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SPACE SITUATIONAL AWARENESS, SPACE TRAFFIC MANAGEMENT, AND ORBITAL DEBRIS: EXAMINING SOLUTIONS FOR EMERGING THREATS

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

JULY 22, 2021

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED SEVENTEENTH CONGRESS

FIRST SESSION

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SPACE SITUATIONAL AWARENESS, SPACE TRAFFIC MANAGEMENT, AND ORBITAL DEBRIS: EXAMINING SOLUTIONS FOR EMERGING THREATS

THURSDAY, JULY 22, 2021

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

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

Present: Senators Hickenlooper [presiding], Blumenthal, Cantwell, Lummis, Young, and Scott.

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

Senator HICKENLOOPER. We call this meeting to order. Please be seated. Good gracious. In my opinion, it should be us standing for you and you should all be aware—well, several things.

One, even though there's not a Full Committee room of people, you can see we are Zooming this too, I think, the majority of the Commerce Committee which is, as you can see, a large committee are looking in. I think every staff—there's a staff member from every Commerce Committee and a number of other Senators watching, not to mention millions at home or not.

I also should give fair warning that this is my first committee hearing that I get to chair as the Chair of the Space and Science Subcommittee of the Commerce Committee. So you'll have to take your own risks with that.

When they told me I was going to get to chair this committee, my Communications staff said I should not say it, but I was over the moon in that sense of——

[Laughter.]

Senator HICKENLOOPER.—this is something that's important not only to Colorado but something that I have had a passion and interest in for a long time.

It's ironic that this first meeting is on Space Trash because it sounds somewhat dismissive and yet, as you all know, this is one of the most important things that we're facing and I think there is by necessity and what I hope comes out of this meeting is a sense of urgency around that.

I think this really is a pivotal time and the potential for catastrophic accidents if we continue with the status quo is real and I think demands action on the part of this committee.

This discussion today is going to be examining Space Situational Awareness, SSA. I'll try and go back and forth between saying Space Situational Awareness and SSA so we don't get buried in acronyms, Space Traffic Management, STM, and then Managing Orbital Debris.

Space Situational Awareness, of course, protects valuable Federal and commercial assets. It allows us to track and notify satellite operators of optical orbit and when there are issues.

We need space situational awareness to coordinate the space traffic management and coordinate satellite operator activities, exactly what they're doing, and make sure that we avoid collisions through appropriate notification.

A number of reports estimate over 4,000 active satellites in orbit, but I think the more perplexing numbers are roughly or well over 100 million pieces of orbital debris that threaten the entire space ecosystem.

I could go down a long list but GPS, weather forecasting, telecommunications, all manner of scientific research rely on satellites in orbit. Safe environment in low orbit is critical to almost every facet of the space industry and its potential growth, and as activity in space is increasing, we see increased satellite launches for both scientific research and for commerce.

This committee has and will continue its critical oversight role in space traffic management, STM, space situational awareness, SSA, and mitigating orbital debris.

We have numerous examples of collisions in space, some of which have been catastrophic. 2007, a Chinese weapons demonstration left over 3,000 debris objects moving through space at high speeds. 2009, U.S. satellite collision with Russian satellite created 1,800 debris objects at least, and since 1999, the International Space Station conducted 29 debris avoidance maneuvers, and there were three in 2020 alone.

Certainly I think, and you all understand this, we can't wait for the next collision to occur before taking action. The groundwork has begun. 2018 Space Policy Directive 3, SPD–3, if you're taking notes at home, made a few things clear on who's responsible for what in addressing this problem.

The Department of Commerce was to assume all civil space situational awareness duties from the Department of Defense. NASA was to update its Orbital Debris Mitigation Standards, and the Departments of Commerce, Transportation, the FCC were to update their licensing processes for satellite launches.

In Fiscal Year 2021 Appropriations, Commerce Committee took further action. They doubled the budget of the Office of Space Commerce and I use that word "doubled the budget" with a certain amount of significance and reflecting the urgency and the critical nature of what we're talking about today, required pilot program for Space Traffic Management Data base.

The work of Ranking Member Wicker, who will be here, if he's not here yet but will be here, I'm sure staff is watching, and Chair-

woman Cantwell, who will be here eventually, as well, on the Space Act is commendable.

The Act codifies Commerce Department STM duties in SPD–3, establishes the Centers of Excellence to advance scientific policy and research in SSA, as well.

The Space Act passed the Commerce Committee twice, recently passed the Full Senate in the U.S. Innovation Competition Act, USICA, also called the Endless Frontier Act, my preferred name, clearly demonstrated that we do need swift action and that part of that immediately is to enact USICA and the Space Act into law.

The Biden Administration is still implementing aspects of SPD–3. So I think continued committee oversight is appropriate and important. We need to maintain our leadership in space. Every one of you understands that.

A big part of this must include space traffic management. The lack of international rules of the road is a serious problem. The regulatory regimes demand attention. They demand serious attention.

The European Union, Russia, China, they're all developing their own STM frameworks, which again how we are able to lead on this and make sure that we set an appropriate framework so that our interests aren't overruled I think is critically important. We need to recognize the importance to our space interests in this. So we need to make sure these writings of regulations are from the outset.

Other issues, obviously international liability law when it applies to negligence but would not necessarily apply to a lack of response to a collision alert. There's a significant amount of R&D necessary to modernize our space situational awareness systems. Collision alerts could be inaccurate, and I think that again this just brings back the urgency of tracking and constant tracking that needs to be for all objects.

There's limited ability of spacecraft to maneuver and so that underscores the importance of both SSA and STM and noticeably Space Act dedicates funding to SSA and R&D.

The Department of Commerce has full support of the subcommittee to carry out its STM and SSA duties swiftly and certainly we look forward to hearing testimony from the witness panel on issues about how to advance U.S. leadership in space, how to protect Federal and commercial interests with space traffic management.

Again, I re-emphasize how grateful we are for you to take time here today.

We have witnesses today. I take parochial privilege to recognize first Professor Holzinger from the University of Colorado in Boulder. He has been a thought leader on STM and SSA and all manner of space-related topics. He led the 2019 Office of Space Commerce Workshop of SSA at the NIST Campus in Boulder.

We also have Karina Drees of Commercial Spaceflight Federation. Commercial space companies are represented by Spaceflight Federation. We have a number of companies in Colorado, but these companies are all over the United States. This is truly broadly a national issue and she can speak on industry activity with Federal agencies, in-space servicing of satellites, benefits to society of safe

access to low earth orbit. We've seen some examples of that in recent days.

Then we have Kevin O'Connell of Space Economy Rising. He was Director of the Office of Space Commerce under the previous Administration. His views on U.S. leadership focus on space safety sustainability.

Then Paul Graziani of COMSPOC Corporation, that's C-O-M-S-P-O-C, a company focused on SSA and STM, will discuss threats and challenges in space environment.

And then last Tom Stroup, President of Satellite Industry Association, represents commercial satellite companies. Again, there are a number of Colorado companies but really a number of companies all over the country that are represented by the Satellite Industry Association.

So with that, I'll resume my position of being over the moon and the opportunity to kick this off. I promise never to make that pun again.

I'd like to recognize Ranking Member Senator Lummis from Wyoming for her opening statement.

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

Senator LUMMIS. Well, thank you, Chairman Hickenlooper, and I love your tie. I think it's absolutely appropriate. He has worn it for this special occasion, our first hearing, and really looking forward to working with you on this topic.

This is going to be a fun committee because of the bipartisan nature of space, because of the developments we're seeing just in the last week, and we're really very excited to join you in addressing some of the issues we're going to begin discussing today.

So welcome, panelists. I'm so pleased that this is our first hearing topic. It's timely and important. Space Traffic Management, Space Situational Awareness, and Orbital Debris, I have no problem being identified as the space junk lady or the trash lady,——

[Laughter.]

Senator LUMMIS.—the space trash lady. I think this is an important topic for our time.

It's just great to be Ranking Member on this subcommittee. The space sector is evolving so quickly. The civilian flight to the edges of space that occurred this week and over the past few years, the number of satellites and spaces increased dramatically as companies have begun to launch mega constellations, just wonderful, exciting time for me to be involved in this topic.

The fact is the space around earth is becoming congested and the problem's only going to grow. There are more than 4,000 satellites in orbit right now, 1,200 of those were launched in 2020, and we have already surpassed that number in 2021. It's estimated that 46,000 new satellites could be launched in the next few years.

In addition to working satellites, Department of Defense is tracking 27,000 pieces of space junk. This junk poses huge risks to our assets in space. Even the smallest pieces of orbital debris, I've learned that even paint flecks, can and have caused serious damage. Each collision creates even more debris. So this is a problem that compounds on itself.

More than just tracking and managing orbital debris, we must look for ways to prevent it in the first place and for companies launching satellites and mega constellations to help with solutions to take out the trash and get rid of the junk.

The innovation that is creating this problem is exciting, but the government must take the lead on SSA, STM, and policy to prevent and remove orbital debris.

The previous Administration understood the importance of this mission and how the changing nature of the space industry necessitated moving some of this responsibility away from the Department of Defense. In 2018, the Trump Administration published Space Policy Directive 3 to put the responsibility of SSA and STM in the hands of the Office of Space Commerce.

Congress appropriated funds to the Office of Space Commerce to create an open architecture data repository to improve SSA and STM. In 2020, the National Academy of Public Administration released a study recommending the Office of Space Commerce to be selected to conduct the SSA/STM Mission.

I'm concerned that we're now 3 years after SPD–3 was published and the Commerce Department has been slow to develop the Open Architecture Repository that is desperately needed.

Instead, it has commissioned more studies to re-examine the already-answered question of which U.S. Government agency is best suited to take on the task.

I would add that I'm also concerned that the Administration has not announced a director to take over the Office of Space Commerce.

I hope that our hearing today with our distinguished panelists will help illuminate the urgency of getting the data repository up and running and provide us with information and ideas of how to work with the private sector to tackle this growing issue.

So thank you, Mr. Chairman, and thank you, panelists, for being here. I yield back.

Senator HICKENLOOPER. Thank you, Senator Lummis. I appreciate your comments but also all your time and effort being the Ranking Member of this subcommittee.

Now I think we go to—I know that—well, let's go with your opening statements and we'll start with Ms. Drees.

STATEMENT OF KARINA DREES, PRESIDENT, COMMERCIAL SPACEFLIGHT FEDERATION

Ms. DREES. Thank you.

Chair Cantwell, Chair Hickenlooper, Ranking Member Wicker, Ranking Member Lummis, and Distinguished Members of the Committee, thank you for inviting the Commercial Spaceflight Federation, CSF, to present our members' views on Space Situational Awareness and the importance of space safety to a sustainable future for the United States in orbit and beyond.

CSF is the leading national trade association for the commercial space industry with more than 85 member companies and organizations creating tens of thousands of high-tech U.S. jobs focused on building a growing space economy supporting science, academia, business, and government.

The U.S. commercial space industry is leading the world today thanks in part to the public/private partnerships this committee has repeatedly supported over the years and continues to support.

As a result of private sector innovation, the U.S. is seeing a marked increase in both the number of launches and the number of satellites deployed in orbit, providing critical capabilities, including broadband internet, earth mapping, and environmental monitoring.

Ensuring a global commitment to space safety and space sustainability has never been more important. Space situational awareness represents the most pressing issue to address today as access to accurate and timely tracking data is essential to ensuring continued safe operations in space for all users.

CSF fully endorses recommendations by both the Space Force and NAPA to transition unclassified SSA activities to the Department of Commerce and acknowledges that this committee has also long supported DOC assuming this mission.

DOC has commenced developing the Open Architecture Data Repository or OADR to collect and integrate government and commercial data into a new database and widely distribute it to space users. This is a great first step.

CSF recommends DOC to staff the Office of Space Commerce with experts in the field to iterate the system from a prototype through a successful operational system. Delays to this implementation could create additional uncertainty for both government and commercial users.

We encourage Congress to provide the necessary financial resources to the Office of Space Commerce to implement this mission.

We also recommend the government offer free SSA data tier while ensuring it's not competing with the private sector for more advanced analytical services. This approach represents a commitment to space safety while providing commercial companies the opportunity to develop innovative tools that will advance our understanding of space operations.

Distinct from SSA, Space Traffic Management encompasses the regulatory policies designed to ensure responsible behavior in space.

Today, the FCC serves as the primary driver of these requirements for U.S. licensed satellite systems. As with SSA, the NAPA Report recommends that DOC assume the leading role with STM.

As the largest consumer of commercial space data in the world, the U.S. remains in a unique position to dictate reasonable STM and orbital debris standards but only if it applies this requirement equally to all companies seeking to serve the domestic market.

In addition, newly developed STM rules must continue to encourage both safe operations and rapid innovation. This balance is critical to prevent satellite systems to simply forum shop to license in foreign administrations without the same rules to sidestep U.S. regulations, leaving an incomplete picture of orbital operations and reducing transparency.

CSF recommends the FCC modify its rules to require any company that serves the U.S. market fully comply with U.S. orbital debris rules to improve global activities while leveling the playing field for companies licensed in the U.S.

CSF further recommends DOC partner with NASA to leverage NASA's technical expertise in developing more effective technical standards, particularly for orbital debris mitigation. NASA has deep institutional knowledge on safe space operations that would benefit the Department of Commerce.

Thank you again for the opportunity to testify today. I look forward to your questions.

[The prepared statement of Ms. Drees follows:]

PREPARED STATEMENT OF KARINA DREES, PRESIDENT, COMMERCIAL SPACEFLIGHT FEDERATION

Chair Cantwell, Chair Hickenlooper, Ranking Member Wicker, Ranking Member Lummis, and distinguished members of the Committee—thank you for inviting the Commercial Spaceflight Federation (CSF) to present our members' views on space situational awareness and the importance of space safety to a sustainable future for the United States in orbit and beyond.

CSF is the leading national trade association for the commercial space industry, with more than 85 member companies and organizations across the United States. Founded in 2006, CSF is focused on fostering a sustainable and growing space economy that democratizes access to space and space capabilities for scientists, students, civilians, businesses and decision makers. CSF members are responsible creating tens of thousands of high-tech U.S. jobs driven by billions of dollars in private investment.

The U.S. commercial space industry is leading the world today, thanks in part to the public-private partnerships that this Committee has repeatedly supported over the years and continues to support. We are grateful for your ongoing commitment to expanding and maturing this important industry, which is a key element of U.S. technological leadership and global competitiveness.

As a result of private sector innovation, the U.S. is seeing a marked increase in both the number of launches from the United States and the number of satellites—which provide critical capabilities, including broadband internet, earth mapping and environmental monitoring, and many other important services—deployed to orbit. In this domain, our competition is, largely, China. With the U.S. now the center of both launch capability—leading the world in commercial launch market share—and the space services market, the importance of ensuring a global commitment to space safety and space sustainability has never been more important.

While much attention is paid to new commercial satellite systems and so-called satellite constellations, it is important to note that such systems are predictable and well-conceived. Indeed, the largest contributors of space debris to this point have been generated by derelict state-owned or non-commercial rockets, and through the testing of anti-satellite weapons—not from commercially-licensed launch vehicles or emerging commercial satellite systems. In this sense, satellite constellations are similar to cars on a dirty highway—it is important to find ways to clean up the highway and ensure it is clean, not simply regulate the cars that are passing over it. At the same time, U.S. satellite operators have a history of responsible on-orbit operations, and this model of U.S. operations needs to be adopted worldwide. I am pleased to be here today to outline these efforts and to provide our recommendations to the Committee.

Space Situational Awareness

Space Situational Awareness (SSA) represents the most pressing issue to address today, and access to accurate and timely tracking data is essential to ensuring continued safe operations in space for all users. The U.S. Space Force 18th Space Control Squadron (SPCS) does an outstanding job collecting data from U.S. government and commercial sensors worldwide to track and catalogue over 26,000[1] objects. SPCS supports U.S. government spacecraft operations and publicly releases unclassified tracking data for spacecraft and debris as small as two inches in diameter[2]. SPCS also provides spacecraft operators, both foreign and domestic, with Conjunc-

[1] *https://www.spaceforce.mil/DesktopModules/ArticleCS/Print.aspx?PortalId=1&ModuleId=489&Article=2129325*

[2] *https://www.nasa.gov/mission_pages/station/news/orbital_debris.html*

tion Data Messages (CDMs), that indicate whether the probability of collision between two objects is greater than 10^{-4}.[3]

To better align agency focus, the Space Force and independent technical authorities, including the National Academy of Public Administration, have recommended that SPCS transition unclassified SSA activities for non-U.S.-government users to a separate entity; specifically, the Department of Commerce (DOC). Space Policy Directive-3 (SPD–3) issued further guidance for this transition.

CSF fully endorses this recommendation, and acknowledges that this Committee has also long supported DOC assuming this mission. The SSA mission is separate and distinct from the regulatory activities performed by the Federal Aviation Administration (FAA), the Federal Communications Commission (FCC), and the National Oceanic and Atmospheric Administration (NOAA), and should be managed by a separate civilian agency. The Department has commenced on developing the Open Architecture Data Repository (OADR) to collect and integrate government and commercial data into a new database and widely distribute it to space users. This is a great first step. CSF has supported the Department of Commerce's efforts to establish a dynamic, flexible, and scalable approach to civilian SSA and STM, and we are eager for DOC to quickly transition from a study phase into an operational phase for this effort.

Recommendations:

1. *The Department of Commerce should rapidly transition from a study phase into operations for the OADR system.* While it is important to develop a system that accurately and comprehensively ingests and distributes tracking data, additional delays to this effort could create additional uncertainty for both the U.S. government and commercial users. We encourage Congress to provide the necessary financial resources to the Office of Space Commerce to complete this mission.
2. *In providing SSA data, the government must offer a free data tier, while also ensuring it is not competing with the private sector for more advanced analytical services.* This approach represents a commitment to space safety, while also providing commercial companies the opportunity to develop innovative tools that will advance our understanding of space operations.

Space Traffic Management

Distinct from SSA, Space Traffic Management (STM) encompasses the regulatory policies designed to ensure responsible behavior in space. Today, the FCC serves as the primary driver of these requirements for U.S.-licensed satellite systems. As with SSA, the NAPA report recommends that DOC assume the leading role with STM.

Importantly, as noted by the recent National Science Foundation JASON report, it would be prudent to restrict or apply significantly stronger requirements and scrutiny to large satellite systems, or constellations, operating above 600 km. This is because debris at this altitudes will remain in orbit for centuries or longer, and the risk associated with passive debris removal is much higher than with lower altitudes. While DOC is the appropriate agency to propagate and maintain a STM regime, it should consult with a technical authority such as NASA to develop the requirements to ensure they are grounded in reasonable engineering analysis and take into account different orbital regimes and risk assessments.

Any newly developed STM rules—which can only come once a full SSA approach is implemented—must continue to both encourage safe operations and rapid innovation. This balance is critical as other countries, primarily China, plan to deploy thousands of satellites to space in the coming years and routinely demonstrate a lack of concern for space sustainability. Overly restrictive STM rules in the U.S. would serve only to hurt U.S. commercial competitiveness and national security, while both literally and figuratively leaving space for China to fill. Satellite systems will simply "forum shop" to license in foreign administrations without such rules in order to evade U.S. regulations, as has historically been the case with most satellite operators.

Indeed, any new U.S. regulations on orbital debris will be undercut by foreign-licensed systems that serve the U.S. market but are not required to abide by FCC or other U.S. Government orbital debris rules. As it stands, U.S. licensed systems must adhere to these regulations, but foreign licensed systems that seek and obtain U.S. market access do not. This regulatory asymmetry perversely incentivizes satellite operators to "forum shop" for countries with more lenient orbital debris re-

[3] that have (i) a time of closest approach within 72 hours, (ii) a probability of collision greater than 1/10,000 (1e-4), and (iii) a miss distance less than 1 km. *https://licensing.fcc.gov/myibfs/download.do?attachment_key=6212177*

quirements, as nearly all satellite operators have done. While U.S.-licensed companies are required to provide data on the health of their satellite systems, foreign-licensed systems operating in the U.S. are not—leaving an incomplete picture of orbital operations, and reducing transparency. This regulatory gap both reduces the efficacy of any current or future U.S. orbital debris mitigation policies and provides a preference for foreign systems over domestic systems.

If the Congress wishes to take any effective action on this matter, it must eliminate this regulatory asymmetry. Otherwise, the U.S. will never lead in space safety regulations worldwide. As the largest consumer of commercial space data in the world, the United States remains in a unique position to dictate reasonable STM and orbital debris standards, but only if it applies those requirements equally to all companies seeking to serve the domestic market.

Recommendations:

1. *FCC should modify its rules to require that any company that serves the U.S. market must comply with U.S. orbital debris rules.* This requirement would significantly improve global orbital debris activities, while leveling the playing field for companies licensed in the United States.
2. *DOC should partner with NASA to leverage NASA's technical expertise in developing more effective technical standards.* NASA has deep institutional knowledge on safe space operations, through its Orbital Debris Program Office (ODPO) and Conjunction Assessment and Risk Analysis (CARA) program office that would benefit the Department.

