SPACE TRAFFIC MANAGEMENT: HOW TO PREVENT A REAL LIFE "GRAVITY"

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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May 9, 2014

SPACE TRAFFIC MANAGEMENT: HOW TO PREVENT A REAL LIFE "GRAVITY"

FRIDAY, MAY 9, 2014

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:07 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Mo Brooks [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
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EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

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Subcommittee on Space

Space Traffic Management: How to Prevent a Real Life "Gravity"

Friday, May 9, 2014
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Lt Gen. John "Jay" Raymond, *Commander, 14th Air Force, Air Force Space Command; and Commander, Joint Functional Component Command for Space, U.S. Strategic Command*

Mr. George Zamka, *Deputy Associate Administrator, Office of Commercial Space Transportation, Federal Aviation Administration*

Mr. Robert Nelson, *Chief Engineer, International Bureau, Federal Communications Commission*

Mr. P.J. Blount, *Adjunct Professor, Air and Space Law, University of Mississippi School of Law*

Mr. Brian Weeden, *Technical Advisor, Secure World Foundation*

U.S. House of Representatives
Committee on Science, Space, and Technology

Space Traffic Management: How to Prevent a Real Life 'Gravity'

CHARTER

Friday, May 9, 2014
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

At 10:00 am on Friday, May 9, 2014, the Space Subcommittee will hold a hearing titled "Space Traffic Management: How to Prevent a Real Life 'Gravity'." There are currently three agencies that play a primary role in tracking and mitigation of orbital debris that may be hazardous to operational satellites or life and property on Earth, if the debris is large enough upon reentering the Earth's atmosphere. The Joint Functional Component Command for Space (JFCC SPACE), part of the Department of Defense, is responsible for tracking orbital debris, the Federal Communications Commission (FCC) asserts jurisdiction for mitigating orbital debris from satellites, and the Federal Aviation Administration (FAA) regulates orbital debris from launch and reentry activities. This hearing will explore the roles and responsibilities of the Department of Defense, FAA, and FCC in policing orbital debris, what authorities are currently granted by Congress to federal agencies, and how they coordinate these activities.

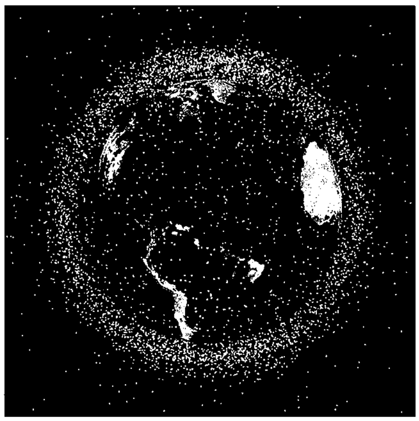
Witnesses

- **Lt. Gen. John "Jay" Raymond** – Commander, 14th Air Force, Air Force Space Command; and Commander, Joint Functional Component Command for Space, U.S. Strategic Command
- **Mr. George Zamka** – Deputy Associate Administrator, Office of Commercial Space Transportation, Federal Aviation Administration
- **Mr. Robert Nelson** - Chief Engineer, International Bureau, Federal Communications Commission
- **Mr. P.J. Blount** – Adjunct Professor, Air and Space Law, University of Mississippi School of Law
- **Mr. Brian Weeden** – Technical Advisor, Secure World Foundation

Background

Recently, concerns about the dangers presented by orbital debris have intensified due to China's anti-satellite test in 2007, and public awareness of the problem increased due to the popular movie *Gravity* released last fall. The growth of the orbital debris population in key orbits around the Earth presents a series of challenges for the United States and other spacefaring nations. Debris can be caused by any number of things and can range in size from a couple centimeters to entire satellites. Each object, no matter its size, poses a threat to our assets in space and to the safe transport of humans and payloads in low-Earth orbit and beyond. Objects, as small as a paint fleck at extremely high relative velocities (approximately 17,500 miles per hour), can cause damage.[1]

At least two major space debris incidents have occurred since 2000. First is the collision between Iridium-33, a commercial communications satellite, and Kosmos-2251, a decommissioned Russian military communications satellite.[2] The collision happened at approximately 26,170 mph and is described as a "hypervelocity collision."[3] It is believed that this incident alone caused over 2,000 pieces of debris.[4]



Map of known hazardous objects in LEO. Credit: NASA's Orbital Debris Program Office

The second major incident was China's test of an anti-satellite or ASAT weapon in 2007. This test was meant to demonstrate the capability to destroy a satellite with a kinetic weapon. This test created the largest single debris event in history.[5] To date, nearly 3,400 pieces of debris associated with this event have been cataloged. According to NASA's Orbital Debris Program Office this debris ranges in size from 5 cm to nearly a meter.[6]

The JFCC currently tracks approximately 23,000 objects in orbit around the Earth. These include 4,000 payloads, of which 1,200 are active.[7]

Joint Functional Component Command for Space

Data gathered by various radar and electro-optical sensors from around the world as well as space-based sensors used to track orbital debris are integrated by JFCC SPACE located at Vandenberg Air Force Base in California. JFCC's mission is largely focused on space situational awareness (SSA).

[1] "Space Debris and Human Spacecraft" retrieved on May 3, 2014. http://www.nasa.gov/mission_pages/station/news/orbital_debris.html#.U2ecJ1c9VZg

[2] "U.S. Satellite Destroyed in Space Collision" http://www.space.com/5542-satellite-destroyed-space-collision.html

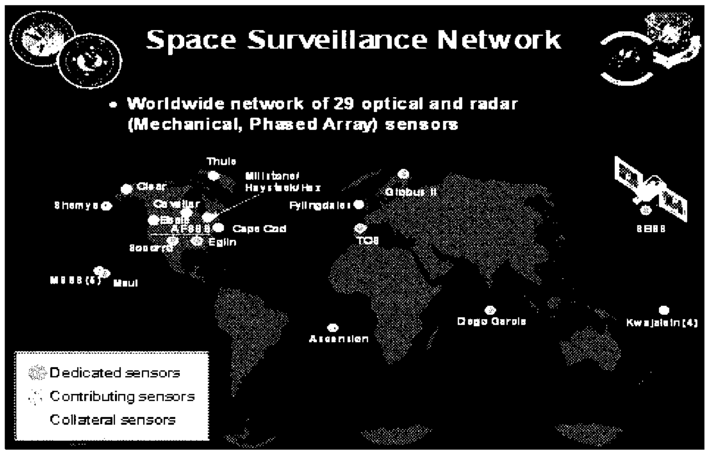
[3] "Satellite Collision Leaves Significant Debris Clouds" – NASA Orbital Debris Program Office http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv13i2.pdf

[4] "International Space Station Again Dodges Debris" – NASA Orbital Debris Program Office http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv15i3.pdf

[5] Fengyun-1c Debris cloud Remains Hazordous" - NASA Orbital Debris Program Office http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv18i1.pdf

[6] *Ibid.*

[7] Briefing from JFCC staff to Committee Staff, April 10, 2014.



Credit: http://www.stratcom.mil/factsheets/11/Space_Control_and_Space_Surveillance/

There are four types of sensors used for SSA; they include phased array radar, conventional radar, electro-optical sensors, and space-based sensors. The data from these sources is integrated and used to provide characterization and predictive data that can help satellite operators avoid collisions.

When JFCC detects a possible close approach, it issues a conjunction summary to inform satellite operators. Approximately 1,400 warnings are issued each day.[8] Once the warning is issued, JFCC has no authority to require an operator to take any evasive action. The decision to move or not move a satellite is left solely to the discretion of the operator. In the case of commercial satellites, this is often a complex decision that involves considerations beyond the creation of orbital debris. In this regard, there is no "traffic cop" in the orbital space environment with regulatory authority to direct satellite operators to move their satellites to avoid a potential collision. It is the sole discretion of the satellite operator to weigh the risks of such maneuvers.

JFCC currently has agreements with 41 commercial entities to share tracking data on assets in orbit and four sharing agreements with allied countries including Australia, Italy, Japan, Canada, and France.[9] In addition to government tracking and SSA efforts, in 2009 a group of the largest satellite operators formed the Space Data Association (SDA) to "support the controlled,

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[8] Written Testimony of Lt Gen. John W. "Jay" Raymond before the House Armed Services Subcommittee on Strategic Forces, April 3, 2014.
http://www.airforcemag.com/testimony/Documents/2014/April%202014/040314raymond.pdf

[9] *Ibid. 7*

reliable and efficient sharing of data that is critical to the safety and integrity of satellite operations."[10]

The SDA works to coordinate the movements of various satellites controlled by the operators that participate in the consortium. This provides the members with advanced warning when a satellite moves from one position to another, key information to which JFCC does not currently have access. JFCC can only predict a particular orbit and position based on orbital mechanics and observations from sensors. If an SDA member were to maneuver their satellite, JFCC would recognize the change, but would not have had advanced warning of it.

Federal Communications Commission

In October of 2005, the FCC announced that all current and future applicants for a license to operate a "space station"[11] of any kind would need to submit a debris mitigation plan to the commission within 30 days of the announcement. The plan required is highly technical in nature and must addresses spacecraft hardware design, minimizing accidental explosions, safe flight profiles, and post-mission disposal. The debris mitigation plan is submitted as part of the license application packet used by FCC to grant licenses to radiate, or transmit, to ground stations.

Prior to this rulemaking action, the FCC had only addressed orbital debris in a cursory manner, but never directly commented on the breadth of its authority to regulate it. The Notice of Proposed Rulemaking (NPRM) issued on March 18, 2002 addressed the question of whether or not the FCC had the statutory authority to regulate orbital debris.[12] In the Second Report and Order issued on June 21, 2004, FCC concluded in response to comments on its statutory authority to regulate that:

> *...adoption of the debris mitigation measures in this Second Report and Order is consistent with our authority and public interest obligations under the Communications Act.... The Communications Act provides the Commission with broad authority with respect to radio communications involving the United States, except for communications involving U.S. government radio stations. The Act charges the FCC with encouraging "the larger and more effective use of radio in the public interest," and provides for licensing of radio communications upon a finding that the "public convenience, interest, or necessity will be served thereby." ... Because orbital debris could affect the cost, reliability, continuity, and safety of satellite operations, orbital debris issues have a bearing upon the "larger and more effective use of radio in the public interest." .... Thus, orbital debris and related mitigation issues are relevant in determining whether the public interest would be served by authorization of any particular satellite system, or by any particular practice or operating procedure of satellite systems.*[13]

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[10] Space Data Association. Retrieved on May 5, 2014. http://www.space-data.org/sda/about/sda-overview/
[11] In the FCC regulations, any object in space that is transmitting on spectrum to a ground station is referred to as a "space station."
[12] Notice of Proposed Rulemaking, March 18, 2002. IB Docket No. 02-54, FCC 02-80; Section III, Subsection A., Paragraph 30. http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-02-80A1.pdf
[13] Second Report and Order, June 21, 2004. IB Docket No. 02-54, FCC 04-130; Section III, Subsection A., Paragraph 12. http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-130A1.pdf

While there is certainly a public interest to mitigate orbital debris in a manner that is consistent with the effective and efficient use of public resources, such as the radio spectrum, it is unclear that the FCC is the appropriate regulatory agency to ensure orbital debris mitigation practices are consistent with public safety and traffic management needs. Additionally, Congress has never granted FCC the specific authority to regulate orbital debris. The agency interpreted the broad nature of the Communications Act of 1934[14] as the basis for its regulations, rather than explicit authorization from Congress.

Federal Aviation Administration

As part of its statutory authority to regulate launch and reentry of commercial launch vehicles, the FAA's Office of Commercial Space Transportation has set regulations in place that govern orbital debris mitigation caused by the transportation of a payload to orbit. These regulations require that: "There will be no unplanned physical contact between the vehicle or its components and payload after payload separation and debris generation will not result from conversion of energy sources into energy that fragments the vehicle or its payload. Energy sources include, but are not limited to, chemical, pneumatic, and kinetic energy."[15]

The National Space Transportation Policy released on November 21, 2013, directed the FAA to "execute exclusive authority, consistent with existing statutes and executive orders, to address orbital debris mitigation practices for U.S.-licensed commercial launches, to include launch vehicle components such as upper stages, through its licensing procedures."[16] This is generally consistent with current practice for the FAA. While the policy did not represent a departure from the status quo, testimony given by Dr. George Nield, Associate Administrator for Commercial Space Transportation before the House Science, Space, and Technology Committee's Subcommittee on Space demonstrated that FAA was seeking additional regulatory authority with regards to space traffic management.

In testimony before the Committee on February 4th, Dr. Nield stated, "The FAA has begun a dialogue with its stakeholders to explore the need for adjustments to the FAA's statutory authority with the advent of commercial on-orbit space transportation….As the prospects for a greater number of commercial transportation vehicles in space increase, it is time to consider closing the current regulatory and safety gap between launch and reentry."[17] Further, Dr. Neild observed that collisions between orbital debris and spacecraft "pose serious safety risks to persons and property in space and the safe operations of orbital systems"[18] and that "the FAA believes it is time to explore orbital safety of commercial space transportation under the Commercial Space Launch Act licensing regime."[19]

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[14] The Notice of Proposed Rulemaking (02-80, Paragraph 30) cites 47 U.S.C. § 303 as the mandate for regulating orbital debris. The section requires the FCC to encourage "the larger and more effective use of radio in the public interest." http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-02-80A1.pdf

[15] FAA Regulations § 431.43 (c)(3)

[16] National Space Transportation Policy. November 21, 2013. Retrieved on May 4, 2014 at http://www.nasa.gov/sites/default/files/files/national_space_transportation_policy_11212013.pdf

[17] Testimony before the House Committee on Science, Space and Technology, Subcommittee on Space, February 4, 2014. Page 3. http://science.house.gov/sites/republicans.science.house.gov/files/documents/HHRG-113-SY16-WState-GNield-201400204.pdf

[18] *Ibid.*, p. 4.

[19] *Ibid.*

The Commercial Space Launch Act does not explicitly address orbital debris mitigation or space traffic management, and it is unclear how this type of expansion of the FAA's statutory authority might be implemented. Additionally, experts who have testified before the Committee on this topic have disagreed. At the same hearing, Dr. Henry Hertzfeld testified that the FAA should, "clearly be defined and preferably limited to those issues directly related to launching and reentry."[20]

Important Questions for Congress

- Is there a need for a "space traffic cop" with regulatory authority to direct satellite operators to maneuver satellites in situations where collision with orbital debris is highly likely? Or, are the current roles and responsibilities for federal agencies adequate?
- If a space traffic cop is needed, what federal agency is best suited for that role and responsibility?
- Is there a need to designate one particular agency to regulate orbital debris, or is a fragmented and specialized system more reasonable?
- What authorities are necessary to limit orbital debris and mitigate its impact?
- What international obligations does the United States need to take into account when designing a regulatory framework for space traffic management?
- How can the federal government support private sector initiatives such as the efforts of the Space Data Association?

[20] Testimony before the House Committee on Science, Space and Technology, Subcommittee on Space, February 4, 2014. Page 3. http://science.house.gov/sites/republicans.science.house.gov/files/documents/HHRG-113-SY16-WState-HHertzfeld-20140204.pdf

Chairman BROOKS. The Subcommittee on Space will come to order. Good morning. Welcome to today's hearing titled,"Space Traffic Management: How To Prevent A Real Life 'Gravity'". In front of you are packets containing the written testimony, biography, and truth in testimony disclosure for today's witnesses. Before I begin my opening statement, let me say that the topic we are discussing is one that I know is of great interest to Chairman Steve Palazzo, and he would be here leading the discussion today if he had not been pulled away by the death of a close friend this week. I also understand he will be including a statement for the record. I would like to offer my condolences to him and his family during this time. I recognize myself for five minutes for an opening statement.

The focus of this hearing is how to prevent a real life "Gravity". As was imaginatively portrayed by Hollywood last year, the threat of debris in key orbits around the Earth is a very real and serious issue. While the movie elevated orbital debris to the forefront of the public's attention, this Committee is no stranger to the topic. Today we will continue assessing the key questions involved in space traffic management, and what Congress may do to ensure the safety and security of the space environment.

There are two important facets of this discussion. The first is an assessment of what we are doing right now to track and mitigate orbital debris. The second is what more needs to be done without burdening the space industry with unnecessary bureaucratic hurdles to success. At present, the Joint Functional Component Command for Space, or JFCC Space, is tracking approximately 23,000 objects in orbit around the Earth, including 4,000 payloads, of which 1,200 are active. The current systems available for tracking cannot detect objects smaller than four inches in size. This means we can't track a fleck of paint traveling at 17,500 miles an hour, which in and of itself, although small, can cause serious damage.

The Chinese anti-satellite test in 2007 demonstrated just how volatile the space environment can be. This test resulted in the largest creation of debris in history. So far, almost 3,400 individual objects associated with this event have been catalogued, and the list is still growing. Additionally, in 2000, the collision of a decommissioned Russian communication satellite, dubbed Kosmos-2251, and an active U.S. Communications satellite called Iridium-33 created a debris field that resulted in over 2,000 pieces of debris. Combined, these two events account for almost a quarter of all the objects that JFCC is tracking.

While tracking existing debris is obviously key to this discussion, we must also focus on preventing the proliferation of these objects in the first place. There are two key agencies involved in the mitigation of debris, the Federal Aviation Administration, and the Federal Communications Commission. Both of these agencies have developed regulations specific to the creation of orbital debris, and I am eager to hear from them today.

The FAA is responsible for the mitigation of debris as it pertains to launch and reentry of transportation vehicles. The National Space Transportation Policy released in November of 2013 directed the Department of Transportation to execute exclusive authority over these activities. While this was not a change in the status quo, Dr. George Nield, Associate Administrator for Commercial Space Transportation at the FAA, testified before this Subcommittee that his agency was ready to start a larger discussion on an expansion of their authority to regulate on orbit activities. It is unclear what specific authority the FAA is asking for, and how it would anticipate working with other agencies to implement this authority. Regardless of the Administration's plans, Congress will need to carefully weigh the costs and benefits of increased authority for the FAA against the possible overregulation of a still very young industry.

In 2005, the FCC asserted jurisdiction to regulate orbital debris from commercial satellites which require their licenses for the use of spectrum. The Commission based this assertion largely on the broad mandate in the Communications Act of 1934 to encourage "the larger and more effective use of radio in the public interest." Although Congress has not provided authority for this type of regulation explicitly, there seems to be some ambiguity in the nature of their mandate to utilize the spectrum effectively and efficiently.

The efforts of Federal agencies should be viewed within the context of separate international and private sector efforts. The United States has the most advanced space situational awareness system in the world, but tracking and cataloging the space environment more effectively may come from key partnerships. We cannot afford to ignore these important partners.

As commercial human spaceflight increases in the coming decades, we must be sure that the nation can protect the health, welfare, and safety of our government astronauts and private spaceflight participants. It is also imperative that we secure key orbits to protect assets that are critical to our economy. Similarly, we cannot allow national security assets that are used to keep our country safe to be threatened by the proliferation of debris.

The debris events caused by the Kosmos and Iridium collision in 2009 and China's ASAT test in 2007 demonstrated that the space environment is vulnerable and ever changing. We must be vigilant to ensure our national interests are protected.

I appreciate the appearance of our witnesses today, and I look forward to hearing from them.

[The prepared statement of Mr. Brooks follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE VICE CHAIRMAN MO BROOKS

The focus of this hearing is how to prevent a real life 'Gravity.' As was imaginatively portrayed by Hollywood last year, the threat of debris in key orbits around the Earth is very real and a serious issue. While the movie elevated orbital debris to the forefront of the public's attention, this committee is no stranger to the topic. Today we will continue assessing the key questions involved in space traffic management and what Congress may do to ensure the safety and security of the space environment.

There are two important facets of this discussion. The first is an assessment of what we are doing right now to track and mitigate orbital debris. The second is what more needs to be done without burdening the space industry with unnecessary bureaucratic hurdles to success.

At present, the Joint Functional Component Command for Space, or JFCC SPACE, is tracking approximately 23,000 objects in orbit around the Earth, including 4,000 payloads, of which 1,200 are active. The current systems available for tracking cannot detect object smaller than four inches in size. This means we can't even track a paint fleck travelling at 17,500 miles an hour, which can cause serious damage.

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The efforts of federal agencies should be viewed within the context of separate international and private sector efforts. The United States has the most advanced space situational awareness system in the world, but tracking and cataloging the space environment more effectively may come from key partnerships. We cannot afford to ignore these important partners.

As commercial human spaceflight increases in the coming decades, we must be sure that the nation can protect the health, welfare, and safety of our government astronauts and private spaceflight participants. It is also imperative that we secure key orbits to protect assets that are critical to our economy. Similarly, we cannot allow national security assets that are used to keep our country safe to be threatened by the proliferation of debris.

The debris events caused by the Kosmos and Iridium collision in 2009 and China's ASAT test in 2007 demonstrated that the space environment is vulnerable and ever changing. We must be vigilant to ensure our national interests are protected.

I appreciate the appearance of our witnesses today and I look forward to hearing from them.###

Chairman BROOKS. I now recognize the Ranking Member from Maryland, Ms. Edwards.

Ms. EDWARDS. Thank you very much, Mr. Chairman, and welcome to everyone to today's hearing.

Mr. Chairman, while the accuracy of the events depicted in the fictional movie "Gravity" can be questioned, there is no doubt that it has made the public at least a little bit more aware of the danger of orbital debris, and that is probably a good thing. But in the real world, the nature of the danger was brought into stark focus by the aftermath of the 2007 anti-satellite test conducted by China. This incident is said to have created an estimated debris population of 150,000 objects larger than one centimeter in size. The resulting increase in space debris has made the space environment more hazardous to military, civil, and commercial satellites and spacecraft for years to come.

So what are we doing to make space travel safe from orbital debris? Well, today a number of government agencies have a role in orbital debris mitigation. Three of those agencies are represented on the panel today. The DoD Strategic Command is responsible for tracking orbital debris. The FCC has jurisdiction for mitigating orbital debris from satellites, and FAA's Office of Commercial Space Transportation regulates orbital debris from commercially licensed launch and re-entry vehicles. However, what isn't quite clear is which agencies have, or could have, legitimate roles in space traffic management. That is, the authority to tell a space operator to move a spacecraft should the potential for collision from debris or another spacecraft require it.

Other questions also come into mind. Should space traffic management be carried out by one or more existing agencies, or perhaps by a new organization? What needs to happen for the information on space debris and potential collisions to get to the people who need it, and when they need it? Is the current system for information transfer working, or does it need improvement? Because the causes and consequences of orbital debris are international in scope, does successful space traffic management require an international approach? And, lastly, what liability should the agency or agencies in charge of space traffic management assume if its direction to a satellite operator to move a spacecraft results in a collision?

These are just a few of the questions that this Subcommittee will need to address if we aim to lay the groundwork for ensuring the safety of future space flight from orbital debris and other spacecraft. Mr. Chairman, these are complex issues, and so I hope today's hearing will start to shed light not only on the important issue of orbital debris, but also on the approaches Congress might consider for potential space traffic management and regulatory regime.

And with that, I yield back the balance of my time.

[The prepared statement of Ms. Edwards follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE

RANKING MEMBER DONNA F. EDWARDS

Good afternoon and welcome to today's hearing.Mr. Chairman, while the accuracy of all of the events depicted in the movie "Gravity" can be questioned, there is no doubt it has made the public more aware of the danger of orbital debris.

And that's a good thing.

The real world nature of the danger was brought into stark focus by the aftermath of the 2007 anti-satellite test conducted by China. This incident is said to have created an estimated debris population of 150,000 objects larger than 1 centimeter in size. The resulting increase in spacedebris has made the space environment more hazardous to military, civil, and commercial satellites and spacecraft for years to come.

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- DOD's Strategic Command is responsible for tracking orbital debris.
- FCC has jurisdiction for mitigating orbital debris from satellites.
- And FAA's Office of Commercial Space Transportation regulates orbital debris from commercially licensed launch and reentry vehicles.

However, what isn't quite clear is which agencies have or could have legitimate roles in space traffic management—that is, the authority to tell a space operator to move a spacecraft should the potential for collision from debris or another spacecraft require it.

And other questions come to mind:

- Should space traffic management be carried out by one or more existing agencies or perhaps by a new organization?
- What needs to happen for the information on space debris and potential collisions to get to the people who need it and when they need it?
- Is the current system for information transfer working, or does it need improvement?
- Because the causes and consequences of orbital debris are international in scope, does successful space traffic management require an international approach?
- And what liability should the agency or agencies in charge of space traffic management assume if its direction to a satellite operator to move a spacecraft results in a collision?

These are just a few of the questions this Subcommittee will need to address if we aim to lay the groundwork for ensuring the safety of future spaceflight from orbital debris and other spacecraft.

Mr. Chairman, these are complex issues.

I hope that our hearing today will start to shed light not only on the important issue of orbital debris but also on the approaches Congress might consider for a potential space traffic management and regulatory regime.

Chairman BROOKS. Thank you, Ms. Edwards.

I now recognize the Ranking Member of the full Committee, from Texas, Ms. Johnson, for a statement.

Ms. JOHNSON. Thank you very much, and good morning. I want to welcome our witnesses to this morning's hearing, and I look forward to your testimony. I will be brief in my remarks, so that we will have enough time to hear from our experts.

Orbital debris, or space junk, as it is sometimes called, is not science fiction. It is a reality, and something that has implications for the way we operate both our crewed spacecraft and our commercial and government satellites. It is a growing problem. Dealing with the increase in orbital debris will not be easy. As our witnesses will testify, the issues associated with this mitigation, and its potential removal from orbit, are complex.

A number of agencies are involved, not all of whom are represented at today's hearing. I am pleased that the bipartisan NASA reauthorization bill that we recently marked up now contains several provisions related to orbital debris. I believe that their inclusion is a useful start to addressing this complex set of issues. That said, I would caution against legislating further in this area until we have a better understanding of the issues involved. This morning's hearing will provide a good starting point for our Members to learn about both the challenge presented by orbital debris, as well as some of the potential approaches to dealing with that challenge. I am pleased that this Subcommittee is holding this hearing.

In closing, I again want to welcome our witnesses, and I yield back the balance of my time.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF FULL COMMITTEEE
RANKING MEMBER EDDIE BERNICE JOHNSON

Thank you very much. I want to welcome our witnesses to this morning's hearings, and I look forward to your testimony. I will be brief in my remarks so that we have enough time to hear from these experts before we have to go vote.

Orbital debris, or "space junk" as it is sometimes called—is not science fiction-it is a reality, and something that has implications for the way we operate both our crewed spacecraft and our commercial and government satellites. It is a growing problem.

Dealing with the increase in orbital debris will not be easy. As our witnesses will testify, the issues associated with its mitigation and its potential removal from orbit are complex. A number of agencies are involved, not all of whom are represented at today's hearing.

I am pleased that the bipartisan NASA Authorization bill that we recently marked up now contains several provisions related to orbital debris. I believe that their inclusion is a useful start to addressing this complex set of issues.

That said, I would caution against legislating further in this area until we have a better understanding of the issues involved. This morning's hearing will provide a good starting point for Members to learn about both the challenge presented by orbital debris as well as some of the potential approaches to dealing with that challenge. I am pleased that the Subcommittee is holding it.

In closing, I again want to welcome our witnesses, and I yield back the balance of my time.

Chairman BROOKS. Thank you, Ms. Johnson. If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time, I would like to introduce our witnesses. Our first witness is Lieutenant General John "Jay" Raymond, Commander, 14th Air Force, Air Force Space Command, and Commander, Joint Functional Component Command for Space, U.S. Strategic Command. As the U.S. Air Force's operational space component to U.S. STRATCOM, General Raymond leads more than 20,500 personnel, responsible for providing missile warning, space superiority, space situational awareness, satellite operation, space launch, and range operations. As Commander, JFCC Space, he directs all assigned and attached U.S. STRATCOM space forces, providing tailored, responsive, timely local and global space effects in support of national U.S. STRATCOM, and combatant commander objectives.

Our second witness today is Mr. George Zamka, Deputy Associate Administrator for Commercial Space Transportation at the Federal Aviation Administration. Mr. Zamka came to the FAA directly from NASA, where he served as an astronaut, and most recently as a research and instructor pilot at the Johnson Space Center. He is a retired Colonel in the Marine Corps, and, as a pilot, has more than 5,000 flight hours in fighter, attack, test, research, and training aircraft. He was selected as an astronaut by NASA in June 1998. He has spent more than 692 hours in space.

Our third witness is Mr. Robert Nelson, Chief Engineer, International Bureau, Federal Communications Commission. He is responsible for leading the Bureau's work on technical issues, including satellite communications and cross-border technical issues. Prior to serving as the Bureau's Chief Engineer, he was chief of the Bureau's satellite division, and chief of the satellite division, engineering branch. Before joining the Commission, Mr. Nelson had various engineering positions in the private sector.

Our fourth witness is Mr. P.J. Blount, Adjunct Professor of Air and Space Law at the University of Mississippi School of Law. He is also an adjunct professor in the Department of Political Science and Law at Montclair State University. Previously he served as research counsel for the National Center for Remote Sensing, Air and Space Law, at the University of Mississippi School of Law. He teaches space security law, international telecommunications law, human rights law, and cyber law. He serves as the assistant executive secretary of the International Institute of Space Law.

Our final witness is Mr. Brian Weeden, Technical Advisor at the Secure World Foundation. As technical advisor, Mr. Weeden conducts research on space debris, global space situational awareness, space traffic management, protection of space assets, and space governance. Prior to joining SWF, Mr. Weeden served on active duty as an officer in the United States Air Force, working in space and intercontinental ballistic missile operations. As part of U.S. Strategic Command's Joint Space Operation Center, Mr. Weeden directed the orbital and analyst training program and developed tactics, techniques, and procedures for improving space situational awareness.

As our witnesses should know, spoken testimony is limited to five minutes each, after which the Members of the Committee will have five minutes each to ask questions. I now recognize General Raymond for five minutes to present his testimony.

TESTIMONY OF LIEUTENANT GENERAL JOHN "JAY" RAYMOND, COMMANDER, 14TH AIR FORCE, AIR FORCE SPACE COMMAND; AND COMMANDER, JOINT FUNCTIONAL COMPONENT COMMAND FOR SPACE, U.S. STRATEGIC COMMAND

General RAYMOND. Chairman Brooks, Representative Edwards, Members of the Subcommittee, it is an honor to appear before you as the United States Strategic Commands Commander of the Joint Functional Component Command for Space. I greatly appreciate the opportunity to address the Committee, and I look forward to working with you to advance our Nation's space capabilities. Before going further, though, I would ask—if I could be so bold to ask you for a favor, and just please pass along my condolences to Chairman Palazzo.

It is my highest honor to represent the 3,300 soldiers, sailors, airmen, and marines and civilians that make up the Joint Functional Component Command for Space. These professionals, along with our exchange officers from Australia, Canada, and the United Kingdom ensure our Nation, our allies, and our joint war fighters have continued access to the space capabilities that enable the American way of life.

JFCC Space is the world's premier provider of space situational awareness data and products. Over the past few years, we have bolstered our commercial and international partnerships. We have implemented two-way sharing agreements, and we have worked collaboratively to refine our sharing processes. Additionally, we are on track to deliver a new command and control system called the Joint Space Operations Center Mission System, or JMS for short, and additional space situational awareness sensors, the combination of which will give us increased capability, and improve space situational awareness for the United States and our partners.

Although maintaining awareness of the space domain is no small task, I am confident that the men and women of JFCC Space are prepared to meet the challenges with a spirit of dedicated innovation and devotion to duty, providing our Nation, our allies, and our joint war fighters assured access to the world's premiere space capabilities. I thank the Committee for your continued support as we strive to preserve the space domain, and enhance the space capabilities which are so vital to our nation.

[The prepared statement of Lieutenant General Raymond follows:]

HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SPACE SUBCOMMITTEE

STATEMENT OF

LIEUTENANT GENERAL JOHN W. RAYMOND

COMMANDER

JOINT FUNCTIONAL COMPONENT COMMAND FOR SPACE

BEFORE THE HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SPACE SUBCOMMITTEE

ON SPACE TRACK MANAGEMENT

9 MAY 2014

HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SPACE SUBCOMMITTEE

INTRODUCTION

Chairman Pallazzo, Representative Edwards, and members of the Committee, it is an honor to appear before you as United States Strategic Command's Commander of the Joint Functional Component Command for Space (JFCC SPACE). I appreciate this opportunity to address the Committee and I look forward to working with you to advance our nation's space capabilities.

It is my highest honor to represent the 3,300 Soldiers, Sailors, Airmen, Marines and civilians that make up JFCC SPACE. These professionals, along with our exchange officers from Australia, Canada and the United Kingdom, ensure our nation, our allies, and our joint warfighters have continued access to the space capabilities that enable the American way of life and provide a tremendous strategic advantage.

SPACE ENVIRONMENT

For decades, the United States leveraged space to our advantage, but the strategic environment has changed and that advantage is no longer guaranteed. The space domain is characterized today by ever-increasing congestion and competition for limited resources. Assured access to space is challenged by the exponential growth in operations driven by international users. Satellite communications bandwidth is a finite resource with a commensurate level of competition for access and use.

Today JFCC SPACE routinely tracks tens of thousands of objects in orbit around the Earth, but the true amount of debris may be an order of magnitude higher. Although we may never be able to detect and track the smallest objects, every piece of debris on orbit poses a potential threat to our operational satellites.

Potential adversaries possess, and continue to develop, a broad set of capabilities that could threaten US access to space while increasing their relative strategic advantage. Several countries have charted a course to develop capabilities in an effort to deny us the use of space, even as they improve their own launch and on-orbit capabilities. Specifically, China improved their space-based imagery and radar and tested a rapid launch capability. Some nations have developed and demonstrated anti-satellite weapon capabilities that represent a potential threat to our space capabilities. Many of these activities could be considered dual-use civilian and military efforts, but have lacked transparency with regard to purpose and intent.

Adversary capabilities could range from brute force jamming of Global Positioning System (GPS) and satellite communications (SATCOM) signals, to highly sophisticated anti-satellite weapons intended to damage or destroy their targets. Today there are eleven space-faring nations that have an indigenous space launch capability. Additionally, at least 50 nations, dozens of companies and a multitude of educational and nonprofit institutions are operating satellites in space. As the barriers to access space are lowered, the number of actors is expected to increase, and our ability to carry out our missions will become progressively more difficult. A responsive and flexible global force must continue to exploit the advantages of space to ensure effective and efficient military operations.

To meet the demands of the dynamic space environment, JFCC SPACE is focused on three operational objectives: provide timely and accurate warning and assessment, support national users and Joint and Coalition forces, and protect and defend our space capabilities and prepare for contingency operations. All of these objectives require increased situational awareness and enhanced command and control (C2).

SPACE SITUATIONAL AWARENESS

Space Situational Awareness (SSA) is fundamental to effective operation and defense of our capabilities. SSA allows us to maintain the current and predictive knowledge of the space domain and the operational environment upon which space operations depend. We rely on SSA to provide timely and accurate warning to alert national and military leaders and our partners of impending threats and hostile actions. Fusion of sensor data coupled with enhanced command and control capabilities enables the rapid situational assessment, to include identifying potential threats, and providing indications and warning to decision makers.

