December 7, 2020 Meeting Report

STANDARDIZATION AND THE COMMERCIAL SPACE INDUSTRY

Space Situational and Domain Awareness, Space Traffic Coordination and Management, and Orbital Debris Mitigation

Meeting Summary

Standardization and the Commercial Space Industry – Space Situational and Domain Awareness, Space Traffic Coordination and Management, and Orbital Debris Mitigation

Monday, December 7, 2020, 11:00 am – 5:00 pm Eastern (virtual)

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Executive Summary

The year 2020 was an exciting one for the rapidly growing commercial space industry. It included two missions transporting a total of six astronauts to the International Space Station and the return of a satellite launching rocket booster to Earth in a parachute-aided ocean splashdown. With safety being an overarching concern, policy developments included an update of the Federal Communications Commission orbital debris mitigation rules, streamlined rules on licensing requirements for commercial space transportation launches and reentries from the Federal Aviation Administration, and the issuance of a Congressionally-directed report by the National Academy of Public Administration which reaffirmed the Commerce Department's Office of Space Commerce as the best suited civil agency to perform space traffic management tasks.

Against this backdrop, the American National Standards Institute (ANSI) convened an informational meeting, *Standardization and the Commercial Space Industry – Space Situational and Domain Awareness, Space Traffic Coordination and Management, and Orbital Debris Mitigation,* on December 7, 2020. The purpose of the virtual meeting was to raise awareness of relevant policy and standardization activity relating to these topics and the growing commercial space industry, and to facilitate dialogue on coordination and participation in standards setting. ANSI serves as administrator and coordinator of the U.S. private-sector system of voluntary standardization.

The meeting drew close to 300 attendees from the United States and 17 other countries. Subject matter experts from government, industry, non-governmental organizations, and academia exchanged information on relevant policy instruments, industry standards, and best practices.

In welcoming remarks, ANSI President and CEO Joe Bhatia stated that ANSI has a successful track record of convening stakeholders and serving as a neutral facilitator to address emerging technologies and national and global priorities. In January of 2020, ANSI convened a half-day meeting on commercial space industry standardization and subsequently issued a survey inviting feedback on priority areas, areas needing coordination, and topics that could be discussed at an ANSI meeting, thus leading to this event. Mr. Bhatia noted the significant commercial growth in this sector, highlighting recent industry activity and policy developments.

Colonel Curtis L. Hernandez, Director, National Security Space Policy, National Space Council, delivered a keynote address describing several Trump Administration policy directives aimed at supporting commercial opportunities in space and advancing U.S. national security interests. He observed that the commercial space industry is at an inflection point where operational standards and best practices will play a key role in helping to realize the potential of this rapidly growing sector.

A panel consisting of federal government agency representatives was moderated by Dr. George C. Nield, President, Commercial Space Technologies, LLC. Kevin O'Connell, Director, Office of Space Commerce, U.S. Department of Commerce, spoke to the need for government and industry to provide U.S. leadership in international space standards development. He noted efforts to develop a standard for space traffic coordination and an open architecture space situational awareness (SSA) data repository. Karl Kensinger, Acting Division Chief, International Bureau Satellite Division, Federal Communications Commission, gave an overview of updates to the FCC's orbital debris mitigation rules. Steph Earle, Acting Deputy Division Chief, Policy and Innovation Division, Office of Commercial Space Transportation, Federal Aviation Administration, described FAA's efforts to advance safe and efficient commercial space transportation operations, including FAA's new regulation streamlining launch and reentry licensing requirements. Dr. Jer Chyi "J.-C." Liou, Chief Scientist for Orbital Debris, National Aeronautics and

Space Administration, provided background on orbital debris mitigation policies, standards, requirements, and guidelines. He emphasized that managing risk from orbital debris requires mitigation and remediation, including greater compliance with the 25-year rule. Jeff Braxton, Chief Analyst for Intradepartmental & Interagency Engagement, U.S. Space Command, stressed that security and defense require operational best practices and behavioral norms.

A second panel comprised of industry representatives was moderated by Therese Jones, Senior Director of Policy, Satellite Industry Association. Charity Weeden, Vice President, Global Space Policy, Astroscale U.S. Inc., called for action to reduce orbital debris and to support the long-term sustainable use of space. Dr. Brien Flewelling, Chief Space Situational Awareness Architect, ExoAnalytic Solutions, reflected that updates to standards and practices should be based on data. Dr. Daniel Ceperley, CEO and Co-Founder, LeoLabs, Inc., discussed how satellite tracking services must keep pace with industry trends. Mike Safyan, Vice President of Launch, Planet, drove home the point that sharing satellite positional information will enhance safety and space traffic management.

A third panel featuring perspectives from NGOs, academia, and others was moderated by Maj. Gen. Jim Armor, USAF (ret.), Founder/CEO, The Armor Group, LLC. Dan Oltrogge, Director, Center for Space Standards and Innovation (CSSI) and Integrated Operations, COMSPOC Corporation, talked about the need for space safety to be based on timely, accurate, and comprehensive SSA data. Prof. Danielle R. Wood, Director, Space Enabled Research Group, MIT Media Lab, described the World Economic Forum design team effort to establish a space sustainability rating as a means of incentivizing industry to act responsibly. Dr. Ruth E. Stilwell, Executive Director, Aerospace Policy Solutions LLC, observed that we must recognize both commercial and military uses of space and move from aspirational to operational agreements. Marlon Sorge, Principal Engineer, Space Innovation Directorate, The Aerospace Corporation, emphasized that standards development for safe space operations must keep pace with the speed of change. Frederick A. Slane, Executive Director, Space Infrastructure Foundation, called for an open space architecture that fosters industry growth and commercial opportunities.

Common Themes on Needs to Support the Industry: The Time for Action is Now

Several speakers remarked on the fast rate at which the commercial space industry is growing and the need for standards and best practices to keep pace with this momentum. It was generally acknowledged that achieving a safe and sustainable space ecosystem is going to require both the public and private-sectors working together on these issues. There is a need for transparent, timely, and actionable sharing of satellite conjunction assessment information. There must be greater compliance with existing policies, standards, and practices related to debris removal. More generally, there is a need to operationalize high level agreements as well as policies and procedures. A coordinated, whole-of-government approach is needed and the time for action is now.

Some notable standards- and policy-related activities currently underway include:

- ISO/TC 20/SC 14 work on space traffic coordination and large constellations
- AIAA work to develop a lexicon for SSA and associated spaceflight safety functions
- CONFERS/ISO work on rendezvous and proximity operations (RPO) and on orbit servicing (OOS)
- World Economic Forum design team effort to develop a space sustainability rating
- Commerce Department development of an open architecture space situational awareness data repository

An open discussion and survey at the end of the event invited audience comments on next steps. Based on the feedback, ANSI will continue to monitor policy and standards activity related to the commercial space industry

sector and remains willing to offer its services as a neutral facilitator for ongoing information-sharing and coordination discussions as appropriate.

Meeting Materials

A recording of the meeting, posted to ANSI's You Tube Channel, is divided into four segments corresponding to the agenda:

- Part 1, Opening, Welcome and Keynote Address: https://youtu.be/JFrU19HwDs8
- Part 2, Government Perspectives: https://youtu.be/tsvLzhtbZ3Q
- Part 3, Industry Perspectives: https://youtu.be/Ut6AEcBMvUI
- Part 4, NGO, Academia, and Other Perspectives, Open Discussion and Closing: https://youtu.be/5iIOcsasmjY

Throughout this summary, speaker remarks are abbreviated and summarized to highlight key points. The recording links are provided for those who wish to hear comments in full.

The meeting agenda, master slide deck, speaker biographies, presentations, and background materials are also available for individual download from ANSI's website. Links to presentations appear in this report alongside the name of the speaker.

Background reading materials

- American Institute of Aeronautics and Astronautics, Nick Tongson
- ASTM International F47 Pamphlet, Katerina Koperna
- "Space Sustainability Rating: Designing a Composite Indicator to Incentivise Satellite Operators to Pursue Long-Term Sustainability of the Space Environment," Prof. Danielle Wood, et al.

Opening

- Jim McCabe, Senior Director, Standards Facilitation, ANSI

Mr. McCabe opened the meeting and reviewed housekeeping items.

Welcome

- Joe Bhatia, President and CEO, ANSI

Mr. Bhatia welcomed participants. For more than a century ANSI has provided a neutral forum for all affected parties – including industry, government, academia, and others – to work together on standards-based solutions that have powerful, real-world impact and that address the most pressing issues facing the U.S. and the world. Through its network of members, ANSI represents the interests of more than 270,000 companies and organizations, and 30 million professionals worldwide. ANSI also serves as the official representative to two of the largest and most recognized international standardizing bodies in the world: the International Organization for Standardization (ISO) and via the U.S. National Committee, the International Electrotechnical Commission (IEC).

U.S. competitiveness in the global economy is closely related to U.S. leadership and influence in the development and use of standards and related conformity assessment activities – both domestically and internationally. A collaborative standardization system – with broad expert engagement from both the public and private sectors – has tremendous impact on our nation's strength, safety, and prosperity. And it is an essential link with U.S. technological leadership around the globe.

ANSI has a successful track record of convening stakeholders and serving as a neutral facilitator to address emerging technologies and national and global priorities. From issues as diverse as homeland security, nanotechnology, unmanned aircraft systems, and additive manufacturing. Depending on the need, ANSI has convened standalone workshops and on-going collaborative activities. Whatever the model, the goal remains the same: to facilitate cross-sector dialogue and to enable the most impactful solutions possible.

This past January, ANSI convened a half-day meeting exploring the need for coordination with respect to standardization and the commercial space industry. ANSI subsequently issued a survey inviting feedback on key priorities, areas needing coordination, and topics that could be discussed at an ANSI meeting. All of this input led to today's event.

Today's program features subject matter experts from government, industry, non-governmental organizations, academia, and more. They have come to share their perspectives on policy instruments, industry standards, and best practices related to the inter-related topics of:

- space situational and domain awareness,
- space traffic coordination and management, and
- orbital debris mitigation.

Each of 3 panels will explore the inter-relationship of policy instruments, industry standards, and best practices—what exists, what is in development, and what more is needed. The overarching purpose of this dialogue is to raise awareness of relevant activity, and to facilitate dialogue on coordination and participation in standards setting.

The past year has been an exciting one for the space industry. Just over 3 weeks ago, the SpaceX Crew Dragon transported 4 astronauts to the International Space Station (ISS) for a six month mission under NASA's Commercial Crew Program. An earlier Crew Dragon flight in May of this year was the first to carry 2 astronauts from U.S. soil to the ISS since the end of the Space Shuttle program in July 2011. Additional crew and cargo missions to the ISS are being planned.

Also, in November, California-based Rocket Lab launched 30 satellites into space orbit from its New Zealand launch site. Most of the satellites were small communications satellites, but others included a space junk removal test, a maritime observation satellite, and an earthquake investigation satellite. In addition, the rocket booster came back to Earth in a parachute-aided ocean splashdown—only the second company in history to achieve that feat. The name of the mission was appropriately "Return to Sender."

Also, in November, the National Reconnaissance Office launched an intelligence gathering satellite aboard a United Launch Alliance (ULA) Atlas V rocket with help from the U.S. Space Force's Space and Missile Systems Center. ULA has successfully launched 141 missions to date, including a Mars 2020 Mission for NASA and the first mission for U.S. Space Force earlier this year.

These are just some of the exciting recent developments within the space industry.

According to data from the Space Foundation, the 2019 global space economy grew more than $9 billion over the previous year, reaching $423.8 billion. Global launch attempts have increased 39% in the last decade, with 103 launch attempts in 2019, averaging almost two a week. And 82 countries now have spacecraft in orbit.

While all of this growth is inspiring, it creates new challenges in terms of increased congestion, increased space debris, and the need for space traffic management (STM). Of course, safety is paramount in all of this. A sound public policy framework supported by voluntary consensus standards and industry best practices are the ingredients needed to ensure a safe space ecosystem for all.

On the policy front, there have been several notable developments this year. In April, the Federal Communications Commission (FCC) issued a report and order updating the Commission's satellite rules on orbital debris mitigation for the first time in over 15 years. The FCC also sought public comment on other proposals related to mitigating orbital debris.

In August, the National Academy of Public Administration (NAPA) released a Congressionally directed report which reaffirmed that the Commerce Department's Office of Space Commerce (OSC) is the best suited civil agency to perform STM tasks, consistent with the intent of Space Policy Directive 3 (SPD-3). Efforts are now underway to obtain the Congressional appropriations needed for OSC to fulfill this critical mission.

In September, the White House released Space Policy Directive 5 (SPD-5) calling on federal departments and agencies to foster practices within government space operations and across the commercial space industry that will protect space assets and supporting infrastructure from cyber threats.

And, in October, the Federal Aviation Administration (FAA) issued its final rule to streamline licensing requirements for commercial space transportation launches and reentries.

We expect to hear more about these and related developments today.

The success of today's meeting will be greatly enhanced by active information sharing and participation. Attendees are encouraged to ask questions so that this is an interactive discussion.

More than 3 years ago, the President signed an executive order reviving the National Space Council, which had effectively ceased operations in 1993. Chaired by the Vice President, the Council advises and assists the President on national space policy and strategy. Its members include Cabinet-level heads of various executive departments and agencies, the chairman of the joint chiefs of staff, and other senior Administration officials.

Colonel Curtis L. Hernandez is the Director of National Security Space Policy at the National Space Council. In this capacity, Colonel Hernandez advises the Vice President and the Executive Secretary of the National Space Council on national security policy implications to military space capabilities. Further, he directs interagency representatives to modify or create national policy as it relates to the United States' military and commercial use of, and access to, space. Known to his colleagues as "Scraps," Colonel Hernandez is a decorated veteran whose previous assignment was Commander of the 30th Operations Group, at Vandenberg Air Force Base in California.

With that, Mr. Bhatia turned the floor over to Colonel Hernandez.

Keynote Address

- Col. Curtis L. Hernandez, Director, National Security Space Policy, National Space Council

Colonel Hernandez thanked Messrs. Bhatia and McCabe. Standards development is a critical component of National Space Policy and it is exciting that this conversation is happening for space situational awareness (SSA), space domain awareness (SDA), space traffic coordination and management (STCM), and orbital debris mitigation. He extends greetings from the Executive Director of the National Space Council, Dr. Scott Pace, and the Chairman of the National Space Council, Vice President Mike Pence.

Currently, Colonel Hernandez is the Director of National Security Space Policy on the National Space Council staff. In his 25 years serving the nation and the United States Air Force, and now the United States Space Force, he has witnessed the evolution and integration of tactical space systems into combat operations. He has also directed 22 launch campaigns, including the first land recovery of a lower stage rocket on the west coast and the first interplanetary mission launch from Vandenberg Air Force Base, California.