APPENDIX A

The Commercial Spaceflight Federation's (CSF)
FY 2022 Commerce, Justice, & Science Appropriations Priority Requests

Agency: Department of Commerce

Account: National Environmental Satellite, Data and Information Service, ORF
Office of Space Commerce

FY22 CSF Request: $49M[4] / FY21 Enacted: $10M / FY22 PBR: $10M

Justification: Space commerce and commercial space applications are experiencing rapid transformation and growth. The Department of Commerce, through the Office of Space Commerce, has the opportunity to further these trends, promoting growth through the expansion of the space economy. OSC can also be at the forefront of sustained U.S. leadership in best practices for operating in space. It is critical that balanced investments occur in space sustainability in order to protect the operational environment. Commercial services exist, which the Office can lean on to protect investments in space by both the government and commercial entities.

Requested Report Language: The recommendation includes $49,000,000 for the Office of Space Commerce, in order to provide appropriate resources for the office's mission to promote the American space industry as well as fund the Space Traffic Management Pilot Program, which a Congressionally-directed NAPA study determined the office as the appropriate entity to manage this initiative. At least $20,000,000 of the recommendation shall be used to purchase commercially-available space situational awareness data and services from the U.S. private sector. We further recommend that OSC avoid paying FFRDCs to develop redundant capabilities already available from the commercial sector.

APPENDIX B

More details on some of the benefits the commercial space industry bring to the American people:

- *Climate change is an existential threat to our way of life and the commercial space industry is playing a critical role in addressing this crisis effectively.* The commercial space industry is helping tackle the Satellites in space are essential to successfully confronting the challenges we face from climate change. Spacecraft built and launched by America's commercial industry provide remote sens-

[4] The $49M top line number, and $20M for SSA data and service buys, are derived from the NAPA study's budget runout for OSC for FY2022.

ing data that allow scientists to better understand our changing planet and enable informed climate-related decision making by governments, industries, and individuals around the world.[5] To learn more details about how the commercial space is stepping up, please see the link in the associated footnote below.

- *The commercial space industry is combining innovation, private capital, and meaningful competition to lower the cost and increase the access to high-speed broadband Internet for tens of millions of Americans living in underserved areas.*[6] To learn more details about how the commercial space is stepping up, please see the link in the associated footnote below.
- *The commercial space industry is advancing science through human-tended experiments on commercial vehicles.* Experiments that explore novel physical and chemical phenomena in weightlessness; explore astronomical events; develop instrumentation; study biological adaptation to spaceflight; develop medical procedures and equipment for future long-duration spaceflight; and make observations in the mesosphere and lower thermosphere will deliver superior science with an expert human performing the experiment in the spacecraft. While automation will suffice for selected experiments, the time is now to ensure we achieve the best science in the best manner possible. Human-tended suborbital experiments flying with the new commercial reusable suborbital spaceflight industry are now possible and are vital to best advance science and technology.[7] To learn more details about how the commercial space is stepping up, please see the link in the associated footnote below.
- *The commercial space industry is providing unprecedented access to hands on STEM education opportunities for K–12 students.* How a 2nd-Grade Class Sent a Science Experiment to Space. "Any school district now that affords football can afford spaceflight."[8] To learn more details about how the commercial space is stepping up, please see the link in the associated footnote below.
- *America's space enterprise is currently undergoing a renaissance space, led by the commercial space industry.* Over the past decade, U.S. commercial space companies have raised $24.1 billion in private equity that has radically increased access to space, enabled distributed networks of small satellites, and laid the foundation for emerging new industries in low Earth orbit, including commercial space stations and free-flyers, and in-space manufacturing.[9] Even as the rest of the economy struggled financially during the pandemic, commercial space companies remained one of the few bright spots for the U.S. economy in 2020 and 2021. To learn more details about how the commercial space is stepping up, please see the link in the associated footnote below.

Senator HICKENLOOPER. Great. Thank you.
Mr. O'Connell.

STATEMENT OF KEVIN M. O'CONNELL, FOUNDER AND CEO, SPACE ECONOMY RISING, LLC

Mr. O'CONNELL. Thank you.

Good morning, Mr. Chairman and Ranking Member Lummis. Thank you for the invitation to return to the subcommittee to talk about the critical issue of space debris.

Mr. Chairman, in my prepared statement, I've actually updated the committee on some of the most exciting developments in the space economy. In short, we see the space economy accelerating and diversifying very quickly.

Space activities already contribute an estimated $5 trillion annually to the U.S. economy and that number is absolutely growing.

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[5] *https://thehill.com/opinion/energy-environment/540686-space-is-critical-to-climate-if-you-cant-measure-it-you-cant*
[6] *https://www.orlandosentinel.com/opinion/guest-commentary/os-op-broadband-internet-20190725-xdqcejglzvcoflsfja5ii7jz34-story.html*
[7] *https://spacenews.com/op-ed-advancing-science-through-human-tended-suborbital-experiments-on-commercial-vehicles/*
[8] *https://www.nytimes.com/2020/10/13/science/blue-origin-school-experiment.html*
[9] *https://spacecapital.docsend.com/view/v7n5255rnz3hm743.*

Second, our appreciation of the value of space in our lives is changing. We increasingly recognize space as a key element of, if not the backbone of the 21st Century economy.

So space will fuel ag-tech, clean-tech, ed-tech, and other innovations while deepening our understanding of changes on this planet and enabling exploration and habitation of outer space.

Many states and other countries are exploring how to leverage space for economic growth, talent development, and innovation, and I offer this background, Mr. Chairman, only to describe what is really at risk if we do not deal promptly with the space debris challenge.

As I have testified before, space debris threatens the astronauts aboard the International Space Station, billions of dollars of existing space investments, and the growth of space commerce.

The NASA SpaceX launch of astronauts to the ISS in April was flawless, save for a near miss with a hunk of space debris. Canada's robotic arm in the ISS was punctured by a piece of debris in May. These calls are too close.

Space debris policy discussions actually date back to the Reagan Administration and have been an increasing priority for the last four Administrations. An increasing number of organizations are vocal on the problem and the need for action.

Space Policy Directive 3, as has been mentioned, recognized the urgency of this problem and directed a whole of government approach to creating new paths for space safety. It acknowledges the historic role of the Department of Defense and the need to shift to a civil space traffic management system, given growing security concerns in space and a parallel growth in commercial space activities.

It also recognized the critical importance of our international space partners. A key tenet of SPD–3 was the need to modernize the Nation's SSA architecture and to leverage commercial capabilities that already exist in the market. Communications, cloud-based data management, analytics, and other technologies that have helped innovate in many, many other industries can be leveraged here immediately.

Meanwhile, entrepreneurs have developed new tools to mitigate risks to space systems and to promote continuing investment in innovation. Debris detection and new ways of characterizing the space environment are key while others are working with autonomy, machine learning, active debris removal, and others to improve space safety.

The open architecture approach that has already been discussed will allow new tools to be incorporated very quickly. Beyond improved collision avoidance, firms are already developing new services as part of the emerging space safety industry.

One complicating factor is how quickly the debris threat is changing, given projections of new space objects and more complex missions over the next decade. U.S. Government efforts should focus on how to quickly acquire, validate, and implement these services.

We are not alone in our space pursuits nor the need to deal with the problem. The United States and its allies routinely discuss these issues in many different forums. Not everyone is onboard,

however. The uncontrolled re-entry of a Chinese Long March 5b rocket in May, the second such occurrence, had the world on edge about whether it might damage property and kill people.

Russia held up progress at the United Nations on the long-term sustainability guidelines until they were finally passed with global consensus in 2018.

There is no doubt that if longstanding American leadership in space safety falters, these countries will step in. The space component of China's Belt and Road Initiative is already designed to lock up emerging space partners and this will be no exception.

Mr. Chairman, I was asked to speak specifically to the role of the Commerce Department on these matters based on my recent role as the Director of the Office of Space Commerce. Since space will play a growing role in the 21st Century economy, the Commerce Department is uniquely positioned to play key roles on space and space commerce.

The congressionally directed NAPA Report, as has already been mentioned, endorsed the roles of Commerce and the Office of Space Commerce in managing a variety of technical projects and partnerships against the challenge of orbital debris.

As the committee may also recall, the Office of Space Commerce was established over 30 years ago as the Executive Branch advocate for the U.S. commercial space industry. Given that mission and the importance of the commercial space industry to our economy and our national security, I believe that the office must be elevated to the Office of the Secretary where it can fully engage departmental leadership.

Finally, Senators, I want to express my personal thanks to this committee for the Space Preservation and Conjunction Emergency Acts of 2020 and 2021.

The committee recognizes the complexity and urgency of the space debris problem and the need for intense and focused action.

The provision to create a center or perhaps centers of excellence for SSA are especially welcome given the importance of additional research in this area.

With that, I'll conclude my remarks and I'll look forward to your questions.

Thank you.

[The prepared statement of Mr. O'Connell follows:]

PREPARED STATEMENT OF KEVIN M. O'CONNELL, FOUNDER, SPACE ECONOMY RISING, LLC (FORMER DIRECTOR, OFFICE OF SPACE COMMERCE)

Good morning, Chairman Hickenlooper and Ranking Member Lummis. Thank you for the invitation to return to the Subcommittee to talk about this important issue. Space debris and how we mitigate its potentially damaging effects on the space economy, our security, and our international partnerships was a top concern of mine while serving as the Director of the Office of Space Commerce at the Department of Commerce. It remains a top concern of mine now even in private life and within my new business and academic pursuits.

The Rise of the Space Economy

Let me start with the opportunity. There has been incredible progress in the space economy since I testified before this Subcommittee over two years ago, fueled by a world-class U.S. space industry and a dynamic ecosystem of entrepreneurs, private finance and insurance, and other participants. U.S. government agencies like NASA, NOAA, and the Department of Defense are shifting acquisition models to en-

courage and take advantage of commercial space developments, as well as space partnerships from London to Tokyo.

In short, the space economy is accelerating and diversifying. Technological breakthroughs in space-based communications are allowing competition with terrestrial fiber and facilitating competitive telephone and Internet service where no fiber exists. Artificial intelligence is transforming a crush of satellite imagery data into useful economic information. More accessible and lower-cost launch opportunities combined with small satellite developments are allowing entrepreneurs to try new ideas and adapt them to quickly bring to market. An imminent wave of in-space servicing activities—inspection, refueling, and repair—will further improve the economics of space activities.

Back here on Earth, there's dramatic growth in private sector finance of space activities, including special purpose acquisition corporations (SPACs), as well as a range of entrepreneurial activities designed to disrupt traditional commercial space services or invent wholly new ones. An even newer cluster of entrepreneurs is focused on training and caring for future space travelers as the United States, with bipartisan support and some of our allies, heads toward a permanent presence on the Moon.

Entrepreneurial activities are focused on improving on existing capabilities, like communications, remote sensing, and launch, while others are inventing new capabilities in areas like space manufacturing, space medicine, and edge computing and cybersecurity for space systems. Another cluster of entrepreneurial activities seeks to create the infrastructure for training, housing, and equipping the next wave of space travelers and to provide infrastructure for sustainable life and normal economic activity on the Moon. As we have marveled about private space travel over the past two weeks, commercially driven concepts like reusable launchers and satellite servicing will make space even more affordable and competitive.

Our understanding of the value of space is changing. Aside from our excitement about space travel, we are quickly moving from a general lack of awareness about the importance of space to a place where space is increasingly recognized as a key element of, if not ***the*** backbone of the 21st century economy. Space-based activities already contribute an estimated $5 trillion in value to the U.S. economy, and that number is growing.

Let me give you one key example. A recent on-line headline noted "all companies are space companies now!" Beyond the tremendous innovation we are seeing within the space community, we are also seeing non-space companies begin to experiment with their own ideas for leveraging space. Drawing upon "space as a service" business models, companies from many different economic sectors are designing new approaches for monitoring resources and increasing productivity, especially given developments in space-based remote sensing, Internet of Things (IoT) sensors and high-speed communications. We are at a point not unlike the advent of desktop computing in the late 1960s and early 1970s.

To say it another way, space is the platform that will fuel AgTech, CleanTech, EdTech, and other innovations, while deepening our understanding of developments on this planet and enabling exploration and habitation of outer space. Many States in our great Nation as well as many other countries are exploring how to leverage space for economic growth, talent development, and innovation.

The Challenge of Space Debris

These exciting space developments sometimes tempt us to think that all of this is automatic, that the conditions for success are locked in. Today's discussion is about the immediate problem of space debris and the need for focused U.S. government and private sector attention to the problem.

Let me provide a couple of examples: the April 2021 NASA and Space X launch of Astronauts to the ISS was flawless, save for a near miss with a hunk of space debris. It was the potentially deadliest sign of the urgency of dealing with the space debris problem. In late May, NASA and the Canadian Space Agency announced that a piece of space debris had punctured Canada's robotic arm aboard the International Space Station; the arm is used for transporting Astronauts during spacewalks and repair missions and for deploying scientific experiments.

Senators, nobody wins a game of "chicken" against space debris. These close calls are too close. Aside from the threat to human life, growing space clutter threatens U.S. and allied investments in space as well as the growth of space commerce. Many of the growing commercial benefits I discussed earlier could be slowed or eliminated if, for example, operators have to add fuel or protective materials to avoid space junk. Business operations can be affected dramatically by a collision.

As this Committee knows, this is not a new problem, nor a partisan one. National policy discussions about this problem date back continuously through the Trump,

Obama, Bush, and Clinton Administrations, with the first mention of space debris as a national policy matter dating back to the Reagan Administration. Long a discussion confined to the space community, space debris has gained widespread attention. Numerous U.S. government and private organizations, including NASA's Aerospace Safety Advisory Board, Secure World Foundation, the Space Safety Coalition, the Satellite Industry Association and others have highlighted the urgency of this very complex problem.

The Need to Advance Innovative Solutions

The space activities we are witnessing today are the pinnacle of American science and engineering, and the best of U.S. government leadership and investment and the efficiency of the private sector. While space debris is a serious and immediate problem, there is no reason why we cannot leverage these same national capabilities to create effective new solutions and the birth of a new space safety industry.

There are at least four tools in our toolkit for mitigating the space debris problem:

- avoiding the creation of new debris
- improving our awareness of the space environment
- improving communications and warnings among all space operators, and
- active debris removal.

While U.S. government investments in these areas vary greatly, there is a growing recognition of the roles that academia and the private sector can play in providing solutions. Commercial technologies for data management, analytics, and visualization that often apply in other disciplines need to be applied here, quickly, and commercial companies are developing new sensors and other unique tools to address this problem. I will say more on that below.

One of the complexities of the space debris problem is how rapidly it is changing. Launch operators CEOs like ULA's Tory Bruno and Rocket Labs' Peter Beck have expressed concern about launch window limitations because of space congestion, and hardly a week goes by without a prominent near miss between active satellites and debris, or between debris objects. If we create solutions for 2021, they will also need to be pertinent to the space environment of 2025 and beyond. Continuous innovation will be needed to mitigate this challenging problem.

The Growing Role of the Private Sector

Space Policy Directive 3, Space Traffic Management (June 2018), recognized the urgency of the space debris problem and directed a whole of government approach to creating solutions. It recognized the need for investments in science and technology to improve our understanding of the space environment. It recognized the historic role of the Department of Defense in providing public space safety information, and the need to shift to a civil space traffic management model given growing security complexities in space and the rapid growth in commercial space activities. It recognized the critical importance of international partnerships in the interest of space safety and sustainability.

These aspects all speak to the importance of continuing U.S. government roles in areas like research, governance, national security and foreign policy considerations, and our international obligations under the Outer Space Treaty. The strategic and economic importance of space assets demand constant focus on protection and freedom of action in space, which largely falls to the United States Space Force and U.S. Space Command.

Space Policy Directive 3 also recognized the need to quickly modernize our national technical approach to improving space traffic management, mainly through improving space situational awareness. This was to be accomplished through creation of an open architecture data repository, where data, starting with DoD's "authoritative catalog"—information derived from classified sources but pertinent to space safety—could be managed, fused, analyzed, visualized, and disseminated in combination with a wide range of civil and commercial data sources. The repository was never seen as the ultimate goal, however: it was envisioned as a source of more timely and precise information for space operators, but also as a key source of information to inform new policies to promote space safety and sustainability.

Enter the private sector. As the value of space has grown, space operators and entrepreneurs have worked together to develop tools to mitigate risk to their systems and to promote continuing investment and innovation. Companies like ExoAnalytics, LeoLabs, and NorthStar Earth and Space have developed new and different ways to detect debris and other activities in multiple orbits; companies like COMSPOC, Slingshot Aerospace, and others are working to provide a continuously updated picture of the space environment for decision-making and channels for increased communications between space operators. Yet other companies are working

on how to leverage autonomy, machine learning, and satellite beacons to confront this problem.

Beyond collision avoidance, companies are providing or planning advanced services for space operators like maneuver planning, orbit optimization, inspection, servicing, and even active debris removal. During a Department of Commerce industry day held last Fall, over 200 commercial firms provided ideas about how to quickly provide solutions to address the space debris and related challenges.

Common to all of these companies is their leverage of state-of-the-art cloud computing, communications, advanced analytics, and other advanced technologies, and a mindset of anticipating customer needs, continuous recapitalization of their capabilities, and innovation. These and many others are the early participants in an emerging space safety industry. Aside from the obvious space safety benefits, the open architecture approach will create new services in other domains like the space insurance industry, which will have more data against to assess risk for different constellations and orbits. This improved knowledge will create a climate of predictability to encourage continuing space investment and innovation.

Speaking of investment, private finance has played an outsized role in fueling the space economy. A June 2021 Space Angels report cites almost $200B of private investment in over 1500 companies during the past decade. Financial institutions are taking a much more detailed look at the ingredients associated with a successful space company: the technology is only part of the story, equal in part to the management team, effective customer outreach, financial projections, and others. As the space economy grows, new financial mechanisms designed to support firms at all stages of growth are emerging, and space investment is increasingly accessible to individuals. Longer-term concepts like space banks and commodities exchanges are gaining attention as new ways to improving investor confidence.

The Changing International Landscape

We are not alone in our incredible space pursuits or in the need to deal with the space debris problem. It is a problem that all space-faring nations must consider.

The United States and its allies routinely discuss these issues in many different forums. NASA works alongside other global space agencies in the Inter-Agency Space Debris Coordination Committee; the Department of Defense considers them in the Schriever Wargame and in the Sprint Advanced Concept Training activities, which include commercial participants. During my time as Director of the Office of Space Commerce, we had routine and technical discussions about orbital debris with our Commonwealth partners, with the European Commission, European Space Agency, and the European Space Surveillance and Tracking Consortium, the Japanese Cabinet Office, and many others. The Space Enterprise Summit, co-hosted with State Department in Summer 2019, included representatives from many of these organizations and focused on the role of international government and business partnerships in addressing the problem.

Not everyone is on board, however. The uncontrolled reentry of a Chinese Long March 5B rocket in May (the second such occurrence) had the world guessing where it would land, whether it would harm people or damage property, and even whether they Chinese government cared about the recklessness implied by their space-faring behavior. Senator Mark Kelly expressed surprise during a Senate hearing earlier this year that neither Russia nor China responds to notices of possible collision issued by the Department of Defense. Russia single-handedly held up progress at the United Nations on the Long-Term Sustainability Guidelines, a set of 21 internationally agreed technical, policy, regulatory and other measures for space safety, for a year until they passed in 2018 with global consensus. As a further sign of their unwillingness to cooperate, Moscow and Beijing have avoided signing the Artemis Accords while they pursue a separate, joint lunar base.

There is no doubt that if long-standing American leadership in space safety falters, these countries will step in. As the U.S. and other governments work to establish new "rules of the road" for space—where we're mostly starting from scratch—the private sector is likely to provide the first, practical examples of how to operate safely in space. However, the space component of Beijing's Belt and Road Initiative is already designed to lock up emerging space partners, and increased involvement in space situational awareness and space traffic management will be no exception. Russian and Chinese proposals in this area are more government focused and less likely to welcome U.S. commercial participation. They may also be exclusionary in other ways to U.S. interests. The U.S. and its allies need to ensure that emerging space countries have alternatives to the onerous terms of Chinese infrastructure deals, whether in space or on the ground.

In short, American leadership on space safety—which we have enjoyed for five decades—is at risk unless we avoid bureaucratic dawdling and fail to adequately re-

source a range of space safety and sustainability initiatives. The loss of leadership will have important strategic and economic consequences.

Role of the Commerce Department

I was asked to comment specifically on the role of the Commerce Department in this area. As the Committee may recall, the Office of Space Commerce was established over thirty years ago as the Executive Branch advocate for the U.S. commercial space industry. Advocacy can take many forms, such as highlighting emerging commercial investment and technology areas, encouraging greater U.S. government leverage of commercial capabilities, helping break regulatory logjams for companies, identifying anti-competitive market behaviors abroad, and others. The Office routinely works with other Commerce Department organizations on issues like cybersecurity standards (NIST), space economic statistics (BEA), space weather and the commercial weather data pilot (NOAA), encouraging minority participation in space enterprise (MBDA), international advocacy for the U.S. space industry (ITA), and others.