Space debris continues to be a significant concern as even the smallest fragments pollute the space domain and can potentially damage or destroy space capabilities. Fielding new sensors with greater sensitivity will allow us to track more and smaller objects, but we must do more than simply improve our vision. We must continue broader efforts to reduce the by-products of space launches, improve plans to dispose of defunct satellites, decrease the probability of accidental collisions between space objects, and thwart deliberate acts of destruction.

JFCC SPACE is responding to today's congested space environment by tracking tens of thousands of objects, and by producing approximately 1,400 conjunction summary messages on a daily basis to inform satellite operators of impending close approaches. Those operators must then assess the risk posed to their assets and weigh the benefit of maneuvering a spacecraft to avoid a collision against the cost of consuming precious fuel and reducing mission life. One of our most vital missions is providing collision avoidance data to NASA in order to protect the International Space Station.

A continuing trend of multi-payload launches with an ever decreasing satellite size will add to on-orbit congestion. In 2012, 72 new satellites were placed in orbit; in one 7-day period in 2013, 78 new satellites were placed in orbit. The trend includes deployment of cubesats -- cube-shaped satellites, 10 centimeters on a side, that are highly capable for their size. In February 2014, the International Space Station (ISS) deployed 33 CubeSats. The Falcon-9 ISS cargo resupply mission is programmed to deploy 5 additional CubeSats, including a Cubesat that deploys 104 chipsats, which are smaller than a credit card. Detecting and tracking multiple objects of chipsat size over 250 miles above the earth is beyond the current capabilities of fielded systems. We anticipate further increase in the complexity of the SSA mission through the deployment of hundreds and perhaps thousands of additional small satellites in the next few years – a challenge that will require increasingly capable sensors analytic tools and highly-trained analysts.

To mitigate these challenges we are taking a multi-pronged approach to enhancing SSA. We are fielding new, more-capable SSA sensors, implementing a new SSA Sharing Strategy, and entering into two-way sharing partnerships.

Service provided capabilities such as, the Geosynchronous SSA Program (GSSAP), the Space Fence, and the Space Surveillance Telescope will fill a critical shortfall in the SSA mission with increased tracking and characterization of objects in space.

Working closely with United States Strategic Command (USSTRATCOM), we are in the process of implementing a new tiered SSA Sharing Strategy. The tenets of this strategy are to share more information in a timelier manner with the broadest range of partners. We aim to promote an interactive, exchange-based relationship with satellite owners and operators where all parties gain. This open exchange of information also supports US and allied efforts to detect, identify, and attribute actions in space that are contrary to responsible use and the long-term sustainability of the space environment.

We have entered into SSA sharing agreements with 41 commercial firms and five nations. Over last year, USSTRATCOM, with interagency coordination, finalized eight commercial and five international agreements. Seven additional commercial/intergovernmental and five more national agreements are in work. The desired end state is the development of routine operational partnerships, creating a true data sharing environment that extends to the robust inclusion of international data. SSA Sharing Agreements are laying the foundation for increased international cooperation, and are aided by efforts to integrate partner nation sensors into the Space Surveillance Network (SSN). Recently, the first such sensor was incorporated, the Canadian Sapphire satellite, and work is being done to place a US Space surveillance telescope and radar in Australia. These successes represent initial steps toward the goal of leveraging existing and planned SSA capabilities of allies and space partners.

Combined space operations are USSTRATCOM's response to US National Security Policy (NSP) and the National Security Space Strategy (NSSS) direction to establish an operational working relationship in the space domain with Allied and like-minded nations. This multinational military effort will strengthen deterrence, improve mission assurance, and enhance resilience. To best protect vital space-based capabilities, we need to operate in space as we do in other domains: with our closest partners and allies.

SUPPORT NATIONAL USERS AND JOINT AND COALITION OPERATIONS

With the knowledge provided by SSA, JFCC SPACE is able to provide necessary support to national users and joint and coalition forces. Our space systems and capabilities exist for this purpose. While it is not my intent to cross into the Services' organize, train, and equip responsibilities; the space capabilities they develop and provide are vital to USSTRATCOM's space operations mission.

Positioning, Navigation and Timing (PNT)

Positioning, Navigation and Timing provided by the Global Positioning System (GPS) is widely recognized by military, civil, and commercial users, and is highly integrated into the Joint Force. The dependence of joint warfighting on GPS services and the asymmetric advantage they provide to our way of warfare means that we must protect and defend this vital capability or face the reality of conducting our operations under very different circumstances.

The reliability of our GPS constellation continues to improve as the Air Force systematically replaces aging satellites with more capable satellites and upgrades the architecture that improves capabilities. These capabilities will reduce the vulnerability of the PNT mission by making the GPS signal more robust/resilient, boosting the power and reliability to users, and providing near real-time command and control to enable space operators to take quick action in the face of growing threats.

Missile Warning

JFCC SPACE is responsible for providing robust, reliable, global missile warning for the US and our allies. While spaced-based missile launch detection is a key element of the mission, ground-based radars are the mainstay of our homeland protection capability. Most of these systems have been operating 24 hours a day, 365 days a year since the early days of the Cold War. Currently, three of our six strategically-placed phased array radars have been upgraded to provide improved detection capabilities and enable autonomous missile defense. Two of the remaining radars are expected to be upgraded by year's end.

In addition to maintaining ground based warning, the men and women of JFCC SPACE continue to maximize the use of our national Overhead Persistent Infrared (OPIR) missile warning capability, the space-based element of our missile warning architecture. In 2013 alone, 9,584 infrared events and 625 missile warning reports were generated and distributed to national leaders and the combatant commands, twice the number recorded in 2012. In addition to protecting the homeland, our OPIR assets provide near-real time support to joint forces in Iraq, Afghanistan, and more recently, Syria. We have only begun to fully understand and exploit the ground-breaking capabilities provided by these new systems and must continue explore innovative ways to use them.

Military Satellite Communications

JFCC SPACE also provides the Joint Force with protected, wideband, and narrowband satellite communications. Information technologies have revolutionized our capability to operate globally. Terrestrial wired, wireless, and cellular networks are connecting the world, but they do not meet the need for a flexible, responsive network to communicate globally, securely, and reliably in all locations and under all conditions. From combat operations to humanitarian assistance, we use military satellite communications every day when no other form of communications is capable or available. Our protected communication capability is the reliable, survivable command and control mechanism for decision makers regardless of the circumstance, even if it is a contested and potentially nuclear environment. Emerging mission sets and advanced technologies have additional communications requirements that present unique challenges, requiring high bandwidth and theater-centric communications capabilities. Highly mobile satellite communications capability provides ground, sea, air, and Special Forces additional flexibility in a dynamic operational environment. The Joint Force requires a complementary suite of satellite communications capabilities, and the enhanced capabilities of Advanced Extremely High Frequency (AEHF), Wideband Global SATCOM (WGS), and the Mobile User Objective System (MUOS) narrowband satellites, along with commercial satellite communications provide forces a vital C2 mechanism for not only wartime operations, but humanitarian assistance missions as well.

PROTECT AND DEFEND AND PREPARE FOR CONTINGENCY OPERATIONS

The importance of JFCC SPACE-provided capabilities highlights our need to protect and defend the Space domain. Space Control requires knowledge derived from SSA to warn and assess threats that pose a risk to US and coalition space operations. Space Control may also include threat avoidance, safeguarding of our on-orbit assets, and the ability to mitigate electromagnetic interference. Our current space systems and set of tactics, techniques, and procedures (TTPs) were not developed with the need to operate in today's contested and congested environment. Nevertheless, these systems will be operating for years to come. In order to effectively operate using the current capabilities, JFCC SPACE will lead the effort in the development of options and TTPs that provide the highest possible level of protection against evolving threats. Further, we will develop or modify existing practices that accept and normalize the reality of contested operations and address risks to space assets by accepting risk of action at appropriate levels and in a practical time-frame to counter threats, ensure mission success, and meet national security requirements.

There is no silver bullet to address the space protection challenges. Better intelligence, improved C2 systems, increased capacity, balanced policies, robust coalition sharing agreements, and improved SSA sensors are critical needs that will allow the US to face challenges of space threats. All of these areas need to be addressed to ensure responsible use of space and our national security. JFCC SPACE, with USSTRATCOM and other Combatant Commands, Allies, and partners will plan and prepare for contingencies that allow the US to maintain the strategic advantage.

ENHANCE OUR ABILITY TO COMMAND AND CONTROL

The JSpOC Mission System (JMS) is currently in the process of replacing our legacy command and control systems designed in the 1980s and fielded in the 1990s. JMS is designed as a decision aid supporting the full range of JFCC SPACE operations. It is not intended to, nor can it, replace our highly trained space operators who remain the primary element of effective decision-making. JMS will provide an architecture that aggregates and rapidly processes data into actionable information for our operators and planners, giving them the understanding and ability to develop courses of action (COA) and provide support to senior leader decision-makers. JMS advanced data processing is critical to the effectiveness of our Joint space forces who must adapt to keep pace with and anticipate the demands of operating in an increasingly congested and contested space domain. Each deployed increment of JMS will significantly enhance our ability to understand the space situation with an improved, integrated operating picture and increased ability to respond to a dynamic space environment. We will continue to build upon this initial capability to ensure our commanders and operators have the situational awareness, tools, and the infrastructure needed to accomplish the mission. Rather than simply processing events, JMS will enable the operator to investigate events and test hypotheses, including most-likely and most-dangerous scenarios, in order to fully develop response options for commanders.

CONCLUSION

We find ourselves in a strategic space environment that requires active stewardship to preserve the capabilities on which our Nation relies. JFCC SPACE is responding to these challenges and will continue to be the world's premier provider of space capabilities - even as it faces a constantly evolving operational and threat environment. This is in large part due to a spirit of dedicated innovation and devotion to duty that drives our Soldiers, Sailors, Airmen, Marines, and Civil Servants to aggressively meet and overcome any and all operational challenges with the resources we are allocated. We will continue to develop new TTPs, and employ new technologies and methodologies to maintain and extend our advantage in space. We will continue to strengthen relationships with allies and industry partners to ensure capabilities derived from and provided by space operations are available for all who peaceably require them. While we continue to face new challenges in space, I am extremely confident that the men and women of JFCC SPACE are prepared to meet these challenges and will continue to provide the warfighter assured access to the world's premier space capabilities. I thank the Committee for your continued support as we strive to preserve and enhance the space capabilities which are vital to our nation.

Lieutenant General John "Jay" W. Raymond
Commander, JFCC-Space

Lt. Gen. John W. "Jay" Raymond is Commander, 14th Air Force (Air Forces Strategic), Air Force Space Command; and Commander, Joint Functional Component Command for Space, U.S. Strategic Command, Vandenberg Air Force Base, Calif. As the U.S. Air Force's operational space component to USSTRATCOM, General Raymond leads more than 20,500 personnel responsible for providing missile warning, space superiority, space situational awareness, satellite operations, space launch and range operations. As Commander, JFCC SPACE, he directs all assigned and attached USSTRATCOM space forces providing tailored, responsive, local and global space effects in support of national, USSTRATCOM and combatant commander objectives.

General Raymond was commissioned through the ROTC program at Clemson University in 1984. He has commanded the 5th Space Surveillance Squadron at Royal Air Force Feltwell, England; the 30th Operations Group at Vandenberg Air Force Base, Calif.; and the 21st Space Wing at Peterson AFB, Colo. He deployed to Southwest Asia as Director of Space Forces in support of operations Enduring Freedom and Iraqi Freedom. The general's staff assignments include Headquarters Air Force Space Command, United States Strategic Command, the Air Staff and the Office of Secretary of Defense. Prior to his current assignment, General Raymond was the Director of Plans and Policy, Headquarters United States Strategic Command, Offutt AFB, Neb.

EDUCATION
1984 Bachelor of Science degree in administrative management, Clemson University, S.C.
1990 Squadron Officer School, Maxwell AFB, Ala.
1990 Master of Science degree in administrative management, Central Michigan University
1997 Air Command and Staff College, Maxwell AFB, Ala.
2003 Master of Arts degree in national security and strategic studies, Naval War College, Newport, R.I.
2007 Joint Forces Staff College, Norfolk, Va.
2011 Combined Force Air Component Commander Course, Maxwell AFB, Ala.
2012 Joint Flag Officer Warfighting Course, Maxwell AFB, Ala.

ASSIGNMENTS
1. August 1985 - October 1989, Minuteman intercontinental ballistic missile crew commander; alternate command post; flight commander and instructor crew commander; and missile procedures trainer operator, 321st Strategic Missile Wing, Grand Forks AFB, N.D.
2. October 1989 - August 1993, operations center officer controller, 1st Strategic Aerospace Division, and executive officer, 30th Space Wing, Vandenberg AFB, Calif.

3. August 1993 - February 1996, Chief, Commercial Space Lift Operations, assistant Chief, Current Operations Branch, Headquarters Air Force Space Command, Peterson AFB, Colo.
4. February 1996 - August 1996, Deputy Director, Commander in Chief's Action Group, Headquarters Air Force Space Command, Peterson AFB, Colo.
5. August 1996 - June 1997, student, Air Command and Staff College, Air University, Maxwell AFB, Ala.
6. June 1997 - August 1998, space and missile force programmer, Headquarters U.S. Air Force, Washington, D.C.
7. September 1998 - April 2000, Chief, Expeditionary Aerospace Force Space and Program Integration, Expeditionary Aerospace Force Implementation Division, Headquarters U.S. Air Force, Washington, D.C.
8. April 2000 - June 2001, Commander, 5th Space Surveillance Squadron, Royal Air Force Feltwell, England
9. June 2001 - July 2002, Deputy Commander, 21st Operations Group, Peterson AFB, Colo.
10. July 2002- June 2003, student, Naval War College, Newport, R.I.
11. June 2003 - June 2005, transformation strategist, Office of Force Transformation, Office of the Secretary of Defense, Washington, D.C.
12. June 2005 - June 2007, Commander, 30th Operations Group, Vandenberg AFB, Calif. (September 2006 - January 2007, Director of Space Forces, Combined Air Operations Center, Southwest Asia)
13. June 2007 - August 2009, Commander, 21st Space Wing, Peterson AFB, Colo.
14. August 2009 - December 2010, Director of Plans, Programs and Analyses, Headquarters Air Force Space Command, Peterson AFB, Colo.
15. December 2010 - July 2012, Vice Commander, 5th Air Force, and Deputy Commander, 13th Air Force, Yokota Air Base, Japan
16. July 2012 - January 2014, Director of Plans and Policy (J5), U.S. Strategic Command, Offutt AFB, Neb.
17. January 2014 - present, Commander, 14th Air Force (Air Forces Strategic), Air Foree Space Command, and Commander, Joint Functional Component Command for Space, USSTRATCOM, Vandenberg AFB, Calif.

SUMMARY OF JOINT ASSIGNMENTS
1. June 2003 - June 2005, transformation strategist, Office of Force Transformation, Office of Secretary of Defense, Washington, D.C., as a colonel
2. July 2012 - January 2014, Director of Plans and Policy (J5), U.S. Strategic Command, Offutt AFB, Neb.
3. January 2014 - present, Commander, Joint Functional Component Command for Space, USSTRATCOM, Vandenberg AFB, Calif., as a lieutenant general

OPERATIONAL INFORMATION
Badges: Master Space Operations Badge, Master Missile Operations Badge
Systems: Minuteman III, Deep Space Tracking System, Counter Communications System

MAJOR AWARDS AND DECORATIONS
Distinguished Service Medal
Defense Superior Service Medal
Legion of Merit with oak leaf cluster
Meritorious Service Medal with four oak leaf clusters
Air Force Commendation Medal
Combat Readiness Medal
Global War on Terror Expeditionary Medal
Global War on Terrorism Service Medal

OTHER ACHIEVEMENTS
2007 General Jerome F. O'Malley Distinguished Space Leadership Award, Air Force Association

EFFECTIVE DATES OF PROMOTION
Second Lieutenant July 20, 1984
First Lieutenant July 20, 1986

Captain July 20, 1988
Major July 1, 1996
Lieutenant Colonel July 1, 1999
Colonel July 1, 2004
Brigadier General August 19, 2009
Major General May 4, 2012
Lieutenant General January 31, 2014

(Current as of January 2014)

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Chairman BROOKS. Thank you for your timely testimony.
The Chair next recognizes Mr. Zamka for his testimony.

TESTIMONY OF MR. GEORGE ZAMKA, DEPUTY ASSOCIATE ADMINISTRATOR, OFFICE OF COMMERCIAL SPACE TRANSPORTATION, FEDERAL AVIATION ADMINISTRATION

Mr. ZAMKA. Chairman Books, Ranking Members Edwards, and distinguished Members of the Subcommittee, thank you for inviting me. This is my first opportunity to speak before the Subcommittee, and I am particularly fortunate to be able to speak about the FAA's efforts regarding orbital debris mitigation. Aside from launch and reentry, orbital debris poses the highest risk to human spaceflight. During my two space missions, we flew upside down and backwards to protect our shuttle windows from orbital debris, and even doing that, we had cracks on our windows from various small debris strikes.

With regard to orbital debris mitigation, it is helpful to review the operations to which the FAA's authority applies, and where it does not. The FAA is the sole Federal Government agency with authority to license commercial space transportation activities. That authority is limited by the Commercial Space Launch Act to the launch and reentry of a vehicle. Under that authority, at the end of launch, the FAA requires the operator of a launch vehicle to safe their vehicle and ensure there is no post-separation contact with their deploying payload, in order to prevent orbital debris generation. The FAA also imposes launch window limitations based on a launch collision avoidance analysis with habitable spacecraft, such as the International Space Station.

The FAA does not currently have authority to regulate on orbit. The only agencies with any regulatory authority in between launch and reentry events are the FCC, for communications satellites, and NOAA, for remote sensing satellites. The FAA interfaces with the FCC and NOAA regularly through payload reviews, and our primary partners in developing effective orbital debris rules are the Department of Defense and NASA.

The NASA Orbital Debris Program Office has been a strong partner in the development of FAA rules, and is an invaluable resource. The DoD's Joint Space Operation Center, or JSPOC, provides tracking information and debris detection data that we use to evaluate the effectiveness of launch debris mitigation efforts. Only the DoD has legislative authority and capability to share space situational awareness information, including notifications of impending collisions, and near collisions, to cooperating space operators, but it lacks any enforcement authority.

An issue of oversight and enforcement authority emerges with the increasing number of commercial space transportation vehicles, which will operate differently from communications or Earth observing satellites. Rather than travel to and remain in one stable orbit, commercial transportation vehicles will move in between orbits and rendezvous with, attach to, and deliver cargo and people to other orbiting space vehicles. These orbital operations could cause collisions that would create orbital debris.

As Congress explores the issue of orbital debris and transportation hazards, the FAA urges the Subcommittee to consider at least two possible options, separately or in combination. First, it should consider whether a regulatory agency should authorize transportation on orbit by license. In that scenario, an agency with the proper expertise would, as part of a license evaluation, review the operator's plans and debris mitigation measures in advance of operations.

In a second scenario, that may require additional discussion, we would consider the benefits of an agency with enforcement authority providing notices of impending hazards and collisions. That agency would serve as a referee, advising of impending high risk events, and facilitating a safer orbital environment for all commercial and governmental operators.

This Subcommittee is familiar with the orbital debris environment that consists of spent rocket bodies and debris traveling in different directions at speeds 5 to 10 times that of a bullet, and carrying tremendous energy into any collision. Because of minimal atmospheric drag in Earth orbit, objects in orbit tend to stay in orbit, at least for a very long time. For example, TIROS–2, which was launched over a half century ago, was recently added to the 60-day reentry prediction list.

Collisions between orbiting objects can cause a lot of debris. We talked about the Iridium/Kosmos collision that created over 2,000 of the 23,000 tracked objects on orbit. Orbital debris affects human spaceflight as well. The ISS has executed 18 debris avoidance maneuvers, and ISS crew Members have been required to shelter in their Soyuz life boats at times when hazardous debris was detected with too little warning to plan and carry out a debris avoidance maneuver.

As space transportation capabilities and operations continue to advance, and as the risk posed by orbital debris increases, plans for mitigation become ever more critical. It is time to explore the orbital safety of commercial space transportation under the Commercial Space Launch Act.

Mr. Chairman, this concludes my prepared remarks, and I will be pleased to answer any questions you may have.

[The prepared statement of Mr. Zamka follows:]

STATEMENT OF GEORGE D. ZAMKA (COLONEL, USMC, RET.), DEPUTY ASSOCIATE ADMINISTRATOR FOR COMMERCIAL SPACE TRANSPORTATION OF THE FEDERAL AVIATION ADMINISTRATION, BEFORE THE HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY, SUBCOMMITTEE ON SPACE, ON ORBITAL DEBRIS MITIGATION, MAY 9, 2014.

Chairman Palazzo, Ranking Member Edwards, and Distinguished Members of the Subcommittee:

Thank you for inviting me. This is my first opportunity to speak before the Subcommittee, and I am particularly fortunate to be asked to speak on the FAA's efforts regarding orbital debris mitigation, as it is an emerging issue very deserving of discussion. My role as Deputy Associate Administrator for the Office of Commercial Space Transportation places me in a good position to report to our nation on the FAA's role in protecting against orbital debris, and to identify where shortfalls may lie.

Operational Environment

The U.S. commercial space industry is growing, and the space operations in which the industry is engaging are becoming increasingly more complicated. Private industry is increasing activities on orbit for government and commercial customers. SpaceX and Orbital Sciences Corporation have successfully delivered cargo to the International Space Station (ISS). Boeing, Sierra Nevada, and SpaceX are developing new vehicles to carry people to and from the ISS. Bigelow Aerospace has entered into a Space Act Agreement with the National Aeronautics and Space Administration (NASA) to connect its expandable activity module (BEAM) to the ISS. The BEAM will be brought to the ISS by SpaceX's Dragon, and will join two free-flying Bigelow demonstration habitats already on orbit.

Orbital Debris Environment

This Subcommittee is familiar with the orbital debris environment that consists of defunct satellites, spent rocket bodies, and smaller orbital debris traveling in different directions at different altitudes.

Objects in orbit travel 5-10 times the speed of a bullet, carrying tremendous energy. The kinetic energy released by a collision with such an object in orbit can be more than 10 times the explosive energy of an equivalent mass of TNT. The largest debris objects in orbit today are over a dozen second stages, at about 8.2 tons each. At the other side of the size range are about 8300 tracked objects less than 15 cm in size. If the projected commercial nanosat market materializes, it will further increase the number of small objects in orbit. Regardless of size, all orbital debris carries destructive kinetic energy into any collision.

Because of minimal atmospheric drag in Earth orbit, objects in orbit tend to stay there for a long time. Objects in LEO tend to remain in space on the order of decades, whereas objects in geosynchronous orbit remain in space for thousands of years. A Delta 1 rocket body that launched in July of 1961, did not reenter the atmosphere until this past February. TIROS-2, which was launched in 1960, recently was added to the 60-day reentry prediction list. Many of us in this room were not even born when that vehicle was launched.

Collisions between orbiting objects can exponentially cause more debris. This domino effect increases the danger and operational difficulties to current and future space stations, satellites, and space-based services. It is estimated that a single 2009 collision between an Iridium communications satellite and a deactivated Russian Kosmos satellite created over 2,000 of the 23,000 tracked objects on orbit.

Using U.S. Space Surveillance Network (SSN) data, NASA has a process for predicting possible collisions between the ISS and orbital debris. The U.S. standard of protecting occupied spacecraft is to maneuver to avoid an object if it is calculated to have a higher than 1:10,000 chance of hitting the asset. The U.S. standard of protecting occupied spacecraft with a 200 km buffer zone provides less than 30 seconds of separation between the ISS and crossing orbital debris. NASA reported that in October 2013, over 800 cataloged objects, including 10 percent spacecraft, one-third rocket bodies, and the rest miscellaneous debris, posed a potential threat to the ISS. This represented a 60 percent increase from the number of tracked objects that were viewed as a potential threat to the ISS in November 1998. Over the life of the ISS, crewmembers have been required to shelter in their Soyuz craft serving as lifeboats three separate times when hazardous debris was detected with too little warning to plan and carry out a debris avoidance maneuver.

FAA Responsibilities and Authority

To best understand the FAA's responsibilities regarding orbital debris, it is helpful to review the operations to which the FAA's authority applies, and where it does not. The FAA is the sole federal government agency with authority to license commercial space transportation activities. That authority is derived from, and limited by, chapter 509 of Title 51 of the United States Code, the Commercial Space Launch Act. This Act provides FAA authority relating to the launch and reentry of a vehicle. The National Space Transportation Policy of 2013 highlights the importance of this FAA authority as it applies to debris mitigation for the transportation activities the FAA authorizes:

> [t]he Secretary of Transportation is responsible for authorizing and providing safety oversight for non-federal launch and reentry operations . . . . In performing these responsibilities, the Secretary of Transportation shall . . . [e]xecute exclusive authority, consistent with existing statutes and executive orders, to address orbital debris mitigation practices for U.S.–licensed commercial launches, to include launch vehicle components such as upper stages, through its licensing procedures.

The National Space Transportation Policy provides regulatory certainty to industry by making clear that only the FAA will address orbital debris mitigation for launch and reentry.

FAA licensing regulations require the operator of a launch vehicle to take measures regarding safety at the end of launch. These regulations may be found at 14 C.F.R. §

417.129 and 431.43, and they apply to launch and reusable launch vehicle components, including upper stages that are left in orbit. Launch operators must ensure that: debris generation does not result from conversion of energy sources that fragments the vehicle or its components; the vehicle does not come in contact with the payload after payload separation; and fuel is vented and other energy sources depleted to reduce risk of explosion. This may include leaving fuel line valves open, leaving batteries in a permanent state of discharge, and removing any other sources of stored energy. Under sections 417.107(e) and 431.43(c) of the regulations, the FAA also imposes operating limitations based on a launch Collision Avoidance Analysis (COLA) to avoid collision with habitable spacecraft such as the ISS. Launch operators must use the results of the collision avoidance analysis to determine acceptable launch windows.

The FAA's ability to mitigate the creation of orbital debris is limited. The FAA currently does not have statutory authority to regulate in-between launch and reentry of a vehicle. The only agencies with any regulatory authority between those two events are the Federal Communications Commission (FCC) for communications satellites and the National Oceanic and Atmospheric Administration (NOAA) for remote sensing satellites. Satellites that operate under FCC or NOAA licenses must address orbital debris mitigation considerations as part of the FCC and NOAA licensing processes.

Accordingly, once SpaceX's Dragon or Orbital Sciences' Cygnus reach orbit and transport cargo to the ISS, they do not have the FAA's regulatory oversight. Because Cygnus does not reenter substantially intact, it does so without FAA licensing. For

Dragon and Cygnus, NASA mandates orbital debris mitigation efforts on-orbit by contract prior to launch for NASA missions. Bigelow's sub-scale model habitats, which were launched from Russia, were not required to have FAA review of the safety issues associated with their operations and maneuvers.

In the execution of orbital debris mitigation responsibility, the FAA interfaces with agencies that have both affected interests and specialized experience. The FAA speaks with FCC and NOAA regularly, but our varying authorities translate into different approaches to orbital safety. Our primary partners in developing effective rules are the Department of Defense (DoD) and NASA. The NASA Orbital Debris Program Office has been a strong partner in the development of FAA rules and is an invaluable resource. The DoD's U.S. Strategic Command provides tracking information and debris detection data used to evaluate the effectiveness of launch debris mitigation practices and processes. The effectiveness of commercial operations from DoD ranges demonstrate the synergy provided by the partnerships in FAA and DoD range safety, experience the FAA is transferring to commercial spaceports.

So what is the issue? One challenge is oversight and enforcement authority over the increasing number of commercial space transportation vehicles that will operate differently from communications or Earth-observing satellites. Some commercial transportation vehicles will carry people and cargo. Some vehicles could carry fuel and conduct maintenance. A servicing vehicle would conduct maneuvers on orbit to perform phasing or other maneuvers as it travelled from satellite to satellite. Although, of course, no operator wants to contribute to the debris environment, any given operator may lack the information and incentive necessary to act for the common good in a given circumstance. Maneuvers in space cost money, service life, and service coverage. Space transportation operators may weigh preservation of their propellants against their perceived risk of collision in a different manner than an independent observer would. An individual operator will not necessarily be concerned with the big picture. The Department of Defense, through its Joint Space Operations Center (JSpOC), has the only legislative authority and capability to share space situational information, including notifications of impending collisions and near collisions to cooperating space operators, but lacks any enforcement authority.

Orbital Transportation Safety

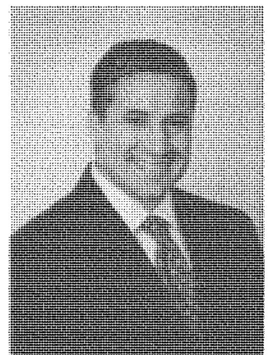
Earlier this year, Dr. George Nield, the FAA's Associate Administrator for Commercial Space Transportation, testified before this Subcommittee that it is time to consider closing the regulatory and safety gap between launch and reentry. As Congress explores the issue of orbital debris and transportation hazards, the FAA urges the Subcommittee to consider at least two possible options, separately or in combination. First, it should look to whether a regulatory agency should authorize transportation on orbit by license. In that scenario, an agency with the proper expertise would, as part of a license evaluation, review the operator's plans and mitigation measures in advance of operations. In a second scenario that may require additional discussion, we should look to the benefits of an agency with enforcement authority providing notices regarding impending hazards and collisions. An agency with enforcement authority could ensure that maneuvers were carried out.

The United States Government, through the FAA, protects the public and property from the hazards of launches and reentries. Similarly, closing the regulatory and safety gap would help protect all space operators from the hazards of additional debris as the result of orbital collisions, and would ensure that all U.S. commercial space transportation vehicle operators employ orbital debris mitigation designs.

The 2009 Iridium-Kosmos collision was a watershed event. The accident brought to light that more work needs to be done to ensure the safe separation of space objects. As space transportation capabilities and operations continue to advance, and as the prospects of a greater number of objects in space increase, certainty in planning for collision avoidance on-orbit becomes ever more critical. It is time to explore orbital safety of commercial space transportation under the Commercial Space Launch Act licensing regime.

Mr. Chairman, this concludes my prepared remarks. I would be pleased to answer any questions you may have.

George D. Zamka
Deputy Associate Administrator



George D. Zamka serves as the Deputy Associate Administrator for Commercial Space Transportation at FAA. He has over 29 years of aerospace experience with the United States Marine Corps and at NASA. Mr. Zamka came to the FAA directly from NASA where he served as an Astronaut and most recently as a Research and Instructor Pilot at the Johnson Space Center.

He is a retired Colonel in the Marine Corps and as a pilot has more than 5,000 flight hours in, fighter, attack, test, research, and training aircraft in more than 30 aircraft types, to include flying in combat. He was selected as an astronaut by NASA in June 1998 and served as Pilot on Space Shuttle mission STS-120 in 2007 and as Commander on STS-130 in 2010. He has more than 692 hours in space.

He has received the Distinguished Flying Cross, Legion of Merit, Defense Meritorious Service Medal, Meritorious Service Medal, Navy Strike Air Medal (six), Navy Commendation Medal with Combat V, NASA Space Flight Medal (two), NASA Outstanding Leadership Medal, and various other military service and campaign awards. He was also awarded the Officer's Cross of the Order of Merit of the Republic of Poland.

Mr. Zamka is a Distinguished Graduate of the United States Naval Academy with a Bachelor of Science degree in Mathematics and received a Master of Science degree in Engineering Management from the Florida Institute of Technology. He also graduated from the United States Air Force Test Pilot School.

Chairman BROOKS. Thank you, Mr. Zamka.
The Chair now recognizes Mr. Nelson for five minutes.

TESTIMONY OF MR. ROBERT NELSON, CHIEF ENGINEER, INTERNATIONAL BUREAU, FEDERAL COMMUNICATIONS COMMISSION

Mr. NELSON. Chairman Brooks, Ranking Member Edwards, and distinguished Members of the Subcommittee, thank you for inviting me to speak with you today about the FCC's role in orbital debris mitigation, and how we fit into the overall efforts of the United States Government with respect to this issue.

In 1973, the FCC licensed the first purely private U.S. communication satellites, and the first such satellite began operations in the geosynchronous orbit in 1974, slightly more than 40 years ago. Under the Communications Act, the FCC is charged with licensing radio communications. The Act recognized that radio transmissions do not stop at national boundaries, and as a result, the Act was drafted with the understanding that regulation needed to extend outside the territorial boundaries of the United States. At the same time, FCC licensing does not extend to U.S. Federal Government transmitters, which are authorized by NTIA in the Commerce Department.

FCC licensing and regulation are governed by a core principle of the Communications Act, that issuing a license requires a finding that the public interest must be served. In that vein, the FCC, in 2004, recognizing work done by NASA and other agencies, adopted debris mitigation regulations for the satellite services it licenses. The FCC concluded that debris mitigation rules would help preserve the United States' continued affordable access to space, the continued provision of reliable U.S. space based services, as well as the contingent safety of persons and property in space, and on the surface of the Earth.

FCC satellite licenses have always included, as one of the terms, of the assignment of an orbital location. Deviation from that license term is basis for an enforcement action. The FCC licensing process includes an opportunity for public comment, and this has, on occasion, resulted in objections to a proposed license modification, based on collision risk. In 2004 debris mitigation rules added a requirement to describe debris mitigation plans. Specifically, the FCC rules require license applicants to describe steps taken to avoid accidental explosions, to identify and avoid collision risks, and to safely dispose of a satellite at the end of its mission. The FCC rules also include a requirement to dispose of geostationary satellites, consistent with an International Telecommunications Union recommendation adopted in 2003, and a requirement that all satellites be left in a safe configuration. The satellite applicant's plans are evaluated as a part of the licensing process.

The FCC is one of three agencies that license U.S. commercial activities in space, the other two being the FAA for launch and reentry activities, and NOAA for remote sensing. Consistent with long established radio frequency management processes, the FCC is the licensing authority for radio frequency use by private launch vehicles and remote sensing satellites. However, the FCC has recognized the FAA's statutory role under the Commercial Space

Launch Act, and it recently reiterated that it would not apply its debris mitigation rules to commercial space transportation activities that are subject to FAA regulation. The FCC also recognized NOAA's statutory role concerning post-mission disposal of the remote sensing satellites it licenses.

Although the FCC licensing process is independent from NOAA and FAA processes, the FCC consults with these agencies as needed. Consultation is often related to status of particular cases and the progress of licensing activities. Further, FCC's regulations and licensing make use of scientific and technical work done by NASA. The FCC does not operate any orbital debris tracking equipment, such as radar and telescopes. And, like much of commercial satellite industry, the FCC's main sources of satellite tracking data are DoD's JSPOC, as well as the satellite operators themselves, derived from their radio links with their satellites.

The efforts to improve space situational awareness of the JSPOC and commercial operators, through such mechanisms as the Space Data Association, are an important element to an overall debris mitigation strategy. To be clear, data sharing between JSPOC and commercial operators is on a spacecraft operator to spacecraft operator basis. The FCC is not an intermediary in this process.

