing its immense strategic value and seeing in it an opportunity to develop economic value by dominating a space-based economy.[10]

To fully assess China's intentions in space, it is important to understand how the PRC is advancing with extraordinary rapidity across a range of space technologies and capabilities. Notably, China is "playing the long game," focusing on the relationship between the defense sector and commercial space innovation and entrepreneurialism and leveraging the existing social commitment to hard work and national pride. Space has become part of China's "Silk Road Economic Belt," part of its plan for geopolitical and economic dominance. In short, the PRC is pursuing a global strategy to win the competition in space, building upon several broad-based approaches.

The first of these is via military-civil fusion (MCF). MCF is focused on building pathways between the traditional defense industrial base and the commercial sector, with the goal of increasing the flow of information, technology, and people between the two. This is not a new development in China – or for that matter, in the United States – but it has new impetus under the current government.[11] According to testimony provided in 2019 by the U.S.-China Economic and Security Review Commission, in 2013 there was virtually no commercial space sector in China. In 2014, the government announced that it would allow the flow of private capital and companies to enter the previously sequestered space sector. In 2016, the Central Politburo elevated MCF to a national strategy. In 2017, President Xi Jinping established a commission for Integrated Military and Civilian Development emphasizing technology development – particularly dual-use technology. Later in 2017, the People's Liberation Army declassified almost 3000 patents, releasing them into the public sector, signaling a new development in the interaction between the PLA and the commercial sector. Also in 2017, the "13th Five Year Plan Sci & Tech Military-Civil Fusion Development Special Plan" named human spaceflight as a MCF "mega project."[12] By 2018, the top seven state funds investing in MCF industries had over $56B in capital. Combined with capital from venture markets, the Chinese government is pouring billions into commercial space companies as compared with just a few years ago.

While the total investment in both government and commercial space is thought to still lag that of the United States, the results are clear to see. For example, China's commercial launch industry has made rapid progress since 2015, with several companies testing advanced rocket capabilities, including fly-back boosters, suborbital flights, and advanced engine designs, including a liquid oxygen-methane engine.[13] Notably, the PLA remains deeply engaged in

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[7] TASS Russian News Agency (2020). Moon exploration projects could help Russia-US cooperation – Roscosmos. 16 May. https://tass.com/science/1157255

[8] Ji, E., Cerny, M. B., Piliero, R. J. (2020). What does China think about the Artemis Accords? The Diplomat, 17 September. https://thediplomat.com/2020/09/what-does-china-think-about-nasas-artemis-accords/

[9] Pultarova, T. (2021). Russia, China reveal moon base roadmap but no plans for astronaut missions yet. 17 June. https://www.space.com/china-russia-international-lunar-research-station

[10] U.S.-China Economic and Security Review Commission Annual Report to Congress (2019). China's ambitions in space: Contesting the final frontier (Chapter 4). https://www.uscc.gov/sites/default/files/2019-11/2019%20Annual%20Report%20to%20Congress.pdf

[11] Kania, A.B. and Laskai, L. (2021). Myths and realities of China's military-civil fusion strategy. Center for a New American Security. https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/Myths-and-Realities-of-China's-Military-Civil-Fusion-Strategy_FINAL-min.pdf?mtime=20210127133521&focal=none

[12] Laskai, L. (2019). Testimony before the U.S.-China Economic and Security Review Commission, 25 April. "China in Space: A Strategic Competition?" https://www.uscc.gov/sites/default/files/Lorand%20Laskai%20USCC%2025%20April.pdf

[13] Curcio, B. and Lan, T. (2018). The rise of China's private space industry. Space News, 25 March. https://spacenews.com/analysis-the-rise-of-chinas-private-space-industry

guiding technical development, particularly those capabilities that it sees of benefit to it. Further, the personnel and relationships between the commercial space sector and the state defense sector are also deeply intertwined.[14]