If the Committee agrees with my assertion that space is a key enabler of the 21st Century economy, I don't know how we maintain our leadership and strategic advantage without a strong space and space commerce focus at the Commerce Department. That places a premium on having the Office interact regularly with Departmental leadership and with senior leaders throughout the rest of the Department.

Those who question the role of the Commerce Department in helping manage the space debris challenge, in concert with other Federal agencies, fail to recognize the tremendous policy and technical contributions of NOAA—which ensures the safe passage of exquisite weather and research satellites every minute of every day and manages the Nation's space weather program—but also the National Institutes of Standards and Technology, the National Telecommunications and Information Administration, and otherwise brings highly relevant experience to oversight, regulation and industry relations. The Congressionally-directed National Academy of Public Administration study on Space Traffic Management published in August 2020 strongly endorsed the roles of the Commerce Department and the Office of Space Commerce in managing a collaborative network of U.S. government, industry, and international partners against the challenges of orbital debris. And to provide best practices and evaluate standards for encouraging responsible behavior in space.

It is my opinion that both the advocacy and the space debris missions are so important that the Office cannot successfully achieve them from deep within NOAA. The Office should be elevated to the Office of the Secretary, (returned to its original home, actually) and provided funding consistent with the magnitude and importance of these tasks. Further, sufficient resources should be provided to the Commerce Department and other Federal Agencies consistent with the urgency of the overall space debris challenge and its consequences, as I have described above. As necessary, funding should be directed to maximum commercial purposes of data, analytics and other services within the open architecture context described above.

Academia's role is also growing in importance, given the great complexity of the orbital debris problem and its rate of change. Since departing Commerce, I have been participated in the activities of MIT's Space Enabled Group, led by Dr. Danielle Wood and affiliated with MIT's Media Lab. Space Enabled has been part of an academic-industry project sponsored by the World Economic Forum to develop a Space Sustainability Rating for industry to assess, on a voluntary basis, factors such as the choice of orbital altitude and the ability of systems to be detected and identified from the ground. Professor Moriba Jah's work at the University of Texas on AstriaGraph—another system designed to track specific objects in space, is another example of pioneering work worthy of expansion and adoption into a scientifically rigorous and open architecture approach to space safety.

Finally, Senators, many of the themes I have mentioned in this last section of my prepared statement are consistent with the Space Preservation and Conjunction Emergency (SPACE) Act of 2020, as initially introduced by Senator Wicker and Senator Cantwell and reintroduced with strong bipartisan support in 2021. I'm thankful to this Committee for recognizing the importance of this topic and for the bipartisan efforts to pass this legislation. Among the many important provisions of this legislation are the proposal for creating a Center or perhaps Centers of Excellence for SSA, ideally at an institution of higher education. In concert with the other provisions, this reflects the need for substantial academic scientific, technical, policy, and economic research associated with a civil SSA and space traffic management system.

I thank the Committee for your time and your consideration of these important issues.

Senator HICKENLOOPER. Thank you, Mr. O'Connell.

Dr. Holzinger.

STATEMENT OF DR. MARCUS J. HOLZINGER, H. JOSEPH SMEAD FACULTY FELLOW, ASSOCIATE PROFESSOR, ANN & H. J. SMEAD AEROSPACE ENGINEERING SCIENCES DEPARTMENT, UNIVERSITY OF COLORADO BOULDER

Dr. HOLZINGER. Thank you, Chairman Hickenlooper, Distinguished Members of the Subcommittee. I'd like to thank you again for the honor of coming here and talking about this critical topic.

The University of Colorado is a top institution in researching related to space and SSA. We have observational capabilities, telescopes, RF dishes, and from that we are involved in all elements of research related to space traffic management and SSA.

Exponential commercial utilization of space is simultaneously inspiring and terrifying. Rapidly growing commercial services and resource exploration in space about earth and near the moon promise meaningful economic growth and increased danger.

Our present situation is much like being in heavy traffic without a sense of right-of-way. We stand at a thrilling precipice. Ahead, there are countless opportunities near the earth, moon, and beyond that promise economic prosperity, innovation, and rules-based international leadership.

I have three central points I would like to communicate to the subcommittee today. Point Number One, the U.S. Government and industry have a historic opportunity to lead the international community in developing SSA and STM norms of behavior and rules of the road.

In the strongest terms, I recommend the United States leads these international and industry consensus efforts on the rules of the road and norms of behavior.

I further recommend considering the Nobel Prize-winning framework developed by Dr. Elinor Ostrom and championed by the late Dr. Mark Meaney for governing shared commons resources, such as space.

Taking this mantle of leadership reinforces continuity of rules-based system of international cooperation and commerce the United States has endeavored to support for nearly a century.

Further, as a principal user of space, industry must heavily participate in determining these rules of the road and norms of behavior. The United States should lead and inspire in civil space.

Point Number Two, now is the right time to articulate clear mission authority and domains of responsibility for all relevant government agencies.

Decisive mission authorization for the Department of Commerce is necessary to maintain and widen our leading technical and space industry position.

Point Number Three, we have a chance to streamline our civil SSA and STM research and development enterprise. This can produce transformative research, economically impactful technology development, and develop the future workforce necessary to realize substantial prosperity in space.

Additionally, nominal coordination between research agencies and consistent funding and support to academia, perhaps in the

form of centers of excellence, will help develop the workforce necessary and produce the research that we need.

Finally, government, industry, and academia should contribute to decadal or periodic surveys that identify high-impact basic research and technology development objectives for civil SSA and space traffic management.

Allow the United States to meet this historic opportunity with preparation. Combined, these actions have real potential to ensure rules-based United States leadership in SSA and STM amongst the international community.

Improved relevance and efficacy of basic research and technology development efforts and ultimately produce a thriving space economy.

With that summary, I thank you again for the opportunity to testify on the criticality of our challenges and opportunities within civil SSA and space traffic management.

I'd be pleased to answer any questions you or the subcommittee have.

[The prepared statement of Dr. Holzinger follows:]

PREPARED STATEMENT OF DR. MARCUS J. HOLZINGER, H. JOSEPH SMEAD FACULTY FELLOW, ASSOCIATE PROFESSOR, ANN & H. J. SMEAD AEROSPACE ENGINEERING SCIENCES DEPARTMENT, UNIVERSITY OF COLORADO BOULDER

Madame Chair, Senator Hickenlooper, and distinguished members of this subcommittee, I thank you for the opportunity and honor of discussing critical problems and opportunities in civil space situational awareness, space traffic management, and orbital debris.

Exponential commercial utilization of space is simultaneously inspiring and terrifying. Even with 'only' 27,000 space objects being sensed, tracked, and deconflicted at any time, the rate of close approaches—once a worrisome novelty—has steadily become a daily occurrence. Worse, there are hundreds of thousands of objects too small to be tracked that can still damage or destroy spacecraft. Human spaceflight has become outright dangerous, necessitating several International Space Station maneuvers annually. Previous National Security Space Strategy (NSSS) statements have called space "congested, contested, and competitive.' This apt phrase captures the truth of what we face in enabling vibrant, prosperous economic utilization of space.

Space Situational Awareness (SSA) and Space Traffic Management (STM) are emerging interdisciplinary fields that focus on how to use radar, telescopes, and other sensors to detect, track, characterize, determine intent, and manage on-orbit space objects. This includes disparate technical disciplines including but not limited to astrodynamics, information theory, control theory, autonomy, electro-optical and radio-frequency systems, machine learning, and human factors/cognitive engineering. Civil SSA/STM focuses on non-defense applications of these capabilities, particularly civil government and commercial spacecraft.

Perhaps a dozen on-orbit collisions have been positively identified, which, combined with anti-satellite tests (ASAT) have led to an explosion of tracked space objects over the past two decades. The number of on-orbit debris are expected to grow for the foreseeable future unless remediation methods are enacted. The overwhelming majority of current space objects are either debris from past misadventures or spacecraft malfunctions. NASA's Orbital Debris Program office suggests that removing up to five large rocket bodies each year could stabilize the debris population [1], however this figure was formed before large commercial constellations began to launch and is likely now an underestimate. Rapidly growing commercial services and resource exploration in space about Earth and near the Moon are increasing the risk of collision and further collateral damage. Our present situation is much like enduring heavy automobile or maritime traffic without a sense of 'right-of-way.'

Yet, for all these dangers, we stand at a truly thrilling precipice. Behind us we see the space domain as the sole province of a few state and commercial actors.

[1] *https://orbitaldebris.jsc.nasa.gov/remediation/*

Ahead, there are countless opportunities near the Earth, Moon, and beyond that promise economic prosperity, innovation, and rules-based international leadership. The United States government and industry possess the unique and critical means and opportunity to lead the international community in developing SSA/STM norms of behavior and 'rules of the road.' We have a chance to streamline our civil SSA/STM research and development enterprise, producing transformative basic research, economically impactful technology development, and the future workforce necessary to realize substantial prosperity in space. Further, with the recommended transfer of civil SSA/STM to the Department of Commerce (DoC)[2] and the formation of the United States Space Force, now is the right time to articulate clear mission authorizations and domains of responsibility for relevant government entities. Behind each of these opportunities lie shoals of challenges. However, it is my sincere belief that with bold vision and judicious action, we can set the 'rules of the road' and norms of behavior of the space frontier, ensuring a windfall of economic prosperity and peaceful interactions for the majority of this century.

Overcoming the following key challenges will be necessary for us to achieve this outcome.

1. *Rules of the Road and Norms of Behavior.* State and commercial actors in the international community have neither achieved consensus nor adopted safe and commercially viable civil rules of the road and norms of behavior. For such consensus to occur, interested parties must participate directly or indirectly in rule-making; it must be plain to state and commercial actors that such rules benefit them.
2. *Coherent, Coordinated, and Sustained Funding for SSA/STM Innovation.* Our current research funding organizations are neither sufficiently funded nor adequately coordinated to lead academia and industry in basic research, technology development, and workforce for real operational concerns and future needs. Through no fault of the cognizant organizations, the current funding structure is insufficient to solve complex systems of systems challenges in the new and developing field of SSA/STM. Coherent, impactful innovation in SSA/STM and efficient tax dollar use will require inputs from a cadre of government, industry, and academic experts, centers of excellence, and sustained congressional support.
3. *SSA/STM Beyond Earth Orbit.* A rising tide of state and civil missions will be sent to the Moon in the next 5 years. Such missions vary from high profile human spaceflight missions such as Artemis to a variety of ultra-small CubeSat missions led by universities. SpaceX has announced its intentions to send missions to Mars. Our core SSA tools, such as observation association, two-line element (TLE) orbit representation, and initial orbit determination break down in many of these cases[3]. These civil and commercial missions beyond geosynchronous Earth orbit will require any new civil SSA/STM enterprise system to seamlessly handle space objects transferring between and residing within Earth orbit and beyond.
4. *Clear Civil SSA/STM Mission Authorization.* Because of the newness of democratized space commerce activities, unclear/piecemeal SSA/STM roles and responsibilities between DOC, FCC, USSF, and NASA are unavoidable. These gaps and ambiguities impose unnecessary challenges, frictions, and costs in quickly responding to civil space needs and commercial endeavors. Clear civil SSA/STM mission authorizations must be articulated and any inter-agency connections and communications streamlined.

Details on opportunities motivated by these challenges are summarized in the following paragraphs.

Rules-Based United States Leadership in SSA/STM

How can we develop, implement, and verify compliance for sustainable SSA/STM 'rules of the road' extending to the Moon and beyond? Further, how can we ensure that international state and commercial actors will embrace such practices, rather than skirt or ignore them? Continuing unsustainable SSA/STM practices will quickly lead us to a tragedy of the commons—an unenviable scenario in which space, our common resource, is no longer usable. As with many fields of cooperation, it is clear that international state and commercial actors must ultimately agree to follow any

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[2] *https://napawash.org/uploads/NAPA_OSC_Final_Report.pdf*

[3] M. Holzinger, C. Chow, P. Garretson, A Primer on Cislunar Space, AFRL Space Vehicles Directorate, 23 June, 2021. *https://www.afrl.af.mil/Portals/90/Documents/RV/A%20Primer%20on%20Cislunar%20Space_Dist%20A_PA2021-1271.pdf?ver=vs6e0sE4PuJ51QC-15DEfg%3D%3D*

rules of the road and clearly understand how these norms of behavior benefit them directly or indirectly. These ideas are not new, and have been most recently endorsed in a joint statement[4] at the G–7 summit in June 2021.

In the strongest terms, I recommend that the United States demonstrate continued and increasing leadership in SSA/STM. The benefits of United States leadership are manifold with few, if any, drawbacks. Fundamentally, taking this mantle of leadership reinforces and supports continuity of the rules-based system of international cooperation and commerce we have supported for nearly a century. Service and resource exploration commercial activities depend greatly upon predictable requirements, environments, and outcomes to function. With the space economy expected to grow exponentially in the coming decades we can look forward to substantial growth in quality jobs, gross domestic product, and tax base. This growth will be accelerated if the United States decisively promulgates a rules-based SSA/STM system of governance that encourages our space industry to seek commercial opportunities while also protecting the future use of space.

The late Dr. Mark Meaney, founding principal investigator for the CU Boulder Space Sustainability Initiative (SSI)[5], proposed leveraging basic existing frameworks and principles that have been highly successful in applications to other shared commons. Dr. Elinor Ostrom received the 2009 Nobel Memorial Prize in Economic Sciences for her 8-principle framework on sharing common resources (Ostrom, 1990)[6]. These principles are:

- Define clear boundaries of the common resource
- Rules governing the use of common resources should fit local needs and conditions
- As many users of the resource as possible should participate in making decisions regarding usage
- Usage of common resources must be monitored
- Sanctions for violators of the defined rules should be graduated
- Conflicts should be resolved easily and informally
- Higher-level authorities recognize the established rules and self-governance of resource users
- Common resource management should consider regional resource management

Ostrom's framework has been successfully implemented in other applications and may be an excellent set of principles for the United States to use when leading development of a rules-based system of governance.

Finally, much like real estate locations on Earth, there are unique locations in space (*i.e.,* orbits) that can have more commercial value than other locations. This is already demonstrated with geosynchronous orbit and the resulting 'slots' organized and assigned by the International Telecommunication Union. Several researchers have proposed orbit 'slots' for spacecraft in other orbits. In addition to this consideration, I suggest that the SSA/STM system of governance consider mechanisms similar to real estate zoning for different types of orbits.

Innovation, Workforce Development, and Jobs in SSA/STM

While much good work has been funded by the Air Force Office of Scientific Research (AFOSR), the Air Force Research Laboratory (AFRL), the National Aeronautics and Space Administration (NASA), and others, the resources awarded to SSA/STM research have been insufficient on three fronts: (1) basic research has been chronically underfunded, (2) because of low funding in academia the resulting rates of PhD graduates with expertise in SSA/STM has been in grave deficit compared to demand, and (3) there is little coordination between funding agencies as to what research is needed and pursued. To be absolutely clear, these issues are not due to neglect or malfeasance, but stem from the newness of the SSA/STM field, sharply increasing demand for solutions, and a shortfall in coherent basic research and technology development coordination between all government entities. I have two suggestions that may help address these problems.

Firstly, whichever government entity is ultimately chosen to have mission authority over civil SSA/STM should have, as part of its mandate, some level of access, visibility, and potentially input into research pursued by other entities (such as AFOSR, AFRL, and NASA). We may consider rotating research program officers

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[4] *http://spaceref.com/news/viewpr.html?pid=57581*

[5] *https://www.colorado.edu/initiative/space-and-sustainability/*

[6] Ostrom, Elinor (1990). Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press. ISBN 978–0–521–40599–7.

from these constituent organizations through such a coordination role to maximize knowledge transfer, buy-in, and awareness amongst government-funded research programs in SSA/STM.

Secondly, we must leverage the wisdom and technical expertise of the larger domain of SSA/STM researchers and operational experts. To do so, we should consider following NASA's lead in engaging impartial entities (*e.g.,* the National Research Council, the National Academies, or other groups) to conduct decadal surveys identifying promising avenues of basic research and technology development. To ensure these decadal survey reports capture research opportunities and real operational needs, I propose that government, industry, and academic researchers and practitioners contribute to these reports.

In addition to functional changes in the research enterprise that could result in more quality jobs and transformative research, the following selected topics comprise a non-exhaustive list of high-impact research and operational gaps in SSA, STM, and debris mitigation.

- We must expand the SSA, STM, and debris mitigation enterprise beyond Earth orbit. For example, our core capabilities in observation association and initial orbit determination often break down in multi-body regions. This includes regions about the Earth-Moon system, Earth-Sun Lagrange points, as well as other destinations for both public and private spacecraft.
- Our space object catalog is outdated and struggles to accurately represent states, enable propagation, and represent uncertainty for all but the most traditional cases. When expanding operations beyond geosynchronous orbit, we're asking our existing algorithms to perform tasks there were never designed for. Fundamental and applied technology development is necessary to resolve this. Emphatically, any new catalog representation we choose to adopt should be able to represent all trajectory types, whether in low-Earth orbit or on an interplanetary transfer.
- New results in decision-making under uncertainty for centralized and decentralized sensor networks may fundamentally change our sensor tasking and orbit update processes. We should explore 'real-time' ingestion, fusion, and tasking of sensor data in both centralized and decentralized sensor networks. Such advances would make substantial efficiency improvements and reduce taxpayer burden and/or business overhead costs.
- Space weather has been shown to substantially impact spacecraft operations. New sensors continue to be launched that allow us improvingly timely space weather status and predictions. Integration of real-time space weather in SSA/STM methods should be pursued. An excellent example of collaboration in this topic between the Department of Commerce and academia is the CU Boulder Space Weather Technology, Research, and Education Center (SWx TREC)[7].
- It is completely appropriate for commercial enterprises to wish to retain proprietary methods for autonomous orbit maintenance and collision avoidance. However, we must still ensure safe autonomous spacecraft operations. Work in certifiable algorithms that provide basic proof of safety for autonomously maneuvering spacecraft or constellations must be performed. Such a method could protect commercial intellectual property while demonstrating necessary flight safety certificates.
- Ultimately, fused SSA/STM information must be understood and acted upon by human operators, much like in air traffic control. Our current SSA in USSF operations handle 1–2 thousand active space objects, where in the future we expect 10s of thousands of active space objects, many more of which may maneuver autonomously. Research in human factors must be performed to understand optimal operator workloads, operator algorithm supervision capacity, and trust in autonomous sensor processing, space object management, and sensor tasking systems.

Appropriate Roles for Government, Industry, and Academia

Whether implemented as a coalition in a public-private partnership or as formal elements of the DoC or other government entities, the following roles and responsibilities should reside within government, industry, and academia, respectively.

Government

- Congress needs to clearly articulate Mission Authorization and domains of responsibility for SSA/STM

[7] *https://www.colorado.edu/spaceweather/*

- Introduce physics-informed operating requirements for different regions in space (*e.g.,* polar sun-synch orbits, geosynchronous orbit, Lagrange points). Consider extension of principles in real estate zoning to these regions. Examples of things to change include our antiquated 20-year deorbit policy is not region-specific. Further, our geosynchronous 'graveyard orbit' has been shown to be unstable in the long term.[8]
- Engage with and lead the international community (other governments, industry, and academia) in adoption and acceptance of rules of the road and norms of behavior.
- Support integrated STM sensor processing, space object management, and sensor tasking/observation request system. Consider market-based options for sourcing sensor processing and tasking from 3rd parties
- Public purchase and availability of sensor observations in support of civil SSA/STM
- Streamline and maintain a coherent long-term stable funding source, including Centers of Excellence, to facilitate transformative research, workforce development, and quality job growth
- Participate in SSA/STM decadal survey activities

Industry

- Participate heavily in formation and adoption of rules of road, norms of behavior
- Coordinate to propose verification standards for safe operations that don't divulge proprietary techniques & methods
- Participate in SSA/STM decadal survey activities

Academia

- Support research needs in SSA, STM, and debris mitigation for both government and industry
- Lead Centers of Excellence
- Increase PhD and MS workforce in SSA/STM allied areas for government and industry employment, as well as entrepreneurial activities
- Provide impartial algorithm verification and validation services for core SSA/STM activities
- Participate in SSA/STM decadal survey activities

Combined, these actions have real potential to ensure rules-based United States leadership in SSA/STM amongst the international community, improve relevance and efficacy of basic research and technology development efforts, and produce a thriving space economy.

With that summary, Senators Hickenlooper and Cantwell, I thank you again for the opportunity to testify on the criticality of our challenges and opportunities in SSA/STM. The subcommittee's work on this matter has the potential to substantially benefit United States and international civil space endeavors. I would be pleased to answer any questions you or the subcommittee may have.

Senator HICKENLOOPER. Thank you, Dr. Holzinger.

Mr. Graziani.

STATEMENT OF PAUL GRAZIANI, CO-FOUNDER, ANALYTICAL GRAPHICS INC., AND CHIEF EXECUTIVE OFFICER, COMSPOC CORP.

Mr. GRAZIANI. Ranking Member Lummis, distinguished members of the Committee, I sincerely thank you for inviting me here and my company that I represent, Commercial Space Operations Center, to testify before you on this critical issue of Space Situational Awareness and what that means to Space Traffic Management and Orbital Debris.