In conclusion, I thank the Committee for this opportunity to describe the FCC's rules concerning orbital debris mitigation, the sources of the FCC's authority on these rules, and the FCC's interaction with other Federal Government agencies concerning this important topic. Thank you very much.

[The prepared statement of Mr. Nelson follows:]

STATEMENT OF

ROBERT NELSON, CHIEF ENGINEER, INTERNATIONAL BUREAU,

FEDERAL COMMUNICATIONS COMMISSION,

Hearing on "Space Traffic Management: How to Prevent a Real Life 'Gravity'"

BEFORE THE SUBCOMMITTEE ON SPACE

U.S. House of Representatives

May 9, 2014

Chairman Palazzo, Ranking Member Edwards, and Distinguished Members of the Subcommittee:

Thank you for inviting me to speak with you today about the FCC's role in orbital debris mitigation, and how we fit into the overall efforts of the United States government with respect to orbital debris.

The Communications Act of 1934, as amended

Under the Communications Act of 1934, the FCC is charged with licensing radio communications. Radio frequencies do not stop at national boundaries. The 1934 Act recognized this bit of physics, and so was drafted with the understanding that regulation would need to extend to transmissions that might originate outside the territorial boundaries of the United States.[1]

At the same time, FCC licensing does not extend to U.S. Federal Government transmitters. Although private industry played a major role in developing satellite technology, in the earliest days of the space age, governmental missions and missions conducted by international intergovernmental organizations predominated. It did not take long, however, for commercial non-governmental activities to emerge. In 1973, the FCC licensed the first purely private U.S. communications satellite ventures, and the first such satellite began operations in the geosynchronous orbit in 1974, slightly more than forty years ago.

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[1] Because the Communications Act of 1934, when it was promulgated, recognized that radio frequencies do not stop at national boundaries, the later development of the FCC's licensing of purely private satellites–which operate in space and therefore beyond national territory--did not require changes to the provisions of that Act. In contrast, the U.S. participation in the since privatized Inmarsat and Intelsat, which were overseen by an international intergovernmental organization, was the subject of the Communications Satellite Act of 1962, and various amendments to that law over the years.

FCC Licensing and Adoption of Debris Mitigation Regulations

FCC licensing and regulation are governed by a core principle of the Communications Act—that issuing a license requires a finding that the public interest will be served.

Concerns about orbital debris grew during the 1990s, and concurrently there was increasing interest in private commercial use of low-Earth orbit. Understanding of orbital debris grew, and the U.S. government, aided by the scientific and technical work of the National Aeronautics and Space Administration (NASA) and other agencies, developed guidelines for mitigating debris, and worked with other space-faring nations to improve debris mitigation practices.

Adoption of FCC Debris Mitigation Regulations

Recognizing these developments, in 2004, the FCC adopted debris mitigation regulations for the satellites services it licenses. The FCC concluded that debris mitigation rules would help preserve the United States' continued affordable access to space, the continued provision of reliable U.S. space-based services--including services for U.S. commercial, government, and homeland security purposes – as well as the continued safety of persons and property in space and on the surface of the Earth.

Even before these rules were adopted, FCC satellite licenses included as one of their terms the assignment of an orbital location. Then and now, deviation from that license term is a basis for enforcement action. The FCC licensing process also includes an opportunity for public comment, and this has sometimes resulted in objections to a proposed license modification based on collision risk. The debris mitigation rules added a requirement to describe debris mitigation plans. Specifically, the FCC rules require license applicants to describe steps taken to avoid accidental explosions, to identify and avoid collision risks, and to safely dispose of the satellite at the end of its mission. The FCC rules also include a requirement to dispose of geostationary satellites consistent with an International Telecommunication Union recommendation adopted in 2003, and a requirement that all satellites be left in a safe, "low energy" configuration through, for example, the venting of remaining fuels and pressurants.

The satellite applicant's plans are evaluated as part of the licensing process, and the FCC has in some circumstances conditioned licenses on modification of that plan, or worked with applicants prior to licensing in order to modify a plan.

When the FCC first proposed rules, one of the concerns raised by industry was that rules would handicap U.S. satellite operators, since foreign satellites could enjoy cost savings by following less stringent practices. For example, because disposal operations for a geostationary satellite require the use of the satellite's limited supply of fuel, holding in reserve the necessary amount of fuel for such operations can shorten by months the length of time the satellite can engage in revenue-generating operations. The FCC was able to address such concerns through the licensing process for the ground stations that non-U.S. satellite operators would need to access in order to serve the U.S. market, by conditioning the grant of a request to use a non-U.S. satellite to communicate with a U.S. ground station on the applicant providing the same information and assurances about the planned debris mitigation of the non-U.S. satellite as is required for a U.S.-

licensed satellite. As a result, the FCC rules apply to all satellites providing commercial service to the United States.

Relationship with other Federal government agencies.

The FCC is one of three agencies that license U.S. commercial activities in space, the other two being the Federal Aviation Administration (FAA) for launch and re-entry activities, and the National Oceanic and Atmospheric Administration (NOAA)for remote sensing. Consistent with long-established radio-frequency management processes, the FCC is the licensing authority for radio-frequency use by private launch vehicles and remote sensing satellites.

When the FCC adopted regulations in this area, it recognized the FAA's statutory role under the Commercial Space Launch Act, and the FCC recently reiterated that it would not apply its debris mitigation rules to commercial space transportation activities that are subject to FAA regulation. The FCC also recognized NOAA's statutory role concerning post-mission disposal of the remote sensing satellites it licenses. Consequently, the FCC neither requires information concerning disposal of those satellites nor makes any determinations concerning such disposal.

Although the FCC licensing process is independent from the NOAA and FAA processes, the FCC consults with the other licensing agencies as needed. Consultation is often related to status of particular cases and the progress of licensing activities. The FCC, NOAA and FAA also consult from time to time on particular policy issues. The FAA includes the FCC in its policy review process for commercial launches, and this has been helpful in identifying situations in which satellites are being scheduled for launch but FCC licensing is not complete, particularly for the increasing number of small satellites that launch as secondary payloads.

In addition, the FCC's regulations and licensing depend heavily on the scientific and technical work done by NASA. In particular, the NASA Orbital Debris Program Office's standards, handbooks, and computer tools have been particularly useful in the FCC's activities, both to the Commission and to license applicants. Many license applicants use those materials in order to develop their debris mitigation plans for FCC approval. The FCC also consults with NASA on technical issues, related either to individual cases or to emerging policy issues.

The FCC and Debris Tracking

The FCC does not operate any of the tracking equipment, such as radars and telescopes, that are used to track orbital debris. Like much of the commercial satellite industry, the FCC has two main sources of satellite tracking data. One is the Joint Space Operations Center (JSpOC), which distributes information from the Space Surveillance Network. The other source, for tracking data about commercial satellites, is information from the satellite operators themselves, derived from their radio links with the satellites. The JSpOC's conjunction assessment program, and the JSpOC's interaction with the commercial satellite industry to provide warnings of potential satellite collisions, are an important element of an overall debris mitigation strategy. To be clear, though, data sharing between JSpOC and commercial operators is on a spacecraft operator-to-spacecraft operator basis. The FCC is not an intermediary in that process. The same is also true of work by commercial operators to improve their situational awareness by pooling satellite position data through cooperative arrangements, for example through the Space Data Association.

Conclusion

In conclusion, I thank the Committee for this opportunity to describe the FCC's rules concerning orbital debris mitigation, the source of the FCC's authority for those rules, and the FCC's interaction with other federal government agencies concerning this important issue.

Mr. Nelson is currently the Chief Engineer for the International Bureau of the Federal Communications Commission. He is responsible for leading the Bureau's work on key technical issues, including satellite communications and cross-border technical issues. He also plays a significant role in the Bureau's preparations for major international conferences and meetings. Prior to serving as the Bureau's Chief Engineer he was the Chief of the Bureau's Satellite Division. Earlier Mr. Nelson served as the Chief of the Satellite Division's Engineering Branch.

Before joining the Commission, Mr. Nelson held various engineering positions in the private sector where he was involved in the design, manufacture, and implementation of domestic and international satellite networks. He has participated as a member of several International Telecommunication Union (ITU) working parties, both as an FCC official and as a private sector representative. Mr. Nelson holds degrees in engineering and management from the University of New Hampshire and Rutgers.

Chairman BROOKS. Thank you, Mr. Nelson.
The Chair now recognizes Mr. Blount for five minutes.

TESTIMONY OF MR. P.J. BLOUNT, ADJUNCT PROFESSOR, AIR AND SPACE LAW, UNIVERSITY OF MISSISSIPPI SCHOOL OF LAW

Mr. BLOUNT. Chairman Brooks, Ranking Member Edwards, distinguished Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss this important topic. Space traffic management is a complex issue, and I will try to briefly summarize my written statement.

Space traffic management as a concept contains two different elements. There—these are the technical capabilities needed to control space traffic, and the legal regime which governs appropriate behavior. I will primarily be addressing the legal aspects of space traffic management, and will do so in the context of the international obligations of the United States.

International space law encompasses a variety of principles that set the bounds of appropriate state conduct in outer space. These principles are broad in scope, and largely undefined. The lack of definition means that the United States is in a unique position to influence the content of these norms to help create a safe and secure space environment. International space law grants all states the right of free access to outer space. Additionally, states shall, under Article 9 of the Outer Space Treaty, engage in space activities with due regard to the corresponding interests of other states, and states are given a right and an obligation to seek consultations when there may be harmful interference between space activities. This treaty provision emphasizes international cooperation and coordination in space activities. Article 9 also creates an obligation to not harmfully contaminate the space environment.

Under Article 6 of the same treaty, states are internationally responsible for the activities of non-governmental actors, and are required to authorize and continually supervise these activities. This is an extraordinary provision in international law which generally does not hold states responsible for the activities of their non-governmental actors. This provision gives states an affirmative obligation to oversee non-governmental actors to ensure that they behave responsibly in space.

As I have already mentioned, these provisions are substantially undefined. They require states to engage in space activities in such a manner as to preserve space for use and exploration by all for peaceful purposes. However, these provisions leave the contours of what constitutes responsible behavior up to states, who have traditionally cooperated and coordinated on an ad hoc basis. Notably, these provisions have failed to set meaningful limits on the creation of orbital debris.

The United States has traditionally been a leader in the development of international space law, and space traffic management should be no different. When provisions of treaties are unclear, state practice in regards to those provisions often help to define the content of the—the content and meaning of those provisions. For example, following the United States lead, Article 6—the Article 6 obligation to authorize and supervise has been implemented by states as licensing regimes.

The United States is in a unique position in the development of domestic space traffic management regime to influence the meaning of international norms and the international frameworks developed to coordinate space traffic management among states. To this end, in my written testimony, I have identified three key principles that should be taken into account when developing a domestic space traffic management system.

First, mechanisms providing for data transparency and access are critical to ensuring proper management of space traffic. It is essential to controlling domestic operations, as well as coordinating international cooperation.

Second, a space traffic management system, whether organized in one agency or many, needs to ensure that the—that a government agency has unambiguous jurisdiction during all phases of space operations. This provides regulatory predictability, which can help foster the commercial space industry, and it also ensures that the United States complies with its obligation to continually supervise non-governmental actors.

Finally, whatever government entity or entities is vested with the jurisdiction to manage space traffic, that agency needs also to vested with technical competence to ensure that it can properly oversee these operations. Jurisdiction to management operations will be meaningless without the technical capabilities to do so.

The maintenance of a safe and secure space environment is in the national interest of the United States. Civil, commercial, and military operations are all dependent on a space environment free of interference from other actors. To this end, the United States should be a leader in developing a space traffic management system that can foster such an environment, both domestically and internationally.

Mr. Chairman, this concludes my statement. Thank you again for the opportunity. I am happy to answer any questions you may have.

[The prepared statement of Mr. Blount follows:]

**Hearing of the Committee on Science, Space, and Technology; Subcommittee on Space
U.S. House of Representatives**

"Space Traffic Management: How to Prevent a Real Life 'Gravity'"

Friday, May 9, 2014 - 10:00 AM

**Testimony of Prof. P.J. Blount
Adjunct Professor, LL.M. in Air and Space Law,
University of Mississippi School of Law**

I would first like to thank Chairman Palazzo, Ranking Member Edwards, and the members of the Subcommittee on Space for the opportunity to address the topic of Space Traffic Management (STM). STM is an increasingly important issue for the United States regarding both domestic regulation and international regulation. STM is a complex issue that combines commercial, civil, and security uses of space. My testimony today will focus primarily on the international obligations of the United States and how U.S. domestic STM regimes can be a critical tool in shaping the development of international STM regimes. My analysis will put priority on the maintenance of United States leadership in space and on ensuring the United States' ability to pursue its national interests.

My core argument is that the United States is in a unique position to be a leader in the development of international regulatory regimes. This in no small part will be aided by the careful development of domestic regimes that can be powerful tools in establishing the international standards that will ensure safe and secure access to outer space for the United States and others. This testimony will proceed in three sections. First, I will address the concept of STM from a definitional perspective in order to properly scope my analysis. Second, I will address the international obligations of the United States in the field of STM. Finally, I will conclude with a model for U.S. leadership in the development of international STM activities. To this end, I will highlight key principles that the United States should consider in developing a regulatory regime that both protects United States' interests and fosters an international system that facilitates safe and secure access to outer space by all actors well into the future.

I. Definitional Issues

STM has become an increasingly important topic for the international space community, but its definition changes depending on context. In 2006, the International Academy of Astronautics (IAA) released an interdisciplinary study on STM, which defined STM as "the set of technical and regulatory provisions for promoting safe access into and out of space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference."[1] This definition is particularly useful in that it sets up a framework for understanding the complex concepts that are involved with STM. While I will use this definition

[1] International Academy of Astronautics, *Cosmic Study on Space Traffic Management* (International Academy of Astronautics, 2006), 10.

and its framework in this testimony, I am not endorsing this definition for adoption into the U.S. law. Instead, I am using it as an analytical tool for parsing out the core issues that the United States will need to account for when developing its own regime. The definition of STM adopted in the domestic regime should be tailored to fit the specific context of the chosen regulatory structure. There are three important aspects to the definition advanced in the IAA study.

The first relevant element of this definition is that it accounts for the two components of STM: technical capabilities and legal provisions.[2] The importance of this cannot be overlooked. Legal regimes without technical regimes are empty protections of the space environment and vice versa. While these regimes interact and overlap, they are distinct. As a legal expert, my testimony focuses on how legal regimes interact with technical provisions, and I leave the technical specifics to those with proper competence.[3] Technical regimes encompass the set of technical capabilities for obtaining space situational awareness (SSA) data as well as the technical capabilities for asserting control over space activities. SSA is "generally defined as information about the space environment and activities in space that can be used to operate safely and efficiently; avoid physical and electromagnetic interference; detect, characterize and protect against threats; and understand the evolution of the space environment."[4] Technical capabilities allow for the physical control of space activities and involve a variety of technologies related to operational aspects such as space debris mitigation and remediation, on-orbit maneuvering, electromagnetic frequency usage, and launch and re-orbit processes.

Legal regimes on the other hand primarily concern jurisdiction of a government agency over the use of space technologies. As a general rule, technological realities are often far ahead of legal rulemaking, meaning that legal regimes need to maintain flexibility in order to adapt to technological change. STM will require a regulatory regime that accomplishes several functions. First, such a regime will need to address issues of access to SSA data and coordination of space activities among relevant actors. Second, the law will need to allocate the jurisdiction over activities related to STM to the appropriate agency or agencies. Finally, legal regimes should ensure that regulatory bodies are able to maintain proper control over space operators to ensure that they are engaging in best practices and using proper technology to preserve the space environment (e.g. implementation of space debris mitigation technologies).

The second important aspect of this definition is that STM covers three accepted phases of space operations: launch, on-orbit, and re-entry.[5] Effective STM requires an ability to coordinate operations during these phases in a unified manner. Safe and secure operations in space necessitate a regulatory regime that can govern space operators during all phases of operations. This should include a pre-launch review to confirm that planned operations have implemented proper technologies. Such pre-launch coordination will also need to ensure that the actors involved have properly planned space operations for the life of the spacecraft from launch

[2] *Id.* at 19.
[3] See for example, Matthew C. Smithman, *The Need for a Global Space-Traffic-Control Service: An Opportunity for US Leadership*, Maxwell Papers (Air War College, 2012) and Brian Weeden, *Going Blind: Why America Is on the Verge of Losing Its Situational Awareness in Space and What Can Be Done About It* (Secure World Foundation, 2012), http://swfound.org/media/90775/going_blind_final.pdf.
[4] Weeden, *Going Blind*, 5.
[5] For a full explication of these different phases of spaceflight see International Academy of Astronautics, *Cosmic Study*, 19.

to end-of-life. Finally, any STM regime will need to be designed to facilitate effective control over an operator to ensure compliance with the law.

The final important aspect of this definition is its articulation of the purpose of STM. STM is meant to ensure that space operations do not interfere with each other in terms of both physical interference and electromagnetic interference. These are different but related issues. Due to the nature of this hearing, I will limit my comments to issues of physical interference, but the coordination of electromagnetic interference should not be overlooked when developing governance structures. The dangers of physical interference are well documented.[6] Space debris is a growing challenge for space operations, and STM regimes will likely be initially designed to cope with this growing threat, because "curtailing the growth of the debris environment is essential to limiting the potential of future satellite collisions."[7] This means that law should manage space debris in three ways. First, as already stated, law will need to be able to assert itself during the pre-launch phase of space operations in order to ensure that the launch vehicle and the spacecraft are designed to minimize the creation of new space debris. Second, the legal regime must govern on-orbit operations, meaning that a government entity should be given jurisdiction over all on-orbit activities and have the ability to compel space operators to comply with legal obligations. Finally, a legal regime will require the capacity to coordinate on-orbit maneuvers in order avoid physical interference. This means that the regime must be designed to facilitate communication and coordination among a variety of stakeholders to avoid situations in which an on-orbit maneuver causes harmful interference.

II. International Obligations and STM

The international space law regime is based primarily on four treaties, which have been supplemented by a variety of other instruments including customary international law and "soft law" mechanisms.[8] As a threshold issue, I would like to make the distinction between international law and domestic law. Domestic law of the United States governs individuals and entities within the jurisdiction of the United States.[9] International Law, on the other hand, governs the way in which the United States interacts with other states. In the U.S. context, international law does not create domestic obligations unless it has been incorporated into domestic law through a proper process.[10] The United States may in fact owe obligations to other countries that are inconsistent with domestic law.[11]

While these regimes are separate in nature, in the context of space activities United States compliance with international obligations is of the utmost importance in maintaining its access to and use of space. This is because, the international regime is built around concepts of coordination and cooperation designed to maintain free access to space by all states. The

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[6] See generally, International Academy of Astronautics, *Cosmic Study*, 31-33.
[7] International Academy of Astronautics, *Cosmic Study*, 33
[8] The four treaties are the Outer Space Treaty,the Rescue and Return Agreement, the Liability Convention, and the Registration Agreement.
[9] *See generally* on jurisdiction, P. J. Blount, "Jurisdiction in Outer Space: Challenges of Private Individuals in Space," *J. Space L.* 33 (2007): 299.
[10] In the U.S. this is primarily accomplished through ratification of treaties by the Senate in accordance with the Constitution's Art. 2.2.2.
[11] For example, this is the issue in *Medellín v. Texas*, 552 U.S. 491 (2008).

United States's ability to operate in outer space is affected directly by the space activities of other states, and engagement in the international community critical to ensuring that all states engage in space activities responsibly. Obviously, the establishment of international STM regimes "will limit the freedom of use of outer space," which is often considered an unpalatable infringement on U.S. sovereignty, but any international regime will need to be the result of consensus from which states can "expect specific as well as collective benefit - including an economic benefit."[12] As a result, the United States should seek to maintain its leadership role in developing international law with the "purpose of achieving the common good" that preserves U.S. national interests.[13]

Below, I will first address the international obligations connected to STM and space debris management that arise under the international space law regime. Then I will briefly discuss new soft law mechanisms and their effect on international STM obligations. This analysis concludes that the international regime is currently weak due to its lack of definite content in terms of rights and duties. In light of the this weakness, the United States should seek to strengthen its leadership in international fora to ensure that any adopted legal mechanisms are consistent with U.S. national interests.

A. The Outer Space Treaty

At the heart of international space law is the Outer Space Treaty.[14] This treaty articulates core legal principles by which states should abide as they conduct space activities. It was drafted during the Cold War with a central purpose of stabilizing state interactions in space in a tense security context. To this end the Outer Space Treaty is written in such a way as to articulate overarching principles for state behavior with few specific obligations. In the current context of space exploration and use, this means that the content of numerous treaty provisions is in flux, and state action is often the primary mechanism through which the content of these provisions is being developed.[15]

The United States has signed and ratified the Outer Space Treaty and is currently bound by the instrument. There are several Outer Space Treaty provisions relevant to STM. First, the principle of free access to outer space is embodied in the first two articles of the Outer Space Treaty.[16] Free access means that all states have equal free access to use outer space for peaceful purposes, and that other states should not interfere with such access.[17] This obligation

[12] International Academy of Astronautics. *Cosmic Study*, 17.
[13] *Id.*
[14] *See generally*, Paul Dembling and Daniel Arons, "The Evolution of the Outer Space Treaty," *Journal of Air Law and Commerce* 33 (January 1, 1967): 419–56.
[15] *See generally*, International Academy of Astronautics, *Cosmic Study*, 39 ("International space law is far from complete.") and P. J. Blount, "Renovating Space: The Future of International Space Law," *Denv. J. Int'l L. & Pol'y* 40 (2012): 515–686.
[16] Dembling and Arons, "The Evolution," 431-2.
[17] *See generally*, International Academy of Astronautics, *Cosmic Study*, 17. *The National Space Policy of the United States* states that the United States maintains a right to engage in self-defence in the area of space which might include that denial of access to space. White House, "National Space Policy of the United States of America" (Executive Office of the President, 2010), 3. This provision should be read as consistent with international law governing the use of force in which defensive activities are considered

is highly undefined and it is unlikely that it explicitly requires, on its face, states to engage in space activities in such a way as to avoid creating debris that could inhibit another state's access to space. Significantly, developing nations have used the free access principle as a justification for creating space debris during the early phases of their space programs.

Second and closely related to the free access principles, Article IX sets out principles that guide state interactions in outer space activities. It requires that states "shall be guided by the principle of cooperation and mutual assistance" and that states shall engage in activities "with due regard to the corresponding interests" of other states.[18] It also creates a corresponding right and duty to engage in consultations when a space activity by one state may harmfully interfere with an activity of another state.[19] Read together, these provisions articulate broad principles that are meant to facilitate free access. Article IX on its face may seem like a powerful provision for STM; however, the terms of this provision are substantially undefined.[20] As a result, Article IX is still being shaped by state action.[21] I have argued in the past that Article IX requires *de minimis* information sharing among states in order for states to comply with obligations.[22] U.S. actions in the past have implicitly endorsed such a stance on information sharing. This can be seen in U.S. activities relating to the intercept of *USA-193*, in which the United States gave an unprecedented amount of detailed technical information about its activity.[23] The principles in Article IX are important but malleable, and responsible U.S. space activities and regulation present a unique opportunity to give content to and operationalize Article IX in a way that encourages responsible behavior when states access space.

Third, Article IX also creates an obligation to not harmfully contaminate the space environment.[24] Harmful contamination is an undefined concept, and one that has traditionally not been invoked by states in relation to space debris creation. Even in the case of the intentional destruction of *FY-1C* during a Chinese anti-satellite test, no state invoked a breach of the obligation to not harmfully contaminate the space environment. This is likely rooted in a historical "right" to create space debris during the use and exploration of space, as well as a reluctance by states to create new limitations on civil or military uses of outer space. Increasing state action on space debris mitigation, though, could change the nature of this obligation.

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peaceful. Any use of self-defense in outer space would only be proper in response to a non-peaceful space activity.

[18] Outer Space Treaty, Art. IX; *see also*, James Rendleman, "Space Traffic Management - Private Regulation?," in *AIAA SPACE 2012 Conference & Exposition* (American Institute of Aeronautics and Astronautics, 2012), http://arc.aiaa.org/doi/abs/10.2514/6.2012-5124, 5.

[19] Outer Space Treaty, Art. IX.

[20] Rendleman, "Space Traffic Management," 9.

[21] *See, for instance*, P. J. Blount, "Developments in Space Security and Their Legal Implications," *Law/Technology* 44 (2011).

[22] *Id.* at 30-35; *see also*, Rendleman, "Space Traffic Management," 9 (arguing that the changing nature of the space environment requires states to develop and maintain SSA capabilities, share SSA data, engage in cooperative monitoring of space activties, and engage in space debris mitigation)

[23] *See generally*, P. J. Blount and Joanne Irene Gabrynowicz, eds., *USA-193: Selected Documents* (National Center for Remote Sensing, Air, and Space Law, 2009).

[24] Outer Space Treaty, Art. VI.

Fourth, Article VII of the Outer Space Treaty sets out a liability regime for space activities, which is further articulated by the Liability Convention.[25] This regime holds that states are liable for damage caused by their space objects. This liability is strict when it applies to damage to aircraft in flight or the surface of the Earth, and is fault based when it applies to damage in outer space.[26] This liability regime has only been invoked once in the case of *Cosmos-957*, and this case sheds little light on the ambiguities in the regime. Currently, the status of a space debris as a "space object" is contested, but the United States has taken the position that space debris that is caused by a state will be covered by the Liability Convention.[27] Additionally, the nature of space debris is such that it is often difficult to attribute debris to a specific state for liability purposes. Going forward, an STM regime could be instrumental in assisting in determining attribution in situations in which space debris causes damage.

Fifth, Article VI creates an obligation for states to authorize and continually supervise space activities of non-governmental actors and gives a state "international responsibility" for the activities of such actors. This is an extraordinary provision in the context of international law, which generally does not hold a state responsible for actions of its private citizens. Article VI is a powerful provision in that it creates an affirmative obligation for states to maintain control over private actors in space, which most certainly includes STM activities such as debris mitigation. Such authorization and supervision is usually accomplished through licensing regimes found in the domestic law of states. As you know, the United States currently has one of the most robust licensing regimes, which has been influential worldwide. However, the United States regime currently falls short fulfilling the obligation of continuing supervision since it does not provide for on-orbit supervision of most space operations.

In addition to Article IX, the Outer Space Treaty has numerous other information sharing provisions as a way to foster international coordination and cooperation.[28] These provisions are often articulated in soft terms and do not create "hard" obligations.[29] However, the importance of these provisions should not be overlooked. As space becomes increasingly used by a variety of actors, coordination of space activities in order to preserve the space environment and to facilitate safe space operations will be critical. Any such coordination will be reliant on international data sharing. Information sharing provisions have been bolstered by other international instruments such as the Hague Code of Conduct.[30] Additionally, international institutions such as the Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and the International Telecommunications Union (ITU) currently serve as the primary fora in which states

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[25] Outer Space Treaty, Art. VII.
[26] Liability Convention, Art. IV.
[27] Blount and Gabrynowicz, *USA-193,* 51-59.
[28] Outer Space Treaty, Arts V (information on phenomena that may harm astronauts), Art. VIII (registration and information about space objects), X (observation of launches), XI (information regarding space activities), and XII (visits to space stations).
[29] For example Article XI only requires states to share information "to the greatest extent practicable and feasible."
[30] Hague Code of Conduct Against Ballistic Missile Proliferation (2002).

share information about their space activities.[31] Information sharing is likely to increase in importance as more entities engage in using space.

B. Soft Law

Soft law is international instruments that are regulatory in nature, but that create non-binding or weak obligations.[32] Soft law is probably best understood as international policy, and represents part of a "growing diversification" in regulatory structures.[33] Soft law comes in a variety of forms, and it generally articulates proper state behavior without articulating legally binding rights and obligations. Instead, soft law seeks to establish unenforceable political and moral obligations to other states. I have argued before that soft law regimes are likely the way forward when it comes to space law making at the international level.[34] This is because soft law mechanisms allow states to experiment with different types of regulation without entrenching regulatory systems prematurely. Soft law can form an integral part of the law making process at the international level by reducing the risks associated with hard law making. I will briefly address three of such instruments that have relevance to STM and could be seen as models for future development.

First is the Hague Code of Conduct, which I have previously mentioned. The Hague Code of Conduct is a soft law measure focused on nonproliferation of ICBM technology. It facilitates the exchange of pre-launch notifications of ICBM and space launches.[35] Such an information sharing regime would be essential in any international STM efforts, though it would need be more robust in order to facilitate the type of information sharing that is needed to ensure on-orbit management of space traffic. This would involve more expansive data and a system for the timely distribution of such data.

Second, the IADC Debris Mitigation Guidelines are a set of internationally agreed upon technical guidelines for mitigating orbital debris.[36] These guidelines have been approved by UNCOPUOS, and are supported by the United States. They serve as a likely model for the initial regulation of space debris. Technical guidelines are subject to change as technology evolves, and soft regulatory instruments are a particularly useful tool when technology is still developing rapidly. It gives states the ability to negotiate and implement guidelines while preserving the flexibility to adapt to new technological realities as they arise. In the short term nonbinding technical agreements and international pressure will likely be instrumental in developing international STM regimes. Long term international STM solutions will likely need structures

[31] UNCOPUOS manages a database of registered space objects, but the information required for registration is minimal. International Academy of Astronautics, *Cosmic Study*, 39. The ITU maintains the Master Frequency Register which includes orbital tolerances in the Geosynchronous Orbit, *Id.* at 22. Additionally, both the International Civil Aviation Authority (ICAO) and the International Maritime Satellite Organization (IMSO) provide information sharing on space activities that affect their respective competencies.
[32] *See generally*, Kenneth W. Abbott and Duncan Snidal, "Hard and Soft Law in International Governance," *International Organization* 54, no. 3 (2000): 421–56.
[33] International Academy of Astronautics, *Cosmic Study*, 38.
[34] Blount, "Renovating Space."
[35] International Academy of Astronautics, *Cosmic Study*, 39.
[36] Inter-Agency Space Debris Coordination Committee, *IADC Space Debris Mitigation Guidelines* (Inter-Agency Space Debris Coordination Committee, 2002).

such as those found in the ITU or ICAO in order to facilitate the regular updating of technical regulations.

Finally, Draft Codes of Conduct, such as the one proposed by the European Union can help to define what is acceptable state behavior. Codes of conduct create a political space in which states can begin to negotiate acceptable behavior. An international STM regime will need to define what is acceptable behavior in space, and such definitions are currently highly contested. Codes of conduct can help establish common ground among states, which can be leveraged to achieve consensus.

III. United States Leadership in STM

The United States has maintained itself as a leader in civil, commercial, and military space use and exploration since the very beginnings of the space age, and it has had a major influence on the development of international legal regimes. It has done this not only through direct negotiation of space treaties, but also through its own practices and international outreach activities. Examples include the use of the term peaceful purposes in the 1958 Space Act, which has become a threshold for all space activity[37]; the nondiscriminatory access to remote sensing data provisions found in *Landsat* data policies, which became one of the bedrock principles of remote sensing law[38]; and the FAA's active engagement in spreading information about its regulations to other states.[39]

In light of the ambiguous nature of the content of international regulations, the regulatory approach adopted by the United States will likely be highly influential in shaping how the international community develops STM regimes. International regimes will need to account for "harmonizing national space legislation, its licensing standards and procedures,"[40] and as a "leader[] in commercial space, [the United States] must engage with the international community and shape international standards to improve safety."[41] The United States is in a unique position to exert great influence on the development of the international principles that will guide international STM institutions, and great care should be taken to craft a regime that will positively influence any developments at the international level wherein severe lacunae exist. It should be emphasized that United States' engagement in the development of the international regime should pursued in such a way as to protect U.S. national interests associated with space activities such as "the Nation's technological advancement, scientific discovery, security and

[37] National Aeronautics and Space Act of 1958, sec. 102.

[38] *See generally*, Joanne Irene Gabrynowicz, "The Perils of Landsat from Grassroots to Globalization: A Comprehensive Review of US Remote Sensing Law with a Few Thoughts for the Future," *Chi. J. Int'l L.* 6 (2005): 45.

[39] The Secretary of Transportation is tasked with "[advocating] internationally for the adoption of United States Government safety regulations, standards, and licensing measures to enhance global interoperability and safety of international commercial space transportation activities." White House, "National Space Transportation Policy," (November 2013). http://www.whitehouse.gov/sites/default/files/microsites/ostp/national_space_transportation_policy_11212013.pdf, 5. *See also*, George Nield, "Statement before the House Committee on Science Space, and Technology, Subcommittee on Space, on Necessary Updates to the Commercial Space Launch Act," February 4, 2014, http://testimony.ost.dot.gov/test/nield1.pdf, 6.

[40] International Academy of Astronautics, *Cosmic Study*, 40.

[41] Nield, "Statement," 5.

economic growth."[42] The United States should engage the international community in order to establish a regime that best supports U.S. interests, whether commercial, civil, or security.

Currently, the United States system for managing space traffic is fragmented among a number of agencies: the FAA regulates launch and re-entry activities and space debris associated with launch activities[43]; the FCC regulates electromagnetic spectrum as well as space debris mitigation[44]; NOAA has jurisdiction over remote sensing satellites and debris mitigation[45]; the State Department is involved with international coordination; and DoD is responsible for SSA data collection and dispersal. Each of these agencies have specific regulatory goals that they are trying to achieve, for instance the FAA's primary goal is safety, DoD's primary goal is national security, State's is foreign relations, and FCC and NOAA are concerned with technical issues and fostering commercial use. All of these interests are important, but at times they can compete. As a result a balance needs to be struck among these interests in order to properly govern space activities to maintain "assured access to diverse regions of space . . . in support of civil and and national security missions."[46] This is not to say that a single agency regime should be preferred over a multi-agency regime, but instead to point out how competing regulatory interests affect the current regulatory structure.

Domestic STM regimes will need to cover a number of aspects of space activities including safe operations, collision avoidance, information on space operations, observations of space operations, and the prevention of space debris.[47] Additionally, these regulatory structures will need to be able to cope "as new actors and capabilities emerge."[48] Regulations will also need to create predictability and safety. This can reduce risk for space actors and promote the United States industrial base by providing clear articulation of what constitutes responsible behavior in outer space.[49] Notably, these regulations will need to be designed to ensure U.S. compliance with Article VI obligations in order to protect the United States from liability exposure caused by private actors.[50]

Whether STM at the domestic level is maintained as a multi-agency system or consolidated into a single agency, several core principles should guide the architecture of the system.[51] Incorporation of these principles into domestic regimes will help to structure a system that can serve as a model for other nations and influence the development of an international regime. These principles are transparency and access, unambiguous jurisdiction, and the maintenance technical competence.

