KEEPING THE SPACE ENVIRONMENT SAFE FOR CIVIL AND COMMERCIAL USERS

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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HON. BART GORDON, Tennessee, *Chair*

SUBCOMMITTEE ON SPACE AND AERONAUTICS

HON. GABRIELLE GIFFORDS, Arizona, *Chair*

CONTENTS

April 28, 2009

Appendix 1: Answers to Post-Hearing Questions

Appendix 2: Additional Material for the Record

KEEPING THE SPACE ENVIRONMENT SAFE FOR CIVIL AND COMMERCIAL USERS

TUESDAY, APRIL 28, 2009

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 2:00 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Gabrielle Giffords [Chairwoman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON SPACE & AERONAUTICS
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

Keeping the Space Environment Safe For Civil and Commercial Users

April 28, 2009
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Lt. Gen. Larry D. James
Commander, 14th Air Force, Air Force Space Command,
and Commander, Joint Functional Component Command for Space,
U.S. Strategic Command

Mr. Nicholas Johnson
Chief Scientist for Orbital Debris
National Aeronautics and Space Administration

Mr. Richard DalBello
Vice President of Government Relations
Intelsat General Corporation

Dr. Scott Pace
Director of the Space Policy Institute
George Washington University

HEARING CHARTER

SUBCOMMITTEE ON SPACE AND AERONAUTICS COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

Keeping the Space Environment Safe for Civil and Commercial Users

TUESDAY, APRIL 28, 2009
2:00 P.M.–4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

I. Purpose

The House Committee on Science and Technology's Subcommittee on Space and Aeronautics is convening a hearing to examine the challenges faced by civil and commercial space users as space traffic and space debris populations continue to grow. The Subcommittee will explore potential measures to improve information available to civil and commercial users to avoid in-space collisions as well as ways to minimize the growth of future space debris. The hearing will focus on the following questions and issues:

- What are the current and projected risks to civil and commercial space users posed by other spacecraft and space debris?
- What information and services are currently available to civil and commercial space users in terms of real-time data and predictive analyses?
- What can be done to minimize the growth of space debris?
- What is the level of coordination among military, civil, and commercial space users in the sharing of space situational awareness information?
- Have shortcomings been identified by civil and commercial space users with regards to the availability of situational awareness information they need? How are these shortcomings being addressed?
- Have civil and commercial space users identified their long-term situational awareness needs? What options are being considered to address them?

II. Witnesses

Lt. Gen. Larry D. James, Commander, 14th Air Force, Air Force Space Command, and Commander, Joint Functional Component Command for Space, U.S. Strategic Command

Mr. Nicholas Johnson, Chief Scientist for Orbital Debris, National Aeronautics and Space Administration

Mr. Richard DalBello, Vice President of Government Relations, Intelsat General Corporation

Dr. Scott Pace, Director of the Space Policy Institute, George Washington University

III. Overview

Ensuring the future safety of civil and commercial spacecraft and satellites is becoming a major concern. The February 2009 collision between an Iridium Satellite-owned communications satellite and a defunct Russian Cosmos satellite above Northern Siberia highlighted the growing problem of space debris and the need to minimize the chances of in-space collisions. That collision also increased the number of pieces of space debris circling the Earth, a debris population that had already experienced a significant increase two years earlier following a Chinese anti-satellite weapons test that created thousands of fragments. As recently as last month, astronauts aboard the Space Shuttle and the International Space Station maneuvered the connected crafts to avoid a piece of space debris that NASA believed could potentially have led to an impact.

While several nations such as Russia, France, Germany and Japan have some form of space surveillance capability, these systems are not interconnected and are neither as capable nor as robust as the United States' Space Surveillance Network (SSN). SSN consists of a world-wide network of 29 ground-based sensors that are stated to be capable of tracking objects as small as five centimeters orbiting in Low-Earth Orbit (LEO)—that is, the region of space below the altitude of 2,000 km (about 1,250 miles). Many remote sensing satellites use LEO, as do all current crewed orbital space flights. However, to be useful, information on potential collisions obtained through tracking efforts needs to be disseminated to all space users, including non-governmental entities. Furthermore, the data needs to be of sufficient accuracy that predictions of possible collisions can be computed with a high level of confidence. That level of confidence is essential in light of the implications of making evasive maneuvers. If a space user knows that a particular object in space poses a collision risk to a satellite or spacecraft, the user can potentially maneuver the satellite or spacecraft to avoid the debris. However, flight changes to avoid potential collisions come at a high price since satellites carry limited quantities of fuel and avoidance maneuvers could result in decreased operational life.

Following congressional direction, the Air Force's Space Command initiated a three-year Commercial and Foreign Entities (CFE) Pilot Program in 2005 aimed at providing space users with tracking information and analytical services. The program gradually transitioned support responsibilities from the National Aeronautics and Space Administration (NASA) to the Air Force's Space Command; up until 2005, orbital data had been provided on NASA Goddard Space Flight Center's Orbital Information Group (OIG) web site free of charge. The Air Force also provides, for a fee, advanced analytical support such as on-orbit assessment of conflicts and pre-launch safety screenings. Legislation allows space surveillance data and analysis to be provided to any foreign or domestic governmental or commercial entity, so long as providing the data and analysis is in the national security interests of the United States. Furthermore, before being provided with such data, a non-U.S. Government entity must enter into an agreement with the Secretary of Defense agreeing to (a) reimburse the Department for costs DOD incurs in providing data support and (b) not transfer any data or technical information received under the agreement without the approval of the Secretary. Nevertheless, desirous of having capabilities of its own, the European Union has initiated an effort to research what is required to develop a European Space Surveillance Awareness System.

Many questions remain as to how to improve space situational awareness with an ever growing population of spacecraft and international operators. Improvements in information services, capabilities, resources, and coordination will all have to be addressed. In addition, although organizations and individuals have examined the pros and cons of potential space traffic management approaches or international "rules of the road," at this point, there does not appear to be a consensus on the appropriate long-term framework for space traffic management.

Testimony at this hearing should provide the Subcommittee with an assessment of (1) what is being done to keep the space environment safe for civil and commercial space users given the growing number of satellites, spacecraft, and space debris, (2) how future propagation of space debris can be mitigated, (3) what space surveillance awareness capabilities and services are currently available, and (4) what challenges civil and commercial users face trying to get enhanced space surveillance awareness information. Keeping the space environment safe for civil and commercial users involves protection from a multitude of factors besides space debris, such as adverse space weather phenomena and radio frequency interference. However, this hearing will focus primarily on issues associated with space debris.

IV. Potential Hearing Issues

The following are some of the potential issues that may be raised at the hearing:

- *What practices do civil and commercial space operators utilize to minimize the risk of collision in space?*
- *Should we be concerned about the projected worldwide growth in space traffic and debris generation? Could the risks of collisions in space grow to unacceptable levels?*
- *What is the status of the U.S. Government-sanctioned Commercial and Foreign Entities (CFE) Pilot Program? What are the lessons learned so far? What are the Department of Defense's (DOD) plans for providing a CFE capability in the future?*
- *What techniques and procedures can space operators use to minimize the future growth of orbital debris? What are the biggest challenges to reducing the growth of orbital debris?*

- *What space situational awareness system would commercial space users like to have in place in 10 years? How far are we from having such a system today and what will need to be done to make it possible?*
- *A comprehensive space situational awareness system that meets the needs of the military, civil, and commercial space sectors would seem to require the involvement of each of those sectors both domestically and internationally. Are there any good governance models that could be used to construct and operate such a comprehensive system?*
- *How does DOD coordinate with commercial space users? For example, what major issues have been raised at the series of meetings between DOD leadership and the CEOs of the top 10 commercial satellite companies focusing on enhancing cooperation to improve surveillance and what are the plans for addressing those issues?*
- *How can coordination among military, civil, and commercial users be enhanced relative to both orbital debris mitigation and collision avoidance?*
- *What can be done to address the shortcomings in current space situational awareness information, predictive capabilities, and supporting infrastructure to enable safe civil and commercial space operations in the future?*
- *What are the key policy questions that need to be addressed in determining the best path forward for keeping the space environment safe for civil and commercial users?*
- *Are international "rules of the road" needed to prevent future in-space collisions and debris growth?*

V. Background

The Space Debris Threat

Space Environment

Since 1957, there have been several thousand payloads launched into space. These launches have contributed to an ever growing population of man-made objects in space, which have themselves generated an even larger amount of orbital debris. NASA defines orbital debris *"as any object placed in space by humans that remains in orbit and no longer serves any useful function or purpose. Objects range from spacecraft to spent launch vehicle stages to components and also include materials, trash, refuse, fragments, or other objects which are overtly or inadvertently cast off or generated."* These objects, ranging in size from that of a microscopic paint chip to a large defunct satellite, can travel at speeds up to 11 km/second.

Most of today's spacecraft operate in two major orbital altitudes. The most populated is Low-Earth Orbit (LEO), where many scientific and human spacecraft operate between altitudes of 320 km and 2,000 km. The other is Geostationary Orbit (GEO), which is populated primarily by communication satellites that orbit as the same speed as the Earth so as to continuously face one region of the planet. These satellites operate at an altitude of approximately 36,000 km. There are approximately 900 operational spacecraft currently in orbit. Of those, approximately 800 are maneuverable.

Extent of Orbital Debris in Space

The first fragmentation of a man-made satellite occurred in 1961. Since then, there have been over 190 spacecraft fragmentations, and four accidental collisions resulting in the generation of debris (there has been only one collision between two intact spacecraft). Even though some of the debris from these fragmentations has fallen out of orbit, numerous other incidents over the years have increased the overall population of space debris dramatically. According to an Aerospace Corporation study, *"the creation rate of debris has out-paced the removal rate, leading to a net growth in the debris population in low-Earth orbit at an average rate of approximately five percent per year."*

The majority of Earth's orbital debris currently resides in LEO between the altitudes of 600 km and 1,500 km, where there is an estimated 300,000 pieces of debris one cm in size or greater. Of that number, there are more that 18,000 objects that are five cm or greater in size. Objects that are between one cm and 10 cm in size are of primary concern to spacecraft in LEO as these are the most difficult pieces to track and have enough mass to completely disable a spacecraft.

The orbital lifetime of debris varies, as some pieces can re-enter the Earth's atmosphere within several days of their fragmentation, while some pieces can stay in orbit for over several hundred years. Currently, more debris is being accumulated in orbit than is falling out of orbit. According to a NASA study completed in 2006 which assumes no new launches of any kind past 2005, in-orbit collisions will sustain the current population of debris, even as other objects decay into the atmosphere. As indicated in a NASA *Orbital Debris Quarterly* publication, by 2055, collisions will become the primary source of debris generation. Even though a majority of the debris lies in LEO orbit, concerns are still growing over the future of GEO as it a highly valuable and fairly costly area to place a satellite. Debris that continuously fly at GEO altitude are too high to be affected by atmospheric drag and rarely fall back to Earth. It is also extremely difficult to track and characterize objects less that 1 m in GEO with current technologies.

Causes of Fragmentation

Space debris comes in many different forms, but the velocity at which these objects move in relation to the object they impact is what makes them potentially lethal. A piece of debris as small as one cm can potentially destroy a satellite, while an object less that 0.1 cm can penetrate an astronaut's suit during an Extra Vehicular Activity (EVA).

Debris can be created in a number of ways, from actual collisions to incidents occurring during spacecraft separation. The most common causes of fragmentations are propulsion-related incidents that involve remaining fuel or pressurized components exploding in discarded rocket stages. This type of event was prevalent in the 1970s and 1980s but has since slowed due to increased mitigation techniques practiced worldwide. Until recently, the objects from these events constituted about 40 percent of current orbital debris.

Other sources of fragmentation debris include accidental collisions, battery explosions, fuel leaks, failures of attitude control systems, failures during orbital injection maneuvers and other unidentified causes. Not all of these fragmentation events create equivalent amounts of debris. The damage and subsequent results of a collision in orbit are dependent on multiple variables such as velocity and design of the structure as well as the angle of collision. For example one collision in the mid-1990s of a European satellite involved a small piece of debris striking an extended antenna, which resulted in only one piece of debris being generated.

The more troubling type of fragmentation event is the intentional breakups that are deliberately taken, such as in the form of an anti-satellite weapons test. Such actions have historically led to very accurate strikes and thus produced larger amounts of debris than other collisions and self generated explosions.

Risks Generated by Orbital Debris

Since January 2007, there have been three major debris generating incidents that have increased Earth's orbital debris environment significantly. As a result, the risks to active and non-active spacecraft have greatly increased. Experts have predicted that it is only matter of time until there is another large debris generating collision.

The International Space Station (ISS) flies at an average altitude of 349 km to 358 km and the Hubble Space Telescope flies at an altitude of 570 km. For the remainder of its manifest, the Space Shuttle will fly only to these two orbits and as such are subject to their orbital hazards. The upcoming STS–125 flight will allow crew aboard the Shuttle Atlantis to repair the Hubble Space Telescope. Recent reviews of the threat of an orbital debris strike have remained nearly constant since its initial review last September. Since that time, the recent Iridium-Cosmos collision has added to the debris field in LEO and represents a 71 percent increase in the amount of threatening debris to STS–125. Due to its low altitude in LEO, the ISS' risk of collision will be lower than that of spacecraft that operate at higher altitudes in LEO. Nevertheless, the ISS still remains at risk from micro-meteoroid and orbital debris strikes. The possibility of having to maneuver the ISS away from harmful debris will remain constant throughout its life-time. Typically, an ISS maneuver takes approximately 30 hours to plan and execute.

In addition to on-orbit risks, there are economic consequences that flow from the increase in orbital debris and a potential lack of adequate situational awareness. The need to maneuver leads to the use of limited spacecraft fuel supplies, which can shorten the on-orbit operational lifetime of the spacecraft. Another economic consequence could be the disruption of data and services of commercial satellites. Even if they aren't actually struck, maneuvering satellites out of harm's is costly, as data and service continuity become disrupted as a result of the maneuver.

Over the past several years, there have been several incidents which contributed to the rise in the number of orbital debris:

- Iridium 33—Cosmos 2251 Satellite Collision: On February 10, 2009, a U.S. Iridium communications satellite collided at a near right angle to a decommissioned Russian Cosmos communications satellite at an altitude of 790 km. This was the first hypervelocity collision of two 'intact' spacecraft ever. According to *Space News,* the collision created at least 823 pieces of trackable debris (with many smaller pieces not yet cataloged) and increased the risk of a debris strike on the Space Shuttle by approximately six percent. The majority of this debris will remain a threat to other satellites in LEO for decades.

- Chinese A–SAT test on Fengyun–1C: In January of 2007, the Chinese government launched an SC–19 missile at one of their country's decommissioned weather satellites and destroyed it. It is the worst fragmentation event in the history of space flight and at the time, accounted for more than 25 percent of cataloged objects in LEO. The estimated debris population larger than one cm in size generated by the collision will eventually exceed 150,000. Resultant debris has already enveloped the Earth and now poses a threat to all spacecraft in LEO.
- Russian spent stage explosion—Russian Arabsat 4: A Russian upper stage from a Proton rocket exploded in February 2007, almost a year after its launch to GEO failed, creating an initial amount of over 1,100 pieces of trackable debris. The cause of the explosion was determined to be leftover fuel in the failed stage that was ignited by several possible sources.