While I'm here representing my company certainly COMPSOC, which is a hundred percent focused on this problem, delivering SSA

[8] *https://www.nature.com/articles/d41586-018-06170-1*

through a commercial business model, I really want to note that I planned that this testimony really represents all the commercial companies that are involved in this business.

We have from the inception of our company had what we call a "big 10" approach that is inviting all other companies to come participate and we have strong relationships and co-invested with most—I'd actually dare to say most of the commercial space situational awareness companies in the United States here and actually several international ones.

So I feel pretty good about representing the industry here as a whole.

I do have some visuals that will support my testimony. So the first one up, and this has been established and we can play the first chart up there which should be playing a video, there we go, so this video—I won't let this run the whole time.

I think it's well understood what a day without space would be like. It's a really bad day. So this video actually by the German Space Agency kind of goes through that, but we'll skip this and then jump right to the next chart which I think is a more interesting video.

So this video coming up here will depict the growth of the tracked objects since Sputnik has been launched and so what you'll see here is both graphic depiction as well as a graph that will actually show how that population increases very dramatically.

So there's really a few take-aways that come from this. If you notice (1) there's a dramatic, just flat-out dramatic growth, as you see that curve going. (2) most of these objects are debris and therefore not controllable. So that's a problem. (3) you'll see some big spikes. So the first one coming up in 2007, as you mentioned, Mr. Chair, that was the Chinese satellite weapons test, the debris 3,000 or so objects created from that tracked objects, and then in 2009 you see the collision that you also mentioned between a low earth orbiting communications satellite and a dead Russian communications satellite.

But what that says is when those collisions happened, either intentional or unintentional, it really increases the problem very dramatically. So that's something that we have to focus on solving.

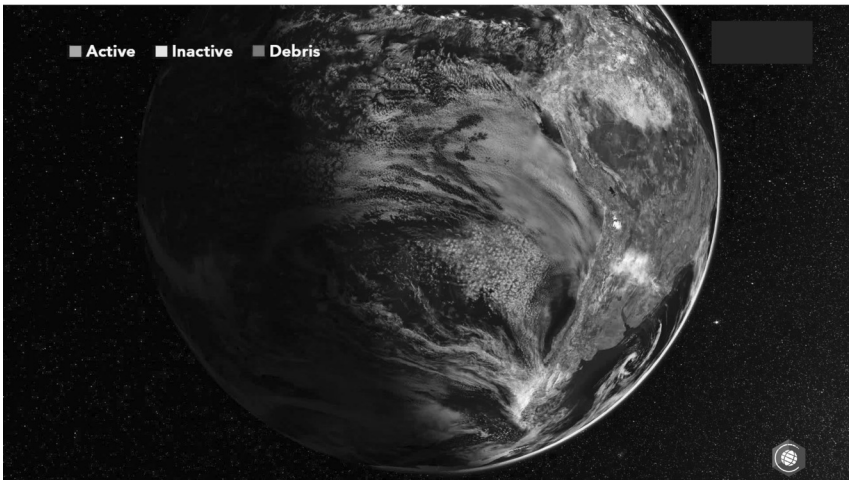
So if we go to the next chart, the next chart will show—it's a better way to look at this debris problem. So what you see here are a spatial density representation and what this shows is—you can see there's the Chinese satellite weapon in the second panel there. You see what happened there. You see the Iridium Kosmos collision, and then what you see is the growth that's happening because of the dramatic increase, and this is very early in the process. This really only goes to 2019. So going forward is much more substantial.

So if we go to the next chart here, the key take-away here is there is an awful lot of stuff. This is that 107,000 satellites that are right now proposed to be launched. So we've got a big problem coming our way and we better start dealing with it or that's really not going to happen. It's going to make that orbit, the low earth orbit really unusable.

So just one more graphic that basically says a lot of people say and they're right not all of those are going to fly, but if you take

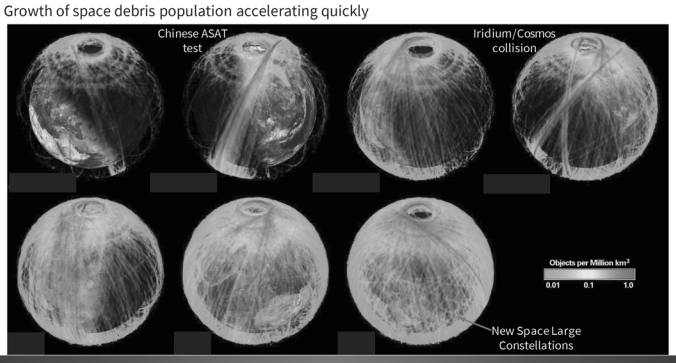
a look at this chart, that green line, that's a log chart there. That green line is showing what the actual and you're seeing that it's tracking to way more than 10 percent and even 10 percent would be a big problem. So I think we've got a lot of space traffic coming our way.

[The charts referred to follows:]



Spatial density of <u>tracked</u> objects ever increasing

- Growth of space debris population accelerating quickly



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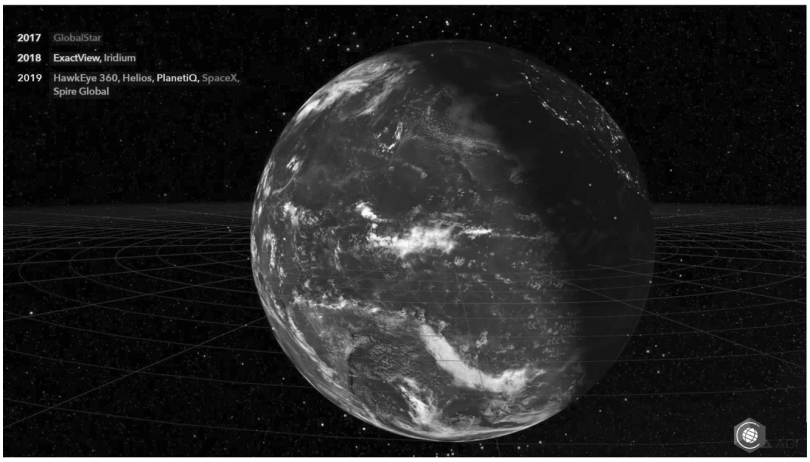
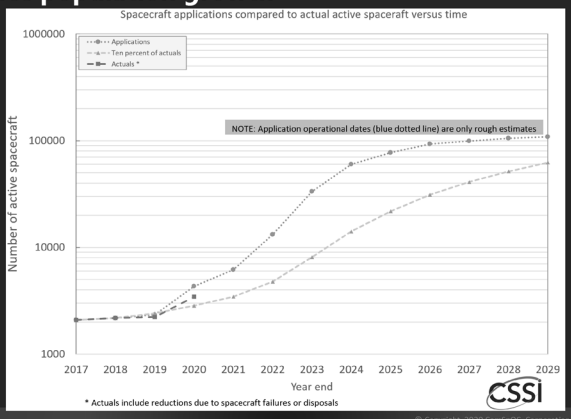


Active space population growth



* Actuals include reductions due to spacecraft failures or disposals

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Summary recommendations

Challenges

- Space-based services are in risk of a catastrophic event
- Pace of commercial space activities is outpacing space safety implementations
- US global space leadership being challenged
- National security satellites increasingly held at risk, which increases the burden on DoD and risk to other satellites

Opportunities

- Fully resource and fund the Office of Space Commerce to execute space traffic management
- Provide clear direction to implement a national STM Pilot for space safety and prioritizing private industry as the foundation
- Seize US leadership role in space economy, space safety and international standards and best practices

COMSPOC 6

Commercial SSA services

COMSPOC

Provides unmatched space situational awareness services using cloud-hosted ***processing*** software and a global network of ***commercial sensors***

COMSPOC 7

Top 20 large constellations at risk of collision

Operator	# S/C	Alt (km)	Current (>10 cm) RSO catalog average number			~200,000 (≈2 cm) RSO catalog average number		
			Estimated collisions in 10 years	*3km warnings in 10 years*	*1km maneuvers in 10 years*	*Estimated collisions in 10 years*	*3km warnings in 10 years*	*1km maneuvers in 10 years*
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Amazon	3,236	590	**0.18**	**3,768,872**	**418,764**	**0.09**	**36,120,810**	**4,013,423**
Boeing_1	1,120	1,200	0.14	331,965	36,885	1.09	4,739,224	526,580
Boeing_2	1,210	550	0.10	234,358	26,040	0.84	3,646,359	405,151
Boeing_3	1,000	585	0.23	1,812,814	201,424	0.59	16,903,756	1,878,195
CommSat	800	600	0.07	1,362,606	151,401	0.03	12,835,938	1,426,215
ExactView	72	820	0.21	326,914	36,324	1.10	2,768,355	307,595
Hongyan	300	1,100	0.04	241,520	26,836	0.16	3,434,841	381,649
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LuckyStar	156	1,000	0.02	318,736	35,415	0.01	2,616,385	290,710
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Yaliny	140	1,000	0.03	321,780	35,753	0.05	2,599,648	288,850

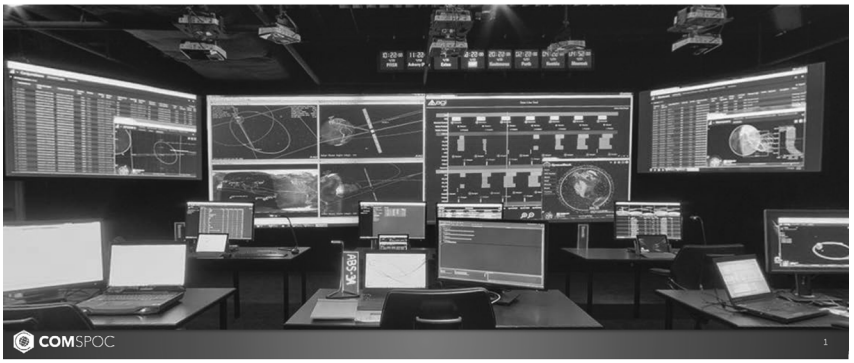
COMSPOC 9

So just to conclude with a few recommendations from our perspective, so (1) it's really critical to energize and motivate the space companies by empowering NOAA and the Office of Space Commerce to fully embrace commercial SSA providers, (2) fully resource and adequately fund the Office of Space Commerce, something we believe needs to happen, (3) there needs to be clear, deliberate, and direct action to acquire, prioritize, implement, and deploy existing commercial SSA systems that stand ready to deliver this capability, and then, last, we certainly strongly support the Space Act. We believe that this is going to be fundamental to our efforts.

Commercial SSA services

COMSPOC

Provides unmatched space situational awareness services using cloud-hosted ***processing*** software and a global network of ***commercial sensors***



COMSPOC 1

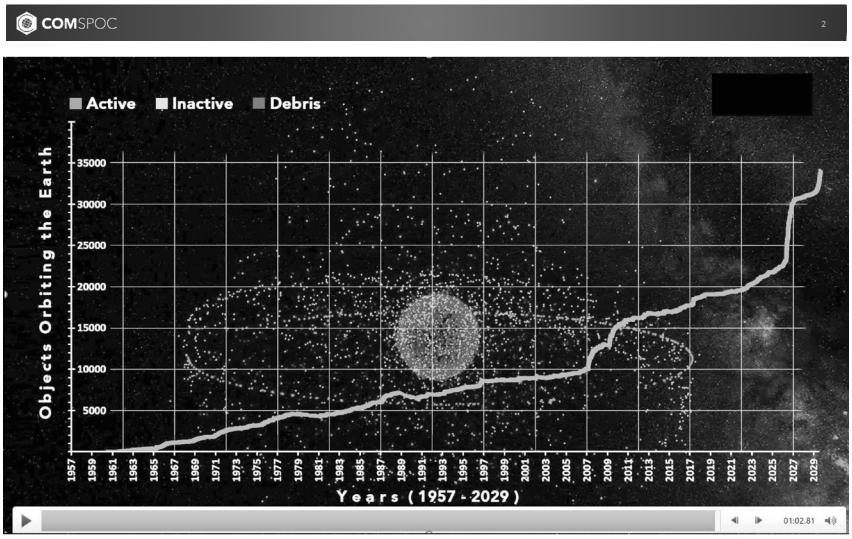
STM challenges and opportunities

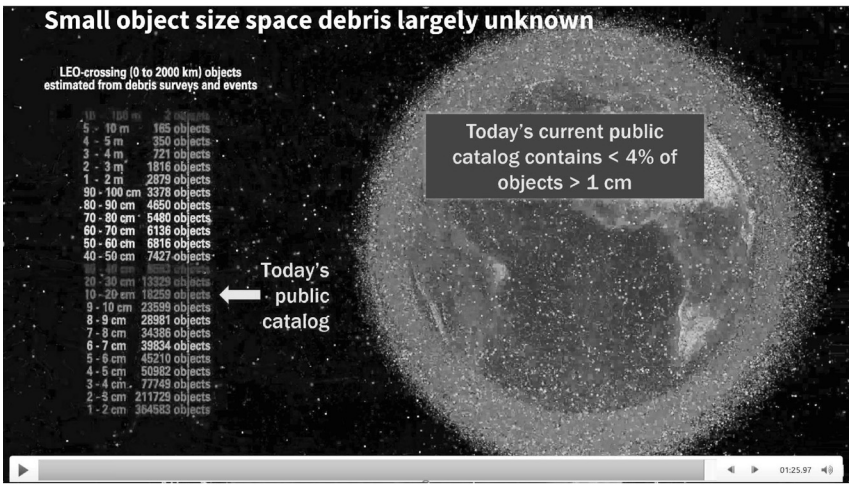
Challenges

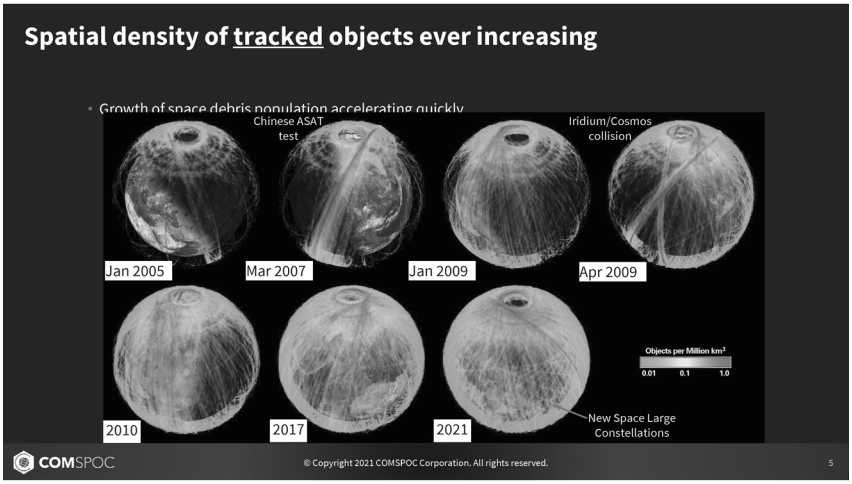
- Pace of commercial space is outpacing space safety implementations
- Europe and other nations prioritizing and implementing space safety faster than the US
- US global space leadership being challenged
- National security satellites increasingly held at risk

Opportunities

- Leverage the pace of commercial innovation and best practices
- Implement a national STM Pilot for space safety and continued space economy growth
- Fully resource Office of Space Commerce to take advantage of existing commercial STM services




Small object size space debris largely unknown
LEO-crossing (0 to 2000 km) objects estimated from debris surveys and events
5 - 10 m 165 objects
4 - 5 m 350 objects
3 - 4 m 721 objects
2 - 3 m 1816 objects
1 - 2 m 2879 objects
90 - 100 cm 3378 objects
80 - 90 cm 4650 objects
70 - 80 cm 5480 objects
60 - 70 cm 6136 objects
50 - 60 cm 6816 objects
40 - 50 cm 7427 objects
20 - 30 cm 13329 objects
10 - 20 cm 18259 objects
9 - 10 cm 23599 objects
8 - 9 cm 28981 objects
7 - 8 cm 34386 objects
6 - 7 cm 39834 objects
5 - 6 cm 45210 objects
4 - 5 cm 50982 objects
3 - 4 cm 77749 objects
2 - 3 cm 211729 objects
1 - 2 cm 384583 objects
Today's public catalog
Today's current public catalog contains < 4% of objects > 1 cm
01:25.97


Spatial density of tracked objects ever increasing
Growth of space debris population accelerating quickly
Chinese ASAT test
Iridium/Cosmos collision
Jan 2005
Mar 2007
Jan 2009
Apr 2009
2010
2017
2021
Objects per Million km³
0.01
0.1
1.0
New Space Large Constellations
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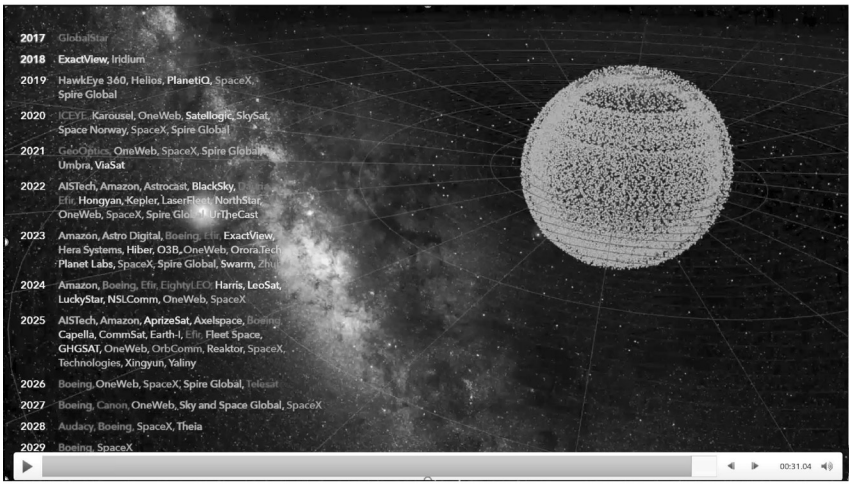


Collision risk growing

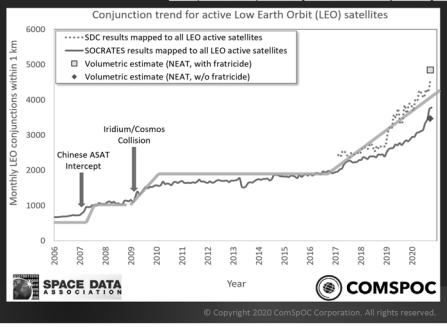
- Space traffic and close conjunctions ever increasing
- Space services are national critical infrastructure

Average monthly conjunction rates surge from 2017 to 2020

Satellite operators are receiving warnings that their spacecraft are within 1 kilometer of another satellite or piece of tracked debris approximately twice as often as they did three years ago.

That was one of the key takeaways from data compiled for *SpaceNews* by Analytical Graphics Inc. (AGI), the Exton, Pennsylvania firm that hosts the Space Data Center, a platform that ingests potential collision risks since 2004.

In low Earth orbit, satellite operators typically evaluate the need for a collision avoidance maneuver when one of their satellites is expected to come within 1 kilometer of another object. Space Data Center and SOCRATES data indicate that in 2017, LEO spacecraft likely came within 1 kilometer of other objects an average of 2,000



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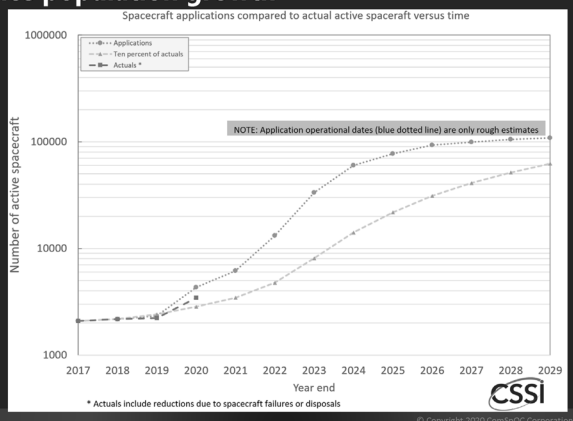
Active space population growth



COMSPOC 8

Top 20 large constellations at risk of collision

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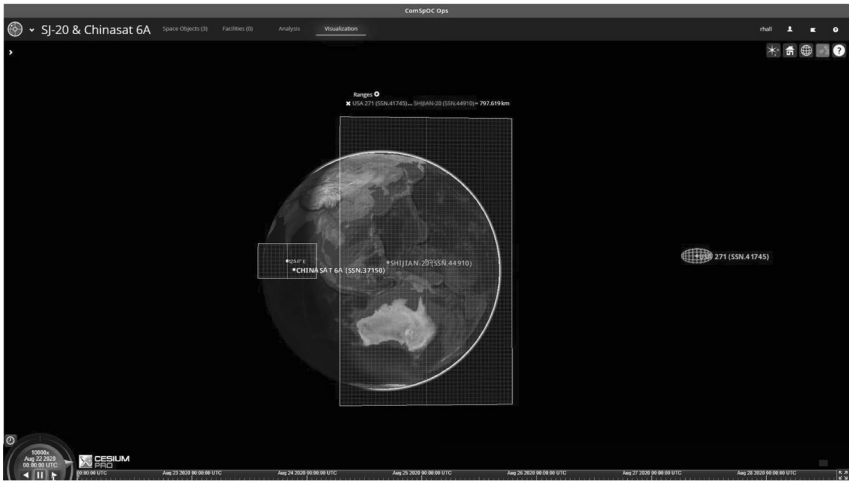
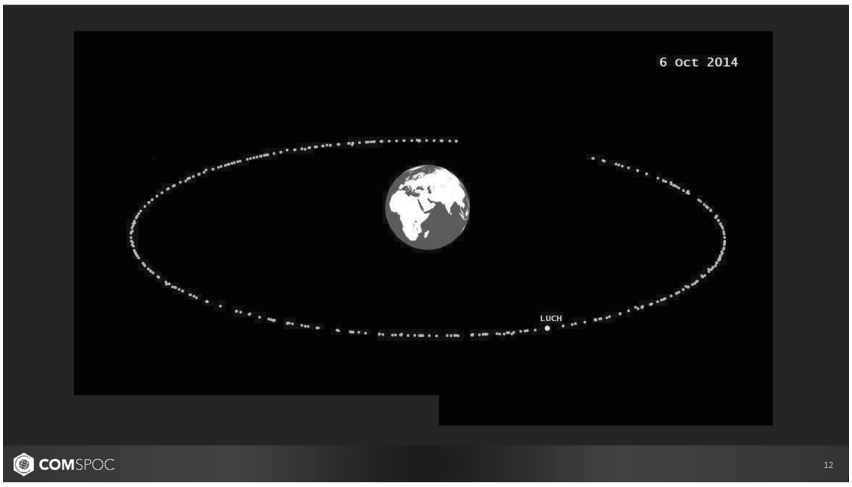
COMSPOC 10


ComSpOC Ops
SJ-20 & Chinasat 6A
Space Objects (3)
Facilities (0)
Analysis
Visualization
rhall
Ranges
797.619km
CHINASAT 6A (SSN.37158)
271 (SSN.41745)
CESIUM
PRO


6 Oct 2014
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12

So again thanks for holding this hearing and thanks for inviting us and the commercial industry stands ready to dramatically help in this moment.

