

**INTERNATIONAL COLLABORATION
AND COMPETITION IN SPACE: OVERSIGHT OF
NASA'S ROLES AND PROGRAMS**

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND SCIENCE

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED SEVENTEENTH CONGRESS

FIRST SESSION

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED SEVENTEENTH CONGRESS

FIRST SESSION

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INTERNATIONAL COLLABORATION AND COMPETITION IN SPACE: OVERSIGHT OF NASA'S ROLES AND PROGRAMS

THURSDAY, OCTOBER 21, 2021

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

The Committee met, pursuant to notice, at 10:06a.m., in room SR-253, Russell Senate Office Building, Hon. John Hickenlooper, Chairman of the Subcommittee, presiding.

Present: Senators Hickenlooper [presiding], Cantwell, Blumenthal, Luján, Lummis, Wicker, Cruz, and Moran.

OPENING STATEMENT OF HON. JOHN HICKENLOOPER, U.S. SENATOR FROM COLORADO

Senator HICKENLOOPER. The Subcommittee on Space and Science will come to order. Today marks this subcommittee's second hearing examining this, today, U.S. leadership in space. Timely and critical discussion—really timely and critical discussion, following recent launch of advanced Chinese aircraft.

We all recognize that NASA is a key agency for a number of programs, but especially important to civil and commercial space sector, enabling us to manage our international relationships in space. Congress last authorized a NASA authorization bill in 2017. We are absolutely thrilled that President Biden has confided in Senator Nelson and designated him to lead NASA, as the administrator. Together, hopefully in close cooperation, we can accomplish national goals within this, what we call, the last frontier.

Dating back into the Cold War, space competition was primarily between Americans and Soviets. Today, 40 nations have a space agency of some sort. Competition also exists between commercial space companies from a number of different nations.

The hearing today will examine several critical issues facing domain. One, how do we ensure the Artemis program remains competitive, on budget, on schedule, so that lunar landings can become a future reality that we can schedule with confidence? Are we going to be able to have spaceships—or space suits developed in time? The Artemis program is crucial to maintaining, what I think of as, the international confidence in America's ability to leader—to be a leader in space.

The next question, is how do we ensure NASA's long-term continuity of purpose, make sure that it is supported with sufficient

appropriations by Congress, and can transcend Presidential administrations, so that we can get to secure funding that, not just this country, but the world will recognize as continuity?

Another question we will address is, is the U.S. future in low Earth orbit after the International Space Station, the ISS? The annual costs, now, is approaching almost \$4 billion annually, just in operations. There are another commercial outposts under development, but there are still questions about how this will all shake out.

We are also going to look at how Space Traffic Management, STM, impacts U.S. missions in LEO, low Earth orbit. How do we mitigate orbital debris to make sure that we have sustainability in our commercial space industry? This subcommittee is going to have to develop new legislation to—to actively remediate some of the debris that is already up there. Which brings the questions, again, of how does space exploration and research get accomplished? How do we bring nations together in common purpose? How do we strengthen science, accelerate innovation and discovery?

Senate passed NASA reauthorization in the bipartisan U.S. Innovation and Competition Act, USICA—although I still prefer the Endless Frontier Act.

Senator WICKER. Here, here.

[Laughter.]

Senator HICKENLOOPER. The Space and Science Committee will continue developing upcoming legislation to support NASA missions and make sure that we find that continuity of funding. I am delighted to welcome the panel. The Honorable Jim Bridenstine, former NASA Administrator under the Trump administration, former U.S. Representative from Oklahoma.

Dr. Mary Lynne Dittmar, from the Coalition for Deep Space Exploration. Someday I want to be associated with a coalition for deep space exploration. She served as Senior Policy Advisor for the ISS National Laboratory.

Mr. Mike Gold, of Redwire Space, former Associate Administrator for Space Policy and Partnerships at NASA.

And Dr. Patricia Sanders, Chair of the NASA Aerospace Safety Advisory Panel, former Executive Director of Missile Defense Agency.

I want to thank each of you for taking the time out of your busy schedules to join us here. I want to make sure that the conversation we have takes advantage of all of your diverse experiences and perspectives. I'm looking forward to the conversation.

Now, I will turn it over to Ranking Member Lummis for her opening comments.

**STATEMENT OF HON. CYNTHIA LUMMIS,
U.S. SENATOR FROM WYOMING**

Senator LUMMIS. Well, thank you, Mr. Chairman. It is so nice that we finally get to do this hearing. We were hoping to do it in Colorado Springs in August, and it would have been so nice to be in your beautiful state, then. But I am so delighted that we are getting to do this now. This is such a distinguished panel of witnesses and there is so much to learn for policymakers, and we rely so heavily on you to brief us, guide us, and support our efforts to sup-

port our space mission. So, thank you so much. I am so glad you got over your COVID and we are all back together again.

This group of panelists is so exceptional. So, thank you for your flexibility in working with us through the change and your willingness to be here today to speak with us. Your expertise is something we just welcome. So, very, very nice to have you here today and finally get to do this.

NASA has a long history of working with international partners and, of course, that is by design. The legislation that created NASA called for it to pursue cooperation with other nations and groups of nations. Our international partnerships have grown since NASA's creation and the success of the International Space Station speaks to the ways in which cooperation in space has strengthened our relationships on Earth. In fact, the first time I got to go to Russia—to Moscow, it was for the purpose of meeting with U.S. astronauts and Russian astronauts, who were there working together in Russia. Even in times of tension on Earth, American and Russian astronauts were able to work together at the International Space Station.

Now, five space agencies are part of the ISS project. The ISS will soon reach the end of its life span, but it cannot mark the end of our partnership. New opportunities and challenges await us, as we step in the era of the Artemis program and the Lunar gateway and eventually, human exploration of Mars.

While we embark on new adventures, we, along with every other spacefaring nation, must use them as opportunities to manage the challenge of space debris. We must work together to ensure we both remove orbital debris, and design equipment and policies to help cut back on the potential for orbital debris. I am encouraged by efforts in the private sector to step up and help with this problem, and I intend to work with my colleagues on solutions at the Congressional level to help tackle the issue.

There are other challenges, as well. Space is not only an area for collaboration. Competition in space looms large and we must work to avoid a cold war-style Space Race. Unfortunately, it seems some countries are less committed to this than others. Some nations do not seem interested in differentiating between military and civilian space operations. This week, we heard reports that over the summer, China launched a hypersonic glide vehicle that circled the Earth in low orbit and reentered the atmosphere. China's labeling this test of a nuclear capable weapon a "routine test of a space vehicle" underlines their unwillingness to separate military and civilian activities in space.

I suspect this trend will continue and it will become increasingly more difficult for the U.S. to view advancements made in space by China as anything other than a threat to our security. To that end, the United States must continue to pursue policies that make it the preferred partner for all other spacefaring nations and help to set norms that promote access, the sharing of scientific advancement, and neighborly attitudes toward other countries' assets in space.

So, I am very much looking forward to this hearing and learning from our distinguished panelists about these issues. I am sure we are going to learn so much today that I cannot wait to hear what you have to say. Thank you, Mr. Chairman. I yield back.

Senator HICKENLOOPER. Thank you, Ranking Member Lummis. Appreciate having Wyoming and Colorado run this committee. You have been a great partner and continue to be a great partner.

Now, I will recognize Ranking Member Wicker for his opening comments.

**STATEMENT OF HON. ROGER WICKER,
U.S. SENATOR FROM MISSISSIPPI**

Senator WICKER. Thank you, Mr. Chairman. Senator Lummis, I came down with COVID the same time as Senator Hickenlooper.

[Laughter.]

Senator WICKER. I hope you are just as delighted that I got over it.

[Laughter.]

Senator WICKER. I guess it just goes without saying. As a matter of fact, Senator Hickenlooper, I found out how, finally, to get on the first few minutes of NBC Nightly News and that is to have an Independent and a Republican and a Democrat all come down with COVID on the same day.

[Laughter.]

Senator WICKER. This morning's hearing will address topics related to international cooperation and competition in outer space. Decades of U.S. cooperation in space, with other nations, has enhanced America's leadership in science and technology, and strengthened ties with international partners. We want to continue that.

NASA has been involved in thousands of cooperative activities with over 100 countries, including 20 years of sustained human presence aboard the International Space Station. Even during the height of the cold war, as Senator Lummis mentioned, space proved to be a rare area of cooperation between the U.S. and the USSR.

Although space can bring nations together, the space domain has become increasingly competitive. Today, we are in a new space race with China. Beijing is seeking to secure both the lunar high ground, and low Earth orbit, LEO, to supersede the U.S. as the dominant space power. This year, China launched the first module of its space station and is eagerly soliciting international partners.

Cooperative endeavors with other nations and the private sector will play a key role in helping America confront China's space challenge. NASA's Artemis deep space exploration program has already been critical in promoting U.S. leadership and cementing our alliances in space. Artemis will return astronauts to the surface of the moon and build—

Senator HICKENLOOPER. Here, here.

Senator WICKER. Cheers from the audience—and build a sustained presence there in preparation for future human exploration of Mars in this decade.

Rather than going it alone, the Artemis program envisions major contributions from international partners such as Canada, European nations, and Japan. In addition to relying on other nations, Artemis will also employ unique capabilities offered by commercial space companies for key aspects of its mission.

I look forward to hearing from our witnesses today on both the opportunities and the challenges NASA faces in competing against

China, as well as carrying out the international commercial partnerships for Artemis, the International Space Station, and other programs.

NASA needs clear Congressional reauthorization and direction to keep Artemis on track and support other cooperative efforts. And I am delighted to report to you all that this is a priority of the Chair of the Full Committee, and I appreciate her efforts in this regard. The Committee's NASA Authorization Act, which passed as part of the Endless Frontier Act, includes many provisions to accomplish those goals. I am proud to have worked with Senator Cantwell and others on the NASA bill. I hope my colleagues in the House will work with us. Let us find a space vehicle to attach that NASA bill to and get it signed into law, at this pivotal time.

Thank you, Mr. Chairman.

Senator HICKENLOOPER. Thank you very much, Senator. We will have to find a space vehicle for the attachment.

Now, we can hear from out witnesses with their opening statements. I think we can start with the Honorable Jim Bridenstine.

**STATEMENT OF HON. JIM BRIDENSTINE,
FORMER NASA ADMINISTRATOR**

Mr. BRIDENSTINE. Thank you, Chairman Hickenlooper, Ranking Member Lummis, Ranking Member Wicker, and Senator Moran. It is great to be back in Washington, DC, testifying before this committee.

I want to thank this committee for the strong, apolitical, bipartisan support that this committee has shown to NASA and its agenda. I think that is critically important for a lot of reasons. When you are doing projects that take multiple decades in nature, we have to have continuity of purpose. Continuity of purpose requires Congress to engage, be involved, and support the efforts of NASA in an apolitical, bipartisan way. And when that happens—this is the most important thing. When that happens, we are able to achieve international cooperation in a way that is often very difficult.

So, when you think about the history, you think about the vision for space exploration, the Constellation program, and the cancellation thereof. We think about the Space Exploration Initiative back in the 1990s and the cancellation thereof. When these things happen, it has—it has an effect on our international partners that is chilling. And they then choose, in many cases, not to partner with us and that is a problem.

But what I will say is that, if you look back at 2017, we passed the NASA Transition Authorization Act in bipartisan way, House and Senate. It was signed by the President in 2017. And, of course, the current NASA Administrator, then senator, came to that event, in a bipartisan way to say, look, NASA needs to have continuity of purpose. So, passing an authorization bill, in my view, is critically important. We have to have that to demonstrate to the world that we have resolve, as a Nation, to accomplish these very impressive things and to stay ahead of our competitors. So, that is, I think, probably the highest order of priority, getting that authorization passed.

Second thing I would like to say, and this is, I think, maybe even more important than the first, as when you think about the future, and that is the challenge of space debris. And Senator Hickenlooper, you nailed that right on the head. It is a big problem. And it is an even bigger problem when you think about the massive constellations that are being launched into low Earth orbit, even right now.

So, we think about how the FCC licenses these constellations. They look at a constellation—let us pretend it is 15,000 satellites large. And they say, there is a certain percentage of those satellites that are going to not be able to maneuver and not be able to reenter. In other words, they become derelict. And they say—they apply a 1.5 percent chance for every satellite. So, if you launch 15,000 satellites that is 225 satellites that are derelict. And then, they say there is an aggregate collision risk for those 225 satellites, and they came up with a probability for a 15,000-satellite constellation that said there is a 1 in 44 chance of a collision in space. Here is the fundamental flaw with that. It only includes derelict satellites, which are 1.5 percent of the satellites. There is still a probability of collision for the other, you know, 98.5 percent of the thousands of constellations—satellites in that particular constellation. We do not know what that is. They have a maneuver capability—we do not know what that probability is.

But let us say there is a collision that is going to happen that is a 1 in 10,000 chance of a collision and if you maneuver, that probability goes down to 1 in a million. That is fantastic. We love that. We do not know that that is the case and so, we are licensing satellites right now, not knowing—it is a known unknown, and yet, we are still licensing the constellations, which I think is not a good idea.

But at the same time, here is what we do know. If it goes down to 1 in a million—which we do not know but let us pretend—and that eventuality happens 10 million times, that means there is going to be 10 collisions. So, if the probability goes down to 1 in a million and there are 10 million maneuvers, then there are 10 collisions. This is a—this is a mass—and by the way, I want to be clear. It goes beyond that. When we start talking about these constellations, we are only talking about satellites that we know that exist, and debris that we know that exists. For everything that we can track that is 10 centimeters or bigger, there are 10 to 100 things that we cannot track, that are equally lethal.

What I am saying is, that the challenge is much bigger than we know, but we know that we do not have any idea what that risk is. And yet, we are still launching these—and licensing these massive constellations without knowing what the risk really is. And I—I am telling you, it is much higher than what the FCC is currently predicting.

I will also tell you, on the 1.5 percent derelict satellites, it is—that is a—that is not right. It is going to be higher than 1.5 percent that cannot reenter.

Finally, I will say this. Just, I think it was, last night, somebody here can testify, Rwanda just filed for a constellation of 327,000 satellites into low Earth orbit. Recently, you had Spain file for a constellation that is 70,000 satellites. And of course, right now, we

have got Starlink, and Kuiper and we have got OneWeb. We have got the European Union; they want to have their constellation. China, Russia—they all have these massive constellations for low latency, high throughput communications which, by the way, I support. But we do not want to destroy space in order to achieve it, which is what I am concerned about. The challenge is that there are—there are things that we absolutely know that we do not know, and we are still moving forward at a very rapid pace. And it is a very big concern, in my view. Orbital debris is number two.

And I know that I am running out of time here quickly, but two other things that are important. I think it was mentioned by a number of senators, we have to have a replacement for the International Space Station. We love it. I know this committee passed an authorization bill out of the Senate that actually has it, no kidding, at, you know, going to 2030. That is a good thing. I would also tell you that there is no guarantee it is going to last that long and China just launched a brand-new space station. That is another big problem. We cannot cede—we do not know the value of microgravity at this point, but what we do know is that, if we do not—if we lose the ISS and do not have a replacement, we are going to be in trouble.

Third thing, I think it is important to have two providers for the Human Landing System.

And with that, I will yield back. Thank you, Senator.

[The prepared statement of Mr. Bridenstine follows:]

PREPARED STATEMENT OF HON. JIM BRIDENSTINE, FORMER NASA ADMINISTRATOR

Chairman Hickenlooper, Ranking Member Lummis, and Distinguished Members of the Subcommittee,

It was my great pleasure to serve as the 13th Administrator of NASA. The men and women that serve our Nation at NASA are the best America has to offer. I would also like to commend the Biden Administration and specifically Administrator Bill Nelson for their commitment to NASA's continuity of purpose. NASA's projects are multi-decadal and even multi-generational in nature. History has testified that whimsical shifts based on administration changes result in billions of dollars wasted and limited progress as our competitors and adversaries advance resolutely. Political leaders who care about exploration, science, discovery, and American leadership must constantly work to keep NASA outside of partisan political wrangling. I worked to that end every day and Administrator Bill Nelson has been working toward the same objective.

There are three specific challenges facing NASA with which this committee can help:

1. Human exploration in low Earth orbit
2. Orbital debris mitigation
3. Redundancy in America's Moon lander

Low Earth Orbit

It is absolutely critical that Congress fund America's replacement for the International Space Station (ISS), which has had humans onboard for over 20 years. The Chinese Space Station is on orbit, demonstrating great progress, and attracting international partners. Humanity is only at the beginning of understanding the immense economic, technological, and medicinal value of microgravity and America is at risk of ceding these capabilities to our greatest competitor. Congress must not let this happen.

America's advantage is its capital markets that are funding commercial human habitation and the brilliant entrepreneurs that are putting that capital to work. While the future of human spaceflight in low Earth orbit (LEO) is commercial, the United States Government has an interest in ensuring the success and steering the direction of these capabilities. Congress needs to fund NASA's LEO commercializa-

tion efforts at \$2 billion per year. This money should be used for development and demonstration of LEO habitation as well as establishing NASA and its partners as ongoing customers of commercial LEO habitation. If Congress does this, capital markets and entrepreneurs will respond in a way that establishes America as pre-eminent in LEO human spaceflight at a cost significantly less than the ISS.

Once LEO commercialization is funded, Congress should require NASA to establish a date for the transition to new space stations with a plan to ensure there is no gap in American human spaceflight in low Earth orbit.

Space Debris Mitigation

Satellite communications are advancing rapidly and will be transformative for humanity. New constellations in geostationary orbit (GEO) are breaking records for capacity and throughput, while drastically dropping the cost per megabit. Constellations being developed for low Earth orbit (LEO) could complement these systems by delivering low latency communications allowing for applications such as tele-robotics and video gaming. Global, hybrid networks (GEO and LEO) will soon deliver additional benefits to online education, telemedicine, mobile banking, and economic opportunity for people around the world waiting to be connected.

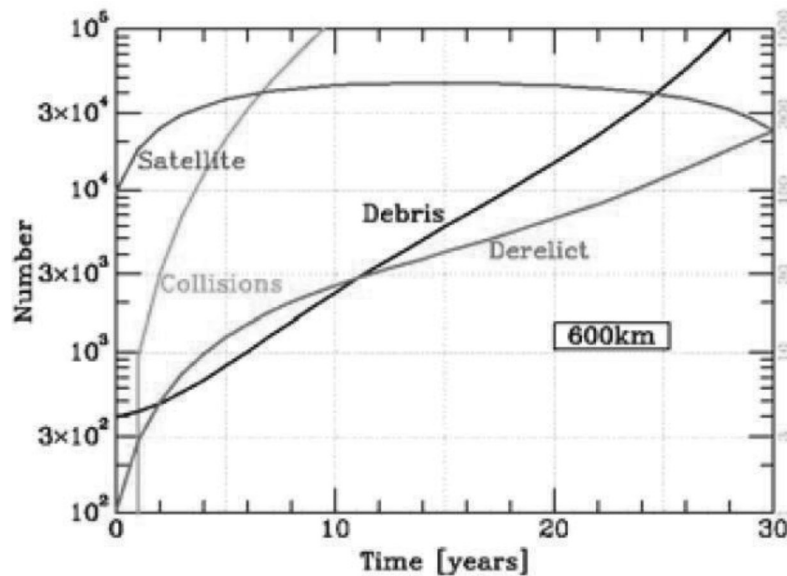
However, the U.S. government and governments around the world are failing to properly manage collision risk. If not remedied, the consequence will be losing access to space entirely, devastating not only satellite communications, but also human spaceflight, national security, weather prediction, disaster relief, climate science, and so much more.

The challenge is that we are beginning an era of large, multi-satellite constellations when FCC rules on debris mitigation apply on a satellite-by-satellite basis. Requiring a failure probability of less than 1/1000 over 5 years makes sense for a single satellite. However, if 40,000 satellites are launched into the same orbital shell, each with a probability of failure of 1/1000, there will be 40 failures on average. In short, the current requirement for low probability of failure becomes the inevitability of numerous failures.

The problem becomes much worse when considering collisions. A study by the MITRE Corporation, commissioned by the National Science Foundation (NSF), suggests that it will not be feasible to operate some of the LEO systems being planned. That study predicts the effects of a LEO system that plans to include over 40,000 satellites at an altitude of about 600 kilometers.

As shown in the following figure from that study, dramatic increases in space collisions, and new space debris, are expected within just a few years. In the longer term “satellites are destroyed [by debris and collisions] faster than they are launched.”¹

¹G. Long, The Impacts of Large Constellations of Satellites, JASON—The MITRE Corporation, JSR-20-2H, November 2020, (Updated: January 21, 2021), at 97, available at https://www.nsf.gov/news/special_reports/jasonreportconstellations/JSR-20-2H_The_Impacts_of_Large_Constellations_of_Satellites_508.pdf



The challenge increases drastically when considering that there are dozens of companies in the United States building constellations all desiring access to LEO. Additionally, China, Russia, Europe, and individual European countries have announced they will be deploying LEO constellations as well. The United States can and must take the lead on creating responsible rules that others in the international community can emulate to mitigate this growing concern.