We are now witnessing and demonstrating the potential to recover and use space resources, an endeavor to commercialize operations on the International Space Station, and a proven commercial capability to conduct on orbit servicing and active orbital debris removal. It is an incredible privilege to participate in national decision and policymaking processes during perhaps the most exciting and consequential period for America's interest in space since the United States decided to go to the moon in 1961. That decision guided the U.S. to lead the greatest expedition in history, the landing of humans on another celestial body.

The aspiration to expand humanity's presence beyond the Earth led the U.S. to focus national will and government resources to generate the technology capabilities and expertise necessary to fulfill that goal. Since Apollo, the U.S. government has capitalized on that investment by deploying space-based capabilities that strengthen national security, stimulate economic growth, and enhance the quality of life for all Americans. It has been this drive, this curiosity, and an abundance of imagination that has made it possible to maintain a human presence in low Earth orbit (LEO) for the past 20 years. Now, it's that imagination and drive with a commercial purpose and private investment that brings us here today.

The space industry is at an inflection point. We are witnessing a remarkable growth and metamorphosis of traditional roles within the industry. New rocket companies, new mega constellations, the deployment of hundreds of satellites from a single launcher, and the privatization of traditionally government space operations are just some of the examples of this change, making headlines with the rapidity that is both amazing and inspiring.

With the increasing commercialization and decreasing cost of space operations, we are on the cusp of capitalizing on the enormous market potential in space, similar to the potential which caught the imagination of entrepreneurs and investors when the new world was discovered in the 1400s. The author Samuel Elliott Morrison best captured this concept in his 1942 work *Admiral of the Sea:* "A new envisagement of the world has begun and men are no longer sighing after the imaginary golden age that lay in the distant past, but speculating as to the golden age that might possibly lie in the oncoming future." Recognizing this potential and looking to focus the nation's effort to make commercialized space a reality, President Trump revived the National Space Council in 2017, which had been dormant since 1993. In his Executive Order (EO), the President directed the Council to foster close coordination, cooperation, technology, and information exchange among the civil, national security, and commercial space sectors. The EO led to a series of foundational policies that are charting the course for America's future in space

and identify a role in which ANSI's unique focus on coordinating the establishment and adoption of voluntary standards can play a significant role.

The first acts the National Space Council took on focused America's intent to reinvigorate human space exploration. Working within the framework of the 2010 National Space Policy, the President directed the Executive Branch in Space Policy Directive 1, on December 11, 2017, to lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system, and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low Earth orbit, the United States will lead the return of humans to the moon for long-term exploration and utilization followed by human missions to Mars and other destinations. This action resulted in our goal to return the next American man and take the first American woman to the moon in 2024. This also generated a discussion in the nation's approach to building the systems necessary to achieve the goal and resulted in NASA's Artemis program and new era document that, alongside international participation, encourages government partnership with commercial innovators to achieve this bold target date.

Acknowledging that regulations can stifle the necessary innovation and growth for the commercialization of space, Space Policy Directive 2 (SPD-2), issued on May 24, 2018, addressed the Administration's intent to streamline our approach to launch and re-entry licensing, commercial remote sensing, radio frequency spectrum, and export licensing and regulations. Further, this SPD proposed to create within the Department of Commerce an entity responsible for commercial spaceflight activities. Behind the scenes, the Space Council was tackling the challenge of addressing orbital debris and space traffic management, anticipating emerging commercial ventures such as satellite servicing, debris removal, in-space manufacturing and tourism, as well as new technologies enabling small satellites and very large constellations of satellites.

On June 18, 2018, the President issued SPD-3, the National Space Traffic Management Policy. SPD-3 guides the Executive Branch's effort to mitigate orbital debris by directing the development of standards and practices, improving space situational awareness interoperability, providing basic SSA and STM services to the public, and encouraging and facilitating commercial leadership in SSA and STM.

With that foundation supporting the growth of commercial industry in space, the Administration turned its attention to the strategic concern of how the nation should defend its interests in space. That resulted in the February 19, 2019 publication of Space Policy Directive 4, and the establishment of the United States Space Force nearly one year ago. Charged with ensuring unfettered use of space for the United States' national security purposes, the United States' economy, and the United States' persons, partners, and allies, the establishment of the Space Force follows a fundamental understanding that space is now a warfighting domain. This is evidenced by competitors' pursuits of technology that threaten our interest in space and amplify risk to a number of space operators. The results of today's discussion and ANSI's role in facilitating the establishment and adoption of standards for SSA, SDA, STM, and orbital debris mitigation is perhaps one of the most important aspects of differentiating hostile activities from benign space operations.

Finally, understanding that space operations rely on computer-based technology and the potentially decimating impact a malicious cyber attack could have on our national goals to grow a commercial presence in space, our strategic goal to send humans to Mars, our national security, and the daily livelihood of millions of Americans, shoring up our ability to withstand potential cyber threats and attacks became critically necessary. Addressing this vulnerability, President Trump issued SPD-5, the nation's first comprehensive cybersecurity policy for space systems. Designed to guide and serve as the foundation for the use approach to the cyber protection of space systems, this SPD fosters practices within government and commercial space operations that protect space assets

and their supporting infrastructure from cyber threats. SPD-5 directs U.S. Government agencies to work with commercial companies consistent with the principles in the SPD to further define best practices, establish cybersecurity-informed norms, and promote improved cybersecurity behaviors across the nation's industrial base for space systems.

We are at an inflection point in the commercial space sector. With a high number of new entrants, the rapid entrepreneurial delivery of new technology, and the desire to bridge the technology with the demanding market, we have the high potential for divergence of standards and practices that at best could delay attainment of goals or at worst result in an on orbit disaster. In relation to SSA and STM, we observe this today as we ponder basic questions:

- What are appropriate commercial data sharing standards?
- How should multiple data sources be curated to derive actionable information?
- How can openness and transparency be maintained?
- What are the appropriate standards that trigger conjunction notification?
- What are appropriate operational standards that contribute to responsible behaviors in space?
- Do the standards that we are considering stimulate participation in mitigation practices?

Colonel Hernandez indicated that he was encouraged and excited that ANSI is sponsoring today's discussion. Establishing appropriate standards is a key component of success for National Space Policy. In emphasizing a principal component of ANSI's purpose, collaboratively working to establish voluntary standards will help to increase efficiency, open markets, boost consumer confidence, and reduce costs as the nation moves forward in capitalizing on the potential of an emerging commercial space industry.

Question & Answer Period – Keynote Address

Mr. Bhatia asked whether, with the new administration coming in, there would be any changes to planned activities. He also asked if there was anything that ANSI could do by way of support.

Colonel Hernandez noted that he could not comment precisely on what the Biden Administration is potentially thinking on space. In his time as staff of the National Space Council, he has observed a unique bipartisan support for many of the endeavors and activities that are being done to include the publication of policy that straddled the aisles. There's a lot of active participation from both sides of the political spectrum. It is his hope that we can sustain and maintain the momentum that we have in improving America's position in the space economy.

Mr. Bhatia commented that ANSI believes in public private partnership and feels the best successes can be advanced in this nation by the public sector and private sector working together. ANSI will be very happy to facilitate input from both the public and private sectors to help create the solutions that we're all seeking. We are very much dedicated to working together as a team.

Colonel Hernandez expressed his appreciation to Mr. Bhatia for his comments. Looking at SPD-3, it definitely highlights the potential for the agility of the private sector to incorporate new tools and methodologies for conducting these activities. At the same time, there's good governance that comes from the structure that government agencies can provide. He agrees on the public private partnership. There's great potential that we as a nation can capitalize on, especially in the development of standards. He appreciates ANSI's promotion of voluntary adoption of these standards. It is important for us to maintain that as we go forward in voluntary participation and development of these standards. He is looking forward to the outcome of today's discussion.

Panel Discussions

Each of the three panels followed the same format: brief moderator/speaker opening remarks, followed by interactive, moderated discussion. Speakers were asked to consider the following questions in relation to the topic of the meeting based on their specific area of expertise:

- What policy instruments and/or industry standards/best practices already exist to address the issue and why are they important for the growth of the commercial space industry?
- What policy instruments and/or industry standards/best practices are in development?
- What can be said about compliance with policy instruments and/or industry standards/best practices at this point?
- What more is needed in terms of policy instruments and/or industry standards/best practices to help support the policy framework?

Panel 1 – Government Perspectives

- Moderator: Dr. George C. Nield, President, Commercial Space Technologies, LLC
- Kevin O'Connell, Director, Office of Space Commerce, U.S. Department of Commerce
- Karl Kensinger, Acting Division Chief, International Bureau Satellite Division, Federal Communications Commission
- Steph Earle, Acting Deputy Division Chief, Policy and Innovation Division, Office of Commercial Space Transportation, Federal Aviation Administration
- Dr. Jer Chyi "J.-C." Liou, Chief Scientist for Orbital Debris, National Aeronautics and Space Administration
- Jeff Braxton, Chief Analyst for Intradepartmental & Interagency Engagement, U.S. Space Command

George Nield set the stage by noting that in response to some high-profile collisions, increasing congestion in low Earth orbit, and growing concerns about the risks of orbital debris, there has been a lot of talk about the need for a civil space traffic management system that would work to enhance the safety of space operations and preserve the space environment. SPD-3 was an important first step in achieving that goal. But almost two and a half years later, Congress has not yet come to an agreement on the recommendations included in that directive. We've reached a point where it is urgent that the U.S. government makes some decisions on both roles and responsibilities, and on implementation options for how we should proceed. If the U.S. continues to defer those decisions, it will likely lose its opportunity to influence how the rest of the world deals with the safety of space operations.

Government and Industry Must Provide U.S. Leadership in International Space Standards Development
Kevin O'Connell, Director, Office of Space Commerce (OSC), U.S. Department of Commerce (DOC)

Kevin O'Connell remarked that the space industry is growing and diversifying very, very quickly and that's key to its success. But leadership in the area of technical standards and industry consensus will create a needed positive impact in areas like improving space safety and coordination, including the broad usability of space data, just to name a couple.

From an international competition standpoint, the United States has the largest and most advanced commercial space industry. But without careful attention to international developments, we will quickly lose our competitive edge. George Nield highlighted the decades-long American leadership in this area. What we're all really trying to do is to make sure that we sustain and advance that leadership. Last week, the U.S. China Economic and Security

Review Commission (USCESRC) submitted its annual report to Congress where it encouraged the government to take a larger role in international standards development. Traditionally, U.S. companies have led the standards development arena but the USCESRC recommended establishing a government committee to work with industry and support U.S. standards goals in this area. The recommendation comes as a result of Chinese efforts to influence the standards development process. But we want to make sure that the U.S. is maintaining a strong voice in standards development. It's something that the Office of Space Commerce is focused on.

Part of the government's role in encouraging the development of the commercial space industry is to support that industry, both at home and abroad, across a spectrum of competitive issues. This is one of the many areas where government can advocate on behalf of industry. Joe Bhatia mentioned the importance of public and private partnerships in this area. Whether the government establishes an official committee focused on standards development, we need to make sure that we're mobilizing all relevant agencies, including everyone on this call to take an active part in promoting standards priorities. And this is especially important in the area of space safety and sustainability, which is essential to the growth of space commerce and to space exploration.

Last week, a U.S. proposal for a new work item in the International Organization for Standardization (ISO) ISO/TC 20/SC 14 on space traffic coordination and management failed to garner the two thirds majority required for approval. While this was disappointing, the U.S. government fully supports this initiative. After the start of the new year, Commerce and other federal agencies and departments will participate in the U.S. technical advisory group (TAG) efforts to develop a new ISO proposal on technical standards for space traffic coordination. The Commerce Department will also work with the Department of State to build international support for the new proposal which advances key U.S. policy principles and goals. One of the first steps is promoting a common understanding of spaceflight safety within the international community, and continuing international and domestic work to promote the long-term safety and sustainability of the space environment.

In addition to working with ANSI, OSC is involved in a number of areas including with the American Institute of Aeronautics and Astronautics (AIAA) STM Working Group to create a lexicon for SSA, and associated spaceflight safety functions. The idea is to establish a common understanding of existing terms, their relationships, and their context. OSC is also participating in ASTM's Technical Committee F47 on Commercial Spaceflight.

In parallel, OSC is working on an open architecture SSA data repository (OADR), as mandated by SPD-3. This is a cloud-based system of data and analysis tools for space operators to accelerate fast paced technological developments into operational applications for working together safely and sustainably in space. Speed is of the essence because of the nature of the problem, and because of how space is growing and diversifying from an economic perspective. DOC holds by far the largest volume of civil space data assets. The terrestrial ocean and space weather data sets are over 38 petabytes. They're used across the department and with collaborators like NASA. OSC will continue to draw upon the deep expertise from the department including in other areas like data fusion and management, and data sharing for a community-built, globally accessible OADR. Recently, OSC hosted an industry day supporting the development of the OADR by soliciting information on commercial solutions to improve data management, fusion and visualization, analysis, and other elements.

Part of the standards development process is formalizing industry best practices. An unexpected surprise was that the industry days actually helped surface some existing and developing best practices that support space safety and coordination. It's no secret that the commercial space industry is well ahead of the government on establishing industry wide standards and best practices. All other considerations aside, it's just smart business. Space is so critical to so many areas of our lives, and increasingly important to the creation of a high-tech

workforce and economic growth. We are seeing the space economy diversify in so many different ways. Standards will be key to the speed and depth of that growth.

FCC Updates its Orbital Debris Mitigation Rules
Karl Kensinger, Acting Division Chief, International Bureau Satellite Division, Federal Communications Commission (FCC) *(Presentation Link)*

Karl Kensinger explained that FCC rules adopted in 2004 require companies seeking licenses from the FCC to submit an orbital debris mitigation plan. The plan must include collision risk, measures to avoid accidental explosions, and end-of-life disposal of spacecraft. This includes the so called 25-year requirement, which is the requirement to remove satellites in LEO within 25 years after the end of a mission. If a plan is inadequate, the FCC can require modification prior to licensing, impose conditions, or conceivably deny the license. The debris mitigation rules apply. The FCC rules apply to non-federal satellites, and they include cube SATs and other small satellites. The FCC rules from 2004 closely tracked the U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP), although there were some areas in which the FCC rules were adapted to suit the licensing process.