[The prepared statement of Mr. Graziani follows:]

PREPARED STATEMENT OF PAUL GRAZIANI, CEO, COMSPOC CORP AND CO-FOUNDER, ANALYTICAL GRAPHICS, INC.

1. Opening

Chair Hickenlooper, Ranking Member Lummis, and distinguished members of the Committee—I sincerely thank you for inviting me and the companies I represent, COMSPOC Corp and Analytical Graphics, Inc., to testify before you on Space Situational Awareness (SSA), Space Traffic Management (STM), and Orbital Debris.

While I directly represent COMSPOC and Analytical Graphics, I want to note that I am delivering testimony today to reflect the commercial SSA industry as a whole, rather than any one company. We've been delivering SSA solutions for over 20 years and established a big tent approach that should serve as the basis for my testimony.

I applaud your leadership today in holding a hearing on this topic. SSA, STM, and Orbital Debris are indeed critically urgent matters that, unfortunately, have fallen victim to years of stagnation by way of repetitious study and debate, confused priorities and limited, misdirected funding—resulting in very little actual progress. While this topic continues to be of significant interest on the floor, it has been allocated too few resources and too little discernable focus for any significant advancement—despite Space Policy Directive-3 (SPD–3), which formally initiated the STM responsibility and implementation effort for the U.S. Government (USG), over 3 years ago. For the sake of satellite operators, commercial SSA providers, human space explorers, researchers and indeed, the general public, my hope is that this hearing and your leadership will ensure it's not too late to provide clear legislative direction such that the responsible agency can execute and implement space safety solutions.

2. Benefits the SSA industry brings to the American people

Quite simply, the SSA industry, and a resulting STM regime, enable a safe, secure and sustainable space operational environment for the continued launch and operation of the critical space infrastructure that delivers essential capabilities and services to the global population: navigation, communications, weather/climate, Earth resources and other imaging, health/medical system support, broadband services, and virtual conduct of sectors of the U.S. economy—or U.S. Commerce. The functions of industry-provided SSA range from the identification and maintenance of position/velocity/orbit information on the on-orbit satellite population, to the determination of knowledge and understanding of potential collision risk situations, to

supporting the planning, selection, and execution of appropriate response actions, all of whichallow operators to conduct safe operations that minimize the risk of accidental collisions that would jeopardize the conduct of and provision of these services.

The average American might not think of satellites in their day-to-day life, but they certainly unknowingly rely on them. Banking, for example—specifically wire transfers—are only possible using precision timing signals only available from navigation satellites. Despite the panic and inconvenience that would ensue at the loss of banking communications, we rely on satellites for much higher stakes.

Consider a natural disaster; whether it's a flood, forest fire, hurricane, or earthquake, satellites help detect, warn and mitigate the loss of human life in these events. Infrared satellites detect forest fires. First responders rely on satellites to find lost victims. Hurricanes are monitored using weather satellites. Any of these events alone can be horrific and even fatal. Further, compound on those scenarios that much of our communications are reliant on satellites. First responders radioing for reinforcements, pilots' connection with air traffic control, phone calls statusing friends and family—are all communications that are at risk without proper satellite safety measures. These are all examples of space-based services upon which the ground, air and maritime domains rely.

The space industry continues to research and innovate, opening new doors to ground-breaking operating concepts, constructs, capabilities, and services. This is evidenced by coverage on commercial space launches introducing possibilities generally undoable even a few short years ago (about when SPD–3 was released). The SSA industry will continue to help keep space open for commerce and its associated research and innovation.

A natural consequence of this activity, along with other factors, causes space to continuously become an increasingly congested and complicated operational environment, magnifying risk to operations and its long-term sustainability. Current USG (via the DoD) spaceflight safety capabilities and services, as well as the Space Situational Awareness (SSA) to support them, fall far short of being able to manage this critical resource in this "new space" regime. However, commercial private industry has been actively innovating, building and providing the necessary SSA and STM capabilities for over a decade.

Space is now indispensable to the American way of life, and STM is fundamental to protecting the valuable resource of space. The benefits of a robust SSA industry will ensure that the space-based services that all citizens use today will continue to be available tomorrow and that new space-based services will continue to flourish.

3. Commercial Positioning

US Commercial SSA providers are world-renowned for their innovation, subject matter expertise, and capabilities. U.S. private industry teams are delivering the most advanced SSA and STM capabilities in existence. Many capabilities have been available for over a decade, while some capabilities are recent, state-of-the-art advancements, due to commercial industry's on-going innovation. Here are a few examples from U.S. private industry:

- Utilizes state-of-the-art algorithms that curate, process and fuse data agnostically—facross all formats, standards and phenomenologies—to generate the world's most accurate orbit information and provide operationally relevant, decision-quality collision warnings
- Leverages open-standards based, service-oriented architectures to facilitate ease of sharing and plug-n-play interoperability with other existing capabilities or future-developed capabilities
- Provides commercial cloud computing architecture to support flexibility, scalability, virtual accessibility, and data security
- Maximizes transparency into data, information, and the processes behind them to support satellite operator confidence-building in risk analysis and assessment procedures to support collision avoidance maneuver decisions, planning, and execution
- Ability to track small pieces of debris down to 2cm
- Expertise to uniquely deploy hundreds of ground-based telescopes in an innovative way to decrease the amount of sun exclusion
- Deploying and routinely using telescopes for daytime tracking at scale
- Acts as the operational arm for the Space Data Association which provides safety of flight services to 700+ commercial and civil satellite operators utilizing the Space Data Center that was deployed and has been continuously operating for 11 years

For the past 3 years, NOAA has been utilizing commercial SSA services from private industry to protect their weather satellites in both low earth and geosynchronous orbit, in part to ensure the most accurate and timely information is utilized.

There are many more examples where individual satellite operators are indeed looking for and leveraging private industry commercial SSA services. However, this remains a minuscular population of operational satellites and doesn't address the scale needed to protect the space operational environment.

A critical infrastructure component of an STM system, is an Open Architecture Data Repository (OADR), which is not available in today's legacy U.S. Government capabilities. In November 2020, DoC's Office of Space Commerce (OSC), conducted an OADR industry day to perform market research for commercial capabilities to support an OADR. Private industry demonstrated the ability to satisfy all 10 required functions of an OADR as stipulated by OSC.

In short, commercial companies are better suited than the government to provide a higher standard of SSA because, by design, their capabilities are more universal/interoperable due to the diversity of their customer base, the pace at which commercial innovates, and the commercial practices that enable the private sector investment. On the opposite end of the spectrum, the government builds capabilities that are very specific and uniquely situated to government owned and operated systems. The nature of government contracting ends up restricting the broad application of products and services available from private industry for SSA and STM, and it stifles the innovation necessary to continue to meet evolving SSA and STM challenges as they arrive in the "new space" operational environment.

4. Importance of international leadership in these areas

SSA and space safety services have long been provided free of charge to the satellite operator community via the Combined Space Operations Center (CSpOC) under the purview of the 18th Space Control Squadron (18SPCS). Using data collected by the Space Surveillance Network, the DoD has performed a laudable job of providing these U.S.-provided SSA Sharing services, to include obtaining the necessary Congressional authority, instituting the requisite operational procedures, and building and maintaining partnerships with various foreign government and commercial entities. The DoD should be commended for its foresight and understanding of the need to support space safety for the sustainability of space operations, as well as its diligence in establishing a paradigm for SSA sharing.

However, the U.S. national security space regime is becoming increasingly threatened due to adversary actions. This is, in part, the reason for the recent reorganization around national security space, to include the re-institution of U.S. Space Command and the standup of the U.S. Space Force. Associated with this reorganization, the DoD has directly stated a compulsory demand to focus on space as a warfighting domain and a desire to transfer SSA sharing and space safety functions to another USG organization (and identified the Commerce Department for this purpose).

Combined with the aforementioned lack of progress in standing up a U.S. SSA/STM regime for these civil/commercial concerns, non-US governmental entities, and their associated non-U.S. commercial counterparts, now have an opportunity and seek to seize the initiative in this mission area. If successful, they would then promote their leadership paving the way for the development of international standards and best practices with respect to space operations, SSA and STM. These efforts could then result in processes, standards, and best practices that, are not favorably pre-disposed to U.S. priorities and concerns; they may even artificially complicate or constrain U.S. space operations, including national security space.

In addition, this would consequently mean that the associated non-U.S. commercial entities would be able to grab the larger percentage of the potential market share for private industry-provided SSA and STM capabilities and services.

Indeed, the current German presidency of the European Union has set a high priority on STM to maintain and promote European sovereignty, not only for its regulatory impact but also to open markets for related goods and services. The European Cooperation for Space Standardization has stood up a regular meeting panel of 20 subject matter experts to coordinate and harmonize European industries and agencies positions on STM related standards and to contribute to the development of STM implementation standards in the framework of the International Organization of Standardization (ISO).

And the EU is not the only non-U.S. effort underway. While the U.S. might hope for the best here (and realize that hope is not a strategy!), there are also efforts underway with potential adversaries like China and Russia that will undoubtedly seek to complicate U.S. management of its space concerns and equities.

5. Recommendations for congressional action on civil SSA and STM

In Summary, the space sector is experiencing explosive growth, this creates a more difficult satellite operational field, protecting our satellites is essential to American every-day way of life, the status quo is unsustainable, and better capabilities exist and are assessable through commercial options.

The U.S. needs to take advantage of the commercial innovation and the rate at which commercial industry delivers solutions that address space safety challenges. Below are recommendations to do so:

- Energize and motivate the space commerce by empowering NOAA and the Office of Space Commerce to fully embrace commercial SSA providers through contracts just like NASA and other agencies do; a no-cost demonstration is not incentivizing private industry to continue to invest and innovate and simply, does not meet the spirit and intent of collaborating with industry for an STM Pilot.
- Implement a national STM Pilot for space safety and continued space economy growth
- Fully resource and adequately fund the Office of Space Commerce to take advantage of existing commercial STM services available from private industry.
- Provide clear, deliberate direction to acquire, prioritize, implement, and deploy existing commercial SSA and STM services available.
- Utilize the market research already performed by the Office of Space Commerce.
- Leverage research and development for studying hard problems where solutions don't exist and to improve upon promising ideas and algorithms; Avoid the unending analysis of alternatives or yet another year of market research or technical studies that have all been performed and results reported. The solutions already exist; they just need to be utilized.

Again, I applaud this committee for taking leadership and holding this hearing. Consistent with the August 2020 National Academy of Public Administration (NAPA), there is an impending crisis as it relates to satellite operations and managing the collision threats, the growth of on-orbit satellites and the critical nature of space-based services provided from satellites. There is an urgent challenge and private industry is well prepared to meet the challenge. We look forward to your direction to remove the obstacles hindering the full utilization of existing commercial solutions.

Senator HICKENLOOPER. Thank you, Mr. Graziani.

Mr. Stroup.

STATEMENT OF TOM STROUP, PRESIDENT, SATELLITE INDUSTRY ASSOCIATION

Mr. STROUP. Chair Hickenlooper, Ranking Member Lummis, and Distinguished Members of the Subcommittee, thank you for inviting me to testify today.

I'm Tom Stroup, President of the Satellite Industry Association, which represents the U.S. commercial industry.

U.S. industry is leading space innovation, driving the need for more precise orbital tracking, SSA, and in the future a space traffic coordination and management regime.

The safety of the space environment is critical to all operators, from navigating through debris fields, rocket bodies and defunct satellites to operators coordinating on orbital planes and best practices for collision avoidance.

The profile of operational satellites will change substantially in five to 10 years. To accommodate this growth, the current framework of regulations and policies requires review and in some cases revision.

The six most important issues today are Number One, timeliness. Rates of launch and deployment have increased dramatically with over 1,200 satellites launched in 2020 alone.

Operators rely on SSA to characterize the environment and anticipate and avoid collision. More advanced services are needed to support future operations and establish safety and sustainability. There is a need for information-sharing, transparency, and coordination among satellite operators as well as U.S. and foreign administrations.

Given the safety aspect inherent in SSA and STCMA, government and government-backed provision of these services is critical.

Number Two, orbital accuracies. Today's free SSA services feature suitable orbital accuracies to support flight safety decisions in some orbital regimes but will fall short as activity increases.

Whether accuracy is suitable is dependent upon operator-selected collision avoidance metric and threshold tracking revisited prioritization, the object's physical properties, orbital regime, and maneuverability. Therefore, a focus should be on improving data accuracy.

Number Three, continued development of commercial tools to augment current services. Several versions of commercial SSA and STCM services exist to augment government systems.

Continued development and adoption of both government and commercial services and STCM system will improve decision-grade information for operators.

Number Four, tracking and advanced SSA analytics. Observations from diverse SSA tracking networks and sensors is required to build a robust, accurate, SSA system.

Number Five, open architecture deposit data repository. Today's satellite operators contribute data relevant to space safety on spacecraft, including positional time histories and predictions, maneuver plans, launch, early orbit, and re-entry data.

Commercial entities continue to lead the development and implementation of OADR capabilities. This data exchange model must be extended globally.

And Number Six, availability of information. SSA and STCM data must be available to all operators, whether commercial or government, regardless of mission, altitude, or nationality.

As such, SIA recommends the following four actions. Number 1, action and funding are needed now. The commercial satellite sector is quickly innovating, driving U.S. leadership in space.

The U.S. must act now to implement a modern SSA/STCM environment to support innovation, including leveraging commercial and government capabilities to yield a U.S.-developed cutting edge space sustainability model.

Number 2, the framework should be established but specific technologies to meet requirements should not be dictated. Space companies are renowned for ingenuity. Allowing innovative ways to meet requirements of a modern space safety framework will encourage development and ensure cost-efficient and effective technologies are utilized.

Number 3, governments should encourage best practices. The commercial space industry has a track record of responsible oper-

ations in space and counts on a safe environment to undertake ongoing and future business.

Solidifying the participation and support of industry to ensure widespread adoption of space safety practices is critical and will reduce the need for unnecessary and often burdensome regulation.

And Number 4, any effective solution must be whole of space and endeavor to meet global needs. A successful modern and sustainable STCM system will include all categories of space activities, U.S. and international alike.

The U.S. cannot accomplish this on its own and if regulations are not appropriate, satellite operators will license systems in foreign administrations rather than the U.S. This will require the relationships and leadership of the U.S. Government, commercial stakeholders, and like-minded nations to achieve space sustainability.

I appreciate the opportunity to appear before you today and I'm happy to answer any questions. Thank you.

[The prepared statement of Mr. Stroup follows:]

PREPARED STATEMENT OF TOM STROUP, PRESIDENT, SATELLITE INDUSTRY ASSOCIATION

Chair Hickenlooper and Ranking Member Lummis and distinguished Members of the Committee, thank you for inviting me to testify before you today. I am Tom Stroup, President of the Satellite Industry Association (SIA).[1,2] SIA is a U.S.-based trade association providing representation of the leading satellite operators, service providers, manufacturers, launch services providers, space situational awareness companies, and ground equipment suppliers.

We are at an important time in the advancement and use of space with U.S. industry bringing vast innovation to space. There are many innovative ways to use space which drive the increased need for more precise orbital tracking, space situational awareness, and, in the future, a space traffic coordination and management (STCM) regime. These uses include everything from large constellations of communications satellites bringing broadband to everyone, commercial human spaceflight, position navigation and timing, and greater space exploration and monitoring. The safety of the space environment is critical to all of our operators: from navigating through debris fields, rocket bodies, and defunct satellites, to operators coordinating on orbital planes and best practices for collision avoidance, to our cubesat operators who must utilize innovative designs to maneuver their satellites without exceeding their size, weight, and power budgets.

SIA projects the profile of active satellites operating in low earth orbit will change substantially in the upcoming 5–10 years. Many ventures have been applying for regulatory approvals, seeking investment and developing designs and are operating on-orbit today, including providing high-speed, low-latency broadband, earth monitoring, and other critical capabilities from orbit. Although a number of large constellations have been proposed, it is important to understand that adding the total number of satellites proposed in regulatory filings worldwide does not equate with what will ultimately be viable, orbiting systems. Nevertheless, it is clear that the current framework of space regulations and policies requires review and, in some cases, revision to prepare for the continued utilization of space, encourage and promote innovation, drive continued investments in the U.S., and promote a safe space environment.

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[1] *SIA Executive Members include:* Amazon; AT&T Services, Inc.; The Boeing Company; EchoStar Corporation; Intelsat S.A.; Iridium Communications Inc.; Kratos Defense & Security Solutions; Ligado Networks; Lockheed Martin Corporation; OneWeb; SES Americom, Inc.; Space Exploration Technologies Corp.; Spire Global Inc.; and Viasat Inc. *SIA Associate Members include:* ABS U.S. Corp.; Amazon Web Services; Artel, LLC; AST & Science; Astranis Space Technologies Corp.; Blue Origin; Eutelsat America Corp.; ExoAnalytic Solutions; HawkEye 360; Hughes; Inmarsat, Inc.; Kymeta Corporation; Leonardo DRS; Lynk; Omnispace; Ovzon; Panasonic Avionics Corporation; Peraton; Planet; SpaceLink; Telesat Canada; ULA; UltiSat and XTAR, LLC.

[2] Viasat does not join in these comments

SIA urges thoughtful consideration of the SSA and eventual STCM regime in a way that facilitates operators appropriately responsible for safe space operations and fosters the ongoing safe and efficient use of the shared space environment.

The most important issues SIA sees today are as follows:

1. *Timeliness:* The current and forecasted rates of launch and spacecraft deployment have increased dramatically, with over 1200 satellites launching in 2020. Currently, space operators rely on space situational awareness (SSA) services and conjunction messages to characterize the space environment and anticipate and avoid collision. While these SSA services are important and useful today, more advanced services are needed to support future space operations and establish space safety and sustainability of the space environment. SIA members believe that there is a need to revise the current space safety construct by procuring and implementing a viable and effective coordination approach for information sharing, transparency, and coordination among satellite owners/operators, U.S. government organizations, and foreign administrations. Given the safety aspect inherent in SSA and STCM, government and government-backed provision of these services is critical.
2. *Orbital accuracies.* Today's public, free SSA services feature suitable orbital accuracies to support flight safety decisions in some orbital regimes, but in many key orbital regimes they will fall short as space activity increases. Whether the accuracy is suitable is highly dependent upon the specific collision avoidance metric and threshold selected by the operator, the type of object, its size or reflectivity, tracking revisit and prioritization, the orbital regime it occupies, and its maneuverability. To accommodate these current orbital inaccuracies, some operators often rely on very conservative assumptions for decisions to implement collision avoidance decisions, resulting in a flood of warnings. A focus should be on improving the accuracy of these datasets.
3. *The continued development of commercial tools to augment current space sustainability and safety service.* Several versions of commercial SSA and STCM services exist today to augment government systems in a highly complementary way. The continued development and adoption of both government and commercial services in a diverse STCM system will improve accuracy of decision-grade information for space operators.
4. *Tracking and advanced SSA analytics.* Observations from diverse SSA tracking networks and sensor types is required to build a robust, accurate SSA system. The data from these observations must be brought together using modern data fusion engines and analytics to produce accurate, decision-quality SSA content and collision alert warnings that operators can rely upon to make timely decisions.
5. *Open Architecture Data Repository (OADR).* Today, satellite operators have proven a willingness to proactively contribute data on their spacecraft, to include spacecraft positional time histories and predictions, maneuver plans, launch, early orbit and reentry data, and other data relevant to safety of flight. Commercial entities continue to lead the development and implementation of OADR capabilities. We need to now extend that space operator data exchange model across the global space operator population under a robust STCM enterprise, providing an OADR that can serve as the gathering place for authoritative spacecraft operator data.
6. *Availability of information.* It is imperative that SSA and STCM data be made readily available to all space operators, whether commercial or government, regardless of mission, altitude or nationality. Given the critical space safety role that this data products and supporting analytics provide, such data must be highly available, with a minimum of SSA and STCM service outages, and operators need to contribute improved data to make this successful.