Space situational awareness and space traffic management (SSA/STM) are important long-term requirements. However, if we don't take action now to mitigate the debris problem, there will be no need for SSA/STM. Space will no longer be accessible. I fully support the Commerce Department being responsible for SSA/STM, but given the immediacy of the problem, we need to use our current framework for mitigation.

Solution:

First, Congress needs to quickly require the FCC to approve satellite constellations based on an aggregate collision risk metric, not one satellite at a time. The FCC proposed this rule in April 2020, but it was never implemented. It was the right policy then and it is even more the right policy today.

Second, Congress must act quickly to require the FCC to define the limits on the nature and number of satellites that can exist in LEO. The FCC has said there are limits, but there has been no action.

Third, once those limits are established, there must be an effort to work with our international partners to appropriately allocate access to the highest value orbital shells. If other nations are not included in this process, they will claim the same territory with disastrous consequences. America's allocation must then be fairly distributed to companies in a way that ensures competition in the marketplace.

Finally, Congress should have the FCC analyze and report on the effects these constellations will have on launch, the International Space Station, the environment, astronomers, and future space exploration.

Artemis: America's Moon Program

NASA determined that it had insufficient appropriations to select two human landing systems for the Artemis program. Congress should appropriate sufficient funds for two human landing systems.

Dissimilar redundancy has worked exceptionally well in the Commercial Resupply Program and the Commercial Crew Program. When one contractor has a setback, the other moves forward, greatly increasing NASA's access to space and the International Space Station. This should be the approach for NASA's Human Landing System and Congress needs to fund it.

Additionally, if the goal is to eventually buy access to the Moon as a commercial service, NASA needs two providers that will compete on cost, innovation and safety. Having two providers will also incentivize the companies to get customers that are not the U.S. Government, lowering the cost to the taxpayer. As a matter of principle, the only thing worse than a government monopoly is a private monopoly to which the government is beholden. I am not suggesting that any specific contractor would intentionally act nefariously. I am suggesting that the government has an obligation to provide the right incentives to benefit the taxpayer.

Thank you for hearing my testimony. I am confident that with your leadership, NASA will continue to do amazing things for our Nation.

Senator HICKENLOOPER. Thank you, Jim, appreciate that. Dr. Dittmar.

STATEMENT OF DR. MARY LYNNE DITTMAR, EXECUTIVE VICE PRESIDENT FOR GOVERNMENT AFFAIRS, AXIOM SPACE, INC.

Dr. DITTMAR. Chair Hickenlooper, Ranking Member Lummis, and Senator Moran, Ranking Member Wicker, Members of the Subcommittee, thanks for the invitation to appear before you today. It is nice to be back in front of this committee with such a distinguished panel to discuss my thoughts on the topics of today's hearing.

I am the former President and CEO of the Coalition for Deep Space Exploration, but I am now, the Executive Vice President of Axiom Space, which is building the world's first commercial space station. So, I wish to note that while I will be discussing some of Axiom's plans as to illustrate my discussion, the positions that are presented here are my own and do not reflect the official opinion of my employer.

With that out of the way, my discussion will focus on competition—that aspect of today's hearing. It is often said that we are at an inflection point in space and while that is true, the phrase glosses over complexities, challenges, and opportunities, already pointed out, that confront us now and in the years to come.

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 that it has built in commercial space to national actors who continue to maintain laser focus on asserting their own national interests.

Axiom is the first, and so far, only company to develop a new space station destined for low Earth orbit without government funds for development, launch, or operations. Beginning by building modules that extend the functionality of the ISS, it will provide capabilities for a broad array of users—researchers, astronauts, government, international customers, and the business community. Critically, for the purposes of this hearing, it is also, in my opinion, best positioned to help challenge China's interests in LEO at the end of life of the International Space Station. And indeed, it was for that latter reason, more than any other, that I joined Axiom.

It is tremendously important for the U.S. Government to recognize and respond, with urgency, to the situation our Nation and space industry is facing. Simply put, it is China's goal to establish a leading position in the economic and military use of outer space, as they have stated publicly, for many years.

China recognizes the immense strategic value of space and intends to seize the opportunity to develop economic value, by domi-

nating a space-based economy. Space has become part of China's Silk Road economic belt, part of its plan for geopolitical and economic dominance.

In my written testimony, I refer to the U.S.-China Economic and Security Review Commission's 2019 report to Congress, which offers the comprehensive analysis of what Beijing calls its "Space Dream" and how it hopes to achieve it. China is playing the long game, make no mistake. Bolstering their space capabilities through military-civil fusion and through the exploitation of weaknesses in the U.S. space industrial base and our glacial pace of acquisition and procurement and of the stovepipe nature of our national agencies.

With regard to LEO, NASA, and by extension its stakeholders, are facing uncertainty. Plans to transition off the ISS at the end of its life require clearly stated objectives, realistic timelines with milestones, and a firm commitment that has not yet been adequately communicated. At present, NASA is describing its objectives partly in terms of continued access to LEO, envisioning hardware development under its new commercial LEO Destinations Program, using the same acquisition strategy that works so well for Commercial Orbital Transportation System, COTS, and eventually for commercial crew.

There are several differences between the circumstances that gave raise to COTS over a decade ago, however, and those in low Earth orbit now. COTS was able to leverage an existing market for launch services, that had developed and diversified over 50 years, to include an understanding of hardware development and a substantial customer portfolio in both government and commercial sectors. COTS was also set up to meet transportation needs that were communicated early in the program.

Today, conditions are markedly different. While now, as then, hardware development is relatively well understood, there is no diversified market in LEO to leverage. Not yet. NASA has yet to clearly define its needs for services after the ISS ends, nor does it plan to do so for some time.

And finally, we face a formidable competitor. At the very same time that NASA is embarking on this approach, American companies have admitted to losing customers to China as it employs strategies to undercut the U.S. commercial space sector through mechanisms such as state-backed financing that market driven companies in the U.S. cannot compete with. In my view, an important national objective for LEO should be to counter potential Chinese hegemony in low Earth orbit. Should Congress choose to authorize LEO programs with this goal in mind, then NASA's acquisition approach should reflect this. It is unclear that the same procurement approach that worked for COTS, in very different circumstances, will work now.

I want to spend just a few minutes talking about demand. Both industry and NASA believe that the market sector is ready to develop next generation orbital platforms. In Axiom's case, this confidence is shared by capital markets. In a few years, Axiom will see its modules attached to station, increasing capacity and capabilities for meaningful science and research. And I have got a quick visualization, if that is available to us to see, so you can see how that

will go. Maybe not. OK, moving on. However, Axiom and other companies providing services in LEO, now or in the future, are dependent upon sufficient demand to close their business cases. If there is not sufficient demand, then the very companies the U.S. is depending on to assure U.S. presence and soft power in low orbit may fail.

In our system, governments do not create markets. They can only serve as customers. However, 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.

If market development is to be a legitimate aim of space policy, much as it is for simple state and commerce, particularly if it is to underpin pursuit of a range of national, as well as business goals, we might also ask if NASA is the appropriate home for that policy. NASA is not an economic development agency, and we should not expect it to act as one. The space agency, that serves this country so well, has core confidence revolving around science, exploration, education, and technology.

At the same time, as a Nation, we must think and act deliberately, with regard to the intersection between markets and space policy. In my written testimony, I offer several suggestions and recommendations that the committee may consider, regarding how government may help.

It has been a pleasure and an honor to appear before you today and I look forward to answering any questions you may have.

[The prepared statement of Dr. Dittmar follows:]

PREPARED STATEMENT OF DR. MARY LYNNE DITTMAR, EXECUTIVE VICE PRESIDENT,
AXIOM SPACE, INC.

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, 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 rela-

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>

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-115SY16-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

tionships, 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

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

⁶National 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-firstsignings-of-artemis-accords>

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

⁸Ji, 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/>

⁹Pultarova, 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>

¹⁰U.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>

¹¹Kania, 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-FusionStrategy_FINAL-min.pdf?mtime=20210127133521&focal=none

¹²Laskai, 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>

\$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, sub-orbital flights, and advanced engine designs, including a liquid oxygen-methane engine.¹³ Notably, the PLA remains deeply engaged in 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, multipronged 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 hearing¹⁵ 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 surveil U.S. technology, interdependencies, business model innovations and other advanced concepts.”¹⁷

¹³Curcio, 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>

¹⁴Lee, 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/>

¹⁵U.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>

¹⁶U.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>

¹⁷Cooley, 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.

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.

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

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>

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>

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.

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

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>

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 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 ecosystem 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 2017²⁴. 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 com-

²⁴U.S. Congress (2017). National Aeronautics and Space Administration Transition Authorization Act of 2017 (Pub. Law 11510, Section 303). 21 March. <https://www.congress.gov/115/plaws/publ10/PLAW-115publ10.pdf>

mercialization 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 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.

Senator HICKENLOOPER. Thank you, Dr. Dittmar. Now, before I introduce Mr. Gold, I want to ask for unanimous consent to enter the following document into the record, an article from "Space News" authored by Mr. Gold, titled, "The Mind—" It is titled, "Mind the Gap in Low Earth Orbit". So, if we ask for unanimous consent, all in favor say aye.

[A chorus of ayes.]

Senator HICKENLOOPER. So be it.

[The information referred to follows:]



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COMMENTARY Mike Gold

MIND THE GAP IN LOW EARTH ORBIT

For more than 20 years, the International Space Station (ISS) has supported continuous international crewed operations. An entire generation has never known a world where people aren't living and working in space.

The success and longevity of the ISS is due in no small part to its international nature. Far too often, we take the ISS partnership for granted, when in fact it represents an unprecedented international collaboration that has proved that global human spaceflight cooperation is both possible and beneficial.

Moreover, for the past two decades, the ISS has proverbially and literally been an outpost on the frontier of science. More than 3,000 experiments have been conducted on the ISS in a diverse array of fields ranging from fundamental physics and Earth observation to biomedical studies and advanced manufacturing demonstrations.

Not only has the ISS supported unique science, the station has also been a singular

source of soft power for the United States. America has served as the heart and glue for the station's international coalition, enabling the U.S. to maintain its role as the world's preeminent spacefaring nation.

However, in the harsh environment of space, nothing is permanent. Ideally, the ISS could serve as a platform for innovation for another decade and NASA should leverage every bit of utility it can get out of the station for as long as it can. Unfortunately, the ISS will inevitably need to be retired, and it is incumbent upon NASA and the entire American space community to avoid a space station gap.

This has happened before, with America losing the ability to launch astronauts into space and depending exclusively on Russia for crewed transportation for nearly

a decade. This capability gap represented a holistic failure of planning and foresight that, thanks to public-private partnerships and commercial space capabilities, the nation is now starting to recover from. Yet, despite having only recently overcome a human space launch gap, the U.S. is already facing a space station gap that could be more pernicious than any other challenge that NASA has faced in the modern era.

THE PRICE OF INACTION

If the space industry and relevant policymakers fail to take robust action quickly, the U.S. will experience a crippling and lengthy space station gap. At a time when scientists are only beginning to understand the importance of microgravity research, development and manufacturing, the U.S. will lose access to low Earth orbit (LEO) and all the scientific benefits this unique environment has to offer. Additionally, America's ability to train astronauts and prepare for long-duration missions to the moon and Mars will be lost, and NASA's

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astronaut corps will shrink to a fraction of its current size.

Moreover, a space station gap will result in ceding both LEO and global leadership to China.

In April, China launched the first element of its new 66 metric ton three-module space station. China has learned from our experience with the ISS and is replicating both the capabilities of the station as well as the diplomatic and geopolitical benefits that a crewed LEO platform offers. During the next two years, China will conduct a flurry of activities to build this next-generation orbital outpost. Unless plans for an American commercial space station are executed with alacrity, this Chinese station will soon become the only crewed platform in LEO. In addition to ceding the benefits of microgravity research, development and manufacturing, as well as astronaut training to China, the U.S. will lose its role as the global leader in human spaceflight.

Space has always been closely intertwined with global politics. The Apollo era competition to land humans on the moon of course serves as the primary example of this, but the ISS's role in geopolitics potentially rivals even that of Apollo. Over the past two decades, the ISS has served as a beacon of global cooperation supporting experiments from more than 100 nations and astronauts from 18. The ISS has deepened existing relationships with longtime American allies while broadening U.S. outreach to countries that are new to human spaceflight. Additionally, under the auspices of American leadership, ISS operations, including launch activities, have been both transparent and safe.

If the U.S. cedes LEO to China, we will abandon not only science and astronautics, but also our values, leaving China to set the agenda for humanity's future in space. China will become the new global leader in astronautics and will enjoy the nontrivial political and diplomatic benefits that such a position brings. By becoming the only nation with a crewed platform in

If the U.S. cedes LEO to China, we will abandon not only science and astronautics, but also our values, leaving China to set the agenda for humanity's future in space.

LEO, China will demonstrate, in both perception and reality, that its technologies and organizational capabilities are superior to the U.S. in this vital arena.

China already weaves space into its overall geopolitical strategy, including satellites and astronaut seats in its trade agreements and treaties. China also wisely leverages space in its relationship with the United Nations and has already selected payloads that will be flown on its space station from a variety of developing countries. A U.S. space station gap wherein China has the only crewed platform in orbit will further a narrative of American decline in the face of Chinese preeminence, the results of which will harm our nation's global soft power and the perception of the U.S. and the values it stands for.

Lastly, it's important to note the devastating effect a space station gap will have on the American space launch industry. America has spent billions of dollars developing new cargo and crew systems. These programs have energized the U.S. space launch industrial base and spurred innovations that have allowed America to recapture the commercial space launch market, which had previously been lost to overseas competition. Without a space station, demand for launch services will drop dramatically, jeopardizing not only American capabilities and science in LEO, but also U.S. launch capabilities and competitiveness. The negative effects of the loss of crewed LEO operations will thereby be felt far beyond NASA and will inevitably become a nontrivial threat to national security as well.

The overwhelming cost to the U.S. of a space station gap could not be more clear.

Fortunately, the solution is equally apparent. Public-private partnerships and the rise of commercial space is transforming the space world.

Due in no small part to innovative leadership by NASA through initiatives such as the Commercial Orbital Transportation Services (COTS) program and the Commercial Resupply Services (CRS) contracts, the private sector has been able to deliver cargo and crew to LEO.

COMMERCIAL LEO DESTINATIONS

The obvious next step is for commercial firms to provide NASA with not just transportation, but a platform in LEO. A commercial space station could deliver all the benefits generated by the ISS along with renewed global outreach, enhanced affordability and continued scientific innovations. However, even with the private sector's efficiencies, designing, developing and deploying a commercial space station will require substantial time and resources.

The private sector can meet this challenge, but it cannot do so alone. As in the COTS and CRS programs, NASA has a critical role to play. Specifically, NASA must serve as a catalyst and customer for the new commercial station. The agency must do all that it can to help stimulate demand for microgravity services. This means supporting projects on the ISS now that demonstrate how the microgravity environment can be used to manufacture new substances, produce advanced technologies and develop cutting-edge medical treatments that could transform a variety of fields here on Earth.

NASA should focus its support on activities with the greatest near-term >

COMMENTARY Mike Gold

< > potential to generate revenue that could help pay for the costs of a future commercial space station.

Unfortunately, although important to both space station operations and American competitiveness, profitable on-orbit manufacturing is unlikely to develop in the near future. Therefore, NASA has an immediate and vital role to play as a sophisticated customer for a commercial space station, and the agency's Commercial LEO Destinations (CLD) project is a step in the right direction.

Over its 60-year history, NASA has been a trailblazer, not just in exploration, but also in technology investment and procurement methodology. Other Transaction Authority, which led to the rise and dominance of the American commercial space industry, was first utilized at NASA through Space Act Agreements (SAAs). SAAs were used for COTS, which garnered substantial private sector investment. Through COTS and other public-private partnerships such as the Bigelow Expandable Activity Module, NASA has expertly utilized its power as a customer to encourage outside investment. NASA purchasing systems and hardware sends a strong signal to investors and entrepreneurs who subsequently follow the agency's lead.

In regard to private sector capabilities, buoyed by private equity, SPACs and venture capital generally, the commercial space field has never enjoyed greater financial wherewithal. NASA would be wise to leverage this unprecedented period to further evolve the commercial space paradigm. Under COTS and CRS, the government paid for the private sector to develop services that the government then purchased. This model was wildly successful and saved the taxpayer billions of dollars. For activities that are within the reach of the private sector, NASA has and should continue to enter into public-private partnerships, allowing the agency to focus its resources on the frontiers of exploration and technology.



Despite past success, the existing commercial space paradigm must continue to evolve, and the next step is for the government to serve primarily as a customer. The private sector has the desire and ability to fund the development and deployment of a commercial space station.

However, for companies to access sufficient capital to field a commercial space station, NASA must lean forward as much as it can to reassure industry that it will be a robust and ongoing customer. NASA's desire to continuously fly two crew members in LEO and perform 200 investigations per year is a good start. If NASA can incorporate such a commitment into the initial CLD SAAs and potentially include additional crew and investigations in the future, such actions will position the private sector for success.

Change is inevitable, but it is also beneficial and necessary for institutions, ideas and even individuals to survive and thrive. The environment in LEO is changing and American capabilities must also change to

meet tomorrow's challenges. China is wisely investing in crewed LEO operations and making strong diplomatic overtures to build a global coalition for its space program. To avoid ceding LEO to China, the U.S. must lean into its traditional strengths, specifically, entrepreneurialism and innovation, both of which are driven by the freedom and diversity that are the twin pillars of American society.

Taking the concept of a commercial space station from idea to reality will require a concerted effort from all of us. NASA, Congress, the executive branch and industry must all work quickly and in unison. Together, we can build a bridge that will allow America to safely and successfully cross over the space station gap, on a path toward a future of peace and prosperity in LEO and beyond for the U.S. and all of humanity to enjoy. **SN**

MIKE GOLD IS REDWIRE'S EXECUTIVE VICE PRESIDENT OF CIVIL SPACE BUSINESS DEVELOPMENT AND EXTERNAL AFFAIRS.

Senator HICKENLOOPER. Now, Dr.—or Mr. Gold, the floor is yours.

Mr. GOLD. Thank you, Senator.

Senator WICKER. Perhaps we could also enter the visual that Dr. Dittmar—

Senator HICKENLOOPER. Absolutely.

Senator WICKER.—was trying to show us.

Dr. DITTMAR. Thank you, Senator Wicker.

[The visual referred to was a video shown at the hearing.]

**STATEMENT OF MIKE GOLD, EXECUTIVE VICE PRESIDENT
FOR CIVIL SPACE AND EXTERNAL AFFAIRS, REDWIRE SPACE**

Mr. GOLD. Thank you, Senator. I will speak for both myself and Redwire. My CEO is right behind me, so he can kick me if I get out of line. So, I appreciate it. Again, gratitude to our Chair, Senator Hickenlooper. I would also like to express my appreciation to Ranking Member Lummis, to Committee Ranking Member, Senator Wicker, and Senator Moran, as well as my appreciation to the talented and intrepid staff that has helped support this hearing. And again, I want to say thank you for this extraordinarily important, timely topic of international collaboration and competition in space.

We often think of space as a vacuum. The word space itself can be interpreted to mean nothing. But I prefer to think of space as everything. Space is what connects the moon to the Earth and all of us to each other. The exploration of space unites this country and the world, in a way no other endeavor can. And the desire to unite humanity is at the very heart of the Artemis mission.

Through Artemis, NASA is assembling the largest, broadest, and most diverse international, beyond low Earth orbit, human space flight coalition in history. However, assembling this unprecedented international collaboration for Artemis was neither simple nor easy. Due to the failure of every single beyond LEO, American human space flight initiative to come to fruition since Apollo, there is great skepticism among both partner and rival nations, relative to NASA's ability to sustain a program to return astronauts to the surface of the moon.

This is why, more than any other rocket engine or piece of technology, bipartisanship is the key to the success of Artemis. Without robust and ongoing bipartisan support, we will not be able to lead a global coalition to the moon, Mars, or any other destination. We cannot unite the world, if we cannot first unite here in Congress. Which is why a bipartisan NASA authorization bill is urgently needed to both reassure partner nations, and send a message of unity, of purpose to our rivals.

I want to thank this committee for already passing NASA authorization language through the Senate, as part of the U.S. Innovation and Competition Act and urge your counterparts in the House to proceed with alacrity so that the entire Congress can adopt a NASA authorization bill that strongly and explicitly endorses Artemis.