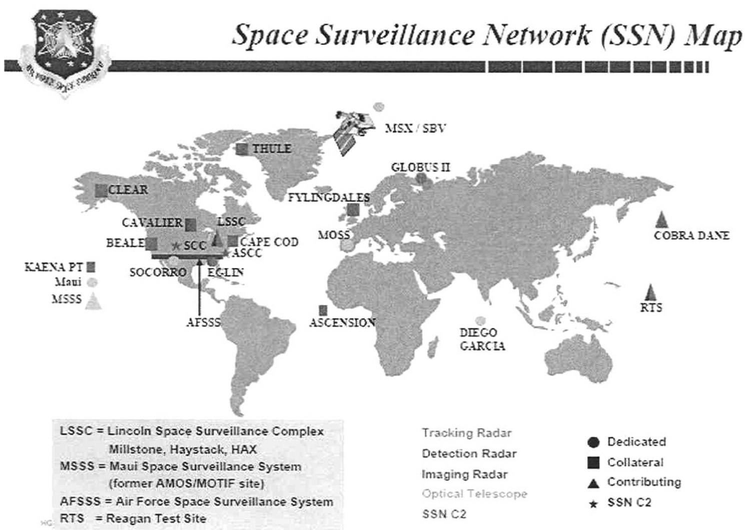
Mr. Nicholas Johnson, a witness at the hearing, will be able to provide additional details on the risks associated with these recent events.

Space Surveillance Capabilities

Although the U.S. has the most capable space surveillance system in the world, other countries also utilize radars and telescopes to perform similar tracking activities. Limited in their space surveillance capabilities, other nations must use information generated by the U.S. system to supplement their own data.

U.S. Space Surveillance Capabilities

Space surveillance refers to the ability to detect, track, and identify objects in space. Surveillance services used by space transportation users include calculation of debris-clear launch trajectories and in-orbit debris tracking and collision warnings. The primary supplier of space surveillance capability is the Space Surveillance Network (SSN), consisting of a world-wide network of 29 ground-based sensors including electro-optical, conventional and phased-array radars. The SSN permits the cataloging of objects in space. According to an April 2009 presentation by a representative of NASA's Orbital Debris Program Office to the NASA Advisory Council, the number of cataloged objects has increased by more than 30% since January 2007. The catalog currently accounts for more than 14,000 objects in orbit.



Source: Air Force Space Command

The SSN can collect data about objects' altitude, orbit, size, and composition. The capabilities of the network are limited by the debris' size and altitude, however. Initially, the SSN could not detect or track objects smaller than 10 centimeters in LEO, and only objects 30 centimeters and larger could be continuously tracked. Remote sensing satellites typically use LEO, as do most manned space flights. In March 2003, the sensitivity of the SSN was enhanced so that objects as small as five centimeters orbiting in LEO can be tracked. As altitude increases, the ability of the SSN's sensors to detect small objects decreases. Consequently, objects in Geosynchronous Orbit (GEO) need to be located through optical instruments (as opposed to radar) and also must be at least one meter across to be tracked. Satellites in GEO orbit the Earth once a day at an altitude of approximately 35,786 kilometers (about 22,236 miles). Satellites in geostationary orbit are primarily used for communications and meteorology.

Protection of NASA assets is a major concern. The Joint Space Operations Center (JSpOC) within the U.S. Strategic Command provides collision avoidance analysis for the Space Shuttle and International Space Station (ISS). During NASA missions, the JSpOC computes possible close approaches of other orbiting objects to the Space Shuttle or ISS. The JSpOC also conducts re-entry assessments for objects including prediction of time, location of atmospheric reentry, and potential ground impact.

Space surveillance capabilities are likely to improve in the next few years. The Air Force's Space Based Space Surveillance (SBSS) Program, initiated in 2003, will consist of a single satellite and associated command, control, communications, and ground processing equipment when operational. The SBSS satellite, scheduled for launch in 2009, is scheduled to operate 24 hours a day, seven days a week, to collect positional and characterization data on Earth-orbiting objects of potential interest to national security. The SSN's only space borne sensor to date, the space-based visible (SBV) sensor carried aboard the Midcourse Space Experiment (MSX) satellite, was retired in June 2008 after nearly 12 years of operation. DOD considers SBSS to be an essential element in developing a space situational-awareness capability. In an article published in *Space News,* it was reported that *"SBSS will allow airmen to monitor satellites in the geosynchronous orbit 24 hours a day, which Space Command can't presently do with its Ground-based Electro-Optical Deep Space Surveillance (GEODSS) system. Airmen on the ground can only collect data on satellites using the GEODSS at night when the sun is reflecting on the targeted satellite."* This is because unlike ground sensors, the space-based SBSS is not limited by lighting conditions, weather, or atmospheric distortion.

One of the SSN's oldest systems is the Space Fence which grew out of an effort by the Naval Research Laboratory to detect and track satellites that did not emit signals as part of their normal operations. Ushered into existence as the Naval Space Surveillance System (NSSS) in 1961, the Space Fence is composed of three transmitters and six receivers interspersed across the southern United States. As reported by *C4ISR Journal,* DOD is considering upgrading the Space Fence with more powerful radars and sites overseas for more expansive coverage. According to an article in *Inside the Air Force,* the service hopes to award a concept development phase contract in July 2009. The upgraded Space Fence will be capable of detecting tenfold the amount of objects in Low- and Medium-Earth Orbit. It also will be able to monitor objects five centimeters in diameter, compared to the 30-centimeter limit of the legacy asset. According to *Inside the Air Force,* the Air Force anticipates *"that the winning contractor will deliver the initial, southern hemisphere coverage Space Fence sensor "no later than fiscal year 2015" and deliver all expected blocks of coverage by FY20." "*

International Space Surveillance Capabilities

Other countries also have space tracking capabilities, but they are not on par with the SSN. For example, according to an article in *Space News,* the Russian-led International Scientific Optical Network, based at Moscow's Keldysh Institute of Applied Mathematics, includes some 25 optical telescopes, mainly in the republics of the former Soviet Union, that can be deployed on a case-by-case basis as part of commercial transactions. But this network's focus is on objects in geostationary orbit, the operating orbit for most commercial satellites but far above LEO regions where debris is of most concern. French, German, and Japanese systems are also in use. For example:

- France has developed a radar system called Graves *(Grand Réseau Adapté à la Veille Spatiale),* a demonstrator which has been operational since 2005 and can watch the sky up to 1,000 km above the French territory. According to its developer, ONERA, the Graves system consists of *"specific radar combined with an automatic processing system that creates and updates a database of the orbital parameters for the satellites it detects."* Graves is operated by the French Air Force.
- The European Space Agency (ESA) collaborates with the operators of the German TIRA system (Tracking and Imaging Radar), located at FGAN (Research Establishment for Applied Science), near Bonn, Germany. According to ESA's Space Debris web site, TIRA has a 34-meter dish antenna. The radar also conducts beam park experiments, where the radar beam is pointed in a fixed direction for 24 hours so that the beam scans 360° in a narrow strip on the celestial sphere during a full Earth rotation. During such experiments, the web site says, TIRA can detect debris and determine *"coarse orbit information for objects of diameters down to two cm at 1000 km range."*
- According to a report on *"Space Debris Related Activities in Japan"* presented by Japanese representatives to the UN's Committee on the Peaceful Uses of Outer Space (COPUOUS) in February, 2009, observation of objects in geosynchronous orbit (GEO) and determination of their orbit characteristics are routinely carried out using Japanese optical telescopes. Research to develop software that can automatically detect smaller objects in GEO is progressing. Japanese representatives also said that LEO observations are being conducted using radar telescopes and that research to observe objects in LEO is also being conducted using high-speed tracking optical telescopes.

U.S. Space Surveillance Services

To be useful, information related to potential in-space collisions that is obtained through tracking efforts needs to be disseminated to all affected space users, including non-governmental entities. If a space user knows that a particular object in space poses a collision risk to a satellite or spacecraft, the user can maneuver the satellite or spacecraft to avoid the debris. However, avoidance maneuvers consume valuable fuel supplies, which translates into a reduced operational life. Since collisions in space increase the amount of debris, it is in the interest of all parties concerned to ensure space users have access to relevant space surveillance data. Initially, the data from the SSN had been made available through NASA's Orbital Information Group's (OIG) web site.

However, in November 2003, the Congress directed the Secretary of Defense through the 2004 *National Defense Authorization Act* [P.L. 108–136, Section 913] to provide space surveillance data to any foreign or domestic governmental or commercial entity, so long as it was consistent with national security. The Secretary delegated implementation responsibility to the Secretary of the Air Force in October 2004. The national policy of providing space surveillance information was further articulated in the President's National Space Policy dated August 31, 2006. In achieving the goals of the national policy, the Secretary of Defense was assigned responsibility for supporting the space situational awareness requirements of the Director of National Intelligence and conducting space situational awareness for *"the United States government; U.S. commercial space capabilities and services used for national and homeland security purposes; civil space capabilities and operations, particularly human space flight activities; and, as appropriate, commercial and foreign space activities."*

With regards to orbital debris, the National Space Policy acknowledges that orbital debris poses a risk to continued reliable use of space-based services and operations and to the safety of persons and property in space. Consequently, the policy states that *"the United States shall seek to minimize the creation of orbital debris by government and non-government operations in space in order to preserve the space environment for future generations."* The policy also states that the *"United States shall take a leadership role in international fora to encourage foreign nations and international organizations to adopt policies and practices aimed at debris minimization and shall cooperate in the exchange of information on debris research and the identification of improved debris mitigation practices."*

Commercial and Foreign Entities (CFE) Pilot Program

Pursuant to the legislative direction, the Air Force Space Command implemented the Commercial and Foreign Entities (CFE) Pilot Program. The CFE pilot program was designed to be implemented in three phases over a three-year period, gradually transitioning CFE support responsibilities from NASA to the Air Force's Space Command. In addition to the free orbital data previously provided on NASA's OIG web site, the Air Force offered to provide, for a fee, advanced analytical support such as on-orbit conjunction assessment and pre-launch safety screenings. The Air Force's goal was to provide increased situational awareness for commercial and foreign operators, thereby improving orbital safety for all space vehicles. The previously cited legislation allows space surveillance data and analysis to be provided to any foreign or domestic governmental or commercial entity, so long as providing the data and analysis is in the national security interests of the United States. Furthermore, before being provided with such data, a non-U.S. Government entity must enter into an agreement with the Secretary of Defense agreeing to (a) pay for any fee charged by the Secretary to reimburse the Department for the costs of providing space surveillance data support under the agreement and (b) not transfer any data or technical information received under the agreement without the approval of the Secretary.

The Air Force selected the Aerospace Corporation to operate the CFE Support Office (CSO) and tasked it to interface with commercial and foreign entities on behalf of the Air Force Space Command and develop the *Space-Track.org* web site to replace the NASA OIG web site. Initially, the CFE pilot program was scheduled to last three years and end in May 2007. However, in October 2006, the Congress extended the pilot's end date to September 30, 2009 [P.L. 109–364, Section 912]. *Aviation Week and Space Technology* recently reported that the CFE program is scheduled to transition from the Air Force Space Command to the U.S. Strategic Command later this year.

According to the Air Force, the CFE Pilot Program was to be implemented in three phases, Phase 1 being a transitionary one where the CSO activated the Space-Track web site offering a limited subset of the NASA OIG web site functionality. During Phase 2, the NASA OIG web site ceased operating and functions such as specific queries, a 60-day decay forecast report, and a satellite situation report were made available.

The CFE Pilot Program is currently in Phase 3. The CSO provides advanced services and products on a fee-for-service basis because of the additional analysis and manipulation required by additional Air Force personnel. Services provided include all services offered under Phase 1 and Phase 2 and more advanced capabilities such as launch support (Pre-Launch safety screenings and/or early orbit determination); conjunction assessment (CA) (determining the likelihood of a conjunction between orbiting objects); end-of-life/reentry support (including reentry support and planned de-orbit operations); anomaly resolution support (including attitude determination and spacecraft configuration); and providing emergency support. Emergency support is required when significant mission degradation or failure occurs for either the affected party's asset or U.S. Government assets, endangerment of human life or degradation of U.S. national security. Emergency support is a free service.

More advanced information and services may soon be available. According to a March 2009 article in *Space News,* the Air Force is moving towards providing *"wider access to its high-accuracy catalog showing the whereabouts of orbital debris and operational satellites as part of an effort to enable commercial and non-U.S. Government satellite operators to better avoid in-orbit collisions, according to U.S. Air Force officials."* The new policy, *Space News* reported, should be announced in June 2009. In a March 2009 response to *Space News* questions, the Air Force's Space Command said that: *"In the near future, the public will also receive more advanced services to include End-of-Life support, Anomaly Resolution support, and potential threat notification support. The vision is to provide these advanced services via the same web site as the [collision-risk analysis] and Launch support service is provided." Space News* cited an Air Force official as having said that a full review of how space traffic management is conducted is being readied for completion before this summer.

Space News also reported that Iridium Satellite has been given special access to otherwise nonpublic Space Surveillance Network information, but only for limited periods. According to Iridium's Vice President for Government Affairs, Iridium was given access to the high-accuracy data starting in January 2007, following China's anti-satellite missile firing that destroyed a retired Chinese weather satellite operating in an orbit near Iridium's. *Space News* reported that Iridium's access to the high-accuracy data was only for the debris from the Chinese anti-satellite test. The publication reported that although the access ended in January 2008, it was renewed in February 2009 to aid Iridium in repositioning an on-orbit spare satellite to replace the one that was destroyed.

The *Space News* article also said that the data furnished by the Air Force was based only on the Air Force's catalog and had not included inputs from Iridium on the exact location of its satellites. The "fusion" of such data is seen as augmenting space situational awareness. According to *Space News, "operator input makes even the most precise Air Force information more accurate because operators know the exact position of their own spacecraft."*

Many questions remain as to how to improve space situational awareness with an ever growing population of spacecraft and international operators. Improvements in information services, capabilities and resources, and coordination will all have to be addressed. One approach, the previously referenced fusion of data, would allow combining multiple sources of information to produce a more detailed and refined estimation of the orbital environment. Efforts are underway to improve the system of integrated data by incorporating foreign information, ground and space based observations, space weather data, and other data sources. This information should help provide more accuracy to automated processes and computations that will reduce the reliance on human analysis.

Notwithstanding DOD's plans to upgrade the SSN, concerns have been raised regarding the Department's level of investment in space surveillance and whether funding may be sufficient to provide the data commercial space users need to protect their satellites. In a March 2009 testimony before the Strategic Forces Subcommittee, House Armed Services Committee, retired Major General James Armor said that the SSN is not sufficiently resourced to support civil and commercial operations. The former Director of DOD's National Security Space Office said that the Air Force does not have the resources to conduct CFE support, adding that *"recent complaints by commercial operators about unwarned movement of DOD satellites and lack of support for moving commercial satellites at GEO, as well as the Iridium Satellite collision with a defunct Russian Cosmos satellite are indications of inadequate resources and lower priority for CFE."* In addition, space users have also indicated concern about insufficient funding. An article in *Aviation Week and Space Technology* recently quoted a satellite communications official as saying that the question is *"whether there will be enough money to get more than the two-line elements currently available."* The article added that *"Industry analysts say the two-line element sets do not satisfy operators' accuracy needs: they want specific data sets that include such information as maneuvering details necessary to predict the ephemeris (daily computed position) of active satellites and to accurately forecast the close approach of drifting debris."*

The Air Force has indicated that 25,000 users and 149 nations have availed themselves of the CFE Pilot Program's services. Lt. Gen. Larry D. James, a witness at the hearing, will provide the latest status on the CFE Pilot Program, including steps envisioned following the Pilot Program's completion. Mr. Richard DalBello, also a witness at the hearing, will provide perspectives from the commercial user's viewpoint.

Other Space Surveillance Analysis Tools and Services

There are other means for space operators to gain access to additional assistance. For example: NASA has developed a software tool to be used by the Agency's programs but also made available to other space users.