As such, SIA recommends the following actions:

Recommendation 1: Action and funding is needed now. The commercial satellite sector is innovating quickly and driving U.S. leadership in space. SIA urges the U.S. government act now to implement a more modern SSA/STCM environment to support this innovation, including leveraging both commercial and government capabilities to yield a U.S.-developed cutting-edge space sustainability model. This activity requires adequate funding and staffing.

Recommendation 2: The Framework should be established, but the specific technologies to meet requirements should not be dictated. Space companies are world-renowned for their ingenuity. Allowing innovative ways to meet the speci-

fied requirements of a modern space safety framework will encourage development and ensure the most cost-efficient and effective technologies are utilized.

Recommendation 3: Governments should encourage best practices. The commercial space industry has a long track record of responsible operations in space and counts on a safe environment to undertake ongoing and future space business. Solidifying the participation and support of the commercial industry to ensure wide-spread adoption of space safety practices is critical and will reduce the need for unnecessary and often burdensome regulations and is action that can be taken now.

Recommendation 4: Any effective solution must be whole of space and endeavor to meet global needs. A successful, modern and sustainable space traffic management system will include all of the types of space activities listed above, U.S. and international alike. The U.S. cannot accomplish this on its own and, if regulations are not appropriate, satellite operators will continue to "forum shop" and license systems in foreign administrations rather than the U.S. This will require the relationships and leadership of the U.S. government, commercial stakeholders and like-minded space-faring counterparts to meet the important goals of space sustainability.

I appreciate the opportunity to appear before you and I am happy to answer any questions.

Senator HICKENLOOPER. Thank you, Mr. Stroup.

I apologize for mispronouncing your name. With a name like Hickenlooper, I'm usually more attentive. I apologize.

We'll go to questions now and I think I'll start with Dr. Holzinger. STM requires obviously not just international cooperation but some level of enforcement, rules with feasibility, and as we have other nations developing their own frameworks, their own rules and consequences, where do you think it is that—how do we demonstrate global leadership on this issue, both in STM and SSA, and make sure that people recognize that we are still the leader?

Dr. HOLZINGER. Thank you, Senator, for that question.

The United States needs to demonstrate its leadership through consensus-based methods. If you look at Dr. Elinor Ostrom's framework for governing commons, it's necessary to have some level of buy-in from all the entities operating in that area. Otherwise, they'll do exactly as some of the other members of this panel have said and they will circumvent those rules. So there's some level of international collaboration that needs to be done and led by the United States.

If we don't do this, if we don't have the United States lead this endeavor, then other individuals or entities will and they will not necessarily form rules or regulations or approaches that are consistent with our national interests.

Senator HICKENLOOPER. Got it. Part of this is the level of awareness of the American people isn?t at what it needs to be, both in terms of the amount of debris in space but also the speed it's traveling at, what happens, how small a piece of debris can still do significant damage.

Mr. O'Connell, as the former Director of the Office of Space Commerce, what steps did you take while leading the office to not only maintain our international leadership but to get the word out to the American people about the risks and I just wanted to ask what advice did you give to your successor?

Mr. O'CONNELL. Thanks very much for the question, Senator.

I would say that from the very first day, ironically, my appointment was announced at the White House the very same day that

SPD–3 was announced at the White House and my life has never been the same since.

What we did do was spend literally every day in some measure on the topic trying to work the many different dimensions, supporting interagency discussions with NASA, the FAA, State Department, et cetera, working on rules of the road partly to encourage the message that we're having here, the growing role of the private sector in space, working specifically on the technical architecture.

We actually put a colleague, Mark Daley, out at Vandenberg to work hand-in-hand with the Department of Defense and they were tremendous partners because they want to get out of this piece of the mission as much as we wanted the opportunity to take it on and so that partnership was continuous throughout to work the technical issues, how is it done today, and then how could it be done better, and then, finally, industry engagement really appreciating all of the companies that are represented here and well beyond.

Last November we held an Industry Day with over 200 organizations that participated virtually to talk about one piece or another of this activity.

In terms of the words for my successor, this is one piece of the responsibility of the Office of Space Commerce, advocacy, regulatory reform. There are others, as well, but this is absolutely the most important mission at this point in time, given what is at stake and given the need to make very rapid progress in this area, and again we can do it using the commercial capabilities for this particular piece of the mission.

Senator HICKENLOOPER. Thank you for your service. That sounds like good advice and certainly doesn?t always happen in government that you have two cooperating agencies transferring responsibility. So that's some reflection of your hard work, I'm sure, as well.

Mr. O'CONNELL. Thank you very much.

Senator HICKENLOOPER. And I've only got a minute here. So I'll ask you both to be concise, but, Ms. Drees and Mr. Stroup, I wanted to ask you each to discuss how the commercial space industry's efforts to advance STM and SSA could complement other Federal missions.

Ms. DREES. That's a great question. So I would say, you know, just overall in general with the satellite industry, they're providing so many benefits to society really and the two that really come to mind are climate change and broadband internet.

So we've got a lot of initiatives underway now through this Administration, through, you know, the climate effort, through OSTP, and this is where commercial industry can provide a lot of value and we're ready to go. We're poised and ready to go and address some of these issues, and broadband internet, as well.

You know, this is one area where the satellite industry is providing Internet access to tens of millions of Americans that wouldn't otherwise receive the access.

Senator HICKENLOOPER. Mr. Stroup, do you want to add anything to that in your 12 seconds or so?

Mr. STROUP. I would say everybody uses satellites virtually every day and the industry has sought to lead by example by establishing a set of best practices and encouraging the development of the regime that we've talked about.

Thank you.

Senator HICKENLOOPER. I appreciate that. I apologize for asking a question that was impossible to answer in the time that was allotted.

I will turn over the questioning to Ranking Member Lummis.

Senator LUMMIS. Well, thank you, Mr. Chairman.

My first question is for Mr. O'Connell. One of my major concerns and several of my colleagues' major concerns is that it's taking a lot of time for the Department of Commerce to set up the Open Architecture Data Repository. So it's been 3 years since the Space Policy Directive 3 was published.

What do you think is holding up the process and what needs to be done to pick up the pace?

Mr. O'CONNELL. Thank you, Senator, for that question.

Again, we worked on it with the office team literally every day during my time at Commerce. I would say one aspect of this is that we needed to get our heads around the different partnerships and some of the technical opportunities that were available in the commercial industry.

Second, it really was a resource question, the extent to which we had a very, very small budget in the office. When I arrived to the office in 2018, no one had led the office for 10 years and it had accordingly a small, very tiny budget, and a very, very small staff. So some of our early days were built up bringing in people who could help out with the many different responsibilities of this.

It's very much a resource issue. It needs to be resourced now. In the NAPA Report there is actually a set of budget estimates that we had prepared during my time at Commerce and was looked at both by the internal Commerce Department management but also by NAPA.

Senator LUMMIS. So the Biden Administration has not yet announced a Director of OSC. And I get it, they've got a lot on their plate right now. But could you talk about the importance of having someone at the helm at OSC?

Mr. O'CONNELL. Sure. Absolutely, Senator. Thanks for that question very much.

Again, the office had a number of missions while we were there. It had the advocacy first and foremost and advocacy is not cheerleading. OK? Advocacy is about identifying investment and technology trends that are coming forward in the market. It's about helping companies break regulatory logjams.

The comment about companies going overseas, we want to avoid that obviously. It's about improving the space economy statistics so that we all make better decisions and we did that with the Bureau of Economic Analysis and our colleagues there, and so on and so forth.

So advocacy, it's our legally mandated mission, in addition to work on regulatory reform, many of the space policy activities of very, very high speeds, high policy activities during the Trump Administration, including the review of national space policy, which

encouraged the use of commercial capabilities, and then obviously all of the responsibilities associated with this.

And so we made progress on all of those fronts, I believe, and obviously we just need to pick up the pace at this point.

Senator LUMMIS. Thank you.

Mr. Graziani and Mr. Holzinger, in your testimony you both talked about the possibility of non-U.S. entities standing up SSA/STM regimes.

Can you elaborate on the consequences of non-U.S. entities taking the lead in this area and for the purposes of people that might be listening on C-Span, sometimes we use acronyms to the point where we don't even know what we're talking about, Space Situational Awareness refers to detecting, tracking, and identifying all objects in earth orbit, and so obviously this is really important as we're launching more and more and so this is a really important topic today.

So Mr. Graziani.

Mr. GRAZIANI. Certainly. Absolutely many nations throughout the world really want to take a key role in SSA and space traffic management and there are a lot of reasons for that.

There certainly are just the national sovereignty, if you will, in being able to control and understand what's going on using your own assets, so I think that that's one of the issues, and then there are military issues certainly because this domain of what you do for space situational awareness, for space traffic management, the space situational awareness also has military applications.

So you have that blend and then it cuts across and it's going to look differently to an adversary of ours, like China or Russia, than it would to an ally of ours, be it Japan or European Union, et cetera.

But, you know, we certainly feel that the United States has been a lead in this for a long time and if we don't maintain that lead, there's going to be consequences to how it is that our companies play in that world. So that's my answer to your question.

Senator LUMMIS. Thank you.

Mr. Holzinger.

Dr. HOLZINGER. Thank you, Senator, for that question.

Much like Mr. Graziani, I agree that it is imperative that the United States lead the endeavor of setting these rules.

If other countries instead lead those efforts, then they are going to be making the rules and regulations and, quite frankly, those will not be to the benefit of our own industry and national interests.

So, fundamentally, it's a national interest for us to lead this effort and to gain as much consensus amongst the international constituency as possible.

Senator LUMMIS. Thank you.

Mr. Stroup, did I pronounce that right?

Mr. STROUP. Yes, thank you.

Senator LUMMIS. Thanks. And this question I would also like to address to Ms. Drees. So thank you both.

Mr. Stroup, you mentioned in your testimony that SSA tracking data is not always precise enough for our space assets to make

safety decisions, and as a result, operators act on extra conservative assumptions.

Is this lack of precision a technology problem or a deficit of information, and how can the accuracy of the data be improved?

Mr. STROUP. Yes. So it's partially a technology issue and as a result sensors are now being added to spacecraft to be able to add to the information that is available.

Senator LUMMIS. Thank you.

Ms. Drees.

Ms. DREES. Yes, I would say at this point the technology has come pretty far along and it's mostly an accuracy of information problem at this point.

Just having the ability to track everything in real time to the point where companies often are coordinating with each other. So that is one of the things that we see as a definite need to fast track the effort.

Senator LUMMIS. Thank you, all.

Mr. GRAZIANI. Senator, I could add something to that from a commercial perspective, which is that there are two things that are happening.

One, we're not collecting the right amount of data that we should, the amount of data that we should, and we're not processing it in the right way. So really the thing that needs to happen, you can either process the data that we have already in a much better way and commercial capabilities are there staying ready to do that, and you can provide more collections of the data that are out there, especially in areas that are not well covered today.

Senator LUMMIS. Thank you.

I want to thank all of our witnesses, and I call on Senator Blumenthal for his questions.

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

Senator BLUMENTHAL. Thank you.

You know, there has been an effort to develop some kind of law that relates to space just as there is an effort to develop a law of the sea, maritime law.

Let me ask you, Ms. Drees. To what extent would clearer either norms or actual laws promote the development of commercial space activity?

Ms. DREES. I think it's a little bit of a fine line. So I think, you know, when it comes to favorable policies, there's a growing need in the United States to have those favorable policies to keep the United States sort of on the top of the space regime, if you will, but, second, and maybe sort of a close relative to that is the regulatory environment and this is where, you know, there is some concern about not having regulation but having the right regulation at the right time so that we don't prevent innovation from a lot of these companies that have that flexibility today.

So that is one of the concerns, but I think it's imperative, first and foremost, that we take that position that we want it as a nation. We want to be able to have the control over the process more or less and set the standard for the rest of the world.

Senator BLUMENTHAL. Normally in the United States one of our great advantages is we have norms and rules and laws that are enforceable, in fact are enforced. So we believe in the Rule of Law which gives a certain trust and credibility.

When you enter into a contract, it's enforceable and you know that the government's not going to simply interfere and demand a bribe or whatever.

So on which side do you think we're erring right now, too little or too much? I'll open that question to the rest of the panel.

Mr. O'CONNELL. Senator, thank you.

I think I wouldn't approach it from a too little or too much perspective. What I'd say is it's still very early days. Operators have pretty much had freedom of action if they choose to move because of a near collision. We won't have that opportunity in the very near future and so I think two things are happening in parallel.

One, appropriately, the diplomats and the defense organizations around the world are having discussions about norms, behavior, just like we would have discussion about norms in any other domain.

At the same time and so much of this is about the speed of this problem and how much it's changing. Industry is likely to set the practical standards by which we make these kinds of decisions. So fortunately in the United States we're required by law to actually stay connected to industry standards.

That is not the case with a lot of other countries that are developing similar systems or systems for space traffic management of their own and so I think we're very much at the point where we have to pay careful attention to how industry is dealing with this as the basis for rules of the road as they progress and then law and regulation.

Thank you.

Dr. HOLZINGER. Senator, that's an excellent question and as an engineering professor, I feel compelled to say that many elements of the regulation should have a physics basis, first principles basis for what rules of road or regulations we impose on them.

For example, geosynchronous space is very different from sun-synchronous polar orbiting space and that's also itself different from missions that we send to the moon and so I think that whatever rules and regulations we choose to propose should be physics-based.

Senator BLUMENTHAL. Any of the others——

Mr. STROUP. I would add I think that we've all talked about space awareness as the first step and then space traffic management coordination and management which I think we feel is the appropriate process to be taken.

Thank you.

Mr. O'CONNELL. Thank you for that question again, and I want to respond to Dr. Holzinger.

You know, we talk a lot about the Open Architecture Data Repository and perhaps it needs a brand change. You know, maybe it's just—but you understand what it does. It was never designed as the be-all and end-all.

What it was first and foremost designed to do was to take the data that comes from the Department of Defense unclassified and

add incredible amount of civil, partner, and commercial data and apply modern data management analytics tools.

The second was that it was designed to enable, it is designed to enable the emergence of a space safety industry. When we improve the precision and accuracy of what we understand places to be in space, it allows industry and we met with many companies that did this are thinking about new services.

Finally, and to your question, Senator, it also becomes in the open world the place where we start to have much better, much more rigorous scientific data for which, for example, the insurance industry will now have a whole new source of data about how to calculate risk in different orbits and in different constellations and things like that.

That's part of the benefit of moving it from the largely national security side here but moving it into the open to apply modern data science and rigorous analytics techniques that will inform policy and regulation.

Senator BLUMENTHAL. Thank you.

Mr. O'CONNELL. Thank you.

Senator BLUMENTHAL. I'm in the middle of an excellent book called *Mercury Rising*. I don't know whether any of you have read it. It's about the very earliest days of the Space Program and Sputnik and John Glenn and so forth and it's kind of a culture shock. It's an excellent book to go forward into today's age from a time when they thought maybe a person's eyeballs would pop out because of weightlessness or the G force of going into space and we've learned a lot but now the problems seem to be magnified and even more numerous with the access that people have to heights and environs that just decades ago would have been unreachable and unthinkable.

So I thank you all for your excellent testimony this morning. Thank you. Thanks.

Senator LUMMIS. Thank you, Senator Blumenthal.

Next up hailing from Florida, one of our most significant states in space issues, is the gentleman from Florida, Mr. Scott.

STATEMENT OF HON. RICK SCOTT,
U.S. SENATOR FROM FLORIDA

Senator SCOTT. Thank you, Senator Lummis. Thank you for hosting this hearing today. I want to thank each of you for being here. As you are right, Senator Lummis, In Florida, space is big. It's very important to us.

When I became Governor, unfortunately, manned flight had been shut down and we'd lost, I think, over 7,500 jobs and so we put a lot of effort into revitalizing our space industry and we put a lot of money into it and the private sector showed up and it has really completely changed the Kennedy Space Center and that whole area of the state and now it's very difficult to find engineers because of all the things that were happening there. We've had a lot of success there and thank all of you for what you've done.

So I want to talk about what you all can do with regard to what's going on in Cuba. I don't know if you're following what's happened in Cuba, but the population in Cuba has showed up and they're protesting. And what's happening now is that the oppressive Cuban

regime is beating up peaceful protesters. They've arrested unbelievable numbers of people. These people are being tortured for just speaking about simple things like freedom.

When Barack Obama was President, he did the appeasement plan there and I'll tell you how well it worked. There's a lady by the name of Sirley Avila Leon that had her hand chopped off after the appeasement, stuck in the mud, hoping she would die of infection, and her trust was she complained that a school was being closed in her neighborhood. That's what's going on down there.

So it's horrible. We need to get Internet back on. If we can get Internet back on, the people of Cuba are going to show up and continue to tell the Castro regime "your time is up," and they're going to demand the freedom that we all cherish.

So for Mr. Stroup, what can the satellite industry do to help us get the Internet back on so the Cuban population can communicate with themselves to continue to fight for their God-given rights of liberty and freedom?

Mr. STROUP. One of the great things about the capabilities of the satellite industry is its ubiquitous coverage and one of the fastest-growing segments is the broadband industry.

So the ability to be able to provide broadband service and giving those people the access to information from outside the world as well as what's happening within Cuba is one example.

Another is the remote-sensing capability of the industry, the ability to provide data, observational data to Cubans. It's something that the industry is doing with the ability to refresh the data every day so that the government is not capable of lying to them about what is happening, what is happening in the streets and elsewhere throughout the country. So those are two of the examples.

When the Obama Administration had discussed normalizing relations, with their opening up relations with Cuba, there were discussions about making direct-to-consumer television services available, again giving them additional information that they otherwise would not have.

Thank you, Senator.

Senator SCOTT. So what can the satellite industry do right now to get Internet back on? Is there anything that either our Federal Government can do or the private sector can do today to get the Internet back on or get people information where they—it's peer-to-peer information where they can communicate with each other?

Mr. STROUP. I think probably the—to the extent that we had the ability to make the receivers available to the members of the public, I don't know the challenges that would be associated with that, but again given the ubiquitous coverage of the service, we've got an ability to provide broadband service to them. Getting the receivers to them may be the bigger challenge.

Senator SCOTT. Yes. And nothing on satellite works toward the cell phone, right, because the antenna's not big enough, is that right?

Mr. STROUP. Could you repeat the question, please?

Senator SCOTT. So there's nothing—so what they all have is cell phones, right? So that?s what they've shut down. They've shut down their ability to communicate data with cell phones. Is there

any way that the satellite industry can get information to cell phones or does it always have to be a significant size receiver?

Mr. STROUP. So actually there are companies that are developing technology to be able to connect directly from satellites to telephones, to mobile phones. Satellites are also used for backhaul to cellular phones, but there are two companies that are working on the ability to connect directly to mobile phones from satellites.

Senator SCOTT. Is that technology available yet?

Mr. STROUP. They have launched their first satellites. It's not commercially available yet.

Senator SCOTT. What's the name of the company?

Mr. STROUP. One is AST Science and the other is Lynk, L-Y-N-K.

Senator SCOTT. AST Science. OK. I'll reach out to them. We've got to figure out how to do this.

You know, the other thing that concerns me is just how much Communist China is involved in Cuba and they're part of how they're shutting down communications. So what can the satellite industry do to help make sure that Communist China does not continue to do what they're doing to try to stop communication in Cuba? Is there anything?

Mr. STROUP. What can the satellite industry do to stop——

Senator SCOTT. What Communist China is doing?

Mr. STROUP. I think certainly making sure that there are signals available. I think that short of jamming the signals across multiple different service providers, I don't know what else Congress can do, other than to continue to make sure that the satellite industry has the access to spectrum to be able to continue the services it's providing.

Senator SCOTT. OK. If you come up with anything of how we can get the Internet back on, it's the biggest issue we've got right now. I mean, if you see the videos, there's a lady that the Cuban—they shot her son. She had to watch him bleed to death. You see protesters just have the heck beat out of them. So it's just disgusting what Cuba is doing right now.

So if you have any ideas, just let me know.

Mr. STROUP. Will do. Thank you, Senator.

Senator SCOTT. Thank you.

Senator LUMMIS. Thank you for those important questions, Senator Scott.

I want to give Senator Hickenlooper a chance to return and so I'm going to complete my line of questioning while we wait for him certainly with gratitude toward our Senators who are participating today and to our panel.

As I mentioned in my opening remarks, more than just tracking orbital debris, there must be a bigger push to prevent debris in the first place and, more importantly, in my opinion, to take out the trash or de-orbit space junk.