Beyond technology that we developed the Artemis, the policy surrounding the program is just as important. America must lead in developing norms of behavior in space, to ensure that the explo-

ration and development of the moon and Mars is conducted in a safe, sustainable, and peaceful fashion. While at NASA, it was the privilege of my lifetime to craft and lead the development and successful adoption of the Artemis Accords, which have now been signed by 12 countries. The principles of the Accords, such as transparency, interoperability, due regard, avoiding harmful interference, the sustainable use of space resources, and mitigating debris are the foundation that humanity's future in space should be built upon.

I hope that NASA continues to expand the family of nations that have adopted the Accords, and that the agency focuses, in particular, on bringing new partners from Africa and developing countries around the world, demonstrating that no matter how large or how modest their contributions are to Artemis, that all nations can join us in this unprecedented journey of discovery to the moon and Mars.

Closer to Earth, the International Space Station continues to represent the pinnacle of global cooperation in human space flight. We must send a clear and unequivocal message to both partners and rivals, that America will remain a leader in low Earth orbit, by extending the ISS through 2030. At Redwire Space, which is the only company to successfully manufacture items on the ISS, we are focused on leveraging the unique nature of the microgravity environment to develop new technologies and innovations that will help to bolster global communications that will heal the sick and that will feed the hungry.

Moreover, America must ensure that we do not suffer from a space station gap, which would cede the scientific, economic, and diplomatic benefits of crewed LEO operations to China. Therefore, in an upcoming authorization bill, we must provide robust support for the development and deployment, by the private sector, of a new commercial space station that will continue the legacy of the ISS, sustaining and expanding American international cooperation in low Earth orbit.

While opportunities for collaboration are many and varied, we must also not lose sight of the ongoing technological competitions in space that American can ill-afford to ignore. Specifically, the countries and companies that master orbital servicing, assembly, and manufacturing, will be the economic and national security leaders of the future. I am proud that, at Redwire, through the development of systems such as Archinaut, a satellite that literally assembles itself in orbit, we are contributing to American competitiveness in this vital arena.

However, much more needs to be done and the upcoming NASA authorization should include explicit support for Archinaut and public-private partnerships generally, that will result in even more ambitious technologies, leveraging deployable structures, robotics, and 3D printing. We can, and I believe, should engage with rival nations, including China, on norms of behavior in space, as well as benign, cooperative scientific activities, such as lunar sample swaps and sharing climate data. However, constant vigilance is the price we pay for liberty, which is why I hope the Senate will continue to urge NASA to redouble the agency support for public-private

partnerships, which are the key to maintaining American competitiveness in space.

The journey of Artemis and NASA is to the Moon, Mars, and beyond. But if we properly balance collaboration and competition, the destination will be peace and prosperity.

Thank you for this opportunity to testify and I look forward to answering your questions.

[The prepared statement of Mr. Gold follows:]

PREPARED STATEMENT OF MIKE GOLD, EXECUTIVE VICE PRESIDENT FOR CIVIL SPACE AND EXTERNAL AFFAIRS, REDWIRE SPACE

I. Introduction

Chairwoman Cantwell, Ranking Member Wicker, Subcommittee Chairman Hickenlooper, Subcommittee Ranking Member Lummis, and distinguished Members of the Committee, I'm grateful to all of you as well as your intrepid staff for the opportunity to testify regarding the vital topic of international collaboration and competition in space.

All of us in the space industry are explorers. However, we're not just exploring the depths of space, we're also exploring new international relationships and innovative partnerships with the private sector. The benefits gained from such activities creates tremendous value and is a critical part of our Nation's journey into the final frontier.

In today's geopolitical environment, maintaining and growing our international relationships in space has never been more important. The space environment challenges us in a singularly harsh manner. Space is a crucible that demands the formation of global coalitions to bear the extraordinary difficulties and risks of exploration and development. International partnerships are not just a luxury but a necessity, and the U.S. is at an inflection point where our Nation's ability to lead future global coalitions will either be bolstered and revitalized or undermined and substantively damaged.

II. Sustaining the Continuity of Artemis

In regard to beyond low-Earth orbit (LEO) human space exploration, our Nation has, unfortunately, struggled to maintain its focus. Numerous beyond LEO human spaceflight programs have been initiated by NASA only to face termination by a subsequent Presidential Administration or Congress. The Vision for Space Exploration, the Constellation Program, and the Asteroid Retrieval Mission, are just a few of the initiatives our country engaged in which did not come to fruition. This failure to sustain a beyond LEO human spaceflight strategy has not gone unnoticed by our international partners. Our colleagues in Europe, Japan, Canada, and across the world have in many ways born the brunt of our national inability to execute on a proposed vision. This pattern of inconsistency has substantively damaged U.S. credibility on the global stage and has forced partner nations to question their relationship with the U.S. in space exploration.

As the Acting Associate Administrator for the Office of International and Interagency Relations ("OIIR"), I was often exposed to this growing skepticism of NASA's ability to sustain a beyond LEO human spaceflight program. My first overseas trip upon joining NASA in 2019 was to Paris to conduct negotiations for the European Space Agency's ("ESA's") contributions to the Gateway. My enthusiasm for international collaboration was met with justifiable skepticism from our European partners about whether the Gateway and Artemis would be sustained or, like previous NASA beyond LEO human spaceflight plans, would fade away and fail due to changing political priorities and/or a lack of funding.

Despite this skepticism, the OIIR team and our State Department counterparts managed to convince not just ESA's leadership, but the Japanese and Canadian governments that Artemis would be different. My primary argument was the bipartisan support that Artemis enjoyed. At the time I pointed to support from several Democratic policymakers, including the Chair of this Committee, Senator Cantwell, for the general goals and structure of Artemis. I personally reassured foreign officials that then NASA Administrator Jim Bridenstine was keenly aware of past history, and he was making every effort possible to build a bipartisan coalition which would sustain Artemis through any future changes in leadership in the White House or Congress. As a matter of fact, I was brought to NASA by former Administrator Bridenstine specifically to build a global coalition since he viewed such international partnerships as the key to sustaining the Artemis program.

Again, despite justifiable skepticism, our international partners agreed to join us and executed binding agreements in support of the Gateway. This support was manifested by the commitment of billions of dollars of international contributions toward building hardware for the Gateway and the Artemis program. Our international partners have embraced Artemis, appropriated substantial funding, and built their own plans around our strategy. In return, the U.S. cannot equivocate, turn back, or show anything less than the steadfast commitment that our international partners have already demonstrated.

Over the course of decades during which the U.S. struggled to sustain a beyond LEO human spaceflight program, the world has changed. China now represents a capable and attractive partner which is courting even our closest allies in Europe, Canada, and around the globe. In stark contrast to NASA, the Chinese space program has enjoyed unwavering political direction and consistency relative to their lunar plans. In the eyes of many, China represents a reliable alternative partner to the U.S. that does not suffer from the vicissitudes of the American political system and is rapidly growing its space-related capabilities and expertise.

Therefore, clear and explicit support for the Artemis program has never been more vital. The U.S. can no longer afford to change direction and must continue to embrace the Artemis program in a bipartisan fashion to preserve American credibility and our Nation's ability to assemble and lead the global coalitions that are necessary to succeed in space exploration.

For all of these reasons, I applaud the Biden administration for maintaining the continuity of the Artemis program with enthusiasm and alacrity. It was an honor to serve with then Acting Chief of Staff and Senior White House Appointee, Bhavya Lal, whose outstanding leadership allowed the Agency generally and Artemis specifically to emerge from the transition, which are always difficult periods, with clarity and constancy of purpose. Moreover, your former colleague and now NASA Administrator Bill Nelson has provided strong and consistent leadership and enjoys a close relationship with the President as well as the Congress which is vital to successfully implementing Artemis.

I would also be remiss if I did not commend the bipartisan leadership of Jim Bridenstine, including reaching across the aisle to place our current Administrator on the NASA Advisory Council. Administrator Bridenstine's unflagging efforts to build a broad and deep political coalition helped to ensure the future of Artemis. I will never forget when, after participating in a Women's Equality Day event at NASA Ames, Speaker Pelosi stated her support for Artemis by instructing the Administrator to work on getting the first woman to the Moon as quickly as possible. Subsequently, Vice President Pence tweeted about the Speaker's message thanking her for the support. Such alignment between two political rivals is all too rare, and kudos to Jim Bridenstine for his efforts to bring disparate leaders together in support of the Artemis program.

Of course, this Committee and its staff has consistently served as a shining example of bipartisanship. In my various private sector positions and while at NASA, I was always grateful for the vision and unparalleled bipartisan nature of the Commerce Committee's space policies. Under both Democratic and Republican control, including during Senator Nelson's tenure, this Committee has represented the best of Capitol Hill, always striving to find common ground and bridging divides.

Now, more than ever, we need bipartisan leadership, which is why Congress passing a NASA Authorization Bill is of paramount importance. As I described previously, it's vital for the U.S. to present a unified vision to both allies and rivals. The best way to accomplish this is through a bipartisan NASA Authorization which includes strong and explicit support for the Artemis program. I want to thank and congratulate this Committee for crafting a NASA Authorization as part of the U.S. Innovation and Competition Act (USICA) of 2021 which has been passed by the Senate. It's critical for the House of Representatives to also take action and for Congress to adopt a reconciled bill as expeditiously as possible. Both partner and rival nations have a sophisticated understanding of the Congressional process. The lack of a bipartisan NASA Authorization bill sends a negative message regarding America's ability to move forward with a unified vision for space exploration. Therefore, this issue must be rectified quickly before it leads to inevitable doubts and concerns that will damage America's ability to execute the critical global partnerships that are such an important part of the Artemis program.

III. Avoiding a Space Station Gap

Another area where policy consistency is critical is in LEO. The venerable ISS, which has now supported a continuous crewed presence for over twenty years, stands out as a dramatic success for American global leadership and policy continuity. Thanks to the ISS, the U.S. has been a hub for an unprecedented partner-

ship that defines the present and will influence the future of human space exploration. An entire generation has been born and grown to adulthood never knowing a world where there isn't an international team of scientists living and working on a space station. I believe that far too often we take this extraordinary accomplishment for granted. Having negotiated the binding Memorandums of Understanding for the Gateway which were based on the ISS's Intergovernmental Agreement, I have a great personal appreciation for the difficulty of assembling the ISS coalition as well as maintaining it. I have always felt that the ISS should receive a Nobel Peace Prize acknowledging the herculean work of those who transformed the station from dream into reality.

Yet again, I would like to thank the Committee for including in the NASA Authorization Act, which passed the Senate, language extending the ISS to at least 2030. The ISS still remains the pinnacle for human spaceflight and we should leverage the station's singular capabilities for as long as possible. Again, Congress adopting an authorization bill extending the ISS will be extraordinarily important to provide our international partners with certainty relative to the future of the station.

Moreover, per the commendable authorization language passed by the Senate, America's goal is to maintain a continuous human presence in LEO. Extending the ISS is an important part of achieving this objective, but of equal importance is ensuring that when the ISS is retired, there is a commercial space station that will carry on its legacy. The ISS itself took decades to construct and America now faces the troubling prospect of a space station gap. The U.S. can ill afford to lose its presence in LEO. Astronautics opportunities, which are the grist for the mill of international collaborations, will always be more plentiful in LEO than for beyond LEO operations. Additionally, we're only now beginning to realize the incredible potential of microgravity manufacturing, research, and development. The microgravity environment represents an entirely new arena for trailblazing scientific and commercial endeavors. What we will learn from and what we can do in microgravity has the potential to revolutionize fields as diverse as drug treatments and medicine to communications, agriculture, and construction.

America cannot lose access to this unique environment at exactly the time when others are beginning to establish a foothold in LEO. Specifically, over the course of the past year, China has launched its own space station which has now received both resupply missions and astronauts. Only a few days ago, China launched their most recent crew to their station, beginning the longest duration mission Chinese astronauts have ever undertaken. Moreover, China is aggressively courting our existing ISS partners, particularly in Europe, to join their new crewed LEO operations. Again, for two decades the ISS has allowed the U.S. to serve as a hub for global astronautics activities. As the world's leading Democracy, we must not cede the substantial diplomatic and political soft power benefits of crewed space station operations to China or any other nation.

Moreover, a space station gap would have a dramatic negative impact on American launch capabilities. Losing the demand for commercial cargo launches to the ISS as well as commercial crew (not long after investing billions of dollars to develop this capability), would impede gaining experience with these systems as well as continued innovation and growth. The damage done to American launch capabilities and international competitiveness would hurt our overall industrial base creating issues not just for civil space operations but for national security space activities as well.

Avoiding a space station gap will not be simple or easy. Developing and deploying a new space station is a nontrivial effort that could take a decade or more. NASA is wisely turning to the private sector to leverage commercial innovation and efficiencies to build and operate this new station. I'm excited to see NASA's Commercial LEO Destinations ("CLD") program progress taking us a step closer to ensuring that the U.S. and our partners maintain a continuous human presence in LEO. At Redwire Space, we are the only organization that has ever successfully printed objects on the ISS and we are a global leader in microgravity manufacturing and R&D. We will apply our company's singular capabilities and experiences with microgravity manufacturing, along with our innovative roll out solar arrays, robotics, digital engineering, sun sensors, star trackers, and other technologies to ensure the success of the CLD effort.

Finally, I want to applaud this Committee for passing language that reinforces America's commitment to maintaining a continuous presence in LEO through the development of a commercial space station. I hope that the House moves forward quickly with a NASA Authorization Bill which includes identical language allowing Congress to send an unequivocal message to partners and allies alike that we have learned from history and that this Nation stands united in support of preventing a space station gap.

IV. Maintaining Technological Leadership Through Public-Private Partnerships

There can be no question that we are in a great powers struggle with China. This rivalry extends to space where the implications of the U.S. falling behind China technologically would have devastating consequences. This is a race that the U.S. cannot afford to lose, however, in many critical areas we are already facing the prospect of falling behind. Specifically, the U.S. must redouble its efforts to support next-generation space-based robotics. We are entering a new era where satellites and robotic systems are merging, and America must embrace this change and excel at these advanced technologies.

For example, at Redwire Space we are developing systems such as Archinaut (also referred to as 'OSAM-2'), a satellite that, after deployment, will use robotics to build itself. In addition to robotic assembly, we are developing satellites that leverage 3D printing to create far larger objects in space than could have ever been placed into a rocket fairing. These space platforms that construct themselves after being deployed in space will offer substantially enhanced capabilities as well as resilience to attack that could never be achieved by traditional satellite systems. While Redwire Space has unparalleled heritage and expertise in this field, China is well aware of the importance of space-based robotics and has already deployed Shijian-17, a satellite with, among other features, a robotic arm that could be used to grapple satellites. Shijian-17 has already flown unusual orbital maneuvers bringing it closer to other satellites generating suspicion and concern. Again, the U.S. must bolster its efforts to equal and exceed Chinese space-based robotic capabilities to protect our industrial competitive edge as well as the Nation's overall economy and security.

As noted previously, China's autocratic regime does have the benefit of policy consistency and the Nation has focused on developing world-class space technology for decades. China's efforts are coming to fruition and the U.S. faces an unprecedented challenge to maintain space supremacy or, in the long run, even parity.

The best and possibly only way for the U.S. to meet this existential threat is for America to embrace its great strengths that China struggles to or cannot reproduce. Specifically, the U.S. must redouble its efforts to leverage American entrepreneurialism. A free society, grounded in the rule of law, with a diverse population, will always innovate at a greater rate than more homogeneous nations where freedoms are severely curtailed. America created the commercial space revolution, and our private space sector is the envy of the world. Programs such as NASA's Commercial Orbital Transportation Services ("COTS") and the Commercial Resupply Services ("CRS") contracts, played a critical role in creating the commercial space industry as we know it today.

In order to effectively compete with China, the Congress, NASA, the Department of Defense, and the Intelligence Community, must all embrace public-private partnerships to an even greater degree than what is occurring today. The government must support commercial development, playing the role of both catalyst and customer for innovative technologies. Commercial space represents a force multiplier that has already transformed the nature of the industry. However, there is much more that can be done by the U.S. government to make efforts such as COTS and CRS the rule rather than the exception. Again, whenever possible, the government should serve as a customer for innovative capabilities that will maintain and accelerate U.S. leadership, particularly in critical areas such as orbital servicing, assembly, and manufacturing. Only by substantially expanding the use of public-private partnerships can the U.S. effectively protect itself and the world from emerging threats that will only become more pernicious in the years to come.

For all of these reasons, the NASA authorization bill should include explicit support to bolster Archinaut specifically and on-orbit servicing, assembly, and manufacturing technologies generally. This is a critical area of technological endeavor that the U.S. must excel in and explicit direction via an authorization bill is key to maintaining American competitiveness.

V. Establishing Norms of Behavior in Space

It is vital for America to lead not only in technology but in policy as well. As in any new frontier, establishing rules and norms of behavior will play a critical role in preventing conflict and ensuring that space is developed in a safe, sustainable, and peaceful fashion. While at NASA, it was my privilege to craft and negotiate the Artemis Accords which, in less than one year since their inception, have now been signed by twelve nations.

The Artemis Accords were successful due in no small part to the unprecedented partnership between NASA and the Department of State, and I want to take this opportunity to thank Jonathan Margolis, Acting Deputy Assistant Secretary for

Science, Space, and Health at the Bureau of Oceans and International Environmental and Scientific Affairs for his support, partnership, and friendship in developing the Accords. I also need to thank another friend and colleague, Gabriel Swiney, the Department of State's lead civil space attorney who was one of the first people I discussed the Accords with. Gabriel's vision and knowledge are reflected throughout the Accords and his skill made them a success. Finally, the Artemis Accords would of course not exist without the outstanding leadership of Jim Bridenstine, who provided strong and unflagging support for the Accords as well as the partnership with the Department of State, and the former Administrator simply wouldn't take no for an answer in his efforts to bring me to NASA.

The Artemis Accords present the model for future policy initiatives wherein NASA and State work in unison. Moreover, the Accords would not have succeeded without the coordination and assistance provided by the National Space Council, and its former Executive Secretary, Dr. Scott Pace. I have greatly benefited from Dr. Pace's support over the years, and his leadership was vital for both the Artemis Accords and the signing of the binding Gateway agreements, particularly the agreement with the Government of Japan. Finally, I want to again thank the Biden administration's leadership including Secretary of State Antony Blinken, National Security Advisor Jake Sullivan, NASA Administrator Bill Nelson, NASA Deputy Administrator Pam Melroy, and Senior Advisor to the Administrator, Bhavya Lal, for their strong support of the Artemis Accords. Again, continuity is vital, and I am personally grateful for the Biden team's robust support for building international partnerships and establishing norms of behavior in space.

Due to the Accords, the Artemis program has established the largest and most diverse human space exploration coalition in history, but much more remains to be done. Specifically, more countries should be added to the Accords and the Artemis program. For example, I hope that NASA and the Department of State continue and accelerate efforts that I worked on during my tenure at OIIR to bring African nations into the family of the Artemis Accords. I believe that the benefits of space exploration and space-based capabilities are particularly important for developing nations and that the unique views and voices of African youth in particular can greatly contribute to the Artemis program. Moreover, China has targeted Africa both economically and politically, and NASA should not cede African partnerships to rival nations. Additionally, it would be beneficial for a few more of our traditional space allies, specifically, France and Germany, to join the Accords demonstrating unified support in Europe for responsible norms of behavior in space. Finally, I hope that efforts at NASA and State are continuing for India to join the Accords. India's robust and growing space capabilities make their support for norms of behavior critical to achieve a peaceful and prosperous future in space for all of humanity to enjoy.

The Accords establish a strong foundation for beyond LEO civil space activities, building a future based on transparency, interoperability, the full and public release of scientific data, avoiding harmful interference, and environmental sustainability. However, new rules and norms need to be established for national security operations. The Tenets of Responsible Behavior in Space, described in a July 7th Memorandum by the Secretary of Defense, represents a good start. However, establishing an international coalition to support these tenets is vital to their success and universal adoption. The Artemis Accords serve as a model for how such coalitions can be built, and I know that myself and others who were involved in developing and implementing the Accords stand ready to assist our colleagues at the Department of Defense and Space Force in their own efforts to establish vital norms of behavior in the national security realm.

In addition to explicitly authorizing the Artemis program, I hope that the upcoming NASA authorization bill includes language complimenting NASA's work in support of the Artemis Accords, signaling to both partners and rivals that the Congress strongly endorses establishing global norms of behavior to ensure a peaceful and prosperous future in space.

VI. Collaborating and Competing with China

For better or worse, the U.S.—Chinese relationship will determine the future of space exploration and development. As described previously, the U.S. cannot afford to fall behind China in critical capabilities such as space-based robotics, in-space manufacturing, and space-based solar power. However, there are nontrivial opportunities to collaborate with China that could benefit both countries and advance global prospects for peace and prosperity.