A second means by which the PRC seeks to compete with the U.S. is taking shape through a long-term, multi-pronged strategy that exploits weaknesses in the U.S. space industrial base, in our glacial pace of acquisition and procurement, and of the stove piped nature of our national agencies. We have reached the point where a whole-of-government approach to space, as intended to be implemented via the National Space Council among other mechanisms, is crucial to our continued competitiveness and leadership. This is particularly true regarding protecting the space industrial base and the emerging entrepreneurial sector, both of which are vulnerable to malfeasance and disruption – the latter clearly illustrated by impacts of the COVID-19 pandemic. In Q&A during a hearing[15] on competition with China in space before the U.S.-China Economic and Security Review Commission, Mike Gold pointed out the PRC thinks about markets strategically, while the U.S. does not. China has an industrial policy organized around state objectives. The U.S., with its focus on free markets, does not.

The 2019 Report to Congress of the U.S.-China Economic and Security Review Commission pointed out the need for a comprehensive, wholistic perspective regarding China's competitive interests in space.[16] A recent report of a workshop in early 2019 co-sponsored by the Air Force Research Laboratory (AFRL) and the Defense Innovation Unit (DIU) detailed a methodical, intentional approach that includes deliberate co-mingling of state-owned entities with commercial space companies. The key elements of the strategy were identified as follows:

- "…theft of intellectual property combined with a concerted and effective drive to create organic, national expertise across key space science and technology areas;
- direct integration of state-owned corporations and their technologies with commercial, space startup-companies;
- penetration of American companies to obtain and further exploit U.S. technology or to influence those companies in a direction that serves China's domestic space priorities;
- investment in the U.S. space industrial base via front companies and multi-level off- shore accounts to facilitate early venture technology surveillance, infrastructure access and control of developing space capabilities and intellectual property;
- obtaining vertical control of the key space capabilities' supply chains or control of sufficient elements of those supply chains to influence space capabilities development in their favor;
- predatory pricing of space capabilities or elements of key space supply chains to control or dominate the market; and
- use of state-sponsored venture capital, finance, and market control mechanisms to surveille U.S. technology, interdependencies, business model innovations and other advanced concepts. "[17]

Congress has responded to these activities most recently through the National Defense Authorization Act of 2020, which calls for the President, in consultation with the National Space Council, to develop "…a strategy to ensure the United States can effectively compete with other national space programs, maintain dominance in the emerging commercial space economy, and has market, regulatory, and other means available to address unfair competition from the PRC…" and also "…a plan to strengthen and streamline cooperation with international allies and partners in space."[18] However, additional action is needed to support the industrial base and by extension U.S. civil and commercial space activities it supports.

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[14] Lee, T. A. and Singer, P. W. (2021). China's space program is more military than you might think. 16 July. Defense One. https://www.defenseone.com/ideas/2021/07/chinas-space-program-more-military-you-might-think/183790/

[15] U.S.-China Economic and Security Review Commission (2019). "A hearing on China in space: A strategic competition? 25 April. https://www.uscc.gov/sites/default/files/2019-10/April%2025%202019%20Hearing%20Transcript.pdf

[16] U.S.-China Economic and Security Review Commission (2019). Report to Congress. https://www.uscc.gov/sites/default/files/2019-11/2019%20Annual%20Report%20to%20Congress.pdf

[17] Cooley, T., Felt, E., and Butow, S. J. (2019). State of the space industrial base: Threats, challenges, and actions. 30 May. Air Force Research Laboratory and Defense Innovation Unit. https://cdn2.hubspot.net/hubfs/4653168/AFRL_DIU_Report_State_of_Space_Ind_Base_30May2019_Final.pdf

[18] U.S. Congress (2019). National Defense Authorization Act of 2020, Pub. Law 116-92 (20 December). https://www.congress.gov/116/plaws/publ92/PLAW-116publ92.pdf

The role of the commercial sector in advancing U.S. leadership and global relationships

As mentioned, several times, the primary strategic objective of NASA's activities in human exploration as seen from a national lens is geopolitical. However, that is not the only objective. In a previous appearance before the Aviation and Space Subcommittee of the Senate Commerce Committee in 2019, I opined that "United States leadership in space depends upon establishing a foundation that provides other nations and a nascent space-based economy with security and assurance regarding our national intentions and long-term commitment to aspire, inspire, and achieve – in short, to *lead*."[19] My viewpoint has not changed; however, my sense of urgency has.