- The Debris Assessment Software (DAS) is designed to assist NASA programs in performing orbital debris assessments and provides the user with tools to assess compliance with the requirements. In addition, NASA has developed a computer-based orbital debris engineering model called ORDEM2000. The model describes the orbital debris environment in the low-Earth orbit region between 200 km and 2,000 km altitude. NASA says that the model is appropriate for those engineering tasks requiring knowledge and estimates of the orbital debris environment and can also be used as a benchmark for ground-based debris measurements and observations. This engineering model will soon be enhanced with the upcoming release of ORDEM2008.
- The Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space for Geosynchronous (SOCRATES–GEO) service offered by the *Center for Space Standards and Innovation* (CSSI) provides commercial space users with an alternative to DOD analyses. Based in Colorado Springs, CO, CSSI is a research arm of Analytical Graphics, Inc. (AGI). SOCRATES–GEO is a partnership between CSSI and several commercial GEO providers where voluntary owner-operator positional data and maneuver schedules are provided to CSSI by the commercial partners. The CSSI analysts and software combine this information with data pulled from the U.S. military's public satellite catalog on debris and other objects.
- As indicated in the European Space Agency's (ESA) Space Debris web site, the consolidation of knowledge on all known objects in space is a fundamental condition for the operational support activities of ESA's Space Debris Office. This knowledge, the web site says, is maintained and kept up-to-date through the DISCOS database (Database and Information System Characterising Objects in Space). DISCOS serves as a single-source reference for information on launch details, orbit histories, physical properties and mission descriptions for about 33,500 objects tracked since Sputnik-1, including records of 7.4 million orbits in total. According to ESA, DISCOS is regularly used by almost 50 customers worldwide.
- ESA's most prominent debris and meteoroid risk assessment tool is called MASTER (Meteoroid and Space Debris Terrestrial Environment Reference). In order to study the effectiveness of debris mitigation measures on the debris population stability, long-term forecasts are required to determine future trends as a function of individual mitigation actions. This type of analysis can be performed with ESA's DELTA tool (Debris Environment Long-Term Analysis).

Collaborative Efforts to Mitigate the Growth of Orbital Debris And Enhance Space Situational Awareness

Because of the global nature of the risks of orbital debris to space users of all nations, several collaborative efforts have emerged in the form of guidelines to minimize the propagation of space debris and research to improve space situational awareness capabilities. While space surveillance focuses on securing positional data, situational awareness oftentimes requires the "fusing" (combining) of multiple data types and sources, thus creating information conducive to decision-making.

International Space Debris Mitigation Guidelines

The Inter-Agency Space Debris Coordination Committee (IADC) is an international governmental forum for the worldwide coordination of activities related to the issues of man-made and natural debris in space. The primary purposes of IADC are to exchange information on space debris research activities between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities, and to identify debris mitigation options. IADC member agencies include ASI (Agenzia Spaziale Italiana); BNSC (British National Space Centre); CNES (Centre National d'Études Spatiales); CNSA (China National Space Administration); DLR (German Aerospace Center); ESA (European Space Agency); ISRO (Indian Space Research Organisation); JAXA (Japan Aerospace Exploration Agency); NASA ; NSAU (National Space Agency of Ukraine); and ROSCOSMOS (Russian Federal Space Agency).

An initial set of space debris mitigation guidelines was developed by IADC in 2002, reflecting the fundamental debris mitigation elements of a series of existing practices, standards, codes and handbooks developed by a number of national and international organizations. The UN's COPUOUS acknowledged the benefit of a set of high-level qualitative guidelines having wider acceptance among the global space community. The Working Group on Space Debris was established by the Scientific and Technical Subcommittee of the Committee to develop a set of recommended guidelines based on the technical content and the basic definitions of the IADC space debris mitigation guidelines, taking into consideration the United Nations treaties and principles on outer space.

This activity resulted in the *Space Debris Mitigation Guidelines* being endorsed by the United Nations' General Assembly in December 2007, a document that outlines space debris mitigation measures for the mission planning, design, manufacture and operational (launch, mission and disposal) phases of spacecraft and launch vehicle orbital stages. Compliance is voluntary; in addition, Guidelines are not legally binding under international law. However, many Member States have incorporated them through national mechanisms. The Guidelines, characterized numerically in the United Nations document, focus on seven areas:

- Guideline 1: Limit debris released during normal operations
- Guideline 2: Minimize the potential for break-ups during operational phases
- Guideline 3: Limit the probability of accidental collision in orbit
- Guideline 4: Avoid intentional destruction and other harmful activities
- Guideline 5: Minimize potential for post-mission break-ups resulting from stored energy
- Guideline 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission
- Guideline 7: Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission.

Shortly after the February 10, 2009 collision between the inactive Russian Federation communications satellite Cosmos 2251 and the operational U.S. satellite Iridium 33, the Director of the United Nations' Office for Outer Space Affairs (UNOOSA) issued a call to all Member States and international organizations to voluntarily take measures to ensure that the *Space Debris Mitigation Guidelines* are fully implemented. The Director stressed that *"the prompt implementation of appropriate space debris mitigation measures is in humanity's common interest, particularly if we are to preserve the outer space environment for future generations."*

5th European Conference on Space Debris

During the 5th European Conference on Space Debris held earlier this month in Darmstadt, Germany, experts from around the world met to discuss a variety of issues associated with space debris such as measurements and debris environment characterization; environment modeling and forecasting, risk analysis for the in-orbit and re-entry mission phases, protection and shielding, debris mitigation and remediation, and debris policies and guidelines.

As noted on the Conference's web site, the Conference's main finding was that mitigation alone cannot maintain a safe and stable debris environment in the long-term future and that active space debris remediation measures will need to be devised and implemented. Conferees recognized that such measures are technologically demanding and potentially costly, but saw no alternative to protect space as a valuable resource for the operation of indispensable satellite infrastructures. The web site conference summary stated that as far as satellite infrastructures are concerned *"their direct costs and the costs of losing them will by far exceed the cost of remedial activities."*

Research on a European Union Space Surveillance Awareness System

ESA is undertaking research on European countries' needs for Space Situational Awareness (SSA). ESA defines SSA as the comprehensive understanding and knowledge of (a) the population of space objects, (b) the space environment, and (c) possible threats/risks. As such, the European SSA differs in philosophy to the U.S. SSN in that "astronomical threats," such as asteroids, will be tracked. In a September 2008 presentation entitled *"ESA's initiative towards a European Space Situational Awareness System"* at the Space for Defence and Security Conference sponsored by the Royal United Services Institute, an ESA representative outlined his agency's progress to date. He provided the background for the research, noting the European Union's (EU) dependency on space assets; the major consequences of a shutdown of even a part of the space infrastructure on the European economy and security; and the fact that the EU does not have the capability to monitor its space assets and identify threats. The ESA representative said that relative to the SSA research program, ESA had (1) established an informal user group representing the full spectrum of potential SSA user communities (civil, military, commercial operators, national space agencies, insurance companies, scientific community, defense intelligence, etc.), (2) initiated several preliminary studies such as a compilation of a SSA Users' Needs list; and (3) prepared an SSA research Program Proposal.

According to the ESA representative, the overall research program will be conducted from 2009 to 2018. With regards to the benefits of a Europe-U.S. cooperative SSA effort, the ESA representative listed those benefits as making the two systems more capable, more robust, and more "credible" (i.e., "through reciprocal independent situational assessment and validation").

Others in the global community also believe an inter-agency coalition should be formed to develop an international space traffic management organization. A February 23, 2009 *Space News* article quotes Air Force Gen. Michael Carey, Deputy Director of U.S. Strategic Command as saying that the Air Force would be willing to help coordinate an international effort to create a space traffic management system, but the service stopped short of suggesting what entity would take the lead in operating such a system.

Future Challenges Associated with Space Debris Mitigation, Removal, and Designation of Responsibility

There are a number of challenges facing the global community with regards to how space debris could be mitigated or removed, how responsibility for space traffic management will be assigned, and whether rules of conduct to minimize space debris need to be explicitly stated.

Space Debris Mitigation and Removal

There are two major methods for stemming the growth of orbital debris. Growth mitigation is currently the primary and only means for combating space debris. This more cost effective method includes all preventative measures taken to reduce the possibility for multiple types of debris generating events. One method of mitigation involves disposing of spacecraft at the end of their operational life time by maneuvering them into the Earth's atmosphere or by placing them into a higher "graveyard orbit." The passivation of aging spacecraft is used to prevent accidental debris generating events that can occur many years after mission completion by reducing stored energy sources by venting or burning remaining propellants and pressurized systems, and the discharging of batteries. There are also preventative design measures that can be added to a spacecraft or rocket during its design and manufacturing stages that can reduce the possibility of future explosions and that limit the amount of debris generated during in-space activities.

The second method is active debris removal. NASA studies have shown that even if there were no new launches of any kind, orbital debris would continue to grow as existing spacecraft and debris continued to collide and propagate. Therefore, various experts have recently come to the conclusion that active debris removal must be viewed as a possible solution as there is no other apparent alternative for proactively reducing debris. Yet, active debris removal is extremely expensive to design, test, and produce and has therefore been a historically low engineering R&D priority. Very few theoretical methods of active debris removal exist, and several studies have been initiated by different space agencies and groups to verify the technical feasibility of several proposed methods.

Responsibility for Space Traffic Management and Rules of the Road

Retired General James Armor testified at the previously noted House Armed Services Committee subcommittee hearing that there is currently no assigned organizational responsibility for space traffic management in the U.S. While acknowledging that the National Security Space Office (NSSO) maintains DOD's joint agency architecture, he noted that responsibilities for space traffic management are located in several other agencies. For example, the FAA's Office of Commercial Space Transportation grants launch and re-entry licenses, the Federal Communications Commission grants orbital locations and spectrum, and the Air Force operates the Space Surveillance system. He drew an analogy with the Global Positioning System (GPS) that started as a strictly military system but rapidly grew to have civil and commercial applications. General Armor recalled how organizational responsibility became vested in a National Executive Committee co-chaired by DOD and the Department of Transportation having oversight over diverse agency functions and resources. He advocated that *"Synchronizing these agencies to jointly start studying a* *space traffic management investment framework might be productive. Working towards a commercially secure space operating environment is an opportunity for global U.S. space leadership that addresses a huge portion of space security. This is also where discussions about rules of the road might be beneficial."*

In addition, there have been other organizations and individuals that have examined the pros and cons of potential space traffic management approaches or international "rules of the road." There is currently no international treaty, document or set of agreed upon guidelines that mandates a legal set of approaches towards space traffic management. The most concrete set of "rules of the road" originate from the space agencies internally. Legal solutions to such concerns as liability issues remain unclear. No standard exists for what constitutes negligence, nor is there a clear approach towards resolving possible incidents between foreign civil, commercial and military spacecraft. At this point, there does not appear to be a consensus on the appropriate long-term framework for space traffic management.

Chairwoman GIFFORDS. This hearing will come to order. Good afternoon, everyone, and welcome to today's hearing of the Space and Aeronautics Subcommittee.

One of my favorite photographs can be seen in the other room, which is the Hubble Deep Field photograph where you look at it from a distance, and it looks like it is a photograph of a bunch of stars, but as you get closer you see, in fact, it is a photo of a bunch of galaxies. And the more you learn about this incredible photograph you realize they just decided to take an image from Hubble into the universe, and it is approximately as large as your thumb if you were to hold it up, and it really goes to show is what Kurt Vonnegut had said, "The universe is a big place."

And that is why it is such a surprise to me and many others on the Subcommittee when we heard the news that two satellites had collided in orbit in February of this year. It is hard to believe that space has gotten that crowded. It was equally difficult to believe that nothing could have been done to prevent the collision, given that one of the satellites was active and by all accounts would have had the capability to move, maneuver out of harm's way. But the collision did happen, and the resulting increase in space debris has made the space environment more hazardous to civil and commercial satellites and spacecraft alike for many, many years to come.

So now it is three months later, and someone like myself who serves both on the House Science Committee and also on the House Armed Services Committee, I believe that I speak for my colleagues on both committees and others as well that we want to know where things stand, and we want to know what we need to do in order to keep an event such as the one that happened in February from happening again.

For example, how confident can we be that we are not going to face a similar hazardous situation in the near future between a commercial satellite and a U.S. or another nation's government spacecraft?

Equally important, what assurance can we have that there will be adequate warning of a potential collision before it is too late to do anything about it? We also want to hear how DOD, NASA, the commercial space operators, and other space-faring nations coordinate in order to minimize the threat of such occurrences. And is the information on space debris and potential collisions getting to the people who need it when they need it?

In short, was the February collision a fluke that could have been awarded—avoided, or do we need to improve our national and international capabilities for keeping the space environment safe for both civil and commercial users? If so, what is needed, and how do we go about getting it put into place?

We hope to get the answers today to these important questions at the hearing, and I believe that we have a good panel of witnesses to help us in our oversight of this important issue. One thing is already clear. The space environment is getting increasingly crowded due to the relentless growth of space debris. Many say that if we do nothing, the problem will continue to get worse.

As our witnesses will testify, the U.S. Space Surveillance Network is currently tracking more than 19,000 objects that are in orbit around the Earth. In addition, it has estimated that there are more than 300,000 pieces of debris as small as a half inch in size orbiting the Earth, including most recently a small spatula and a tool kit as well.

So it is clear to me that if space-faring nations of the world don't take steps to minimize the growth of space junk, we will eventually face a situation where low-Earth orbit becomes a risky place to carry out civil and commercial space activities. This subcommittee wants to avoid that kind of space future if we can, and this hearing is going to be an important milestone in that effort.

With that I want to welcome our distinguished panel of witnesses, and I look forward to your testimony.

And with that I would like to recognize Mr. Olson for any opening remarks he would like to make.

[The prepared statement of Chairwoman Giffords follows:]

PREPARED STATEMENT OF CHAIRWOMAN GABRIELLE GIFFORDS

Good afternoon and welcome to today's hearing of the Space and Aeronautics Subcommittee.

To quote the late Kurt Vonnegut, "the universe is a big place . . ."

That's why it was such a surprise to me and many others when we heard the news that two satellites had collided in orbit in February of this year.

It was hard to believe that space had gotten that crowded.

It was equally difficult to believe that nothing could have been done to prevent the collision, given that one of the satellites was active and by all accounts would have had the capability to maneuver out of harm's way.

But the collision did happen.

And the resulting increase in space debris has made the space environment more hazardous to civil and commercial satellites and spacecraft alike for years to come.

It's now almost three months later.

As someone who serves on both the Science and Technology Committee and the House Armed Services Committee, I want to know where things stand, and what we're going to do to keep such an event from happening again.

For example, how confident can we be that we aren't going to face a similar hazardous situation in the near future between a commercial satellite and a U.S.—or other nation's government spacecraft?

Equally importantly, what assurance can we have that there will be adequate warning of a potential collision before it is too late to do anything about it?

How do DOD, NASA, the commercial space operators, and other space-faring nations coordinate to minimize the threat of such occurrences, and is the information on space debris and potential collisions getting to the people who need it when they need it?

In short, was the February collision a fluke that couldn't have been avoided, or do we need to improve our national—and international—capabilities for keeping the space environment safe for civil and commercial users?

If so, what is needed, and how do we go about getting it put in place?

We hope to get answers to these and other important questions at today's hearing, and I believe we have a good panel of witnesses to help us in our oversight of this important issue.

One thing is already clear—the space environment is getting increasingly crowded due to the relentless growth of space debris.

As our witnesses will testify, the U.S. Space Surveillance Network is currently tracking more than 19,000 objects that are in orbit around the Earth.

In addition, it is estimated there are more than 300,000 pieces of debris as small as half-inch in size orbiting the Earth.

That's a lot of debris! And of course there is the temporary bump-up in the amount of debris that results whenever the odd astronaut spatula or toolkit floats away from the International Space Station . . ..