Specifically, NASA and the Department of State should continue to advocate for China to sign the Artemis Accords. Although China is not a part of the Artemis program, and the Accords were written to ensure that nations participating in Artemis

abide by international treaty obligations and norms of behavior such as the full, free, and timely release of scientific information, China signing the Accords would send a strong signal of unity and global consensus relative to the simple and intuitive principles of the Accords. The Accords were a product of lengthy negotiations between eight different space agencies and ministries of foreign affairs. The substance and text of the Accords represents the common ground among countries with a diverse set of policy positions (*e.g.*, the U.S. opposes the Moon Agreement whereas Australia is a signatory). The Accords were written to be as inclusive as possible and, in particular, the United Arab Emirates officials who participated in the drafting process were a strong voice for ensuring that the Accords could be signed by any nation with a desire to support peaceful space operations and development. The Artemis Accords were explicitly and exquisitely crafted to unite nations with disparate views, bringing the world together to prevent conflict and ensure harmonious activities on the Moon and Mars. China committing to the Accords would be a welcome development that I believe would benefit both nations and global space policy discourse generally.

During discussions at the United Nations Committee on the Peaceful Uses of Outer Space, the State Department has invited China and all nations to sign the Artemis Accords. Beyond such interactions at the United Nations, I recommend that the State Department continue the practice of convening Civil Space Dialogues with China, to discuss the Accords and norms of behavior in space. If China were to join the Artemis Accords, like with other signatories, it would provide specific, actionable commitments that the country would be held to for civil space operations on the Moon, asteroids, comets, and Mars.

I have high hopes that a productive conversation could be held with China on norms of behavior due to my experiences with several global efforts that included Chinese participation. For example, prior to joining NASA, I served as an industry member of the Hague International Space Resources Governance Working Group, which brought together experts from around the world to draft 'building blocks' in support of establishing rules for space resource exploration and utilization. One of China's leading law professors participated in the Hague Working Group and his input was robust, constructive, and productive. As a matter of fact, some of the text and ideas generated by the Hague Working Group were adopted as part of the Artemis Accords.

Moreover, I am currently supporting the efforts of the Global Expert Group on Sustainable Lunar Activities ("GEGSLA"), which is a NGO that, as the name indicates, is bringing together policy and legal experts from across the world to develop norms of behavior for the Moon. The GEGSLA involves many of the same academic, industry, and government experts as the Hague Group, including several Chinese nationals who have been working side-by-side with, among others, American commercial space leaders to establish rules of the road for lunar activities which are based upon not only the Outer Space Treaty of 1967, but the prior work done by the Hague Group and the Artemis Accords. While I know from personal experience that coming to agreement on even general principles for space exploration and development can be extremely difficult, I firmly believe that this is an area where the U.S. could and should engage with China in an attempt to identify common ground.

At the next Civil Space Dialogue between the U.S. and China, in addition to norms of behavior, other forms of collaboration could be discussed. For example, a swap of lunar samples would be a low-risk means of initiating cooperation in space with China, which NASA could engage in while staying well within the bounds of the Wolf Amendment. Finally, the U.S. is already collaborating with China and other nations on the Space Geodesy Project, which produces a wide variety of information for Earth observation and climate science. Additional collaborations with China on climate research is another area which, if handled correctly, could benefit both nations without running afoul of the requirements of the Wolf Amendment.

VII. Conclusion

Collaboration and cooperation must both be harnessed to ensure that humanity's journey into the undiscovered country of space is safe, peaceful, and prosperous. Again, we cannot afford to fall behind in critical new areas of space technology and must maintain the continuity of the Artemis program as well as maintain a continuous crewed presence in LEO. However, we must also reach out to both allies and rivals to collaborate whenever possible to support norms of behavior in space and mutual areas of scientific interest and concern such as climatology.

As mentioned previously, Redwire is a global leader for in-space manufacturing. We have an expertise in building microgravity products that will enable ambitious space exploration missions and improve life on Earth. Redwire, and all of us in the private sector, must join with our colleagues in government to build not just tech-

nology, but the future. This is an in-space manufacturing endeavor that will demand unprecedented work, coordination, and support from across industry and government. Although we will face many challenges, I remain confident in America's ability to build a new era in space of peace, freedom, and prosperity, benefiting the world and many future generations to come.

Senator HICKENLOOPER. Thank you. And you did not even mention the companies that Redwire has in Colorado.

Mr. GOLD. I will say, since it is just between us, they are three of our best.

[Laughter.]

Senator HICKENLOOPER. All right. Now, we are ready to hear from Dr. Sanders.

STATEMENT OF DR. PATRICIA SANDERS, CHAIR, AEROSPACE SAFETY ADVISORY PANEL, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. SANDERS. Thank you, Senator Hickenlooper, Senator Lummis, and Wicker, and Members of the Subcommittee. I thank you for the opportunity to appear before you today to discuss NASA's international collaboration and competition in space.

The panel that I chair has the serious charge to provide both NASA and the Congress with advice for the intelligent management of the risks that are inherent in human space flight. NASA has been at the forefront of human space flight for decades, formulating the missions, defining the requirements, executing the programs, performing management integration, and leading launch processing and mission operations.

NASA still leads in human space exploration, but the Agency's role is evolving with critical implications for safety and risk management. The Agency is not the same as it was 10 years ago and will not be the same in even another 5 years. The rapid growth of commercial space services, and increasing global interest in space, have changed the environment and the landscape will not return where NASA is the only, or even the major, actor. This has tremendous upside potential and equally tremendous challenges for managing the risk of human space exploration. At the same time, the exploration endeavors NASA leads are ever more complex and have ever more risk involved.

NASA has been gradually and tactfully and successfully adjusting to a changing role and set of responsibilities, as it shifts from principally executing its programs and missions to commercially and internationally acquiring significant key elements and services. And our Panel firmly believes that NASA must now take a more strategic examination of the Agency's evolution in the emerging environment, while continuing to manage a safe and complex human exploration campaign.

NASA's challenge is the melding of traditional and innovative approaches, including significant systems engineering and integration complexities, and the certification of commercial human space flight capabilities with high levels of risk. There are clear advantages to leveraging industry innovators and international partners, but NASA must still manage and be responsible for the overall risks, even when the Agency neither controls nor dictates the material solutions for all of the components. To do this, we believe that

NASA, first, must determine how to exercise appropriate accountability, or how to hold its vendors accountable, for the safe and successful accomplishment of its mission.

Second, we believe it is imperative to define the overall architecture for the highly complex Artemis mission. The Agency should identify how each individual element, regardless of provider, fits the architecture, and the top-level requirements for each element to fulfill its necessary function in the overall structure. This should allow NASA to focus on the right set of priorities at the right time and to communicate expectations to all the contributors: internal, commercial, and international, in a consistent manner.

Third, all of this is complicated by the Nation's current lack of a comprehensive regulatory framework for human commercial spaceflight. NASA retains full accountability for its missions, but no external government regulations or standards exist to set a baseline level of expectation for the provider related to human safety. The few existing regulatory pieces leave a gap related to human on-orbit safety, and the space industry that impacts human safety. In particular, as has already been mentioned, there is an immediate and compelling need to designate a civil agency to oversee and coordinate space traffic management.

Given the importance of space to international security, technological leadership, and international competitiveness, it is vital for the Nation to act now to preserve the safety of space operations and their environment.

In closing, I note some consistent advice themes from the Panel. First, it is a need for a constancy of purpose, as mentioned, sustained commitment, and a clear understanding of the objectives. Second, is the importance of setting challenging but achievable schedules, and not allowing undue schedule pressure to lead to decisions adversely impacting safety and mission assurance. And third, is technical baselines and schedules that are mutually consistent, realistic, and achievable, and supported by adequate and stable resources.

We encourage NASA, in partnership with the Congress, to hold fast to the foundations of risk management, while embracing and not fearing alternative methods to achieving those fundamentals.

And I look forward to your questions. Thank you.

[The prepared statement of Dr. Sanders follows:]

PREPARED STATEMENT OF DR. PATRICIA SANDERS, CHAIR, AEROSPACE SAFETY AND
ADVISORY PANEL, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Senator Hickenlooper and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss NASA's international collaboration and competition in space.

As you know, the Aerospace Safety Advisory Panel is charged with advising both the NASA Administrator and the Congress with respect to the safety and risk of human space flight as well as other safety related matters at the Agency. In opening, I would like to emphasize that the Panel feels the responsibility to provide advice that promotes the driving down of risk to the lowest reasonable level consistent with accomplishing the mission. Space exploration is inherently dangerous; the environment is hostile, and the systems needed to survive in it are complex. Our charge is not to avoid any and all risks, but to provide advice and feedback for the intelligent management of those risks.

NASA has been at the forefront of human space flight for decades, and for much of that time it executed the programs, formulated the missions, defined the requirements, and performed management integration of all the elements composing the

system. NASA personnel performed the engineering analyses, and they led launch processing and mission operations.

NASA leadership in human space exploration is still preeminent, but the Agency's role is evolving with critical implications for how risk and safety will be managed in the future. The Agency is not the same as it was ten years ago, and most assuredly, it will not be the same in another ten years—even five years—from now. With the rapid growth of available commercial space services, and increasing global interest in space, the environment in which NASA operates has changed; NASA will not return to a landscape in which it is the only, or even the major, actor. These developments have tremendous upside potential—and are accompanied by equally tremendous challenges for managing the risk of human space exploration. Concurrently, the human exploration endeavors NASA is leading are becoming ever more complex, and with more risk, from the lunar exploration to eventual excursions to Mars and beyond.

Over the past several years, NASA has been adjusting to a changing role and set of responsibilities as it shifts from principally executing its programs and missions to commercially acquiring significant key elements and services. The Agency has gradually and tactically adapted and succeeded in meeting challenges as they arise. Regardless of their tactical achievements to date, the Panel firmly believes that it is critical at this time that NASA take more strategic scrutiny of the role the Agency should undertake going forward. How the Agency plans to evolve and transition to an organization that more frequently procures human space flight capabilities as services, while managing a safe and wholly new human exploration campaign, is a key strategic question that has the Panel's attention. We continue to emphasize the importance for NASA to strategically define its mission, its guiding principles, and its vision for the Agency's leadership role in the future in order to ensure that risk is managed appropriately.

The emerging challenges for NASA involve the melding of traditional and innovative program approaches, including the significant systems engineering and integration complexities, and the certification of commercial human space flight capabilities that carry high levels of risk. The Panel has noted clear advantages to leveraging the industry innovators, but NASA must still manage and be responsible for the overall risks, even when the Agency does not control nor dictate the material solutions for some of the campaign components and services, such as the Human Landing System. It is critical for NASA to be able to manage the integrated risk and achieve the right balance with its providers.

To do this, first, the Panel believes that NASA needs to figure out how to exercise appropriate accountability—or how to hold its vendors accountable—for the safe and successful accomplishment of its mission across the full spectrum of acquisition and development approaches. As the breadth and types of relationships develop, expand, and become more complex to achieve NASA's mission safely, and with good understanding of the risk involved, it is critical for the Agency to have and to use the appropriate tools including acquisition processes and contractual structures. There is not a one-size-fits-all approach anymore, and having an overarching view of what the Agency is trying to achieve should lead to a flexible and thoughtful deployment of the tools in the toolbox.

Secondly, the Panel believes it is imperative to define the overall architecture for the highly complex Artemis mission sets. The Agency should identify how each individual element—regardless of provider—fits the architecture, and define the top-level requirements that must be met in order for the element to fulfill its necessary function in the overall mission structure. This work can then form the foundation for the system engineering and integration. The complexity of the Artemis ecosystem, along with the expected evolution of requirements—which involves creating and maintaining an architecture that can be updated, adjusted, and can incorporate the latest innovation or new technology—can more effectively be managed by an integrated approach best achieved in a program construct. This should allow NASA as a whole to focus on the right set of priorities at the right time and to communicate expectations to all the contributors—internal, commercial, and international—in a consistent manner. In addition, all players understanding enterprise-level requirements, organized in a program construct, early in the process helps to identify opportunities and areas to pursue open architecture paradigms and reduce expensive, complicated, and bureaucratically burdensome design and contractual changes later.

Thirdly, I note that NASA's approach is complicated by the Nation's current lack of a comprehensive regulatory framework for human commercial spaceflight. Presently, NASA retains full accountability, but no external government regulations or rules exist, which may help the Agency manage risk, or even set a baseline level of expectation for the provider, related to human occupant safety. There are some

regulatory pieces in place. At the highest level is the Outer Space Treaty. The Federal Aviation Administration is responsible for licensing commercial launches and reentries, with a specific focus on the safety of the uninvolved public on the ground. The Federal Communications Commission is responsible for licensing radio broadcasts from space. The National Oceanic and Atmospheric Administration is responsible for licensing remote sensing operations. NASA and the Department of Defense are key players in space, but they are not regulatory agencies. That leaves a gap in authority specifically related to on-orbit safety, both for humans and the management of an increasingly more active satellite industry that will eventually impact human safety. Given the importance of space to national security, technological leadership and international competitiveness, our Panel believes it is vital for the United States to act now to preserve the safety of space operations and the safety of the environment. Consequently, I would be remiss if I did not repeat a standing Panel recommendation to the Congress. We feel very strongly that there is an immediate and compelling need to designate a civil agency to oversee and coordinate space traffic management. NASA, lacking any other framework, has established guidelines and standards for space traffic management, but there must be leadership and coordination at the national level.

Finally, I would like to reiterate some consistent advice themes from the Panel:

- First, we have consistently maintained that mission success requires a constancy of purpose, a sustained commitment, and a clear understanding of objectives.
- Second, a key issue, repeated year after year, is the importance of setting challenging but achievable schedules, and not allowing undue schedule pressure to lead to decisions that adversely impact safety and mission assurance.
- Third, it is important to establish technical baselines and schedules that are mutually consistent, realistic, and achievable—supported by adequate and stable resources.
- And, we have continuously maintained that while NASA should never lose sight of the fundamentals in risk management for successful program execution, there is no one approach that dictates success, and there should be an openness to learning and accepting alternative means to understanding and controlling margins.

So, as NASA continues its deep space exploration, we encourage the Agency, in partnership with the Congress, to hold fast to the foundational standards of risk management while embracing new approaches and not fear alternative methodologies to achieving those fundamentals.

Thank you. I look forward to your questions.

Senator HICKENLOOPER. Great. Well, thank you all for your—your comments and appreciate the—the breadth of experience you bring to the table.

We will now start a round of questions. Each of us will get—well, hopefully, will get 5 minutes. We try to stay on schedule. It is always hard. I always ask if, in responding to a question, if you can keep it to a minute, that allows us to get four questions in. If necessary, we can come back to a second round of questions or—there are so many questions to ask each of you. Anyway, I will start.

I will start with Mr. Gold. Appreciate your work at NASA with the international partners and establishing these—the Artemis Accords and that cooperative spirit. In your testimony, I looked at it last night, you said “space is a crucible that demands the formation of global coalitions”. So, how can Congress support NASA’s goals to expand the coalition of international partners in space?

Mr. GOLD. Thank you, Senator. I can tell you, and I am sure the former Administrator would agree, NASA pays a lot of attention to Congress. And the rhetoric, you know, obviously, legislation that has passed, it determines whether NASA is aggressive in going out and forming international coalitions or holds back and really what the Agency does.

So, I think it is extremely important, again, in an authorization bill, that there be explicit encouragement to the Agency, both to expand our international cooperation, generally, as well as specifically to expand, again, the family of the Artemis Accords. That there are so many countries that need to be involved that the Agency should be aggressively reaching out for, we need to lead by example and establish norms of behavior before there is conflict in space. And I know it is cliché, an ounce of prevention now, will prevent a pound of trouble down the road. So, including even a sense of Congress, about the Accords, international growth, and being aggressive to establish norms of behavior, I think, would be extremely helpful to assure a peaceful future.

You know, other countries may or may not, you know, agree to the same norms that we do, but if we lead by example, we can take pressure there and create a coalition of willing.

Senator HICKENLOOPER. Absolutely. That is—I think you are spot on. I could not agree more.

Mr. GOLD. Absolutely.

Senator HICKENLOOPER. But I want to take—and Mr. Gold talked a little bit about this, the implications of a—of a gap. And I guess, Dr. Dittmar, let me ask you, where do you see the—what are the implications if we do end up with a space station gap, where the United States is not taking a leadership position?

Dr. DITTMAR. So, as—thank you for the question, Senator. As has already been pointed out, China has a space station that is flying in low-Earth orbit. This is actually their first module of a station that they are going to build out. And China is leveraging that space station. They have formed partnerships with UNOOSA. They have already—they recently announced that they had agreements to fly over 1,000 payloads. We have had American companies that have already said that they are beginning to lose customers to China and the Chinese station, because the Chinese are using state authority to subsidize access to station for commercial customers, as well.

And so, if what we are saying is that we want to have a follow-on station that is privately—a public-private partnership, or is owned by a private entity, that entity absolutely depends upon access to customers that are not being, in effect, stolen away by a state agency, that is doing that, you know, intentionally to, sort of, undermine that capability.

The other thing, frankly, is that, you know, robust presence in low Earth orbit, for Americans, has been a part of policy, whether stated or not, in the United States for more than 20 years—actually longer than that and—going back to the origin of NASA. And when you look toward an authorization bill, and I think it is really important to foot stomp, that U.S. presence in low Earth orbit is expected in perpetuity, that it is the policy of the United States that we will continue to do so, through whatever means. However, I think—and low Earth orbit is, frankly, our foothold going out into outer space. We need continuity of human space flight and human activity, beginning on the ground, through low Earth orbit, into deep space. And that chain is very, very important to American security, to American business, to American research and science, to American technology development and we cannot afford a gap.

Senator HICKENLOOPER. Yes. Well, we agree on that. Dr. Sanders, the GAO has expressed concern on the maturity of advanced lunar spacesuits. It is a classic case. But I think a lot of what all—everyone has talked about, and especially Mr. Bridenstine, the safety of these missions is—there are risks from 100 different directions. And can—I was going to ask you to describe how you believe that—that robust Congressional funding—that continuity of funding and authorizations could support—help NASA support the goals of safety and making sure that, you know, mission schedules can end up impacting safety and assurance.

Dr. SANDERS. Well, we have been a consistent proponent of adequately resourcing all of the complex requirements necessary for safely executing. When resources are not adequate, or not stable, the—NASA and their decision-making process on designs, end up making design choices that may be are premature, maybe they are—take risks that they would not necessarily take if they did not have to live within a resource that is not adequate, or they do not have the stability of the resources, it forces you to make choice sooner than you might want to take. It forces you to sometimes, down select earlier than you understand all the implications of competing designs. And so, it is very important to have the adequate resources and to have them in a stable fashion.

Senator HICKENLOOPER. Right. Great, I appreciate that. I am already out of time. I cannot believe how fast this goes by. But I am not done with all of you. Mr. Bridenstine, you will get your moment.

I am going to turn it over now to the Committee Chair, Senator Cantwell, who has been working on these issues for a long time, as long as—probably longer than most of you—most of us. Anyway, let me turn it over to the Chair.

**STATEMENT OF HON. MARIA CANTWELL,
U.S. SENATOR FROM WASHINGTON**

The CHAIR. Thank you, Chair Hickenlooper, and thanks for holding this subcommittee hearing, and to you and Senator Lummis for spending so much time to try to bring focus to the needs for authorizations. And thank you to the witnesses.

I think I will start with you, Mr. Bridenstine. Obviously, one of the past times you came before this committee, you spoke very fervently about the need for authorization, and yet it has been since 2017 since we have actually had an authorizing bill. So, I sometimes feel like NASA wants to have the money without the authorization. That is, that it works, not to resolve the conflicts that we have with members that, basically, it just realizes, as long as you can just get the dollars it is OK. Well, that is not OK. And so, I just want to be clear with the panelists, if you could give me some feedback on some of these issues. Do you think that we need an authorization bill?

Mr. BRIDENSTINE. Yes, 100 percent.

Dr. DITTMAR. Yes.

Mr. GOLD. An authorization bill is vital to send messages to our partners and rival nations, with unity purpose of Congress, yes.

The CHAIR. Dr. Sanders?

Dr. SANDERS. Yes.

The CHAIR. OK. So, do we need to have more testing and analysis of rocket launching and the capabilities that we are looking for in the next system?

Mr. BRIDENSTINE. Do we need more testing and analysis?

The CHAIR. Yes.

Mr. BRIDENSTINE. You can always have more testing. There is not doubt. And more analysis. At some point—and I like the way Patricia Sanders mentioned it earlier—we have to manage risk. So, it depends on what system we are talking about and—but certainly, there is value to more testing.

The CHAIR. Dr. Dittmar?

Dr. DITTMAR. So, having been involved in the development of the space station, I would just echo what Jim said, which was—

The CHAIR. I am just talking about—I will get to space stations in a minute.

Dr. DITTMAR. Specifically rockets?

The CHAIR. Yes.