In April 2020, the FCC issued an update to incorporate new assessment methods and criteria for its rules to codify some of the existing licensing practices that had developed since 2004, based on experience in individual cases. One of the goals of the update was to examine the suitability of some of the current criteria for large constellations and, in particular, with a focus on some of the debris mitigation criteria that are stated in terms of individual satellites. The update had two components: one was a report and order that adopted changes to the rules, and the other was a further notice of proposed rulemaking that sought additional comment on some aspects of the FCC rule update. The revisions that were made coincide with revisions to the ODMSP led by J.C. Liou. The FCC changes adopted numerical values for several existing requirements that includes the collision risk per satellite and the casualty risk assessment. The values track those specified in the ODMSP and grow out of the NASA standards and the assessment tools that NASA has developed and that are now widely used by commercial operators for completing debris assessments for their systems.

The FCC adopted additional updates. There is a requirement that applicants certify that upon receipt of a space situational awareness conjunction warning, the operator will review and take all possible steps to assess the collision risk and mitigate that risk if necessary. There is a requirement that applicants must include statements related to protecting inhabitable spacecraft (a LEO concern), statements related to maneuverability, tracking ability, and identification of the satellites and information about the operator's efforts to share data for space situational awareness. There are also other disclosures that are adapted for specific subsets of satellite operations, including use of deployment devices and release of liquids that may persist in space, and proximity operations of one spacecraft approaching another closely.

The current status is that two of the rule updates became effective September 24 that had to do with a clarification on the control of transmitting stations and a provision concerning coordination of orbit raising maneuvers for geostationary satellites. Other updates are subject to Paperwork Reduction Act requirements. The efforts to address those are underway and so those provisions will become effective at a later date. There were petitions for reconsideration filed earlier this year and there's a formal pleading cycle for those that recently closed.

The further notice of proposed rulemaking invited additional comment on a number of issues partially related in many respects to large constellations. There is a proposal to adopt the metric from the ODMSP with respect to

accidental explosions. There is a set of questions about approaches to addressing collision risk and casualty risk for satellite constellations on a system-wide basis. These were the FCC criteria that are specified as per satellite criteria. Questions go to whether there should be a different or more stringent standard or a more comprehensive standard developed for large constellations involving multiple satellites. There was a question about requiring maneuverability for spacecraft and space stations located above a certain altitude in low Earth orbit, and other possible limits on post mission orbital lifetime. Many of these are related to whether the so called 25-year requirement is overly permissive in that it permits satellites to stay on orbit for a much longer time than is desirable.

Finally, the Commission requested comment on adoption of several requirements. They go more to legal and economic issues. One is a possible indemnification requirement that requires license recipients to indemnify the U.S. government for any claims that would arise under the international treaty regime, which does involve government liability. The other relates to use of a surety bond that is tied to successful post mission disposal of the spacecraft.

There were approximately 40 comments filed prior to the October 9 deadline and roughly an equal number of reply comments submitted on November 9.

FAA is Working to Advance Safe and Efficient Commercial Space Transportation Operations
Steph Earle, Acting Deputy Division Chief, Policy and Innovation Division, Office of Commercial Space Transportation, Federal Aviation Administration (FAA)

Steph Earle noted that the FAA is involved in standards as a matter of law. U.S. Title 51, Section 50905, requires that the FAA facilitate standards development, meaning voluntary industry consensus standards. Their engagement has included standards for SSA, STM, and orbital debris mitigation from a commercial space transportation perspective. Some of the newer areas for commercial space transportation standards include areas like commercial crew safety, spaceflight participants, and cybersecurity for launch or reentry vehicles. FAA is extremely interested in these areas as far as voluntary standards are concerned to develop better regulations and to facilitate faster and more efficient operations in U.S. commercial space transportation. FAA continues to work with industry standards partners, as well as the FAA's Commercial Space Transportation Advisory Committee (COMSTAC).

It was pointed out earlier that the FAA has released regulation 450, which is a very large regulation on launch and reentry licensing requirements that combines four regulations into one that is streamlined. But what it really does is change the way that FAA looks at their regulations, moving from a purely prescriptive regulation to a performance-based approach. Industry standards are very important in that regard. As more industry standards are reviewed and accepted by FAA, it simplifies the application, review, and timelines. As they go to a more performance-based approach, they hope to have more industry standards that lead to better coordination and understanding.

FAA has also been working on an orbital debris rule for close to a decade and looking at updating their regulations. They are a participant in the update of the national orbital debris mitigation standard practices but, like the FCC, as a regulatory agency, FAA cannot simply take the debris mitigation standard practices for the government and apply them to commercial operations. They must go through rulemaking, receive public comment, and look at the cost benefit analysis for that specific industry. Space transportation, including launch and reentry, has some unique aspects when it comes to orbital debris. FAA looks forward to getting that rule out within the next year. FAA also

has some existing rules on upper stages as a source of debris, and safety has been addressed. Launch collision avoidance could be a source of debris and FAA has moved that forward into the streamlined regulations.

Managing Risk from Orbital Debris Requires Mitigation and Remediation
Dr. Jer Chyi "J.-C." Liou, Chief Scientist for Orbital Debris, National Aeronautics and Space Administration (NASA)
(Presentation Link)

J.-C. Liou provided background on the history of orbital debris mitigation policies, standards, requirements, and guidelines (U.S. government, NASA, the international community, and industry). Orbital debris mitigation has been included in every National Space Policy since 1988. Specific machine requirements to limit the generation of new debris were first developed by NASA in 1995. NASA then worked with the Department of Defense to establish the U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP) in 2001, and the ODMSP was updated last year. NASA worked through the Interagency Space Debris Coordination Committee (IADC) to establish the IADC Space Debris Mitigation Guidelines in 2002. These became the foundation of the United Nations' (UN) Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (COPUOS) in 2007 and the ISO standards in 2010 (ISO 24113). The orbital debris mitigation standard practices, requirements, and guidelines evolve over time and will continue to be updated as necessary.

What more is needed in terms of the standards and best practices? The answer to this question will be driven by the challenges faced today and in the future. There is both a long-term problem and a short-term problem.

The long-term problem is illustrated by the massive increase in orbital debris despite decades of efforts to limit the generation of new debris. This shows no sign of slowing down. It underscores the potential for a collision cascade effect. Good policy guidelines and best practices to limit the debris population increase have been in place since 1995. The problem is the global space community is not doing a good job at following existing best practices. A good example is the 25-year rule with which compliance is only about 30%.

For satellite operators, the short-term problem is that there is far more small debris than large debris. Impacts to operational spacecraft can have catastrophic consequences. Mission-ending risk is driven by millimeter-sized orbital debris. Conjunction assessments and collision avoidance maneuvers against large tracked objects account for less than one percent of the overall mission-ending risk from orbital debris.

As stated in SPD-3, the goal of STM is to enhance the safety, stability, and sustainability of space operations. Thus, risk from orbital debris is a priority. Protecting spacecraft from mission-ending debris impact should be the number one safety priority for future space missions. For SSA and STM, there is a critical need for standards and best practices to protect missions from impacts by small millimeter-sized orbital debris.

In the long-term, the global space community must do a better job of complying with existing orbital debris mitigation policies, standards, and best practices to slow down the debris population increases. We need to work together to establish long-term goals, combining mitigation and remediation to preserve the space environment for future generations.

Security and Defense Require Operational Best Practices and Behavioral Norms
Jeffrey Braxton, Chief Analyst for Intradepartmental & Interagency Engagement, U.S. Space Command

Jeff Braxton commented that the Department of Defense is not doing STM as it is defined in SPD-3, including things that underpin it. DOD is sharing what it has, but needs to do better. We are at an inflection point, at least

from a policy and legal perspective. We need to get moving on it, doing the things that the other speakers talked about.

From a security and defense perspective, the space domain needs to be stable, safe, secure, and sustainable. This is underpinned by a couple of things. It comes down to operational best practices. We also need to come up with customary behavioral norms that responsible users of space can either agree on or share in a manner which inspires others to behave in the same way.

What does security and defense look like when there is much more civil and commercial space activity in cislunar space and interplanetary space? This all needs to be addressed under these operational best practices and norms of behavior. Colleagues have thrown around the idea of how maritime got established—we can look to that for inspiration.

Question & Answer Period – Panel 1

What advice would you give to industry as they continue to develop standards and best practices?

(Kevin) The most important thing is to really work together as early as possible and to work with the government as early as possible in developing those standards. Jeff Braxton added a contextual point that 80% of the space economy is commercial and that percentage is bound to grow. The largest cluster of industry is in the United States and the extent to which U.S. industry, in concert with our allies, can come up with ideas and coordinate that with the government, that's wonderful. We are seeing new market segments emerging and it would be great to have more conversations like they're having in The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) on areas such as on orbit refueling, and other new mission areas. Technology is moving at such a speed that the only way to stay relevant is to make sure that there is strong industry input.

Could you review some of the next steps you see and the expected timing for rulemaking?

(Karl) We have to work through the comments filed, the record, identify key issues, and develop recommendations at the staff level that will go up to the commissioners. No specific timeframe to share. As many already know, the FCC chairman has had a long tenure and will be moving on to other endeavors on January 20. There is also a change in one of the other long-standing commissioners so there will be some changes at the leadership level. Obviously, that may influence the timing of actions and decision-making. While often there is a strong correlation between party identity and policy views, that has not been the case with orbital debris and space safety issues. The leadership comes to these issues with an open mind and an interest in doing the right thing for space safety and for commercial enterprises. We get a much more diverse vetting as a result.

Talking about space traffic management standards, how do they differ for commercial space transportation as compared to spacecraft standards?

(Steph) On one of the slides that J.-C. put up, you saw the mass go down a bit when the U.S. government started its debris mitigation standard. Some of that is because of the launch aspects of it. The rocket equation basically says that 85% of your rocket is fuel, one quarter is payload, and three quarters is rocket. So, rockets and upper stages make up the bulk of the massive objects on orbit. Of the 50 objects that were supposed to be removed, or that are the most dangerous objects in orbit, 38 of them were rocket bodies. When you're talking about returning an upper stage, it's a very different prospect than returning your payload after 10 or 15 years, just because of the massiveness. When we look at STM and commercial space transportation, there's a difference between the rules

that might apply to commercial space transportation and the rules that apply to satellites. The goal of safety is the same but how we implement it is a bit different between the two. We have two industries, the satellite industry and the commercial space transportation industry, that are merging together. We want to make sure that both are safe and that we receive the benefits of both. We've looked at aviation and maritime, as we try to develop the best space policies. We're focused on making sure we understand how our industry plays in all this.

Some organizations have suggested using active debris removal (ADR) to fix the orbital debris problem. Do you think we need a policy or standard on ADR?

(J.-C.) SPD-3 states that the United States should pursue active debris removal as a necessary long-term approach to ensure the safety of our space missions in key orbital regimes, but it should not detract us from the current focus on orbital debris mitigation. We already have a policy regarding the standards and best practices for active debris removal. The first principle of ADR is very simple: do no harm. But because of the complication of non-technical issues, such as legal ownership and costs, standards and best practices for active debris removal will be more difficult to develop. Also, from the environmental management perspective, the priority is to limit the generation of new debris, which is a far more effective way to manage the orbital debris problem, at least for now. We do have time to develop low-cost technologies for active debris removal which will enable environmental remediation in the future.

The trend appears to be that civil and commercial space are supporting security and defense entities. But from an academic perspective how, if at all, do you see security and defense entities supporting civil and commercial space, say 50 years from now? And what are some key milestones along the way of getting there?

(Jeff) Right now, from a security and defense perspective, we're able to increasingly harvest the goodness of commercial satcom to do our mission. It's become the backbone of a lot of what we do. That includes commercial remote imagery supporting our intelligence community, the intelligence communities of our closest allies, and other partners. If you push it out 25 or 50 years, we have to make sure that we can secure and defend it as appropriate. We've started doing more in a combined arms & operations sense with our allies and other partners. We've been working on that the better part of a decade. When we get to the point of how are we are going to do things like mineral extraction from asteroids, we might think we would never do that but there's going to be others in the world who will. We need to understand and account for that. Standards are just as important as operational practices. They need to be complimentary and mutually supporting one another. Couple those with how you behave properly: doing the right thing even when no one's looking because it's the right thing to do, and not needing to be told by international or domestic law, etc. There's a compliance piece. Some of the milestones: taking care of the easiest or most important stuff first. Establishing standards and operational practices even if it's only by custom for what is the responsible way to do things, and then continuing to evolve how we secure and defend strategic lines of commerce in space, as well as the civil lines that go alongside of that.

Picking up on the international aspects, is there any interest from other countries in the standards, agreements, regulations, or requirements related to space traffic management? Secondarily, if there were some accepted standards out there now, how would that change what the Commerce Department is doing and thinking about doing in the future?

(Kevin) There is extraordinary international interest in what Commerce is doing. We've had conversations with a wide variety of Commonwealth allies, European SST, the Japanese, and other countries. We're starting to have detailed conversations with our allies about centers, space expertise, repositories, artificial intelligence, etc. There's a need to improve in so many different areas that everyone can contribute. When people say "we don't

have any space capabilities," this is an analytics and a visualization problem. International enthusiasm is high. It would not change our path at Commerce. We're working aggressively on it right now. NAPA reflected that in its review of our activities and others. It's necessary for us to move ahead and very cooperatively with our allies and like-minded partners as we tackle this tough challenge.

Given the current debris environment and its growth rate, at what level and when might we see the growth rate level off and achieve a steady state? Can you reiterate your assessment?

(J.-C.) NASA conducted a study about 10 years ago based on a very simple assumption: What if we stopped launching anything into space? What would happen if we suspended the global space activity, i.e., no more launches? Would the orbital debris population start to decrease? We completed the study and published the results in the journal *Science*. Unfortunately, the results show that even if we suspend global space launch activities, the orbital debris population will not decrease over time. Rather, accidental collisions among existing objects will eventually force the debris population in LEO to gradually increase over time. So, we have crossed the threshold of instability already, at least in LEO. The good news is that the trend of the increase is slow. In reality, the increase will be worse than the results of that study, because it was based on a no more new launches assumption. We have done other studies. What if we have regular launches, and follow the existing orbital debris mitigation guidelines and best practices, especially the 25-year rule in LEO, what will happen? As long as the global community has a very high level of compliance with existing orbital debris mitigation standards and best practices, including the 25-year rule, at a 90% level, we will be able to control the debris population to a very slow linear increase over 100 or 200 years. The simple answer is that we will not be able to stabilize the debris population unless we consider active debris removal. The increase is very slow and we have time to consider activity debris removal which is consistent with the policy position stated in SPD-3.

How is space traffic management addressed by space vehicles, systems capabilities, and availability? Should we start working on those regulations? What do you see the FAA's role is and what the current law dictates in terms of roles and responsibilities?