It is clear that if the space-faring nations of the world don't take steps to minimize the growth of space junk, we may eventually face a situation where low-Earth orbit becomes a risky place to carry out civil and commercial space activities.

I want to avoid that kind of space future if we can, and this hearing is going to be an important milestone in that effort.

With that, I want again want to welcome our distinguished panel of witnesses, and I look forward to your testimony.

I now want to recognize Mr. Olson for any opening remarks he may care to make.

Mr. OLSON. Thank you, Madam Chairwoman, for calling this afternoon's hearing. I believe this is the first time that the Committee has considered this issue, the Subcommittee has considered this issue, and my thanks to the witnesses for taking time out of your busy schedules to appear before us today. I know you have invested many hours of preparation for today's hearing, and I am grateful for your efforts and your expertise.

Satellite collisions and the danger posed by satellite debris have captured the public's and industries' attention. As the Chairwoman alluded to, the Iridium-Cosmos collision should serve as a stark signal that space-faring nations can no longer be complacent about the threats posed to all who use space.

Congress through the Administration must also take note as we endeavor to establish future policies and programs that rely on routine access in use of space. There are many issues I look forward to hearing about today and to ask questions about our path forward.

As more countries join the ranks as space-faring nations, all of us must determine ways to prevent future collisions, to mitigate the threat of debris, how best to track debris, how to minimize debris generation during future launches, and to better understand the economic and operational effects that space debris poses on civil, commercial, and military users.

Once again, this committee is addressing an issue that has moved from the realm of science fiction to one of science fact. Can we track a bolt that came off a dead satellite moving at thousands of miles an hour to prevent it from hitting a still-working spacecraft that is critical to our daily lives or to the lives of a crew that is on board that spacecraft? The chance of this may not be as great as the chance of me getting into a fender bender going down the Gulf Freeway during rush hour, but the consequences are much greater than a traffic jam caused at one rush hour. No other nation is as heavily invested in space-based commerce, national security, and environmental monitoring research as the United States of America.

Given the critical role that space plays in our daily lives and one that is so critical to preserving a high standard of living, we simply must improve our ability to monitor and mitigate the threats posed by other satellites and space debris. And we can't stop at our borders. I think it is critical that we must also convince other space-faring nations of the urgency to adopt similar strategies, especially as more and more satellites are lofted into more and more crowded orbits.

To the unknowing, the term space traffic management may sound a bit geeky or a little esoteric, but as I was preparing for this afternoon's hearing I was quickly convinced that the term has real meaning and describes a discipline we all need to pay close attention to. I am aware that government-owned and operated satellites rely on intensive monitoring programs to avoid collisions with other satellites and debris, but as more and more satellites come into use, especially from commercial users, many of whom are from overseas countries, the challenge of maintaining safe separation will grow.

Again, I want to thank our Chairwoman for convening this timely and important hearing, and thanks again to our witnesses. I am anxious to hear your testimony and ask you some questions later on.

Madam Chairman, I—Chairwoman, I yield my time back.

[The prepared statement of Mr. Olson follows:]

PREPARED STATEMENT OF REPRESENTATIVE PETE OLSON

Madame Chairwoman, thank you for calling this afternoon's hearing, which I believe is the first time this subcommittee has explored this issue, and my thanks too, to our witnesses for taking time out of your busy schedules to appear before us today. I know that you have invested many hours in preparation for today's hearing, and I am grateful for your efforts and your expertise.

Satellite collisions and the dangers posed by space debris have captured the public's and industry's attention. As the Chairwoman alluded to, the Iridium/Cosmos collision should serve as a stark signal that space-faring nations can no longer be complacent about the threats posed to all who use space. Congress and the Administration must also take note as we endeavor to establish future policies and programs that rely on routine access and use of space. There are many issues I look forward to hearing about today and to ask questions about our path forward.

As more countries join the ranks of space-faring nations, all of us must determine ways to prevent future collisions, to mitigate the threat of debris, how best to track debris, how to minimize debris generation during future launches, and to better understand the economic and operational effects that space debris imposes on civil, commercial and military users.

Once again, this committee is addressing an issue that has moved from the realm of science fiction to one of science fact: Can we track a bolt that came off a long dead satellite moving at thousands of miles an hour from hitting with a still working spacecraft that is critical to our daily lives or to the lives of a crew inhabiting that spacecraft? The chances of this may not be as great as the chance of me getting into a fender bender on the Gulf Coast Freeway, but the consequences are greater than ruining one rush hour.

No other nation is as heavily invested in space-based commerce, national security, environmental monitoring and research as the United States of America. Given the critical role that space plays in our daily lives, and one that is so critical to preserving our high standard of living, we simply must improve our ability to monitor and mitigate the threats posed by other satellites and space debris. And we can't stop at our borders. I think it critical that we also convince other space-faring nations of the urgency to adopt similar strategies, especially as more and more satellites are lofted into more and more crowded orbits.

To the unknowing, the term 'space traffic management' may sound a bit geeky and esoteric, but as I was preparing for this afternoon's hearing, I was quickly convinced that the term has real meaning and describes a discipline we all need to pay close attention to. I am aware that government-owned and operated satellites rely on intensive monitoring programs to avoid collisions with other satellites and debris, but as more and more satellites come into use, especially from commercial users, many of whom are from overseas companies, the challenge of maintaining safe separation will grow.

I want to thank our Chairwoman for convening this timely and important hearing, and to again thank our witnesses. I am anxious to hear your testimony and ask some questions about the way forward.

Chairwoman GIFFORDS. Thank you, Mr. Olson. 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. First up we have Lieutenant General Larry D. James, who is a Commander of the 14th Air Force, Air Force Space Command, and the Commander of the Joint Functional Component Command for Space. Welcome.

We also have Mr. Nick Johnson, who is the Chief Scientist for Orbital Debris for NASA. So welcome, Mr. Johnson.

We have Mr. Richard DalBello, who is the Vice President of Government Relations at Intelsat General Corporation. Glad you are here.

And finally have Dr. Scott Pace, who is the Director of the Space Policy Institute at George Washington University.

As our witnesses should know, you will each have five minutes for your spoken testimony. I know that is not a long period of time, but it will keep us on track. Your written testimony will be included for the record for the hearing, and when you have all completed your spoken testimony, we will begin questions. Each Member will have five minutes to question the panel.

And we would like to begin with General James.

STATEMENT OF LIEUTENANT GENERAL LARRY D. JAMES, COMMANDER, 14TH AIR FORCE, AIR FORCE SPACE COMMAND; COMMANDER, JOINT FUNCTIONAL COMPONENT COMMAND FOR SPACE, U.S. STRATEGIC COMMAND

General JAMES. Well, Madam Chairwoman, Ranking Member Olson, and distinguished Members of the Space and Aeronautics Subcommittee, I am honored to be here today for my first opportunity to appear before you as United States Strategic Command's Commander of the Joint Functional Component Command for Space. It is a distinct privilege to address you on the challenges faced by civil and commercial space users and to represent the men and women of JFCC Space who employ space capabilities around the globe every day.

Today I will focus my discussion on what the current space environment looks like, how we work with commercial space users through the Commercial and Foreign Entities Pilot Program, and identify some of the challenges we face as we work to meet the growing challenges of operating safely in an increasingly-complex and congested environment.

Space traffic growth today is both a challenge and a concern. In 1980, only 10 countries were operating satellites in space. Today nine countries operate space ports, more than 50 countries own or have partial ownership in satellites, and citizens of 39 nations have flown in space. In 1980, we were tracking approximately 4,700 objects in space, 280 of those objects were active satellites, while another 2,600 were debris. Today we are tracking as you said approximately 19,000 objects, 1,300 active payloads, and about 7,500 pieces of debris. So in 29 years space traffic has quadrupled.

We have made progress in improving our space situational awareness, however, as you noted February's collision between an active Iridium communications satellite and an inactive Russian satellite and a January, 2000, test of a Chinese ASAT continue to shape our future planning by tangibly demonstrating the vulnerability of our space assets.

With increased use of space by a growing number of state and non-state users and the increased threats to our valuable space systems, it is paramount that the Department of Defense in collaboration with its partners in the U.S. Government, work hand in hand with civil, commercial, and international operators to ensure a space environment, a safe environment. The DOD does have a sound relationship with commercial space providers and operators, particularly those commercial communication and remote imaging organizations that support U.S. and national security activities. The relationship includes formal contractual arrangements for the provision of service to the DOD, routine strategic-level meetings between the commercial satellite CEOs and DOD senior civilians and officers, and numerous working-level meetings.

As part of the Commercial and Foreign Entity Pilot Program or CFE Program, commercial users can access the *AirForceSpaceCommandSpaceTrack.org* website to obtain unclassified element-set data on current catalog objects. If a user would like more information, they must sign an agreement for CFE support via the website and submit a specific request for specific support.

The CFE Pilot Program has been successful in transitioning the routine provision of satellite positional information from NASA to Air Force Space Command. Air Force Space Command has also developed an initial set of legal agreements. These agreements allow for the provision of additional services such as conjunction assessments and launch support and help identify the long-term desires of commercial and foreign entities for space situational information.

The DOD intends to operationalize its support to commercial and foreign entities in the fall of 2009. The goal is to seamlessly transition the program from an Air Force Space Command Pilot Program to U.S. Strategic Command operational activity. The Joint Space Operation Center at Vandenberg Air Force Base will be the central node for sharing of information. We will continue to work closely with the commercial and foreign space communities to understand their evolving needs and desires for space situational awareness information and continue to grow our cooperative relationships to share information in ways that will improve space flight safety.

Space situational awareness is more than understanding the space environment, tracking objects, and conducting conjunction assessments. We need to be able to discriminate between natural and manmade threats. We need to understand the location, the status, and purpose of these objects, their capabilities and their owner's intent. This comprehensive knowledge allows decision-makers to rapidly and effectively select courses of action to ensure our sustained freedom of action and safety in what is a contested environment. To get there we require more network sensors and information systems that seamlessly share information to more effectively use our current resources.

The U.S. must continue to lead the community of space-faring nations and encourage responsible behavior in the space environment. The United States' dependence on space across our military, civil, and commercial sectors requires improved space situational awareness and command and control capabilities to ensure our ability to safely and effectively operate in an dynamic and contested environment. Working in collaboration with our other departments and agencies in the U.S. Government, DOD must continue to build relationships, processes, and capabilities within the global space community that allow us to operate effectively together to meet the needs of national defense.

Thank you for inviting me here today, and I look forward to your questions.

[The prepared statement of Lieutenant General James follows:]

PREPARED STATEMENT OF LIEUTENANT GENERAL LARRY D. JAMES

Madam Chairwoman, Ranking Member Olson, and distinguished Members of the Space and Aeronautics Subcommittee, I am honored to be here today for my first opportunity to appear before you as United States Strategic Command's (USSTRATCOM) Commander of the Joint Functional Component Command for Space (CDR JFCC SPACE).

It's a distinct privilege to address you on the challenges faced by civil and commercial space users, and to represent the men and women of JFCC SPACE who employ space capabilities around the globe every day. These Soldiers, Sailors, Airmen, and Marines are a dedicated and innovative joint force, working hard to generate timely, accurate and thorough space situational awareness (SSA) and conduct command and control of our worldwide space forces. Their professionalism ensures, to the maximum extent possible, that the U.S. and our Allies may operate freely and safely in space.

Today I will focus my discussion on what the current space environment looks like, how we work with commercial space users through the Commercial and Foreign Entities (CFE) Pilot Program and identify some of the challenges we face as we work to meet the growing challenge of operating safely in an increasingly complex and congested space environment.

CURRENT SPACE TRAFFIC ENVIRONMENT

Space traffic growth is both a challenge and a concern. In 1980 only 10 countries were operating satellites in space. Today, nine countries operate spaceports, more than 50 countries own or have partial ownership in satellites and citizens of 39 nations have traveled in space. In 1980 we were tracking approximately 4,700 objects in space; 280 of those objects were active payloads/spacecraft, while another 2,600 were debris. Today we are tracking approximately 19,000 objects; 1,300 active payloads and 7,500 pieces of debris. In 29 years, space traffic has quadrupled.

It's challenging to accurately predict the growth of active payload space traffic and debris. In addition to the growth of national security and commercial satellites from existing and new space-faring nations, we believe the global diffusion of space technologies, especially the availability of small spacecraft technologies and providers, will lead to a larger and more diverse population of active spacecraft.

Based on the last 10 years of launch activity, we conservatively project the number of active satellites to grow from 1,300 to 1,500 over the next 10 years. We also estimate the overall number of tracked objects could increase from 19,000 to as much as 100,000 depending largely on anticipated increases in sensitivity of future sensors such as the Space Fence. The increased sensitivity will allow us to track existing but undiscovered small debris. However, there will still be potentially lethal objects in space too small to be tracked by the Space Surveillance Network (SSN).

We have made progress in improving our SSA; however, February's unfortunate collision between an active Iridium communications satellite and inactive Russian satellite, and the January 2007 Chinese test of an anti-satellite (ASAT) continue to shape our future planning by tangibly demonstrating the vulnerability of our space assets. To date we have cataloged over 870 pieces of debris as a result of the Iridium/COSMOS collision. The ASAT test by the Chinese left over 2,400 pieces of potentially destructive orbital debris that we're still tracking 24 X 7. In both cases, there are likely thousands of smaller pieces our sensors can't track. A combined total of only 58 items have re-entered so far, with the remainder expected to be in orbit for decades. This debris will slowly decay due to natural forces and will remain a hazard to manned and unmanned space flight in low-Earth orbit, and to satellites transiting that region, from low to higher orbits.

With an increased use of space by a growing number of State and non-State users and the increased threats to their valuable space systems, it is paramount that the Department of Defense (DOD)—in collaboration with its partners in the U.S. Government—work hand-in-hand with civil, commercial, and international operators to ensure a safe environment.

DOD AND COMMERCIAL SPACE USER COORDINATION

The DOD has a sound relationship with commercial space operators, particularly those commercial communication and remote imaging organizations that support U.S. and national security activities. The relationship includes formal contractual arrangements for the provision of service to the DOD, routine strategic-level meetings between the commercial satellite CEOs and DOD senior civilians and officers, and numerous working-level meetings.

As part of the CFE Pilot Program, commercial users can access the Air Force Space Command (AFSPC) *Space-track.org* web site to obtain unclassified element set data on current catalogued objects. If a user would like more information, they must sign an agreement for CFE support via the web site and submit a request for specific support. The request is first reviewed at AFSPC to ensure it meets policy and security requirements. Once cleared through AFSPC it is sent to the 614th Air and Space Operations Center (614th AOC) via 14th Air Force for operational review and processing. The 614th AOC works directly with users to process requests.

The recent Iridium/COSMOS collision provides an excellent example of the relationship we have with commercial users and what we are doing to ensure safe space operations. The Joint Space Operations Center (JSpOC) began increased conjunction assessment screening of Iridium assets four hours and fifty minutes following the conjunction, and now screens over 330 objects daily to ensure safe space flight operations for both DOD and commercial space users supporting DOD missions.

Despite our efforts and the milestones reached, we continue to face challenges. Specific challenges we are working hard to resolve include sharing of SSA data, improving timeliness and accuracy of data, and protecting sensitive information. The DOD has engaged with most of the major commercial satellite operators who provide support to the U.S. Government to discuss their needs for SSA as well as their ability to provide inputs to our awareness. AFSPC has initiated a working group which includes commercial operators to identify specific technical solutions that will allow the sharing of additional spacecraft positional and status information to enhance collective space flight safety. Additionally, AFSPC recently conducted an industry day at the 25th Annual National Space Symposium in Colorado Springs and hosted a round table discussion with owner/operators, sharing short- and long-term goals of the CFE Pilot Program.