Dr. DITTMAR. No, what I was going to do was simply speak to engineering. OK, so—so it is always useful to have test data, but there is also an appropriate use of test data and then, a point at which just more and more testing simply adds cost and schedule.

The CHAIR. And Mr. Gold?

Mr. GOLD. Senator, this country has not had a human space flight program beyond low Earth orbit in a very, very long time. We are going to have to relearn some critical lessons, as well as developing new technologies and new systems along the way. So, testing and making sure that we have a safe system that is robust and effectively competes with China and other nations is going to be critical, leveraging the wonderful private sector companies in your State, as well as those three that Senator Hickenlooper mentioned, of Redwire in Colorado.

The CHAIR. OK. Dr. Sanders?

Dr. SANDERS. Strong proponent for adequate testing and analysis. As Mr. Bridenstine had said, it is not possible ever to completely and fully, totally eliminate risk and you want to manage it. But the way to manage it is through knowledge and we—as much knowledge as we think we have about systems, we continue to learn things about parachutes, about compatibility of the components, materials—

The CHAIR. Do you think NASA Houston needs to have more oversight over the Artemis program and its schedules and launches?

Mr. BRIDENSTINE. I think their—

The CHAIR. Than is currently provided.

Mr. BRIDENSTINE. I think their—well, oversight from the Congress or—

The CHAIR. No, from NASA Houston.

Mr. BRIDENSTINE. Oh, from NASA Houston, for the Artemis program.

The CHAIR. Yes.

Mr. BRIDENSTINE. Well, certainly there are a lot of different centers that are involved in the development of different components of the Artemis program. I think it is important that NASA has a robust capability to do the integration and I think, until recently,

that has been lacking. But my understanding is—and I am not there anymore, but my understanding is they have really plussed up the systems integration piece that has been missing for a while.

The CHAIR. Dr. Dittmar?

Dr. DITTMAR. With apologies, Senator, I am not as—I am not as current with what management has distributed across the center.

The CHAIR. OK. Basically, I am bringing up topics that are part of the dispute between what the Senate and the House wants to do on a NASA authorization. So, I am just trying to get your viewpoints on that because part of the issue is, we have to debunk, you know, where we are. We cannot do an adequate oversight job if we do not have an authorization bill. We cannot come back on the measurements if we do not have some input here about what kind of structure we need.

But we are sitting here with, obviously, a new—as Mr. Gold was saying, a pretty big, new adventure, at least from the number of stops we are talking about. And then, what we are talking about going beyond the moon. To say nothing of we really do not have any accurate dates or cost estimates or what we want out of each of these systems. What do we want out of the launch systems and the capabilities? What do we want out of the ISS and its capabilities? What do we want on the lander system? What do we want, you know, on the beyond lander—I am sorry, beyond the Moon?

So, here we are having this discussion without reference and without oversight, really, because we do not have an authorization bill that is on a piece of paper, who is in charge, who is going to answer these questions, and how are we going to have this debate in Congress? So, what is coming across is the amount of money that people want to keep going, but then, it is always not enough. And then, the choices that people make do not necessarily adhere to redundancy and resiliency.

So, I think it is just imperative that we get an authorization bill. And so, I am trying to figure out from you all, what you think some of these stumbling blocks really, truly are between our colleagues. So, Mr. Bridenstine?

Mr. BRIDENSTINE. Ma'am, I think—I think that is all—I agree with everything you just said. I think that is exactly right. And I would also say that one of the biggest values of having an authorization bill—yes, oversight is a big piece of it, but for NASA to have continuity of purpose over time requires an apolitical, bipartisan consensus on how we are moving forward. And if we can put that in an authorization bill, it sends a signal to everybody, globally, that we have resolve to accomplish these objectives. And then, as this hearing is titled, we have the opportunity to go get international partners.

If we do not have that resolve—if the international partners do not trust that we are actually going to accomplish what we are saying we are going to accomplish, the first thing they are going to do is, they are going to go to China, which already has, you know, what they call the Chinese International Space Station and now they have entered into an agreement with Russia for going to the moon and establishing a lunar base. Our international partners have a history of partnering with other nations when we do not

have that continuity. So, the authorization is important for that purpose, too.

The CHAIR. OK. Mr. Gold?

Mr. GOLD. Senator Cantwell, when Administrator Bridenstine sent me overseas to negotiate the Gateway Commitments, it was because of statements that you made that we were able to complete that negotiation. I was told outright, by an international partner, "Why should I believe anything that you are saying?" Relative to Gateway, Artemis, and NASA's plans. And it was only by arguing the bipartisan support that Artemis had, that we were able to bring them and their collaboration to the table and prevent them from going over to China. Without an authorization bill, those doubts will continue to fester.

The CHAIR. Well, one of the reasons why NASA's authorization is on the USICA, America's competitiveness bill, is because we have passed this twice now, out of the Senate, to have no results in the House. So, we are very adamant here, in a bipartisan fashion, what needs to be done and I am just trying to use today as a way to figure out what is this stalemate that we have with our House colleagues truly about.

Now, I do not know if anybody wants to talk about the nature of a public lander—that issue. But obviously, that is one of the stumbling blocks, as well, is that people would like to have a process and go back and look at a public lander. Although, I think some people are saying, you know, the IP would belong to the government, all sorts of—so, how do we—how do we get a resolution of this issue?

Do we have other members waiting? Sorry.

Senator HICKENLOOPER. I think you are on such an important point that—

The CHAIR. OK. OK, thank you. I do not know if we have colleagues here, so I do not want to hold up somebody if they are on—

Senator HICKENLOOPER. No, you are—there is no one in the queue.

The CHAIR. Thank you. That is—

Senator HICKENLOOPER. They are all voting. They are voting.

The CHAIR.—too bad for—too bad for the witnesses. Yes, go ahead, Mr. Bridenstine.

Mr. BRIDENSTINE. So, when we think about a human landing system for the moon, I think it is—we need to look back at the Commercial Resupply Program and the Commercial Crew Program. Both of those have proven to be very resilient. Even when one partner had a challenge, the other one would step forward and continue to move forward. We saw that—you go back to 2014 on commercial resupply of the International Space Station, we saw, you know, at the time it was orbital ATK. They had a problem resupplying the International Space Station in rocket failure. A lot of cargo blew up. And then, in 2015 SpaceX had a rocket blow up with the international docking adaptor and other cargo.

But we had a resilient program where we could—we had dissimilar redundancy and we were able to use an Atlas rocket with a Cygnus cargo capability and basically, resupply the International Space Station. And we had international partners on that, Japan,

that helped, you know, support the resupply and even Russia supported the resupply.

So, the answer is we need this similar redundancy. Having a single provider for a human landing system, I think, imposes risk. That risk is budgetary. That risk is schedule. That risk is oversight. That risk is transparency. And I think, if we have competition, multiple providers that are competing on cost, on innovation, on safety, and those providers operating commercially are getting customers that are not necessarily the government, I think that is a good thing for the program. I think that was the original intent. I think that is why when, you know, Congress initially funded the Artemis program there was an anticipation there would be two, at least two, in the—in the competition. I was fully supportive of that and that is what we were pushing for.

The CHAIR. I am more trying to get—our colleague, the Chair of the House committee wants a public lander. And so, I was trying to get comments about that.

Mr. BRIDENSTINE. I think—I am going to say things I have said before and it is going to, maybe, get me in trouble with members of the House. I do not know. But I will tell you that I think any time you introduce a competition between the government and the private sector, the government wins, and the private sector loses. I think that is a challenge. I think—I think we have enough commercial capability now to have two commercial human landing systems. And I think, if we had adequate funding—you know, whether it is coming from the Executive Branch that is not providing it, or Congress, I think the adequate funding for two commercial human landing systems, at least, maybe even more, would be the right solution.

Mr. GOLD. Senator, I think the private sector has proven itself. It has delivered cargo to the International Space Station. It has now delivered crew to the International Space Station. The private sector can and will be able to meet that mission. What we are missing now, as you mentioned, dissimilar redundancy and direction and funds. And those are two things that we certainly hope Congress will be providing via an authorization bill. And certainly, we are advocating for the House to move and move quickly.

The CHAIR. Well, we are trying to resolve these issues. So, the point you should take away—and NASA, really, if they are listening should take away is, we need an authorization bill. We are not going to continue to have this game where you just get appropriations. It is not going to serve the Artemis program or NASA well, but we have to resolve this issue. And frankly, you know, it is frustrating to me to see the spirit of NASA turned into, you know, the cheering of billionaires or competition with each other, because I am pretty sure that is not what our mission of Artemis is about.

And so, somehow, we have gotten away from our focus, you know, on what we are trying to do from a technology perspective. And I believe in NASA's innovation in technology. I want them to apply the same spirit they had in fixing the problems on the Apollo project, to fixing and getting this authorization done. But if we have to address this public issue and get our House colleagues in a room and figure out what is the sticking point here, we should do better than just—just dismissing it and saying the private sector

can do better. We just had this debate with the FAA and oversight of the aviation sector. We clearly saw where there were pitfalls.

So, we have to figure this out and resolve our differences so we can get legislation, so Congress can do its oversight job, so that Senator Hickenlooper can continue to play a great role here in pushing this, and then, we can get to the international aspect of this. But right now, we are—you know, we are—it has been since 2017 since we have had a bill. And so, you ask yourselves why—why are we in this situation where the dates that are on a piece of paper right now, make no sense, as it relates to the Artemis program. Everybody knows that. So, how is that a good strategy? So, let us resolve these issues.

Dr. Sanders, do you have any suggestions about how to resolve this issue about a public lander versus commercial landers? Do you have any input? Or Dr. Dittmar?

Dr. SANDERS. I think that, yes, the commercial industry is capable—increasingly capable. But NASA always still has to be accountable for what—for the success and safety of their mission. So, it is important for them to be able to have enough influence and interaction in order to have that—ensure that accountability.

And also, NASA has a great deal of experience, a great deal of talent from—that they have acquired over decades. And so, there is a time for collaboration as this is going on and we saw that in commercial crew. There were times when SpaceX and there are times when Boeing have had—had problems to solve and NASA has been able to help them solve those because of the experience they have.

So, I do not think it is a clear, straight, turn it over to commercial, nor is it a clear, straight, that NASA develop everything by itself.

The CHAIR. Well, that is why I predicated my question earlier on that list and wanted to know what you thought about giving NASA Houston a larger role on that oversight. Look, we have seen where the same mistake was made by the FAA in deferring too much to aviation manufacturers, when it came to the oversight. So—and we have huge technological advances. And so, there is a lot to know and to be tested.

So, we need to get—have this structure—I want a very strong NASA oversight of these companies—very strong. I am not supportive of NASA stepping away and turning it over to the commercial side. But we have to figure out what that looks like, from an authorizing perspective, and put that in a piece of paper.

Mr. Gold or Dr. Dittmar?

Dr. DITTMAR. I would just add quickly, with regard to the lander, I do not know what the particular rationale is underlying the various positions, but one thing that might be pointed out is, if NASA is engendering—and I am in agreement with Jim, I think we need at least—two would be good. We definitely need redundant capability if we are going to take this approach. If—you need to do a path, basically. So, if you are going to do that—you know, one thing the government can always do is assert, what amounts to, imminent domain, right at first use, so that if—and I am speculating, if the issue having to do with the public lander has to do with whether or not the government could count on being able to use it,

as it saw fit, in the same way that it can with regard to a government loaned asset.

And there has been a great deal of discussion. I am one of the people having the discussion over the last several years, having to do with what is the appropriate role of government in signaling, particular to international allies, as Mike has already pointed out, and adversaries.

What is the full faith and measure of the U.S. Congress mean and what is the difference between how it is that you see a government owned asset versus a public asset, OK, versus how you see a privately owned asset?

Maybe one way to have the discussion is to talk about what rights the government has to assert in the case where it needs to use, OK, and to, in fact, basically say to private companies, "Sorry, we understand you have other customers. We understand you have business and agendas. But we have to set those aside, under these circumstances." I do not know if that is a path forward, but it is just an idea.

The CHAIR. Well, I think oversight is the question here. My sense is there is a feeling of loss of oversight with these commercializations. And, as I said, we have dealt very deeply with this, as it relates to the FAA and to the manufacturers. And you have a lot of people, even within the organization at the FAA, stepping away saying, "Oh, they know better. Let them go ahead."

Dr. DITTMAR. Yes.

The CHAIR. And we need a very strong NASA and very strong NASA oversight.

Dr. DITTMAR. I believe to do that, what you also need to have, and when you think of authorization, is very clear statement of objectives. What are the objectives, OK, and so far as how the government sees them and how Congress sees them? Because without that, it is very difficult to even begin to be able to do oversight because you do not know what objectives you are trying to meet.

The CHAIR. You could not have said it better, thank you.

Mr. GOLD. And Senator, perhaps you have the solution already, in terms of the compromise with the House, relative to oversight. I believe the question of government versus commercial is a false dichotomy, that we are stronger when we are working together. As Mary Lynne mentioned—Dr. Dittmar, that NASA has got so much incredible experience and the private sector has innovation, dollars, affordability. We need to combine that effectively and, hopefully, going to the House, bolstering oversight and insight of the programs and having two entities moving forward, I hope, could address the issues that you are raising.

The CHAIR. You are raising an interesting point, but I think no one's against companies going out there and doing commercial space travel. OK, go for it. But we are talking about how we are now going to conduct our next Artemis mission.

Mr. Chairman, you have been so lenient, and I see my colleague has returned. So, I am sure there are more questions by my other colleagues. Thank you so much to the witnesses and thank you for your diligence on trying to get this authorization over the goal line. Thank you.

Senator HICKENLOOPER. Thank you, Madam Chair, and I was copiously taking notes, as I trust you all were with her questions. I also have to vote, so I am going to turn this—the chairing of this meeting over to Senator Lummis, our Ranking Member, and then, she will proceed. But I will be back. So, you know, do not think you are going anywhere soon.

[Laughter.]

Senator LUMMIS. Well, thank you, Mr. Chairman. And thank you again, panelists, for tolerating our vote series that is interrupting the conversation. Former Congressman Bridenstine remembers those days very well.

First question is for Mr. Gold, and it has to do with the importance of strong public-private partnerships and a good line of communication between NASA and the commercial space industry, particularly on regulatory and policy issues. So, Mr. Gold, I would like you to talk a little bit about the importance of the NASA Advisory Council's Regulatory Policy Committee.

Mr. GOLD. Thank you, Senator. Public-private partnerships in America are the envy of the world. It is incredible. This really, second Golden Age that we are having in space due to, not just the private sector, but the support that NASA has given—that combination of capabilities. Elon Musk has gone on the record that there would not be a SpaceX if it was not for NASA. So, being able to combine public and private sector benefits and advantages are so critical.

And one of the other aspects that separates us out from foreign competition, other nations, are FACAS, the Federal Advisory Committees, that we have an explicit and official ability to combine private sector feedback and advice. And in this world, as Senator Cantwell just mentioned, where we are dealing with some pretty extraordinarily policy issues, the NAC Regulatory and Policy Committee is really the only place where NASA can go to get private sector feedback that represents, not just companies that, you know, are new—like, SpaceX and Blue Origin, Virgin Galactic—but also, Boeing and Lockheed, the traditional and terrific space companies that have brought us so far.

So, having that common ground, where both the new and the traditional space companies can come together to advise NASA is just critical and will allow us to leverage the power of the private sector, in support of NASA's goals.

Senator LUMMIS. Thank you. Would anyone else like to comment on that? Well, thanks. That is a pretty strong statement in favor of their work. So, thank you.

Mr. GOLD. The embarrassing thing to me, Senator, is that two of the members of that committee are now astronauts that we had. So, I am falling behind my colleagues who are on that committee—

[Laughter.]

Mr. GOLD. Audrey Powers, Sirisha Bandla.

Senator LUMMIS. No worries. You bring your own qualities to that. This is for anyone who wishes to jump in on it. How would you say China and Russia manage their orbital debris? And are there things we can do to encourage them to do more?

Mr. BRIDENSTINE. So, everybody claims that they follow the, you know, the guidelines that NASA creates and is adopted broadly by the U.S. Government. And then, it goes and goes to international fora and people say, you know, we all agree on these guidelines.

In practice, do all nations follow those guidelines? Absolutely not. And so, that is a challenge. It is one of the reasons, when I was a NASA administrator, I got Mike Gold engaged in the Artemis Accords. We needed to use the Artemis program—and I think this is an important thing. We—we look at the Artemis program, we get all these countries that want to be part of the Artemis program. How do we leverage that to create an international environment that is conducive for the future of human space flight? And so, we put in there that you had to adhere to the debris mitigation guidelines that are set forth by NASA. And interestingly, everybody has already agreed to that, so nobody could ultimately disagree. But here is the thing. If you want to participate in Artemis, now you are committed. You have got to follow these guidelines. And I think—so, the question is, how do you—how do you compel other nations to follow what the guidelines are?

And, oh by the way, and this is another challenge that we have, as I mentioned in my opening statement, in this country we have, you know, these mega constellations now, that are also placing at risk, low Earth orbit. And I am not naming anyone. There are lot of them in this country. And as I mentioned earlier, there are a lot of other countries that have constellations, as well. Rwanda, as I mentioned, 327,000 satellites being filed for at the ITU. So, we do not have the authority, as a Nation, to turn around and tell other countries, “You are not allowed to have your own constellation”, when we ourselves are licensing exactly the same things.

Senator LUMMIS. Yes.

Mr. BRIDENSTINE. So, the solution set, Ranking Member Lummis, is to recognize that there is a limitation to how much stuff can be put into any orbital shell. There is a limitation there. Once that—and, by the way, I do not know that that has been recognized by anybody at this point. But once it is recognized, we need to define what those limitations are. And those limitations can be determined by the cross-section or the size of the satellite, the mass of the satellite.

So, we think about how much stuff can you put in any orbital regime and then, we say, OK, now that we know that there is a limitation, we have defined what that limitation is, there needs to be a process by which we allocate access. When I say we, there needs to be an international kind of effort to this, where access is allocated in an orderly way. And when the United States gets its allocation that we, in fact, do allocate in a market competitive way, where we allow access to a number of different companies that are trying to accomplish the same thing, so we do not end up with monopolistic behavior.

I really think, if you look at the—kind of, the way the ITU works for geostationary orbit, I think that that might be a good model for low Earth orbit. It is going to have to be because the other result is this. We are all launching stuff into space, and it is going to—it is going to be not good. It is a race.

Senator LUMMIS. Yes.

Mr. BRIDENSTINE. And when you have a race like this, and everybody is operating—it is the prisoner’s dilemma. Everybody is operating to benefit themselves and, at the end, everybody loses.

Senator LUMMIS. Mm-hmm.

Mr. BRIDENSTINE. It is the tragedy of the commons and I think that is what we are facing right now in low Earth orbit. And there is no regulatory regime that manages it appropriately, and there is certainly not an international regime to manage it appropriately.

Senator LUMMIS. OK, so the ITU—

Mr. BRIDENSTINE. International Telecommunications Union. It is a subset of the U.N.

Senator LUMMIS. And would the U.N. be the proper organization to also be the umbrella organization for this?

Mr. BRIDENSTINE. Well, so wow.

[Laughter.]

Mr. BRIDENSTINE. It is a challenge, for sure, because I would say that the ITU works, and I will tell you why. And Mike and I were just talking about this earlier. There are countries that are at war with each other, that want to have a satellite in geostationary orbit, and they go to the ITU to work it out. So, it works, and it has worked very well in geostationary orbit. Right now, there is nothing for low Earth orbit and I think that is a problem.

Senator LUMMIS. Does anybody else want to weigh in on this before we move on?

Mr. GOLD. Senator, if I may. Space should be about joy and discovery, not danger and fear.

Senator LUMMIS. Mm-hmm.

Mr. GOLD. And per your question about China and Russia, that is what we are getting with their debris. You know, now I am going to steal from the former Administrator there, who would often talk—and we would be remiss if we did not mention ASAT testing in the context of this discussion. That due to a Chinese ASAT test, there is debris that is still up there. And I believe it was America that had to warn China that there was debris, created by their own ASAT test that was threatening their own space station. You know, the Foreign Minister would always point that out.

So, they are not particularly responsible actors. There is Chinese debris, you know, debris that comes down from every launch. We do not know where it is going to land, often. And last couple launches, it could have even hit America. We do not know.

So, as Jim was describing, what we need to do—and I do not think the U.N. is the entity to do it in, at least initially. We need to do what we have done with the Artemis Accords, and I am still grateful for the Administrator—former Administrator—for that opportunity, is to build a coalition of the willing, in terms of what good looks like. Lead by example on the debris issue and then, use that to force United Nations, or form a new kind of ITU, to be able to develop it.

Also, debris represents not just the problem, but as a private sector Redwire guy, it is an opportunity to innovate, to develop new technologies that can address this issue. We should have active debris removal missions, so that we can develop new systems that not only will help address the debris problems, but will create new sat-

ellite technologies and other systems that can benefit a wide variety of economic national security areas for the country.