(Steph) This is a mode of transportation unlike any other. It's not established the same way that other areas are. It's a very hard question when you have new actors constantly coming in and new activities starting. As we try to address the correct STM policies and standards, you have to continually take these new actors and activities into play. We have not cracked that yet as far as STM. Even in launch operations, can you create a standard with companies that have launched 10, 20, or 100 times, versus companies that have never launched? It's going to take some time to figure that all out. It's also different in GEO than in LEO and space traffic management needs to take that into account. There are also different risks.

Is there a plan in the FCC to standardize how launch risk is calculated? The launch risk issue is really one for the FAA, but do you have any comments on that? What's holding back the development and issuance of standards from the FCC right now? What are the pacing items in terms of why we're not there yet?

(Karl) Yes, launch risk is a question for the FAA. Just to be clear on the broad dividing line: The FAA licenses the launch vehicle activities leading up to the delivery of payloads into orbit, while the FCC addresses radio frequency operations for all non-federal launch vehicles and payloads. With respect to orbital debris mitigation, given the FAA's role, FCC focuses just on the payloads that it licenses for longer term on orbit operations. Depending on what's meant by launch risk – depending how long your view is, what flows from the launch – FCC's efforts with respect to the addition of numerical criteria for the payload activities we license is intended to provide some standards or align our regulations with what's followed in the U.S. government more generally.

What is your sense of the urgency and importance of this issue? Is this something we need to keep on analyzing and talking about or is the time for action really now?

(Kevin) It's an urgent problem that gets more complex by the day. We absolutely need to act. At Commerce, we're making a push right now for the resources that we need to take on the SPD-3 mission, as endorsed by NAPA. There is a need to move ahead quickly, because not only is there a demand but we're also seeing alternative views of how to do this. We favor a bottoms-up discussion based on the speed of the technology and the dynamism in the industry. It's hard to apply a standard when something different and new is coming along every single day. But that is the nature of the space economy going forward. We are really averse to top down legalistic approaches to try to mandate a solution that we will have to debate internationally for the next decade. There is a need to act now which is a whole-of-government effort.

(Karl) There is urgency and it strikes home at the FCC. There are a significant number of companies interested in developing large constellations, small constellations, that have new concepts for operations, etc. Those are cases that come up and that need to be addressed in a reasonable time period. A larger perspective to address those individual cases is extremely important and we welcome all the work that's going into that in the future.

(Steph) We need to start now. We need greater action and greater coordination. And we need to be a little bit out of the box because there are a lot of issues. Public safety is about the public being the customer. When talking about space traffic management, who is the customer? Is it the person that is being regulated or everyone else? We're not regulating for the sake of regulating, but to enable our economy, safety, and our future.

(J.-C.) The key is to comply with existing policy guidelines and best practices—with what we already know. That is priority number one. At the same time, there is a need to address the risk from small orbital debris for the safe population of future space missions.

(Jeff) We do not need to do this from the top down as much as we need to do it. The danger of the top down approach is that it will stymie innovation in an environment which is moving fast. We need to balance being authoritative and regulatory with that. We need flexibility to strike that balance. It is more than large constellations or small constellations. It's about anyone who's doing anything in the domain, manned or unmanned, single satellite or six million satellites—it's about everything. We have to think about the future, not just the struggles right now. We need to get on with it.

Panel 2 – Industry Perspectives

- Moderator: Therese Jones, Senior Director of Policy, Satellite Industry Association
- Charity Weeden, Vice President, Global Space Policy, Astroscale U.S. Inc.
- Dr. Brien Flewelling, Chief Space Situational Awareness Architect, ExoAnalytic Solutions
- Dr. Daniel Ceperley, CEO and Co-Founder, LeoLabs, Inc.
- Mike Safyan, Vice President of Launch, Planet

Action is Needed to Reduce Orbital Debris and to Support the Long-Term Sustainable Use of Space
Charity Weeden, Vice President, Global Space Policy, Astroscale U.S. Inc.

Charity Weeden explained that Astroscale's vision is to provide a safe and sustainable space environment for the benefit of future generations. The company is working to develop innovative technologies, advance or establish business cases, and inform international policies, best practices, and standards that reduce orbital debris and

support the long-term sustainable use of space. It is involved in a number of industry groups. Among them is CONFERS which has submitted a draft standard to ISO, namely ISO/CD 24330, Space systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — Programmatic principles and practices. It is also participating in the World Economic Forum's Space Sustainability Rating (SSR), which is a unique effort to assign a public rating to operators' debris mitigation activities.

Dialogue between stakeholders is absolutely necessary to move industry best practices and standards forward, but action needs to follow the talk. As a major stakeholder in orbit, industry needs to be forward leaning in advancing designs and operations that support both economic and physical sustainability in space. Ground based or space-based SSA, and a suite of on orbit services such as disposal support, debris removal of defunct massive objects, and life extension of satellite spacecraft that simply need more fuel will be the foundation for a new approach to STCM that involve commercial opportunities.

Today there are domestic policy and regulatory instruments that require updating. There are also international and inter-governmental high-level practices that require implementation at the domestic level. Several industry-led groups will feed into these governmental efforts.

Amidst this swirl of global activity and dialogue, two things are needed: traction and speed. Traction, in the sense that practical and effective steps to mitigate debris can be agreed upon, as well as visionary and globally accepted STCM by a wide swath of stakeholders, and the speed to match the urgency of the situation.

Updates to Standards and Practices Should be Based on Data
Dr. Brien Flewelling, Chief Space Situational Awareness Architect, ExoAnalytic Solutions

Brien Flewelling provided a perspective on how standards impact the way ExoAnalytic Solutions thinks about the problem as an SSA data provider. Space traffic is evolving, both in its constituency and in the activities represented by new space operations. One need only look to recent satellite servicing resource extraction and sample return successes for the evidence of this. Standards must evolve to keep up with the changing environment, and as government is increasing the diversity of organizations involved in contributing to the space traffic management problem. As new responsibilities are being embraced, we need to work together to ensure that there is sufficient infrastructure to support the evolving mission from the sensing standpoint, and in terms of policy and other types of mechanisms.

As an SSA data provider, ExoAnalytic Solutions enables understanding of the observed systems, their behavior, and their interactions within this environment, with each other and with other hazards such as debris. It important to consider incorporating data collected in the execution of these increasingly ambitious operations as part of the considerations for updates to standards and practices to meet the evolving challenges. Standards have been based on the assumptions and, in some cases, common understanding of best practices, but in many cases we are defining new precedents and new activities. Learning and trust-building measures should be part of the process.

As policies are being updated, many are opting for automation as the solution to risk management and avoidance. Automation, while a useful solution, should not be developed on the basis of sparse data. In the event that management fails, and we require remediation, debris removal will help ameliorate some of the effects of a congested environment resulting from today's practices. Executing these types of missions well will potentially require new flight safety services above and beyond the basic services associated with standards-based situational awareness. To this end, ExoAnalytic Solutions provides observation services and support of flight safety and mission assurance, and is working to extend our capabilities for GEO SDA above 10,000 kilometers and out into

cislunar space. As we consider new standards and update our policies, we should keep in mind many of the lessons learned in low orbits and how they will impact us as we take the economy into deeper space.

Satellite Tracking Services Must Keep Pace with Industry Trends
Dr. Daniel Ceperley, CEO and Co-Founder, LeoLabs, Inc.

Dan Ceperley explained that LeoLabs is a commercial platform for space traffic safety and space domain awareness in low Earth orbit. The company was founded to aid the new deployments and growth in the industry. About four years ago there were approximately 400 active satellites in LEO. Now there are over 2,000, and there are tens of thousands slated for launch over the next few years. When you look at this impressive growth in the space industry, there is one big problem: a lack of data. There are about 14,000 pieces of debris tracked in LEO today—objects 10 centimeters and larger. There's a lot of smaller pieces of debris that are potentially mission-ending. If you look down to two centimeters in size, the number actually grows to around 250,000. That means 95% or more of the risk is not tracked today.

LeoLabs' business is built on two technical platforms: a radar network, and a data pipeline. The company builds and operates phased array radars on the ground. It has three in operation today and will complete three more in the next year or so. These are built rapidly, going from breaking ground to delivering data in less than a year. They build S-band radar specifically focused on tracking objects down to 2 centimeters in size. They also run a software platform that analyzes this data and gets it in front of operators and analysts quickly so they have actionable information.

There are a number of industry trends that the company is keeping an eye on. The first is larger constellations and more frequent deployments. The second is automation which enables flying large constellations and managing these constellations through the satellite lifecycle from launch and early operations through missions and service delivery to deorbit. The third big trend is modern computing architectures being adopted by the space industry. This enables the industry to handle large data sets and provide real time services. Lastly, standard interfaces for SSA data are moving into orbit. The most useful data for satellite operators, regulators, and insurers are things like conjunction alerts, maneuver alerts, and the like. Most organizations don't want to be experts in radars, or telescopes, and so the focus on simple measurements, radar measurements, and optical measurements is going away. LeoLabs is watching these trends closely because they're driving the large constellations and advancement of the state of the art and tracking services.

Sharing Satellite Positional Information will Enhance Safety and Space Traffic Management
Mike Safyan, Vice President of Launch, Planet *(Presentation Link)*

Mike Safyan explained that Planet designs, builds, and operates the world's largest fleet of remote sensing satellites. The company has two active small satellite fleets: 1) SkySat satellites which provide high resolution imagery—they have 21 of those flying in LEO; and 2) Dove series satellites (called a "flock" constellation) comprising over 100 small satellites that are about five kilograms (the size of a loaf of bread) operating in LEO. The two fleets operate in the range of 400 to 500 kilometers, so the lower end of LEO, and they have different methods of maneuvering. The SkySats carry onboard propulsion and utilize that for on orbit orbital maintenance and the occasional collision avoidance. The Dove series satellites maneuver using a technique called differential drag. Since they're low in orbit, atmospheric force can be used to minimize or maximize drag and use that for maneuverability.

Space safety and safe debris mitigation have always been a part of Planet's mission. The company is continuing to launch satellites to low orbits such that the total lifetime in orbit is a handful of years. They operate in what can be

considered a “self-cleaning” region of LEO. In other words, they don't need to deploy active deorbiting, end-of-life maneuvers, as they can rely on drag force to decay the orbit down and the satellites burn up in atmosphere. The company is trying to lead the small satellite industry by example for how to maintain a safe space environment. This includes openly sharing positional satellite information, since good and accurate data is such a key part of maintaining space traffic. Sharing this information helps operators to assess what is a real conjunction threat versus what's a false positive and cuts down on an otherwise noisy and uncertain data set.

Question & Answer Period - Panel 2

If you had a magic wand and could fix one aspect of orbital debris mitigation and space traffic management, what would it be?

(Mike) For satellite operators, more open sharing of satellite positions, more ground-based and space-based sensors so that we can get a better sense of where everything is, better atmospheric models to predict how objects will travel in the future, and more transparency around active maneuvers that operators are doing.

(Dan C.) Increase the transparency and traceability of information provided about the location of a satellite, piece of debris, or potential collision. This includes a lot of metadata: how much data went into the predictions, how recently was it collected, and what are the accuracies, biases, and uncertainties in the sensors and in the processing. As more services are coming online, there may be multiple opinions for a given event. The metadata associated with those opinions is important to really understand the quality of the service, and to act on the best information available.

(Charity) Move faster to agree and adopt the right amount of debris mitigation remediation. This is a very difficult problem to solve globally to get all actors on board. We can’t have just one nation conducting most of the debris mitigation and others not following suit. Speed is really important – we don't have a decade to wait.

(Brien) Build the infrastructure necessary to solve this problem and not just limp along the way we've done it in the past. The abundance of data necessary to support decision processes must be collected at a rate necessary to support those processes, and that necessitates a different approach. We need more sensors and to realize what it takes to scale to the problem of today and projections of the problem tomorrow. Remove the barriers to address this massive problem.

What are the biggest obstacles to coordination between operators receiving conjunction warnings? What is needed on an international level to move forward in improving coordination?

(Dan C.) Internationally, having a common understanding of the risk environment in these orbital regimes. There’s been a lot of really good work on statistically understanding what's the likelihood of collision and how's that growing over time. But we need to shift to actionable information based on detailed tracking and risk analyses of all the conjunctions that occur over a period of time to construct evidence-based policies, and to serve as the foundation for communication for satellite operators around the globe. It’s also a critical element of the active debris removal industry toolkit that's missing today.

(Charity) Improve transparency. This needs to change radically and, in a way, it is. We have more congestion in orbit, and more operators willing to reach out, but are they willing to disclose maneuver plans, ephemeris, or provide public information about their operations? This is an obstacle.

(Brien) There are some good reasons why information is protected and should be. If you can fly more efficiently than another business, that matters in terms of your ability to succeed or fail. It's a difficult environment to operate in because the risk from debris may be to your system, your bottom line, because you have to expend resources. As we assess the risk and the consequence of failing to have safe operations in space, recognize that it impacts more than one system, one entity—it has ramifications throughout the economy that is very interdependent on space services.

The current de facto standard for industry flight safety is Space-Track.org. Do you have comments on the usefulness of this site, especially the challenges and limitations that you face based on data and service quality? How can commercial data help enable end users to verify the application of standards in the operation of satellites?

(Dan C.) We are receiving conjunction data messages about seven days before the time of closest approach, and multiple messages leading up to that time of closest approach, all of which are really good. Things that could be improved include making the system more interactive, as it is primarily alerts at present. The ability for satellite operators to interact quickly with the system and experiment with proposed maneuvers and do risk assessments for a potential maneuver is quite important. The collision avoidance service needs to be more comprehensive, as right now it's very much focused on active satellites, and on large objects, not small debris.

(Brien) Space-Track.org is representative of the basic services described by SPD-3. Our goals are to be more timely, more accurate, and more current if we can. It really depends sometimes on who has the most recent data. It doesn't really matter if it's one system or a multiplicity of systems that can provide you those reports. There are those who would like to see us move to a more competitive paradigm to provide the most current and accurate solutions.

(Mike) For large objects already in orbit, active debris removal is a really important part of remediation. In terms of non-technical solutions, a really big one is funding. Governments need to spend more, funding both their own efforts and commercial efforts to remove, say, the top fifty most dangerous objects currently in orbit. Small objects are a harder problem to solve. There are not well understood and reliable methods to clean up small debris. There needs to be more tracking so that there's more awareness. We should avoid creating small debris. A great example is a ban on anti-satellite testing. It's irresponsible when governments intentionally blow up their own satellites regardless of where they are in orbit. It creates small pieces of debris and that just adds more junk in a place where we don't need it.