COMMERCIAL AND FOREIGN ENTITY PILOT PROGRAM

The CFE Pilot Program has been successful in transitioning the routine provision of satellite positional information from NASA to AFSPC for developing an initial set of legal agreements. These agreements allow for the provision of additional services such as conjunction assessments and launch support, and help identify the long-term desires of commercial and foreign entities for space situational information.

The AFSPC *Space-track.org* web site has been providing unclassified satellite catalog data to approved account holders since 2004. To date, we have hosted over 37,000 users spanning over 110 countries with 75 percent of the users coming from the U.S., Canada, France, Germany, United Kingdom, and Australia.

The next phase in the CFE Pilot Program evolution provides advanced services to commercial and foreign entities which establish or have a pre-existing agreement with the DOD. These services include conjunction assessment and launch support delivered through web services. The long-term solution includes integrating commercial and foreign entity advanced services in the JSpOC Mission System with the ability to ingest data directly from these entities on a voluntary basis.

There have been a number of important lessons learned from the pilot program. These include a greater understanding of: 1. the specific commercial and foreign desires and rationale for space situational information; 2. the operational agility and limitations of commercial and foreign operators; 3. the necessary resources required to satisfy commercial and foreign desires for information; and 4. the potential value of the information commercial and foreign operators might share among themselves and with the DOD. The DOD intends to operationalize the support to commercial and foreign entities in the Fall of 2009. The goal is to seamlessly transition the program from an AFSPC pilot program to a USSTRATCOM operational activity. The JSpOC will be the central node for the sharing of information. We will continue to work closely with the commercial and foreign space communities to understand their evolving needs and desires for SSA information, and continue to grow our cooperative relationships to share information in ways that will improve space flight safety.

Although we have made large strides in SSA, it is imperative that we address the shortcomings in current SSA information, predictive capabilities, and supporting infrastructures, and develop an SSA vision for the future.

CHALLENGES AND WAY AHEAD

Space situational awareness is more than understanding the space environment, tracking objects, and conducting conjunction assessments. We need to be able to discriminate between natural and man-made threats. We need to understand the location, status and purpose of these objects, their capabilities, and their owners' intent. This comprehensive knowledge enables decision-makers to rapidly and effectively select courses of action to ensure our sustained freedom of action and safety in what is clearly a contested environment. To get there we require more automated, net-centric capabilities to command and control space forces, and networked sensors and information systems that seamlessly share information to more effectively use our current resources. This will give us the ability to rapidly react—real-time data flow to the JSpOC for processing and analysis, and then real-time flow of the refined product back to the user.

The overarching command and control and SSA program that will lead us towards our vision is the JSpOC Mission System. The program fuses multi-sourced space object tracking data with status and capability details, and provides automated assessment and decision-making aids.

The Enhanced Space Sensors Architecture (ESSA) project will be folded into the JSpOC Mission System and brings valuable sensor data into a net-centric architecture. The technology being developed and demonstrated by the ESSA project puts sensors' space object imaging and metric tracking information on the network for faster analysis, evaluation, and end-use by operators and decision-makers at all levels. The JSpOC has participated in two demonstrations of ESSA, and is scheduled to participate in its third demonstration in May.

The U.S. space surveillance architecture currently detects and tracks thousands of objects, but critical gaps remain in an ability to fully track and characterize all on-orbit objects, analyze and predict conjunctions, and protect not just military satellites, but also commercial and civil satellites critical to national security. The SSN provides acceptable coverage in the northern hemisphere, but we have a significant coverage gap in the southern hemisphere. By filling this gap we increase the JSpOC's ability to rapidly detect, track, and characterize new payloads and maintain awareness of maneuvering spacecraft. A key program to address this gap is the Space Fence. The Space Fence will be the most accurate dedicated radar in the SSN and will provide critical coverage from the southern hemisphere. With the capability to perform 750K observations per day and track over 100,000 objects, the Space Fence will significantly reduce coverage gaps and significantly improve our low-Earth and medium-Earth orbit SSA.

Our sensor network is currently able to track objects as small as 10 centimeters across. We do this well for low-Earth orbits; however, our ability decreases as we track objects in geosynchronous (GEO) orbit. We need to improve our capability to track and assess smaller objects in all orbits if we are to keep pace with the potential threats from the emerging small satellite technologies, and to gain better awareness of the hazards posed by small space debris. Today, many GEO objects go days without being tracked. The Space-based Space Surveillance (SBSS) satellite will provide the ability for the uninterrupted scan of the entire GEO belt every 24 hours—vital to maintaining positional knowledge, called "track custody" of high interest objects in deep space. Additionally, this new system's revisit rate for all GEO objects will greatly reduce the "lost list" of objects that change position between observations. I look forward to the successful fielding of SBSS, and the marked improvement to situational awareness it will bring.

With respect to cooperation with friends and allies, AFSPC experts are supporting the DOD and Department of State in discussions on SSA cooperation with the European Space Agency and European Union, as well as key European allies. These discussions provide a foundation for expanded trans-Atlantic cooperation on space situational awareness in support of common civil, commercial and military requirements. They also can serve as a model for discussions on SSA cooperation with our friends and allies in other regions.

The U.S. must continue to lead the community of space-faring nations and encourage responsible behavior in the space environment. The JSpOC is the nexus of SSA and the focal point for ensuring safe, effective operation of our space forces and those of our partners. We need to gather real-time, quality data, have the ability to exploit that data rapidly and accurately, and then export decision-quality information across a range of customers from the intelligence community to deployed forces, foreign partners, and commercial users.

CONCLUSION

The nature of space operations is rapidly evolving. The United States' dependence on space across our military, civil, and commercial sectors requires improved SSA and command and control capabilities to ensure our ability to safely and effectively operate in a dynamic and contested environment. Working in collaboration with other departments and agencies in the U.S. Government, DOD must continue to build the relationships, processes, and capabilities within the global space community that allow us to operate effectively together to meet the needs of national defense. I am truly honored to lead such a talented group of men and women. Perfection is our standard and you can be proud of your Soldiers, Sailors, Airmen and Marines that expertly tackle the challenges we face every day.

BIOGRAPHY FOR LIEUTENANT GENERAL LARRY D. JAMES

Lt. Gen. Larry D. James 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 James 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 James entered the Air Force as a distinguished graduate of the U.S. Air Force Academy in 1978. His career has spanned a wide variety of operations and acquisition assignments, including Space Shuttle Payload Specialist, Air Staff Program Element Monitor, Global Positioning System Satellite Program Manager and Chief of Operations, 14th Air Force.

General James has commanded at the squadron, group and wing levels, and was Vice Commander of the Space and Missile Systems Center. He has served on the staffs of Headquarters U.S. Air Force, U.S. Space Command and Air Force Space Command. He also served as the Senior Space Officer for Operation Iraqi Freedom at Prince Sultan Air Base, Saudi Arabia. Prior to his current assignment, the General was Vice Commander, 5th Air Force, and Deputy Commander, 13th Air Force, Yokota Air Base, Japan.

EDUCATION

1978—Distinguished graduate, Bachelor of Science degree in astronautical engineering, U.S. Air Force Academy, Colorado Springs, Colo.

1983—Master of Science degree in astronautical engineering, Massachusetts Institute of Technology, Cambridge

1984—Squadron Officer School, by correspondence

1988—Program Managers Course, Defense Systems Management College, Fort Belvoir, Va.

1989—Air Command and Staff College, Maxwell AFB, Ala.

1993—Air War College, Maxwell AFB, Ala.

1997—Joint Professional Military Education Phase II, Armed Forces Staff College, Norfolk, Va.

2002—National Security Management Fellowship, Syracuse University, N.Y.

2006—Combined Forces Air Component Commander Course, Maxwell AFB, Ala.

2007—Intelligence Community Executive Leader Program, Kellogg School of Management, Northwestern University, Chicago, Ill.

2007—Joint Forces Maritime Component Commander Course, Naval War College, R.I.

ASSIGNMENTS

1. July 1978–August 1981, Project Officer, Advanced Space Guidance Systems, Directorate of Technology, Space and Missile Systems Organization, Los Angeles AFB, Calif.
2. August 1981–January 1983, student, Massachusetts Institute of Technology, Cambridge
3. January 1983–December 1987, Space Shuttle Payload Specialist and Chief, Global Positioning System Space Systems Division, Headquarters Space and Missile Center, Los Angeles AFB, Calif.
4. January 1988–July 1988, student, Defense Systems Management College, Fort Belvoir, Va.
5. August 1988–July 1989, student, Air Command and Staff College, Maxwell AFB, Ala.

6. August 1989–June 1991, Program Element Monitor, Global Positioning System, Directorate of Space Programs, Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.
7. June 1991–July 1992, Executive Officer to Director, Space Programs, Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.
8. August 1992–July 1993, student, Air War College, Maxwell AFB, Ala.
9. September 1993–July 1994, Commander, 45th Spacecraft Operations Squadron, Cape Canaveral Air Force Station, Fla.
10. July 1994–July 1995, Commander, 5th Space Launch Squadron, Cape Canaveral AFS, Fla.
11. July 1995–January 1996, Deputy Commander, 45th Operations Group, Patrick AFB, Fla.
12. January 1996–May 1997, Deputy Chief, Space Control Mission Team, Air Force Space Command, later, Chief, Requirements and Programs Branch, Integration Division, U.S. Space Command, Peterson AFB, Colo.
13. May 1997–August 1998, Chief, Integration Division, Directorate of Plans, U.S. Space Command, Peterson AFB, Colo.
14. August 1998–June 2000, Commander, 614th Space Operations Group, and Chief of Operations, 14th Air Force, Vandenberg AFB, Calif.
15. June 2000–April 2001, Executive Officer to Commander, North American Aerospace Defense Command, Commander, U.S. Space Command and Commander, AFSPC, Peterson AFB, Colo.
16. April 2001–June 2003, Commander, 50th Space Wing, Schriever AFB, Colo.
17. June 2003–July 2004, Assistant Director of Air and Space Operations, Headquarters AFSPC, Peterson AFB, Colo.
18. July 2004–July 2005, Vice Commander, Space and Missile Systems Center, Los Angeles AFB, Calif.
19. July 2005–May 2007, Director, Signals Intelligence Systems Acquisition and Operations Directorate, National Reconnaissance Office, Washington, D.C.
20. May 2007–December 2008, Vice Commander, 5th Air Force, and Deputy Commander, 13th Air Force, Yokota Air Base, Japan
21. December 2008–present, Commander, 14th Air Force (Air Forces Strategic), Air Force Space Command, and Commander, Joint Functional Component Command for Space, USSTRATCOM, Vandenberg AFB, CA.

MAJOR AWARDS AND DECORATIONS

Defense Superior Service Medal with oak leaf cluster
Legion of Merit with three oak leaf clusters
Bronze Star Medal
Meritorious Service Medal with three oak leaf clusters
Air Force Commendation Medal

OTHER ACHIEVEMENTS

Top third graduate, Air Command and Staff College
Top 10 percent graduate, Air War College
National Finalist, White House Fellow Program

EFFECTIVE DATES OF PROMOTION

Second Lieutenant May 31, 1978
First Lieutenant May 31, 1980
Captain May 31, 1982
Major April 1, 1988
Lieutenant Colonel April 1, 1992
Colonel Dec. 1, 1997
Brigadier General Feb. 1, 2004
Major General Aug. 2, 2007
Lieutenant General Dec. 9, 2008

Chairwoman GIFFORDS. Thank you.
Mr. Johnson, please.

STATEMENT OF MR. NICHOLAS L. JOHNSON, CHIEF SCIENTIST FOR ORBITAL DEBRIS, JOHNSON SPACE CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Mr. JOHNSON. Madam Chairwoman and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the important topic of space debris.

While the adage, "what goes up must come down," still applies in the space age, most satellites take a very long time to fall back to Earth. In many cases this descent can take hundreds or even thousands of years.

Thus, the numerous operational satellites as well as the human-occupied International Space Station now circling the globe, performing vital functions of communications, navigation, Earth observation, science and research, exploration and defense, are accompanied by a much larger population of defunct spacecraft, derelict launch vehicle orbital stages, intentional refuse, and the products of more than 200 satellite explosions and collisions.

For 30 years, NASA has led the world in scientific studies to characterize the near-Earth space debris environment, to assess its potential hazards to the current and future space operations, and to identify and to implement means of mitigating its growth.

Since 1988, the United States National Space Policy has specifically addressed the need to limit the growth of the space debris population. The current National Space Policy signed by the President in 2006, charges U.S. Government agencies and organizations with seeking, "to minimize the creation of orbital debris by government and non-government operations in space in order to preserve the space environment for future generations."

The Policy also states, "The United States shall take a leadership role in international for—to encourage foreign nations and international organizations to adopt policies and practices aimed at debris minimization."

In 1995, NASA was the first U.S. Government organization to establish formal space debris mitigation guidelines. In 2001, the U.S. Government Orbital Debris Mitigation Standard Practices, based upon the NASA Space Debris Mitigation guidelines, was adopted after a lengthy and thorough inter-governmental review and coordination with the aerospace industry. The fundamental elements of these standard practices were adopted in 2002, by the major space-faring nations under the auspices of the Inter-Agency Space Debris Coordination Committee, whose members represent the space agencies of ten countries, as well as the European Space Agency. In 2007, the United Nations, through the Committee on the Peaceful Uses of Outer Space, adopted a similar set of space debris mitigation guidelines.

While NASA continues to promote the curtailment of the generation of new space debris, we must also operate in the existing debris environment. To this end, NASA designs spacecraft to withstand small particle impacts, and the Agency works with the U.S. Space Surveillance Network to avoid collisions between our space assets and the known resident space objects.

NASA procedural requirements call for conjunction assessments or close-approach predictions to be performed for all our maneuverable spacecraft. During 2008, NASA twice maneuvered a robotic spacecraft of the Earth Observation System in low-Earth orbit and once maneuvered a tracking and data relay satellite into geosynchronous orbit to prevent potential collisions. Twice since last August the International Space Station has conducted collision-avoidance maneuvers.

The recent collision of two intact satellites underscores NASA's 1970's era finding, reiterated more recently in a NASA study published in Science in 2006, that the amount of space debris already in Earth orbit is sufficient to lead to more accidental collisions, which in turn will lead to an unintended increase in space debris and increased risks to operational space systems. In the future such collisions are likely to be the principle source of new space debris.

The most effective means of limiting satellite collisions is to remove non-functional spacecraft and launch vehicle orbital stages from Earth orbit. However, the remediation of the near-Earth space environment presents substantial technical and economic challenges. The threat posed by orbital debris to the reliable operation of space systems will continue to grow unless the sources of space debris are brought under control. The international aerospace community has already made significant strides in the design and the operation of space systems to curtail the creation of new orbital debris but more can be done.

Currently, the Department of Defense's Commercial and Foreign Entities Program is the principle means of distributing space situational awareness data to space system operators and the general public. Enhancement of this program, both to serve a larger number of users and to increase the variety of services available, especially conjunction assessments, offer the greatest near-term and lowest cost improvement to space safety.

I would be happy to respond to any questions you and other Members may have. Thank you.

[The prepared statement of Mr. Johnson follows:]

PREPARED STATEMENT OF NICHOLAS L. JOHNSON

Madam Chairwoman and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the important topic of space debris. While the adage "what goes up, must come down" still applies in the space age, most satellites take a very long time to fall back to Earth. In many cases, this descent can last hundreds, even thousands, of years. Consequently, after more than 4,600 space missions conducted world-wide since Sputnik 1, a large number of human-made objects have steadily accumulated in Earth orbit. Thus, the numerous operational satellites as well as the human occupied International Space Station now circling the globe, performing vital functions of communications, navigation, Earth observation, science and research, exploration, and defense, are accompanied by a much larger population of defunct spacecraft, derelict launch vehicle orbital stages, intentional refuse, and the products of more than 200 satellite explosions and collisions.