Senator LUMMIS. Mr. Bridenstine.

Mr. BRIDENSTINE. First of all, I want to double down on what he said. I think Mike is exactly right—Mr. Gold, as his nametag says, is exactly right.

When we talk about—think about the FAA and we go back to the 1950s when the FAA was created. In those days, the United States did it alone and we were making great advances and it worked. We were able to have a lot more airplanes into a lot less space. Interestingly, because we took the lead, and we took that model around the world, an organization formed called ICAO, International Civil Aviation Organization. And they took the leadership of the FAA and they applied it globally. So now, when I fly my airplane, Navy pilot by trade, when I fly my airplane all over the world, I know exactly how to fly in whatever country I go to because we are all following the same rules. But it would not have happened if we would have, you know, gone to, you know, some international organization and said, “Here is what we need to do”, and try to get agreement from our competitors. That would not have worked. But when the United States takes the lead, ultimately there becomes a standard that other countries can join. And I think that is exactly the idea that Mike was talking about just a few seconds ago.

We have to lead on this and when we do, I think we are absolutely going to, you know, change the world so that all of those constellations, that we all believe in, for low latency, high throughput communications, can be successful.

Senator LUMMIS. Well, this is a fascinating subject and I hope to pursue it further. But I want to recognize my colleague. This is Old Home Week. Not only is Mr. Bridenstine a former Congressman, but of course, so is the gentleman from New Mexico, Senator Luján, who we recognize now.

**STATEMENT OF HON. BEN RAY LUJÁN,
U.S. SENATOR FROM NEW MEXICO**

Senator LUJÁN. Thank you to our Ranking Member and to our Chair for this important hearing. Holding this hearing matters to us not just here in America, but in New Mexico.

Now, in New Mexico, we have an incredible innovation ecosystem that supports the space industry. There is substantial research being done at the universities, the Air Force research labs, the Satellite Space Operations office, and two of our three NNSA Department of Energy National Laboratories. We have the home to the first commercial space port in the United States, where Virgin Galactic successfully launched its most recent space flight, as well.

Now, to our former Administrator and colleague in the House, small launch companies are facing pressure as governments all over the world subsidize their launch industries. To ensure that NASA keeps a capability that many, including yourself, have said is critical, do you think NASA should expand the scope of the Rideshare office to be a small satellite launch office, charged with assessing mission needs relative to all available launch options, in order to determine the best solution on a mission-by-mission basis?

Mr. BRIDENSTINE. So, I will start by saying this. When I was in the House, I was a big champion of the Venture Class Launch Services Program, which was basically a bill that enabled NASA to—to support small launch companies in a, you know when you are trying to launch a small vehicle to a very specific orbit, we are talking 500 kilograms to 1500 kilograms, we did not have the capability, you know, five or 10 years ago to do that to a very specific orbit. So, the Venture Class Launch Services Program was used to let the private sector know that the U.S. Government has an interest in seeing the ability to launch small payloads into specific orbits. And it worked and now, we are seeing a lot of these companies develop that capability.

I would also say, when I was the NASA Administrator—you mentioned Virgin Galactic. I mean, we had value from the fact that we could put our payloads at NASA on those vehicles. Of course, it benefited them, but it benefited NASA.

The challenge that we had at NASA is, you know, you can get microgravity testing with drop tests, where you might get a couple of seconds of testing. You can do parabolic trajectories, where you might get, you know, minutes, like, eight or 10 minutes—or, I am sorry, 30 seconds, or whatever. But then, when you talk about, after that, you have got to go to, you know, low Earth orbit. So, a lot of these small launches, whether they are usually suborbital, there is opportunity there that, I think, you know, Virgin Galactic, Blue Origin, are making available to NASA.

So, I do believe the United States of America has an interest in making sure that these companies are successful, because it is in the interest of our country that they are successful, for a whole host of different testing and science reasons. That being said, as far as that particular program, I would love to give you an answer—maybe do a little more looking into it and give you a more specific answer about that specific question.

Senator LUJÁN. I appreciate that. And the next question I have is for both our former Administrator, Dr. Dittmar, and Mr. Gold. One of the bills that I am working on is building off an idea that has proven to be successful with other Federal agencies, and that is establishing a foundation. We are working on one with the Department of Energy. One exists with the National Institutes of Health. And it has been able to strengthen public-private partnerships to be able to attract that private capital and to make these investments.

Now, as the former Administrator and leaders in the private industry for space, do you agree that if we fail to harness the full commercialization potential of NASA, we will fall behind countries willing to do so?

Mr. BRIDENSTINE. I absolutely think so. And I think, you know, my friend, Mike Gold, talks about it as, you know, our competitors in the world are never going to out entrepreneur the United States of America. And the best innovation that we see coming usually comes from small, innovative companies. And so, I think, in many cases, it is in our interest to make sure that we have those public-private partnerships for these unique opportunities.

It is important to also remember that—that when we have those public-private partnerships, the goal is for those companies to go

get customers that are not the U.S. Government. And if they do that, it drives down the cost to the American government. And we need to make sure, when we enter into public-private partnerships, that there is still competition in the marketplace, so that the competitor is competing in cost and innovation and safety.

Senator LUJÁN. Dr. Dittmar?

Dr. DITTMAR. And so, I would just agree with everything that was just said here. And I think public-private partnerships—you know, public-private partnerships, they have become, you know, quite the thing to talk about in space over the last 20 years. But they have been extant in this country since we started the country. They have been used in a variety of different ways to create infrastructure.

And we are looking for a whole ecosystem in space, right? One that supports everything from ground test equipment, all the way up to orbital space flight and then, beyond. There are opportunities we probably have not even thought of yet, in terms of how to utilize public-private partnerships to advance that.

What the United States needs it to be able to have enough strategic flexibility that it can pull whatever levers it needs to to, sort of, be able to advance the private sector, as well as advance government—government intention and have those things work together. So, yes.

Senator LUJÁN. Appreciate that. And Mr. Gold, I am going to ask for you and Dr. Sanders to maybe submit your answers to the record on that particular question. And then, the other question I have for the panel, that I would ask for you to submit to the record—we will submit it, is the importance of spaceports and especially the example that I shared with Spaceport New Mexico about the continued improvements to America's spaceports are needed to grow, not only our industry partnerships, but also for safe and sustainable government use.

So, I will submit that to the record.

I want to be respectful to Mr. Blumenthal's time, as well.

And I want to thank the Ranking Member for her acknowledgment today.

Senator LUMMIS [presiding]. The Chair recognizes Mr. Blumenthal.

**STATEMENT OF HON. RICHARD BLUMENTHAL,
U.S. SENATOR FROM CONNECTICUT**

Senator BLUMENTHAL. Thank you, Madam Chair. Nobody is going to out entrepreneur the United States sounds like famous last words. And the idea of a public-private partnership, when it comes to space, the idea of an ecosystem brings back memories of my law school days when people were saying we should have a course at Yale Law School on the Law of Space. Only at Yale Law School would anyone make that suggestion. And it was dismissed as one of those bubblehead, imaginary topics.

But there is no real law of space, is there? I mean, and should there be? Should we be thinking about, if we are going to have commercialization in space? You compared it, Administrator, to flying into other countries. But there is a means of enforcement there. You can ground pilots. You can take action that provides enforce-

ment of rules of the road, so to speak—rules of the sky, rules of landing and taking off, and equipment, and so forth. But there is not any in space. And so, I mean, if there are three or four commercial flights going up on the same day, maybe from the same place, you have got a lot—you are going to have a lot of objects up there. You already have a lot of objects bumping into each other, except they just do not have human beings on them. And having human beings, and having commercialization for expanded purposes, either of surveillance or other missions, complicates it. Should we be thinking about laws and enforcement mechanisms in space?

Mr. GOLD. So, Senator, as the only recovering attorney on this panel, I may go ahead and take that one. And for the record, it is not just Yale. I am actually giving a lecture at Georgetown Law School tomorrow on Space Law. So, it has certainly taken—taken root.

I do want to open with that there are laws in space. There is the Outer Space Treaty of 1967. There is the Registration Convention, the Agreement on the Rescue of Astronauts. So, there are a series of international agreements that set rules that nearly every country, or spacefaring country, certainly have agreed to abide by. However, there is a substantial gap that you are pointing out now, where, in the Outer Space Treaty, in Article 6, it requires authorization and continuing supervision of private sector activities.

And we here in the U.S. have yet to define how that continuing supervision will occur for non-traditional activities—be it satellite service, which we have mentioned, private sector space station, orbital debris removal, rovers—commercial rovers on the moon. We have not defined that yet. We have been using Band-aid solutions, via the FAAST and the FCC. But one of the most important things that Congress could do would address this issue, just to create a process that is predictable, and we know what to do here in the U.S. Because, frankly, it is a competitive issue. That predictability is key for investment and if we want to keep our country's here and keep innovation and keep entrepreneuring here in America, we need a predictable, reliable, and transparent regulatory system for commercial activities, which we do not have explicitly, yet.

Senator BLUMENTHAL. I think that is an excellent answer and obviously, I should have been more definitive or more specific in saying there is no law. There are, in fact, gaps in the law. Which means I probably should attend your lecture tomorrow at Georgetown. And I realize that law is the least glamorous or exciting aspect of space exploration. But I am very interested in your answer that, as in many other areas of life, certainty and predictability are very important for the risk takers and the scientists to make progress.

Mr. GOLD. Exactly. If you are going to invest, the last thing you want to see is an unpredictable regulatory environment. If you are going to ensure an activity, you need that certainty. So, I know it is not as sexy as fun, but it can be as important as any technological development to space not only occurring, but particularly occurring here in the United States.

Senator BLUMENTHAL. Spoken like a true recovering lawyer. Thank you. Thank you all for your testimony today and it has been

very enlightening. I have been following it from afar, in between hearings, and we really thank you for being here.

Senator LUMMIS. The gentleman yields back and the gavel is returned to the Chairman, the gentleman from Colorado.

Senator HICKENLOOPER. Thank you, Ranking Member Lummis. What did I miss? No.

[Laughter.]

Senator HICKENLOOPER [presiding]. We have a couple of people that are trying to get in remotely, and luckily, I happen to have more questions and I think Senator Lummis might have some—a couple more questions, too.

So, if I can re-enter the low Earth orbit of information, and let us go back to, Mr. Bridenstine. You spoke, I think, compellingly about the overcrowding in LEO and you did not even really get into that whole notion of, once you have collisions, how many more fragments are created and that you end up with a cavalcade of collisions. And that 1.5 percent really gets scary because that is too high, in and of itself, and I followed your math of how we get to 1 in a million. But there are a lot of probabilities between here and there and I think that is—it is unacceptable, when you begin to look at what—how rapidly you could escalate.

So, anyway, I think—again, how would you look at what should Congress be doing? Who should be—have the regulatory responsibility there? And we are all—we are fully aware of the discussions there, but I would love to hear your opinion.

Mr. BRIDENSTINE. So, the—right now the regulatory authority for debris mitigation falls to the FCC, the Federal Communication Commission, and that is based on a law passed in the 1930s. Mr. Gold could probably tell me the specific date. But there was a law passed in the 1930s that gave the FCC the authority to regulate Spectra. And from that, you know, satellites, you know, emit, you know, all kinds of transmissions. And so, from that, they say we have the ability to regulate satellite, you know, debris, and orbits, and that kind of thing. Which, by the way, it is good that they are doing it because if they were not doing it, nobody would be doing it. So, they extrapolated the law to take that authority among themselves.

I do not know—in fact I am confident that the FCC is not the agency that should be doing that. And the House and Senate have passed a bill that was signed that gives that authority to the Commerce Department. That has not been adequately funded at this point. They need, you know, resources to stand up a team of folks that can actually put into place the regulatory environment for this—for this capability.

Senator HICKENLOOPER. So, are you agreeing that that notion of having a separate escalating one of the departments from Commerce up to—

Mr. BRIDENSTINE. Yes. I know exactly what you are saying. So, the Office of Space Commerce.

Senator HICKENLOOPER. Yes.

Mr. BRIDENSTINE. Yes, so 100 percent.

Senator HICKENLOOPER. Office that is the word I was looking for, office.

Mr. BRIDENSTINE. Yes. The Office of Space Commerce is, right now, under NOAA. It is not—and look, we all love NOAA, but it is not their highest priority to do space situational awareness and space traffic management, let—and debris mitigation and remediation, as you mentioned earlier. So, since that is not—NOAA is not, probably, tremendously enthusiastic about that.

I do believe it is a high enough priority. It needs to report to the Office of Space Commerce. It needs to report directly to the Secretary of Commerce and be responsible to the Secretary for achieving the outcomes that we are looking for.

As far as what the FCC needs to do right now, given the risk that is in front of us, they need to consider that even satellites that can maneuver do have a collision risk. And that risk does not just come from other satellites, it comes from lethal, non-trackable debris. For every piece of debris, we can track that is 10 centimeters and bigger, there are, you know, 10 to 100 pieces of debris that we cannot track. So, they need to take that into account when they start thinking about the collision risk for—for, you know, low Earth orbit.

Once we recognize that there is a lot of risk here that, right now, is not being accounted for, I think it is important for us to say, OK, how many objects are we able to put into any orbital shell? And once we define that, then there needs—this is where the international pieces comes in. We recognize that there is a limitation. The question is, how do we allocate access to those orbital shells? And we need to have a process by which nations can get access to that and the United States of America needs to make sure that its allocation is, of course, adequately spread among, you know, competitive companies for a competitive marketplace.

Right now, none of that is happening. It is a race, and the race is, ultimately, going to result in disastrous consequences, if we are not careful.

Senator HICKENLOOPER. It reminds me a little bit of the old—do you remember the—as popularized in movies, via Hollywood, the Oklahoma Gold Rush—Land Rush, where they would all ride out and they had to stake off their little territory and they would be shooting each other and—I mean, it is, to a certain amount, out of control.

Dr. Dittmar, just continuing on that, this importance of having international agreement on how we are going to regulate this debris that is up there already. And this is one of those things—I mean, the first thing, when I have nightmare, it is usually about cybersecurity. But this is now becoming—it is—it is equally imposing onto my sleep patterns.

So, how would you look at the—what should Congress' role be toward building, or moving toward an international agreement on the appropriate regulation of space debris?

Dr. DITTMAR. So, following on conversations that we have, sort of, already been having here on the table, one of the things that is really critical about authorization acts is that they are signaling devices. They signal not just to the United States, with the intent of Congresses and especially its investment in continuity of purpose, but they also signal to the international community. So, other

countries look to see what Congress does. They look to see what is written into policy that is then expressed in an authorization act.

And one thing I would like to see—I am in complete agreement with Jim, with regard to elevating the Office of Space Policy, completely making sure that it is consistently staffed across administrations, to the extent that you can. You can certainly express an intent, OK, and the intent of Congress, that it is adequately staffed and resourced with the appropriate expertise, OK? And then it is a direct report to the Department of Congress and the head of the Department of Congress. And so, doing so, while you are investing it, OK, with the authority to begin, then developing the sorts of regimen.

You know this has been—Jim has talked about one—you know, one approach, which is sort of to look at, literally, what you can get into orbital shells and start thinking about regulation that way. But to invest them with the authority to be able to actually begin to be able to work in that way. Just doing that, OK, will convey to the United States how serious, I mean, how seriously the United States is taking this.

It is going to also help. There is a big PR war going on. I mean, it is a competitive issue. But there is a huge PR going on—war going on. You just, basically, need to send a message to essentially all the stakeholders here. “All right, look, no, we are serious about this. We are going to start pulling this together. We need to develop a regime. We are going to invest this office with the authority to be able to do that.” And it also signals, to the rest of the world, now, the United States is serious. We are going to take a leadership position here. Here is how is going to be, who is going to be accountable for actually being able to do it? And I know that sometimes, from the outside, that does not seem like much, but it really is a big deal.

Senator HICKENLOOPER. Oh, I buy that. And just as a frame of reference, the Office of Space Commerce, I believe, still does not have an executive director. So, we are in the market of hiring. So, if you have networks or connections, step forward and take one, you know, take one for the country, if you could.

All right, one more question and I will turn it back to Ranking Member Lummis. And I guess I will ask Mr. Gold this, since we are looking at global leadership and technological leadership. You know, obviously leading-edge technologies are evolving and innovating at lightning speed in our commercial space industries. Which technologies do you think are most critical to make sure that the United States does not cede the leadership role to our competitors, such as China?

Mr. GOLD. Yes. Thank for such a terrific question, Senator. There are really two areas that I would highlight. One is, we are at a period where robotics and satellites are merging to create something entirely different. At Redwire, for example, I mentioned the Archinaut satellite, which is—uses robotic arms to build itself. We are also developing satellites that will literally print themselves, leveraging the 3D printing technology that we have done on the International Space Station. So, when it comes to this orbital servicing, assembly, manufacturing, we cannot fall behind China and

others in this area. And the key to developing that is more public-private partnerships.

The other area I would cite is microgravity. That the microgravity environment is a whole new arena for scientific and commercial research. I believe it is why China is investing in their LEO space station. And we are just beginning to understand the biotechnology, the fiber communications development, new super-computer chips. Everything functions differently in low Earth orbit and the microgravity environment. And we must invest and develop those capabilities because it is going to change everything.

So, those are the two areas I would recommend focusing on.

Senator HICKENLOOPER. All right. They are good ones. I will turn it over to Ranking Member Lummis.

Senator LUMMIS. Thank you.

Senator HICKENLOOPER. I might come back with one more question, though.

Senator LUMMIS. Thank you, Mr. Chairman. One of the strategies that China has been using to increase its footprint in space is helping developing countries gain access to space. For example, in 2019, China provided satellite development and launch services to Ethiopia to launch that country's first satellite.

So, it seems to me the U.S. is generally more focused on relationships with nations that are already spacefaring. Do you see a value in the U.S. helping countries without programs access space? And how do you think we could or should do that? Mr. Bridenstine.

Mr. BRIDENSTINE. So, I will go first and then, I will turn it over to the others. So, the—when we think about the value of low Earth orbit, specifically, Mike mentioned a lot of items, as far as, you know, biotechnology and things like that. We think about pharmaceuticals, immunizations, the ability to create human tissue using your own DNA. Your own adult skin cells we can use to create your own tissue for regenerative medicine. The idea that we can use advanced materials, we can create—you know, potentially in future, we will be able to create an artificial retina for the human eyeball. So, people who have macular degeneration do not have to lose their eyesight.

So, these are things that are begin tested, right now, on the International Space Station. And when we cede that—when we cede that to China, if we do not have a replacement for the International Space Station, they are going to be able to benefit economically from all of those values of microgravity that we are not going to have access to, in the way that we currently have access to.

Now, as far as the international piece, you know, our—we have built capacity for countries in the past. We think about—well, I do not want to name any specific countries, but we have worked very hard on all of our international partners on the International Space Station. Fifteen countries operate the ISS. We have got, you know, 19 different countries that have had astronauts on the ISS. Those capacities are largely built by us.

And when we decide we are not going to have a next generation space station, which right now is the signal our country is sending by not funding the next generation human space station—I would say I saw, you know, defense—or, you know, the appropriations bill

for CJS. I think it had \$101 million in there for LEO commercial destinations, which I think is fantastic. But—but that is still not enough, just to be honest. We need more. We do not want to cede that territory to our biggest competitor, primarily because all of that capacity we built for these other countries is going to go to them. And they are going to start benefiting from that.

So, we have to maintain the leadership here. I think it is absolutely important. Countries that—when we think about Artemis and the Artemis Accords, we have been inviting countries that do not even have a space program, to participate in Artemis in whatever small way they can participate. Because, in my view, space is a tool of diplomacy for this country. It is something that every country wants, and we can help provide it.

So, when we think about the big picture, kind of, how the Nation thinks about agreements around the world, I think space needs to be on the table, regularly. When we—even when we do trade agreements, when we do any kind of large negotiation with another nation or many nations, space needs to be on the table because it is a great tool of diplomacy that can improve our position.

Mr. GOLD. Senator, it is a great question and even better opportunity for me to vent. The Intergovernmental agreement, the IGA, which was the agreement that established the International Space Station—it is extraordinarily difficult, if not impossible for other nations to join the IGA, which has prevented NASA from reaching out to other countries that do not have space programs or have space programs they just started.

The Artemis Accords were, in many ways, a reaction to that, that we wanted to create a vehicle that, no matter how modest your program was—even if it was just a couple of graduate students, that you could contribute to this unprecedented journey to the moon. And in the initiation of the Artemis Accords, you had countries like Luxembourg that has a relatively small but mighty space program and they are—by the way, shout out to the Embassy there at Luxembourg that has been so supportive. But also, United Arab Emirates which, again, has done amazing things in space but was not a traditional ally, certainly not on the International Space Station, yet.