[42] White House, "National Space Transportation Policy," 1.
[43] 14 C.F.R Chapter III (2014); and White House, "National Space Transportation Policy," 5; and Nield, "Statement," 3.
[44] 47 C.F.R. part 27 (2014).
[45] 15 CFR Part 960 (2014).
[46] White House, "National Space Transportation Policy," 2.
[47] International Academy of Astronautics, *Cosmic Study*, 41-42.
[48] White House, "National Space Transportation Policy," 1 and Nield, "Statement," 3.
[49] White House, "National Space Transportation Policy," 5 & 7 and Nield, "Statement," 2-3, 7.
[50] Nield, "Statement," 5.
[51] There are feasible frameworks that can be built around either a single agency or a multi-agency regulatory paradigm.

A. Data Transparency and Access

As already noted the United States has an international obligation to engage in numerous types of information sharing, but there is no positive obligation to engage in the sharing of SSA data. While Article IX of the Outer Space Treaty could be read in such a way as to create such an obligation, there is little support in state practice that such an obligation exists.[52] Despite the lack of a positive obligation the United States is currently a leader in space data distribution.[53] The Department of Defense provides publicly unclassified SSA data via the SATCAT,[54] but this data has been criticized as "untimely and insufficient."[55] Most countries with SSA capabilities do not distribute this data.[56] The U.S. does not distribute classified SSA data, which includes data concerning military satellites, thus while maintaining one of the few publicly available databases, the U.S. system has come under criticism for distributing incomplete datasets.[57]

Transparency is a critical component of any STM regime. Transparency in SSA data allows space operators to engage in space operation in a responsible manner, and enables regulators to make proper regulatory decisions.[58] National security interests are connected to space data distribution, but national security is also served by ensuring that space actors have the ability to identify and avoid threats to their operations.[59] A regime that ensures "an orderly and transparent use of orbits will be necessary in the self-interest of military actors as well."[60] While there may be some space data that is sensitive, an increasing amount of information on the orbital parameters of classified satellites is becoming available in the public domain undermining such secrecy. The gaps in the U.S. system have led to the development of the Space Data Association (SDA), which is a conglomerate of space operators that have agreed to share information among themselves.[61] SDA represents a positive development, but the United States could do more in facilitating safe operations by granting transparent access to its SSA data. Transparency is a value that will be important to the future development of future

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[52] *But see*, Rendleman, "Space Traffic Management," 9.

[53] The U.S. military has distributed such data since 1958. Weeden, *Going Blind*, 16. The IAA notes that the United States and Russia have the most developed capabilities for collecting SSA data and that other states "maintain tracking of space assets, but lack the capability to monitor space traffic as a whole." International Academy of Astronautics, *Cosmic Study*, 35.

[54] *See*, Weeden, *Going Blind*, 12-16. It should be noted that this system is not without critique for its coverage gaps and the dated state of the technology it relies on. *See generally*, Matthew C. Smithman, *The Need for a Global Space-Traffic-Control Service: An Opportunity for US Leadership*, Maxwell Papers (Air War College, 2012) and Weeden, *Going Blind*, 6-7.

[55] Smithman, *The Need*, 160.

[56] Russia and China do not publish SSA data publicly and the EU does not plan on doing so either. Smithman, *The Need*, 160.

[57] Smithman, *The Need*, 160.

[58] The IAA notes a total of six orbital elements that describe satellite motion in a transparent manner. See International Academy of Astronautics, *Cosmic Study*, 34-5. The U.S. database only distributes minimal data. Weeden, *Id.* at 36.

[59] International Academy of Astronautics, *Cosmic Study*, 18-19. The IAA study notes that the nature of military operations creates specific issues for STM, but that military operations will eventually benefit from international coordination on STM. *Id.* Weeden argues that open SSA data will "play and increasingly important role in in international security and stability." Weeden, *Going Blind*, 11.

[60] International Academy of Astronautics, *Cosmic Study*, 53.

[61] It should be noted that SDA includes governmental members. Brian Weeden, *Going Blind*, 9-10.

international regimes, and the United States should be a leader in promoting data sharing at the international level.

Related to transparency is access to space traffic data, since "there is a need to provide all satellite operators with the basic information necessary to operate in a safe and efficient environment."[62] This is especially true if, a multi-agency regulatory model is maintained. In the current fragmented regime, there is no central clearinghouse for information on space traffic, despite the fact that "[i]nformation sharing and mutual assistance are counted among tools employed by system operators to mitigate threats."[63] While agencies do coordinate actions, operators must avail themselves to a variety of sources to gain access to full sets of data on space activities. This is the gap that SDA is attempting to fill.[64] Giving an agency the competency to provide interagency coordination could smooth the licensing procedure and provide a specific locus within the STM regime for obtaining data on space activities. Additionally, such an entity could also serve as the interface for international data sharing. Increasing access to SSA data would be consistent with U.S. interests, and this data is critical in making accurate predictions of potential collisions.[65] International data could be collected and integrated into U.S. datasets in order to give United States' operators more robust information and to give regulatory agencies an enhanced ability to determine what actions need to be taken to ensure safe and secure space operations.[66]

B. Unambiguous Jurisdiction

Currently in the United States system, there is divided jurisdiction over private space operations. The FAA regulates launch and re-entry activities of space actors, the FCC governs satellites that need radio-communications frequencies (which is practically all satellites and spacecraft), and NOAA governs satellites with remote sensing capabilities. All three have jurisdiction over space debris mitigation through reviews of operational plans during the licensing processes. Notably, though, no agency has complete on-orbit jurisdiction. So for instance, while a satellite operator can be required to implement shielding on a satellite in order to reduce the likelihood of debris creation, there is no agency that could force that operator to move its satellite in the case of a possible collision. This gap in jurisdiction is problematic as space becomes more populated, and filling it is a needed measure in order to ensure that U.S. space operators comply with acceptable standards.

Establishing such jurisdiction is important in ensuring that the United States' can fulfill its international obligation to "continually supervise" its non-governmental actors in space as required by Article VI of the Outer Space Treaty. Such a regime could lead to the creation of best practices for responsible conduct that could become integral parts of international standards for behavior. Additionally, vesting an agency with on-orbit jurisdiction will give much

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[62] Weeden, *Going Blind*, 10.
[63] Rendleman, "Space Traffic Management, 3.
[64] Weeden, *Going Blind*, 9.
[65] International Academy of Astronautics, *Cosmic Study*, 67
[66] Weeden notes that while "it is technically feasible for one state to build the network of sensors required to accomplish tracking" space objects economic and geographic factors severely limit a states ability to effectively gather this data. Weeden, *Going Blind*, 8.

needed legal certainty to commercial space actors, which can help to foster commercial activities.

C. Ensuring Technological Competence

STM is an undertaking that requires a great deal of technological capabilities, and there is a need to establish a regime that can manage these technologies. Currently, DoD maintains a prominent role in gathering space data, and the FCC, FAA, and NOAA all maintain specific control over technical aspects of launch vehicles and spacecraft. However STM is organized though, it is important to ensure that regulatory agencies have the technological capability and expertise to maintain these activities.

In the current licensing regime agencies in charge of licensing are given jurisdiction based on specific technological functions of the object being regulated. Jurisdiction is divided along functional grounds, which ensures that the regulating agencies have specific technological expertise. Fragmenting jurisdiction along these lines, while not without it's problems, is an effective way to ensure that there is proper attention and expertise given to regulating each aspect of a spacecraft's operations.

SSA data gathering is a more complex issue. SSA has definite national security implications, but any STM regime will need complete data in order to execute proper conjunction analyses. Commentators have argued for a number of approaches such as leaving these functions with DoD and upgrading them[67]; relying on private entities to collect and maintain data and to execute conjunction analysis[68]; and transferring these capabilities to the civilian sector to better increase global access.[69] There are drawbacks to each of these: if the system is upgraded and access to data is expanded, DoD maintenance will always draw fire for lack of transparency;[70] if commercial entities such as SDA are trusted with the task, then there is an effective transfer of a state's Article VI supervision duties to nongovernmental actors; and if these technologies are transferred to the civilian sector, then a massive technology transfer to an agency that does not have previous experience with such technology must take place.

Closely linked to data gathering is the operationalization of this data. SSA data must be analyzed in order to determine when there is the risk of conjunction events. Currently, DoD performs this function to a limited extent.[71] An agency given on-orbit jurisdiction will either need to be able to run conjunction analyses on its own or be able to obtain reliable and up to date information on possible collision events from another agency or third party. Without this type of information, a regulatory agency will not be able to effectively maintain control over space activities.

Ensuring that there is proper technical expertise in regulating agencies also allows the United States to be able to actively engage in international fora and advance technical standards that best ensure safe and secure space operations. By maintaining this expertise within

[67] *See generally*, Smithman, *The Need.*
[68] *See generally*, Rendleman, "Space Traffic Management."
[69] *See generally*, Weeden, *Going Blind.*
[70] International Academy of Astronautics, *Cosmic Study*, 18 ("The naturally secret nature of military activities makes it difficult to see how they can fit in a system that has to be based on transparency").
[71] Smithman, *The Need*, 158.

government agencies, the United States can be a leader in driving the development of technical regulations.

IV. Conclusion

STM operations are becoming increasingly important as space activities proliferate globally. As the United States considers the regulatory regime that will govern STM in the domestic sphere, it should also consider the underlying international legal obligations and the effect of domestic regulations on the development of international STM institutions.

In establishing the STM regime, regardless of whether it is designed around a multi-agency model or a single central agency model, specific principles that the United States' should consider in order to effectuate an effective regime are:

- Transparency and Access
- Unambiguous Jurisdiction
- Ensuring Technological Competence

Incorporating these elements will ensure that the United States promulgates domestic regulations that are not just compliant with international legal regimes, but also have an impact on the development of international law in a positive manner consistent with United States interests in the peaceful use of outer space across the spectrum of private, civil, and military activities.

Thank you again for the opportunity to testify on this topic. I look forward to answering your questions.

P.J. Blount
Bio

P.J. Blount (B.A./A.B.J., University of Georgia, 2002; J.D., University of Mississippi School of Law, 2006; LL.M. in Public International Law, King's College London, 2007; Ph.D. in Global Affairs, Rutgers, expected 2016) is an adjunct professor in the LL.M in Air and Space Law at the University of Mississippi School of Law and an adjunct professor in the Department of Political Science and Law at Montclair State University. Previously, he served as Research Counsel for the National Center for Remote Sensing, Air, and Space Law at the University of Mississippi School of Law. He teaches Space Security Law, International Telecommunications Law, Human Rights Law, and Cyberlaw.

Blount's primary research areas are legal issues related to space security and cyberspace governance. He has published and presented widely on the topic of space security law. Blount serves as the editor of the *Res Communis Blog* (http://rescommunis.olemiss.edu); as a staff editor of the *Journal of Space Law*; and as an editorial board member of the *Journal of Astrosociology*. Additionally, he serves as the Assistant Executive Secretary of the International Institute of Space Law, participates as a judge in the Manfred Lachs Space Law Moot Court Competition. He is a member of the State Bar of Georgia.

Chairman BROOKS. Thank you, Mr. Blount.

The Chair now recognizes Mr. Weeden for five minutes.

TESTIMONY OF MR. BRIAN WEEDEN, TECHNICAL ADVISOR, SECURE WORLD FOUNDATION

Mr. WEEDEN. Thank you, Chairman Brooks, Ranking Member Edwards, distinguished Members of the Subcommittee. Secure World Foundation is dedicated to the long term sustainability of the space environment so that all of humanity can continue to use space for benefits here on Earth. The growth in space debris, and increasing congestion of critical regions of Earth orbit, present significant challenges to space sustainability, and addressing those challenges is a key part of our work.

Regarding the threat that space debris poses, there are three categories of complementary activities that can help address that challenge. The first is space debris mitigation, limiting the creation of new debris from human activities in space. The second is active debris removal, also known as remediation, which aims to remove some of the existing pieces of debris to help prevent future growth in the debris population, or to reduce the collision risk to satellites in highly congested regions. The third activity is space traffic management, which I defined in my testimony as minimizing the negative impact of space debris on space activities. All three of these activities are enabled by a fourth, space situation awareness, broadly defined as characterized in a space environment, and its impact on activities in space.

The U.S. government's strong efforts on space debris mitigation over the last decade and a half are a good start, but need to be part of a more comprehensive approach. My written testimony outlines three major steps that can be taken in this direction. The first is to find ways to harmonize the implementation of debris mitigation guidelines across the various regulatory agencies that currently have authority. Doing so can result in a more efficient and effective process, with benefits to commercial industry and innovation.

Second, this Subcommittee can call on the executive branch to articulate a comprehensive strategy for dealing with existing space debris, which may potentially include active removal.

Third, this Subcommittee can work with the executive branch, and other Committees with jurisdiction, to re-examine the rules and responsibilities for space situation awareness and space traffic management.

The key question facing this government moving forward is whether or not the Department of Defense should continue to be the single Federal agency responsible for all space situation awareness activities, and providing operational space traffic management for the world. I believe the answer is no. While space surveillance began as a national security function, it has evolved into more than just national security. It plays a fundamental role in the breadth of space activities being conducted by not only the military, but also civil government agencies, and the private sector.

Thus, I believe it is time for the U.S. government to shift responsibility for part of the SSA mission that directly supports safety of space flight to a Federal entity other than the DoD. The shift will allow this new entity to focus on building relationships with commercial and foreign actors, take better advantage of private sector innovation, and establish trusted services with all space actors. The DoD would certainly retain responsibility for, and a focus on, the national security aspects.

Making this challenge is not—making this change is not without considerable challenges. First and foremost is determining which Federal department or agency should be assigned this new role. One option is to assign it to an agency that already has existing authority for regulating and licensing private sector space activities. Another option to assign it to a Federal agency that already has significant expertise in space operations and space debris. A third option would be to assign it to a new Federal agency with both regulatory powers and operational responsibility. Which of these options is best depends upon the long term priorities and goals for the U.S. government, and the role it wants to play in global space activities.

This proposed shift in responsibility, I believe, puts the U.S. government in a better position to harness the private sector innovation currently ongoing, and improve its own capabilities and security in orbit. It is very similar to the DoD's current approach for both satellite communications and space-based remote sensing. In both of these areas, the government focuses its efforts on exclusive niche capabilities the private sector cannot provide. The end result has been an increased capability for the military, lower cost to the taxpayer, and a booming commercial industry.

It has become almost trite to point out that the space world has changed, but in the context of this hearing, it is worth making the point again. The continuing expansion and the number of space actors, the types of space activities, has created a complex space environment. Technological diffusion has commoditized space capabilities, fueled a surge of private sector innovation, and created the possibility for many new uses of space for benefits here on Earth. It is vitally important for the U.S. government to evolve its approach to stay abreast of this ongoing change and continue to maintain its leadership role in supporting the safety of space activities, and encouraging innovation.

Thank you for your time, and I will be happy to answer any questions you may have.

[The prepared statement of Mr. Weeden follows:]

Hearing of the Committee on Science, Space, and Technology

U.S. House of Representatives

"Space Traffic Management: Preventing a Real Life 'Gravity'"

Friday, May 9, 2014 - 10:00 AM

Testimony of Mr. Brian Weeden

Technical Advisor, Secure World Foundation

1. Introduction

Mr. Chairman, distinguished members of this subcommittee, thank you for the opportunity to testify today on this important issue. Secure World Foundation is dedicated to the long-term sustainability of the space environment so that all of humanity can continue to use space for benefits on Earth. The growth in space debris and increasing congestion of critical regions of Earth orbit present significant challenges to space sustainability, and addressing those challenges is a key part of our work.

On February 10, 2009, an inactive Russian military communications satellite, designated Cosmos 2251, collided with an active commercial communications satellite operated by U.S.-based Iridium Satellite LLC.[1] The incident occurred approximately 800 kilometers (500 miles) above Siberia. The collision produced almost 2,000 pieces of debris that have been cataloged so far and many thousands of pieces more that are too small to track with our current technology. Much of this debris will remain in orbit for decades or longer, posing a collision risk to other objects in Low Earth Orbit (LEO).

This was the first-ever collision between two satellites in orbit[2] and it served as a wake-up call for the entire space community to the threat that space debris poses to active satellites as well as of the long-term negative impact catastrophic collisions can have on the space environment. The collision increased the amount of space debris in what was already one of the most densely populated and heavily used regions of Earth orbit by both governments and the private sector.

The collision profoundly impacted how satellite operators viewed the space environment. Before the collision, it was common for satellite operators to invoke the "Big Sky" theory when asked

[1] A summary of the Iridium-Cosmos collision can be found in the SWF Fact Sheet on the event: http://swfound.org/media/6575/swf_iridium_cosmos_collision_fact_sheet_updated_2012.pdf

[2] There have been previous collisions in orbit between two pieces of space debris or between a satellite and a piece of space debris, but not between two satellites.

about the possibility of collisions between space objects. There had been some efforts by a few operators to detect and avoid satellite collisions, but collisions were generally regarded as not being a significant threat. More importantly, the vast majority of satellite operators were flying blind – they had little to no access to information about what other objects were near their own satellite. The Iridium-Cosmos collision forced the space community to come to grips with the reality of today's space environment.

My written testimony covers several important issues that are relevant to dealing with the challenge of space debris and supporting the safe operations of existing and emerging civil and commercial space operations. First, it begins with an overview of the current space environment and the challenge posed by space debris. It then discusses the three main ways of dealing with space debris – mitigation, removal, and space traffic management (STM). It then turns to the importance of space situational awareness (SSA), which provides the foundation that enables all the other activities, and looks at the evolution in both SSA and STM. Finally, I discuss the current federal agency roles and responsibilities to support these four areas and provide a series of options for moving forward.

The key question facing the U.S. government moving forward is whether or not the Department of Defense (DoD) should continue to be the single federal agency responsible for all SSA activities and providing operational STM for the world. I believe the answer is no. Instead, I believe it is time for the U.S. government to shift responsibility for the part of the SSA mission that directly impacts on-orbit safety and sustainability to a non-DoD entity. There are three main options for doing so, each of which has its strengths and weaknesses. The best option depends on what the long-term priorities and goals are for the U.S. government and the role it wants to play in global space activities.

It is important to note that there is no consensus on what terms like SSA and STM mean across the space community. The different definitions that exist are the result of varying perceptions on what the true challenges are and different motivations as to what the solution should be. Thus, one of the first steps to resolving these issues is to recognize the nuances in the definitions and perceptions of these terms and establish the context in which this subcommittee is approaching the issue. In the case of this hearing, the context is supporting existing and emerging civil and commercial space operations, and it will frame the remainder of my testimony.

I would also like to make clear my personal context for approaching this subject matter. My first exposure to these issues was as a captain in the United States Air Force, where I spent three years in the Air Force unit responsible for tracking human-generated objects in space. My experiences on both the operational side and as an instructor helping to develop tactics, techniques, and procedures gave me insight into the national security aspects of the mission. Since leaving the Air Force in 2007, I have spent the last several years continuing to study and analyze these issues. During that time, Secure World Foundation's ongoing interactions with a number of U.S. government agencies, the private sector, and the international community have provided me with a broader perspective from multiple stakeholders.

2. Background on the Current Space Debris Environment

More than 70 entities (countries, commercial companies, and international organizations) currently operate more than 1,100 satellites in orbit around Earth,[3] providing a wide range of social and private benefits. These include enhanced national and international security, more efficient use and management of natural resources, improved disaster warning and response, and near-instantaneous global communications and navigation.

Space debris - dead satellites, spent rocket stages, and other fragments associated with humanity's six decades of activity in space - represents a growing threat to active satellites. The DoD tracks close to 23,000 pieces of human-generated debris in Earth orbit larger than 10 centimeters (4 inches) in size, each of which could destroy an active satellite in a collision. Research done by scientists from various space agencies indicates there are an estimated 500,000 pieces of space debris between 1 and 10 centimeters (0.4 to 4 inches) in size that are largely untracked, each of which could severely damage an active satellite in a collision.

As space debris is generated by humanity's activities in space, it is concentrated in the most heavily used regions of Earth orbit where many active satellites also reside. These regions include the LEO region below 2,000 kilometers (1,200 miles) in altitude and the geostationary Earth orbit (GEO) region, approximately 36,000 kilometers (22,000 miles) above the equator. Of the two regions, LEO currently presents the most pressing challenge for long-term sustainability and increasing collision threats to satellites from space debris.[4]

Former NASA scientist Donald Kessler was one of the first to predict what has since become known as the Kessler Syndrome.[5] As the amount of space debris in orbit grows, he predicted there would be a critical point where the density of space debris would lead to random collisions between space debris. These random collisions would in turn generate more debris at a rate faster than space debris is removed from orbit by the Earth's atmosphere. Unlike the dramatic scenario presented in the movie *Gravity*, this process would take place much more slowly over decades or centuries. Space was not a pristine environment before humans began to fill it with satellites. There has always been a natural debris environment in space due to meteoroids. Kessler's

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[3] The most accurate public estimate of the active satellites current in Earth orbit is the database maintained by the Union of Concerned Scientists available here: http://www.ucsusa.org/nuclear_weapons_and_global_security/solutions/space-weapons/ucs-satellite-database.html

[4] The debris threat in the GEO region is not yet as significant as in LEO, but that may change in the near future. For an excellent overview of the debris threat in GEO, see Mcknight, DS and Di Pentino, FR, "New insights on the orbital debris collision hazard at GEO", *Acta Astronautica*, http://dx.doi.org/10.1016/j.actaastro.2012.12.006

[5] Don's own summary of the history of the Kessler Syndrome can be found here: http://webpages.charter.net/dkessler/files/KesSym.html

prediction was that these cascading debris-on-debris collisions would result in a human-generated debris population that would pose more of a threat to satellites than the natural debris.

There is now a general consensus among scientists that this critical point has come to pass and there is enough human-generated space debris concentrated in the critical region in LEO between 700 and 900 kilometers (430 to 560 miles) to create more debris even if no new satellites were launched. Computer simulations conducted by six different space agencies predict that this critical region will see additional catastrophic collisions similar to Cosmos-Iridium every 5 to 9 years.[6]

These debris-on-debris collisions will not lead to an infinite growth in the debris population. Rather, they will lead to a future equilibrium point that has a larger population of debris than today. This increased amount of debris will increase the risks and thus the associated costs of operating satellites in critical regions such as LEO. These increased costs could come about through the need for more spare satellites to replace those lost in collisions, heavier and more overly engineered satellites that cost more to build and launch, and increased operating costs to try to detect and avoid potential collisions. These rising costs will likely hinder commercial development of space and will place additional pressure on government budgets, potentially resulting in the loss of some of the benefits we currently derive from space or preventing discovery of new benefits.

3. Dealing With Space Debris

Efforts to tackle this problem fall into three major categories. Each category addresses a different aspect of the problem – limiting the creation of new space debris, addressing the legacy population of space debris already in orbit, and minimizing the negative impact of the existing debris on space activities.

3.1 Space Debris Mitigation

Space debris mitigation is limiting the creation of new debris through human activities in space. Debris mitigation includes designing satellites and space systems so as to minimize the amount of debris they release during normal operations, developing methods to reduce the risk of fragmentation or explosion at the end of life by venting leftover fuel or discharging batteries, and properly disposing of spacecraft and spent rocket stages after they are no longer useful.

The United States has been a world leader in both developing space debris mitigation guidelines and in implementing them through national regulation. NASA was a founding member of the Inter-Agency Space Debris Coordination Committee (IADC) where it worked with other major

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[6] These simulations can be found in the study "Stability of the Future LEO Environment", IADC-12-08 Rev 1, January 2013: http://www.iadc-online.org/Documents/IADC-2012-08,%20Rev%201,%20Stability%20of%20Future%20LEO%20Environment.pdf

space agencies on developing technical debris mitigation guidelines and continues to conduct scientific research on space debris.[7]

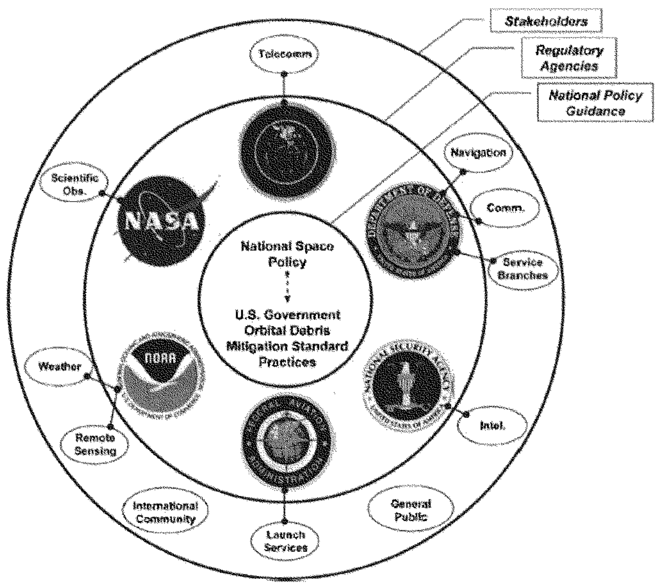

Figure 1. General structure of U.S. debris policy implementation[8]

The U.S. government has also put in place some of the most comprehensive policy and regulatory instruments to implement these technical guidelines in national space activities.[9] At the top level, the 2010 National Space Policy of the United States identified "Preserving the

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[7] The IADC Space Debris Mitigation Guidelines can be found here: http://www.iadc-online.org/Documents/IADC-2002-01,%20IADC%20Space%20Debris%20Guidelines,%20Revision%201.pdf

[8] This image is from Percy, TK., Landrum, DB, "Investigation of national policy shifts to impact orbital debris environments", *Space Policy,* http://dx.doi.org/10.1016/j.spacepol.2014.02.003 Used with permission.

[9] An overview of these authorities and the relevant regulations can be found in a conference room paper presented by the U.S. delegation to the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space on March 24, 2014: http://www.oosa.unvienna.org/pdf/limited/c2/AC105_C2_2014_CRP15Add01E.pdf

Space Environment and the Responsible Use of Space" as one of its seven intersector guidelines. It directs federal agencies to implement the U.S. Government Orbital Debris Mitigation Standard Practices in their space activities. The various federal agencies that conduct governmental space activities each have their own policy guidance and framework for implementing these directives. There are some parts of the implementation that is coordinated through the interagency process, but also some parts that are left to agency discretion.

There are also three federal agencies with existing regulatory authority over non-governmental space activities that implement and enforce space debris mitigation guidelines on the private sector. The National Oceanic and Atmospheric Administration (NOAA) under the Department of Commerce has the authority to license non-governmental space-based remote sensing of Earth. The Federal Aviation Association (FAA) under the Department of Transportation has licensing authority over commercial launch, re-entry or reusable vehicles, commercial launch or re-entry facilities, and also commercial human spaceflight. The Federal Communications Commission (FCC) also has the authority to provide licenses to radio frequency spectrum for non-governmental satellite activities.

In general, the space debris mitigation guidelines are currently implemented for non-governmental space activities as part of the licensing processes in each of these three agencies. However, there are differences in the requirements set by these agencies. For example, the FCC requires that licensees present a plan for debris mitigation during both normal operations and post-mission disposal, whereas NOAA requires that licensees present a plan for just post-mission disposal of their remote sensing satellite. The FCC also requires licensees to follow the 25-year rule in de-orbiting all pieces from a space launch whereas the FAA does not.[10] These differences in licensing requirements and rules are largely due to the differences the two agencies have in their approach to risk mitigation as a result of different legislative and policy mandates. Furthermore, only NOAA currently has regulatory authority over operational space activities.

There needs to be an in-depth study of the debris mitigation portions of the licensing requirements of these three agencies. Harmonizing the requirements across the licensing process would help ensure that the relevant risks are being addressed without undue burden on the private sector. This study should also look for gaps between the existing regulatory authorities and emerging categories of private sector space activities. For example, the technology is currently being developed for satellite communications using optical wavelengths instead of radio frequencies. Satellites using this new technology would likely fall outside of the commonly accepted definition of the FCC's current mandate, and thus may fall outside of the current licensing regime.

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[10] A brief discussion of this and other differences can be found on page 144 of the recent National Research Council study of NASA's Orbital Debris Mitigation Programs: http://www.nap.edu/catalog.php?record_id=13244

3.2 Active Debris Removal (ADR)

The existing population of space debris will continue to grow over time, even without any new space launches and even with full compliance with the existing mitigation guidelines. Last year, a study conducted by six space agencies using six different models found an average increase of 30 percent in the LEO space debris population over the next 200 years, even with 90 percent adherence to the debris mitigation guidelines.[11]

Thus, NASA and other space agencies have concluded that actively removing existing space debris, a process also known as remediation, will be necessary at some point. These removal or remediation efforts can take one of two different directions depending on the goal. If the goal is to reduce the growth in the debris population and reduce the threat over the long term, then the objective should be to remove five to ten of the largest debris objects per year. This would eliminate these large objects as potential sources of new debris should they collide with another object. But if the goal is to reduce the threat to operational satellites in the short term and medium term, then the objective should be to remove the small debris objects in the size range between 1 and 10 centimeters (0.4 and 4 inches). These objects are currently untracked by space surveillance systems and while an impact with them is unlikely to result in a catastrophic collision, it could severely damage an active spacecraft.

Technical experts from around the world have been working intensely on both of these problems over the last several years, and there are some promising technical solutions for removing either large objects or small objects. However, it is largely a choice between the two goals. There is unlikely to be a "silver bullet" solution that can deal with both objectives. Moreover, none of these techniques has been operationally demonstrated in orbit and all of them pose a wide range of legal, policy, and other non-technical challenges.[12] Solving those challenges will require close coordination and cooperation among the engineers and scientists working on the technology, as well as the lawyers and policymakers developing policy and regulatory oversight.

At the moment, the full scope of the U.S. government's efforts on ADR is unclear to the outside observer. The 2010 National Space Policy tasks both the DoD and NASA to "pursue research and development of technologies and techniques... to mitigate and remove on-orbit debris." I am aware of only one small contract awarded by NASA to do a risk-reduction study on one particular technology for debris removal. ***It would be useful for the Executive Branch to clarify what its strategy is for developing and assessing these technologies, and how NASA and the DoD are working together on this issue.***

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[11] These simulations can be found in the study "Stability of the Future LEO Environment," IADC-12-08 Rev 1, January 2013: http://www.iadc-online.org/Documents/IADC-2012-08,%20Rev%201,%20Stability%20of%20Future%20LEO%20Environment.pdf

[12] An overview of these challenges can be found in Weeden, B, "Overview of the legal and policy challenges of orbital debris removal," *Space Policy*, http://dx.doi.org/10.1016/j.spacepol.2010.12.019

At some point it will be necessary to conduct one or more on-orbit technology demonstration missions for ADR to both prove the concepts and do further risk reduction. Such missions would also be very useful for working out some of the specific legal, policy, and other non-technical challenges of conducting debris removal, particularly if they involved commercial entities and international partners.

There are also potential alternatives to ADR. Some have proposed a concept known as just-in-time collision avoidance (JCA) to minimize or even eliminate debris-on-debris collisions. Instead of removing space debris, JCA would change the orbit of one of the pieces of space debris involved in a very close approach, thus preventing a potential collision.[13] One way to do this would be to use ground-based lasers to alter the trajectory of a piece of debris.[14] However, this technology it also in the early stages and JCA techniques also present a number of legal and policy challenges. ***More study and analysis is needed to determine whether or not JCA is a more cost-effective solution than ADR, or whether the two are best used in tandem.***

3.3 Space Traffic Management

The third major category of efforts to deal with space debris is space traffic management (STM). It should be noted that there is no consensus on what this term means, nor even what it should be called. For the sake of clarity, I will define STM in this testimony as measures taken to minimize the impact of space debris on space activities.

Under that definition, the largest element of STM is detecting and mitigating collisions between active satellites and other space objects. While there is some similarity between how this is done in space and air traffic management, the two concepts are not completely analogous. The most important difference between the two is the speed at which objects in space move. The speed of an object in orbit is dictated by its orbital altitude. The lower in altitude an object's orbit is, the faster it must move to avoid being pulled into the atmosphere by the Earth's gravity. At 800 kilometers (500 miles) altitude, an object in orbit travels at approximately 7.5 kilometers per second (17,000 miles per hour). The most likely scenario for a collision is when two objects in similar orbits at the same altitude cross paths near one of the Earth's poles, and in those cases the combined relative speed can be upwards of 10 to 14 kilometers per second (22,300 to 31,300 miles per hour).

Unlike the portrayal in the movie *Gravity*, this means that most objects on a collision course in space move too fast for the human eye to see and that the collision will happen much faster than

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[13] An overview of the JCA concept and a comparison to ADR can be found in McKnight, DS, Di Pentino, F, Kaczmarek, A, and Dingman, P, "System engineering analysis of derelict collision prevention options", *Acta Astronautica*, http://dx.doi.org/10.1016/j.actaastro.2013.04.016

[14] An overview of one concept for using ground-based lasers to do JCA can be found in Mason, J, Stupl, J, Marshall, W, and Levit, C, "Orbital Debris-Debris Collision Avoidance", arXiv, http://arxiv.org/abs/1103.1690

any human could possibly react to. Active, real-time space traffic control of space objects by humans is not realistic, with the possible exception of two objects that are conducting a planned orbital rendezvous. Moreover, even an automated reaction to avoid a collision at the last minute is likely not feasible. The extremely short amount of time to react would require a massive amount of thrust to alter the spacecraft's orbit.

Instead, STM is almost entirely a predictive process done by computers and sophisticated software. This process, known as conjunction assessment, uses estimates of the orbital trajectories of tracked space objects, the error in those estimates, and models of the Earth's atmosphere and other perturbations to predict where space objects will likely be a few days into the future. This process does not result in a definitive "yes" or "no" answer as to whether or not two objects in orbit will collide. The numerous uncertainties present in each input to the calculation mandate that the best it can do is provide a probability of collision between two objects.

Based on these conjunction assessments, a warning is provided to the satellite operator or operators involved along with the probability of collision. It is currently up to each operator to determine their own tolerance for risk and use that as a basis for determining whether or not to maneuver the satellite to change its trajectory and avoid the close approach. This is not always a straightforward decision to make, as maneuvering consumes fuel that could reduce the operational lifespan of the satellite and may interrupt the services it provides or the mission it is conducting. Moreover, maneuvering comes with its own risks as it may in some circumstances make the situation worse or create an even more dangerous close approach in the future.

Risk tolerance will vary between satellite operators and with the mission the satellite is performing. For example, NASA has determined that if the probability of collision between a piece of space debris and the International Space Station is greater than 1 in 100,000, a maneuver will be conducted if it will not result in significant impact to mission objectives.[15] If the probability is greater than 1 in 10,000, a maneuver will be conducted unless it will result in additional risk to the crew. As another example, the French government recently announced that it had conducted an avoidance maneuver for one of its military satellites because the probability of collision was greater than 1 in 2,000.[16]

The other major difference between air and space traffic is that the vast majority of space traffic has no ability to maneuver to avoid any collisions. Less than five percent of the tracked space objects bigger than 10 cm are active payloads and not all active payloads have maneuvering

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[15] An overview of NASA's collision avoidance procedures can be found here: http://www.nasa.gov/mission_pages/station/news/orbital_debris.html

[16] de Selding, P, "France Maneuvers Intel Satellite to Avoid Dead Weather Spacecraft," *SpaceNews*, 23 April 2014: http://www.spacenews.com/article/military-space/40317france-maneuvers-intel-satellite-to-avoid-dead-weather-spacecraft

capability. In fact, the number of non-maneuverable payloads is growing, due to the recent boom in small satellites. Commonly referred to as cubesats or microsatellites, they are becoming increasingly popular with universities as part of engineering programs, but also with new space actors such as start-up companies and developing countries. Between November 2013 and February 2014, there were three space launches that together placed more than 100 cubesats into LEO.[17]

Although cubesat technology is advancing very quickly and these systems can have surprisingly advanced capabilities, many lack any sort of propulsion system. This means that even though they may be performing an active mission, when involved in a close approach with another space object they are for all intents and purposes just another piece of space debris. Their small size also makes them difficult to track with conventional radars and telescopes. Furthermore, many cubesats are being developed and operated by new space actors who may not have the experience to do so safely or responsibly.