(Charity) Our priority should be the prevention of small pieces of debris. We need to make sure that large pieces of debris don't become small pieces of debris and that's where the remediation case comes in. In terms of the value of Space-Track.org, it is free and accessible, and that's hard to compete with when there are other services that have a cost. The more that operators place a value on clean orbits, the more they're going to need additional support for space situational awareness. That could be increased timeliness, increased accuracy of understanding orbits and debris, or characterization. These additional SSA services are going to have a cost and operators need to build that into their necessary operational costs for the lifetime of an object.

What are the biggest technical issues that data providers foresee as we hopefully get funding for a civil open architecture SSA data repository in the U.S.? What are operators' biggest concerns in interfacing with the OADR? Should operators be forced to share performance data in something like the OADR?

(Mike) From an operator's perspective, the OADR is a great step in the right direction. This is a service that's needed because it can't just be commercial operators talking to each other. We're missing out on government operators, international operators, and different elements of the space industry. There are so many different players and we all have to be talking to each other. The more we move towards shared data and better coordination, the better.

(Brien) From a data provider's perspective, it's trying to move to a high quality of service product, to move to information that can be relied upon by the operators. It all comes down to the amount of human decision time that is available. In LEO, the time is very short. In GEO, there may be more time but a lot of the conjunction data messages and information being provided is just too uncertain to warrant. If you go further out, the challenges are immense. There's a host of technical challenges associated with that.

(Dan C.) We need to move to a data rich environment. Traditionally, we've been in a pretty sparse data environment where maybe we get an update every couple of days, or at most a couple of times a day. That makes it really challenging to automate collision avoidance systems to add artificial intelligence (AI) and machine learning into the mix and achieve the scale that's required to keep up with the space traffic safety challenges that are coming with the new environment. That means larger constellations of sensors on the ground watching space. It means bigger data pipelines in order to get that information into actionable form, and in front of operators in a very timely manner. Industry is stepping up quite well to address these challenges. With respect to the OADR, it's important to consider the difference between the architecture and the actual implementation. The architecture is focused on things like specifications, data types, interfaces, etc. When it comes to implementation, it's what systems are delivering services to implement the specifications and standards set by the architecture. In the past, the public service was the only provider on the market, but we're now seeing multiple commercial implementations come into the marketplace which is really healthy and will drive innovation.

There are 120,000 satellites that have been announced to launch by 2029. What industry standards or best practices regarding satellite constellation design do we need to develop to get there without ending up with the Kessler syndrome?

(Charity) We had a bit of what we would like to see immediately in our response to the FCC's further notice of proposed rulemaking—that is to agree on the way to measure risk. It might sound like a very simple thing but there's not agreement there. We'd like to see regulators assessing risk based on the aggregate, or the entire constellations' risk profile. Second, it doesn't seem reasonable that the 25-year rule is an appropriate level anymore in the new way we are using the low Earth environment. Bringing the end-of-life timeframe down to no more than five years as soon as possible to reduce congestion would be a prudent next step for the space economy.

(Mike) There needs to be a higher standard applied to very large constellation sizes especially when it comes to the reliability of their platforms, because even a small percentage of failures or unexpected outcomes can have a large impact. A system that is 95% reliable makes sense if you're launching a handful of small satellites to keep costs down and want to allow for innovation with experimental satellites or academic and research satellites. But when you're talking about thousands of satellites, a failure rate in the handful percentage ends up being really significant. OneWeb was a great example of an operator taking that type of scenario planning into account and saying we're trying to build our satellites as reliably as possible but, in the event that there's a failure, we're going to make it as easy as possible to deploy an active debris removal system.

(Brien) If you looked at the problem of trying to safely fly up to 120,000 satellites as a kind of a distributed control problem, it would be easier if one entity owned all of those satellites. But we have to collaboratively figure out how to do this together which introduces communications lags and other things that complicate the process. There's a lot of folks who want to solve this with automation, because if you can standardize all those processes and take the human out of the loop, that makes us feel safer. These control problems get very challenging if the decision processes are made in the absence of accurately measured information. The frequency with which you need an update on the basis of new data has to be faster than the rate at which the objects you're trying to safely control are maneuvering. If you're not coordinating when those maneuvers are happening—if those aren't on the basis of some projected plan—and they're a surprise to people who are providing data and then trying to use that data for a decision process, you've inserted much uncertainty into the problem.

(Dan C.) There is a need for a standard around risk reporting. What is the risk environment today? What are the specific risks a constellation faced and what did they do about it? That would be a good basis for establishing audits and keeping an eye on actual activities that are occurring in orbit. A lot of the regulatory focus today is prior to launch but there's little follow up in orbit. As space and especially LEO become more heavily trafficked, there will be a need for more detailed follow up. Without some standards around reporting, they'll be a lot of uncertainty. This is one area that we could focus on. The Department of Commerce would be well positioned to take on that role and use the reports to understand what policies need to be enacted or improved, or where best practices are working quite well.

Monitoring satellites' health in the early operations phase, immediately after launch and deployment, has traditionally been a challenging time. What best practices might address this challenge?

(Mike) Planet has a low speed UHF radio that we've open sourced for the small sat community. It has been 100 percent successful on first contact and in identifying our satellites which includes a radio ranging functionality which can help narrow down the position of an object. This is helpful right after launch where you have a big cluster of several satellites coming off the same deployment. There have been discussions around RFID tags, or "license plates" on orbit that either can be integrated into the system or operate independently on their own limited battery supply and not rely on the functionality of the host satellite to be able to identify and help track the object. There's additional risk if a launch provider has to coordinate deployments over a large portion of an orbit or several orbits. This has to be an industrywide effort where launch providers are able to provide upper stages that can help differentiate those objects through carefully designed deployment sequences and avoid collisions in those early orbits.

(Dan C.) We need to look at ground systems as well. In the public service, there can be weeks to a month of uncertainty about the tracks on all of the payloads that have come off a single rideshare launch. As the number of satellites scales up in LEO, you really can't tolerate that amount of time. A new generation of SSA systems is critical. You need to be able to acquire information about the launch and the payloads within an hour after launch, produce accurate states on those payloads, and get that into the hands of operators. LeoLabs has been heavily involved in this. The timelines need to be dramatically reduced as larger fleets are deployed to remove uncertainty.

(Brien) These types of very focused services are long duration, dedicated efforts. Are those basic services, or value added, advanced services?

How do you balance revenue and profitability of your enterprise versus establishing standards that may limit it? What financial incentives would your company see as a positive development in driving space sustainability?

(Charity) Astroscale is in a unique position because it provides the service of space sustainability but at the same time is an operator in space that must adhere to the standards, practices, and regulations that are applicable. Space operators will not be profitable if they're dodging debris all the time. Developing the technologies that help drive down the cost of an end-of-life service for debris removal is essential. In terms of financial incentives, we'd like to see increased government participation in debris mitigation and remediation efforts. As we build out the space traffic coordination and management architecture, we are also concurrently building possibilities for sustainable exploration beyond Earth orbit. Some ideas being discussed right now are requiring insurance, indemnifying the government (as long as there is a cap), fines, or performance bonds. These economic incentives should be discussed and developed by a dedicated government and industry group with a timeline.

(Mike) There's been an evolution over the years with small satellite operators having a bit more leverage in negotiations with launch providers. Today, the small satellite market is a consequential element of launch businesses. That leverage can be used to encourage good behavior with the launch providers, for example, writing into contracts that the upper stage has to deorbit within a certain amount of time or we won't take that service. Sometimes that might come at a financial cost to the company, such as a reduced payload capacity, but we may decide that it's in the best interest of a safer space environment. Being part of different efforts like the Space Safety Coalition (SSC) or the Space Sustainability Rating helps to demonstrate that this is the direction where the industry is moving and, if you are not on board with that, we will not work with you.

Can you provide some high-level thoughts and general closing comments on what needs to be done to achieve space sustainability? Are there priorities that were not covered that you want to mention?

(Mike) A real kind of coalescing point has been the FCC's proposed rules around debris mitigation. There hasn't been a strong understanding from both industry and government on a standard collision avoidance maneuver. What is the minimum threshold needed to actually avoid a collision? What technologies are sufficient to do collision avoidance? What is the probability of collision threshold? There are some common practices but a whole-of-government approach is needed. The number of objects is proliferating quite quickly so there isn't a lot of time. The sooner we get to industry understanding, the better.

(Dan C.) Data really underpins this discussion of best practices, requirements, and policies. That's a good direction for the industry to be going, and we can start to craft policies and procedures for space activities. The number of satellites is growing rapidly and the diversity of activities is increasing, but we can keep up with it, have a faster feedback cycle, and fine-tune the procedures to keep satellites safe and hopefully keep the space environment fairly clean. Another thing is that we've started to see the market for SSA data providers open up, and there is competition now where previously there was only a taxpayer-funded service. This is driving the state of the art forward and is going to be critical to scale up the amount of data that's being collected and the speed at which it is reported. Without that competition, the data services are simply not going to be able to keep pace with the development of the satellite fleets in space.

(Brien) Oftentimes when we talk about data, it's do we have the right data or timely enough data to help avoid a collision. It's amazing what you can learn if you have data at scale across the different objects in the space environment, the things that you can learn. We need data to support space safety, for the sake of collision avoidance sake, but also for all the other questions we didn't know to ask but now we should ask because we are operating in this environment differently. Also, whatever policy we define, and however it is updated, we need to

be able to verify that the policy is being followed. If that's not a requirement for civil space traffic coordination and management, then we've missed the boat, and we will fail to scale to where we're going in the future.

(Charity) Governments worldwide have been looking at this issue for decades. We should encourage them to continue to do so but also increase industry engagement, as industry can bring speed and innovation to the problem. Whether it's multi-national companies or groups like the Space Data Association that are global in nature, there's a lot of promise when you bring industry into the dialogue. We should encourage governments worldwide to get industry involved.

Panel 3 – NGO/Academic/Other Perspectives

- Moderator: Maj. Gen. Jim Armor, USAF (ret.), Founder/CEO, The Armor Group, LLC
- Dan Oltrogge, Director, Center for Space Standards and Innovation (CSSI) and Integrated Operations, COMSPOC Corporation
- Prof. Danielle R. Wood, Director, Space Enabled Research Group, MIT Media Lab
- Dr. Ruth E. Stilwell, Executive Director, Aerospace Policy Solutions LLC
- Marlon Sorge, Principal Engineer, Space Innovation Directorate, The Aerospace Corporation
- Frederick A. Slane, Executive Director, Space Infrastructure Foundation

Space Safety Must be Based on Timely, Accurate, and Comprehensive SSA Data
Dan Oltrogge, Director, Center for Space Standards and Innovation (CSSI) and Integrated Operations, COMSPOC Corporation

Dan Oltrogge explained that he wears a lot of hats that are relevant to this discussion. He serves as administrator of the industry-led Space Safety Coalition (SSC), which was formed just over a year ago and serves a critical function of assembling commercial Best Practices for the Sustainability of Space Operations that operators can use to aspire to higher standards than consensus international guidelines or minimum regulatory mandates. SSC adopts and strives to promote and implement existing industry consensus guidelines and standards and builds on that with an additional set of best practices. He also is the lead U.S. representative under ISO/TC 20/SC 14 and participates with ANSI in those standards, and in standards development in The Consultative Committee for Space Data Systems (CCSDS). He currently is leading the development of standards like the orbit data message, and co-leading the conjunction data message enhancements. He is working to establish new standards for both space traffic coordination and management and large constellations. He is also the Director of Integrated Operations and Research at COMSPOC Corporation. The space traffic coordination and management demonstration that they completed a month and a half ago clearly showed the need for comprehensive data fusion and advanced analytics. That fusion needs to be at the raw observational level to get actionable products.

Space actors have a legacy of under estimating the risk of, and from, space debris. In the early days, we deployed numerous bits of debris as experiments, or left derelict deployment mechanisms such as cables, canisters, platforms, upper stages, and spacecraft—the mass numbers mentioned earlier this morning are huge. We didn't appreciate how those actions would adversely affect the space environment in the long haul.

Now, as we're entering the new space era with launching many satellites and launch vehicles, we're into a grand experiment and there's a lot that we don't know. For example, we have many large constellations. How many are actually going to be viable and launched? What's the marketplace going to be for those large constellations? To what extent is better design and manufacturing, testing, and quality control going to map to reliable robust

spacecraft? How will appropriate orbit selection be handled to translate to space sustainability? How responsible will large constellation operators be? How effective might AI and machine learning be in disposing of collision risk? How effective will active debris removal be?

It is vital that we understand that space debris issues are much easier to understand before fragmentation events occur. Space safety must be based on SSA data that is sufficiently timely, accurate, and comprehensive to meet the needs of how we're using it in the operational construct, and we're not there yet. The rapid innovations of commercial industry represented by safety conscious space operators, commercial SSA providers, and active debris removal companies must be integral to this picture. The SSC and its best practices provide a pathway for enabling the partnership that's needed.

Incentivizing Industry to Act Responsibly Through the Space Sustainability Rating
Prof. Danielle R. Wood, Director, Space Enabled Research Group, MIT Media Lab

Danielle Wood provided background on the development of the Space Sustainability Rating (SSR). The World Economic Forum Global Future Council on Space held a competitive process to select a design team. The team included MIT, the University of Texas at Austin including Professor Moriba Jah, the European Space Agency's space debris office, and Bryce Space and Technology. We worked very closely together and many people have provided advice and input along the way. We have finished a first draft of defining what the components of a Space Sustainability Rating should be, particularly focusing on aspects that have to do with what happens during the operation of a satellite, during the design, operations, and end-of-life phases. We are looking at topics such as how does an organization participate in collision avoidance and data sharing, in meeting international standards, and in activities that in the future may draw upon the benefits of commercial services, or abilities to deorbit. We also asked how difficult is it to track space missions from Earth. All these are technical components that can be evaluated through objectively stated questions. We are going to do beta testing soon with satellite operators who have volunteered to evaluate whether our questions make sense and can be answered in a reasonable way. That will lead to a process to select a long-term organization that can play a role as the operator of the SSR. We are currently receiving letters of intent from organizations that are interested in operating the SSR. In 2021, we will be reviewing these to identify an organization or consortium of organizations to take on that role.

Recognize Commercial and Military Uses of Space and Move from Aspirational to Operational Agreements
Dr. Ruth E. Stilwell, Executive Director, Aerospace Policy Solutions LLC

Ruth Stilwell observed that there is discussion whether space traffic management is the right term. There are three key elements: 1) the prevention of collisions between objects when one or more has the ability to maneuver, 2) the prevention of increased collision risk by mitigating the number of non-maneuverable objects in the orbital domain, and 3) the removal of existing higher risk objects in space.