So, through the Accords now, it is so important that we reach out to developing countries. I was so proud when Brazil joined the Artemis Accords, because that was our first Latin American country. And I certainly hope that we can proceed in Africa where, by the way, China has been very aggressive, in terms of international, diplomatic development. We need African countries in the Accords, supporting not just the Artemis program, but sensible norms of behavior. And I think that is our best vehicle to proceed and get these countries involved.

Senator LUMMIS. Dr. Dittmar, you were nodding.

Dr. DITTMAR. So, I would agree that it has been difficult for other countries to join the IGA, but I would also point out that the ISS has been used as a means to bring many countries, who are not spacefaring countries, into a larger community. It has, at this point, hosted—has, national projects of one type over another, for well over 105 countries, at this point, over its lifespan. And so, it has served as a tool of tremendous international diplomacy, not

just among the original 15. If I was back in—I am back, old enough back in the days that Brazil was in discussion about that, right? So, this is very nice to, sort of, see that come around again with Artemis Accords. But so, it has actually done that.

From the Axiom side, for example, as we are developing that space station, we are getting a lot of interest from internationals who see the commercial opportunity as a way to, sort of, bring themselves into the larger community of nations that are flying professional astronauts from those countries who are able to, sort of, use that. So, there is a lot of interest. I mean, we are finding that just even from a business point of view, let alone, sort of, national interest point of view.

I think if we cede this to China. I am alarmed, frankly. And I mentioned earlier that the reason I joined Axiom was I saw them as best positioned at this particular point in time, and I still believe that. But I am alarmed by what I see as the potential for a gap, which we have already talked about earlier.

And it goes back to what I said about objectives, right? I mean, in my written testimony, one of the things I said, and I think I said it orally, too, is that, you know, our objective needs to be assert and maintain U.S. leadership in low Earth orbit. Not just in low Earth orbit, but in all of space. But when we are talking about low Earth orbit that has always been done through exercise of soft power and use of soft power to bring other countries to our side.

So, I think it is absolutely critical that we continue to do this.

Senator LUMMIS. Dr. Sanders, is this something you wish to address?

Dr. SANDERS. Well, I will talk about the International Space Station and just quickly reiterate a point that was made earlier about the importance of having a persistent presence in low Earth orbit. We look at it from the Panel's perspective on the risk reduction that it provides for further exploration. And if you do not have that kind of persistent presence, in order to understand the effects of low Earth orbit of microgravity and the environment on the human physiology, for example, as well as other things, than you are not going to have the ability—you are going to have greater risk when you go further away. And so, there is—there needs to be that and there needs to be a good transition period, a good transition hand-off to whatever follows the ISS. And there needs to be something to follow the ISS, however we do it.

Senator LUMMIS. Thank you very much, Panel. I yield back.

Senator HICKENLOOPER. Thank you, Senator Lummis. Senator Cruz has joined us. Are you ready for your questions?

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

Senator CRUZ. Sure. Thank you, Mr. Chairman. Welcome to the witnesses. Good to see all of you again. Thank you for your good work.

As everyone on this panel knows, the International Space Station has been a big priority of mine for a long time. And not only is it a critical tool for projecting American leadership in space, something all the more important with the Chinese successfully putting the core module of their space station up, in April of this year, but

we have also invested over \$100 billion in it. And to be fiscally responsible and prudent, we need to get maximum use out of that investment.

Multiple times, the Senate has taken up legislation I have introduced to extend the ISS through 2030. The extension through 2030 was part of the NASA Authorization Act, which the Senate passed unanimously at the end of last year. It was also part of that same NASA Authorization Act that was included this year in the U.S. Innovation and Competition Act, which was passed by the Senate in May. And it is something that the current Administrator, Senator Nelson, strongly supports, as well. And so, both the current Administrator and the prior Administrator, we worked together on this extension. It is common sense. It is bipartisan. We are waiting on the House to act. And we will see if and when the House does act. But at least on the Senate side, it is 100 to nothing that this extension makes sense.

And I will mention to the Chairman, so there were battles in the prior administration because there were a few misguided voices in the Trump Administration that wanted to retire the ISS early. And Senator Nelson and I, on this subcommittee, took turns taking a two by four to the administration on that question. And it only took about 300 to nothing votes for them to realize that, perhaps their position was not going to prevail in the Senate. But we need to see the House act.

Let me ask the witnesses—look, I think we are going to get the extension done, in one vehicle or another. It is the right thing to do. It is long overdue. But given the experience of the panel, I am curious, technologically, from a safety perspective, what is keeping the station from lasting longer than 2030? From lasting through 2035 or 2040? There is a lot of expertise on this panel and so what is your collective judgment?

Mr. BRIDENSTINE. I will go ahead and start. First of all, Senator, the wounds from the two by four have recovered quite nicely and I think you are—

Senator CRUZ. To be clear, Jim, you were not the one advocating this.

Mr. BRIDENSTINE. No, I—I am aware of that but I was part of the administration. And look, here is the thing. I think what we are seeing now is that the foresight that you had at the time was right, because we are not ready for what comes after the International Space—we are not ready for it. Building a space station takes a long time, especially when you are doing it in a way that has never been done before which, in the future, will be commercial. I do not foresee Congress appropriating funds for a second International Space Station. I do not foresee that.

Now, that being said, here is the thing that I think is important. Extending it to 2030, I know the Senate has already passed that, and I support that. I would also tell you that there is no guarantee we are going to make it to 2030. Certainly, we should, if we can. We have seen already a crack on the International Space Station. We have seen a hole on the International Space Station. If you look at the outside of the space station, it has been, you know, pelted by debris. And of course, there is always modifications, upgrades that have to happen in order to keep it, you know, moving forward.

So, it is a—it is a marvel of engineering. Mike Gold used to tell me quite frequently we need to put it in for a Noble Peace Prize, which I think is right. It is a tool of diplomacy. It has been just a phenomenal capability for our country all around, not even considering how much science is coming from it right now.

So, the key is, extending it. Yes, there is a challenge. We know it cannot last forever. How far can it last? I do not think we have that answer. Right now, I think it is—we are in great shape.

Senator CRUZ. Well, and let me ask a related question, which is what do you all think is the timing for a replacement of comparable capability? And when is that transition realistically possible? And how do we ensure that the ISS is operational—that we do not cede low Earth orbit, for a period of time, to the Chinese, that we maintain U.S. leadership continuously?

Mr. BRIDENSTINE. So, the future is going to depend on how much it gets funded. Right now, it has been funded at nothing compared to what it needs. I think it was, like, \$15 million, or something like that, for the transition to a new commercial, you know, space station. But what we need—and the CGS Appropriations Bill had \$101 million, which met the President's budget request. That coming from the Senate—the Senate had \$101 million in there to meet the President's budget request, which is fantastic. But I am telling you, sir, it is still not enough.

When we think about how long it takes to develop a space station, especially in a way that has not been done before, I do not know how long, I am not going to give you an answer on the date that that, but here is what—here is that I think the Senate should do. The Senate should absolutely declare that NASA needs to tell it when it is going to—what is the objective to have that new space station and then, the Senate needs to fund the requirements to achieve that.

I do not think the right answer is to continue—first of all, extending the space station is the right thing to do. But continuing that, in perpetuity, believing that it is going to last forever, I think is not the right approach. And I am not suggesting that is what the Senate is doing, at all.

But NASA needs to say, you know, "Here is how we are going to replace it. Here is what it is going to cost." They need to put that in the President's budget request with many years—you know, 5-year outlook, and then, come to you and say, "This is the money that we need". And right now, I do not see that happening the way it should happen.

Dr. DITTMAR. And that begins with, I think, NASA needs to completely fulfill the spirit of what was written into the 2017 NASA Transition Authorization Act, having to do with the transition plan. And a transition plan needs to have, you know, timing, milestones, clear objectives, how those objectives are going to be met. And then, once that is in place, then you can begin to have a conversation about follow-ons.

So, as you know, Axiom—because we have—you know, we have spoken to you about this, Axiom's approach, you know, was funded on a competitively awarded agreement that was negotiated with NASA. And that \$101 million that Jim was talking about, when you look at how NASA is planning to allocate it, does not meet the

commitment to Axiom for 2022. The work that needs to go to work on the space station side of it, in other words, for the station to do the analysis that is needed, in order to ensure that Axiom can reach orbit and dock by 2024, is not funded completely in that amount. Let alone, looking at the creation of dual path, you know, for having maybe more of an alternative to it.

So, I would agree, definitely more funding is needed. But also, NASA needs to be clear about objectives and the means that it sees at this point. Understanding that any transition plan is going to be a stake in the sand at the moment, it is going to have to be iterated upon, but it needs to be much clearer about what those objectives and milestones are.

Mr. GOLD. So, Senator, I do not know if I can enter this into the record, but I borrowed my son's ISS folder for today's testimony. I am such a fan. We talk about a lot of recycling on Earth, and I can tell you it is even more important on orbit. As you pointed out—and again, I appreciate your support and your two by four. That kept us going, you know, during some difficult times. We need to squeeze every minute and ounce of capability out of the ISS.

And in terms of when we should be retiring it—I mean, again, I am a recovering attorney but, you know, the engineers tell me there are seals that will wear out, etc. But there is still going to be good hardware and we should look at, yes, maybe there is a point of retirement, but continuing to leverage the hardware that we can continue to use as part of another system or as part of a smaller system.

And as we discussed before you arrived, you know, at Redwire Space we are the global leader of microgravity research, development, and manufacturing. The only company to actually build things on the ISS. And we are looking at a future with biotech and organs, etc., that you can build. We cannot see those technological capabilities or the diplomatic or political benefits of low Earth orbit to China. So, we need to have a two-pronged approach. One, extend the ISS to 2030, which I included in my written remarks. And then, ensure that we proceed with enough funding and capability to deploy a free-flying commercial space station so that it is operational while the ISS is still there, and we do not create a gap in low Earth orbit that would be disastrous for us and the Nation. And as you point out, you have fans at NASA in doing that. You know, Senator Nelson—Administrator Nelson has been a great supporter and we have talked a lot about the need for an authorization bill. You have former staff that was working on that authorization bill that is now over at NASA. So, I think you have got great allies at the Agency.

Senator CRUZ. Thank you.

Senator HICKENLOOPER. Great. Thank you, Senator. Appreciate you making the effort to get over here. I think we are at that point where I am forced by tradition and circumstance to let you go.

The hearing record will remain open until November 18, 2021. Any Senators who would like to submit questions for the record, for the witnesses, should do so by November 4, 2021. To all of you witnesses, in addition to my gratitude, we ask that your responses be returned to the Committee by November 18, 2021.

Again, I would like to thank each of you for your testimony today, but really, your service in terms of maintaining or helping to create America's role as a leader in space, but also to maintaining.

That concludes our hearing for today. We are adjourned.
[Whereupon, at 12:03 p.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. KYRSTEN SINEMA TO DR. MARY LYNNE DITTMAR

NASA Reauthorization. The U.S. Innovation and Competition Act (USICA) includes legislative language to reauthorize the National Aeronautics and Space Administration (NASA) that I developed on a bipartisan basis last year with Senators Cantwell, Wicker, and Cruz. NASA was last authorized in 2017.

Question 1. Why is it important for Congress to reauthorize NASA after failing to do so for many years?

Answer. It is important and necessary for Congress to pass authorization acts for several reasons. Authorization laws are intended to create, continue, and modify programs. These bills provide policy guidance and ensure that the goals of an agency are met. For NASA, it is critical that constancy of purpose is prioritized through authorization acts, so that the agency's multi-year investments and programs can maintain stability with regard to schedule and cost, and thus, support the agency as it strives to meet its goals. Authorization acts also 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 also to those who do not wish us well. Finally, authorization acts provide a critical tool for Congressional oversight.

Question 2. Do you support the reauthorization language in the USICA bill?

Answer. There are many strong components of the Senate-passed bill. As I mentioned in my testimony before the committee, I applaud Congress for including language (once again) that it is the priority of the United States to maintain a continuous human presence in LEO (section 2620 (1–3, 3(b))). In light of the findings and recommendations in the DoD Defense Innovation Unit's 'State of the Space Industrial Base' released on November 18, Congress may consider further strengthening the language to read "continuous American presence in space, beginning with low Earth orbit." The report can be found by accessing the linked pdf below.

https://assets.ctfassets.net/3nanhbfr0pc/43TeQTAmDYrm5DTDrhjd3/a37eb4fac2bf9add1ab9f71299392043/Space_Industrial_Base_Workshop_2021_Summary_Report_-_Final_15_Nov_2021c.pdf

In addition, I support the reauthorization language that extends the ISS to "at least 2030" (Section 2521, and conforming amendments. Beyond 2030, the costs of maintenance, operations, and particularly the engineering lifecycle data should be evaluated carefully, as well as the ongoing role of the ISS. Certainty is required by commercial providers who are developing follow on stations to close their business cases which in turn is imperative to meet the higher order requirement to ensure continuing U.S. interests and human presence in low Earth orbit after the ISS end-of-life.

However, regarding space suits (Section 2616, (1))), I would suggest that driving NASA to partner "to the maximum extent practicable with industry-proven spacesuit design, development and manufacturing suppliers" may limit innovation. Partnering with such entities is a good idea but so is partnering with entities that "credibly demonstrate the capability to meet requirements as determined by NASA". To that end, I would also suggest that rather than providing NASA the option to partner with "1 or more private entities", this should be changed to "2 or more", based on precisely the same logic that the re-authorization employs in its position that the Human Landing System (HLS) should involve 2 or more providers.

Regarding Section 2627, "Payments Received for Commercial Space-Enabled Production on the ISS", I commend the committee for placing this into context by directing the NASA Administrator to take into account "the relative maturity and profitability" of the applicable product or service. However, "profitability" of a product or service may or may not be a simple metric, depending upon how the development of that product or service has been funded by a company. Most importantly,

however, the low Earth orbit “economy” does not yet exist; it is a nascent entity that at its best creates goods and services that are executed in part in space but are based wholly on Earth. Congress should be doing everything in its power to enable companies to demonstrate profitability in production efforts—a goal that is still a long way off—to encourage investors to come to the table to support them and most importantly to support the commercial space stations that Congress intends should eventually take the place of the ISS. Those companies will be the customers of such stations and the entities trying to raise capital now on the private market must be able to assure their investors that business cases can close by ‘going concerns’ that have time to fully demonstrate their viability on the ISS without government levying a “lien” of sorts that will then be deposited into a government-managed space exploration fund.

Beyond the specific language of NASA reauthorization language, I also strongly support the language regarding Space Situational Awareness and encourage Congress to fund this effort and give it full attention and encouragement. Last week’s Russian ASAT test illustrates (again) the need for U.S. leadership and orchestration of the complex issues related to SSA. It is critical that Congress work with the Administration to confirm a Director for OSC who will provide clear leadership to OSC and provide a focal point for interagency and across-industry collaboration. Further, OSC should be elevated into a separate bureau—the Bureau of Space Commerce—instead of being left within the National Oceanic and Atmospheric Administration (NOAA). OSC should be given authority over clear goals, namely: promoting commercial space and championing it within the government, aiding in the development of standards and norms of behavior in space, identifying and addressing regulatory gaps. Moving OSC out from NOAA will give it the independence to establish a new, clean cut, directive organizational culture.

International Space Competition. As discussed in the hearing, the United States faces growing international competition in space. The Chinese government is building its own space station, recently launched a hypersonic missile, and is spending billions of dollars on establishing and promoting new space capabilities that cross-over from military to civil applications and back again (‘military civil fusion, or MCF’). In addition, companies in the United States and several abroad have applied for tens, or in some cases, hundreds of thousands of satellites in low-Earth orbit.

Question. What actions should Congress take to ensure that NASA and the United States remain global leaders in space?

Answer. It is undeniable that China is moving fast in LEO, and forging partnerships with members of the international community for activities onboard their station and in cislunar space. In my testimony, I noted that China is playing the long game, and it is critical that in assessing China’s intentions in space, Congress understand how the People’s Republic of China (PRC) is advancing rapidly across a range of space technologies and capabilities. The U.S.-China Economic and Security Review Commission (USCC) produced a report to Congress in 2019 that outlined the need for a comprehensive, wholistic perspective regarding China’s competitive interests in space. In my testimony, I included the USCC’s findings on China’s strategy to catch up and overtake the U.S. in preeminence in space.

In the National Defense Authorization Act of 2020, Congress responded to the USCC report by codifying recommendations for action. Namely, the defense bill called 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 by the PRC . . .” and also “. . . a plan to strengthen and streamline cooperation with international allies and partners in space.”¹

NASA, and by extension 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. China’s ability to plan and make investments 5–10 years out under a military-run program and an increasingly totalitarian government is intended to enable Chinese hegemony in space with a fairly high degree of certainty. This, unfortunately, is an area where the U.S. must look itself in the mirror and understand that it must dedicate itself to constancy of purpose and multi-year strategic planning and investment. We have maintained our leadership role in space for many years thanks to the great public servants of NASA and ingenuity of the American people, but China is making great strides in their goal to meet pace with America. If the U.S. Con-

¹ 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>

gress hopes to maintain its leadership role in low-Earth orbit, for example, a forward thinking and thoughtful plan for a post-ISS world must come sooner than later. Our international partners, U.S. commercial partners, and the scientific community must be engaged as Congress strategically positions the U.S. to continue thriving and exploring space.

To go further, Congress must recognize that space as a domain extends far beyond NASA's remit. Congressional committee structure makes it difficult to meaningfully define strategy for the U.S. future in space, which is in many ways the same thing as the U.S. future and leadership on Earth. Space is simultaneously a contested and crowded corridor for transportation of goods, services, and assurance of security, an economic engine promoting job growth, an operational domain for civil, military, and commercial entities, a key component of U.S. infrastructure, a collaborative and competitive zone for foreign powers, a security-critical 'location', a driver of technology advancement, plays a key role in monitoring and possibly mitigating climate change, and much more. As pointed out in the aforementioned DIU publication, the state of the U.S. space industrial base is "tactically strong but strategically fragile." In my opinion the U.S. is not prepared for the increasing competition in space. Becoming prepared will require a "whole of government" approach that Congress has not yet evidenced, beginning with addressing institutional barriers in committee scope, collaboration, and oversight. Full utilization of a bipartisan bicameral "space caucus" would be a start, as would work on joint hearings, for example on the establishment of an "economic security corridor" extending from the Earth to the Moon (and beyond). Another approach would be to extend support for NASA's Artemis Accords by authorizing both Artemis and the Accords and advancing their international goals, as the Committee just did in this most recent hearing.

Role of University Partnerships. Much of the hearing discussion focused on the International Space Station and near-earth orbit satellites. Arizona universities support these missions, and additionally, the universities are leaders in other NASA projects. For example, Arizona State University's OSIRIS-REx Thermal Emission Spectrometer has collected samples from an asteroid and will return to Earth in 2023. Meanwhile, the University of Arizona's Near-Earth Object (NEO) Surveyor Mission will help NASA complete its Congressional mandate to discover 90 percent of all near-Earth objects larger than 140 meters in length.

Question 1. How can we ensure that crucial science and planetary defense missions, such as OSIRIS-REx and the NEO Surveyor, receive the support from NASA to be successful?

Answer. NASA's Human Exploration programs and its Space Science missions are two sides of the same coin; the human aspiration and intention to inquire of the universe "Where did we come from? Where are we going?" Our understanding of the universe is advanced step-by-step through robust support and decades-long development and funding of space science programs such as OSIRIS-Rex and the NEO Surveyor. However, these particular missions play a dual role; that of generating knowledge needed to develop the systems we need to protect our planet from NEO incursions. Critical programs such as OSIRIS-Rex and the NEO Surveyor need champions in Congress who will continue to support these and other missions through strong authorization and appropriations language. This can be difficult in the face of many other pressing—and apparently more immediate—national priorities; however, the question of planetary defense is only a question until it's not.

Question 2. In your opinion, how can NASA best utilize university partnerships to perform research, advance science, and help NASA reach its goals?

Answer. University partnerships are important for engaging the next generation of science and engineering leaders across the United States, and for expanding both the nature and quantity of collaborative partnerships related to NASA's mission and extending that mission. For example, NASA's L/SPACE Academy, a collaborative partnership between NASA and Arizona State University (ASU), provides the opportunity for undergraduate students to participate in free, online, and interactive programs that encourages students to learn about NASA missions and connects them with industry professionals. <https://www.lspace.asu.edu/> In addition, ASU is the lead university for the Psyche Mission—an extraordinary mission to a 'metal asteroid'. The Psyche team in turn has set up an online course about the mission which encourages participation and learning not only about Psyche but in related STEM fields. ASU was also the 2020 winner of NASA's Big Idea Challenge—<https://bigidea.nianet.org>—which provides opportunity for partnerships with universities and other entities. Finally, competitions run by NASA that provide opportunities for universities to collaborate with the agency and with other companies has been a part of NASA's rich legacy of stimulating both basic and applied research since the earliest days of the space program. Finally, ASU is also a partner in the MILO

Space Institute—an innovative partnership between ASU and Lockheed Martin to establish momentum toward public-private partnerships in science. Not to be overlooked, Arizona University is a key contributor to pathfinding NASA missions such as the Phoenix Mars Lander, the James Webb Space Telescope, which will enable humanity to peer back through time to the earliest moments after the beginning of the universe, and OSIRIS-Rex.