Regarding low Earth orbit (LEO), which will be the focus of the rest of this testimony, NASA plans to transition activities now onboard the ISS to one or more commercial platforms in LEO, as well as some intended for deep space to the lunar orbiting outpost known as Gateway. In LEO, effecting this transition successfully requires closing the gap that now exists between public investment (NASA and the ISS National Lab) and revenue generation sufficiently to lead private investors to fund new orbital facilities for both public and private use. In turn, this requires hardware developers to create a portfolio of services attractive to a robust group of customers. In the case of Axiom, this includes first offering qualified customers the opportunity to fly to the ISS – establishing the procedures and agreements necessary to develop joint operations with NASA as well as conducting science and research - and later to Axiom's own modules while attached to the ISS. This in turn will lead to astronaut missions with a full complement of activities onboard Axiom station, on a commercial basis, once it detaches from the ISS.

To help visualize the latter, here is a quick video showing the assembly sequence:
https://www.dropbox.com/s/z1s1paok8z8frax/Assembly%20Sequence_stills.mp4?dl=0

Axiom's first private astronaut mission to the ISS is scheduled to fly in January of 2022, less than 6 months from now. Although he is not representing his country as a professional astronaut, one member of the first mission crew is an Israeli national and former Israeli Air Force fighter pilot who founded an investment firm that targets companies whose intention is to generate positive, measurable social and environmental impact alongside a competitive financial return. A close friend of Ilan Ramon, a member of the STS-107 crew who perished during the breakup of the shuttle Columbia in 2003, he will be conducting research onboard the ISS that is funded in part by the Ramon Foundation. A second member of the crew – which will be commanded by Michael Lopez-Alegria, a 4-time shuttle astronaut and former commander of the ISS – is a Canadian philanthropist and investor. Together with a third crew member and pilot who is American, all of the crew will be conducting research during their flight, bringing international payloads in through the ISS National Lab and opening the door to future missions with professional astronauts and researchers from other countries. Other commercial companies such as Nanoracks, Made In Space/Redwire, and others have also developed their customer portfolios to include international customers.

NASA, and by extension the U.S. space companies serve as a vehicle of U.S. "soft power", shaping favorable behavior and outcomes among foreign entities, customers, and over time, competitors who do not operate according to American laws and values. American companies understand, rely upon, and promote protection of intellectual property, fair exchange, mutual respect, and enhancement of customer experience. Commercial partnerships with nations, institutes and firms abroad can also provide a means for countries to "bootstrap" into a human spaceflight or space science program, working with American companies to develop science and engineering initiatives supporting space activities, establishing long-term relationships. In the case of the ISS, increasing the number and duration of these relationships strengthens the viability of commercial companies offering services in LEO, enabling NASA to eventually transition off the ISS and turn its full attention to deep space with the assurance that its needs and those of its partners will continue to be met.

It should be noted that this is not a "new" phenomenon; American businesses have played a crucial role in establishing relationships with other countries in a variety of sectors – not just space – and have frequently engaged in diplomatic initiatives and helped to deepen international ties. In space, all this proceeds from existing partnerships with NASA and is expanding to incorporate other sectors and customer bases over time.