We need to be outward looking in this process because it is an international concern, and it cannot be solved by the U.S. alone. There is a shared interest between states, operators, insurers, and militaries to maintain the long-term safety of the orbital domain. At the same time, the potential value of the orbital economy makes it clear that safety cannot and should not be maintained solely through an attempt to restrict future access. The focus needs to be on safely expanding the capacity of the orbital domain. And this expansion comes through standards, regulation, and technology.

It's important to recognize that this is not just a commercial problem. The military use of space is an important priority, and needs to be kept in mind in the process. The line between a civil operation and a military one is blurry.

For example, GPS is a constellation that is a military asset, but its civil applications are clear. So, when we talk about a whole-of-government approach, it needs to include space for the reality of its military use. The activities to develop standards need to consider the limitations that are imposed by the diplomatic constraints of developing best practices that ideally would apply to all actors in space. If we want a comprehensive solution, we need to be cognizant of the fact that certain agreements will not be reached because states will not give up sovereignty. There are models that we can effectively use, e.g., ICAO, in how they've addressed civil use of aviation as well as military use. It is important to ask: Where is agreement possible given the existing constraints? Between whom are agreements possible? What needs to be at the U.S. level? What can be achieved through multilateral diplomacy? And so forth.

Colonel Hernandez made a key point: Standards provide us with the opportunity to distinguish between benign activity and a potentially hostile act. This is important, not just in a military construct. As new technologies and operational concepts emerge, things may not always look as they seem. On orbit servicing may look a lot like a hostile act to everyone except for the two parties that contracted for the service. How do non-participating actors know that they are observing a benign activity? As we talk about standards, it's common to look at the technical side of the equation. But in terms of situational awareness, there is a need for transparency particularly with regard to intent. What information are parties willing to share?

The 21 UN Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space (COPUOS), Annex II, include aspirational terms like provide, improve, and promote. How do we move from the aspirational to the operational? How can the work of standards organizations evolve into international agreements? Voluntary industry consensus standards and UN guidelines based on absolute consensus are a starting point. But this needs to trigger mechanisms to turn this work into action.

Standards Development for Safe Space Operations Must Keep Pace with the Speed of Change
Marlon Sorge, Principal Engineer, Space Innovation Directorate, The Aerospace Corporation

Marlon Sorge noted that the areas that we're discussing today are ultimately related to safety issues, which makes them a little different than standards that help things function together more efficiently.

Space operations are changing very quickly. We are seeing huge increases in the number of operational satellites and the size of constellations, as well as small satellites that perform functional services. There are entirely new forms of operations like on orbit servicing and active debris removal. There are whole new regions of space that are getting use that weren't used before. All these changes are bringing an enormous amount of potential opportunities as well as safety challenges and risks. The standards community must find the balance between enabling those opportunities and mitigating those challenges and risks.

Another change is that a large percentage of space activity is now commercial. The constraints that commercial organizations face must be considered. Standards must be well-justified, perform a function, and help to advance the goal of safe space operations. We have a huge range of operational satellites, from very small to very large, with missions ranging from single satellites to ones that may have constellations of 1000s. We need to design our rules, guidelines, and standards in order to accommodate all of this.

The speed of change is really a driver here. So many things have happened in the last few years in space that would not have seemed possible before. Satellites are going up to do maneuvering for other satellites. We are landing first stages so that they can be reused again. Traditionally, we've had a lot of time to develop standards.

We are increasingly losing that, getting more and more behind, and so we need to be developing standards in a way that is flexible and that lets us keep pace with the speed of change that is going on.

An Open Space Architecture that Fosters Industry Growth and Commercial Opportunities is Needed
Frederick A. Slane, Executive Director, Space Infrastructure Foundation

Fred Slane began his remarks by observing that best practices and standards provide a measurable baseline agreed upon by those with a direct and material interest. Standards development organization projects should be open and inclusive, with participation from industry, government, and academia, groups whose perspectives are represented in our discussions today.

Today's forum is prompted by space industry growth. We need to address policy, best practices, and standards in anticipation of huge growth over the next ten years. Growth means growing capability and generating profit over time. Spending on programs where standards are available but are not used cannot be accounted for as part of growth. Rather, policy instruments should encourage spending, including commercial investment, on programs which use existing and appropriate standards or leverage and grow the standards base. We need policies and best practices that provide the broadest commercial return and that maximize opportunities.

Bringing together stakeholders with different concerns and perspectives to construct what a domain is going to do is called creating an architecture. We want to minimize the architecture risk and create as many space opportunities as possible. Architectures in the works at this time include CONFERS and OADR. Standards development should focus on core architectural elements. We want an open architecture, the rules of which are well understood and commonly shared, though the specifics of implementation can be proprietary. U.S. government space agencies should participate in developing the core space architecture and the standards to support it. That is current policy but may not be adhered to as much as is desirable. The architecture needs to be open, scalable, and extensible.

<u>Question & Answer Period - Panel 3</u>

Given the diverse set of standards development organizations (SDOs), do you have concerns about the likely disparity between standards that result and which standards might become enforceable under U.S. regulations?

(Dan O.) Yes, to duplication of standards being a concern. We need everyone to follow the same rules which becomes difficult if we have an issue of harmonization amongst the standards that we have. While multiple SDOs are making great work assembling relevant standards, what may be missing is government adopting standards that it chooses to embrace in particular subject areas. With multiple standards, standards users can choose the ones that best fit their needs and that may not be in the best interest of the FCC, FAA, NASA, or Space Force. A lack of U.S. subscription to particular space standards across our civil, commercial, and government branches can lead to "standards of convenience."

Reliability has been a critical design attribute for satellites yet, of course, they still fail. How will the Space Sustainability Rating inform designers and manufacturers to design and build better space systems?

(Danielle) The Space Sustainability Rating is intended to apply to missions throughout the life cycle: during the development phase, the operations phase, and the end-of-life phase. There are different kinds of operators, such as universities, small companies, big companies, governments, with different mission objectives. Some may not

necessarily be focused on reliability but on proofs of concept, on demonstrating what they can do with large constellations. We should be aiming for safety.

During pre-launch, an operator concerned with reliability could make orbit location choices that will allow them to be less of a risk for collisions and for debris creation based on information about the history of that orbit. There's also a question of what materials and features to put into the satellite. There's currently not a lot of evidence-based data on that to make it easier to track or service a satellite.

During the operational phase, an operator must participate in data sharing and collision avoidance coordination. Remember that different kinds of satellite operators have different capabilities. We want to give credit for efforts that they're making to share information and to participate in collision avoidance coordination, in voluntary networks such as the Space Data Association. Commercial organizations can help with space situational awareness, providing new options to space operators who do not have the internal capacity to have high quality knowledge of their own location.

The final piece is the end-of-life phase. The question arises, will a satellite get deorbited on time, while it's still healthy, in order to be safer? Or can its orbital life be safely extended? This is a very common question, especially for science missions. These are important, internally-driven questions that have an impact on the external community.

All of these questions and actions at pre-launch, post-launch, and end-of-life play into the Space Sustainability Rating.

When we talk about reliability, one of the things that we are challenged by is that we don't necessarily have a common language for the terms we use to describe reliability. Is that part of what you're putting into the Space Sustainability Rating?

(Danielle) We're not trying to put forward a normative definition of reliability. We don't expect to have the same definition in general because some missions are driven by individual satellite performance while others are driven by group performance. The question goes to how we think about smaller to lower-cost satellites that follow what's often called the lean method. We need to collect data to describe how the input in testing and design relates to reliability or quality of the mission for one satellite and also groups of satellites. It's an ongoing process where operators are organizing the information.

The 21 Guidelines for the Long-term Sustainability of Outer Space Activities took years to come to consensus on through the UN Office of Outer Space Affairs. What else do we need? Transparency?

(Ruth) We do need transparency and that is an important step forward but it's not the sum total of the work. If you read the long-term sustainability guidelines, they provide the latitude to do the things we've been talking about where there can be multiple standards used by multiple actors, and they can diverge instead of converge. The flexibility that gets written into almost any consensus document creates ambiguity that we have to address. So, the long-term sustainability guidelines are important because they are principles that we agree on. But they don't give us operational, actionable information. Other than a broad construct of what governments will do, how they do it is very much up to the underlying states.

This is not what the standards-making world wants to hear but a voluntary consensus standard is either impossible to achieve or of very little value when you finally get it. If it is both consensus and voluntary, one of two things

happen. Either you work very hard to reach agreement on a very soft standard that people still might not comply with or the parties agree to a standard that they have no intention of complying with, because it's beyond what they believe is acceptable. It should either be voluntary or consensus but not both because both puts you in a situation where you spend years agreeing to something that does not get implemented. However, you have to mitigate for something not being voluntary or not being consensus. The way you mitigate for that is through a standard of transparency.

For example, if two standards organizations come up with different safety standards, it is important to know that one country is using one standard and another country is using another standard because if you understand which standard is being applied, you can react appropriately. The safety risk is when you don't know which standard is being applied. And you're either having to guess or assume that it's neither. So, transparency is a critically important step in moving forward particularly early on in the standards process, where you may have significant hesitation to agree to a standard. Put another way, if we can't get agreement on what we're going to do, can we at least agree that we will share information with each other so that we know what the other actors are going to do in the airspace. When it comes to the civil-military balance, often that's as far as you can get.

So, the long-term sustainability guidelines are most important and valuable because they represent an agreement that there is a problem for which action is necessary. The next step from those guidelines is what are we going to do to trigger that action, now that we have all agreed that it is necessary.

With the caveats that Ruth just levied on us, what do you think are the different approaches that we may need when moving forward in developing best practices and standards, especially for SSA, space traffic management, and debris?

(Marlon) As has been noted, space activities now cover a wide range of operators, goals, satellite sizes, constellations, etc. We need our approach to standards development and best practices to keep up with the speed of change. We need to be moving toward more prescriptive rules telling us what needs to be done in the bigger sense, not how it needs to be done. Two or three years down the road there's going to be new ways to do things and today's approach may be obsolete. As with everything, it comes at a cost in terms of understanding what it means to be compliant and what your options are.

Ruth brought up a good distinction between voluntary and consensus. You've worked with CONFERS, which is an industry association looking for voluntary rules. Could you comment on your experience with industry associations in developing standards?

(Fred) We need to parse voluntary consensus standards. Voluntary, in the context of most standards – those that have not necessarily been adopted as regulatory – means that compliance is going to be between parties that agree to use it. So, generally, we're talking about contracts. Consensus does not mean unanimity. Rather, it's hearing all sides of a discussion and agreeing to go forward with a set of requirements. Not everyone has to agree to all the requirements, but you have to have a process where everyone gets to be heard. Again, if compliance is between those who chose to comply and the standards are tailorable – and most open voluntary consensus standards are – then that is the environment you're working with in setting a standard. Voluntary consensus standards have a special place in U.S. law.

(Dan O.) The point was eloquently made that we need to have standards that are either consensus or voluntary. But at the same time, voluntary consensus standards are of use. For example, the Space Safety Coalition's voluntary consensus standards, amongst a subset of like-minded operators and companies, is of extreme use. It

has helped inform the U.S. government on implementing long-term sustainability guidelines. On the regulatory front, we need standards that have measurable, verifiable, contractually-suitable language that can be incorporated into our country's regulatory and operational frameworks. We should have clarity on that within our own country.

(Ruth) This discussion highlights that terms mean different things in different environments. In the context of the UN long-term sustainability guidelines and COPUOS, absolute consensus is needed. It's different than when you're talking about an industry standard and a voluntary consensus process where the participants have reached those agreements. When we're asking for a global international agreement enforceable by governments, this is a very different construct. This is why transparency is a very effective tool to fall back on. It allows different countries to have different standards that are applied to work in an international environment and we know what standard they are following. It's when we don't know what standard is being applied that we compromise the safety of the collective environment. We are not actually in disagreement. We are looking at this same issue from different perspectives: how it's enabled in different environments, who is developing the standard, and for what purpose.

Any closing comments or other points you want to make?

(Ruth) The biggest risk to the work we are doing is that we will all agree and still it will not get done. Many hard-working, diligent people are producing a lot of work without a clear mechanism on how to operationalize those outputs.

(Dan O.) We talk and talk and the information is out there, but we lack action. Our country's segmented regulatory bodies and swim lanes tends to bifurcate rules and governance. We need to start thinking about not just space traffic coordination and management, but look at air traffic, maritime, high altitude airships, and launch collision avoidance, and how that integrates with the whole space picture.

Any closing comments on how space sustainability relates to the broader definition of sustainability on Earth?

(Danielle) In early 2021, you can join the Space Sustainability Rating design community as we provide updates and progress on beta testing and continuing to refine the SSR based on input from actual operators of satellites. More broadly is this cautionary note of taking the good ideas that we have and implementing them. What kind of future do we want to leave to next generations, in orbit around the Earth and in places like the cislunar environment where we're going to have more activities? It's easy to talk about non-human based satellites as a category of operations in space. But very soon we'll need to do even further coordination across the human operated and non-human operated, within low Earth orbit and beyond. We have to start preparing ourselves for that which is not yet obviously, technically feasible. And try, if possible, to organize the policies and things that are needed before the actual demonstrations are happening. It's been happening, as a great tradition, throughout the space era. The early writers of tools like the outer space treaty did a good job of trying to be open to a future of quite surprising technology. Let's keep that tradition going and start to ask, since technology is moving so fast, how can we really anticipate things that are not even in our present vision yet? We know we need to get ready for them.

What have we missed?

(Marlon) We need to get ourselves moving, as there's a lot that needs to get done. We are going to be better off if we get ahead of the problem rather than having a buildup of significant issues like space debris, and then having to dig our way out later on. There are a whole range of challenges that we need to address: technical issues, policy,

the practical, organizational issues, how you actually make things happen. The way to figure those out is to dive in and do something.

On behalf of the professors on the panel here, can we hear a little bit about STEM and planting the seeds for the next generation to take on this challenge? Why did you choose space standards development as your profession?

(Fred) After retiring from the original U.S. Space Command in 2001, we saw a need to get involved in some of the standards development work that was going on at the time. We encountered some people not familiar with the standards process and not following the right way to move ahead and make progress. Out of frustration, when we knew there was a better pathway forward, a few of us got together. We agreed we needed a way to raise funds for subject matter experts to go to standards meetings. We're a nonprofit and our Board of Directors controls the organization. There isn't anybody to tell us no and we can talk about the things that we feel are important. A second point is that there are approximately 500 technical standards that exist today in the voluntary consensus space library. Most are communications standards but some are systems and operations including debris, and we're starting to see space traffic management. We have about 13-15 countries involved in these discussions and we have well populated meetings. For anyone who is concerned about any of these things that we've been talking about, get involved now. Don't wait. We need to move ahead.