Characterization of the Near-Earth Space Debris Environment

For 30 years, NASA has led the world in scientific studies to characterize the near-Earth space debris environment, to assess its potential hazards to current and future space operations, and to identify and to implement means of mitigating its growth. The near-Earth space debris environment ranges in altitude from 100 to more than 20,000 miles above Earth, and the debris itself ranges in mass from less than an ounce to many tons. Consequently, this population of space debris is a matter of growing concern for all space-faring nations.

Today, the United States Space Surveillance Network, managed by U.S. Strategic Command, is tracking more than 19,000 objects in orbit about the Earth, of which approximately 95 percent represent some form of debris. However, these are only the larger pieces of space debris, typically four inches or more in diameter. The number of debris as small as half an inch exceeds 300,000. Due to the tremendous energies possessed by space debris, the collision between a piece of debris only a half-inch in diameter and an operational spacecraft, piloted by humans or robotic, has the potential for catastrophic consequences.

United States and International Debris Policy

Since 1988, the United States National Space Policy has specifically addressed the need to limit the growth of the space debris population. The current National Space Policy, signed by the President in 2006, charges the U.S. Government agencies and organizations with seeking "to minimize the creation of orbital debris by government and non-government operations in space in order to preserve the space environment for future generations." The policy also states that "The United States shall take a leadership role in international fora to encourage foreign nations and international organizations to adopt policies and practices aimed at debris minimization . . .."

In 1995, NASA was the first U.S. Government organization to establish formal space debris mitigation guidelines. In 2001, the *U.S. Government Orbital Debris Mitigation Standard Practices,* based upon the NASA space debris mitigation guidelines, were adopted after a lengthy and thorough intergovernmental review and coordination with the aerospace industry. The fundamental elements of these standard practices were adopted in 2002 by the major space-faring nations under the auspices of the Inter-Agency Space Debris Coordination Committee, whose members represent the space agencies of 10 countries, as well as the European Space Agency. In 2007, the United Nations, through the Committee on the Peaceful Uses of Outer Space, adopted a similar set of space debris mitigation guidelines.

NASA Debris Avoidance and Mitigation

While NASA continues to promote the curtailment of the generation of new space debris, we must operate in the existing debris environment. To this end, NASA designs spacecraft to withstand the impacts of small debris, and the Agency works with the U.S. Space Surveillance Network to avoid collisions between our space assets and other known resident space objects. NASA procedural requirements call for conjunction assessments, i.e., close approach predictions, to be performed for all our maneuverable spacecraft. During 2008, NASA twice maneuvered robotic spacecraft of the Earth Observation System in low-Earth orbit and once maneuvered a Tracking and Data Relay Satellite in geosynchronous orbit to avoid potential collisions. Twice since last August, the International Space Station has conducted collision avoidance maneuvers.

For the 35 years from mid-1961 to mid-1996, the population of cataloged objects (i.e., objects that are four inches in size or larger) in Earth orbit increased at an average rate of 270 per year. However, with the concerted efforts of the major space-faring nations of the world, the rate dropped dramatically to only 70 per year for the next decade. Unfortunately, the intentional destruction of the Chinese Fengyun-1C weather satellite in January of 2007 and the accidental collision of American and Russian spacecraft in February of this year have increased the cataloged debris population by nearly 40 percent, in comparison with all the debris remaining from the first 50 years of the Space Age.

The recent collision of two intact satellites underscores a NASA 1970s-era finding, reiterated more recently in a NASA study published in *Science* in 2006, that the amount of debris already in Earth orbit is sufficient to lead to more accidental collisions, which in turn will lead to an unintended increase in space debris and increased risk to operational space systems. In the future, such collisions are likely to be the principal source of new space debris. The most effective means of limiting satellite collisions is to remove non-functional spacecraft and launch vehicle orbital stages from orbit. However, the remediation of the near-Earth space environment presents substantial technical and economic challenges.

Conclusion

The threat posed by orbital debris to the reliable operation of space systems will continue to grow unless the sources of debris are brought under control. The international aerospace community has already made significant strides in the design and operation of space systems to curtail the creation of new orbital debris, but more can be done.

Currently, the Department of Defense Commercial and Foreign Entities program is the principal means of distributing space situational awareness data to space system operators and the general public. Enhancements to this program, both to serve a larger number of users and to increase the variety of services available, especially conjunction assessments, offer the greatest near-term and lowest cost improvement to space safety. In the longer-term, technical advances in space surveillance, including more capable sensors and higher accuracy data, are likely needed.

I would be happy to respond to any question you or the other Members of the Subcommittee may have.

BIOGRAPHY FOR NICHOLAS L. JOHNSON

As NASA Chief Scientist for Orbital Debris at the NASA Johnson Space Center since 1997, Mr. Johnson serves as the agency authority in the field of orbital debris, including all aspects of environment definition, present and future, and the operational and design implications of the environment to both manned and robotic space vehicles operating in Earth orbit. He is responsible for conceiving and conducting research to define the orbital debris environment, for determining operational techniques for spacecraft to protect themselves from the environment, and for recommending techniques to minimize the growth in the future orbital debris environment. He leads the U.S. delegation to the Inter-Agency Space Debris Coordination Committee (IADC) and since 1997 has served as the U.S. technical expert on orbital debris at the United Nations. He served concurrently as the Program Manager for NASA's Orbital Debris Program Office from 1997 to 2006. Mr. Johnson has 30 years experience in orbital debris research and applications and is the recipient of the NASA Distinguished Service Medal, the NASA Exceptional Achievement Medal, and the DOD Joint Meritorious Civilian Service Award for his work in this field.

Chairwoman GIFFORDS. Thank you, Mr. Johnson.

Mr. DalBello.

STATEMENT OF MR. RICHARD DALBELLO, VICE PRESIDENT, LEGAL AND GOVERNMENT AFFAIRS, INTELSAT GENERAL CORPORATION

Mr. DALBELLO. Chairwoman Giffords, Ranking Member Olson, and distinguished Members of the Subcommittee, thank you very much for this opportunity to discuss the role that the commercial satellite industry plays in keeping the space environment safe for the civil and commercial users.

The commercial satellite industry has been providing essential space services almost for as—almost as long as humans have been in space. Today Intelsat operates a fleet of over 50 satellites. In response to business opportunities and changing market needs we routinely replace satellites and relocate them in orbit. To change the orbital location of a satellite, we must delicately move a minibus-sized object, multi-ton object traveling thousands of kilometers an hour through the crowded geostationary arch, avoiding the potential for collision with or for disturbing the radio communications of any of—any one of the hundreds of commercial and government satellites in that orbit.

By and large this project—process takes place without government regulation or oversight, using rules developed through experience and implemented by consensus among the commercial operators themselves. This remarkable example of international and inter-company cooperation and self-reliance is premised on a simple realization; that the results of a collision could be catastrophic.

In flying our satellites Intelsat relies on data from our own spacecraft and information derived from the U.S. Air Force's Commercial and Foreign Entities Program. During special activities such as satellite relocations and transfer orbit missions, we also exchange data with other satellite operators whose satellites are operating near or adjacent to our satellites.

There are, however, drawbacks to relying on the CFE data. These data do not have a—have the required accuracy for credible collision detection. The data also lacks the spacecraft maneuver information that is necessary to properly predict the orbit, the orbital location of active satellites.

An operator that is relying on the CFE data alone must increase the calculated collision margin to avoid potential close approaches. This wastes fuel and satellite life and introduces uncertainty into the equation. Because of the relatively imprecise nature of the publicly-available data, the U.S. Air Force has also established the interim CFE Data Analysis Redistribution Approval Process, more commonly known as the Form-One Process. Through the Form-One Process operators can request additional, more precise information on specific close-approach situations.

However, the current Form-One Process is difficult to incorporate as an operational tool. There is no approved, DOD-approved Form-One guidance document that articulates the boundaries of the program, nor is there any written specification of the operational procedures that a compliant operator should follow when using the process. This lack of clarity also creates uncertainty.

In response to the shortcomings of the current program, a number of global satellite operators have begun a dialogue on how to best ensure information sharing within the industry. One proposal currently being discussed is the creation of a global data center. That would allow operators to augment data coming from the CFE Program with precision orbit data and maneuver plans from their respective fleets. Today a prototype of the data center is operating with seven of the largest global operators regularly contributing data from over 120 satellites. While there is still significant work left to refine the process, the initial results from the data center prototype are promising.

Although such private initiatives have great value, it is essential that the U.S. Government continue to play a leadership role on the issue of space traffic control. In pursuit of this objective, we would offer the following specific recommendations. These are detailed more completely in my written testimony, but just in bullet form.

Provide adequate funding for space situational awareness. The space situational network that we have today was developed during the Cold War, mostly for looking for missiles coming over the horizon. There is a lot of opportunity for good, productive investment in upgrading that capability.

Maintain and expand the U.S. Commercial and Foreign Entities Program. As Lieutenant General James pointed out, it is current—the program is currently a pilot, and it is important that we mature that program to an operational status.

Third, develop new mechanisms for sharing space traffic information between and among nations. Several other countries, including France and the UK and Australia, Russia I am sure has a network. There are many countries who have networks monitoring space. The question is how are we going in the future to share information between those networks.

Fourth, take advantage of the data readily available from the private sector. We all monitor all of our satellites all the time. It is information that is more precise than the information that the government can have by sensing us in space. We would gladly share this information in the interest of creating a safer space environment.

And finally, be creative in the development of new data sources. We have offered to fly a sensor on every one of our commercial satellites that is going to space, and if you were go put a sensor on every commercial satellite and every scientific satellite that went up over the next five years, you would have for almost no investment you would have an amazing view of the heavens.

So in conclusion, within the next decade many more countries will gain the ability to exploit space for commercial, scientific, and government purposes. It is essential that the world's governments provide leadership on space management issues today in order to protect the space activities of tomorrow.

[The prepared statement of Mr. DalBello follows:]

PREPARED STATEMENT OF RICHARD DALBELLO

Commercial Management of the Space Environment

Chairwoman Giffords, Ranking Member Olson, and distinguished Members of the Subcommittee, thank you for this opportunity to discuss the role that the commercial satellite industry plays in *"Keeping the Space Environment Safe for Civil and Commercial Users."* The commercial satellite industry has billions of dollars of assets in space and relies on this unique environment for the development and growth of our businesses. As a result, safety and the sustainment of the space environment are two of our highest priorities. This afternoon I would like to provide a quick survey of past and current industry space traffic control practices and to discuss a few key initiatives that the industry is developing in this area.

Background

The commercial satellite industry has been providing essential space services for almost as long as humans have been exploring space. Over the decades, this industry has played an active role in developing technology, worked collaboratively to set standards, and partnered with government to develop successful international regulatory regimes. Success in both commercial and government space programs has meant that new demands are being placed on the space environment. This has resulted in orbital crowding, an increase in space debris, and greater demand for limited frequency resources. The successful management of these issues will require a strong partnership between government and industry and the careful, experience-based expansion of international law and diplomacy.

Throughout the years, the satellite industry has never taken for granted the remarkable environment in which it works. Industry has invested heavily in technology and sought out the best and brightest minds to allow the full, but sustainable exploitation of the space environment. Where problems have arisen, such as space debris or electronic interference, industry has taken the initiative to deploy new technologies and adopt new practices to minimize negative consequences.

In the late 1970s and early to mid 1980s, both Russia and the United States engaged in the testing of anti-satellite weapon systems. Both countries abandoned these efforts, in part because the creation of additional space debris was inconsistent with their plans for the full exploration and exploitation of the space environment. Similarly, the future preservation of the space environment will rely on every nation's appreciation that its own self-interest lies in preserving this precious common good.

The major commercial satellite operators routinely share information and resources with each other and with governments to help ensure the protection of the unique and irreplaceable space environment. Intelsat operates a fleet of more than 50 satellites—the largest geostationary commercial fleet ever assembled. In response to business opportunities and changing market needs, Intelsat regularly replaces satellites and relocates satellites in orbit. Recently, in response to a request from DOD, Intelsat moved a satellite that had been operating over the United

States to the other side of the world in order to provide critical UAV services in Afghanistan and Iraq. This entire process was completed in less than two weeks.

The majority of our fleet is in geostationary orbit. This orbit is 32,000 km above the Earth in a region where the movement of our satellites exactly matches the rotation of the Earth, thereby making the satellite seem "fixed" in the heavens. To change the orbital location of a satellite, Intelsat must delicately move a minibus-sized, multi-ton object, traveling thousands of kilometers per hour, through the crowded geostationary arc, avoiding the potential for collisions with, or for disturbing the radio communications of, any of the more than 250 other commercial communications satellites in that orbit. Other satellite companies that operate in lower Earth orbits—some a few hundred kilometers above the Earth—must deal with many more operational objects and a substantially increased debris environment. The recent collision between the Iridium satellite and a non-operational Russian satellite took place in this lower Earth orbit.

With the exception of the initial grant of approval by a national regulator, by and large, the management of satellite operations takes place without governmental regulation or oversight, using rules developed through experience and implemented by consensus among the commercial operators themselves. This process has been used effectively and without incident since the commercial satellite communications era began in the 1960s. This remarkable example of international and inter-company cooperation and self-reliance is premised on a simple realization that the results of a collision could be catastrophic.

In low-Earth orbits (generally 200–1000 km above Earth), objects and debris will slowly, over a decade or so, re-enter the Earth's atmosphere. In the narrow geostationary orbit (32,000 km above the Earth) the debris from a collision would endure for tens of thousands of years, effectively rendering a portion of the GEO arc useless.

Space Traffic Control—Past and Future

I would like to take a moment and describe Intelsat's past and current approach to space operations. I would also like to describe the current state of data-sharing among commercial satellite operators and suggest a new paradigm for easing critical communications among operators and between operators and governments.

As I alluded to above, commercial satellite operators, working with limited government oversight, have over the years developed their own internal protocols and procedures to ensure the safe operation of their fleets. Operators have also become adept at informal coordination and information exchange with operators who are 'flying' satellites adjacent to or near their satellites.

At the beginning of the space age and through most of the 1970's and 1980's there was no serious examination of 'space traffic control' since there was a great deal of space and, quite literally, no traffic to control. As the world entered the 1990's deregulation, privatization, and the rapid expansion of the video market all served to power a growth in communication and broadcast satellite activity. By the late 1990s, Intelsat decided that it would be prudent to gather better information on the space environment, so it contracted with the Aerospace Corporation via the Space Operation Support Office (SOPSO) to conduct close-approach monitoring.

The Aerospace Corporation developed a fully automated two-tier program that determined satellite close approaches based on miss-distances and conjunction probabilities. The initial detection was based on the publicly available NORAD data known as the Two Line Element sets (TLE). Once a potential conjunction between two space objects was identified, Aerospace would request the more accurate special perturbation (SP) ephemeris data from the Air Force to confirm the conjunction. The Aerospace Corporation shut down the SOPSO office abruptly in November 2002.

In 2003 Intelsat contracted MIT Lincoln Lab to perform close-approach analysis. It was a semi-automated system and the conjunction detection was based on miss-distances only. Because MIT had a contractual relationship with the Air Force, and therefore direct access to the more precise observations from the deep space surveillance network, the conjunction monitoring was based on a single-tier process. However, the monitoring was restricted to non-active space objects, such as debris. This restriction was due to the difficulties in detecting past maneuvers and predicting future maneuvers of active satellites. Such maneuvers tend to invalidate longer term close-approach predictions.