The combination of these factors means that ensuring proper national oversight of cubesat activities is an important issue for policymakers and regulators. ***Existing national regulations and licensing procedures need to adequately cover cubesats and ensure that overall safety and responsible behavior is maintained while still enabling innovation and new entrants into the space sector.***

In addition to on-orbit close approaches, another important element of STM is the interface between orbital traffic and air traffic. In 2013, 300 tracked space objects re-entered the Earth's atmosphere according to data provided by the DoD and NASA.[18] Nineteen of these were controlled re-entries by spacecraft or rocket stages. The rest were uncontrolled re-entries of more than 100 metric tons of dead payloads, spent rocket stages, and smaller bits of debris. Tracking data on these objects are combined with models of the Earth's atmosphere to predict where they might re-enter. However, this process has significant uncertainties and currently it is not possible to predict with any certainty exactly when and where a space object will re-enter the atmosphere more than a couple of hours in advance, except under very specific circumstances.

The odds of a re-entering space object hitting an aircraft in flight is extremely remote, largely because air traffic is concentrated over a relatively small fraction of Earth's landmasses. However, there are certain circumstances, such as the tragic breakup of Space Shuttle Columbia on its re-entry approach over the United States, where a large amount of orbital debris may pose

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[17] An overview of the growth in cubesats can be found in Jones, N, "Mini satellites prove their scientific power", *Nature*, 16 April 2014: http://www.nature.com/news/mini-satellites-prove-their-scientific-power-1.15051

[18] This information comes from a presentation by Mark Matney from NASA to the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space on February 13, 2014, available here: http://unoosa.org/pdf/pres/stsc2014/tech-27E.pdf

a hazard to air traffic. In the future, if sub-orbital tourism becomes a thriving industry or commercial space launch services expand further, it may be necessary to more closely manage their interactions with air traffic.

3.4 Space Situational Awareness (SSA)

All of the efforts to deal with the threat of space debris – debris mitigation, debris removal, and STM - rely on SSA. SSA, broadly defined as characterizing the space environment and its impact on activities in space, is a fundamental requirement for successfully tackling the many challenges related to the long-term sustainability of space activities. SSA began as the military space surveillance mission and in recent years has expanded to include more types of information as well as additional services.

The DoD currently has the most comprehensive SSA capability in the world.[19] This includes operating the largest tracking network of ground and space-based sensors and maintaining one of the most complete catalogs of objects in Earth orbit. Its Space Surveillance Network (SSN) consists of more than 30 radars and optical telescopes located around the world and in orbit. Tracking data from the SSN are collated and analyzed by U.S. Strategic Command's (USSTRATCOM) Joint Space Operations Center (JSpOC) at Vandenberg Air Force Base in California. The JSpOC maintains a catalog of space objects and uses that catalog to provide a variety of services and functions. It also makes a low accuracy version of part of its catalog publicly available on the Internet.

There are other countries that have their own SSA capabilities, with Russia being the most advanced. None have the global coverage of the DoD, but even the DoD's SSA capabilities have shortcomings. The main drawback is in the location and distribution of the tracking sites. Many of their tracking radar locations are optimized for their original missile warning functions and are thus located on the northern borders of the United States. This means that the system's coverage is focused mainly in the Northern Hemisphere. Thus there are large gaps in the tracking coverage for LEO space objects and sometimes significant time between tracks. There are efforts underway to alleviate some of these gaps, as in the recent decisions to move a radar and an optical telescope to Australia, but most of the gaps will remain. ***More cooperation and data sharing with other countries and private sector entities with their own SSA capabilities is the most prudent way to address this gap.***

A bigger challenge is the need to combine the tracking of space debris and other non-cooperative space objects with owner-operator data on active satellites. A satellite operator typically has much more precise data on the location and trajectory of their own satellite than can be

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[19] An overview of global SSA capabilities can be found in Weeden, B, Cefola, P, and Sankaran, J, "Global Space Situational Sensors," paper presented at the 2010 Advanced Maui Optical and Space Surveillance Conference. Available from: http://swfound.org/media/15274/global%20ssa%20sensors-amos-2010.pdf

determined by remote analysis. Moreover, satellite operators also are aware of upcoming maneuvers they plan to conduct. Without knowledge of these maneuvers, future predictions of their satellite's trajectory and any potential close approaches it has can be disastrously wrong.

3.5 A Holistic Picture of Space Sustainability

The relationship between the four concepts discussed in this section - debris mitigation, debris removal, STM, and SSA - is shown in Figure 2. Mitigation, removal and STM are all complementary initiatives that tackle different aspects of the space debris challenge – past, present, and future. Only by undertaking all three can we deal with the problem in a comprehensive manner. All three are supported by and rely on SSA. Without appropriate and accurate information on the space environment and activities in space, none of the others are possible.

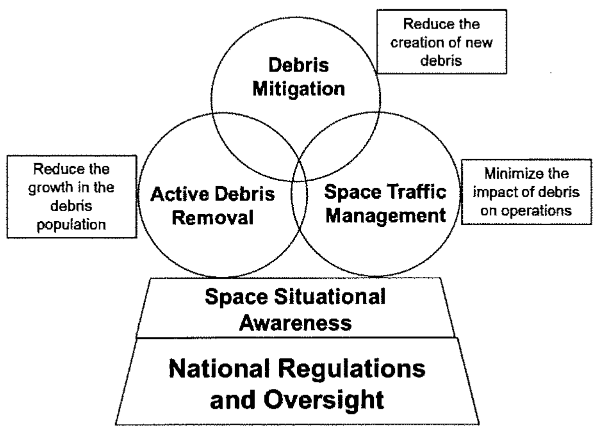

Figure 2. A framework for space sustainability

From a national perspective, it is important to have in place the proper regulations and oversight mechanisms to support all four of the activities outlined above across both governmental and non-governmental space activities. These include pragmatic and well-defined licensing requirements for the private sector as well as the ability to monitor and enforce those requirements, and clearly defined roles, responsibilities, and interagency protocols in place between the various government entities. At the same time, it is also important to keep in mind the international context, and the interactions and relationships between the activities and capabilities of the United States and the many other countries currently active in space. ***As is the case with air traffic management, working with other countries to develop standards, protocols, and mechanisms for safe STM is essential.***

4. Towards the STM System of the Future

There has been a significant shift in SSA and STM activities over the last few years. Before the 2009 Iridium-Cosmos collision, the DoD was one of the few entities to look seriously at conjunctions between space objects.[20] This is partly because of its national security focus but also because the DoD was one of the few entities with access to the data necessary to do the analysis. At the time of the Iridium-Cosmos collision, the DoD was conducting a daily screening for potential close approaches between a select list of important U.S. government satellites and other space objects. This list did not include Iridium satellites, and so there was no advance warning of the collision. The Russian military was also performing a similar function for some of its own national security satellites using its own tracking data, and it too failed to notice the potential collision because the dead Cosmos satellite was no longer included in its screening process.

4.1 Current SSA and STM Authorities and Practices

After the collision, the DoD was faced with a difficult choice. As the organization with the best SSA capability in the world, it could help prevent such future collisions. Doing so would be in its own best interests, as it is also the organization with the most active satellites in orbit and the most reliant on space capabilities. More collisions would produce more debris that could threaten critical U.S. national security space capabilities. One way the DoD could address this problem would be to give satellite operators access to the more precise tracking and trajectory data it uses for its own internal assessments. Doing so would allow satellite operators or other entities to perform their own conjunction assessments. However, national security considerations led the DoD to instead change their own conjunction assessment process to include a screening of all operational satellites for all satellite operators. This eventually became part of USSTRATCOM's SSA Sharing Program[21] and ever since, the JSpOC has been providing hundreds of warnings of close approaches to satellite operators around the world each year.

These warnings have both greatly increased awareness of the magnitude of the challenge and encouraged satellite operators to take collision threats and responsible behavior in orbit more seriously. USSTRATCOM has also worked hard to overcome the significant technology and personnel challenges it faces in delivering this service and has also worked with many satellite operators to improve the warnings. It is likely, although not provable, that the warnings provided by the JSpOC have prevented other collisions in orbit from occurring.

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[20] A summary of the U.S. military's conjunction assessment protocols prior to the collision can be found here: http://www.thespacereview.com/article/1314/1%29

[21] An overview of the history of the SSA Sharing Program, including references to the Congressional legislation authorizing the program, can be found in this SWF Issue Brief: http://swfound.org/media/3584/ssa_sharing_program_issue_brief_nov2011.pdf

4.2 Shortcomings in the Current System

However, the current process still has serious shortcomings. The mathematical process by which the JSpOC generates these warnings is still largely a "black box," with little information provided on their accuracy or reliability. Studies done by both commercial and U.S. government satellite operators indicate that the close approach warnings provided by the JSpOC may have as much as a 50 percent false positive rate and 50 percent false negative rate.[22] Other studies conducted by international satellite operators indicate that at least three percent, and in some cases as many as 20 percent, of the DoD's locations of operational satellites are wrong. This is largely because the JSpOC does not have access to satellite operators' data on the location of their own satellites or information about any upcoming maneuvers. The JSpOC is unable to correct this at the moment because their computer systems are currently unable to automatically process satellite operator or other outside data.[23]

The current DoD policies for protecting the orbital locations of national security satellites have also created problems. The JSpOC does not publish orbital trajectory information for many U.S. and some allied national security satellites, nor trajectory information for other objects from the same launch, such as spent rocket stages. As more and more launches involve secondary payloads, this policy has led to withholding the trajectory information on these objects as well, resulting in situations where universities, scientists, and even some NASA researchers cannot get trajectory information to try to locate and communicate with their payloads.[24]

All of this has led to dissatisfaction on all sides over the current situation. From the satellite operators' perspective, the JSpOC is not responsive or flexible enough to provide the services they need, nor does it give any insight in the reliability of the services and warnings it provides. At the same time, the DoD is being asked to take on this new requirement to provide these services for all satellite operators without significant additional resources such as personnel and funding. The DoD is also being asked to provide these services with obsolete computer systems that are more than 150 percent over capacity and were not designed to share data with or accept data from sources outside the traditional DoD tracking network.

There are also cultural and bureaucratic challenges that DoD is struggling to overcome. Its primary focus is on national security and protecting DoD assets and capabilities. Neither providing a public safety service for the entire world nor supporting the development of

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[22] Morring, F, "USAF satellite-conjunction advisories called inaccurate", *Aviation Week & Space Technology*, 2012, February 24: http://www.aviationweek.com/Article.aspx?id=/article-xml/awx_02_24_2012_p0-429306.xml

[23] For a detailed overview of the history of these systems and the failed attempts to replace them, see: http://swfound.org/media/90775/going_blind_final.pdf

[24] Some of these challenges are referenced in a recent National Research Council study on NASA's Orbital Debris Mitigation Programs: http://www.nap.edu/catalog.php?record_id=13244

commercial activities are missions that the military is usually expected to tackle, especially when those missions require it to work day-to-day with many different commercial companies and foreign countries around the world. The DoD also lacks the flexibility in its acquisitions programs to be able to take into account the needs of its commercial and foreign customers in designing future capabilities and services.

4.3 The Emergence of Non-governmental Actors in SSA and STM

As a result of these shortcomings, a growing number of civil and commercial satellite operators are looking to other entities for assistance. One major source is the Space Data Association (SDA), a non-profit organization created by three major commercial satellite operators in 2009. Its membership currently includes more than 20 commercial satellite operators and three government agencies who are together responsible for more than 360 active satellites in orbit and more than half of all satellites in GEO.[25] Its Space Data Center (SDC) provides SDA members with a range of services, including much more detailed conjunction assessments that take into account a satellite operator's own satellite trajectories and planned maneuvers, and assistance in resolving radio frequency interference (RFI).

There are also very recent developments towards potential private SSA services in the near future that may provide significant alternatives to the JSpOC or other governmental programs. Earlier this year, Analytical Graphics, Inc. (AGI) announced its new Commercial Space Operations Center (ComSpOC). The ComSpOC plans to offer paid subscription access to a number of advanced SSA services, including much more accurate orbital trajectory information than what the DoD provides publicly, more accurate and timely conjunction assessments, assistance in planning avoidance maneuvers and assistance in resolving spacecraft anomalies. AGI is currently negotiating with dozens of optical telescopes, radars, radiofrequency systems, and other sensors already in existence around the globe to provide data for the ComSpOC. There are also a number of other private sector initiatives that are still in the early stages and could provide significant SSA capabilities in the near future.

Overall, these private sector activities show considerable efficiency and sophistication. The total cost of creating and operating the SDC since its inception is on the order of several million dollars. Most of the functions of the SDC are automated and the servers themselves are virtualized and distributed across three different geographic regions. This means that they require a very small number of analysts to operate, are fault tolerant, and can respond very quickly to increased computational needs. Although the ComSpOC is much newer and not yet fully operational, early indications are that it has some very sophisticated SSA capabilities. In both cases, there is strong evidence of private sector innovation being more agile than, and potentially

[25] An overview of the SDA and its current membership and services can be found in this presentation from its March 2014 Public Users Meeting: http://www.space-data.org/sda/wp-content/uploads/downloads/2014/03/20140310_SDA_Users_Mtg_p.m._Session.pdf

even surpassing, governmental capabilities. This innovation should be embraced and encouraged, not stymied.

An important consideration to keep in mind is that SSA is not something that any one entity can do entirely by itself. It requires combining data from a large number of geographically distributed sensors on Earth and in space with operator data on precise locations and upcoming maneuvers. SSA also has many different commercial, civil, and national security applications that are unlikely to be fulfilled by a single entity. Moreover, it is unlikely that any one entity will be trusted enough by all space actors to serve as a single, global SSA provider. Instead, I see SSA evolving to a model where there are multiple data providers that act as hubs, each serving a set of trusted users. In this model, a key element is the degree of cooperation and data sharing between the hubs.

4.4 The Future SSA and STM System

Taking all these considerations into account, ***the key question facing the U.S. government moving forward is whether or not the DoD should continue to be the single federal agency responsible for all SSA activities and providing operational STM for the world.*** I believe that the answer is no. While space surveillance began as a national security function, SSA has evolved into much more. It plays a fundamental role in the breadth of space activities being conducted by not only the military but also civil government agencies and the private sector. It encompasses not only building and operating a geographically distributed network of radars and telescopes to track space debris, but also combining those tracking data with data from satellite operators on the location of their own satellites and upcoming maneuvers. Finally, it requires a willingness and ability to work with a wide range of international entities.

At the core of this problem is the issue of trust. There is currently a lack of trust among the various stakeholders in SSA that is hindering efforts to improve SSA to address the pressing challenges outlined earlier. This lack of trust stems from deficiencies in the current system and organizational culture, and inertia. The DoD does not trust others in its mission to protect U.S. national security and is wary of providing information that could reveal its capabilities or limitations. This attitude leads it to operate its services as "black boxes" with little to no information provided as to how the analysis was done or its accuracy.

Commercial and government satellite operators are unwilling to base the safety of their valuable assets on services and analyses that cannot be validated or verified. They also have no input on capabilities and requirements for the new SSA architectures and services the DoD is pursuing. Some governments are also unwilling to fully trust the SSA data and analyses being provided by the DoD, hindering the ability of the global community to use SSA as the foundation for political agreements to enhance space sustainability and security. This includes efforts currently underway to create best practice guidelines for enhancing space sustainability, develop international standards for safe space operations, and establish and enforce norms of behavior and develop transparency and confidence building measures to improve security.

4.5 Diversifying SSA and STM Away from the DoD

I believe it is time to consider creating an operational role in SSA and STM for a federal entity other than the DoD. Assigning this role to a non-DoD government entity provides several benefits. First, it increases the likelihood that the U.S. government will be able to provide timely, accessible, and agile services to civil and commercial customers. Second, it would be more likely for a non-DoD entity to be able to integrate many different types of SSA data from many different sources. This would increase SSA for both the U.S. government and all other users. Third, by being able to provide better services and integrate more data, this shift puts the U.S. government in a better position to ensure that it will continue to play a leadership role in SSA. Failing to do so increases the likelihood of a shift away from the U.S. government towards private sector and foreign actors, a shift that could have consequences for U.S. national security.

This non-DoD entity would be mainly an integrator of data collected by other entities, rather than a primary collector itself. The DoD would still operate its existing networks of radars and other sensors, many of which perform missions other than SSA. However, the DoD would be responsible for passing sanitized data from its tracking networks to this non-military organization. The non-DoD entity would be responsible for maintaining a catalog of space objects and information about space weather. This would enable them to provide conjunction analyses and other safety-related services to all space actors to support safety of spaceflight and space sustainability. The DoD would retain responsibility for national security aspects of SSA, including characterizing space objects and determining intent and threats, by combining the civil SSA data with other sources of data. Figure 3 provides a graphical summary of this division of labor.

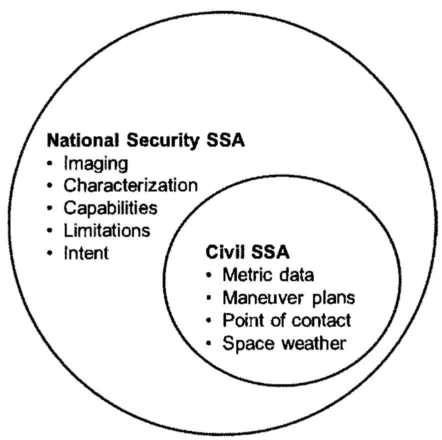

Figure 3. Division of labor between national security and civil SSA authorities

The non-DoD agency would be able to also ingest data from other sources to perform its mission, including satellite operators, other governments, private organizations, and even amateur satellite observers. These data would be provided on a voluntary basis, enabling other data providers to exclude information on their own national security space objects if desired. Such exclusions would come with the implicit assumption that they are then liable for responsible operation of and any damage caused by those protected objects in accordance with international law and established norms of behavior. This is essentially the same exclusion that applies to state aircraft under current air navigation treaties.

Shifting responsibility for basic SSA services to a non-DoD agency allows it to focus on building relationships and establishing trusted services with all users while simultaneously allowing the DoD to focus on the elements of SSA that are critical to national security. The non-DoD agency can work more closely with satellite operators and potentially even some of the private sector SSA services to focus on safety of spaceflight. The DoD can take the basic catalog provided by the other agency and add additional classified sources of data to provide the more robust capabilities necessary for detecting and countering threats to U.S. national security space systems.

4.6 Organizational Options for a New SSA/STM Authority

Making this change is not without considerable challenges. First and foremost is determining which federal department or agency should be assigned this new role. One option is to assign it to an agency that already has some authority for regulating and licensing private sector space activities. Giving an agency both regulatory authority and direct access to the information to enforce that authority could result in both better regulations and a more efficient process. However, current regulatory authority is divided across the FCC, FAA, and NOAA and each has its own specific competencies. Moreover, the FCC and FAA do not have any significant organizational expertise in actually performing space operations.

Another option could be to assign it to a federal agency that already has significant expertise in space operations and space debris such as NASA or NOAA. NASA is the lead federal agency for space debris research and development of space debris mitigation guidelines. It also operates a number of its own satellites. NOAA also operates some of its own satellites in both the LEO and GEO regions and does have some regulatory

However, NASA does not have any authority to regulate private sector space activities, and it does not make sense to give it such authority. Assigning this role to NASA would also require deciding which NASA field center or centers would perform the new mission. This is likely to be a contentious debate, as Johnson Space Center, Goddard Space Flight Center, and Ames Research Center are all involved in various aspects of space debris, SSA, and STM.

A third option would be to assign this role to a new federal agency, something akin to a "Coast Guard" for space. Just as the U.S. Coast Guard is responsible for safety on the nation's waterways and maritime regions, and works hand-in-hand with the U.S. Navy on national security issues, a similar agency could be created to deal with space. The Coast Guard has responsibility for issues ranging from developing and maintaining infrastructure to regulating private boating activities and enforcing those regulations.

This is an option that has been much discussed in the past and has its own positives and negatives.[26] On the positive side, it is a proven model for providing a public safety service that interacts closely with national security. Assigning this new agency with both an operational role in SSA and STM and a regulatory role for licensing of private sector activities could provide significant efficiencies and complementarities. On the negative side, implementing this option has significant political and administrative challenges. It would require an almost complete overhaul of the existing governance structure for space and reassigning functions spread across several federal agencies to this new entity.

In choosing any one of these options, an important consideration will be the extent to which this non-military entity has the power to require satellite operators to comply with its instructions. There are those who wonder why the existing conjunction warning system does not mandate that satellite operators move their satellites. The answer is mainly due to the fact that no government has authority over all space objects. In the air traffic model, aircraft under active control are in an air space where there is clear national sovereignty and control by a single State. In space, launching states exert sovereign control over their space objects but there is no control over the orbital regions they are passing through.

The one set of circumstances where such power may be necessary in STM is where there is a potential threat to a spacecraft carrying humans. If an active satellite is deemed to have a probability of colliding with spacecraft carrying humans, right-of-way should be given to the spacecraft with humans. However, this is likely to be an infrequent scenario. Most active, robotic spacecraft orbit at much higher altitudes than spacecraft carrying humans. This is due to the Van Allen radiation belts, which for the most part limit long-duration human spaceflight in Earth orbit to an altitude of around 500 kilometers (310 miles) or lower.

4.7 National Security Considerations

This proposal to shift some responsibility for SSA away from the DoD will prompt concerns from some that it will jeopardize U.S. national security. The primary reason for all of SSA to

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[26] Two good discussions of this topic are "The Guardians of Space" by LtCol Cynthia McKinley in the Spring 2000 edition of *Aerospace Journal* (http://www.airpower.maxwell.af.mil/airchronicles/apj/apj00/spr00/mckinley.htm) and "Proposing a Space Guard" by James Bennett in the Winter 2011 edition of *The New Atlantis* (http://www.thenewatlantis.com/publications/proposing-a-coast-guard-for-space)

remain with the DoD is that it allows the military to control the data and protect the locations of sensitive U.S. national security space assets. While it is true that shifting part of the SSA mission to another entity will make it harder to hide those objects, I believe that battle has already been lost. The accelerating diffusion and innovation of SSA capabilities by commercial entities, foreign actors, and even private citizens has already eroded the DoD's control of information on the existence and location of space objects. I believe it is better for the U.S. government to harness that innovation to improve its own capabilities than to try and stymie it.

A good analogy can once again be made with the air traffic regime that faced a similar dilemma. The Convention on International Civil Aviation, signed in Chicago in 1947, made the air traffic rules only applicable to civil aircraft. State aircraft (defined as those of military, customs, and police services) were exempt and only required to operate with "due regard for the safety of navigation of civil aircraft.[27]" Under this model, the air traffic management system focuses solely on civil and commercial traffic. Military aircraft are formally exempt and the only stipulation is that they do not jeopardize the safety of civil traffic. In reality, military aircraft often follow the same air traffic protocols as civil and commercial aircraft except in very specific situations where national security considerations take priority. ***I believe the same principle of due regard is appropriate for the future of STM as well.***

The DoD's current approach to both satellite communications and space-based remote sensing may also offer useful analogies for the future of SSA. At one time, the U.S. military tried to acquire and operate all of the satellite communications and remote sensing capability it needed. That desire quickly met with reality as military systems were unable to meet the operational demand. Today, more than 80 percent of all satellite communications capability used by the U.S. military flows over commercial satellites, including nearly all of the bandwidth for unmanned aerial vehicles supporting counterterrorism operations around the globe. Meanwhile, privately operated remote sensing satellites are providing an increasing share of imagery products to national security customers. Commercial industry was able to provide more flexible, timely, and cost effective capabilities, and those capabilities have only gotten better as government demand for them has increased.

There are still niche national security mission needs that are not provided by the private sector where the U.S. military still develops and provides its own capabilities. These include strategic, hardened, protected satellite communications and exquisite intelligence collection capabilities. The end result of this approach where the government focuses its efforts on what the private sector cannot provide has been increased capability for the military, lower costs to the taxpayer, and a booming commercial industry that is innovating faster than ever before.

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[27] The various editions of the Chicago Convention can be found on the website of the International Civil Aviation Organization (ICAO): http://www.icao.int/publications/pages/doc7300.aspx

5. Conclusions

It has become almost trite to point out that the space world has changed, but in the context of space debris, SSA, and STM, it is worth making the point again. The current systems for providing those services were designed and developed in a different age, when space activities were dominated by the two super powers. Today's world is much different. The continuing expansion in the number of space actors and the types of space activities has created a much more complex space environment. At the same time, technological diffusion has commoditized space capabilities to fuel a surge of innovation and has created the possibility for many new uses of space for benefits here on Earth.

It is vitally important for the U.S. government to evolve its approach to stay abreast of this ongoing change. The U.S. government's strong efforts on space debris mitigation over the last decade and a half are a good start, but need to be part of a more comprehensive approach. Space debris mitigation needs to be accompanied by renewed emphasis on STM, development of the technical capability for targeted removal of space debris, and significant improvements in SSA.

Part of this comprehensive approach includes re-examining the current federal agency roles and responsibilities for regulating and overseeing private sector space activities and providing services to support those activities. These roles and responsibilities are currently spread out across four government agencies across three departments, with regulatory and licensing powers separated from the capability to monitor space activities and potentially enforce those regulations. There are differences in how the three agencies responsible for regulating private sector activities implement the space debris mitigation guidelines. The sole agency responsible for monitoring space activities – the DoD – is not the agency best equipped to handle civil safety and commercial support responsibilities. Moreover, there does not appear to be a strategy for developing the capability to actively remove space debris.

There are steps that can be taken to address these issues. First, this subcommittee can look at ways to harmonize the implementation of the debris mitigation guidelines by the three agencies with regulatory power. Doing so could result in a more efficient and effective process, with benefits to commercial industry and innovation. Second, this subcommittee can work with the various departments and agencies and other committees with jurisdiction to re-examine the roles and responsibilities for SSA. I have made the case that part of that mission should go to a federal agency other than the DoD. There are three general paths for doing so, each with their own advantages and disadvantages. Third, this subcommittee can call on the relevant executive branch agencies to articulate a comprehensive strategy for developing the capability to remove debris from orbit. This includes deciding whether to pursue large or small debris objects, the most promising technologies for doing so, and putting in place programs to mature those technologies towards one or more on-orbit technology demonstration missions.

There are also specific areas of research and analysis that could be useful in supporting the subcommittee's work on these issues. These include:

- A study on the current implementation of orbital debris mitigation guidelines by NOAA, FAA, and FCC that focuses on specific areas where they might be harmonized, whether or not they adequately cover existing and planned future private sector space activities, and whether or not they adequately deal with cubesats;
- A study comparing the relative costs and benefits of ADR to remove large pieces of debris, ADR to remove small pieces of debris, JCA to prevent debris-on-debris collisions, or some combination of the three;
- A study to determine which elements of SSA are necessary to support safety of spaceflight and commercial space activities, along with the requirements for timeliness, accuracy, and precision of SSA data to provide those elements;
- A study that weighs the various options for assigning part of the SSA mission in support of civil safety to a federal non-DoD agency; and
- An assessment of the U.S. government's current strategy for developing and maturing technologies for actively removing orbital debris.

Thank you for your time and attention. I would be happy to answer any questions you might have.

Biography for Mr. Brian Weeden

Mr. Brian Weeden is the Technical Advisor for Secure World Foundation (SWF) and has 15 years of professional experience in the national and international space security arena. His wealth of technical knowledge and expertise has established him as a thought leader for providing critical analysis that supports development of space policy.

Prior to joining SWF, Mr. Weeden served nine years on active duty as an officer in the United States Air Force working in space and intercontinental ballistic missile (ICBM) operations. As part of U.S. Strategic Command's Joint Space Operations Center (JSpOC), Mr. Weeden directed the orbital analyst training program and developed tactics, techniques and procedures for improving space situational awareness.

In his current role as Technical Advisor, Mr. Weeden conducts research on space debris, global space situational awareness, space traffic management, protection of space assets, and space governance. He also organizes national and international workshops to increase awareness of and facilitate dialogue on space security and sustainability topics. He is also Vice-Chair of the World Economic Forum's Global Agenda Council on Space Security.

Respected and recognized as an international expert, Mr. Weeden's research and analysis have been featured in The New York Times, The Washington Post, National Public Radio, USA Today, The BBC, Fox News, China Radio International, The Economist, The World Economic Forum's Annual Meeting in Davos, academic journals, presentations to the United Nations, and testimony before the U.S. Congress.

Mr. Weeden holds a Bachelor of Science Degree in Electrical Engineering from Clarkson University, a Master of Science Degree in Space Studies from the University of North Dakota, and is also a graduate of the International Space University Space Studies Program (2007, Beijing). He is currently a Doctoral Candidate in Science and Technology Public Policy at George Washington University.

Chairman BROOKS. Thank you, Mr. Weeden, and I thank the witnesses for their testimony. As an aside, it looks like we are going to have our second set of votes somewhere around 11:30, roughly 40, 45 minutes from now. Hopefully we will be able to complete these proceedings before those House floor votes are called.

Reminding Members that Committee rules limit questioning to five minutes, the Chair will, at this point, open the round of questions. The Chair recognizes himself for five minutes.

As a part of my five minutes, and recognizing the prerogative that the Chair has, I would like to, at this point, recognize the Falcon Rocket Team from Huntsville, Alabama. If you would please stand? We have got Coach Bobby Murphy here with us, Members John Aslan, Jack Aslan, Victor Murphy, Dave Green, Matt Kellogg, and Jorge Estrada. The competition is tomorrow. They are representing the State of Alabama. And I want to encourage you all to do what you can to represent our community, inasmuch as we often boast that we are the birthplace of America's human space flight program. And thank you for being here for this hearing today. This challenge that we are facing today may be one that we need you all to solve tomorrow.

With that having been said, let me proceed with my—well, with that having been said, let me proceed with my first question. Dr. Henry Hertzfeld of the George Washington University recently testified before the Committee that FAA should "clearly be defined, and preferably limited to, those issues directly related to launching and re-entry." His comments appear to be somewhat inconsistent with the request that the FAA is making here today. Can each of you comment on Dr. Hertzfeld's statement concerning the FAA's potential role in this space debris matter? Go ahead, at your leisure. Whoever wants to poke the button first.

Mr. ZAMKA. Mr. Chairman, it seems like I might be the liable first guy. The FAA's current authority ends at the end of launch. That is the last time an operator has contact with their launch vehicle. The FAAs current authority begins at the beginning of reentry. That is when the safety checks begin. So, that is our current authority. What we have experience with is talking to the operators, and dealing with orbital debris mitigation. We are also on-site as the operators are conducting their operations, as part of our inspection and enforcement function. So, we have existing experience and credibility with the launch operators.

What I will refer you to in my testimony that is new, and that would be worth considering, are the new classes of vehicles that will operate on orbit. These are vehicles taking personnel, cargo, and servicing up to human space stations, and also servicing satellites.

General RAYMOND. I would just add that, consistent with what my panelist partner just said, we work very closely with the FAA on the licensing of launch vehicles. In commercial space launches that we conduct off of our ranges, we have FAA representation there with us as we go. I would just add that we are—consistent with the national space policy, we think it is important that you look at—that this hearing happened, and that you look at different agencies to be able to take on the lead Federal agency role. We are not going to pick one or the other, but I think it is important that you explore that, and we are interested in exploring that going forward.

Mr. NELSON. Well, the FCC hasn't ruled in—on any of these—on this issue. It is probably important to point out FAA has had a role in the past, for instance, with air transport and human, and you know, human transport issues. And the fact that they are involved directly with a launch vehicle situation, carrying that through may be an appropriate situation, in regard to transport or, you know, further launch operations.

Mr. BLOUNT. I actually do not answer this question. My testimony is to who should have this authority. I think that there are ways that we can envision either a single agency, or fragmented agency authority, were we have different agencies handling different functions. However, I do think that General Raymond's point about having a lead Federal agency is very important. An agency that can coordinate this information, make sure that all the involved parties and stakeholders are coordinated, is very important. And I think that currently FAA looks like the most appropriate for that, but I don't think that it is necessary that it goes there.

Mr. WEEDEN. I would add that one of the key questions here is what kinds of powers are we talking about, and would that extend to telling satellite operators what to do? I mean, that is a very complicated question, because a lot of these scenarios, when you are getting into potential close approaching space objects, we don't know a yes or no answer whether or not two things will collide, except in very, very specific cases, like, for example, a planned rendezvous between two satellites. In most other cases, it comes down to statistics and probability, and so you are having to make a judgment call based upon what is your level of risk. And I think the hesitancy by Dr. Hertzfeld is to give a government agency the power to somehow tell a private operator what that level of risk should be, and what they should do with it.

Now, I think, on the other side, the situations where that would probably need to be exercised are not as numerous as many people might think. Most close approaches are between either two pieces of debris that no one controls, or a satellite under control and a piece of debris. The only situations where maybe that might come into play of mandatory control would be if, perhaps, human safety was in question.

Chairman BROOKS. Thank you. At this point, the Chair recognizes the Ranking Member, Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you to the witnesses. I want to follow up on this, because, Mr. Zamka, in your prepared statement, you are urging us to look at two issues. One is whether a regulatory agency should authorize transportation on orbit by license, and then the second is the benefit of an agency with enforcement authority providing notices regarding impending hazards and collisions.

And I guess—I mean, from my standpoint, I am really not prepared to legislate yet, because I feel like there is still a lot we need to know. So I wonder if you might comment about what parties would need to be at a table, and in what venue, to begin to explore what Congress needs to do in this area, and might that be a better approach than going right to identifying an agency that would have authority—sweeping authority that we don't even know about yet?

Mr. ZAMKA. Yes, ma'am. Thank you for the question. We really just want to begin the exploration as to what the solution might be. A very important part of that is having the right players at the table. So industry, who has to deal with the risk and the expense, for instance, of deciding to do a debris maneuver to avoid a collision, is certainly an important player. There are a lot of working solutions out there amongst commercial operators, and there are numerous ways of dealing with it, shy of regulation, shy of enforcement. We don't want to get ahead of any particular solutions that are out there. But, I would certainly say that industry, and the agencies that are involved with on-orbit authority now, would certainly be good players.

Ms. EDWARDS. And before I go to Mr. Nelson, I will—General Raymond, I wonder if you could comment about the role that you would see at a future environment with a whole bunch of other actors at play, both domestically and internationally. What, then, is the role of the Department of Defense in this?