Open Discussion, Next Steps, and Wrap-Up

- Jim McCabe, ANSI, with moderators/speakers/participants

Mr. McCabe invited participants to weigh in with any comments or questions that had not been raised. He noted that the planning committee for today's event wanted to have time for discussion of where do we take this conversation from here. Comments/questions and responses are noted below.

There was a comment that we're carrying too much of the old space mindset into the current discussions on STM. Reactions to that?

(Dan O.) SPD-3 is our national directive on STM. In assembling a proposal on STCM, the primary international resistance was against our use of the "M" in STM because, internationally, we are a lot further away from getting consensus on management, which implies enforcement, regulations, monitoring, and that sort of thing. So maybe one of the old mindset things is actually only a couple of years old of us referring to this as space traffic management. The first step is to get consensus on how we coordinate the space traffic, how we coordinate the SSA data, how we gather it, exchange it. As mentioned earlier, definitions matter. That's something we need to consider if we want to get consensus internationally. We may need to break these apart and think of space traffic coordination separately from space traffic management.

Do the panelists think we have the right sufficient foreign policy institutions and tools to develop and collaborate on commercial space standards?

(Fred) We have the right organizations involved in establishing positions to take into an international forum. For example, one of the things we've been working on recently is the CONFERS activity where DARPA said this would be nice to go along with the technology development. Industry got together in a consortium and decided what we wanted to take to a standards development organization. The consortium is international but largely U.S. In developing the positions to take forward, we had discussions with different government organizations (e.g., NASA,

DoD). So, the short answer to the question is yes. The more interesting part of the question is who are they and how do we interact. We don't really have rules set up for that but we know that we want to have these different parties involved in these discussions, proper international introduction of concepts, harmonization of terms, and the ability to be open in our discussions with those who are competitors and allies.

What is the status of activities in regards to the Space ISAC and SPD-5?

(Jim Mc.) ANSI released a request for information on behalf of the Space ISAC and the Aerospace Corporation in the context of SPD-5 asking about space cybersecurity standards. We got a good response to that. Thanks to all who responded. ANSI has provided the responses to the Space ISAC and the Aerospace Corporation for further review and analysis. There is a meeting on December 9th of a Space ISAC task group to review those and determine next steps.

The topic of intellectual property (IP) and profitability concerns was raised.

(Jim A.) Maybe this is for a future panel, but our incentive in joining CONFERS was more defensive than it was looking to set standards. We were afraid that the standard setting organization was going to be counterproductive to innovation in the new on orbit servicing and space arenas that standards hadn't yet settled. So, it was more to protect our IP and to make sure that it didn't go in a direction that would hurt our profitability in the long run. As it turns out, it didn't. It was good and we were able to come up with very good, broad operating principles and practices that were way above the specific IP issues, so it was very beneficial. But for a future discussion, you could look at those IP and profitability issues that are driving a lot of the new space companies to look for creative ways to doing the space business.

Some additional audience comments:

- Operators need to be responsible for SSA going forward.
- We need coordination between FAA and NASA to be streamlined and organized.
- How is STM being addressed internationally? The FAA air traffic control model doesn't apply. There are multiple companies providing services, and transparency was stated as most important. What is the future model for STM to avoid collisions for everybody?
- Was the concern about the term "management" authentic or was it a cover for other reasons for resistance? There was concern in the EU about the specific and strong connotations of the term "management." There was an ESPI report (they believe) that expressed the term "coordination" would be preferable for those reasons and some of the reasons that Dan Oltrogge gave. The concept of coordination is related to that of management. The latter inherently raises questions about authority. But the current international and uncertain state of an STM/C framework is not forthcoming on authorities. Therefore, a more fundamental concept and activity is that of coordination, which arguably emphasizes cooperation more so. So, there's a lot of focus on the terms that we use.

Further thoughts and reactions to some of those comments?

(Ruth) When we talk about STM and multiple operators, the focus tends to be on this concept of collision avoidance between one or more maneuverable objects. That's just a small part of the problem that we have in the orbital domain and where standards are necessary. Looking forward – and the Space Sustainability Rating is a very important part of it – what do you have on board that can improve the quality of the environment, including time that you spend out of popular orbits? It's a bigger picture than this sort of SSA collision avoidance that we need to

look at. That includes requirements to deorbit as well as active debris removal because the large part of our debris problem is not from a collision with one or more maneuverable objects. We've seen two near misses in the last 12 months, between two non-maneuverable objects that came within close proximity that could have created a significant debris field. So, without looking at cleanup and deorbit, we're missing big parts of the problem, when we talk about space traffic management.

(Dan O.) We need to look at all aspects of debris remediation, debris mitigation, and collision avoidance, those three legs of space safety. Not sure that space traffic coordination or management includes debris remediation, or mitigation; that maybe falls out of it. It was noted this morning that the Air Force is doing space traffic coordination, not management. That's in the smaller context of the bigger picture of how we get to space safety. In ISO and CCSDS, we are definitely focused on much more than collision avoidance and SSA but also the whole mitigation and remediation piece.

Can we come up with a plan of the key standards we want to create? Who should be involved? What's the schedule to get those standards done? It needs to be done in close coordination with NASA and FAA.

(Dan O.) The first step is exactly what ANSI has assembled here – it's information exchange. At the start of this meeting, policymakers/top decision-makers were talking about the need for standards. It's not clear that at the policy level people know what already exists. This forum is very important because it gives us an opportunity to share standards that already exist, work items that are already in progress, and only then do we need to figure out what more do we need. Then we can figure out how to staff that work and drive it to a published standard.

(Marlon) One of the other things that's come out of this discussion is you can see where there's going to be more or less difficulty from an organizational standpoint in coming to agreements. For example, the whole discussion about space traffic coordination versus management and where the resistance is.

Any key standards gap or opportunities that jumped out at people? We've heard quite a bit today about STM, about the Space Sustainability Rating, projects underway on large constellations, orbital debris mitigation, etc. Anything that resonated as a key takeaway?

(Dan O.) To have a product that reflects the positional predictions/knowledge of the estimated current population takes 12 gigabytes to share uncompressed. We estimate that when we have tracking upgrades and track potentially 10 times more objects than we do today, that figure grows to 120 gigabytes. And that information does not include error estimates, which would probably at least double the size of the product. So, one forward prediction of data products could easily come to 250 gigabytes for one delivery. The point is that we are now really coming to appreciate the importance of data exchange. There's a lot of good work but a lot more we can do to make data exchange easier for the operators and the SSA providers.

Anything that you would like to re-emphasize as a key point from today?

(George) It's not clear that the absence of a particular standard is the top priority. We're hearing consistent themes of "It's time for action" and the need for transparency, the data that we do share needs to be actionable, we need to operationalize policies and procedures, and so forth. The missing piece is a coordinated and blessed government focal point from the U.S. The Commerce Department doesn't yet have the resources that they need from Congress to move out. We need the U.S. government to come to a conclusion so that it can engage more efficiently with the rest of the community. We're doing some great work. There are a lot of people in government who are trying to do their part but it is not yet coordinated as a whole-of-government, whole-of-nation, whole-of-

global-space-community that we need to get to. We need to know where the focal points are, and who can coordinate all the many players who are interested in this very complex subject. Maybe with the new Administration and the Congress, all of us can ensure that there's appreciation for the importance of this issue. And we can get a new gear in terms of what the government role is, and what the responsibilities are of the various players so that we can all work together in an efficient fashion.

(Participant comment) We need to streamline and have good coordination. We have to define a specific set of goals, and the organizational and financial support that we need. For example, we want to make standards for communication, avoidance, flight controls, safety, etc. We need to get the players together and the budget to get it done, if necessary. We don't have a goal, plan, realization, schedule.

There will be a short survey at the end of the event to provide further input. Other thoughts to share?

(George) As we think about what are the next steps and who can do what, NASA has a lot of expertise and capability on the research side. That is something that really isn't practical for the most part in private industry. NASA has so much to contribute in terms of both characterizing the environment and helping the entire community understand what practices might help us going forward. Even though they might not be right in the middle of some of the regulatory issues, they have a lot of capability and we have to make sure that they can be included in the overall effort.

Is there interest in holding more of these information sharing meetings related to the growth of the commercial space industry? If so, what topics would people want to see covered?

- Yes, to more events, if they are more highly targeted and shorter.
- SPD-5 and cybersecurity space standards is a possible topic.
- Standards that an operator may choose or want to employ for mission assurance and financial sustainment may be quite different from what a country wants to adopt from a sustainability perspective. That can get lost in the standards discussion.

Is there interest in discussing human spaceflight practices, launch safety, spaceports, and other topics that we didn't really cover today?

- For the next meeting, can we call in FAA and NASA and get their inputs on what they think are high priorities and how we can coordinate between NASA research capabilities and FAA practical needs for operations? Then converge with results that will be fairly well defined.
- Our next step might be to have a smaller committee look at different elements. That could lead to maybe more coordinated planning. Maybe something on a smaller scale than an information sharing event like this. Look at specific standards and organizations that are dealing with those and when standards might be developed.
- If attendees have questions about how/where to participate, ANSI can put you in touch with folks.
- Colonel Hernandez mentioned an important need regarding operational practices that signal intent on orbit to help distinguish hostile versus non-hostile intent. Another good discussion is how to address actively controlled satellites that are signaled as a potential conjunction (a TCAS for space vehicles).
- What's the scope of STM? Are there other layers of standardization? SSA? Debris?
- On the government side, there could be a whole government team addressing things from their perspective.

- (Fred) For a lot of folks, it would be very educational to participate in a discussion on a specific standard and its development process. A lot of folks talk about standards but haven't been part of the discussion.
- ANSI does offer online classes to help educate the community on what's involved in developing standards, particularly those that go through the American National Standards process.
- There is an open invitation for people to participate in ASTM Technical Committee F47 on Commercial Spaceflight. SDOs across the board welcome and invite new subject matter experts to participate in standards setting.

Mr. McCabe thanked everyone for participating. Please reach out with other suggestions by email to jmccabe@ansi.org. There is a brief survey after we conclude to get input on anything that ANSI could do better or differently next time.

Meeting Participants

First Name	Last Name	Title	Company
Michael	Barton	Sales Manager	A.I. Solutions, Inc.
Brandon	Bailey	Space Cyber Guy	Aerospace Corporation, The
Patrick	Bauer	Systems Director	Aerospace Corporation, The
Lori	Gordon	Civil Systems Protection Leader	Aerospace Corporation, The
Beth	Scruggs	Engineer	Aerospace Corporation, The
Marlon	Sorge	Principal Engineer	Aerospace Corporation, The
Ryan	Speelman	Director- Cyber Security Subdivision	Aerospace Corporation, The
Gradimir	Radovanovic	Consultant	Aerospace Engineering Solutions International
Chris	Carnahan	AVP	Aerospace Industries Association
Ilsa	Mroz	Miss	Aerospace Industries Association
Ruth	Stilwell	Executive Director	Aerospace Policy Solutions LLC
Amjad	Soomro	Sr. Computer Engineer	AFRL
Elena	Vellutini	Dr.	Agenzia Spaziale Italiana
Rick	Creighton	Safety Director	AH Beck Foundation Co. Inc
Mike	French	VP	AIA
Heather	Brennan	Managing Director, Publications	AIAA
Steve	Sidorek	Director, Public Policy and Government Relations	AIAA
Nick	Tongson	Director, Standards	AIAA
David	Vondle	Partner	Akin Gump Strauss Hauer & Feld
Cory	Sanicky	Researcher	Aldrin Space Institute
Vivek	Vittaldev	Sr. Flight Dynamics Engineer	Amazon
Kelsie	Krafton	John N. Bahcall Public Policy Fellow	American Astronomical Society
Joe	Bhatia	President & CEO	American National Standards Institute

Anne	Caldas	Sr. Director, PSA	American National Standards Institute
Stephanie	Carroll	Sr. Meeting and Event Mgr	American National Standards Institute
Kelley	Cox	Director Business & Membership Development	American National Standards Institute
Beth	Goodbaum	Communications Specialist	American National Standards Institute
Michelle	Maas-Deane	Director, Homeland Defense and Security Standardization Collaborative (HDSSC)	American National Standards Institute
Priscilla	Magee	Consumer Outreach Manager	American National Standards Institute
Jim	McCabe	Senior Director, Standards Facilitation	American National Standards Institute
Mary	Saunders	Vice President for Government Relations	American National Standards Institute
Fran	Schrotter	Sr. VP & COO	American National Standards Institute
Melissa	Wylie	Program Administrator, Standards Facilitation	American National Standards Institute
Jana	Zabinski	Director, Communications	American National Standards Institute
Jay	Schwartz	Software Engineer	AMSAT-NA
Lane	Hallenbeck	Executive Director	ANAB
Keith	Klemm	Senior Accreditation Manager	ANAB
Andre	Lacroix	Central Quality, Norms and Standards	ArianeGroup
Sam	Buckwalter	Engineer	ARINC IA
Jim	Armor	Founder/CEO	Armor Group, LLC, The
Afina	Lupulescu	Senior Product Developer	ASM International
Warren	Adams	Director	ASME
Allyson	Byk	Director, Nuclear Codes and Standards	ASME
Angela	Peura	NASA SCaN Policy	ASRC Federal
Katerina	Koperna	Technical Comm Manager	ASTM International
Brian	Meincke	VP	ASTM International
Leonard	Morrissey	Director, Global Business Development and Strategy	ASTM International
Matthew	Pezzella	Manager, Government and Industry Affairs	ASTM International
Craig	Updyke	Director, Global Policy	ASTM International
Lissy	Velez	Program Manager	ASTM International
Jon	Fifield	Chief Engineer	Astronics AES