Since January 2007, Intelsat has relied on an in-house close approach monitoring system. This system follows the two-tier model and relies on the US Joint Space Operations Center (JSpOC) to validate potential conjunctions detected using the TLE data that is available through the U.S. Government's "*Spacetrack.org*" web site. We routinely screen our satellites using the TLE data, and, during special activities such as satellite relocations and transfer orbit missions, we also exchange data with other satellite operators whose satellites are operating near or adjacent to our satellites. The exchanged information usually consists of the latest orbital information, near-term maneuver plans, frequency information and contact information for further discussion.

There are drawbacks to the current close-approach monitoring process. In addition to a lack of standards for TLE modeling, TLE data do not have the required accuracy for credible collision detection. An operator that is forced to rely on TLE data must increase the calculated collision margin to avoid potential close approaches. In most cases, threats identified using the basic TLE data are downgraded after coordination with other operators or further evaluation with more precise orbital data. In addition to the inaccuracies of the TLE data, these data also lack reliable maneuver information. This limits the usefulness of the TLE for longer-term predictions, since maneuver information is necessary to properly predict the orbital location of active satellites. Today, operators relying on chemical propulsion systems will maneuver about once every two weeks to maintain their orbital position. Accurately predicting the orbital location of a satellite will become more difficult as more satellites employ ionic propulsion systems and are, essentially, constantly maneuvering.

Adding complexity to this problem is the fact that there is no single standard for representing the position of an object in space. Different operators characterize the orbital position of their satellites differently, depending on the software they use for flight operations. In addition, there is no one agreed upon protocol for sharing information, and coordinating operators must be prepared to accommodate the practices of other operators. To do this, operators must maintain redundant file-transfer protocols and tools to convert and reformat information so that it is consistent with other owners'/operators' software systems for computing close approaches. Separate tools are necessary to exchange data with each operator. Some operators write their own software tools for monitoring and predicting the close approach of other spacecraft while others contract with third parties for this service. The magnitude of the effort to maintain "space situational awareness" grows quickly as the number of coordinating operators increases. Unfortunately many operators are not able or willing to participate in close approach monitoring due to lack of resources or capabilities.

Because of the relatively imprecise nature of the TLE data, the U.S. Air Force established the "Interim CFE Data/Analysis Redistribution Approval Process" (Commonly referred to as the Form 1 Process) for granting operators access to information that goes beyond the basic TLEs. Through the Form 1 Process, operators can request additional information (the special perturbation, or SP, data) on specific 'close approach' situations. Although helpful, it is cumbersome to rely on the Form 1 Process as an operational tool because it requires advance notice, which is often impossible in emergency situations. In addition, conjunction events often require close cooperation and interactive communication. Today, the Form 1 Process relies primarily on e-mail as a method of communication and the U.S. Government does not guarantee the rapid turnaround necessary in most cases.

The U.S. Government is currently reviewing its policies on the distribution of TLE data. One proposal would require the negotiation of individual "tailored agreements" between the U.S. Government and satellite operators requesting information. Other proposals have suggested that the U.S. Government might be willing to provide additional conjunction assessment services on a reimbursable basis. At this writing, it is unclear how or whether the CFE program, which was originally scheduled to terminate this year, will continue.

Recently, Intelsat conducted an informal survey of satellite operator professionals who routinely interact with the JSpOC and the CFE process. Their reaction indicated that there are a few key areas where the current process could be immediately improved:

1. **Clarify the Process—**To manage expectations, publicly clarify the process that should occur from the moment a Form 1 request is submitted to JSpOC until the analysis is returned to the operator. The JSpOC should also designate a POC for questions.
2. **Make the Process Interactive—**To reduce uncertainty, JSpOC should provide a receipt to acknowledge that the operator request has been received (or that JSpOC has received the information it requested) and provide notification of status change as operator requests go through the system, or as the JSpOC responds to perceived threats.
3. **Distinguish between Routine and Emergency Requests—**Allow operators to include a priority flag for time-sensitive requests so critical issues can receive attention first.

4. **Where Possible, Indicate Data Quality—**To assist the operators in making decisions, provide quality flags, where possible, to indicate the quality of the data used by the JSpOC in conducting their analysis.

Data Center Proposal

In response to the shortcomings of the current TLE-based CFE program and the recognition that better inter-operator communication is desirable in and of itself, a number of satellite operators have recently begun a broad dialogue on how to best ensure information-sharing within the satellite communication industry. One proposal currently being discussed in the international operators' community is the "Data Center." As conceptualized, the Data Center would be an interactive repository for commercial satellite orbit, maneuver and frequency information. Satellite operators would routinely deposit their fleet information into the Data Center and retrieve information from other member operators when necessary. The Data Center would allow operators to augment existing Two Line Element (TLE) data with precision orbit data and maneuver plans from the operator's fleets. The Data Center would also:

- Perform data conversion and reformatting tasks allowing operators to share orbital element and/or ephemeris data in different formats;
- Adopt common usage and definition of terminologies;
- Develop common operational protocols for handling routine and emergency situations;
- Exchange operator personnel contact information and protocols in advance of need.

If the Data Center were to gain acceptance, it could perform additional functions, such as the close-approach monitoring tasks currently being conducted by the operators. In this phase, U.S. Government-provided TLE data could be augmented by the more precise data available from the operators. This would improve the accuracy of the Center's conjunction monitoring and could provide a standardized way for operators to share information with the U.S. Government and other governments. In the early stages, information on non-operational space objects would still need to be supplemented by TLE data from the Air Force CFE program and/or other government programs. U.S. Government, or other government support would still be required when precise information is needed to conduct avoidance maneuver planning.

A prototype active Data Center was established to study the feasibility of such an approach following workshops of the major commercial owners/operators held in February 2008 in Washington, DC and December 2008 in Ottawa. A majority of the operators present agreed on the need to simplify the data exchange process to minimize risk for safety of flight and on the importance of creating a common Data Center. The operators agreed to work on a prototype Data Center as a proof-of-concept to improve coordination for conjunction monitoring.

The prototype Data Center expanded quickly and today seven operators are participating and regularly contributing data from over 120 satellites in geostationary orbit. The participating operators receive daily close-approach alerts when the miss-distances and conjunction probabilities fall below certain thresholds and a daily neighborhood watch report showing the projected separations of satellites that are flying in an adjacent control box. The participating operators provide their ephemeris data in the reference frames and time systems generated in their flight software and the Data Center performs the transformation and reformatting to a common frame for close-approach analysis. This greatly simplifies the efforts and reduces the burden on individual operators and thus encourages participation. A strict data policy has been put in place to ensure privacy of the data. The Data Center is not allowed to redistribute the data received from the owners/operators without approval from the owners of the data. While there is still significant work left to refine the process, the initial results from the Data Center prototype are very promising.

The principal goal of the Data Center is to promote safety in space operations by encouraging coordination and communication among commercial operators. The Data Center could also serve as a means to facilitate communication between operators and governments. Details on the implementation of the Data Center, services to be provided, usage policies, structure of the organization and by-laws have yet to be determined and would ultimately require agreement among the member operators. The development of a Data Center could provide new visibility and awareness of the geostationary orbit, allow all satellites to be flown in a safer manner and reduce the likelihood of an accidental international incident in space.

The Data Center is a tool for commercial operators to exchange information about their active spacecraft. However, the operators must still rely on the U.S. Government to monitor dead satellites and other objects drifting in geostationary orbit, that could collide with an active satellite. The safety of commercial space activities can be ensured only if there is a commitment from the U.S. Government, and other governments equipped with the same type of radar or optical observation capabilities, to monitor uncontrolled space objects and to alert commercial operators, in real time, of the risks of collision with their operational satellites.

To be sure, the motivations behind the civil and military space activities of nations are far more complex than those of the commercial satellite industry. However, the central goal of preserving the operational space environment binds all space participants with a common purpose. It is important to note, in particular, the very critical role played by the geostationary orbit. Should this unique circular orbit be polluted by a space collision, the impact on military and commercial communications would be devastating.

For all of these reasons, the U.S. Government should play a leadership role on the issue of Space Traffic Control. In pursuit of this objective, we would offer the following specific recommendations:

- **Provide adequate funding for Space Situational Awareness—**Space Situational Awareness (SSA) is the ability to monitor and understand the constantly changing space environment. The task of locating and tracking active satellites and space debris is one of the most challenging aspects of SSA. Currently, the U.S. Air Force's JSpOC plays a key role internationally in tracking, and reporting on, all man-made objects in orbit. The JSpOC receives on-orbit positional data from the Space Surveillance Network, which is composed of both optical and radar sensors throughout the world. This allows the JSpOC to attempt to maintain accurate data on every man-made object currently in orbit. Today the JSpOC is tracking more than 10,000 objects in space. Like all parts of the Pentagon budget, funding for expansion of the Space Surveillance Network is under pressure. In light of recent events, Congress and the Air Force need to provide higher priority for this funding.
- **Develop new mechanisms for sharing space traffic information between nations—**The U.S. is not alone in its SSA efforts. Russia, several European states, China, Australia, and others are making investments in SSA capabilities. Each of these data sets, taken alone, is not likely to solve the emerging space traffic problems. It is also critical that nations strive to create rapid, reliable, and non-bureaucratic institutions for sharing the new data they are collecting.
- **Maintain and expand the U.S. Commercial and Foreign Entities (CFE) program—**Established by the U.S. Congress as a pilot program, CFE now provides a limited but essential set of U.S. Government data on existing space objects for release to certain commercial and foreign entities. Although CFE has been advantageous for governments and industry, the accuracy of the data currently provided is not sufficient for precise collision detection/assessments, support of launch operations, end of life/re-entry analyses, or anomaly resolution. The CFE pilot program was originally set to expire this year. It is essential that the current program be formalized and expanded to meet the evolving needs of global space operators.
- **Take advantage of the data readily available from commercial satellite operators—**It would be extremely valuable if satellite operators and governments could find a way to share their collected data in an organized, cooperative fashion. Such a sharing process could result in the creation of a "Global Data Warehouse" for space information. Governments and operators might be encouraged to submit information on the orbital elements of space objects as well as their maneuver plans and operational frequencies. If information were gathered in a central depository, warning and alert messages could be distributed automatically in a common format to participating operators, while protecting sensitive commercial or government data. Intelsat, along with other satellite operators, has offered to share its information, free of charge, with the U.S. Government.
- **Be creative in the development of new data sources—**As I mentioned previously, most commercial operators rely on the Air Force Space Command's "JSpOC," for tracking man-made objects and debris in orbit. The JSpOC receives satellite position data primarily from the global Space Surveillance Network. As upgrades to this network are likely to be expensive and long-term in nature, it is important that we look at creative solutions to re-

spond to our growing needs. As an alternative to expensive terrestrial infrastructure and dedicated government programs, DOD should try to take creative advantage of every commercial platform going to orbit. Every commercial launch is an opportunity for a technology testbed, or the deployment of a novel operational capability. Rather than develop and launch dedicated assets to address this problem, the Air Force should consider launching low-cost sensors on every satellite going to orbit. By including commercial and scientific satellites in this endeavor, it would be possible to obtain a holistic view of the space environment in a few years, with little government investment. Intelsat alone has 10 satellites currently under construction or in development. Our colleagues and competitors in the industry are similarly positioned with respect to their new spacecraft investments. Imagine, if you will, the improvement to our understanding of the space environment if every satellite launched over the next five years were part of an integrated, global monitoring system for space.

- **Begin an international dialogue on 'Rules of the Road' for space—**Although there are reasonable differences of opinion regarding the value of additional laws or international agreements, there seems to be general acceptance among space operators that certain guidelines or norms developed by consensus may play a useful role in ordering our future space activities. A good example is the space debris guidelines developed by the Inter-Agency Space Debris Coordinating Committee, an intergovernmental body created to exchange information on space debris research and mitigation measures. The development of other non-binding guidelines should be investigated. Such non-binding guidelines might include:
    - A formalization of existing rules regarding the movement of spacecraft between orbital locations;
    - Protocols for informing other operators when one of their spacecraft could potentially cause damage to other space objects;
    - Protocols for managing the loss of control of a satellite.

Within the next decade, many more countries will gain the ability to exploit space for commercial, scientific and governmental purposes. It is essential that the world's governments provide leadership on space management issues today in order to protect the space activities of tomorrow. Bad decisions and short-term thinking will create problems that will last for generations. Wise decisions and the careful nurturing of our precious space resource will ensure that the tremendous benefits from the peaceful use and exploration of outer space are enjoyed by those who follow in our footsteps in the decades to come.

BIOGRAPHY FOR RICHARD DALBELLO

SUMMARY OF QUALIFICATIONS

- Creative administrator with more than 15 years of experience in the communications and aerospace industries
- Detailed knowledge of U.S. Government legislative and regulatory processes
- Comprehensive understanding of international organizations and policy processes
- Proven skill in international business, trade, and negotiations
- Dynamic leader and team builder capable of motivating others towards success

RECENT WORK HISTORY

Intelsat General, August 2005–Present

Vice President, Legal and Government Affairs for the leading global provider of commercial satellite services to U.S. Federal, State and Local Governments, NATO members, and to the integrators that support them.

- Oversees all aspects of legal, contracts, and procurement departments for $300 M satellite services provider
- Chief lobbyist and legislative coordinator
- Provides policy support for key business development initiatives
- Serves as Intelsat General's public voice through high-profile editorials, articles, conferences, and radio and television appearances

- Manages Human Resources and security functions

Satellite Industry Association/Satellite Broadcasting and Communications Association, August 2001–August 2005

President of premier trade organizations representing U.S. and international satellite manufacturers, launch service companies, and direct broadcast and satellite radio service providers.

- Managed a staff of 20 and a budget of $4 million
- Served as key industry adviser to policy-makers in Congress, the FCC, and the Administration on commercial communication and direct broadcast satellite issues
- Organized over 50 pleadings and hundreds of informal meetings regarding critical spectrum allocation decisions at the FCC
- Led industry efforts to revise satellite export control regulations resulting in the introduction of draft legislation in the Senate

Spotcast Communications, December 1999–August 2001

General Counsel of global wireless-media and content-delivery company with operations in Europe, Asia, and the United States.

- Managed securities compliance for private and institutional funding rounds totaling in excess of $15 million
- Drafted and negotiated contracts and license agreements in the United States, Hong Kong, Singapore, and France
- Managed foreign and domestic external legal counsel
- Developed and implemented policies to ensure that personal customer data was handled in a way consistent with emerging national and international privacy laws
- Managed company's patent and trademark portfolio and eventual sale of these assets when the company ceased U.S. operations

ICO Global Communications, April 1997–December 1999

Vice President, Government Affairs and Business Development for London-based satellite company offering mobile communication services around the globe.

- Established company's North American office
- Developed and implemented strategies to secure critical operating licenses resulting in negotiated spectrum transition agreements with U.S. broadcasters
- Functioned as business development liaison between North America and London on projects involving broadband data and navigation technologies
- Managed U.S. export license process for critical space hardware

White House, February 1993–April 1997

Assistant Director (Office of Science and Technology Policy) for satellite communications, space technology, and aeronautics

- Coordinated White House efforts which led to the privatization of INTELSAT and INMARSAT
- Served as White House representative to business, international, and contractor communities during space station redesign effort
- Developed government-wide policy to assure commercial access to the U.S. Global Positioning System (GPS)
- Developed funding rationale and investment plan for NASA and DOD Advanced Launch Vehicle programs

NASA, March 1991–February 1993

Director (Commercial Communication Satellite and Remote Sensing Division) for research and commercial applications programs at four NASA centers and various universities

- Managed $20 million R&D and technology application program to transfer NASA communication satellite and remote sensing technology to the private sector
- Negotiated NASA/industry and NASA/university technology agreements

- Directed industry-sponsored experiments program for the Advanced Communication Technology Satellite (ACTS)

OTHER RELEVANT WORK EXPERIENCE

- **U.S. Congress—***Project Director, Office of Technology Assessment*
- **U.S. Department of Commerce—***Director, Office of Space Commerce*
- **San Francisco Superior Court—***Law Clerk*
- **California Supreme Court—***Intern*

EDUCATION

- University of Illinois, Urbana, IL, B.A. Political Science—1975
- University of San Francisco School of Law, San Francisco, CA, J.D.—1979
- McGill University, Montreal, Quebec, LL.M.—1984

Chairwoman GIFFORDS. Thank you.
Dr. Pace.