So from all of you, I'd like to hear about the possibilities and challenges of de-orbiting debris and some of the current private sector initiatives to do so. This is something that I would think has to be a priority for us.

So let's start with Ms. Drees and hopefully just go down the line.

Ms. DREES. Thank you, Senator, for the question.

I'll make two points on that. So, Number 1, a lot of the new satellites being developed today are cube sats or small sats and they have the technology essentially available to essentially bring the satellite back down into the top layer of the atmosphere and burn up in the atmosphere. So at the end of its useful life, that's essentially the next step in the process.

In order to address your question about what do we do about some of the legacy systems, the older systems that remain up in higher orbits, I think the good news story there is there are companies that are coming online that are helping to fix that problem either in terms of robotics or other companies that are trying to find other methods to gather up some of the debris and, you know, potentially destroy or burn it up.

I'll turn it over to Kevin.

Senator LUMMIS. Thank you.

Mr. O'Connell.

Mr. O'CONNELL. Thank you, Senator.

So, you know, we've been talking a lot about organizations and the Open Architecture Data Repository. We really have four tools in our toolkit. We may have more but we certainly have four.

One is not creating new debris as we go up and there's some important technical developments in that area from academia and industry that are going to provide light coverage for satellites and things like that.

Second is improving space situational awareness, third is space traffic management function, and the fourth is active debris removal.

In addition to that, there's a whole emerging sector called Satellite Servicing which is going to help improve the life of satellites while in space. Further, space tugs will be able to move things from orbits to graveyard orbits, as they're affectionately referred, and other places. So there are options in our toolkit to deal with this.

I think the active debris removal, we're seeing a lot of interest in this in Japan and in Europe. I know there are a number of companies in the United States that would like to see more of an emphasis, more of an investment in some of the basic technologies that they will need to do that, but we're not without a capability to deal with this in many different ways.

Senator LUMMIS. Thank you.

Dr. Holzinger.

Dr. HOLZINGER. Thank you, Senator.

So maybe there are two points I'd like to make on this topic. Number 1 is that most systems or methods, techniques to remove spacecraft from orbit, remove debris from orbit may appear to others to sometimes be dual use. So one person's rendezvous vehicle, you know, could have multiple potential interpretations, and so any time, you know, we're looking toward de-orbiting objects or managing debris, I think transparency is key in terms of what it is we're going to take down and de-orbit and why.

There was a NASA study some years ago that suggested that deorbiting five large rocket body style objects each year would freeze the current debris population, mitigate it to that extent. That was before, I think, many of the mega constellations had been proposed

and begun to be launched and so I would imagine that that number is higher these days.

The final points I'll briefly make, again being an academic, I get to see a lot of the new and latest research on these topics, just for awareness I will mention that the graveyard orbit above geo is also largely unstable in the long term and there are very few select orbits in the graveyard orbit that won't ultimately end up causing collision issues over the next 50 or hundred years.

Senator LUMMIS. Thank you.

Mr. Graziani.

Mr. GRAZIANI. Great question and glad you brought this up. I'll start off as Dr. Holzinger just mentioned, the graveyard orbit for geosynchronous.

So the one thing that does happen now is operators, once their spacecraft are getting toward the end of life, will try to move their spacecraft from geosynchronous up to that.

Now one of the things that's happening is there's more and more interest in orbits between the Earth and the Moon or Cislunar and so as that kind of pans out, that's more and more of a problem and more junk up there that previously we didn't actually go through that often because only interplanetary and to the moon.

Next, I think this was mentioned a couple of times and I agree that pulling the large pieces of debris that are already up there down so they don't become thousands and tens of thousands of small pieces of debris is key. It's doable and something—and there are many different companies that are working on that and that's substantial, and then continuing to work backward here, there's at least one company that has proposed—Launch Space Technologies Corporation has proposed orbiting debris catching pads that will try to catch the very small debris, the debris that is not trackable. It's a very innovative approach and one of the companies that's—it's a U.S.-based company and they're looking to partner with both the DOC as well as NASA and even the Department of Defense to help that become a reality and that's in answer to small and trackable debris.

Then continuing to go backward before that and the point you made, that is, that observing, having a much better space situational awareness system that allows us to know where everything is and then take action to prevent the collisions from happening is also key.

Right now we're on track to have a major collision in low earth orbit roughly every 10 years and that problem is only getting worse and worse. So that the SSA side of this and the STM is a critical part of the answer to your question.

Senator LUMMIS. Thank you. This is really helpful.

Mr. Stroup.

Mr. STROUP. My colleagues have done a good job of answering the question, but I would also add that SIA has developed a set of space safety principles and one element of it that hasn?t been touched upon is that most Leo satellites are designed to de-orbit and to burn up on re-entry. So our principals encourage addressing these issues as part of their operation commercially.

Thank you for the question.

Senator LUMMIS. Thank you all, panelists.

I yield back to the Chairman, the gentleman from Colorado.

Senator HICKENLOOPER. Thank you, Ranking Member Lummis.

I'd now like to turn it over to the Chair of the overall Commerce Committee, the great Senator from Washington, Maria Cantwell.

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

The CHAIR. Thank you. Thank you, Senator Hickenlooper, and thank you and Senator Lummis for holding this important hearing. Thank you to all the witnesses who are here.

This is a very important topic for many companies in the Pacific Northwest because we're continuing to focus on space in so many different ways. We like to think that we're the Silicon Valley of space issues.

I think I've mentioned even in this committee I met people who told me they were working on materials for a space hotel. I thought they meant like in your backyard, giving you more space so your relatives could come and visit, like an REI solution. They said no, up there. I'm working on materials for up there. OK. So let's just say that people are planning ahead in the Pacific Northwest.

So, Dr. Holzinger, what are the—you've been having this discussion about traffic and traffic management and I'm a firm believer in using all the information we can to develop a system for that because we're going to need to, but what can our universities do now? What is the appropriate role for some of these institutions that could help, you know, in doing this?

Dr. HOLZINGER. Thank you, Senator Cantwell.

Our universities have a couple of critical roles in this activity. Principally, especially at the R1 research universities, our activities center around researching the fundamental basic research and developing technologies that enable SSA/STM and improve those activities, so basic research and applied research to do those things.

Another aspect of our endeavor in this front is to train the work force. So that means training Master's students, Ph.D. students to perform these activities, and, anecdotally, I might offer that across the country, approximately 300 Ph.D. students are graduated in aerospace each year but only a small fraction of those are actually in space.

We've already heard from one Senator before that it's difficult to find engineers that are sufficiently trained in this activity and that's a challenge, you know, of course, that we face and that, of course, relates to our previous activity in research.

Traditionally, Ph.D. students are funded on research for five-six years and, you know, continuity of funding for that research is a critical element of that activity.

The CHAIR. So what would you think that study would look like or what would that degree be called?

Dr. HOLZINGER. So that degree sits pretty squarely in what I would imagine to be aerospace engineering and turns out that the University of Colorado actually already has a graduate certificate on space domain awareness that ties together many of these aspects.

Some of those aspects are physics-based, some are more information theory and controls-based, and others tie into things like

human factors and how operators can actually interpret what's going on up on orbit and make sense out of those things.

The CHAIR. Well, now that the deputy at NASA, Pam Melroy, she's basically said that this is a situation that's getting dire, so not a lot of commercial activity in the last 10 days. So what do you think commercial space perspective is on the situation?

Dr. HOLZINGER. Could you repeat that last part?

The CHAIR. The commercial space perspective on this issue, as we have people who are planning activities, and as the Deputy Director is calling it, we need a reliable space traffic system and the situation is getting dire. So how do you think about where we are with commercial activity and this issue and the urgency of getting something done?

Dr. HOLZINGER. So in my opening statement, I'll repeat some of these statements, it's both inspiring and terrifying what the commercial space industry is doing. It's inspiring because it's an excellent thing. It's an excellent avenue to grow our economy and there's a lot of future potential and prosperity that we have the potential to reap in the future.

It's terrifying in the sense that the current standards and methodologies that we use stem ultimately from the 1960s, 1970s, and 1980s and haven't really leveraged the modern techniques that have been developed over the past couple decades and so from a university perspective, you know, I think that the best thing that we can do is to improve those means, methods, and techniques, and to have as much transparency and open information about those activities as possible on the commercial front.

The CHAIR. And then identifying the type of technology we need because if we're talking about smaller objects and it's hard to track or hard to track their telemetry of how fast they're going, is that what we need?

Dr. HOLZINGER. Absolutely. So elements of that in terms of infrastructure include things like more sensors with better detection thresholds, the ability to collect and fuse that information in close to real time, the ability to fuse that information also with current space weather and to be able to issue indications and warnings of potentially deleterious effects.

The CHAIR. Thank you.

Thank you, Mr. Chairman. Thank you again for this hearing.

Senator HICKENLOOPER. Thank you, Madam Chair.

Now we're going to turn it over remotely to Senator Young from Indiana. He has a few questions to ask.

Senator Young.

STATEMENT OF HON. TODD YOUNG,
U.S. SENATOR FROM INDIANA

Senator YOUNG. Thank you, Chairman, and I, of course, want to thank the entire panel for your presence here today.

When I spoke with Administrator Nelson during his nomination process, we discussed the gray zone of warfare. It's a form of combat that lies between the threshold of traditional warfare in areas like cybersecurity, artificial intelligence, robotics, and war.

According to a recent unclassified threat assessment, numerous countries are attempting to capitalize on these potential vulnerabilities.

I'll open this to the panel, but, Mr. O'Connell, first, please, I'll start with you. What steps can and should the Department of Commerce and NASA take to prevent other countries from interfering with or outright attacking our infrastructure in space and perhaps you could touch on whether or not further coordination is necessary with our national security agencies to combat these threats?

Mr. O'CONNELL. Senator, thanks very much for the question and a dimension of this that we have not spoken about previously is the fact that the Department of Defense wanted to get out of the piece of the mission that we've been talking about, the commercial notifications, the private sector notifications, partly because of the growing security complexity in space.

I don't believe the Commerce Department has any role in combat operations obviously, but we will obviously have awareness of a variety of activities that are underway in the private sector and, frankly, with our allies, as well.

During my time at Commerce, we enjoyed discussions, not just general ones but also technical ones, with our Commonwealth allies, with our European allies, with Japan, and many, many others about the importance of a civil space traffic management system. The extent to which many of these things will be looked at in the open may actually deter people from doing things such as you speak about, Senator, and so I don't think the Commerce Department has a role on the military path part of that but certainly it is the reason why DoD wanted to get out of this piece of the mission, namely, to work on space domain awareness, as it's referred to, and the locational piece that we were taking over at Commerce certainly fueled their ability to move in that direction and deal with more serious security threats.

Mr. GRAZIANI. Mr. Chairman, if I could add to Mr. O'Connell's comments, one of the things that happens when commercial companies are providing space situational awareness for space traffic management to the Department of Commerce is that those systems stand up and in a similar way that imagery systems, commercial imagery systems kind of provide a full transparency out there, over and beyond what systems that the U.S. Government has provided by and operated by the National Reconnaissance Office, in the same way commercial space situational awareness capabilities can bring that similar transparency to things going on in space.

So, for instance, right now some of these anti-satellite weapons that both China and Russia are launching are up there as satellites that are seen by these commercial SSA systems and are the commercial companies warn on those just like they warn on others and you'll have Russian signal intelligence satellites. They're getting very close to U.S. commercial communications satellites and the same thing with Chinese anti-satellite weapons and so the commercial SSA systems by their nature bring a transparency that will help with that problem.

Senator YOUNG. I see, I see. Mr. Stroup, do you have any reflections as it relates to this topic, sir?

Mr. STROUP. Yes. I'd like to address the cyber-security aspect of it.

The SIA developed a set of cybersecurity best practices a few years ago. Most of our members, most commercial satellite companies sell to the Defense Department and coordinate with the DoD to make sure that they're compliant with DoD cybersecurity requirements. So it's an issue that the industry takes very seriously.

Thank you.

Senator YOUNG. Sure. Anyone else?

[No response.]

Senator YOUNG. OK. I would just note that, you know, there's obviously a convergence here between your national security assets that we have located in space and then what you might think of as an extension of our supply chain, our global positioning system satellites, you know, our various other space assets, you know, at a commercial level that are needed, and this distinction between traditional national security assets on the one hand and commercial assets on another, as we've seen with the shutdown of pipelines here in the United States, it's not become blurred. It's really become a race.

So we're going to have to tear down the stovepipes and ensure that there's better coordination with our national security agencies moving forward.

So if you have any further thoughts about this moving forward, I'd welcome the opportunity to work with any of the panelists.

Thank you.

Mr. O'CONNELL. Senator, I have one point on that. The extent to which supply chain issues are in play here obviously Commerce does play a key role.

I'll make one observation, though, which is that in traditional space companies, larger space companies, there is more of a sensitivity to the de-orientation toward defense articles, et cetera, and so there is probably less vulnerability in the supply chain.

What we found when we looked at some of the smaller entrepreneurial companies was that they were more exposed on the supply chain issue. So I think the balance will be as we tighten up our supply chains, we need to be careful not to choke off opportunities for American entrepreneurs to leverage friendly country technologies. It's an important issue.

Senator YOUNG. Yes. Thank you.

Senator HICKENLOOPER. Point well taken. Thank you, Senator Young.

Thank you all for your presence here today. Obviously Colorado's got 500 aerospace companies, 30,000 employees. We're just a reflection of how important this is, and I think you all have contributed to that recognition that this is a significant form of commerce and I think this is the right place where the responsibility has to reside and that the relationship between government and business and how we look at best practices versus regulatory frameworks is crucial.

I think this committee is open to really hearing clearly as this work goes forward, hearing clearly without slowing down in any way the process, making sure that we respect that sense of urgency that you have all brought to the hearing is crucial.

I want to thank the Ranking Member for filling in. I had to go to a vote where there was going to be a tie vote. So I could not be AWOL. Appreciate all your indulgence.

The hearing record is going to remain open for two weeks, until August 5, 2021. Any other Senators who are listening are welcome to submit questions for the record should do so by July 29, and we hope that your responses will be returned to the Committee by August 5. We give you all of like 6 days, 7 days to respond. We apologize but again the sense of urgency pervades.

I want to thank everyone again just for your time and your effort. I couldn't help but recognize as we talk about the acceleration of the rate of change, right, in terms of space traffic that it is—on highway traffic and I realize this is a very loose analogy, but traffic increases up to a certain point and then there is a point where things stop. Accidents increase, traffic rate slows dramatically. The systems begins to fall apart, and I think in that loose sense this is an analogy that we're rapidly approaching that point where the dramatic increases in traffic are going to wreak havoc if we don't address them now and you're all doing that and again thank you all.

With that, I bring this hearing to an adjournment.

[Whereupon, at 11:31 a.m., the hearing was adjourned.]

A P P E N D I X

Response to Written Questions Submitted by Hon. Maria Cantwell to Karina Drees

Question 1. Since the Obama Administration, space policy experts have debated whether the Department of Commerce or Department of Transportation is the appropriate home for civil space traffic management responsibilities. As I noted at the hearing, experts like Pamela Melroy, now the Deputy NASA Administrator, have said what matters most is committing to an agency and giving it the resources to succeed because the need for reliable space traffic management services is getting dire. What is the commercial space industry's perspective on this issue?

Answer. The commercial space industry supports the Department of Commerce assuming civilian Space Situational Awareness (SSA) and Space Traffic Management (STM) responsibilities. Our industry recommendation is consistent with that of the National Academy of Public Administration report, which noted that Commerce is the most appropriate and most capable Federal agency for this important mission. We would encourage the Department of Commerce to expeditiously conclude the ongoing SSA study period with multiple outside entities and proceed into rapid development and deployment of an operational civilian SSA capability.

Additionally, as Deputy Administrator Melroy highlighted, it is critical that any agency (in this case, Commerce) be provided sufficient resources and encouragement to successfully execute on this effort.

It is also important to note that the Federal Communications Commission (FCC) maintains a role defining orbital debris regulations for U.S.-licensed communications systems. CSF respectfully encourages the Committee and FCC to work together in closing the regulatory loophole that enables foreign-licensed systems to waive into the U.S. market without complying with FCC orbital debris regulations. This situation increases risk for all satellite operators—both commercial and Government—and an effective STM regime would be incomplete without a uniform requirement on all companies serving the U.S. market, regardless of country of licensing.

Question 2. A recent report by the JASON defense advisory panel found that, given the trajectory for upcoming satellite launches, we may be inching towards a point where certain orbits are so congested that they become unusable. But it is clear how much benefit modern society gains from space services, ranging from GPS to broadband that can reach rural, previously unserved areas. Amazon and SpaceX both have Washington state facilities dedicated to helping launch a total of between 15,000 and 45,000 satellites, with the goal of providing connectivity all over the world. In light of this report, what are some key actions the committee should consider taking, balancing space sustainability with enabling the important benefits that could be provided by the commercial space industry?

Answer. The JASON report appropriately noted the work that commercial companies—many of which are CSF members—are doing in coordination with the U.S. Government and the scientific community to ensure a sustainable space environment. The report correctly highlights that non-geostationary orbit (NGSO) satellite systems operating well above 600 km significantly increase the risk of persistent debris lasting decades, centuries, or longer in orbit—clearly a major challenge. At the same time, the report praises commercial satellite systems operating at or below this 600 km level due to the self-cleaning nature of these orbits that eliminates the possibility of persistent orbital debris.

CSF would encourage the committee to explore several key policy actions along with FCC and the Department of Commerce, specifically that NGSO satellite systems operating significantly above 600 km should not be licensed or should at least be subjected to far more stringent regulations than those operating below 600 km, including requirements for propulsive operations, mandatory deorbit within five years of end of system life, and comprehensive data sharing. Without these require-

ments, systems operating above this altitude create unacceptable risk for the entire space ecosystem.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. EDWARD MARKEY TO KARINA DREES

Question. Could you please describe how commercial orbital servicing, assembly, and manufacturing capabilities might be used as an innovative solution to address the orbital debris issue? And specific to the National Aeronautics and Space Administration, what kind of mission might the Agency support to demonstrate the ability of commercial orbital servicing, assembly, and manufacturing capabilities to mitigate orbital debris?

Answer. CSF's more than 80 member organizations are proud to partner with NASA and other Federal R&D agencies to provide innovative solutions to advance the state of the art, enhance safety, and improve affordability in space exploration and utilization. Long-term, sustainable activity in space requires an integrated effort that includes the development of innovative capabilities like in-space manufacturing and spacecraft servicing. U.S. commercial industry has made great technical strides and significant private investments into development of technological capabilities around in-space robotic assembly and manufacturing, and these capabilities should be leveraged to the maximum extent possible through additional public-private partnerships. We look forward to continuing to bring the best of commercial industry to support America's leadership in space.

On-orbit Servicing, Assembly, and Manufacturing (OSAM) technologies provide key enabling capabilities for both the mitigation and removal of space orbital debris. With the development of mission modelling for rendezvous and proximity operations through servicing, manipulation of objects with precision robotics through assembly, and the manufacturing with attachment of objects through manufacturing, these methods can help mitigate orbital debris, along with responsible action by satellite system operators. By funding and focusing on this technology ecosystem, satellites can be equipped to be multi-functional with the capability of not only prolonging the life of an asset or increasing the capability of a spacecraft, but by using these same technologies to deorbit or place debris in places where it will not affect future missions into Earth's orbit. OSAM technologies are critical for both mitigating the existing debris problem with non-compliant objects and creating new space systems that are designed from the onset for sustainability, repair, and replacement in a way that doesn't make the issue worse.

A demonstration of rendezvous and proximity operations that include assembly of a local payload or spacecraft would be a discrete mission that allows for multiple technology demonstrations of grabbing an object and then placing it along the spacecraft to be transported to a new location. This would be accomplished using robotics that are located on the servicing & assembly spacecraft as well as the mission modeling and planning that are required to be utilized for future OSAM missions.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BEN RAY LUJÁN TO KARINA DREES

Optical and Radio Telescopes. New Mexico houses one of the world's premier astronomical radio observatories, the Very Large Array. It can map large-scale structure of gas and molecular clouds in deep space and pinpoint ejections of plasma from supermassive black holes. The VLA is also a high-precision spacecraft tracker that NASA and ESA have used to keep tabs on robotic spacecrafts exploring the Solar System.

Question 1. With recent commercialization focused around small-satellite constellations, how will SSA and STM ensure that these constellations and their debris do not interfere with scientific research that utilizes optical and radio telescopes?

Answer. CSF member companies are committed to protecting ground-based radio and optical astronomy sites through responsible operations and by implementing key technological innovations like spacecraft darkening, phased array antenna technology that dynamically avoids sensitive radio astronomy sites, and more.

Specifically, the JASON report appropriately highlights that several operators have a deep technical interchange with the scientific community, including with the Very Large Array, to collaboratively develop, test, and implement solutions to mitigate any impacts to astronomy instruments. CSF supports the National Science Foundation's Spectrum Innovation Initiative that helps to both increase spectrum

available to commercial users while also ensuring no impact to radio astronomy systems.

CSF shares the JASON report's concern relative to satellite systems operating above 600 km, specifically that these systems are visible for far longer each night and could create lasting concerns for ground-based astronomy systems. NASA has also commented on the record that it supports lowering the altitude of NGSO satellite systems below 600 km.