General RAYMOND. Well, clearly, ma'am, the Department of Defense is focused on national security, and space situational awareness is absolutely foundational to everything that we do in space for a national security purpose. So, when you have these discussions, one of the things that I think we need to really be careful about as we go forward is making sure that we have the ability to do what we need to do to protect our nation, and protect our nation's satellites.

Ms. EDWARDS. All right. And Mr. Nelson?

Mr. NELSON. Yeah, I—following up on what I said earlier, and Mr. Zamka's comment, I would suggest, at least from the point of view of an orbital maneuver situation, or enforcing an orbital maneuver to take place, that, at least from the point of view of the folks that we work with, it is in their best interest to move, and that is how they would take a look at it. If they were aware that there was—a potential collision was coming along, I am sure that they would end up moving that satellite in order to take care of that. It is just inherently in their best interest, even from—especially from a financial point of view.

So, from having to have somebody that would have to go through and actually force them, and say—to do that, it is probably an unlikely situation to carry through. And, further, as you point out, the international aspects of this, we only have a certain percentage of the satellites that are on orbit. And the issue of telling some other foreign country's satellite to have to move is—it raises its own issues.

Ms. EDWARDS. Thank you. And, Professor Blount, I wonder if you could talk to me about the liability that the agencies either should have or do have who should be in charge of space traffic management, and what liability they should assume when it is a direction to a satellite operator to move a spacecraft, or its failure to provide a timely alert that results in a collision, or debris?

Mr. BLOUNT. It—can I clarify that question, that you are asking about the liability of the Federal agency to the space operator?

Ms. EDWARDS. The liability of that the agency has or should have.

Mr. BLOUNT. I think that liability is a very interesting question, because these are, obviously, very expensive pieces of equipment that are moving at very fast speeds, and can cause a lot of damage. And there is—when you define a Federal agency that is going to be in charge, they take on a responsibility. And part of these points that I have—point out that we should have in the legislation is this idea of technological capability.

And so, right now, that capability is vested with the DoD, and if we name a Federal agency, let us say the FAA or the FCC, then there becomes a question of where are they getting their data? Are they going to have to rely on DoD to get their data, and then are they going to do this collision analysis, or are they going to have to rely on DoD to do the collision analysis, or are they going to have to rely on SDA to do the collision analysis? And so, until the problems of where data comes from, and how it is going to be managed by that agency, come through, then it is going to be very difficult to determine who is going to be liable for these actions.

I will just quickly add that, at the international level, the state is liable, and so the way that we manage our domestic assets is going to be very important, the way that we interact internationally, because we could be on the hook for something that a commercial actor does.

Ms. EDWARDS. Well, and it does seem to me—and, Mr. Chairman, I will conclude. It does seem to me that there is a fair amount of risk that is inherent when you can't entirely be accurate if it comes to predicting how you move a satellite, or how you move a spacecraft. So, you know, these liability issues I think we are going to have to explore if we are going to go shoving responsibility to some other lead agency.

And with that I yield. I mean, I think, Mr. Chairman, we have a lot more questions to ask and answer before we come to a point where we need to legislate in this area. Thank you.

Chairman BROOKS. Thank you. The Chair now recognizes Mr. Bucshon of Indiana.

Mr. BUCSHON. Thank you, Mr. Chairman. I want to focus on what do we do with the debris that is already there? And, I mean, we are talking mostly about regulating—a regulatory climate right now, but I am interested in—anyone can answer this. What is happening with R&D about how to either capture or deflect the orbit of existing space debris? Because I think—it seems to me that 50 years from now, we may not even be able to fly in space if we keep going the way we are at all, because we won't be able to get out of the way of stuff flying around the Earth.

So is there anything going on on? Obviously, when you capture this stuff, you have to be going at similar speeds, or else it is just going to destroy whatever you try to capture it with. Mr. Zamka, maybe you could start?

Mr. ZAMKA. Yes, sir. It is a difficult problem because of the high speeds involved, and, essentially, you would have to rendezvous with that particular piece of debris in order to capture it, and then bring it down. As part of our Center of Excellence function—thanks very much for supporting that—we have six tasks in work to begin to characterize that debris, be able to better predict where it is going to be, and then identify potential efforts at remediation. There are some things that are out there that could increase the drag, or use a magnetic field to begin to bring those pieces down sooner, but it is a difficult problem.

Probably the most important thing relative to today is that any plan to remediate debris on orbit is dependent on not creating more debris now. As we have seen, any single accident can create a tremendous amount of debris.

Mr. BUCSHON. Yeah, and—like you pointed out, deflecting the orbit, either magnetically or physically, is a possibility, I guess. And some of the—I mean, it seems like we could probably come up to solve the problem for the bigger stuff, but all the little stuff, you know, like the stuff that hit the space shuttle, it is going to be really, really hard to get that stuff out of the orbit, it seems like.

Mr. ZAMKA. Yes, sir. One of the challenges we have is that human spaceflight, our telecommunications satellites, and a lot of our Earth observing satellites are all in the same low Earth orbit regime, which is where a lot of the debris is, so that is where we have to work.

Mr. BUCSHON. Yeah. Mr. Weeden, you had a comment?

Mr. WEEDEN. Yes. There is quite a bit of work going on on this within the scientific and technical community, both on studying the problem, and on looking at some technology that is still in the early level, but is—early stages, but with the promising ones that might need to be adapted down the road. NASA works with a number of other space agencies to do studies on this issue, and they have done a lot of modeling. One of the big questions the technical community is grappling with is, do we go after the big things, or the little things? Because it generally is different types of technology. You are not going to have one solution that does both. And we probably—and doing both means twice as much money, probably.

And the difference is if the big debris is the source of new debris in the future. So, removing them, you are kind of controlling long term growth. But the small debris is the current threat to satellites, so removing that is a short term lowering of risk. And that is kind of a choice between which strategy is more important. And that debate is going on right now within the scientific community.

Mr. BUCSHON. Okay. As far as mitigation in the future, and this would apply probably only to U.S. players, because we can't control the international community, but is there any talk about penalizing financially people that generate space junk? Anyone want to talk about that? I mean, it seems to me, if you are a private entity, or you are—and you put something up into space, and it generates a bunch of problems——

Mr. WEEDEN. Um-hum.

Mr. BUCSHON. —you know, who—what can we do about that? Is there a way to financially address that?

Mr. WEEDEN. There have been discussions and proposals, mostly in academic journals in the past, of some sort of a tax or something on people that generate debris. The recurring problem is, who has authority to put that in place? As you mentioned, it is an international environment. There are more than 60 countries that are now launching satellites and space objects, and each of them has authority over their own private sector activities.

Mr. BUCSHON. Yeah, let me just point out, I mean, I am not promoting new taxation——

Mr. WEEDEN. Yeah.

Mr. BUCSHON. —like if you fly something into space, you get taxed ahead of time. However, let me just point out that the reality is if there is not some incentive not to do something, I wouldn't call it a tax, I would call it penalty. If you do—say you send something up, it blows up, and generates 1,000 pieces of space junk, you know, if you send something up, nothing happens, it comes down, fine. But if, you know, there has to be some incentive for people not to generate this stuff.

Mr. WEEDEN. I would say, there is an added complication that, in the areas where debris is the worst, mainly low Earth orbit, between about 600 to 800 kilometers, it is mostly government satellites. There is not a lot at the—at the moment, there is not a lot of private actor—private sector activity there.

Mr. BUCSHON. But there will be.

Mr. WEEDEN. There will be in the future, but at the moment there is not a lot there. So the question is, how do you incentivize governments?

Mr. BUCSHON. Yeah. Good luck. I yield back.

Chairman BROOKS. Thank you, Mr. Bucshon. The Chair now recognizes Mr. Schweikert of Arizona.

Mr. SCHWEIKERT. Thank you, Mr. Chairman. It is sometimes terrifying what makes us laugh, isn't it? It is—first question, and I just want to make sure I sort of understand some of the hierarchy and the mechanics. First off, a U.S., but private commercial satellite, DirecTV, or satellite television, or something of that nature, it is put up in space. Does it carry insurance? Mr. Nelson?

Mr. NELSON. Yes. Most companies do have insurance on their satellites. Larger ones may actually self-insure, so they will put up money based on——

Mr. SCHWEIKERT. But whether they, you know, put up the fund, or—but somehow there is an insurance product there?

Mr. NELSON. Yes.

Mr. SCHWEIKERT. How about if I am the French, or East Indian, or, you know, private telecommunication, or private cable, you know, or television provider? Do they carry insurance? Do they have, you know, a national indemnity? And considering they are often, you know——

Mr. NELSON. It, you know, different countries have different rules concerning how they go about—as an example, what I am aware of is the United Kingdom. For any of the folks that might launch under their flag, they have a Space Act, and some of the requirements, for instance, is indemnification of the crown, so to speak. So they—it depends on the country, and what the rules are associated with their activity.

Mr. SCHWEIKERT. And Mr. Chairman, and to our witnesses, where I am trying to head is, these are very expensive objects, both, you know, the—those from the private, and those that are governmental, have great, great value. We already know that there is sort of an insurance regime of some mix. It may not be, you know, universal in design. So we know we have incentives because of the value. We know there is some structure out there. So what happens today? How do they communicate today?

General, let us say we have—you see something heading towards my DirecTV satellite. Do you communicate with them?

General RAYMOND. Congressman, thanks for the question. Absolutely. We are very interested in maintaining a safe space domain. So the—my organization, and specifically the command center that I have, the Joint Space Operation Center, located at Vandenberg Air Force Base, tracks the 23,000 objects that you have heard about. And of those objects, we—not only do we track them, but we detect for potential conjunctions.

Mr. SCHWEIKERT. But what I am after right now, because you—that was part of your testimony, and that was very helpful, is sort of the communication regime right now. So it is the satellite that is providing television for Australia——

General RAYMOND. Right.

Mr. SCHWEIKERT. —do you communicate with them?

General RAYMOND. We do. So if—is—where I was going, if we detect a potential conjunction on any active satellite that is up in space, any country, if we detect a conjunction, we will make an emergency notification, because it is in all of our best interests not to have a——

Mr. SCHWEIKERT. Now, does it go—is it bilateral? Does it come the other direction, where the private tracking firm that is managing, you know, do they communicate back to you?

General RAYMOND. Yes, sir. We have two-way sharing agreements with 41 different companies. We have it with five different nations. There is two-way sharing going back and forth. Largely, though, the tracking capabilities that are out there are our tracking capabilities, and largely we are the ones that are doing this for the world.

Mr. SCHWEIKERT. And do any of those private firms ever provide their statistics saying, hey, we actually believe you missed our orbit by a few yards, a few this, few degrees? We have some wobble, you know, we have some elliptical? What—I mean, do they share that sort of data back and forth?

General RAYMOND. For those that we have agreements with, they provide owner—what we call owner-operator—the address in space, if you will. We track it with a radar. They have the exact address of theirs, and we—they do provide that back and forth. The challenge that we have today is that our command and control system that we have doesn't allow us to automatically ingest that. We are putting a new command system in place as we speak called the Joint Space Commission Operation Center System that will allow that automated—automatic ingestion of owner-operator data.

Mr. SCHWEIKERT. Okay. Mr. Chairman, as my buddy here—and we were talking sort of one-off a moment ago, as we see the commercialization of space, we know we have the incentives. We have very valuable objects up there. You know, we know we have the need. We know we have sort of a communication structure, and we also know it is ultimately going to be international. Is there a way where we could ever get these parties where they have sort of an automated information exchange back and forth, and others are also carrying the cost of this? So, thank you, Mr. Chairman, yield back.

Chairman BROOKS. Thank you, Mr. Schweikert. The Chair next recognizes Mr. Hall, the former Chair of the Science, Space, and Technology Committee.

Mr. HALL. Mr. Chairman, I thank you. I, of course, thank you for holding this hearing. I guess, General Raymond, some time ago, maybe 15 years ago, we had a hearing on astronauts—on asteroids, and, to our surprise, we found out one had just passed in what they said was 15 minutes of the United States. Nobody knew about it, and no one gave us any warning about it, or spoke about it. And I invited people from France, England, Japan, and others. Japan is the only one that answered, because it is a world problem, not just the U.S., but got very little hope from most of the—very few of them showed.

We had some good hearings on that, and some things that would scare you to death. I guess give us some kind of a sense of the process that goes in when you want to protect our national security and our commercial assets could be threatened by orbital debris, and what other degree there is? Or how much warning did NASA have to avoid their threats that they have had? I don't think they have had one—been instances where they have. Just give us a general answer to my question. If it is too general, I will——

General RAYMOND. Sir, we track, as we said, every object. We do that for NASA as well. We actually have NASA operators that sit on our JSPOC floor with us. We take very seriously the protection of the International Space Station. You heard from a previous panelist that the space station had moved 16 times. In fact, just last month, we recommended to NASA that they move it twice.

There is a layered approach to doing this. We detect where the debris is, and then, as it gets into a certain area around the space station, we then put more energy on that debris, refine the orbital accuracy of that—of our position estimate of that debris, and then we make recommendations with the folks sitting on the floor. So it is something that we take very seriously, and there is a set process with NASA operators. We also do that for all of our DoD satellites. And, again, as I mentioned earlier, for any conjunction that we see is going to hit on an emergency basis, we notify the world.

Mr. HALL. I know you must have processes for the government operators, to warn them about any possible collision, but what type do you—work do you have with the private operators? How do they know this, and how do you contact them? Or how do they contact you, or how do they watch you and listen for you?

General RAYMOND. Sir, we have a tracking network of about 21 different centers around the globe that track what I will call element sensor addresses in space of objects, debris, or satellites. We post that on a website, www.spacetrack.org. Anybody can get on there, and all of the addresses, or a large portion of the things that are in space, we put out there publically for everybody to have.

Mr. HALL. Now, the private operator just is—operation—government operators to know of your work?

General RAYMOND. They have that data. For those that enter into agreements with us, we actually go beyond that, and we provide some services to them in addition to that data. And then, again, on an emergency basis, even for those that don't have——

Mr. HALL. How many of them know that they need to have that agreement with you?

General RAYMOND. They all know, and we have got 41 different companies now that have it, and we have got five different nations that we have signed agreements with, and there are five or six more in the hopper right now going through the negotiations of that as we speak.

Mr. HALL. I think your work is very, very important, and I thank you. I yield back, Mr. Chairman.

Chairman BROOKS. Thank you, Mr. Hall. The Chair next recognizes Mr. Rohrabacher of California.

Mr. ROHRABACHER. Thank you, Mr. Chairman. I apologize, I had another hearing, a markup from another Committee, and I will be reading your testimony. And I think this issue is vitally important for the future of not only the United States, but of all of humankind. The debris issue is not a secondary issue. Debris is something that will limit humankind's ability to use space for our benefit, and to uplift mankind, humankind. This is—and we are getting to a point of saturation now where either we deal with it, or we will suffer the consequences of this limited—and this limit on the benefits that we can utilize space for.

One need only take a look at how we rely on space for weather, for communications, you name it. We have got—we have brought down the cost of telephone calls so dramatically with the use of space. We have agriculture that now depends on space, and GPS. We have whole economies based on space that are now in jeopardy because we are not cleaning up our trash. And we need to make sure that we are just not—track it. It is like—tracking trash in space is not the answer. What the answer is, eliminating the trash from space.

And this shouldn't be just something the American taxpayer needs to bear the burden of. We need to make sure that we have an initiative. We should—hopefully this hearing will provide step number one towards creating an international initiative to clear space debris from orbital space. And I would imagine that our friends in the EU, and Russia, and perhaps—I can't speak for China, considering the fact that they have contributed so much to this problem as of late. But we should make this an international effort, and the steps should be made to get this thing moving. Otherwise, we are putting all of these wonderful assets that we have invested in, and that are currently helping improve the condition of humankind, we are putting them at risk.

Let me note we—the Chairman, our Chairman of the full Committee, just mentioned that—we talked about near Earth objects, and—when he was Chairman, and I think that we probably have something where we are tracking them a little bit more than what we were then, but I don't think that we have done anything that—right now that we could count on to say, if we see a near Earth object that is going to hit the Earth and destroy large numbers of people, whether or not we have a system in place that we could then activate to deflect that near Earth object. I don't believe that system is in place.

Well, we have got two major threats there, things we should be able to work on with our allies, and friends throughout the world, in order to achieve this as a human goal, a goal for all of humankind, as I say. So thank you very much for your testimony, I will be reading it. I am sorry that I missed the—and I would be happy to yield to my colleague from Maryland. Is that—will you—did you want some time? I would be happy to yield.

Chairman BROOKS. Does the gentleman from California have any more questions?

Mr. ROHRABACHER. I am done.

Chairman BROOKS. All right. Thank you. The Chair, at this point, subject to the call for votes on the House floor, is going to entertain a second round of questions, and I am going to defer my second round at this point, and recognize the Ranking Member from Maryland, Ms. Edwards.

Ms. EDWARDS. Thank you very much, Mr. Chairman. And the reason I wanted Mr. Rohrabacher to stay is because, in Mr. Weeden's testimony, he had a recommendation for the executive branch to clarify its strategy for assessing the orbital debris removal, and it really struck a chord because in our bipartisan Committee passed bill just a couple of weeks ago, we actually included a provision in there that would require NASA, in collaboration with other relevant Federal agencies, to review the concepts and technological options for removing orbital debris from low Earth orbit.

So, I mean, getting to this question of not just looking at it and knowing where it is, all very important, but what's going to be our strategy for removing it? Because we actually need to free up some of that space too for all the additional activity that is going on. And so I wonder if any of you have any views, Mr. Weeden, starting with you, about what an effective approach NASA might take to address this particular provision, assuming that it does become law?

Mr. WEEDEN. That is a very interesting—very challenging question, because, at the moment, there is no single technology that seems to be the answer. There are a couple of different technologies that have some promise. And so I think a first step would probably be to figure out what those technologies are, and then look for, how are we going to mature those technologies? Because, at the moment, they are—they exist. We generally know, theoretically, they are probably going to work, but most of them have not been demonstrated in an operational manner.

So it will be identifying what the most promising technologies are, and then some sort of a strategy to mature them, do risk reduction, and—toward some sort of a demonstration mission on orbit of one or more of these technologies. And I think that is probably going to have to be an international demonstration—mission in nature, given the nature that all the debris is international, right? A county can only really touch the things that it owns, and so there is going to have to be some level of cooperation there.

Ms. EDWARDS. Well, given that the United States mostly tracks all of it, it would—I would assume that we should be able to get some cooperation. General Raymond, is there a role that DoD can play in terms of maturing some of these technologies?

General RAYMOND. Ma'am, there are a lot of discussions that are going on around the world on this problem, and it is an important issue. I think there are roles that we could help. I have not heard, to date, though, any specific technology that is out there that I see is something near term that us going to be able to solve this problem.

Ms. EDWARDS. Mr. Nelson, I think you wanted to——

Mr. NELSON. Yeah. I think Mr. Weeden touched on it. The technologies, and being able to take the items out of orbit, and getting them out of orbit, is very important. Obviously, the sooner you get it out, the likelihood is that they won't crash into something else.

The point—the issue, though, it comes down to is whether or not you take out—and you are—made that mention as well, somebody else's piece of debris. The flags are flying on—even if it is not usable, that particular item is, you know, has the flag of another country. So there probably is going to have to be some sort of treaty work, or something along those lines, or agreements made between nations in order to be able to effectively work that out.

Ms. EDWARDS. Right. Well, I know that Goddard Space Flight Center has some rather robust activity going on now to try to look at ways to re-service some of these decommissioned satellites as a way to get them back in service, not put, you know, new ones up, but that too is a long way down the line, but something that I think we need to invest in. And with that, Mr. Chairman, I will yield.

Chairman BROOKS. Thank you. Mr. Rohrabacher, we have time for another round of questions on your end, if you have any additional questions. The House floor vote has not yet been called.

Mr. ROHRABACHER. I would just like to suggest that we make this the first step, and not just a public relations—I mean, this is a problem, you know. We can do something in Congress to work with these folks, and to work with people internationally. I have—when I travel overseas, I am on the Foreign Affairs Committee, I always—when I go to another country, I go and talk to their space people. And every time I talk to the space people, whether it is Russia, or Japan, or Europe, they all are in tune with the—this is a challenge that we—that we are going to have to someday deal with, because it is coming to the point now where it is imperative to deal with it, because it is limiting what we can do in space.

So, let me see, it was—I would just say—okay. Have any of you had any talk with, for example, the Russians, or the EU, or Japan on this issue?

Mr. ZAMKA. Sir, the FAA is engaged with a lot of international partners, to include the European Space Agency, and we have letters of agreement with Spain and Curacao.

Mr. ROHRABACHER. Right.

Mr. ZAMKA.Because it is such a big international problem, there is international will to attack it. One thing that we have an opportunity to do here is identify a civil agency that can represent the United States, which is the biggest operator out in orbit, to take a leadership role as we begin to address the problem.

Mr. ROHRABACHER. Well, is, you know, one—I remember one of the directors of the space program in Russia telling me that they had been thinking about some—almost a bulldozer type of thing, where you had a—some kind of a big shield in front of a—something that would go forward and get a hold of some of this debris. We actually—are we studying anything that would be—I mean, there is one idea. I mean, I am not saying that is good or bad. Are we really—have—you mentioned that we don't have any—or is there a program on that is actually trying to develop the technology in this?

Mr. WEEDEN. At the moment I am only aware of one NASA funded program to do some technology development. It refers to what is known as an electro-dynamic tether, which is a spacecraft that can use the combination of electrical field and the Earth's magnetic field to maneuver without using fuel, aside from sunlight.

Mr. ROHRABACHER. Um-hum.

Mr. WEEDEN. And it is—the technology is fairly early stages, but it could be one of the more efficient ways of moving around to gather debris. I am not aware of any other U.S. government funded programs to do the technology development. But I will say that, in reference to your question about international efforts, next month there is going to be a meeting hosted by CNES, the French Space Agency, that has participation from Japan, from NASA, from Russia, from a number of other countries, to—it is a 3 day workshop, looking at technology, and engineering solutions for his.

Mr. ROHRABACHER. Really?

Mr. WEEDEN. And this——

Mr. ROHRABACHER. Where will that be?

Mr. WEEDEN. That will be in Paris. This is—and they have held this workshop every two years. This is the third instance of it.

Mr. ROHRABACHER. And what days are they?

Mr. WEEDEN. It will be June 16, 17, 18, around there.

Mr. ROHRABACHER. Okay. Mr. Chairman, I would suggest that someone from this Committee go to that hearing—or that meeting.

Chairman BROOKS. Is that a request?

Ms. EDWARDS. Mr. Chairman, he may have to compete with the Chairman and the Ranking Member.

Chairman BROOKS. Does the gentleman from California have any more questions? All right. Let me exercise my prerogative and now ask my question.

General Raymond, if an event like the Kosmos-Iridium collision happened today, how would JFCC respond? Specifically, can you give the Committee a sense of the process that goes into actions to protect our astronauts on the International Space Station, or other national security and commercial assets that could be threatened by such an event?

General RAYMOND. Yes, sir, thank you for the question. If we—if an event happened where two satellites collided, obviously, it would generate debris. We would detect that debris with our network of sensors around the globe. We would characterize that debris. We would get an orbital element, or the address in space, if you will, of that debris, and we would refine that over time, and we would put that debris into our catalog.

Once it is in the catalog, as I discussed earlier, we have the process in place that we do for every active satellite on orbit. We would screen against that debris to ensure that we provided proper warning, if something were to collide.

Chairman BROOKS. That is the vote call, but we still have 15 minutes before we have to be on the House floor. Quick follow-up question, how long does it take, generally speaking, for the orbital debris to have its orbit decay to the point where it goes back to Earth, and it is no longer an issue?

General RAYMOND. Mr. Chairman, there is a lot—there is lots of factors that go—that are involved in that.

Chairman BROOKS. Is there some kind of average number of years, or decades, or a range?

General RAYMOND. Sir, I would—I don't have that at my fingertip, and I don't think there really is—it—there are so many factors that are involved. It is altitude, size, shape, speed, velocity. There are a whole bunch of things. We do predict re-entries, and we track those re-entries. We know—we track those, we warn against them, when they are going to re-enter. But I can't tell you, you know, I can't give you a time for how many years. But when it gets close, we can characterize that re-entry, and we warn against that as well.

Chairman BROOKS. Mr. Nelson, you wanted to add something?

Mr. NELSON. Yes. It is, you know, the General actually hit on the issues. It is basically the altitude, the shape of the object, the mass of the object, and it can range quite—there is a very, very large range, from, you know, tomorrow to, you know, maybe a million years from now. So—depending on where that particular object is. So that brings up the issue of basically taking it out of the orbit.

Chairman BROOKS. Mr. Weeden?

Mr. WEEDEN. Just to give you some ballpark numbers, at the altitude of the International Space Station, I would say a rough estimate, on the order of months to maybe a very short number of years. When you move up higher, let us say around 800 kilometers, where most of the remote sensing satellites are, and the greatest congestion of debris is, and the collision was, and the Chinese anti-satellite was, at that altitude, you are talking decades or longer. And once you get beyond 1,000 kilometers, for all intents and purposes, it is up there pretty much, as far as we are concerned, forever.

Chairman BROOKS. All right. Thank you. General Raymond, as a follow up to my earlier question to you, FAA requested, in their written testimony, for the authority to require operators to move positions if a possible collision is detected. How would your process change, if at all, if that authority is granted to the FAA?

General RAYMOND. Sir, the FAA would still rely on the data that we get from our sensors. We would be providing that data. Today we—again, we warn of those conjunctions. We do not have the authority to make some—make a satellite operator move. And I can for DoD satellites, but I can't make commercial satellites, because I don't have that authority, but they would take our data that we have and use that data in their new role.

Chairman BROOKS. Thank you. Any other follow up on that? Yes, Mr. Zamka?

Mr. ZAMKA. Yes, sir. Regarding the request to have the ability to require an operator to move, that can be done in a number of ways. Earlier is better. Earlier interaction, perhaps, agreement with the operator as part of the licensing process as to what the criteria would be for which they would move. Probably best of all would be an industry based consensus on what is the agreeable time to effect a move because probabilities are involved, and a lot of expense for the operator, frankly.

Chairman BROOKS. All right. I thank the witnesses for their valuable testimony, and the Members for their questions. The Members of the Committee may have additional questions for you, and you—we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments and written questions from the Members. The witnesses are excused, and this hearing is adjourned.

[Whereupon, at 11:27 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Lt Gen. John "Jay" Raymond

CHARRTS No.: HSSTCS-01-001
Hearing Date: May 09, 2014
Committee: HSSTCS
Member: Congressman Palazzo
Witness: Lieutenant General Raymond
Question: #1

Orbit Clutter

Question: There are many orbits that are especially cluttered with debris right now. Can you give the Committee a sense of what orbits you are most concerned about and why losing access to those orbits would be a problem for the nation?

Answer: The vast majority of identified debris is located in the low earth orbit (LEO) regime, which is where the International Space Station resides, as well as the majority of active satellites. If debris were to proliferate to the point that made LEO inaccessible, human space flight, both governmental and commercial, would be compromised, as well as the wide variety of earth observation missions, such as environmental monitoring, meteorology, and imagery.

In response to the debris threat, the US developed a National Space Policy (NSP), which addresses how to protect Space by controlling or mitigating space debris, and calls for compliance with the Orbital Debris Mitigation Standard Practices. As part of USSTRATCOM's campaign, we strive to collaborate with like-minded nations and organizations to reinforce and expand our collective desire to ensure the freedom of access to, and use of, the space domain for peaceful purposes.

CHARRTS No.: HSSTCS-01-002
Hearing Date: May 09, 2014
Committee: HSSTCS
Member: Congressman Palazzo
Witness: Lieutenant General Raymond
Question: #2

Moving Space Assets

Question: DoD monitors large debris and in many cases, satellite owners and federal agencies are able to move space assets out of the way of approaching debris. Apparently, the need for such maneuvers is increasing. How many times did operators choose to take evasive maneuvers due to conjunction notifications by JFCC in 2013 and 2014? Do you expect this number to increase in 2015?

Answer: In 2013 there were 76 low earth orbit (LEO) and 17 geostationary Earth orbit (GEO) maneuvers. To date in 2014, there have been 31 LEO and 10 GEO maneuvers, which exceed 2013 by 4 and 2 respectively. All indications are that this trend will continue to increase in the years ahead.

CHARRTS No.: HSSTCS-01-003
Hearing Date: May 09, 2014
Committee: HSSTCS
Member: Congressman Palazzo
Witness: Lieutenant General Raymond
Question: #3

Possible Collisions

Question: Please describe the process that JFCC goes through in working with private operators as well as government operators to warn them of possible collisions. How is this different with large operators versus small operators? Are all operators treated equally or does JFCC have better relationships with specific operators? Do you have any concerns with the current framework you use to get information about possible collisions? Is there some kind of ranking system involved in determining how big of an alarm to sound on a possible collision? Is there more urgency on a collision that is more likely, or do all warnings go out to operators the same way? Are there any domestic operators that do not share maneuver data with you ahead of time? Would requiring this help you?

Answer: JFCC SPACE performs conjunction assessment screenings on all active on-orbit payloads once per day for both private and government operators, and warns them of possible collisions through direct email and the website Space-Track.org. For conjunctions within high-interest emergency criteria, JFCC SPACE will make every effort to phone the affected operators. Regardless of their size, all operators receive the same emergency conjunction assessment service. In addition, operators who have signed SSA Sharing Agreements with USSTRATCOM are eligible for advanced services, which include expanded screening volumes. Currently, neither domestic nor foreign operators are required to submit their maneuver data, though many do on a recurring basis. Although we are confident in the current system and process we use for conjunction assessment, receiving this maneuver information from *all* operators would improve the quality of conjunction assessment and spaceflight safety.

CHARRTS No.: HSSTCS-01-004
Hearing Date: May 09, 2014
Committee: HSSTCS
Member: Congressman Palazzo
Witness: Lieutenant General Raymond
Question: #4

Cubesats and Chipsats

Question: At present there is very little monitoring of cubesats and chipsats. As these types of low- cost satellites become more and more popular, how does JFCC plan to deal with their proliferation? Is there an obvious solution to ensuring you have the tools you need to track these small satellites?

Answer: JFCC SPACE is tasked with the Warning and Assessment mission for USSTRATCOM. As such, I am responsible for detecting, tracking, characterizing, warning and responding to threats against our space-based platforms and supporting ground links. The foundational capability for this mission is Space Situational Awareness (SSA). At this time, JFCC SPACE can track cubesats, but we cannot track chipsats.

To help mitigate with the proliferation and tracking challenges, we are taking a multi-pronged approach to enhance our SSA. We are:

- fielding new SSA sensors (e.g., Space Fence);
- reaching out to industry to incorporate mechanisms to enhance the tracking of cubesats and chipsats (e.g., optical tagging, radio beacons) and removed from orbit at end of life;
- expanding the number of safety of spaceflight/SSA information sharing agreements that we currently have (i.e. 41 commercial owner/operators and five nations) and increasing future cooperative projects such as integrating SSA data from partner sensors; and
- continuing to implement JSpOC Mission System upgrades to fuse and display SSA data.

We find ourselves today in a strategic space environment which requires active stewardship to preserve the capabilities on which our nation relies. JFCC SPACE will continue its pursuit of innovative ways to improve our ability to track these small satellites.

CHARRTS No.: HSSTCS-01-005
Hearing Date: May 09, 2014
Committee: HSSTCS
Member: Congresswoman Edwards
Witness: Lieutenant General Raymond
Question: #5

Space Traffic Management

Question: How would you define 'space traffic management' and what do you view as the priorities for enabling space traffic management?

Answer: In order to contend with an increasingly congested, contested, and competitive space domain, space traffic management aims to combine the resources and capabilities of the US Government (via STRATCOM) with other entities such as NASA, the FAA, International, Civil, and commercial partners to ensure spaceflight safety, promote U.S. commercial space transportation, and to protect commercial and military assets consistent with the policies and responsibilities laid out in the National Space Policy (NSP), National Security Space Strategy, (NSSS), and Unified Command Plan (UCP).

Three structures for STM have been proposed: 1) a coordinated, distributed governance, 2) federal agency coordinating body, and 3) lead federal agency

To enable space traffic management, USSTRATCOM, in collaboration with interagency partners, needs to develop a clear understanding of intended functions, benefits, costs and risks, and establish a united front (of partners) to provide consistent messages and services.

CHARRTS No.: HSSTCS-01-006
Hearing Date: May 09, 2014
Committee: HSSTCS
Member: Congresswoman Edwards
Witness: Lieutenant General Raymond
Question: #6

Collision Avoidance

Question: I understand that it is important to provide credible and transparent collision avoidance information to commercial satellite operators-both domestic and international-about potential on-orbit collisions they need to avoid. By the same token, we cannot lose sight of the fact that DOD's Space Surveillance Network does have a primary purpose. Is there a way to satisfy national security concerns associated with releasing information related to tracking space objects?

Answer: Yes.

Partnerships with civil, commercial, and foreign entities are essential to success. Robust, exchange-based partnerships will enhance spaceflight safety and increase resilience placing the US, its allies, and other formal partners in a better position to protect assets.

Recognizing the need to adapt to the evolving space environment, USSTRATCOM is adopting an updated approach with the public and partners to provide higher quality information, in greater quantities, in a more timely fashion.

The new sharing paradigm established 3 categories of users for Space Situational Awareness (SSA) information, placing increased focus on the needs of partners:

- Public: Today, space-track.org serves as the main source of the most extensive collection of satellite positional and spaceflight safety information for academic, research and development, and amateur observers. This service will remain a key element of the US government's commitment to providing SSA information for spaceflight safety. USSTRATCOM will add a new category of tracked objects, make minor modifications to website information and processes, and move some USSTRATCOM resources towards providing enhanced SSA information to SSA Sharing Agreement holders and US National Security Partners.
- SSA Sharing Agreement Holders – Commercial and government owner/operators that have a signed SSA Sharing Agreement with USSTRATCOM will continue receiving the advanced spaceflight safety services currently afforded by the agreement, and will also have access to higher quality, more timely information on more objects.
- US National Security Partners – Allied and partner nations, and organizations that directly contribute to coalition/combined space operations, enhancing the accomplishment of military missions.

CHARRTS No.: HSSTCS-01-007
Hearing Date: May 09, 2014
Committee: HSSTCS
Member: Congresswoman Edwards
Witness: Lieutenant General Raymond
Question: #7

Current Collision Communication Process

Question: There is, by necessity, a communications and interface role with various satellite operators in relaying pertinent information, should a potential collision be identified. Are you satisfied with the current communication process? What improvements do you see as necessary in the future?

Answer: As soon as a satellite launches, JFCC SPACE reaches out to the operator to initiate contact and introduce conjunction assessment services. Our current communication process ensures that we provide conjunction assessment warnings to all operators for whom we have contact information. In the event of a close approach, we provide conjunction warnings through direct email, the website Space-Track.org, and in high-interest events, by phone. We encourage operators to provide their ephemeris for collision avoidance screenings and continue data exchange until the collision risk is resolved.