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[19] Dittmar, M. L. (2019). Testimony before the Senate Commerce, Science and Transportation Committee Subcommittee on Aviation and Space, 9 July (p. 2). "NASA's Exploration Plans – Where We've Been and Where We're Going." https://www.commerce.senate.gov/services/files/19109A37-22BF-4268-9E5C-553880A435BE

The long-standing partnership between the government and commerce to promote American values and engage with other nations rests upon certain principles, however, including fair competition. At present, both Russia and China are competing with the United States by subsidizing launch costs and access to the Russian segment of the ISS and to Tiangong, the Chinese space station, respectively. Recently, a U.S. commercial company, Nanoracks, revealed that it had lost a commercial customer to the Chinese station for the first time.[20]. These developments threaten revenue sources for commercial space companies as national programs enter the commercial market with disruptive effect. Mechanisms to address unfair practices exist and have been used effectively in the past (for example, the 1993 agreement between the Russian Federation and the U.S. regarding commercial launch services, which enabled the Russians to enter the market without upsetting normal competition)[21], however they must be prioritized by the U.S. government that recognizes the impact of such practices to the growing space economy and to America's leadership in space.

The PRC certainly recognizes the power of utilizing space activities – especially human spaceflight – to enhance national prestige and deploy soft power. To this end the Chinese have recently announced plans to fly 1,000 payloads on the Tiangong as it continues construction of the station.[22] In 2018, the PRC announced an agreement with the United Nations to "develop the space capabilities of United Nations Member States via opportunities onboard the CSS" (China Space Station)[23]. Since that time nine experiments have been selected, with more in the pipeline.

Constancy of Purpose: Clear Policy Objectives and Strategy Should Drive Acquisition Approach

In LEO, NASA, and by extension its commercial partners and emerging companies aspiring to operate in orbit, are facing uncertainty. Plans to transition off the ISS at the end of its life requires clearly stated objectives, realistic timelines with milestones, and a firm commitment that has not been adequately communicated to date. In Axiom's case, the competitively sourced award that provides the company with exclusive access to begin attaching modules to the ISS by 2024 opens the door to a phased transition of U.S. government payloads, commercial or international payloads to Axiom once the modules are operational. However, Axiom's success - and that of other providers - would be greatly enhanced by a publicly released transition plan and "date certain" for ceasing operations on the ISS, developed in tandem with the international partners in the program. The date should be far enough in the future that it enables NASA to complete currently understood work but not so far that it exacerbates existing uncertainty.

Any such plan should begin with clear objectives. At present, NASA is describing objectives in terms of hardware development in its new "Commercial LEO Destinations" program, adopting the same acquisition strategy that worked for its Commercial Orbital Transportation System (COTS) program and eventually for the Commercial Crew Program. There are several differences between the circumstances that gave rise to COTS over a decade ago, however, and those in low Earth orbit now. First, COTS was able to leverage an existing market for launch services that had developed and diversified over 50 years to include a substantial customer portfolio in both government and commercial sectors. Secondly, COTS was set up to provide cargo and later crew conveyance (under "Commercial Crew Program") that was well understood, the need for which was communicated early in the program.

In LEO, neither of these conditions obtain. While hardware development is well-understood, there is no diversified market to leverage, and NASA has yet to clearly define its needs after the ISS ends. The assumption that the same procurement approach that worked for COTS – in very different circumstances, where the market is just now emerging – is the best model for the CLD program, is questionable.

Furthermore, other than to ensure one or more platforms are available after the ISS ends, it is unclear what objectives NASA is trying to meet on behalf of the nation. Clear policy direction is needed. For example, in my

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[20] Foust, J. (2021). China's space station emerges as competitor to commercial ventures. Space News, 5 August. https://spacenews.com/chinas-space-station-emerges-as-competitor-to-commercial-ventures/

[21] Office of the U.S. Trade Representative (published in the Federal Register, March, 1994). Text version of the Federal Register notice is available at: https://www.govinfo.gov/content/pkg/FR-1994-03-10/html/94-5498.htm

[22] David, L. Can the U.S. and China cooperate in space? Scientific American, 2 August. https://www.scientificamerican.com/article/can-the-u-s-and-china-cooperate-in-space/

[23] United Nations Office for Outer Space Affairs (2018). United Nations and China invite applications to conduct experiments on-board China's Space Station. http://www.unoosa.org/oosa/en/informationfor/media/2018-unis-os-496.html

view an important national objective is to counter potential Chinese hegemony in low Earth orbit. If Congress would authorize LEO programs with this goal in mind, then NASA's acquisition approach should reflect this, using mechanisms that balance NASA's evolving role and needs in low Earth orbit with the risks, benefits, and management practices best suited to meet U.S. geopolitical interests.