Taylor	Mcphail	Communications Manager	Astroscale
Luc	Riesbeck	Space Policy Research Analyst	Astroscale
Madison	Walker	Policy Intern	Astroscale
Charity	Weeden	VP, Global Space Policy	Astroscale
Brian	Daly	Assistant Vice President	AT&T
Peter	Musgrove	Lead Member of Technical Staff	AT&T
Rick	Garceau	Senior Associate	Aviation Management Associates, Inc.
Chris	Kunstadter	Global Head of Space	AXA XL
Brian	Harvey	Tech Management	BA & Associates
Audrey	Allison	Vice-President, Global Spectrum Management	Boeing Company, The
Lawrence	Brase-Jr	Technical Fellow	Boeing Company, The
Joy	Fitzpatrick	External Standards Lead	Boeing Company, The
Matt	Jones	Director, Space & Advanced Technology	Boeing Company, The
Austin	Roe	Data Security Architect	Boeing Company, The
Eliza	Weber	Engineer	Boeing Company, The
Daniel	Bartlett	Analyst	Booz Allen Hamilton
Ken	Hailston	Dr.	Booz Allen Hamilton
Gerry	Simon	Chief Architect	Braxton
Jackie	Smithson	CSI	Broken Arrow Police Department
Jose	Ocasio-Christian	Chief Executive Officer	Caelus Partners
Tom	Fahy	CEO	Capitol Meteorologics
Vesselin	Vassilev	Dr.	CASTRA
Ines	Alonso	Ms.	CDTI
Tim	Maclay	CEO	Celestial Insight, Inc.
Darren	Mcknight	Technical Director	Centauri
Frank	Löber	Director	CGI
Tracie	Clifford	Instructor	Chattanooga State Community College
Jim	Snodgrass	Sr. Account Exec	Cimquest
Brad	Taras	Product Manager	Cinch
Juan-Carlos	Dolado Perez	Mr.	CNES
Pascal	Faucher	Defense and security	CNES
Steve	Nagy	Senior Management Analyst	Cognosante
Matt	Garrett	QAE	Coherent Inc
Mingwei	Wang	Project Manager	COMAC America
George	Nield	President	Commercial Space Technologies, LLC
Mercedes	McPhee	Policy Analyst	Commercial Spaceflight Federation

Dan	Oltrogge	Director, CSSI and Integrated Operations	COMSPOC Corporation
Bryan	Mckernan	Chief Revenue Officer	Consortiq LLC
David	Van Der Merwe	PhD Candidate	CUT
Paulo	Sakai	Dr.	DCTA IAE
Jesse	Chambers	General Engineer	Department of Defense
Bill	Shores	SETA Contractor	Department of Defense
Marc	Becker	Mr.	DLR
Regina	Peldszus	Dr.	DLR
Sabine	Philippmay	Dr.	DLR
Mark	Daley	Deputy for Operations	DOC Office of Space Commerce
Diane	Howard	Chief Counsel for Space Commerce	DOC Office of Space Commerce
Kevin	O'Connell	Director	DOC Office of Space Commerce
Alexandre	M C Dutra	Technical/Commercial Director	Dutra e Associados Consultoria Aeronáutica e Projetos Aeroportuários
Darren	Hamilton	Director - Space Systems Engineering	EchoStar Satellite Services L.L.C.
Sergiu	Marzac	Technical Programme Manager	EUROCAE
Anna	Von Groote	Director Technical Programme	EUROCAE
Michel	Margery	Policy Officer	European Commission
Rodolphe	Munoz	Legal officer	European Commission
Sylvie	Espinasse	Head of the ESA Washington Office	European Space Agency
Charles	Galland	Policy Officer	Eurospace
Samantha	Bennett	Risk Manager	ex GE
Marcus	Bever	Astrodynamics Engineer	ExoAnalytic Solutions
Clinton	Clark	Vice President	ExoAnalytic Solutions
Brien	Flewelling	Chief SSA Architect	ExoAnalytic Solutions
Steph	Earle	Acting Deputy Division Chief	FAA
Ryan	Fowler	HazMat Safety Inspector	FAA
Tara	Halt	Program Analyst	FAA
Alanna	Randazzo	Manager of Research	FAA
Dorie	Resnik	Aerospace Engineer - Structures	FAA
Glenn	Rizner	Senior Technical Advisor	FAA
Chris	Sweet	UAS HazMat Inspector	FAA
Lacey	Thompsin	Research Analyst	FAA
John	Vanhoudt	Senior Staff Engineer	FAA
Emil	Cherian	Senior Advisor, Space Communications Resilience	FCC
Karl	Kensinger	Acting Division Chief	FCC

Peter	Trachtenberg	Attorney-advisor	FCC
Janet	Ge	Director	Flexport
Kevin	Hardy	Risk Management Program Inspector	Florida Division of Emergency Management
Colin	Alberts	Vice President	Freedom Technologies Inc.
R	Tomes	Adjunct	Georgetown University
Charlie	Sasser	Senior Officer	Georgia Technology Authority
Andy	Updegrove	Founding Partner	Gesmer Updegrove LLP
Jose Miguel	Lozano	Vice President Space	GMV Innovating Solutions Inc
Matthew	Bloise	Product Analyst	Greene Tweed
Tim	Greene	Platform Manager	Greene Tweed
Daniel	King	Research Engineer	Greene Tweed
Travis	Mease	Product Manager	Greene Tweed
Ira	Mcdonald	President / Software Architect	High North Inc
Tommy	Gardner	Chief Technology Officer, HP Federal	HP Inc.
Herbert	Zucker	Member	HR-ZTECH, LLC
Tali	Nir	Certification Manager	IAI
Eno	Siewerdt	Air Nav Services Expert	ICAO TCB PER17801
Michael	Boyles	Trade Specialist	International Trade Administration
Kevin	Doyle	International Trade Specialist	International Trade Administration
David	Bergman	VP Standards	IPC International
Chris	Jorgensen	Director Technology Transfer	IPC International
Ryan	Shepperd	Member of the technical Staff	Iridium
Ben	Greene	Senior Scientist	Jacobs Technology Inc.
Akira	Akiyoshi	Standardization Specialist	Japanese Standards Association
Bear	Afkhami	Director of Innovation & Development	JMA Solutions, LLC
Sami	Asmar	Manager of Strategic Partnerships	JPL (Caltech/NASA)
Linda	Karanian	President	Karanian Aerospace Consulting, LLC
Ilias	Gkotsis	Mr.	KEMEA
Takahiro	Mohri	Senior Manager	KONICA MINOLTA, INC.
Austin	Beer	Software Engineer	Kratos
Kameron	Simon	Engineer	Kratos
Shelby	Coon	Senior Market Manager, Industrial	L.A.B. Industries
Shohini	Sen-Britain	Postdoctoral Researcher	Lawrence Livermore National Lab
Daniel	Ceperley	CEO	LeoLabs, Inc.
Alan	Declerck	VP, Bus Dev & Strategy	LeoLabs, Inc.
Dawn	Beyer	Senior Fellow	Lockheed Martin

Timothy	Cichan	Space Exploration Architect	Lockheed Martin
Bradley	Claus	S2E2 Chief Engineer	Lockheed Martin
Kathleen	Hohenadel	Program Director	Lockheed Martin
George	Moran	Chief Engineer	Lockheed Martin
Scott	Richardson	Senior Manager	Lockheed Martin
David	Martel	UAS Coordinator	LVMPD
Chuck	Hulme	Director, Spacecraft Management	Maxar Technologies
Mike	Dyman	Sr. Engineer, S&MA	MDAA
Jared	Stout	Director, Congressional and Regulatory Policy	Meeks, Butera & Israel
Danielle	Wood	Director, Space Enabled Research Group	MIT Media Lab
Martin	Faga	Consultant	MITRE
Tom	Heimbach	Systems Engineer	MITRE
William	Jones	Dr.	MITRE
Ed	Olechna	Communications Engineer	MITRE
Theresa	Suloway	Engineer	MITRE
Aaron	Temin	Principal Cybersecurity Engineer	MITRE
Karina	Drees	CEO	Mojave Air & Space Port
Kush	Meenawat	Entrepreneur	N/A
Robert	Rovetto	Mr.	N/A
Zheng	Tao	Senior Project Manager / Systems Engineer	N/A
Alfredo	Colon	Engineer	NASA
Paul	Gill	Manager, NASA Technical Standards Program	NASA
Scott	Hull	Orbital Debris Engineer	NASA
Tupper	Hyde	Chief Engineer	NASA
J.-C.	Liou	Chief Scientist for Orbital Debris	NASA
David	Murakami	Researcher	NASA
Lauri	Newman	Conjunction Assessment Risk Analysis Manager	NASA
James	Schier	Chief Architect, Space Communications and Navigation	NASA
Dan	Smith	Data Standards Manager	NASA
Daniel	Wentzel	Project Manager	NASA
Erin	Miller	VP of Operations for Space ISAC	National Cybersecurity Center
Stephen	Ganoe	Engineer	National Fire Protection Association

Seth	Statler	Director of Government Affairs	National Fire Protection Association
Curtis	Hernandez	Director, National Security Space Policy	National Space Council
Kevin	John Vargas	Mr.	NAVFAC EXWC
Jaleesa	Needham	Project Manager/Engineer Team Lead	NAVSEA
Whitney	Jones	Executive Assistant	NCC Space ISAC
Scott	Crynock	Senior Project Engineer/PM	NCDMM / America Makes
Andrew	Nelson	President	Nelson Aerospace Consulting Associate
Vladimir	Murashov	Senior Scientist	NIOSH
Jason	Boehm	Director Program Coordination Office	NIST
Gordon	Gillerman	Director, SCO	NIST
Jennifer	Marshall	Program Manager for Public Safety Standards Coordination	NIST
Dianne	Poster	Senior Advisor	NIST
Nai-Yu	Wang	Senior Research Engineer	NOAA NESDIS
Darwyn	Banks	NRO Mission Assurance Executive	NRO
Suleman	Shafqat	Mr.	NUST
Muhammad	Suleman Shafqat	Mr.	NUST
Chris	Leck	Deputy Head	Office for Space Technology & Industry, Singapore
Andrea	Jaime	Business Development Manager	OHB SE
Séverine	Jacquet	Business Development Manager	OHB System AG
Fred	Judson	Director	Ohio UAS Center
Jessy Kate	Schingler	Dir Policy and Governance	Open Lunar Foundation
Juno	Woods	Director of Engineering Research & Strategy	Open Lunar Foundation
Simon	Johnson	CEO	OpenStratosphere
Ryan	Benson	Mr.	Paragon Space Development Corporation
Colby	Harper	CEO	Pathfinder Wireless
Nicolas	Puzenat	Project Manager	PCM
Mike	Safyan	VP of Launch & Regulatory Affairs	Planet Labs Inc.
Jesse	Boyer	Fellow--Additive Mfg	Pratt & Whitney (Raytheon Technologies)
Shawn	Linam	CEO	Qwaltec, Inc.
Ron	Kohl	President (Ret)	R J Kohl & Assoc

Rick	Podliska	Senior Policy Advisor	Rep. Bill Posey
Robert	Sikon	Retired	Retired
Sami	Mian	Chief Technology Officer	Rizse
Kathiravan	Thangavel	Student	RMIT UNIVERISTY
Madalina	Trelia	Assistant Researcher	Romanian Space Agency
Al	Secen	VP Aviation Technology and Standards	RTCA, Inc.
Pete	Doty	VP, Operations COE	SAE International
Logen	Johnson	Aerospace Engineer	SAE International
Mike	McNair	Vice President - Aerospace	SAE International
Judith	Ritchie	Director, Government & Industry Affairs - Aerospace	SAE International
Lisa	Spellman	Executive Director	SAE International
Alan	Adair	Mr.	Safran Data Systems
Thierry	Balanche	Sales Director	Safran Data Systems
David	Day	Chief Compliance Officer	Sagetech Avionics, LLC
Michael	Maloney	Founder	Satellite Design for Recovery
Therese	Jones	Senior Director of Policy	Satellite Industry Association
Brian	Weeden	Dr.	Secure World Foundation
Vincent	Brown	Counsel	Senate Rules Committee
Christopher	Allison	Sr. Systems Engineer	Sierra Nevada Corp. Space Systems Group
Eylon	Sorek	CEO	SkyX Solutions Inc
Itzik	Turkel	CTO	SkyX Solutions Inc
Carole	Mattessich	Director	Smart Airports + Aviation Partnership (managed by National Institute of Aerospace)
Frederick	Slane	Executive Director	Space Infrastructure Foundation
Cary	Hardy	Membership Manager	Space ISAC
Andre	Dupuis	President / CEO	Space Strategies Consulting Ltd
Jeff	Foust	Senior Staff Writer	SpaceNews
Marcia	Smith	Editor	SpacePolicyOnline.com
Rachael	Tompa	Engineer	SpaceX
John	Treires	Director of Sales, DoD	Spire
Conor	Brown	Director of Sales Engineering	Spire Global - Federal
Jeremy	Bennington	VP, PNT Assurance	Spirent Communications
Dustin	Young	Product Development Manager	SSPC
Jon	Gustafson	Senior Principal	Stantec
Christophe	Hamel	CEO	Studio Aerospace LLC
Benoit	Curdy	Digital Transformation	Swiss Federal Office of Civil Aviation
Chuck	Dickey	Principal	TCTB, LLC
Tim	Douglas	Manager, Flight Dynamics Operations	Telesat

Kangfei	Gan	Mr.	Telesat
Jason	Parker	Sr. Flight Dynamics Engineer	Telesat
Islam	Hussein	Vice President	Thornton Tomasetti
Rob	Leibrandt	Vice President	Trace it, LLC
Lisa	Loucks	President	T-Zero Spaceflight Services, LLC
Moritz	Holst	Aerospace Specialist	U.S. Commercial Service
Brandon	Tabata	Co-Project Coordinator	UCR-UAS
Angela	Katz	Plastics Segment Leader - Global	UL LLC
Kenneth	Vessey	Senior Staff Engineer	UL LLC
Vernon	Thorp	Director, Commercial Sales	ULA
Kalpa	Henadhira	Mr.	UMass Lowell
Fabrizio	Barberis	Dr.	Universita' degli Studi di Genova
Bob	Arlen	Researcher	University of California, Davis
Olga	Bannova	Research Professor	University of Houston
Supriya	Chakrabarti	Director, LoCSST	University of Massachusetts
Tony	Hallett	CEO & Cofounder	Unmanned Response
Michelle	Dina	Director of Education	Unmanned Safety Institute, Inc.
Kim	Cardosi	Dr.	US DOT/Volpe Center
Jeff	Braxton	Chief Analyst	US Space Command
Jessie	Newman	Intern	Velocity Government Relations
Lindsay	Atherton	GR	Velos
Tylor	Cingle	GR Associate	Velos
Hilary	Cohen	Associate	Velos
Shawn	Williams	Mr.	WEG, LLC.
Christopher	Bair	Associate	Wilkinson Barker Knauer
Lynne	Montgomery	Partner	Wilkinson Barker Knauer
Jason	Dallman	Senior Staff Software Engineer	Woodward
Gregory	Kuniansky	Sr. Staff Software Engineer	Woodward
Qassim	Abdullah	VP & Chief Scientist	Woolpert
Gael	Le Bris	Sr. Technical Principal	WSP USA
Seshu	Kiran	Founder/CEO	XAIR