Communication with new and existing operators can be improved in two ways. First, operators can expedite accurate cataloging of new objects by providing pre-launch information such as launch parameters and object characteristics. After launch, operators can continue to communicate with the JFCC SPACE by providing maneuver plans and post-maneuver confirmations. We are working to enhance two-way sharing as much as possible. In response, JFCC SPACE will be able to maintain a more accurate catalog, and in turn, provide higher quality conjunction assessments. The implementation of planned system upgrades, such as the JSpOC Mission System, will also enable the JSpOC to provide more timely responses to operators through automated data flow.

Responses by Mr. George Zamka

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE

"Space Traffic Management: How to Prevent a Real Life 'Gravity'"

Questions for the record, Mr. George Zamka, Deputy Associate Administrator, Office of Commercial Space Transportation, Federal Aviation Administration

Questions submitted by Rep. Steven Palazzo, Chairman, Subcommittee on Space

1. **How applicable are your agency's air traffic management experiences to the more diverse and dynamic space enterprise?**
    a. **What additional capabilities, staff, or expertise would be required to reach a comparable efficiency for space traffic management? Is a comparable system necessary?**
    b. **What type of relationship would the FAA envision with the FCC and DoD if traffic management authority was granted to AST?**
    c. **How would FAA work with the Space Data Association and private industry?**

Response: There are many differences between operations in space and those taking place in the national airspace. However, the underlying principles used to ensure public safety are similar. In addition to aviation expertise, the FAA maintains robust space expertise and works closely with space operators and other government agencies.

How space traffic management should exist or what agency roles would be are topics that would require additional interagency discussion. However, space traffic management would not necessarily be comparable in size or organizational structure to the FAA's air traffic system, thus requiring far fewer personnel than air traffic control. With regard to interagency coordination, the FAA and other civil agencies do not maintain space surveillance assets or capabilities. DoD operates the network that provides space surveillance information to interagency users, including the FAA. A civil agency responsible for space traffic management would need to have the ability to closely coordinate and communicate with all interested agencies, including DoD and FCC, and industry, as appropriate. Additionally, an agency with space traffic management authority could certainly draw from the expertise of non-governmental entities like SDA, for example to develop practices for communicating warnings, courses of action for analyzing potential conjunctions, and innovative approaches that are appropriate for space traffic management.

2. **Satellite operators, including civil government and military operators, who are members of the Space Data Association have contractually agreed to share their orbital maneuver plans in a database before they are actually made. This database (the Space Data Center) then automatically checks that the planned maneuver does not create a risk of collision or, if it would, it issues appropriate warnings. This seems to reflect a voluntary, positive, and novel form of space traffic management across international lines. Are new, binding regulations for commercial, civil, and military satellite operations necessary?**

Response: Although satellite operations are not within the oversight purview of the FAA, we note that the work being performed by the SDA does have limitations. Space Data Center analyses are based only on the owner and operator data of active member systems, and not on the classified DOD catalog. Consequently, the Space Data Center does not provide the best analysis for debris objects, which comprise 90% of the cataloged objects, nor does it screen maneuvers against the entire classified catalog. Due to the classified nature of the DOD catalog, only a U.S. Government entity can access the most accurate data provided by DOD.

3. What type of interaction would FAA envision with the FCC in a new regulatory framework where a license was issued for on orbit operations and how would this differ from your current relationship with FCC?

a) Would you anticipate operating as a hub for information, or as a traffic cop in space?

Response: Currently, the FAA issues licenses for certain phases (i.e. launch and reentry) of commercial space transportation vehicle operations, while FCC issues licenses for communications (e.g. satellite datalinks, radio, etc.). The FAA believes that if it were provided oversight authority for commercial transportation system operations on orbit to include new classes of transportation vehicles that operate differently from communications or Earth-observing satellites, it would not significantly alter the relationship that the FAA currently holds with the FCC, given that the focus of the FAA's responsibility (transportation) would remain the same.

a. It is important to distinguish between the licensing of commercial space transportation on-orbit activities, and space traffic management services provided to commercial entities operating on orbit. The former represents an extension of the work currently performed by the FAA Office of Commercial Space Transportation, while the latter would be an entirely new mission for a civil agency, such as the FAA, which could play a role in providing information to facilitate collision avoidance.

Regarding the term "traffic cop in space", it is considered too broad a term for the complexities involved with orbital safety. Given that 90% of the objects on orbit are un-maneuverable debris, the role of a space traffic manager could be to assess and facilitate the planned maneuvers of active systems within the congested space environment.

As we explore orbital transportation safety, engagement through a licensing process early in the design of vehicles and planning of missions is an area where the costs of mitigating collision risk could be least expensive to implement. If the FAA were authorized, it could establish with the operator how to avoid accidents beforehand, so that the operator would make the correct decisions through the design and life cycle of the vehicle. The FAA would be overseeing the operator throughout design and operations to ensure compliance.

4. In your testimony, you indicate that if FAA had enforcement authority it could ensure that maneuvers were carried out. Often times the decision to move an asset to avoid orbital debris is made by considering more than just the chance of collision.

a) What type of process do you envision for this enforcement?

b) Has FAA contemplated the economic hardships that could be caused if companies were forced to move regularly despite their assessment that the risk is not great enough to move?

c) Have you discusses these proposals with industry yet? What was their response?

Response:

a. As the amount of orbital debris continues to grow, moving a commercial satellite to avoid a potential collision is becoming a routine occurrence. The collision avoidance process requires notification that a conjunction (or close approach) is imminent, followed hy an appropriately timed maneuver to reduce the probability of collision. For commercial operations, uncontrolled systems require an assessment, prior to deployment, of the risk of collision, debris mitigation plans, and the risks to human spaceflight. For controlled systems, debris mitigation plans are necessary prior to deployment, and a regulatory risk threshold is necessary to establish the maximum risk the U.S. commercial system should accept. U.S. commercial operators must operate their systems in a safe manner and within regulated norms. ISO develops high quality voluntary International Standards which promote innovation and protect health, safety and the environment as well as advance the space industry. These international consensus standards are heavily influenced by U.S. contributions. Only the practices and norms that end up being captured in regulations would be binding on commercial operators.

b. Maneuvering to avoid a high-risk collision should not be deemed an economic hardship; much like an oil tanker maneuvering to avoid a reef is not considered an economic hardship. Maneuvering is the cost of operating safely in orbit for extended timeframes. Unnecessary maneuvering can cost operators fuel that could be used to extend the satellite's orbital lifetime. We believe that combining the most accurate federal data with the most current operator data would contribute to an increased level of confidence that a maneuver is, or is not, needed. Because the aftermath of an orbital collision affects more than the just the operator, in addition to considering individual risk to a commercial operation, collective risk should be considered. For example, an operator could choose a 1 in 10 chance of collision for a system at the end of its service life, as it could represent only a minor loss in revenue and it could be due for replacement anyway. Acceptable risk levels are already specified by the FAA for the launch of vehicles entering orbital trajectories.

c. The FAA has discussed the topic of space traffic management with the Commercial Space Transportation Advisory Committee and with the Satellite Industry Association president. Both organizations are continuing to assess the potential impacts on the operations of their member organizations.

Questions for the Record
from Ranking Member Donna F. Edwards

To Mr. Zamka

1. Do your agency's regulations on orbital debris mitigation encompass the upper stages of commercial launch vehicles, and if so is the launch provider then required to respond to two sets of regulations or do both agencies coordinate with the launch provider? If there is a problem with an upper stage as potential debris, which authority takes precedence?

Response: Yes, our regulations address debris mitigation for upper stages of all commercial launch vehicles. Further, our regulations on debris mitigation are the only regulations a launch vehicle operator must address for vehicle upper stages.

The FAA has exclusive authority for orbital debris mitigation for commercial launches. This authority is codified in Title 51 and reiterated in the current National Space Transportation Policy. It is important to note that upper stages are normally preprogrammed, so orbital debris mitigation activities must be addressed prior to launch. The collision avoidance process is executed during the launch window. If an established collision risk threshold is exceeded or the planned trajectory approaches within 200 km of a habitable orbiting space object, the launch is held until the trajectory is clear of the identified threat. Safing an upper stage on orbit or reentering an upper stage are the last actions necessary for upper stages to comply with debris mitigation rules.

2. How would you define 'space traffic management' and what do you view as the priorities for enabling space traffic management?

Response: How space traffic management could work and what it would consist of are topics of ongoing discussion. The Office of Commercial Space Transportation is considering that STM could include notification to operators of hazards and the ability to evaluate potential responses.

The priorities for the FAA in working with stakeholders are:

- Work with Congress to determine how best to authorize and oversee commercial transportation operations in outer space.
- Work with NASA, DoD, industry, and academia to establish best practices.
- Work within the interagency space community to define roles, responsibilities, and appropriate methods of sharing and coordination.

3. What types of on-orbit operations other than collision avoidance, if any, might require regulation? How soon do we have to start worrying about regulating those operations?

Response: Avoiding collision on-orbit is the primary driver for exploring oversight authority under the Commercial Space Launch Act. The FAA has already received payload review requests from commercial companies who desire to operate private space stations and satellite servicing operations. One U.S. company already has two subscale commercial space stations in orbit for testing and demonstration purposes. Servicing should encompass proximity operations and docking, which could also require collision avoidance mitigation measures. Commercial satellite servicing is expected to be operational by 2018.

Responses by Mr. Robert Nelson

Responses from Robert Nelson to Questions for the Record

The Honorable Steven Palazzo:

1. **In your written testimony you allude to the FCC's authority under the Communications Act of 1934 as the basis for the Commission's regulations governing orbital debris.**
    a. **Can you give the Committee a more specific description from where the commission derived this authority?**
    b. **Does the Commission believe the boundary of its authority is in orbital debris guidelines or does it plan to assert more jurisdiction over traffic management?**

RESPONSE:

The FCC Order adopting orbital debris regulations cite, as authority for that action, Sections 1, 4(i), 301, 303, 308, 309, and 310 of the Communications Act of 1934, as amended. The authority citations for the rules adopted in that order vary based on the particular rule parts modified (Part 5—Experimental Radio Service, Part 25—Satellite Communications, Part 97—Amateur Radio Service).

The FCC Order included the following discussion of statutory authority (footnote text displayed within square brackets):

> [T]he Communications Act provides the Commission with broad authority with respect to radio communications involving the United States, except for communications involving U.S. Government radio stations.[fn 50: 47 U.S. C. § 305(a). The Commerce Department's National Telecommunication and Information Administration is responsible for assignment of frequencies for use by U.S. government stations.] The Act charges the FCC with encouraging "the larger and more effective use of radio in the public interest," [fn. 51: 47 U.S.C. § 301.] and provides for licensing of radio communications, [fn. 52: 47 U.S.C. § 301] upon a finding that the "public convenience, interest, or necessity will be served thereby." [fn. 53: 47 U.S.C. § 307(a).] Satellite communications are an important component of the national and world-wide radio communications infrastructure.[fn. 54: *First Report and Order*, 18 FCC Rcd at 10764 (para. 2)(observing that the satellite industry is a "crucial component of the global communications marketplace").] Because orbital debris could affect the cost, reliability, continuity, and safety of satellite operations, orbital debris issues have a bearing upon the "larger and more effective use of radio in the public interest." In addition, orbital debris can negatively affect the availability, integrity, and capability of new satellite systems and valuable services to the public. Thus, orbital debris and related mitigation issues are relevant in determining whether the public interest would be served by authorization of any particular satellite system, or by any particular practice or operating procedure of satellite systems.[fn.55: Courts have held that the Commission may consider public safety factors as part of its licensing procedures. *See Simmons v. FCC*, 145 F.2d 578, 579 (D.C. Cir. 1944)(finding that the "public interest, convenience and necessity clearly require the Commission to deny applications for construction which would menace air navigation"); *Deep South Broadcasting Co. v. FCC*, 278 F.2d 264, 267 (D.C.Cir. 1960) (confirming FCC authority to consider structural aspects of a radio tower as a "clearly relevant puhlic interest consideration"). For a discussion of the FCC's legal authority concerning orbital debris, *see also* MEO/LEO Constellations: U.S. Laws, Policies, and Regulations on Orbital Debris Mitigation, American Institute of Aeronautics and Astronautics Special Project No. SP-016-2-1999 (1999).]

> Furthermore, debris prospectively generated from satellites licensed by, or authorized by, the FCC could affect the public interest in protecting the safety of manned space flight, as well as the safety of persons and property on the surface of the Earth. Because robotic spacecraft are typically controlled through radiocommunications links, there is a direct connection between the radiocommunications functions we are charged with licensing under the Communications Act and the physical operations of spacecraft. Accordingly, we conclude that the actions taken in this Second Report and Order are within the scope of our authority under the Communications Act.

The Commission is examining two types of proposed rule changes with respect to orbital debris mitigation. First, as part of the FCC's comprehensive examination of its licensing rules for satellite communications under Part 25 of the rules, industry suggested changes to the FCC's debris mitigation rules. FCC staff is currently examining these proposals, which address ways to simplify the administration of these FCC rules, but do not involve alteration of their scope. Second, the FCC has an open proceeding in which it is considering whether there are changes needed to frequency allocations to facilitate commercial launch activities. That proceeding is limited solely to radio-frequency matters and does not include any proposed changes to orbital debris mitigation rules.

The FCC has not specifically addressed "space traffic management" apart from its work relating to orbital debris and radio-frequency regulation. (The FCC has not defined "space traffic management"; however, other commentators have described it as "the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference".)

2. **There are several companies publically discussing the possibility of putting up a commercial space station that humans can visit or that astronauts could do experiments on. Presumably these private space stations would require a license from the FCC for transmitting on spectrum. Does the Commission believe it has the authority to require an orbital debris mitigation plan from this type of private space station?**
    a. **What are the limitations of the FCC's perceived regulatory authority in space?**

RESPONSE:

The FCC's rules require the submission of an orbital debris plan as part of an application for a space station license. Accordingly, applicants for an FCC authorization for the types of space stations described should submit a debris mitigation plan.

In general, the limitations of the FCC's regulatory authority, both in space and on the Earth, are specified in the Communications Act of 1934, as amended, and in legislation concerning the exercise of regulatory authority, such as the Administrative Procedures Act. With respect to orbital debris mitigation, and as indicated in my testimony, the FCC recognizes the specific legislative enactments granting the FAA authority concerning commercial launch activities, and NOAA with authority concerning the licensing of commercial remote sensing activities, including the disposal of commercial remote sensing satellites.

3. **How does the FCC work with international partners to ensure that foreign providers that transmit to U.S. ground stations are following orbital debris mitigation plans?**
    a. **What enforcement actions are available to the FCC if foreign providers do not follow these regulations?**
    b. **How often has the FCC exercised these enforcement actions?**

RESPONSE:

The FCC's rules require that when a U.S.-licensed earth station operates using a space station licensed by another country, the space station's debris mitigation plans must be disclosed. This disclosure usually occurs through one of two types of procedural mechanisms--either as part of an application for an earth station license, or through a "market access" request, which if granted provides access by a satellite system to certain types of already licensed U.S. earth stations. For these two types of requests, the FCC works primarily with commercial operators, although in some instances that operator may be a governmental entity.

As an alternative to providing specific debris mitigation plans, an applicant can ask the Commission to make a finding that satellite operations are subject to "direct and effective" debris mitigation regulation by another country. The FCC has made such findings for specific satellite projects regulated by France and the United Kingdom. Where discussions with foreign governmental bodies are required in connection with such findings, the FCC works with the State Department.

The FCC, the State Department, and NTIA have also developed a framework for potential waivers of the FCC's licensing requirement for receivers operating with foreign radionavigation satellite service systems, and orbital debris mitigation is one of several substantive considerations under that framework. Under this process, the State Department is the primary point of contact for discussions with foreign radionavigation satellite service operators. (Several commercial radionavigation satellite operators have also approached the FCC directly seeking such waivers, primarily in connection with Wide Area Augmentation System payloads procured under contract with the FAA.)

If a foreign-licensed satellite does not follow its plans and/or the FCC's debris mitigation requirements, FCC actions could include monetary fines and license revocation, setting aside of market access, or other appropriate procedural actions to terminate use by U.S. earth stations of the space station involved. The FCC could also consider past conduct in future licensing or market access decisions. To date, there have been no instances requiring such enforcement action.

4. **What are the enforcement actions available to the FCC to guarantee satellite operators will indeed follow the appropriate protocols for end of life on a satellite?**
    a. **Does the FCC periodically check in with operators to see that they are leaving enough fuel to move the satellite at the end of the satellite's life?**
    b. **Since there is no fuel gauge on a satellite that tells you how much fuel is left, what assurances do you have that an operator is appropriately prepared for end of life plans?**

RESPONSE:

Possible enforcement mechanisms include monetary fines and license revocation. The Commission may also consider past conduct in evaluating future license requests.

The FCC does not periodically check in with operators concerning remaining fuel, and instead relies on other regulatory mechanisms to ensure that sufficient fuel will remain at the end of a satellite's useful life to conduct the maneuvers necessary for taking the satellite out of operation.

For geostationary satellites, the FCC uses regulatory mechanisms at the applications stage to ensure the sufficiency of fuel reserves, by requiring a license applicant to identify the amount of fuel reserved for end-of-life maneuvers, and in deriving that amount to account for fuel gauging uncertainty. Our experience is that this approach results in licensees meeting or exceeding end-of-life requirements, unless prevented by factors other than fuel constraints, such as catastrophic failure of a critical satellite component.

For non-geostationary satellites, end-of-life protocols are handled on a case-by-case basis. To date, licensees have been forthcoming with data concerning remaining fuel in connection with requests for license modifications or extensions where satellite longevity is a relevant consideration.

We do not have the capability to either gather or check the validity of this information independently. Although there is no fuel gauge akin to an automobile fuel gauge on spacecraft, it is our understanding that operators can gauge fuel levels through book-keeping methods (calculating fuel consumed based on thruster firing duration and anticipated fuel flow rate) and through information derived from telemetry from the spacecraft. As an example, some operators are able to derive relatively precise figures for remaining propellant mass from propellant tank temperature increases when tank heaters are turned on for a set duration.

As a general observation, instances in which a satellite does not meet end-of-life disposal objectives are almost all a result of catastrophic failure of a critical satellite component or system. Such failures result in early mission termination and a technical inability to execute planned end-of-life procedures.

The Honorable Donna F. Edwards

1. **Do your agency's regulations on orbital debris mitigation encompass the upper stages of commercial launch vehicles, and if so is the launch provider then required to respond to two sets of regulation or do both agencies coordinate with the launch provider? If there is a problem with an upper stage as potential debris, which authority takes precedence?**

RESPONSE:

The FCC currently licenses launch vehicle radio-frequency use through the experimental licensing process. The FCC recognizes the statutory role of the FAA in regulating launch vehicles, including upper stages, and does not require orbital debris mitigation information concerning FAA-licensed launch activities as part of the experimental licensing process.

2. **How would you define 'space traffic management' and what do you view as the priorities for enabling space traffic management?**

RESPONSE:

The FCC has not adopted a definition for the term "space traffic management." However, one influential study described space traffic management as "the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference".

With that definition in mind, there are in my personal professional opinion three priorities for space traffic management.

One priority is the continued improvement in the quality of space situational awareness data, and the mechanisms for sharing that data among satellite operators, including both government and commercial operators. In addition, there is also the need for continued development by operators of procedures for responding to actionable data.

A second priority is continued work by the FAA to integrate space object re-entry activities into airspace management. The FAA is undertaking this work pursuant to its re-entry vehicle licensing authority. I anticipate that lessons learned and experience gained from that process may also be important for managing similar events that may fall outside the scope of the FAA's current authority because they do not involve re-entry of a substantially intact object. The FCC has not approved any plans that rely on controlled, destructive re-entry over the oceans with debris surviving to reach the earth's surface. However, previous license requests have proposed such plans, and it is reasonable to expect that future missions may require air space management support.

A third priority is continued development of radiofrequency allocations to support emerging commercial space ventures. The FCC has a pending rule making proceeding addressing some aspects of this priority, and I fully expect that the FCC will continue to work with commercial operators and our government colleagues to address these needs.

3. **What types of on-orbit operations other than collision avoidance, if any, might require regulation? How soon do we have to start worrying about regulating those operations?**

RESPONSE:

There will continue to be a need for adjustments in radio-frequency regulations as space commercialization progresses. We anticipate that this will be a continuous process over the coming years. The FCC proceeding proposing to allocate spectrum to support commercial launch frequencies is a current example. That proceeding also included a Notice of Inquiry that began the public process of identifying what frequency allocations may be needed for on-orbit commercial operations.

Another area in which we anticipate possible additional regulatory activity is with respect to on-orbit servicing. While there are currently no licenses or license applications for such operations, several commercial ventures are under development and may require FCC licensing review within the next few years.

A third significant area of regulatory activity relates to small satellites, such as the so-called "cubesats". These satellites already constitute a significant source of the FCC's satellite-related licensing workload, and there is every indication that the number of such satellites launched will continue to increase. This is particularly likely given increasing commercial interest in and use of small satellites. While it is possible that existing regulations are sufficient to address this development, it will be important to monitor whether adjustments in regulations are necessary, and, if so, to make such adjustments.

Responses by Mr. P.J. Blount

Responses to Questions for the Record
P.J.Blount

Questions for the Record submitted by Rep. Steven Palazzo, Chairman, Subcommittee on Space

1. The overall goal of orbital debris mitigation and tracking is enhanced safety of the global orbital environment, with that in mind, how can we use our experience to convince the international community to follow suit?

The space law regime developed during the Cold War serves as a guide for engaging the international community on the issue of space traffic management. The regime, in the interest of easing Cold War tensions, encourages - but does not compel - states to engage in international cooperation in space activities and in exchanges of information on space activities. The regime also states that space shall be used "for the benefit and interests of all countries" (Outer Space Treaty, Art. I). The underlying philosophy of the legal regime is that the use and exploration of space is a cooperative project amongst sovereign states. The United States has been a leader in using space technology for global good through projects such as Intelsat, Landsat, GPS, and the NOAA meteorological satellites. These public goods provided wholly or in part by the United States have led to the improvement of life for individuals on a global scale. Such global goods need to be protected "for the benefit and interests of all countries."

The United States should to continue to emphasize to the international community the global benefits that such programs have for individuals worldwide. This message should be coupled with transparency and access to information about it's space programs to the greatest extent possible without unduly compromising the national security interests of the United States. Specifically, space situational awareness data unrelated to national security should be shared with other states. This will enable these states to improve their own risk analysis mechanisms and encourage them to in turn share their own data. Through technological leadership and data openness the United States can maintain its position as a leader in international organizations (e.g. UNCOPUOS, IADC, ITU, etc.) that negotiate the various international instruments that govern space activities. A "lead by example" model is particularly apt to space activities since "best practices," rather that hard legal rules, are often the preferred way of regulating space activities.

1(a). Since we all share the same orbital space how can the United States work with nations that have emerging space industries to mitigate orbital debris?

First, the United States should use diplomatic pressure to ensure that these states take part in international fora on space activities. Emerging space programs need to be aware of international governance mechanisms and should be engaged in the international discussion. As more states embrace the necessity of space traffic management, it will be easier to convince emerging space faring nations of the importance of responsible behaviour through the dialogue that occurs in international fora.

Second, The United States should share as much information as possible with these states. This includes both technical information (such as the information that the Department of

Defense shares with operators on space traffic) as well as governance information (such as that shared by the FAA Office of Commercial Space Transportation in its outreach programs). If emerging nations understand the risks attached to orbital debris and how to implement law and policy to avoid those risks, they will be better prepared to integrate their space activities without causing risks to the United States or other space faring nations. Encouraging these states to abide by best practices early in their space programs should be of paramount concern. Again though, such information sharing should be as broad as possible but should not compromise national security.

Finally, the United States should be prepared to share technology that helps to reduce debris creation. Many developing nations have argued that the creation of space debris is natural early in a program while technology is still being developed. The United States can intervene to help these states bridge that technological gap. An important step towards accomplishing this was the removal of some space technologies from the United States Munitions List to the Commerce Control List. The United States should examine which debris mitigation technologies would enhance the interests of the United States if shared with other countries, and take steps to ensure that emerging space programs have access to these technologies.

1(b) What percentage of global space activities are governed collectively by the US oversight and how can we ensure there is uniformity between our systems and other nations?

According to the Union of Concerned Scientists there are 1167 satellites in orbit and 502 of those are US satellites (info current through 1/31/14, http://www.ucsusa.org/nuclear_weapons_and_global_security/solutions/space-weapons/ucs-satellite-database.html). This means that at least 43% of active satellites are governed by the United States. This number does not take into account satellites of other states or international organizations in the control of which the United States may participate, nor does it include other space objects, such as debris that the United States may retain jurisdiction over). However this number is illustrative since the second largest spacefaring nation is Russia which has 118 satellites in orbit (10%). Since the United States has the most to lose if the space environment is compromised, it has a special interest in maintaining a safe and secure space environment, and the ability to do so is often dependent on other states engaging in responsible behavior.

The best way to ensure that the systems adopted by different states work seamlessly together is through processes established by international organizations. For instance, proper management of the Geostationary orbit has been achieved through the ITU by the cooperation of states based on a perceived need to solve a collective problem. Similarly, the guidelines produced by the Interagency Debris Coordination Committee (IADC) are an example of how international engagement can result in cooperative solutions to collective problems. The United States should continue to play a leadership role in these international organizations in order to shape future international governance mechanisms in such a way as to foster responsible activity in space. Streamlining information sharing processes at the international level to ensure timely reactions to risks in space activities should be an important goal of the United States.

To this end one of the key functions of a domestic space traffic management regime should be to provide a point of contact for international space actors, so that space traffic operations can be coordinated smoothly both among US operators and among US and international operators. Again, traditional outreach activities through diplomacy will be critical in engaging other nations and ensuring their cooperation.

2. What is the best definition of space traffic management moving forward and how would you develop domestic and international consensus for that definition? Is developing the definition a technical, political, or legal problem?

The definition for space traffic management will change with its context. The definition adopted by the international community will likely differ in scope and substance from the one adopted domestically for regulatory purposes. While space traffic management at these two different levels has many overlapping goals, there are also differences in the purpose of the adopted definition. For example, the international definition may place emphasis on the goal of international peace and security, whereas a domestic definition may place emphasis on the allocation of jurisdiction.

The definition articulated by the IAA in its study on space traffic management (and discussed in my full written testimony) is an apt definition for adoption at the international level. Under that definition space traffic management is "the set of technical and regulatory provisions for promoting safe access into and out of space, operations in outer space and return from outer space to Earth free from physical or radiofrequency interference." This definition covers a broad range of activities and mechanisms of control, which is important since nations will have systems that differ structurally at the domestic level. Additionally, this definition was adopted through an interdisciplinary process, which is important because it recognises the dual technical-legal nature of control of space traffic. Space traffic management at the international level is currently governed by technical rules and guidelines such as the IADC guidelines and the ITU Radio Regulations. Strong binding legal mechanisms (outside of the Radio Regulations) will likely be absent internationally in the near term, however technical guidelines serve as important international epistemic units that can be adopted into domestic legal systems.

The legal definition that should be adopted at the domestic level in the United States should be more specific than the international definition due to the purpose and scope of such a definition. For example the international definition includes radio-frequency interference, but domestically the competence to oversee satellite communications is already well established in the FCC and could be left out of an adopted space traffic management regime. I would suggest, as a starting point, that the United States domestically define space traffic management as

> the technical and legal system for ensuring that US space operators engage in space activities in a safe and secure manner in all phases of their operations, including launch, on-orbit activities, and re-entry. The goal of this system should be to protect US national interests by preventing harmful interference to US space operations and to prevent harmful interference caused by US space operations. This system facilitates international coordination and supports the development of standards and best practices for space operations.

This definition would give the regulatory agency clear goals as well as flexibility to pursue a variety of regulatory mechanisms to achieve those goals. It would also allow for Congress to allocate jurisdiction over different parts of the the space traffic management system to one or multiple agencies as it sees fit.

Defining space traffic management is primarily a legal and political issue as opposed to a technical issue. As a technical matter space traffic management seems to be well defined, but its implementation through law and policy is not. At the international level, the political nature of international relations makes legal definitions difficult. This is especially true in light of the national security implications of space activities, which leads states often to prefer ambiguity over clear definition. So for instance, one of the leading proposed documents in space traffic management, the European Code of Conduct, only seeks to lay out broad politically binding principles as opposed to legally binding principles. At the domestic level, the question is one of a legal nature. The need for a space traffic management system of some sort is widely accepted and supported by governmental as well as nongovernmental actors. The specifics of defining such a system legally remains a major hurdle, as such a system would be the first of its kind. This means that there will need to be some measure of legal innovation and regulatory flexibility built into the initial system. This is similar to the approach taken by Congress and the FAA in establishing the Human Space Flight Requirements. Such an approach is appropriate when there is a technical need and a political goal, but the various legal mechanisms for achieving the goals are completely untested.

3. In your testimony you discuss the need for both technical capabilities and legal provisions and that one without the other will create "empty protections." As a legal expert, can you describe the process that is needed to ensure legal protections are integrated with those technical requirements?

In order to integrate the technical requirements with the legal requirements it is critical to ensure that the regulating agency (i.e. the agency that has jurisdiction to compel a space operator to comply with an order) has access to the needed technical data and the technology to use that data. There are three aspects to these technical capabilities: 1) collecting the data through space surveillance, 2) analysing the data, and 3) disseminating the data to interested parties. Currently, these functions are carried out by JSpOC.

There are various models that could be adopted in order integrate the use of technology within the legal framework. For example, the FAA's air traffic management system collects, analyzes, and disseminates data to users of airspace. In this model the agency maintains both the collection technology and the legal authority to compel compliance by users. However, space traffic management may need a more complex model, primarily because the military technology used to collect space data is also part of the nations' early warning system, and transfer of this technology to a civil agency would likely be inappropriate. Additionally, the open dissemination of this data also raises national security concerns.

Any statute adopted to establish a US space traffic management should clearly establish what data will be given to the regulating agency and also grant that agency the authority to analyse that data. Since a technology transfer from JSpOC to a regulatory agency would be both unlikely and ill advised, there should be a statutorily defined set of space situational awareness data that gets transferred to the regulating agency. The agency should then be given authorization, as well as an accompanying appropriation for the technology, to run independent analysis on that data. While JSpOC's analysis is important, legitimate questions could be raised in relation to a regulatory agency's ability to effectively manage space traffic and to effectively engage in international coordination activities due to a lack of transparency in the data. Any administrative order by an agency will likely be challengeable in the judicial system, and the data that was used to make the decision should be transparent both to maintain legitimacy of the system by allowing challenges and to give the agency the ability to defend itself against such challenges. It is my opinion that an agency must have the ability to analyze data independently of the military to exert proper legal control. Statutory specificity as to the nature of the data transfer will be essential in facilitating this and in ensuring that the agency receive adequate data to perform its functions without compromising national security. By delineating between data which would not be transferred for legitimate national security reasons and data which would be transferred, the statute can provide the mechanism that allows for the agency to maintain legitimacy through transparency of action.

Additionally, this agency should be authorized to engage in cooperative activities to enhance its space traffic database from sources outside the United States system and share its information with non-US space operators to enhance space security and safety. As such it should be authorized to disseminate and share both raw and analyzed data to appropriate stakeholders to enhance space security. Again, the ability to disseminate this data will be dependent on the clear delineation of data within the statute itself in order to avoid national security issues.

3(a) Can the technical requirements exist as a form of self-regulating best practices, or must they be enumerated through specific legislation?

Self-regulating systems and the development of standards and best practices are to be encouraged, but can not be relied upon to fully achieve the goals of space traffic management. Industry best practices are an important part of any commercial activity and space is no different. Initiatives like the Space Data Association (SDA) are valuable contributions to the maintenance of space security and safety, and the expertise held by such initiatives will be an important resource in the development of a regulatory regime. While they can increase the efficiency of commercial activities, they fall short of establishing a full regulatory regime needed to protect US national interests for several reasons.

The first, industry standards and best practices are usually only enforceable in hindsight. In other words, an accident occurs and is then followed by a legal proceeding where best practices are evidence used to determine fault. In many industries this is an effective way of managing risk, unfortunately in space it is not. For example, if SDA were to determine that there was a potential conjunction between a commercial satellite and a piece of uncontrollable debris, it could notify that operator. That operator then makes an independent decision whether or not to engage in a maneuver to avoid the conjunction, but best practices are only one of the decision criteria that the operator will use to make that determination. The operator may choose to weigh the cost of moving the satellite against the cost of losing the satellite, and determine that playing "orbital chicken" is the best economic decision. Unfortunately though, if the conjunction does occur, then it is not just the operator that suffers loss. All space operators share in the loss of part of the operational space environment. Self regulation in this context lacks the ability to compel compliance, which can damage US national interests by decreasing the ability to access and use space.

Related to this problem is that space operators need protection for their multimillion dollar investments. In the above scenario, the result is increased risk across the industry based on the act of a single self-interested party. This leads to an increase in the cost of engaging in space activities through items such as insurance premiums, as well as increased risk to interruption of service to customers during maneuvers or through conjunctions with the debris itself. Space operators may prefer an impartial agency making difficult maneuver decision as a way to mediate competing interests. A regulatory structure will be critical in giving commercial actors the confidence they need to invest in space technologies and further development the US commercial space industry.

A final issue is that international space law governs space activities in a unique way compared to other international activities due to the importance of space technologies to the world as a whole. Space law contains unique provisions that attach liability and responsibility for the actions of non-governmental actors to their national governments. This means that if damage were to be caused by a US satellite to a foreign satellite, the United States under the Outer Space Treaty and the Liability Convention could be held liable in an international forum for the damage. The United States would need to show that it fulfilled its obligation to "supervise" its non-governmental actor. A self-regulating system would likely fall short of compliance with this international obligation. In this scenario, by allowing space traffic management to be a self regulating system, the United States takes on increased risk by releasing its control of activities for which it is responsible.

4. Given the increasing amount of debris in low Earth orbits, what should federal agencies consider when building new satellites? For example, should agencies plan for additional fuel for maneuvering, additional weight and size for shielding, different orbits?

Federal agencies should consider a wide range of debris mitigation technologies and options when building new satellites. They should consider options that help to avoid creating new debris, to avoid collisions with debris, and to withstand debris impacts. These considerations should include shielding, maneuvering capability, end of life planning, and orbital parameters, among other items. The US Government Orbital Debris Mitigation Guidelines and the IADC Orbital Debris Mitigation Guidelines both serve as excellent starting points for technical information on best practices for debris mitigation. Which technical mechanisms are used will depend on the specifications of each individual satellite, and one size fits all solutions should be avoided. Federal Agencies should be sensitive to technological changes as well as changes in the space environment as they develop new satellite systems.

5. Commercial operators are not the only entities in space. There are also critical national security assets maneuvering on orbit. What are the possible threats associated

with developing an international regime for space traffic management as it relates to national security or even commercial viability? How do you account for necessary secrecy of national security payloads and their movements in such a regime?

National security concerns can not be ignored in the development of a space traffic management system. The main concern is that too much data could be released that would place US national security assets at risk through a variety of Anti-satellite attacks. For instance, accurate orbital location parameters of a satellite could place that satellite at increased risk of being targeted in a kinetic attack, or radio-frequency information could place the satellite at risk for jamming or hacking. These concerns are not to be taken lightly, and legitimate risks to national security should always be avoided in the creation of a system. However, these risks can be avoided and an effective space traffic management system can be achieved.