At present, it is unclear that the current acquisition approach reflects a systematic strategy addressing higher order objectives – or indeed, what these objectives are. This is a critical point, because the consequences of these decisions have tremendous implications for the future of U.S. human spaceflight in low Earth orbit, and possibly beyond. Clear objectives and deliberate strategy must come first and should guide the acquisition approach – not the other way around.

A similar, systematic approach should be reflected in the next iteration of the ISS Transition Plan called for in the NASA Authorization and Transition Act of 2017. It is well understood that any transition plan will be a work in progress, iterated upon as circumstances continue to evolve. However, objectives and a strategy for meeting them is every bit as critical as the tactical "transition" plan (of which acquisition is a part.)

The same can be said for resources. Whatever the objectives, strategy and tactical aspects of an ISS Transition Plan may be, adequate budgets available on a consistent basis are critical to meet objectives. The practice of relying on Continuing Resolutions (CRs) in lieu of regular order and budgets passed on time creates uncertainty and increased risk of failure. Unnecessary risk is beyond frustrating: It poses a threat to U.S. competitiveness and the ability to continue a permanent U.S. presence in LEO after the ISS program ends.

Whither Market Development in Space?

NASA is not an economic development agency. We should not expect it to act as such, either. The space agency's core competencies revolve around science, exploration, education, and technology as well as hardware development. If the U.S. government is serious about statements made in past years across the Congress to achieve a vibrant, commercial space sector operating in low Earth orbit and beyond, a conversation should be had about ensuring that appropriate economic goals and the means to achieve them are enshrined in policy. The responsibility to organize and foster growth of the commercial space sector should be housed within a designated place in our government that is appropriately resourced and staffed with the requisite expertise. The roles and experience of the Department of Commerce make it the obvious choice. Bearing in mind the sense of urgency, informed must be made in the immediate future that would help guide NASA regarding implementation, lest we risk falling behind China as well as other nations.

In LEO, hardware development is reasonably well understood. Both industry and NASA believe that the private sector is ready to develop next-generation orbital platforms. In Axiom's case this confidence is shared by capital markets. As mentioned at the beginning of this testimony, Axiom is developing its station entirely on investor funds and projected revenues from services, contracting with NASA to provide data and insight as the project proceeds. However, Axiom and any other company providing services in LEO, now or in the future, are dependent upon sufficient demand to close their business cases. If there is not sufficient, sustained, and growing demand, then the very companies the U.S. is depending on to assure U.S. presence – and soft power – in low Earth orbit, may fail. New entrants who bring innovation to the space ecosphere know that they must generate demand or fail. Suppliers who support the entire aerospace and defense sector rely upon sustained demand – indeed, this is one of the most important aspects of government programs. If suppliers fail, then the U.S. may have to look overseas for production. In the case where overseas production is critical to U.S. industry – as we are now seeing in the IT and telecom sectors – threats to U.S. security emerge. The same is true in space.

While governments cannot create markets, NASA can fund and conduct research that is too costly, risky or difficult for industry to undertake and provide the results to industry for use in engaging with customers. Businesses, in turn, are responsible for developing customers. In LEO, policy objectives that are beneficial to both the U.S. government and to industry - engagement with international countries and business, deployment of soft power by American industry, encouragement of new entrants into space technology and services, continued investment by capital markets, sustained U.S. presence in orbit around the Earth after the ISS ends – as well as other objectives I have not discussed such as using LEO platforms to create and enhance education and diversity programs to develop

America's next generation of scientists and engineers – all depend on sufficient demand to sustain commercial platforms.

Actions the government can take: Recommendations

- Utilize the regular order for negotiating and passing Appropriations Acts, avoiding the use of CR's and other stop-gap funding measures that increase uncertainty and negatively impact NASA's ability to pursue policy and programmatic goals.