Arizona's Apollo History. During the Apollo mission in the 1960s and 1970s, NASA astronauts trained at Sunset Crater National Monument near Flagstaff, Arizona, where the volcanic landscape approximated the lunar surface. Astronauts also trained at Meteor Crater in the high desert of northern Arizona.

Question. Could these locations in Arizona be beneficial to Artemis astronauts as they train for their lunar missions?

Answer. Training for spaceflight missions is informed by all that has been learned before, from previous missions and training programs. If the locations are still deemed to be close approximations of the lunar surface—in particular the environment around the south pole of the Moon, where the Artemis missions are intended to be carried out—then they would certainly be reasonable candidates for training.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. RAPHAEL WARNOCK TO
DR. MARY LYNNE DITTMAR

Regulatory Framework for Commercial Spaceflight. In recent years, we have seen the tremendous growth in the commercial space sector. As multiple witnesses have noted, the responsibility of regulating this industry is spread across a variety of Federal agencies, with differing levels of technical expertise and industry outreach.

Question 1. How can Congress improve interagency cooperation to better serve America's commercial space sector?

Answer. The Office of Space Commerce (OSC) is the designated lead agency for representing commercial space sector interests in interagency discussions, yet the office's director position remains vacant. It is critical that Congress work with the Administration to confirm a Director for OSC who will provide clear leadership to the function of OSC.

Further, OSC should be elevated into a separate bureau—the Bureau of Space Commerce—instead of being left within the National Oceanic and Atmospheric Administration (NOAA). OSC should be given authority over clear goals, namely: promoting commercial space and championing it within the government, aiding in the development of standards and norms of behavior in space, identifying and addressing regulatory gaps. Moving OSC out from NOAA will give it the independence to establish a new, clear cut, directive organizational culture.

Once OSC is elevated and established in its roles and responsibilities, interagency cooperation will be made easier with the benefit of jurisdictional clarity.

Question 2. Do you believe that Congress Federal regulatory oversight of commercial space endeavors should be more concentrated within one agency than exists under the current regulatory landscape? If so, what are the considerations that Congress should keep in mind as it designates or establishes such an office?

Answer. There are benefits to different agencies regulating certain aspects of commercial space. FAA's Office of Commercial Space Transportation (AST), guided by Chapter 509 of Title 51, ensures the safety of the uninvolved public and their property, protects national policy goals, and enables industry growth by providing guidance, launch licenses, experimental permits, and promotional support including R&D. FAA AST has developed considerable expertise in commercial space transportation and has done a good job meeting the challenges that come with a rapidly growing industry. FAA AST requires continued oversight from Congress to balance the needs of industry to develop without premature regulatory burdens with the need to ensure, as far as possible, public safety.

The Office of Space Commerce (OSC) has been tasked with shaping civil space situational awareness, modernizing oversight and regulation activities, and promoting the U.S. civil space industry internationally. This office's role is more important than ever—with a growing debris field around the earth, posing a serious threat to unfettered access to space, and our national assets that exist in the space domain—many of which contribute in a critical way to U.S. national security and our day-to-day activities. In addition, in the recent past OSC has played an important “convening” role for the commercial space industry, encouraging a free exchange of ideas, and building cross-agency bridges through sponsorship of events with the Department of State and the U.S. Trade Organization. These events and exchanges are

an important part of the government function and a way that the government can encourage industry growth.

Question 3. How should Federal agencies best engage with industry to ensure that Federal regulation of commercial space entities meets the need for public safety and oversight without unnecessarily curbing innovation?

Answer. The U.S. Commercial Space Launch Act of 1984 as amended (51 USC 50901) is the primary law guiding Federal oversight, regulation, and promotion of the U.S. commercial space transportation industry. The law mandates that the Secretary of Transportation ensure that all launch and reentry activities shall protect public safety of property and support U.S. national security and policy interests, and that the Secretary shall issue licenses to U.S. applicants who show that they do and will continue to meet safety requirements. The CSLA has been amended several times since 1984. Critical to the regulatory regime's enabling nature is its exclusive focus on protecting the uninvolved public and their property. Space transportation continues to be seen as a dangerous and risky activity, *i.e.*, not a common carrier mode of transportation with an expectation of safety and success for those who opt to participate. Thus, in the case of human spaceflight, the law expressly limits regulation for their safety and calls for informed consent of the flight participants. The intention of this "learning period" is to allow the industry time to grow and develop best practices ahead of the eventual arrival of regulatory action by the government.

The commercial space industry in the United States is dynamic and evolving. A great example of this growth can be seen by the increase in launches licensed by the FAA per year. In 2011, the FAA licensed only one launch, in 2016, they licensed 11, and in 2021 so far, 47 licensed launches have occurred.¹ While the industry has certainly experienced immense growth over the past decade, it would be unrealistic to determine it deserves the same type of regulatory landscape as that of commercial aviation, which transportations thousands of people globally each day. Given the technical and economic challenges in rocket science, this bounding of regulatory risk—while still protecting American citizens and interests from harm—gives entrepreneurs and investors' confidence that they will get permission to fly.

Continued encouragement by Congress on the development of safety standards and best practices between industry and the government will lead to an informed and mutually beneficial relationship for all parties involved, while not prematurely hamstringing the growth and progress of the commercial space sector in a time where America sees foreign powers rapidly developing this critical technology of their own.

FAA/AST faces a growing workload, as launch cadences continue trending upward. As mentioned, AST requires the resources to meet this exciting challenge. Furthermore, Congress should invest directly in the consensus standards effort identified by FAA's Commercial Space Transportation Advisory Committee (COMSTAC) as the agreed-on consensus choice for human spaceflight standards-writing.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. KYRSTEN SINEMA TO
MIKE GOLD

NASA Reauthorization. The U.S. Innovation and Competition Act (USICA) includes legislative language to reauthorize the National Aeronautics and Space Administration (NASA) that I developed on a bipartisan basis last year with Senators Cantwell, Wicker, and Cruz. NASA was last authorized in 2017.

Question 1. Why is it important for Congress to reauthorize NASA after failing to do so for many years?

Answer. Since Apollo, no NASA beyond low Earth orbit ("LEO") human spaceflight program has come to fruition, leaving our international partners justifiably skeptical of the Agency's ability to sustain such efforts and achieve success. This stands in stark contrast to China which has maintained both consistency and continuity for their own beyond LEO human spaceflight efforts and their space program generally. The best way to reassure our partners in Europe, Japan, Canada, and throughout the world is for Congress to pass a bipartisan reauthorization bill that demonstrates uniform support for the Artemis program and key aspects such as the Lunar Gateway which international partners are contributing billions of dollars to.

Question 2. Do you support the reauthorization language in the USICA bill?

¹"FAA Licensed Launches." Licensed Launches. Federal Aviation Administration, April 19, 2021. https://www.faa.gov/data_research/commercial_space_data/launches/?type=license.

Answer. Yes, the language in the USICA provides critical support for Artemis as well as for other important issues such as the extension of the International Space Station (ISS) to 2030 and ensuring the development of a commercial space station to ensure that the U.S. maintains a constant crewed presence in LEO.

International Space Competition. As discussed in the hearing, the United States faces additional international competition in space. The Chinese government plans to develop its own space station and recently launched a hypersonic missile. Other nations have applied for tens, or in some cases, hundreds of thousands of satellites in low-Earth orbit.

Question. What actions should Congress take to ensure that NASA and the United States remain global leaders in space?

Answer. Again, Congress should pass a bipartisan authorization bill that explicitly supports the Artemis program. Moreover, Congress should extend the ISS until at least 2030 and direct NASA to support a future commercial space station by serving as a robust customer for such a platform including the purchase of seats not just for U.S. astronauts but for international partners as well allowing the Agency to maintain its traditional barter system and leadership role in space exploration.

Congress should also take action to ensure that the U.S. does not fall behind China and other nations in orbital servicing, assembly, and manufacturing. Specifically, Congress should explicitly direct NASA to support critical programs such as OSAM-3 and the deployment of an Earth Science Platform which will bolster our knowledge of climate change while developing critical new capabilities to ensure that the U.S. doesn't fall behind China in this vital field of space-based robotics/next-generation persistent platforms.

Role of University Partnerships. Much of the hearing discussion focused on the International Space Station and near-earth orbit satellites. Arizona universities support these missions, and additionally, the universities are leaders in other NASA projects. For example, Arizona State University's OSIRIS-REx Thermal Emission Spectrometer has collected samples from an asteroid and will return to Earth in 2023. Meanwhile, the University of Arizona's Near-Earth Object (NEO) Surveyor Mission will help NASA complete its Congressional mandate to discover 90 percent of all near-Earth objects larger than 140 meters in length.

Question 1. How can we ensure that crucial science and planetary defense missions, such as OSIRIS-REx and the NEO Surveyor, receive the support from NASA to be successful?

Answer. Congress should include explicit direction in authorization and appropriations bills directing NASA to leverage Archinaut-based technologies to enhance the capabilities of science and planetary defense missions while lowering their costs.

Universities also have an important role to play in support of new commercial space stations. Specifically, Redwire Space is proud to be a partner with Arizona State University in support of the Orbital Reef, a next-generation commercial space station. Other Orbital Reef team members include Blue Origin, Sierra Space, and Boeing.

Question 2. In your opinion, how can NASA best utilize university partnerships to perform research, advance science, and help NASA reach its goals?

Answer. NASA should leverage universities to support key programs and missions, taking advantage of educational institutions' robust capabilities and to support vital workforce development to ensure that the U.S. does not fall behind China or other nations in space development and operations.

Arizona's Apollo History. During the Apollo mission in the 1960s and 1970s, NASA astronauts trained at Sunset Crater National Monument near Flagstaff, Arizona, where the volcanic landscape approximated the lunar surface. Astronauts also trained at Meteor Crater in the high desert of northern Arizona.

Question. Could these locations in Arizona be beneficial to Artemis astronauts as they train for their lunar missions?

Answer. Absolutely. Continued ground training in Arizona and in other states will be a critical part of ensuring that Artemis astronauts are prepared to tackle the numerous challenges they will face exploring the Moon and Mars.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. RAPHAEL WARNOCK TO
MIKE GOLD

Regulatory Framework for Commercial Spaceflight. In recent years, we have seen the tremendous growth in the commercial space sector. As multiple witnesses have noted, the responsibility of regulating this industry are spread across a variety of Federal agencies, with differing levels of technical expertise and industry outreach.

Question 1. How can Congress improve interagency cooperation to better serve America's commercial space sector?

Answer. Thank you for asking such an important question. Establishing a proper regulatory framework which balances innovation and commercial development with preserving the space environment and meeting our international treaty obligations is vital. The most glaring issue that needs to be addressed is to establish an explicit system for providing "continuing supervision" as required by the Outer Space Treaty of 1967 for commercial activities including private sector space stations; orbital servicing, assembly, and manufacturing; commercial lunar rovers; and mining activities on the Moon or asteroids.

Congress should designate an entity within the Federal Government to exercise this continuing supervision activity by creating a 'Mission Authorization' process that would require companies to describe their proposed activities prior to launch and subsequently update the government of any substantive changes. This would provide a benign means of meeting the 'continuing supervision' requirement that wouldn't unduly burden entrepreneurs while still generating the information necessary that, per the requirements of the Artemis Accords, would be publicly shared with the United Nations to prevent confusion and conflict in space.

Question 2. Do you believe that Congress Federal regulatory oversight of commercial space endeavors should be more concentrated within one agency than exists under the current regulatory landscape? If so, what are the considerations that Congress should keep in mind as it designates or establishes such an office?

Answer. Further concentration of regulatory oversight for all commercial space endeavors into a single agency would be ideal. However, for such a paradigm to succeed, this single agency not only needs the proper authority, but must also be properly resourced in terms of funds and experienced personnel to avoid causing undue burdens that would harm American competitiveness, job growth, and scientific activities such as combating climate change.

Question 3. How should Federal agencies best engage with industry to ensure that Federal regulation of commercial space entities meets the need for public safety and oversight without unnecessarily curbing innovation?

Answer. All Federal agencies that engage in regulating commercial space activities should create or leverage existing Federal Advisory Committees to ensure that industry and government are acting in concert with each other to maximize both innovation and safety. Government and industry are stronger when they're working together. For example, during the hearing a question was asked about the NASA Advisory Council's Regulatory and Policy Committee (NAC RPC). This Committee is comprised exclusively of industry representatives and is vital to ensure that NASA and the private sector are communicating with each other on important regulatory and policy issues. In stark contrast, the NAC itself has only one industry representative which is completely at odds with the large and important role private sector entities play in executing NASA's mission. NASA should proceed with appointing more industry representatives to the NAC and its various committees, redouble its use of the NAC RPC, and other agencies/departments, such as the Departments of State and Commerce, should develop their own Federal Advisory Committees focused on commercial space activities.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. KYRSTEN SINEMA TO
DR. PATRICIA SANDERS

NASA Reauthorization. The U.S. Innovation and Competition Act (USICA) includes legislative language to reauthorize the National Aeronautics and Space Administration (NASA) that I developed on a bipartisan basis last year with Senators Cantwell, Wicker, and Cruz. NASA was last authorized in 2017.

Question 1. Why is it important for Congress to reauthorize NASA after failing to do so for many years?

Answer. The space environment is changing rapidly and is not the same as it was in 2017. Reauthorization of NASA at this time would be advantageous to set expectations for the Agency in the current and emerging environment.

Question 2. Do you support the reauthorization language in the USICA bill?

Answer. The USICA bill is very complex and wide-ranging. I would only comment on Part II which addresses space and only in general terms relevant to the charter of the ASAP. The Panel is pleased to see the emphasis placed on Space traffic Management and Space Situation Awareness which is consistent with the recommendation we made in 2020. We also support, as important safety and risk management approaches, the emphasis on continuing presence in Low Earth Orbit, the support for competing designs for the Human Landing Systems, the need for work on advanced space suits, and a step-wise approach to space exploration.

One issue not addressed in the USICA bill is the much needed revision of the language in the NASA Authorization Act of 2005 concerning Human Space Flight Independent Investigations. The ASAP noted, as far back as 2015, that the language, while perhaps appropriate and logical for the ISS and Space Shuttle, was inadequate and obsolete for the emerging environment that included reusable and commercially provided space vehicles. In 2015, the ASAP made the following recommendation:

The 2005 Authorization language should be reviewed with today's systems in mind. . . including details on the level of vehicle damage requiring investigation, the temporal issues of when mission phases begin and end, and NASA's oversight role in mishap investigations conducted by its providers, as well as when the need for oversight is required. The mishap response procedures should be thought through, documented, and in place well before any actual flights.

The 2005 Authorization language is even more inadequate when considering the emerging space travel involving non-NASA participants. Yet this recommendation remains open and increasingly relevant.

International Space Competition. As discussed in the hearing, the United States faces additional international competition in space. The Chinese government plans to develop its own space station and recently launched a hypersonic missile. Other nations have applied for tens, or in some cases, hundreds of thousands of satellites in low-Earth orbit.

Question. What actions should Congress take to ensure that NASA and the United States remain global leaders in space?

Answer. Congress can support NASA and United States global leadership by (1) providing adequate and stable resources to support a consistent program of work and a responsible and realistic schedule for that work, and (2) providing an appropriate regulatory framework to support the entire national space environment, including government and commercial entities.

Role of University Partnerships. Much of the hearing discussion focused on the International Space Station and near-earth orbit satellites. Arizona universities support these missions, and additionally, the universities are leaders in other NASA projects. For example, Arizona State University's OSIRIS-REx Thermal Emission Spectrometer has collected samples from an asteroid and will return to Earth in 2023. Meanwhile, the University of Arizona's Near-Earth Object (NEO) Surveyor Mission will help NASA complete its Congressional mandate to discover 90 percent of all near-Earth objects larger than 140 meters in length.

Question 1. How can we ensure that crucial science and planetary defense missions, such as OSIRIS-REx and the NEO Surveyor, receive the support from NASA to be successful?

Answer. The ASAP has not focused on science and planetary defense missions, but recognizes their importance. Support and resources from the Congress will be critical to NASA support.

Question 2. In your opinion, how can NASA best utilize university partnerships to perform research, advance science, and help NASA reach its goals?

Answer. NASA can best achieve its goals by taking advantage of the full range of capabilities available to it, including those from universities, commercial industry and international partners.

Arizona's Apollo History. During the Apollo mission in the 1960s and 1970s, NASA astronauts trained at Sunset Crater National Monument near Flagstaff, Arizona, where the volcanic landscape approximated the lunar surface. Astronauts also trained at Meteor Crater in the high desert of northern Arizona.

Question. Could these locations in Arizona be beneficial to Artemis astronauts as they train for their lunar missions?

Answer. I am not sufficiently familiar with the specific locations mentioned to comment.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. RAPHAEL WARNOCK TO
DR. PATRICIA SANDERS

Regulatory Framework for Commercial Spaceflight. In recent years, we have seen the tremendous growth in the commercial space sector. As multiple witnesses have noted, the responsibility of regulating this industry are spread across a variety of Federal agencies, with differing levels of technical expertise and industry outreach.

Question 1. How can Congress improve interagency cooperation to better serve America's commercial space sector?

Answer. A number of Agencies today engage with or otherwise have an influence on the commercial space sector to include: NASA, DoD, DOT, FAA, DOC, FCC and the State Department. Interagency cooperation on space issues has generally been positive. Therefore, it may not be necessary for Congress to be concerned about improving interagency cooperation.

Interagency cooperation has not been an area of focus for the ASAP, but some actions that we do believe Congress could take to better serve the United States commercial space sector—and NASA—would be to

- Avoid programmatic gaps and delays by providing adequate and timely resources for government-funded space programs. A long-term perspective is needed for since these systems can take years to develop. Following a normal appropriations process rather than adopting Continuing Resolutions would be a key step.
- Ensure that roles and responsibilities for space-related departments and agencies are clear and do not have any inappropriate overlaps or holes.
- Update the outdated, existing procedure for investigating human space flight mishaps (as previously recommended by the ASAP).
- Identify a lead Federal agency for Space Traffic Management and provide the necessary authority, immunity from lawsuits, and resources to do the job (as also previously recommended by the ASAP).

Question 2. Do you believe that Congress Federal regulatory oversight of commercial space endeavors should be more concentrated within one agency than exists under the current regulatory landscape? If so, what are the considerations that Congress should keep in mind as it designates or establishes such an office?

Answer. The ASAP has not specifically considered whether oversight of commercial space endeavors should be concentrated under one agency. It is possible that consolidation and streamlining could be accomplished by transferring functions from other organizations to one, perhaps significantly simplifying the approval process for space operators. Alternatively, or as an interim step, it may be possible to streamline the regulatory process without making major changes to responsibilities, staffing and budgets, by designating a new or existing agency to serve as the regulatory “front door” for commercial space operators. This office might then work to consolidate and streamline the needed regulatory approvals and a consistent government response.

Question 3. How should Federal agencies best engage with industry to ensure that Federal regulation of commercial space entities meets the need for public safety and oversight without unnecessarily curbing innovation?

Answer. One possible approach would be for Congress or the White House to establish top-level guidance to do just that—to ensure public safety and to encourage, facilitate, and promote commercial space transportation. As another step toward ensuring that a regulatory agency does not curb innovation, it is important to provide adequate resources for staffing with the appropriate expertise and experience to keep pace with advances in technology.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. SHELLEY MOORE CAPITO TO
DR. PATRICIA SANDERS

Question 1. As you are probably familiar with, Fairmont, WV is home to the Katherine Johnson Independent Verification and Validation (IV&V) facility. The Katherine Johnson IV&V Center provides NASA the highest achievable levels of safety and cost-effectiveness for mission critical software and has the capabilities for so much more. I have spoken a lot on this issue with Former Administrator Bridenstine and with current Administrator Nelson. I believe West Virginia has the facilities, like the Katherine Johnson IV&V Facility, and the people who can be the backbone for the Artemis program. As chair of the NASA's Aerospace Safety and

Advisory Panel (ASAP), could you speak to the value of the IV&V to NASA's mission.

Answer. Independent Verification and Validation is important to all software development. This is especially true for all of NASA's safety critical software.

Question 2. I am proud of the capabilities housed at the Katherine Johnson IV&V center, however I hear too often that they feel underutilized. Is that the case?

Answer. The Panel is aware that NASA employs the capabilities of that facility for all software developed by NASA and frequently for software developed by NASA contractors. We are not cognizant if that fully employs the full capacity of the Center.