For satellite systems operating above 600 km, an effective SSA and STM regime is critical to ensuring that persistent orbital debris does not create lasting challenges from ground-based astronomy instruments. Accordingly, CSF would encourage regulatory action that require all satellite operators serving the U.S. market to (1) comply with the same orbital debris standards, instead of the current situation that enables foreign-licensed providers to avoid them; (2) provide high-fidelity tracking data into an open database (*i.e.,* one operated by the Department of Commerce) accessible by all operators to reduce the risk of on-orbit conjunctions; and (3) ensure spacecraft de-orbit within five years of end of operational life.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. RAPHAEL WARNOCK TO KARINA DREES

Research Efforts. From the landing of the first man on the moon to NASA's more recent breakthrough with the Perseverance Rover, the United States has been a global pioneer in space exploration. As we look toward the emergence of commercial space flight, we must ensure we have reliable data and research on space situational awareness (SSA) and civil space traffic management (STM). Addressing the scientific and technological needs of the commercial space flight industry will be critical to the gathering SSA data and civil STM research.

Question. How can Congress support the research efforts of the commercial spaceflight industry with regard to managing space traffic?

Answer. CSF's more than 80 member organizations are proud to partner with NASA and other Federal R&D agencies to provide innovative solutions to advance the state of the art, enhance safety, and improve affordability in space exploration and utilization. Long-term, sustainable activity in space requires an integrated effort that includes the development of innovative capabilities like in-space manufacturing and spacecraft servicing. U.S. commercial industry has made great technical strides and significant private investments into development of technological capabilities around in-space robotic assembly and manufacturing, and these capabilities should be leveraged to the maximum extent possible through additional public-private partnerships. We look forward to continuing to bring the best of commercial industry to support America's leadership in space.

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A demonstration of rendezvous and proximity operations that include assembly of a local payload or spacecraft would be a discrete mission that allows for multiple technology demonstrations of grabbing an object and then placing it along the spacecraft to be transported to a new location. This would be accomplished using robotics that are located on the servicing & assembly spacecraft as well as the mission modeling and planning that are required to be utilized for future OSAM missions.

In addition, we encourage continued SSA research efforts with industry and academia to further characterize the spaceflight environment. The commercial satellite industry is highly motivated to operate safely, including avoiding debris creation, and responsible deorbiting practices. A growing in-space safety industry is emerging of ground based radars to collect more accurate SSA data, new AI and related software tools for automating and optimizing collision avoidance maneuvers. These efforts could all be improved by implementing the "open-architecture data repository"

strategy that the Office of Space Commerce developed from 2018–2020, which was endorsed on by the National Academy of Public Administration in 2020, and funded by the Omnibus Appropriation for FY 2021. Dozens of spacecraft operators and support service providers are continuing to self-fund R&D to improve commercial SSA capabilities and look forward to working the U.S. Government to integrate their data into the OADR to allow continued and sustainable growth of Earth orbit utilization to address important telecommunication and environmental monitoring/science needs of the American people.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO DR. MARCUS J. HOLZINGER

Research and Development Needs. There are over 100 million pieces of orbital debris circling the Earth. This debris poses a risk to human life, for instance on the International Space Station, but also to the aspirations of the burgeoning space industry, which has a footprint of nearly 100 companies in Washington state alone. The last time this Committee considered this issue, I was appalled to learn from Dr. Moriba Jah that there are large knowledge gaps in how orbital debris behaves in space, which we need to know if we are going to protect our people and our assets. The SPACE Act, which Ranking Member Wicker and I have passed twice through the Committee, includes funding for this necessary research.

Question 1. What are the most pressing issues for further research and development and how best do you think our universities and companies can help resolve them?

Answer. Thank you for your questions, Senator Cantwell. In the near term, candidate topics for research and development should be enabling and promise substantive impact on civil SSA (Space Situational Awareness)/STM (Space Traffic Management). These topics include:

- Investigation of basic SSA/STM algorithms non-Keplerian orbits beyond GEO (Geosynchronous Earth Orbit)
- Discussion and modernization of state and uncertainty representation for tracked objects · Fundamental and operational research on SSA/STM human factors and cognitive engineering regarding how decisions are rendered, and trust is built, much like Air Traffic Control. We must understand human SSA/STM operator workflow and interfaces with autonomous and support algorithms.
- Advanced methods in data visualization and interpretation should be pursued. STM is more complex than Air Traffic Management (ATM), and methods developed for ATM are not necessarily transferrable to STM.
- Investigate spaceflight safety, sustainability, and commercial viability for orbit allocation strategies in LEO (Low Earth Orbit), MEO (Medium Earth Orbit), and beyond GEO · Methods and approaches to achieving cooperation and consensus in developing norms of behavior and 'rules of the road' amongst commercial, government, academic, and international stakeholders for SSA/STM. · Integration and exploitation of new results in decision-making under uncertainty in both centralized and decentralized sensor tasking and decision support systems.
- Rigorous verification and validation methods to validate spaceflight safety of commercial spacecraft and constellation command and control algorithms without compromising proprietary commercial information.

Combined, these basic research problems and technologies offer the potential to drastically improve spaceflight safety, maintain our future access to space, and ensure sustained commercially viable enterprises. Further, if the United States is able to successfully answer these questions, we will both possess an authoritative and incontrovertible set of approaches for international leadership in SSA/STM and will have, in the process, developed substantial domestic workforce resources necessary to execute successful civil SSA/STM. The research listed above is not exhaustive, however I wish to emphasize that properly answering these fundamental, enabling, and impactful problems will require $10–20M/year in sustained funding for at least a decade. Universities and companies can directly support these endeavors through federally funded and internal research and development efforts. Specific Federal programs are discussed in more detail in the following questions. As part of this research, I recommend that at least 1–2 SSA/STM Centers of Excellence be competitively selected and funded. Successful centers should involve multiple universities,

industry partners, and technical collaborators within OSC (Office of Space Commerce).

Question 2. Given your experience as a researcher, what steps should the Federal government, including specific Federal agencies, take to help advance R&D required for space situational awareness and space traffic management?

Answer. Below I enumerate three specific steps that the Federal government should take to facilitate advancement of required research and development for SSA/STM:

1. Sustained substantive funding for academia in basic research for academia from OSC, AFOSR (Air Force Office of Scientific Research), AFRL (Air Force Research Laboratory), NASA (National Aeronautics and Space Administration), etc. This serves the dual purpose of addressing the need for basic and applied research and SSA/STM workforce development. Centers of Excellence should be a component of this funding, but there should be other smaller funding mechanisms available to include excellent ideas that come from outside of these Centers of Excellence.
2. In my original written statement, I proposed that the government entity with mission authority (*e.g.,* OSC) over civil SSA/STM should have, as part of its mandate, some level of access, visibility, and potentially input into research pursued by other entities (such as AFOSR, AFRL, and NASA). We may consider rotating research program officers from these constituent organizations through such a coordination role to maximize knowledge transfer, buy-in, and awareness amongst government-funded research programs in SSA/STM.
3. I wish to re-emphasize my proposed government-led SSA/STM decadal survey from my original written testimony. We must leverage the wisdom and technical expertise of the larger domain of SSA/STM researchers and operational experts to inform what research topics should be further explored. To do so, we should consider following NASA's lead in engaging impartial entities (*e.g.,* the National Research Council, the National Academies, or other groups) to conduct decadal surveys identifying promising avenues of basic research and technology development. To ensure these decadal survey reports capture research opportunities and operational needs, I propose that government, industry, and academic researchers and practitioners contribute to these reports. These studies should be funded by the Federal agency with mission authority (*i.e.,* OSC).

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. KYRSTEN SINEMA TO DR. MARCUS J. HOLZINGER

FCC Satellite Rules. Some have concerns that an industry "best practices" approach on space debris will not be able to ameliorate this issue. Some satellite operators may not abide by such industry practices given the relatively low cost of launching satellites into space and the competitive nature of the satellite business. Against this backdrop, some feel the FCC's satellite rules have not yet fully considered the number of satellites now coming into orbit nor do the rules contemplate the constellation of satellites that some satellite companies are launching into space.

Question 1. What steps should the FCC consider pursuing to address this issue?

Answer. Thank you, Senator Sinema, for your questions.

The FCC is currently required to render licensing decisions without (1) sufficient SSA/STM community research and consensus into best practices, norms of behavior, and rules of the road, (2) independent analysis of proposed commercial architectures, and (3) deep internal expertise in astrodynamics, SSA/STM, relevant sensors, and human operations. The FCC should continue and expand their collaboration with the Department of Commerce Office of Space Commerce (OSC) and the USSF to bring our current orbit deconfliction and deorbit requirements into the 21st century. Development of norms of behavior, rules of the road, and orbit allocation/approval guidelines should engage federal, private, academic, and international stakeholders. Further, the FCC should consider transitioning orbit approval requests to OSC when those capabilities exist and focus on core FCC capabilities such as frequency allocations and licensing.

Role of Universities to Study Space Situational Awareness (SSA). In your written testimony, you recommend establishing a Center of Excellence to study SSA, preferably at an institute of higher education. Arizona universities have a long history of partnering with NASA to study our solar system. Examples include the University of Arizona's Asteroid Science, Technology and Exploration Research Organized

by Inclusive Education Systems (ASTROIDS) Lab and Arizona State University's Mars Space Flight Facility.

Question 1. Why does it make sense for universities to host a proposed Center for Excellence for SSA? What criteria should be used when selecting an institute of higher education to host such a Center?

Answer. Successful execution of a robust civil SSA/STM enterprise will require extensive supporting research as well as substantial existing workforce and workforce development resources. Consortiums of universities are the correct entity to host proposed Centers of Excellence for SSA/STM because (1) their core capabilities lie in basic and applied research and (2) they are the principal means by which SSA/STM workforce development is performed. University-led Centers of Excellent address both fundamental research and workforce development needs while being extremely cost-effective with taxpayer funds. Criteria for selecting University teams for SSA/STM Centers of Excellence should include:

1. Excellent and highly impactful proposed basic research and enabling technology development that both maximizes and trades against spaceflight safety, future access to space, and commercially efficient/profitable use of space.
2. Demonstrated existing basic and applied research and workforce development in SSA/STM (as opposed to related fields, such as Astronomy or Planetary Science).
3. Extensive throughput and high-quality SSA/STM training of undergraduate, M.S., and Ph.D. students to support workforce development needs.
4. Substantial existing research relationships with AFRL Space Vehicles and Directed Energy Directorates and USSF operations centers; proximity to these sites would be ideal.
5. Deep comprehension and understanding of existing USSF SSA/STM methodologies and approaches, as well as a thorough understanding of spacecraft and constellation operational needs.
6. Extensive existing relationships and technology transfer with the SSA/STM industry and commercial spacecraft operators; proximity to these companies would be ideal.
7. Expertise in and access to electro-optical and radiofrequency sensors to validate basic research and proposed technology efficacy.

Near-Earth Objects. In addition to materials orbiting the Earth, near-earth objects such as asteroids pose risks. The University of Arizona is leading NASA's Near-Earth Object Surveyor Mission, which will enhance our ability to detect any potential hazardous asteroid or comet that comes within 30 million miles of Earth's orbit.

Question 1. Why is it important for NASA to keep track of all near-earth objects that may collide with Earth?

Answer. NASA's Planetary Defense enterprise's efforts to track and characterize all near Earth objects (NEOs) are important and complementary to SSA/STM needs for two principal reasons.

First, NEOs and artificial spacecraft can and often do transition between sun-centric (heliocentric) regimes and the Earth-Moon system. We must necessarily track NEOs and artificial debris in heliocentric space to ensure timely and orderly handoff between Earth-Moon-focused SSA/STM activities and Planetary Defense concerns. I draw your attention to the recent '2020 SO' object detected by NASA's Planetary Defense enterprise that entered the Earth-Moon system in October 2020, whose trajectory possessed several Earth and Moon close-approaches. It was determined during this period that the 2020 SO object is likely a rocket booster from the 1967 Surveyor mission.

Second, as we extend SSA/STM to cislunar and lunar regimes, most spacecraft and debris in these regimes will present telescope optical signatures that are remarkably similar to heliocentric NEOs. In the near future OSC will need to coordinate SSA/STM efforts in cislunar/lunar space with NASA's Planetary Defense activities.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. RAPHAEL WARNOCK TO TOM STROUP

Research Efforts. From the landing of the first man on the moon to NASA's more recent breakthrough with the Perseverance Rover, the United States has been a global pioneer in space exploration. As we look toward the emergence of commercial space flight, we must ensure we have reliable data and research on space situa-

tional awareness (SSA) and civil space traffic management (STM). Addressing the scientific and technological needs of the commercial space flight industry will be critical to the gathering SSA data and civil STM research.

Question. How can Congress support the research efforts of the commercial spaceflight industry with regard to managing space traffic?

Answer. For SIA members, space sustainability and a safe, predictable operating environment are vital to protect substantial on-orbit investments and the services and networks they enable. As the number of users who rely on satellite-enabled services continues to increase, maintaining and enhancing the safety of the orbital environment is essential to the continued provision of communications, imagery, remote sensing, and other next-generation applications and services. Given industry needs, SIA is working to promote commercial innovation and solutions to: (i) build effective, feasible standards and guidelines for space sustainability; (ii) encourage the effective utilization of technologies, many of which have been created by U.S. companies, for space object tracking and SSA; and (iii)develop primary and supporting technologies to perform active debris removal, satellite servicing, and life extension missions.

In addition to providing adequate funding for a civil SSA/STCM service within the Office of Space Commerce, Congress can assist industry by supporting space weather research and space debris characterization research, funding R&D for active debris removal technologies, and integrating commercial SSA/STCM efforts into the OSC Open Architecture Data Repository.

Currently, a number of SIA members actively support research and development to further advance space weather models and forecasting tools (*e.g.,* teaming with academic researchers to assimilate satellite-based, space weather observations into coupled ionosphere-magnetosphere models), and to develop and improve understanding of space debris prevalence and behaviors (*e.g.,* performing surveys and classification of debris objects and producing advanced orbit models to predict their future courses). The adequate funding of these activities is critical to the future of on-orbit operations for both government and commercial organizations, as space weather anomalies and debris-generated effects may cause not only the loss of singular satellites, but could cause the loss of satellite signals, including GPS, for days resulting in billions of dollars of loss to the U.S. economy.[1] Accurate space weather prediction is also critical to determining orbital decay in LEO and minimizing debris on-orbit.[2]

While commercial organizations are actively working on debris remediation mechanisms including active debris removal, the global impact and potential long-term effects of space debris will require government funding for debris remediation. Today, the top 50 most dangerous pieces of space debris are almost entirely rocket bodies launched by national governments,[3] suggesting that government financing of debris removal technologies will be critical to maintaining a sustainable space environment.

Finally, several versions of commercial SSA and STCM services exist today to augment government systems in a highly complementary way. The continued development and adoption of both government and commercial services in a further research and development efforts to create a diverse STCM system will improve accuracy of decision-grade information for space operators.

Funding needs for further research and development to enhance this critical mission of space safety should come exclusively from the responsible organization(s), and should only be requested when capabilities are not already available through existing sources, including other government agencies and government funded labs, universities, and, most especially, commercial organizations.

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[1] Goward, Dana. "Racing the Sun to Protect America", NextGov, 14 May 2021, *https://www.nextgov.com/ideas/2021/05/racing-sun-protect-america/174029/*

[2] *Space Weather Phase 1 Benchmarks,* Report by the Space Weather Operations, Research, and Mitigation Subcommittee, Committee on Homeland and National Security of the National Science & Technology Council, June 2018 *https://trumpwhitehouse.archives.gov/wp-content/uploads/2018/06/Space-Weather-Phase-1-Benchmarks-Report.pdf*

[3] O'Callaghan, Jonathan. "These Are The 50 Most Dangerous Objects Orbiting Earth Right Now", Forbes, 20 September, 2020, *https://www.forbes.com/sites/jonathanocallaghan/2020/09/10/experts-reveal-the-50-most-dangerous-pieces-of-space-junk-orbiting-earth-right-now/?sh=3729fe7d7c21*

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. SHELLEY MOORE CAPITO TO TOM STROUP

Question 1. Orbital debris has become a challenging and potentially dangerous obstacle for satellites. Through NASA's OSAM–1 program, West Virginia's Robotic Technology Center has been able to develop and advance technology that would extend the lifespans of existing satellites. I have mentioned this before, but I am proud of the work being done in West Virginia and feel this capability can be a solution.

Could you speak to some of your members' current or upcoming capabilities for avoiding collisions?

What are some measures the satellite industry are taking—that the Federal government could learn from—to foster safe and efficient use of the shared space environment?

Answer. SIA takes stewardship of the space environment very seriously. SIA released its set of Space Safety Principles in 2019[1] as a model for sustainable space best practices for all space stakeholders, and SIA's space safety working group regularly engages across U.S. government organizations as well as the United Nations on space safety issues. Indeed, maintaining a safe space environment is critical to the successful economic utilization of space. Commercial satellite network operators emphasize different aspects of space safety approaches, depending on their orbital regime, licensing status, spacecraft type, etc., in general the measures taken by our members include: (1) designing spacecraft with high reliability and the ability to maneuver; (2) sharing information on the location and future location of spacecraft to other owners and operators, and working closely with the U.S. Government in sharing data with complete transparency; (3) developing and implementing collision avoidance technology and methods in cooperation with the U.S. Government; and (4) deorbiting satellites in a timely manner at end-of-life to ensure that "space junk" is not left in active orbits.

SIA's members work to be leaders in managing the space environment, particularly by openly sharing information about their own positions and intentions. However, not all space objects are controlled with similarly high levels of responsibility. Broken pieces of rockets, satellites which did not safely deorbit before they reached the ends of their lives, and other types of debris are present in all orbital regimes. These objects cannot move to avoid a collision and do not communicate their own positions; responsible space operators must act unilaterally to avoid them.

While the U.S. Department of Defense nominally tracks all these objects and publishes their positions for free, even DoD-supplied information about such a complex and dynamic situation can be imprecise and outdated. At best, this leads to inefficiency when collision avoidance is practiced needlessly; at worst it may provide an unmerited sense of security that could lead to incidents. Multiple U.S. commercial providers, ranging from small businesses to major contractors, have stepped into the gap by collecting data independently and offering advanced analytics and more precise collision warnings. As the profile of active satellites grows and evolves rapidly over the next decade, both government-provided and government-backed commercial SSA systems will become even more critical to space safety.

The Federal government can fully fund a civil authority on space traffic, which would support spaceborne activity by using sensors and available data to observe and track satellites and debris at all altitudes. A civil authority on space traffic, such as the Office of Space Commerce, could promulgate regulations that ensure space safety while maintaining an understanding of the need to address economic impact. Such an authority could also manage programs to collect timely data and perform enhanced analyses, making optimal use of unique U.S. commercial capability in pursuit of the global good of safe and efficient spaceways.

It is important to note, as I stated in my testimony, that not all operators adhere to the same rules and standards, and most foreign administrations do not have robust orbital debris regulations—the U.S. clearly has the most robust regulations today, and steps should be taken to ensure that the U.S. continues to lead the regulatory environment here while not rewarding foreign licensed systems that evade U.S. regulations.

Question 2. According to the Forest Service, just over 75 percent of West Virginia is made of forested land. With the introduction of low earth orbit (LEO) systems to the broadband ecosystem, I am curious to the amount of open sky needed to operate ground terminals.

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[1] *Space Safety Principles,* Satellite Industry Association, 2019 *https://sia.org/policy/space-debris-mitigation-sustainability/*

Are you able to speak to the potential relief these LEO Internet service providers (ISPs) could bring to unserved West Virginians?

Are there concerns that heavily forested areas, like many areas in West Virginia, may not be able to access these services due to interference?

Answer. Today the commercial geostationary and non-geostationary orbit satellites are bringing broadband services across the country including West Virginia. Next generation satellite systems operating in low Earth orbit are bringing high-speed, low-latency broadband across the country, including to West Virginia. These systems are already bringing previously unserved West Virginians broadband with speeds exceeding 100 Mbps and latency below 30 milliseconds, which is on par with most terrestrial services.

Due to the propagation of the radio-frequencies allocated to next-generation satellite services both within the U.S. and globally, service is best when a user has as clear a view of the sky as possible, and heavy tree coverage can degrade service, especially early on in a system's deployment. The amount of open sky required for optimal service varies by provider, depending on how many satellites the provider has in operation, the altitude of operations, and the specific frequencies used for communications to user equipment. For instance, with only a limited number of satellites deployed, a user may need a wider view of the sky to ensure a direct line of sight to a satellite in orbit. But that also means that the viewing angle will decrease with time as these systems are more fully deployed. As more satellites operate in orbit, users will need a smaller viewing angle to be sure at least one satellite is in view at all times.

For LEO systems early on, the general recommendation is to have a clear field of view of 100 degrees around the center of the user equipment, and a higher elevation (*i.e.,* placement on a roof or a pole rather than on the ground). However, as more satellites are launched, these field of view constraints will decrease, enabling a wider variety of users. Again, these constraints and solutions will vary by system.

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