Primarily, as argued above (Palazzo Question 3) clear delineation of which data would be provided to the regulating agency by the JSpOC is essential in protecting national security interests. by clearly defining the data that would damage national security, the statute would enable a bifurcated system in which a civil agency could maintain transparency and openness and the military could still protect national security. For instance, the general location of space objects is no longer as secretive as it once was (as an example, the basic orbital parameters of the Air Force's classified *X-37B* are easily found with a quick Internet search), but its exact orbital location may not be. As a result, general location information on military satellites could be shared while exact parameters were kept secret. This would enable the mission of both JSpOC and a regulating agency. An additional feature is that JSpOC's own analysis of the space situational data would be able to serve as an important fail safe for the civil agency.

If the civil agency is using data that does not implicate national security, then it should also be able to use this data in a potential multilateral space traffic management regime or in bilateral sharing agreements. In developing any such regime, the United States should decline to enter into an agreement that would require the disclosure of data that the regulating agency does not have due to national security concerns. Having a civil agency with an effective space situational awareness database will place the United States in a leadership position through which it can pursue the goal of a safe, secure, and accessible space environment.

<u>Questions for the Record submitted by Rep. Steven Palazzo, Chairman, Subcommittee on Space</u>

1. How would you define "space traffic management" and what do you view as the priorities for enabling space traffic management?

As stated above (Palazzo Question 2), I think that space traffic management should be defined differently according to the context of the definition. The international definition will be different from the domestic definition. I suggest as a domestic definition that space traffic management is

> the technical and legal system for ensuring that US space operators engage in space activities in a safe and secure manner in all phases of their operations, including launch, on-orbit activities, and re-entry. The goal of this system should be to protect US national interests by preventing harmful interference to US space operations and to prevent

harmful interference caused by US space operations. This system facilitates international coordination and supports the development of standards and best practices for space operations.

The priorities in adopting such a system should be protecting national security and protecting commercial and civil space assets by providing technical and legal mechanisms through which a regulating agency can pursue establishing safe and secure space operations. Legally, such a system should provide for a clear statutory allocation of jurisdiction to an agency or agencies. Additionally, it should clearly define the technical data that the regulatory agency is to receive from the US space situational awareness system and what the agency may do with that data. Additionally, during its initial development the system should allow for the flexibility to pursue innovative regulations.

2. If two satellites potentially collide, directing one of the two to move results in economic costs for that satellite operator since unplanned propellant use is likely to shorten the operational lifetime of the satellite.

2(a) How should it be determined which satellite should be moved, and should any compensation be provided to the operator of the satellite that is directed to move?

Determinations by a federal regulatory agency should be determined on a case by case basis using a clear set of factors that should be weighed in order to make such a determination. Economic cost to the operator would be one of those factors. Other factors would include, but not be limited to, things such as the type of satellites involved, the size of the satellites involved, relative technical capabilities, and nearness to end of life.

Orders to compel an operator to move a satellite should be open for challenge after the fact as there will likely not be time to challenge the maneuver order before the maneuver must be made. The statute should define the agency's primary concern as avoiding collisions and define economic damages as a secondary concern. The agency should adopt a clear set of guidelines for weighing the decision criteria. Courts can then examine the record and determine whether the agency acted arbitrarily or capriciously under the statute, and allow damaged parties compensation for wrongful orders.

There are other models for compensation regimes for operators, and industry input will likely be valuable in determining what a desirable regime would be. Depending on the frequency of such orders, operators may wish to self insure or to include such risks in on-orbit insurance. As industry practice evolves, operators compelled to move may be able to bring claims against an actor not compelled to move but in violation of industry best practices. Another model could be for a federal compensation program implemented through a licensing fee that pays into a fund to compensate operators. A number of variations of such a joint risk management scheme could be envisioned. The downside to such a system would, of course, be the increased cost of space operations, which might be significant in order to make the fund large enough to be adequate. However, as discussed below (Edwards Question 2(d)), such a system could give the United States leverage when working with collisions that involve non-US satellites.

2(b) Should crewed spacecraft have the right of way over robotic space craft?

Yes, in the current space environment, crewed craft are rare and should be granted right of way. The loss of life on orbit should be avoided.

2(c) Should commercial satellites have a right of way over government satellites, vice versa, or should such decisions be treated on a case-by-case basis?

These decisions should be handled on a case by case basis. Again a variety of factors will come into play. Specifically, the function of the governmental satellite will be of primary importance. For instance, military satellites might function under an absolute presumption of right of way for national security reasons, whereas civil and scientific satellites might have a rebuttable presumption of right of way that can be overcome. Again, the regulating agency's main objective should be avoiding the collision, and clear criteria for making these decisions should be adopted.

2(d) How do we enforce collision avoidance policies involving non-US Satellites?

Currently, there is no way to enforce collision avoidance policies on non-US satellites. In fact if the United States creates a space traffic management system, foreign space actors will likely be able to freeload off the system *vis-a-vis* US satellites, since the regulating agency - to avoid a collision - would be required to compel the US operator to move if cooperation from the the foreign operator could not be secured. However, there are a variety of strategies that could be used to bring foreign operators into cooperative relationships with the US system.

The regulating agency, through the State Department, should be authorized to negotiate cooperative agreements in which it can work with foreign regulatory agencies to resolve possible conjunction events. Additionally, it should release transparent data to enable foreign space operators to manage their risks when there is no US satellite involvement. The United States should have a continued presence in international fora, and advocate for a space situational awareness information sharing regime, at the very least. The US could also push for an international space traffic management regime, and use diplomatic pressure to get space farers to engage in such a regime. Such a regime, though, would likely be very difficult to negotiate.

If a compensation regime were adopted, it is feasible that the United States could open its regime to foreign operators. Such a model would require the foreign operator to subject itself to the agency's jurisdiction in exchange for the protection of compensation if compelled to maneuver a satellite. Again, this would lead to increased costs on space actors, but the protection may be worth the costs. However, other states may be reluctant to allow their nongovernmental operators to engage in such a system due to a loss of control.

3. From what I understand, the protection of the environment is considered part of salvage. An abandoned ship leaking oil can cause significant harm to the environment. So if the party doing the salvage mitigates the oil leak, he performs a valuable service. Should orbital debris cleanup in space be viewed in a similar fashion? If so, how do we get international agreement that this will be the case?

A rule in favor of salvage rights in space was excluded from the Outer Space Treaty, instead a regime that perpetually linked states to space objects (and likely debris from those objects) was adopted. There are number of reasons why the rule was left out. First was the concern for liability. The drafters rightly categorized space activities as ultrahazardous, so in order to encourage states to act responsibly the drafters attached liability permanently to the launching states of an object. Additionally, the Cold War space race meant that space technology was highly competitive and highly secretive. As a result, the drafters left out means by which space farers could gain access to each other's technology. This principle is echoed in the Rescue and Return Agreement, which requires states to return the space objects of others that land in their territory.

A threshold question is whether such a right is desirable in space and whether it would be in the US' interests to endorse such a rule. In the current context of US law, satellites and their components are export controlled technologies. Some of these technologies are on the United States Munitions List and are treated as militarily sensitive technology. Creating a general right of salvage means that non US actors would have a right to gain access to US technology that is protected. Endorsing a general right to salvage is likely not in US interests for national security reasons.

If it were to be found to be in the United States' interests to pursue such a right internationally, it would likely be difficult to achieve. Other space powers, namely China and Russia could be opposed to such a right as they could view salvage as a way for the US to clandestinely develop anti-satellite technology (a concern that the United States would also likely have in relation to those two states as well). Further, it would require the negotiation of a treaty that would change established space law. This would be a difficult negotiating process that may bear little fruit in light of the lack of any new space treaties for over 30 years.

4. According to a recent Congressional Research Service report, the most prominent legal issue associated with debris removal relates to the ownership of objects in space. The report stated that "*Absent some form of consent or international agreement, the United States would be limited to retrieving and removing objects only from its own registry*". Can you elaborate on the legal issues associated with the removal of space debris, especially as it pertains to debris whose ownership cannot be factually documented?

As already stated, the drafters of the space treaty regime chose to link space objects to states perpetually. One of the ways that they did this is linking liability to launching states. The other way that they did this is by giving a state "jurisdiction and control" over space objects in its registry. All registered space objects are under the jurisdiction and control of the registering state. This means that if the US were to remove or retrieve an object that was not on its registry it would be acting extra-jurisdictionally and outside the scope of its authority. Likely, if an object were unregistered, but ownership could be attributed, the US would lack the legal ability to remove that object without some showing of a jurisdictional link to the US (e.g. a US corporation interest in the satellite).

The law is very unclear in relation to objects that cannot be factually documented as belonging to a state either through a registration link or through some other jurisdictional nexus. Truly orphaned space objects were not contemplated by the drafters of the space treaty regime, as a result the treaties are silent on how these objects are to be treated. While such objects are technically outside the jurisdiction of the United States, they are not within the jurisdiction of another state. A rule of salvage could be implemented through state practice on these types of objects in which the salvaging entity would take on liability burdens in exchange for title, but at the moment there is no clearly applicable international law.

Debris removal operations due to the many strictures of international space law, will likely have to be developed on a bilateral basis through international agreements or through contracts with private entities, which can assist in allocating risk and benefit. Such agreements are best suited for dealing with the complex issues that will arise on a case by case basis in debris removal.

5. The United Nations Committee on the Peaceful Uses of Outer Space adopted space debris mitigation guidelines in 2010.

5(a) While those guidelines are just that - non-binding guidelines - to what extent are individual nations actually adopting them and is there a way to gauge progress internationally on implementation of those guidelines?

I currently do not have data on the number of states that have formally adopted the guidelines. States are indeed increasingly adopting debris mitigation measures into their laws, with France being one of the most recent (to my knowledge) to implement detailed rules. Data on such implementation would likely need to be gathered from statements filed at international fora such as UNCOPUOS and IADC to get a full picture of the domestic implementation of these guidelines. The efficacy of the Debris Mitigation Guidelines is indeed difficult to gauge and information exchanges in relation to such measures should be endorsed and encouraged by the United States.

5(b) What is the next step for the international community in terms of orbital debris?

The next step for the international community is the establishment of a formal mechanism for information sharing in relation to space situational awareness data. A formal process, which could be voluntary initially, could help to build increased international cooperation in relation to space traffic management. Such a system would fall short of a full regulatory process, which could make it a palatable avenue for states to cooperate and build confidence in each others operations. Increased cooperation is the first step to enhancing space security and safety.

6. Is there a need for a broader range of communication on space traffic management and on-orbit debris mitigation among space situational awareness information providers and information users? If so, what communication functions would best contribute to space traffic management and how, in practice, could such communications be provided, and by what entity? What issues is this communication is done at the international level?

Yes, the more data points that can be implemented in a space traffic management database, the better that system will be able to predict potential conjunctions. Open communication channels are essential to effectively achieving the goals of space traffic management. At the domestic level, there should be one agency from which an operator can obtain the relevant needed information, and in turn, the agency needs to receive information from that operator preferably in real time. The agency will need to have proper technology to implement this information flow. Additionally, the agency will need to have real time access to US space situational awareness data that does not implicate national security. The scope of the space situational awareness data that the agency receives should be clearly delineated in the authorizing statute. It should then provide open access to this data as well as data that it gets from cooperating with other sources such as individual operators, SDA, or other nations.

The ability of a US agency to provide open and transparent data, allows the United States to take a leadership role in establishing best practices at the international level. By approaching the international community with a global good that can be improved through increased collaboration of all parties, the United States could help to establish a global data exchange amongst states and operators. Increased transparency in space activities could lead to increased security from collision risks as well as better attribution for intentional acts (which could decrease risk by serving as a deterrent). The "more eyes the better" approach also helps to give commercial actors increased certainty, which reduces risks to investments in space.

Finally, open and transparent data could also help lead to scientific and technical innovations in the field of debris mitigation. Such innovation will be vital if the debris problem continues to grow.

Responses by Mr. Brian Weeden

Responses to Questions For the Record

Submitted By Mr. Brian Weeden

June 24, 2014

Questions from Rep. Palazzo

1. **The overall goal of orbital debris mitigation and tracking is enhanced safety of the global orbital environment, with that in mind, how can we use our experience to convince the international community to follow suit?**
   a) Since we all share the same orbital space, how can the United States work with nations that have emerging space industries to mitigate orbital debris?
   b) What percentage of global space activities are governed collectively by US oversight and how can we ensure there is uniformity between our systems and other nations?

1. a) There are two important priorities in engagement with emerging space actors. The first is to raise awareness of the challenges presented by space debris and the risks of irresponsible actions in space. Providing data on the orbital debris population and the risks it presents to existing satellites is an important piece of raising awareness. Close approach warnings provided by USSTRATCOM have also played a significant role in raising awareness among emerging space actors, and these warnings should continue.

The second priority is communicating the lessons the U.S. government and its private sector actors have learned from their decades of experience in space activities. These lessons fall into two categories – lessons learned by U.S. federal agencies on providing oversight of private sector actors and lessons learned by spacecraft operators on improving the safety of space activities. The goal should be to accelerate the learning curve of emerging space actors without their having to make many of the same mistakes that have been made in the past.

b) According to publicly available data, slightly more than 40% (around 500 of approximately 1200)[1] of the satellites currently in orbit are either operated by the U.S. government or by U.S. private sector entities. While the U.S. and its private sector is likely to remain the single largest user of space for the near future, its overall "market share" of total space activities likely to decline as more countries and their private sector actors being to conduct space activities.

Absolute harmonization of governmental oversight of private sector activities across all spacefaring States is not possible. Under the existing international legal regime, each State is responsible for its own space activities and those of its private sector entities. Beyond adhering to the basic principles and responsibilities enshrined in the various treaties, it is up to each State to put in place its own oversight mechanisms. Implementation of and compliance with the space debris mitigation guidelines is currently voluntary, and even if all States chose to implement debris mitigation, how they did so would differ depending on their own system of government, national legal framework, and the maturity of their institutions.

The space world does not have a single international institution to coordinate and oversee the development of a coherent regulatory system as the aviation world has with the International Civil Aviation Organization (ICAO). In recent years there has been discussion of whether or not we need an equivalent to ICAO for the space world or whether ICAO should add the space domain to its domain.[2] At the moment, the academic debate over this is unsettled and there are a range of opinions. I believe that further study is needed before any steps are taken in this direction.

However, even without a single, coordinating body important steps can be taken towards improving the homogeneity of debris mitigation and other regulatory goals. There are existing international bodies such as the Inter-Agency Space Debris Coordination Committee (IADC), the

[1] The most up-to-date public source for what active satellites are in orbit is the database maintained by the Union of Concerned Scientists at http://www.ucsusa.org/nuclear_weapons_and_global_security/solutions/space-weapons/ucs-satellite-database.html

[2] The most thorough work to date arguing for an ICAO for space is Jakhu, R.S., Sgobba, T., & Dempsey, P.S. (Eds) (2012) *The Need For an Integrated Regulatory Regime for Aviation and Space*, available from http://www.springer.com/law/book/978-3-7091-0717-1

Consultative Committee for Space Data Systems (CCSDS), the International Organizations for Standardization (ISO), and the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) that already play a role in developing, documenting and homogenizing best practices for space safety and sustainability. Meaningful engagement in these bodies by the U.S. government on an interagency basis and by the U.S. private sector could significantly improve the harmonization of governance of space activities at the national level.

2. **What is the best definition of space traffic management moving forward and how would you develop domestic and international consensus for that definition? Is developing the definition a technical, political, or legal problem?**

2. The most comprehensive study on space traffic management to date, published by the International Academy of Astronautics in 2007, defined space traffic management as "the set of technical and regulatory provisions for promoting safe access into and out of space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference".[3] I believe that is the most comprehensive definition that currently exists and it is a good basis for moving forward.

At the national level, the primary challenges to getting consensus on a definition are largely legal, although there is a political element stemming from interagency competition. Does the definition meet the regulatory authorities currently given to U.S. federal agencies? Does it create or clear up interagency conflicts and disputes? Does it create competition among agencies for new powers and budget? What legal implications and requirements does the definition create for both federal agencies and the private sector actors they oversee? Do those requirements improve the safety of private sector space activities or do they impose undue burdens? All of these questions would need to be answered before a definition for space traffic management is enshrined in U.S. law and responsibilities given to federal agencies.

At the international level, the challenge is largely political with some legal underpinnings. Much of the debate over the definition is over whether space traffic is "managed" or "controlled" and by whom. At the heart of this debate is the issue of State sovereignty and whether or not there would be one State, a

[3] International Academy of Astronautics, Cosmic Study on Space Traffic Management (International Academy of Astronautics, 2006), p. 10. Available from: http://iaaweb.org/iaa/Studies/spacetraffic.pdf

small number of States, or even an international body that would have the power to dictate space traffic management rules and permissible space activities to other States. It also includes the issue of whether or not military or national security satellites fall under the space traffic management rules. Some see space traffic management as a means of controlling or hindering national security space activities.

I believe the best way forward for developing international consensus on the definition is engagement. This includes engagement in the form of developing consensus on the importance of space sustainability and the need for space traffic management and also in the form of developing consensus on what space activities are covered by the space traffic management rules and how they will impact national sovereignty. Taking the same approach as the air traffic world and exempting "state" satellites from space traffic management rules and focusing them on commercial and civil satellites is likely to yield positive benefits as it sidesteps much of the sovereignty issue.

3. **In your testimony, you suggest that more cooperation and data sharing with other countries and the private sector is the most prudent way to address gaps in tracking coverage.**
   a) What are the possible downsides to relying on other countries for tracking data?
   b) Could you envision a scenario where we rely on tracking data from Russia, but because of global events we lose access to that data? In this scenario, how would we react?
   c) What are the risks of providing U.S. data to foreign entities?
   d) How can the U.S. be certain that data transmitted to even allied partners is not retransmitted to other less friendly nations?

3. a) I do not envision a system where the U.S. is reliant on any country because there will always be a need for the U.S. to have its own tracking system. The question is to what degree the U.S. cooperates with other countries and the private sector to utilize their tracking data to complement its own in lieu of spending U.S. taxpayer money on building more of its own capabilities. Much of this complementary data would likely come from our allies and the private sector, including satellite operators.

The possible downsides to cooperating with other countries for tracking data are increased costs and challenges in making sure their data are compatible with our systems (and vice versa), loss of control over sensor tasking and maintenance downtime leading to unavailability, and inability to protect tracking data on U.S. national security space activities. These potential downsides would need to be weighed against the challenges of funding a much more expensive U.S.-only system, securing basing rights across the world for new sensors, and the on-going operations, maintenance, and logistics costs for operating those sensors.

b) We already are "reliant" on Russia for data in support of human spaceflight. They provide tracking, command, control, and communication capabilities for the International Space Station (ISS). This relationship has been tested with the recent events in Crimea and both countries have, so far, placed continued cooperation on the ISS mission ahead of their political differences. If the cooperation involved a less politically important mission than operating the ISS, such as perhaps just tracking space debris, I could foresee a political situation that would lead to either side to cutting off the data. As we have seen with the sanctions over Crimea, that would invariably lead to the other side cutting off data as well. The end result would be a situation where each side still had their own national tracking capability but lost the enhanced capability gained from the data exchange.

While not preferable, such a scenario would not leave the U.S. blind as we would still have our own data from our own systems and those of our allies. At worst it would lead to a degradation of capabilities. The most likely consequence would be increased time between tracks of LEO space objects while they are orbiting over Russia. However, the situation would be no different than we have today with the existing gaps in coverage of the Space Surveillance Network (SSN) over nearly all of Asia, Africa, South America, and almost the entire southern hemisphere.

c) Most of the technologies for metric tracking of space objects (i.e., providing data on an object's orbital trajectory) are well-known and present in the scientific and commercial domains. This is particularly true for optical telescopes, less so for radars. Even so, there could be specific situations where U.S. data with foreign entities could lead to technology transfer, although the likelihood is low.

It may also be that providing U.S. tracking data to foreign entities provides some clues about the capabilities and limitations of our systems, such as how often we can track an object, how precisely we can refine its orbit, or how small an object we can track. However, there are existing operational techniques for minimizing this type of intelligence that could be put in place fairly easily.

d) Protecting sensitive data shared with allies is not a problem unique to the space world. We face the same challenges in providing data in other domains to our allies, including intelligence data. One approach would be to examine the techniques and protocols we use in those domains to help ensure that any sensitive space tracking data we share is protected as well.

Beyond that, I think another key aspect is to clearly delineate tracking data on national security space activities from that on civil and safety-related activities. Again, I think the air traffic world can be instructive here. There is a considerable amount of data sharing among all countries on information about civil and commercial aircraft movements, while at the same time virtually all countries also protect data about the movements of their national security aircraft. There are likely lessons from how that is done in the air traffic world applicable to space.

4. Given the increasing amount of debris in low Earth orbits, what should federal agencies consider when building new satellites? For example, should agencies plan for additional fuel for maneuvering, additional weight and size for shielding, different orbits?

4. Federal agencies need to design their satellites with two main things in mind to deal with space debris. The first is how to mitigate the threat existing space debris poses to their satellite. This begins with a risk assessment of the threat by debris in the orbital region the satellites will reside in and looking for ways to minimize the threat through constellation, architecture, or orbit design. Using current technology, it is generally not practical to shield most satellites against debris larger than one or two centimeters in size due to the added mass. Once on orbit, federal agencies operating satellites should have in place procedures for detecting and responding to potential close approaches with larger space debris objects.

This includes determining the acceptable level of risk tolerance for each particular satellite and mission area, which in turn will determine the threshold for making avoidance maneuvers.

The second main concern is to ensure that federal agencies are good stewards themselves of the space environment. This includes designing the satellites so as to minimize the creation of debris during launch, deployment, and on-orbit operations as well as having the conjunction assessment and collision avoidance procedures in place during its operational lifetime. At the end of a satellite's operations, the responsible agency needs to have a plan in place for proper disposal of the satellite, either by boosting it out of a critical region, de-orbiting it into the Earth's atmosphere, or placing it in an orbit that will naturally decay within the 25 year guideline.

5. **As FAA has pointed out in testimony before this Committee, there is no authority to regulate on orbit operations and traffic management. How do relevant federal agencies currently cooperate and interact to ensure there is no duplicative regulations or unnecessary bureaucratic hurdles for industry?**
   a) What additional steps or further capabilities would aid interagency collaboration?
   b) How would FAA's request authority impact FCC regulations?

5. In examining the existing regulatory mechanisms and licensing requirements from the FAA, FCC, and NOAA, it is clear there is some existing duplication and conflict between what the three agencies require from private entities. But as an outsider, it is unclear to me as to the formal mechanism by which federal agencies currently cooperate and interact for establishing regulations. There are existing interagency mechanisms such as the Defense Space Council and the National Security Staff but these are focused on national security issues and may not be ideal for dealing with regulatory issues.

a) One factor Congress may need to consider is whether there is any language in the existing legislation authorizing the FAA, FCC, and NOAA to regulate and license the private sector that creates duplication or bureaucratic hurdles. For example, a U.S. commercial remote sensing satellite currently requires two licenses, one from NOAA for remote sensing and one from the FCC for spectrum, and each licensing agency has its own requirements and process. If the different licensing requirements stem from the Congressional language, then there may be an opportunity for harmonization. A complicating factor is whether or not any differences in regulatory requirements stems from an agency's unique culture, mission, or legal authority. These may be more difficult to resolve without significant changes that could have other consequences.

b) I do not see the FAA's request as having a significant impact on the FCC's regulations. Even if the FAA were given on-orbit authority, the FCC would still have authority for pre-launch licensing of spectrum. There may even be some benefit to on-orbit FAA authority for helping resolve issues with radiofrequency interference from on-orbit activities, as long as there is a process for the two agencies to coordinate.

Questions from Rep. Edwards

1. **How would you define 'space traffic management' and what do you view as the priorities for enabling space traffic management?**

1. The definition for space traffic management that I used in my testimony was "measures taken to minimize the impact of space debris on space activities". That was specifically because of the focus of the hearing on space debris mitigation. The most comprehensive study on space traffic management to date, published by the International Academy of Astronautics in 2007, defined space traffic management as "the set of technical and regulatory provisions for promoting safe access into and out of space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference".[4] I believe that is the most comprehensive definition that currently exists for STM overall and it is a good basis for moving forward.

[4] International Academy of Astronautics, Cosmic Study on Space Traffic Management (International Academy of Astronautics, 2006), p. 10. Available from: http://iaaweb.org/iaa/Studies/spacetraffic.pdf

The main priority for moving forward on STM is to establish which federal agency or agencies have responsibility for on-orbit activities and the part of the SSA mission that supports STM. I believe that effective STM will require transferring the conjunction assessment (CA) and collision warning for all operational satellites, and possibly the maintenance of the satellite catalog, from the DoD to another non-DoD federal entity. To create a non-DoD federal entity with on-orbit authority while leaving the associated SSA functions with the DoD will create an inefficient scheme that will negatively impact all parties involved.

2. **Because owner/operators know more precisely where their satellites are during and after maneuvers, the satellite community established the Space Data Center, a network for sharing high-accuracy operational data. Should this a model be replicated on an international level? What are the risks and potential benefits, if any, of going in this direction?**

2. The Space Data Association (SDA) is already an international entity. It is incorporated in the Isle of Man. Its Executive Board includes the commercial satellite companies Intelsat (United States), Inmarsat (United Kingdom), SES (Luxembourg), and Eutelsat (France) and its current membership includes Thuraya (United Arab Emirates), Es'hailSat (Qatar), ArabSat (Saudi Arabia), Surrey Satellite Limited (United Kingdom), and Telesat (Canada).[5] The Space Data Center (SDC) run by the SDA is also international in its architecture. It is cloud-based and designed so that its databases are replicated across multiple geographic regions in order to mitigate potential outages.

The SDA did have challenges in its creation. The primary one was building trust between itself and its members. The members needed to trust that the SDC would not be providing information to their competitors that could result in a commercial advantage and that the SDC could provide reliable analysis.

[5] An overview of the current status of the SDA from its March 2014 Users Meeting can be found here: http://www.space-data.org/sda/wp-content/uploads/downloads/2014/03/20140310_SDA_Users_Mtg_p.m._Session.pdf

Another significant challenge was creating a system that could accept data from all of the members. There are many different standards in use by satellite operators for calculating and communicating the trajectories of their own satellites. The SDC had to develop software that could work with data in many different formats. Satellite operators also may have different levels of risk tolerance, so the SDC had to allow them to customize at what level of probability an operator is notified of a conjunction.

The benefit of the SDA is clear. It sits between its members and the JSpOC and provides enhanced analysis of conjunction messages sent by the JSpOC to those operators. By mixing in the owner-operator data, including planned maneuvers, the SDC can provide more accurate warnings than just the JSpOC by itself. It can also help two satellite operators communicate when there is a conjunction between active satellites.

3. **If two satellites potentially collide, directing one of the two to move results in economic costs for that satellite operator since unplanned propellant use is likely to shorten the operational lifetime of the satellite.**
    a. **How should it be determined which satellite should be moved, and should any compensation be provided to the operator of the satellite that is directed to move?**
    b. **Should crewed spacecraft have the right of way over robotic spacecraft?**
    c. **Should commercial satellites have right of way over government satellites, vice versa, or should such decisions be treated on a case-by-case basis?**
    d. **How do we enforce collision avoidance policies involving non-U.S. satellites?**

3. a) Currently, if the JSpOC or SDC detects that two operational satellites have a conjunction, they provide both the respective operators with the relevant details and it is up to the operators to decide who should maneuver (if at all). This is because the operators have information that neither the JSpOC nor SDA have such as any upcoming station-keeping maneuvers or what impact a maneuver would have on the services they provide. Most collision avoidance maneuvers are actually wrapped into maneuvers that have been already planned for station-keeping or orbit raising. This process also allows the operators to

ensure that any avoidance maneuver won't result in an even more dangerous situation due to the other also maneuvering.

I believe that in the case of conjunctions between active, robotic spacecraft this method is preferable to a situation where a government agency had the power to mandate a commercial operator to maneuver. Creating a process for such a mandate would require a much higher level of data sharing between satellite operators and governments as well as coordination between governments in the very likely situation that the operators fall under different national jurisdictions.

b) In the case of a conjunction between a robotic spacecraft and a crewed spacecraft, the crewed spacecraft should absolutely have right-of-way, and it is the one scenario where a governmental authority to mandate a maneuver is justified. However, it should be noted that these situations are likely to be rare, at least for the near to mid-term. Crewed spacecraft in Earth orbit currently operate below 500 km altitude, largely due to the increased radiation risk and orbital debris risk above that altitude. At the same time, relatively few operational robotic spacecraft operate below 500 km due to the increased atmospheric drag and thus higher fuel costs to stay in orbit for extended periods. The vast majority of conjunctions with crewed spacecraft will be from space debris.

c) In my opinion, the same procedures that are currently in place for dealing with conjunctions between robotic spacecraft mentioned in a) above should also be applied to conjunctions between commercial and governmental spacecraft. The main exception is for conjunctions between classified national security satellites and commercial satellites. There are currently more than 100 U.S. government and allied satellites for which the JSpOC does not publish any orbital data in order to try and protect their location (and in some cases their existence). This protection should come with the explicit requirement that these satellites maneuver for any conjunction with a commercial satellite. This is because contacting the satellite operator to discuss who would move or even to order them to move would reveal the existence of these satellites and their locations, thus defeating the protections.

d) Enforcing collision policies between non-U.S. entities is extremely complicated and under the existing international legal framework probably not feasible. Under Article VIII of the Outer Space Treaty, each State retains jurisdiction and control over the space objects on its national registry.

There is language in Article IX of the Outer Space Treaty and the other space treaties that support a protocol of a joint decision over who will maneuver. These include the requirement to operate in space with due regard to the interests of other States parties, the principle of cooperation and assistance, the requirement for a State Party to notify others of a potentially harmful interference, and the right of any State Party to request consultation on an activity they feel could cause potentially harmful interference.

4. **The United Nations Committee on the Peaceful Uses of Outer Space adopted space debris mitigation guidelines in 2010.**
    e. **While those guidelines are just that—non-binding guidelines—to what extent are individual nations actually adopting them and is there a way to gauge progress internationally on implementation of those guidelines?**
    f. **What is the next step for the international community in terms of orbital debris?**

4. The Scientific and Technical Subcommittee of UNCOPUOS began working on the issue of space debris in the early 1990s. Its space debris mitigation guidelines are based largely on those developed by the IADC and were adopted by the Subcommittee in 2007. They were endorsed by the UN General Assembly (UNGA) in December 2007.[6] The UNGA invited member States to implement the guidelines through relevant national mechanisms. In addition, ISO has recently published an international standard on the space debris mitigation guidelines.[7]

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[6] A brief history of the UN debris mitigation guidelines can be found in: http://www.unoosa.org/pdf/bst/COPUOS_SPACE_DEBRIS_MITIGATION_GUIDELINES.pdf

[7] The ISO standard on space debris mitigation can be found here: http://www.iso.org/iso/catalogue_detail?csnumber=57239

e) Since 2007, various countries have provided information to UNCOPUOS on how they either have implemented the guidelines or how they are in the process of doing so. There is no definitive list of countries that have implemented the debris mitigation guidelines, but the United States, United Kingdom, France, Germany, Canada, Russia, China and Japan are among countries that have briefed COPUOS on their development of specific national legislation to implement the space debris mitigation guidelines.

Over the last year, the European Space Agency's Space Debris Office has been conducting research into how many satellites are following the guidelines. Specifically, they have been looking at how many satellites have complied with the 25-year rule. The research suggests that depending on the metric somewhere between 40% and 60% of satellites are properly disposed of at the end of their mission life in accordance with the guidelines. However, this research has not been widely published as of yet due to political concerns over naming specific countries and specific cases, some of which involve national security satellites.

f) On the technical front, the IADC is currently focused on reviewing and validating the models used to predict future space debris population growth and assessing the need for active removal of debris objects. Additional work is focusing on assessing which space debris objects are the highest priorities for removal and assessing and developing the technologies to remove them. An important next step will be determining what the best strategy for addressing active debris removal will be and on-orbit technology demonstration and validation.

On the political front, UNCOPUOS is currently debating a set of guidelines for best practices towards promoting the long-term sustainability of space activities. These guidelines include both operational best practices for space debris and safe space operations as well as best practices for regulatory oversight of national space activities. Many nations are also involved in negotiations of an International Code of Conduct for Space Activities which includes some norms of behavior that enhance and support debris mitigation and safety on orbit. Both of these discussions are intended to conclude in

2015. The next step for each will be implementing the best practices and norms in space activities and promoting them among all space actors, especially new ones.

5. Is there a need for a broader range of communications on space traffic management and on-orbit debris mitigation among space situational awareness information providers and information users? If so, what communications functions would best contribute to space traffic management and how, in practice, could such communications be provided, and by what entity? What issues arise if this communication is done at the international level?

5. Yes, there is a need for more communications between SSA data providers and end-users on the aspects of SSA related to safety of spaceflight (specifically, maintaining a catalog of space debris objects, conducting conjunction assessments, and providing conjunction warnings). This is largely because end-users and data providers have different sets of information at their disposal and no one has the entire picture.

There needs to be more communication between government agencies that are planning and developing SSA capabilities and their end users. This is particularly true of the U.S. military which is in the process of developing the JSpOC Mission System (JMS) to replace its existing computer systems. There has been little to no opportunity for non-U.S. military entities to work with the U.S. Air Force on the services this system will provide, despite it being the primary source of SSA data for all space actors. With the JSpOC currently providing conjunction warnings for all satellite operators around the world, it effectively makes them all end users of JMS. Developing it without consideration of their needs will almost certainly lead to an inefficient system and could drive users towards other services or data providers.

At the moment, SSA is evolving towards a system where there are multiple data "hubs", each with a trusted set of users. The JSpOC and SDA are examples of such hubs, as is the emerging EU space surveillance and tracking (SST) system. Even among our closest, allies, this is the direction we are moving. The U.S. recently signed a MOU on Combined Space Operations (CSpO) between itself, the United Kingdom, Canada, and Australia that calls for each country to establish their own space operation center and coordination between the centers. The reason for this development is that there is no single entity that all space actors trust, and countries relying on space for national security want at least some independent SSA capability to protect their own assets and verify the data coming from others.

In this model, the key issue is the level of data sharing and communication between the hubs. No single hub will have the entire SSA picture and so some level of communication and sharing will be necessary. But communication between the hubs will have to overcome both a lack of trust and potential incompatibility between the data formats and systems. Providing some level of transparency into their operations could help foster trust, and developing and implementing standards for exchange of data could help with compatibility.

Space is an international activity and there is no avoiding communication at the international level. However, it does have challenges. The most significant is one of national security. Space activities have traditionally had strong national security roots and today more and more countries are realizing the value space has for national security purposes. The increased militarization of space will increased the reluctance to share data on space activities that might reveal capabilities and limitations of SSA systems or sensitive activities on orbit.