- Establish clear policy goals for LEO (and beyond). As part of this, consider whether the time has come to make market development a legitimate aim of space policy, and whether the Department of Commerce might lend better focus and expertise to that effort. This discussion should consider the changing nature of NASA's role. When NASA can buy a service from the market, it will act only as a customer. When NASA must engage in development, it should do so with a very deliberate, objective-based strategy that may include not only whether a service is available, but whether purchasing from the market is in accord with national goals. In neither case, however, should NASA be expected to exercise oversight of the market.

- Formalize policy goals in another NASA Authorization Act. In the recent past, NASA Authorization Acts such as those in 2005, 2008, 2010 and the NASA Transition and Authorization Act of 2017 called for international and commercial partnerships in the exploration of space. "Constancy of purpose" as reflected in the Acts has been of great benefit in assuring program stability. Equally important, Authorization Acts send a signal to the international community of the intent of Congress to continue to assert U.S. leadership in space – a signal that is important not only to our allies, but to those who do not wish us well.

- Encourage NASA to deliver a transition plan for the ISS that establishes clear objectives, working milestones, schedule, clarity regarding its own needs beyond the life of the ISS, in accord with Section 303 of the National Aeronautics and Space Administration Transition Authorization Act of 2017[24]. In addition to the requirements specified by that Act for the plan, NASA should also discuss its role and rationale throughout the transition period in meeting national objectives (including geopolitical ones) as well as its own. Ideally, this rationale should drive, rather than be driven by any given acquisition approach.

- Recognize that both Russia and China are determined to achieve global leadership in space, and that the PRC has embarked upon a long-term, multi-tiered national strategy aimed at success. This strategy includes MCF and a long-term view of markets with deliberate efforts to undermine the U.S. industrial base and to "buy-into" U.S. entrepreneurial efforts for the purposes of transferring technology and/or expertise. Consider an interagency process, perhaps coordinated by the National Space Council or the National Security Council, to detect and deny such efforts early.

- Support U.S. commercial entities by adopting a "light touch" regulatory regime whenever possible.

- Shift U.S. Government investment in LEO to a more balanced approach that is less on hardware development and more on conducting research that may be useful in establishing demand while ensuring that U.S. commercial companies and their international and domestic customers have access to the ISS in the interval between now and ISS end of life (EOF). Specifically:

    (1) Reduce uncertainty (see above recommendation about an ISS transition plan) and avoid abrupt changes in policy that disrupt business plans and customer relationships. Recent examples of this include the NASA commercialization policy, and more recently a review by NASA of the existing policy that enables American companies to fly payloads of their international customers via the ISS National Lab, which stopped payload processing for weeks. Such abrupt changes negatively

[24] U.S. Congress (2017). National Aeronautics and Space Administration Transition Authorization Act of 2017 (Pub. Law 115-10, Section 303). 21 March. https://www.congress.gov/115/plaws/publ10/PLAW-115publ10.pdf

impact the ability of companies to build demand for their services and undermine the role of American businesses in a competitive landscape (encouraging migration of those customers to Tiangong), thereby creating additional risks to the NASA plan to transition LEO to commercial providers, which is in turn the lynchpin of the U.S. government's policy objective to maintain U.S. presence in LEO in perpetuity.

(2) Fully utilize the ISS as a platform for commercial development during this interval, encouraging commercial research, development, and use across diverse sectors to facilitate the process of growing market demand. This should include areas such as entertainment, marketing, private and professional (national) astronaut missions. Commercial use should be balanced with the needs of researchers and government agencies, but with the recognition that the clock is ticking regarding development of demand needed to close the gap between government investment in public-private partnerships, investor funding, and revenue generation.

(3) Consider establishing an interagency process to look at the economic development of low Earth orbit in a holistic way, focusing on how government money is spent to encourage and possibly incentivize innovation and entrepreneurship. "Hope is not a strategy"; rather, as a nation we must think and act deliberately regarding the intersection of markets and space policy.