STATEMENT OF DR. SCOTT PACE, DIRECTOR, SPACE POLICY INSTITUTE, ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS, GEORGE WASHINGTON UNIVERSITY

Dr. PACE. Thank you, Madam Chairman and Ranking Member Olson, distinguished Members of the Committee, thank you for the opportunity to be here today.

The long-term sustainability of the space environment from low-Earth orbit out to the moon is, of course, of fundamental importance to many national interests, from national security to the global economy. So I commend the Committee for holding this hearing today and appreciate it.

The space environment, as has been pointed out, is very different today from what it was in 1957, when the first satellites were launched, and the concerns about sustainability today arise not so much from the activities of the traditional space-faring nations like the United States, but from new entrants and potential entrants such as Iran and North Korea, who have virtually no capabilities to monitor and control space objects. So, if you will, there are certainly some new irresponsible drivers on the highways these days.

It is easy to understand the appeal of terms like space traffic control, space traffic management, but these can be misleading on a variety of both technical and political grounds. That is, the space environment is not like aviation or the highways. Satellites cannot maneuver as easily as cars or airplanes might, and of course, operating an international regime, questions of sovereignty are much different than they are for the highways.

Where the analogy of traffic management does work is in the idea of having common understanding of definitions, standards, operating procedures, and practices for space operators to communicate with each other. As with the civil aviation, and, of course, I am hopeful they will communicate in English, this has been helpful to us, a good example of the evolving international norms with these standards and procedures can be found in the Inter-Agency Debris Coordination Committee guidelines as Mr. Johnson mentioned on minimizing orbital debris. These guidelines deal with breakup of space systems, end of mission life, satellite disposal, and avoiding intentional harm.

The IADC guidelines on orbital debris emerge from discussions of best practices among technical experts rather than legal arguments among international lawyers. IADC discussions include government, academic, commercial experts from many countries with a focus on what made operational sense, and we should continue to encourage efforts that look at best practices in real-world space operations and develop further voluntary guidelines.

I should point out that the former head of the French Space Agency, Gerard Brachet, is currently leading international discussions along this line that have included the United States and other major space powers, and it is my understanding that the U.S. has found this constructive.

To support these norms and other international interests, there is a clear need for better space situational awareness for all sectors, civil, commercial, national security. A first step in improving monitoring is to enable better, faster standardized information exchange among satellite owners and operators. And some good news here is that international open standards are close to approval. The Consultative Committee for Space Data Standards, which is made up of all the major space agencies in the world, including I would point out China and Russia, approved a draft recommended standard for orbit debris messages in July of last year. The CCDS, this international body, over 400 space missions have chosen to use CCDS communication standards. So there is a large-installed base, I think, of interest there for promulgating these new standards.

At Congressional direction, the Air Force operates a Commercial and Foreign Entities Program that distributes satellite positions known as two-line elements, as you have heard, and related messages free of charge. This has been an excellent start toward improved data sharing across the different space sectors, but it is only partly satisfactory. The two-line element data is not the most precise, and sometimes it is out of date or otherwise incorrect. It is perfectly fine for cataloguing. It is not so fine for conjunction analyses as you have heard.

This leads to false alarms about potential conjunctions due to the broad error envelopes associated with the TLE position predictions, and such alarms in turn consume more analytical resources and requests for more precise and timely data to resolve potential concerns. The commercial satellite industry as you have heard proposes to increase data sharing, and this is, I think, again, another excellent start, but there are some natural concerns. For example, we may not want to say where some satellites are, even if they exist. We may not want to reveal what our full capabilities are or their limitations. There is concern about liability and the timeliness of any data provided, and there is a normal competition for public resources as we are all familiar with.

So there is still an international need for independent verification of the information provided. There are a variety of analogies for how to organize and govern these models for data sharing, which I provided in my written testimony, which I would be happy to discuss, but I think the most important thing to realize is that the core policy problems associated with this are primarily on data policy and information dissemination. It is not about technology per se. It is about what we want to do to secure our common interests, and it is my hope that the United States will recognize the value of sustainable space environment as an international public good that, in turn, supports our own strategic national interest. We are more reliant on space than virtually any other country, and therefore, our leadership in this area I think is in our national interest.

Thank you.

[The prepared statement of Dr. Pace follows:]

PREPARED STATEMENT OF SCOTT PACE

Thank you, Madam Chairman, for providing an opportunity to discuss this important topic. The long-term "sustainability" of the space environment, from low-Earth orbit and out to the Moon, is of fundamental importance to many national interests, from national security to the global economy.

Introduction

Space activities contribute to the long-term well being of society through improved scientific understanding in every field of knowledge, most notably with respect to the global environment. The design, development, and operation of space systems constitute major technical and managerial challenges in systems engineering and thus help strengthen the engineering capacities of participating nations. China and India are but the latest examples of nations that see the value of space to their further development.

Most immediately, space systems such as satellite communications, environmental monitoring, and global navigation satellite systems are crucial to the productivity of many types of national and international infrastructures such as air, sea, and highway transportation, oil and gas pipelines, financial networks, and global communications.

Information services enabled by the unique capabilities and global reach of space systems are crucial to the functioning of the global economy. In a time of global economic crisis, the United States and other space-faring nations need to cooperate more closely to protect space systems from intentional or unintentional interference.

The space environment today is a very different from what it was in 1957 when the first satellite was launched, or 1972 when the international convention on liability for damage caused by space objects was signed. In the past two years, a Chinese anti-satellite test and communications satellite collision have added thousands of orbital debris to the local space environment, much of which will be in orbit for many years to come. Today, the Joint Space Operations Center is tracking over 19,000 man-made objects and that number is growing.

The space environment is not safe—it might be fairly characterized as an environment in which everything is trying to kill you and your spacecraft. It can however be made sustainable in that the vital functions we use space for today can be reliably maintained for generations to come.

Concerns about sustainability arise not so much from the activities of traditional space-faring nations, like the United States, but from new entrants such as Iran and possibly North Korea who have virtually no capabilities to monitor and control space objects. Concerns arise with respect to China, which has significant and impressive space capabilities, but whose ASAT test showed an alarming disregard or lack of understanding of orbital debris. Finally, there are non-state actors like universities, who are deploying increasingly small satellites for commercial and scientific purposes that may be challenging to monitor in the crowded near-Earth environment.

Space Sustainability

The irreversible accumulation of orbital debris constitutes the most obvious concern for the sustainability of space use. However, it is not the only factor and I'd like to mention two that are often overlooked:

Space weather—yes, space has weather of a sort. There are geomagnetic storms from the Sun, varying energies from the Van Allen radiation belts around the Earth, ionosphere disturbances and scintillations, and geomagnetic induced currents. Coronal mass ejections from the Sun and their associated shock waves can compress the Earth's magnetosphere and induce geomagnetic storms with effects on Earth as well as local space.

Space weather cannot be controlled, but monitoring and prediction are becoming more important as humans go farther out into space and more of the global economy depends on the reliable functioning of space systems. Space weather monitoring is becoming less of a "science project" and more of an operational requirement alongside traditional weather monitoring systems in space.

Radio frequency interference—there is no point in going to space if you cannot communicate home. No nation "owns" the radio frequency spectrum but all nations depend on keeping it free from interference, whether intentional or unintentional. Space-based services are particularly vulnerable to interference because satellites in space cannot easily increase their transmitted power in the face of increased noise. Many space services are not traditional two-way communications, but include passive monitoring, active sensing, and one-way broadcasting. As a result, critical frequency bands require special international protection, e.g., those used for GPS, weather and climate monitoring, and satellite communications.

There is growing pressure on all these bands from terrestrial commercial technologies and regulatory protections are more important than ever. In this regard, the Federal Communications Commission, in partnership with the National Telecommunications and Information Agency has an important role in protecting the national security, public safety requirements, and scientific needs of federal agencies relying on space systems.

Returning to the topic of orbital debris, it is easy to understand the appeal of terms like "space traffic control." The drama of International Space Station astronauts taking temporary refuge in their Soyuz return capsule and greater awareness of space operators taking precautionary maneuvers seem to argue for putting someone in charge. Unfortunately, "space traffic management" can be misleading on both technical and political grounds. The space environment is not like that of aviation or highways in that satellites cannot maneuver easily. Further, the space environment belongs to no one and thus there is no central authority that spacecraft owner/operators can use to protect regions of space vital to them. An international agreement authorizing an independent organization to provide and enforce where sovereign space assets may travels is a difficult concept for many nations.

Where the analogy with traffic management does work is in the idea of having a common understanding of definitions, standards, operating procedures, and practices for space operators to communicate with each other. As with international civil aviation, I am hopeful that they will communicate in English. Rather than imposing a "top down" space authority, there are promising avenues for an evolving consensus on "rules of the road" and confidence-building measures based on international norms for all types of space activity.

Guidelines and Standards

A good example of evolving international norms can be found in the Inter-Agency Space Debris Coordination Committee (IADC) guidelines on minimizing orbital debris. These guidelines deal with the break-up of space systems, end-of-mission-life satellite disposal, and avoiding intentional harm. Another good example is the international condemnation of the Chinese ASAT test that showed international awareness of the risks posed by tests that create long-lived orbital debris.

To support these norms and other national interests, there is a clear need for better space situational awareness for all space sectors—civil, commercial, and national security. While space traffic control may not be feasible, better space traffic monitoring is feasible. A first step in improved monitoring is to enable better, faster, standardized information exchanges among satellite owners and operators. Some good news here is that international, open standards are close to approval. The Consultative Committee for Space Data Standards (CCSDS) approved a Draft Recommended Standard for Orbit Data Messages in July of last year. The CCSDS is an international body of all major space agencies and over 400 space missions have chosen to use CCSDS communication standards. These missions have included everything from the U.S. rovers on Mars to the Chinese Chang'e missions to the Moon.

Use of CCSDS standards allows for (but does not mandate) operational cross-support among space agencies. Representation is quite broad, with expert participation from the French space agency (CNES), the European Space Operations Center (ESOC), the German Space Operations Center (GSOC), the Japanese space agency (JAXA), Intelsat, Inmarsat, the U.S. Air Force, and NASA's Goddard Spaceflight Center, and the Jet Propulsion Laboratory. Representation is not systematic, however, and often depends on a few dedicated individuals whose work is tolerated but not always supported by home institutions busy with other priorities. A more intentional U.S. strategy that resources and staffs international standards work would improve the coordination of U.S. positions and the chances for greater international support of those positions. For example, I would see closer coordination by the Air Force Space Command, National Reconnaissance Office, and the Operationally Responsive Space Office with on-going NASA efforts as a good near-term opportunity.

An important characteristic of CCSDS standards are that they are open and transparent and do not require the transfer of sensitive technologies. This is necessary if international satellite operators are to be able to share location data with each other—if not the characteristics of the satellites themselves. A more difficult challenge for space traffic monitoring will be in determining where a spacecraft might have been or where it will be. This requires mathematical modeling techniques of propagation or interpolation from existing information to make predictions. These models can vary quite a bit and will often contain proprietary techniques that make it difficult to make comparisons between different models. While models can and should evolve, it will be important to international acceptance that any proposed standard for a predictive model not be proprietary but subject to open inspection and improvement.

As satellite architectures evolve, information exchanges and practices can be expected to evolve as well. For example, it is difficult to track objects smaller than 10 centimeters in Earth orbit but networks of nano-satellites may be that small or smaller. Each such satellite or group of cooperative nano-satellites might be modeled as sphere of fixed size. Independent verification of their location might in turn require active measures such as transponder beacons or passive ones such as laser reflectors. Larger satellites could be used to carry piggyback payloads that observe their local environment and supplement information from dedicated ground and space-based sensors.

Different areas of space are used for different kinds of satellites and operational practices in low-Earth orbit, geosynchronous orbit, and polar/sun-synchronous orbits will be different. Groups of communications satellites operated by the same owner in geosynchronous orbit tend to be relatively slow moving with respect to each other and can be spaced closely. Conversely, communications satellites operated by different owners in low-Earth orbit may be moving at high speeds relative to each other and will need wider spacing for safety. In analogy to air traffic, satellites may be stacked into different altitudes and inclinations to ensure separation; with separations being wider for satellites operated non-cooperatives (i.e., by different organizations).

The IADC guidelines on orbital debris emerged from discussions of best practices among technical experts rather than legal arguments among international lawyers. Those technical discussions included government, academic, and commercial experts from many countries with a focus on what made operational sense. At this stage, it seems premature to specify any binding "rules of the road" for space but it is time to look at real-world operations and see if there are useful practices that could be documented in similar voluntary guidelines. The former head of the French space agency, Gerard Brachet, is currently leading international discussions along this line that have included the United States and other major space powers.

Improving Data Sharing

At congressional direction, the Air Force operates a Commercial and Foreign Entities Support program that distributes satellite positions (know as two-line elements) and related messages free of charge. This has been a good start toward improved data sharing across the different space sectors, but only partly satisfactory. The two-line element (TLE) data is not the most precise and is sometimes out-of-date or otherwise incorrect. This leads to false alarms about potential conjunctions due to the broad error envelopes associate with TLE position predictions. Such alarms in turn consume more analytical resources in requests for more precise and timely data to resolve potential concerns.

The Air Force rightly gives top priority to human missions in space and national security functions. Unfortunately, they don't have the resources to look at everything (e.g., a continuous catalog-on-catalog collision screening) and some risks will not be addressed until it's too late. This is my understanding of what happened in the case of the recent Iridium-Cosmos collision in which it was only apparent what happened after the fact.

To meet the need for more analytical attention as well as data from optical sources, radar sources and satellite owner/operators, the commercial satellite industry has proposed data sharing through and international data clearinghouse. It is understandable that firms with billions of dollars of assets at risk in space would want to take steps to protect those investments. The primary challenges to implementing a data sharing warehouse are not technical or economic, but policy, notably how to balance commercial and security interests in the dissemination of data.

While a single, inclusive space situational awareness program, operated by the government or industry may seem to be the obvious answer the "one size fits all" approach will likely not work for multiple reasons.

- The government may not want to say where some satellites are or even if they exist
- The government may not want to reveal what its full capabilities are or its limitations
- There is concern about liability and timeliness for any data provided
- There is the normal competition for public resources
- There will still be an international need for independent verification

These are some of the obvious concerns that would arise in managing information about U.S. Government, international, and private sector satellites in a single source.

Aside from security, there is often a concern that the United States bears and would continue to bear a disproportionate share of the international space situational awareness (SSA) burden since we have the most capabilities. That is true but I would also say that we also have a disproportionate share of the dependency on space and improved data sharing is in our national self-interest. International cooperation provides an opportunity to access SSA data (e.g., optical, radar) from geographically dispersed areas of the world that would be expensive for us to access and an opportunity to routinely get data from satellite owner/operators who have better data than routinely found in government systems, at least compared to what is published in TLE form. While building new radars is quite expensive, it might be possible to exploit radio astronomy telescopes, but at some displacement of science observing time. Thus, outreach should include the international scientific community as well as foreign government and commercial industry.

The United States is already participating in an expanding dialogue with the European Union and the European Space Agency (ESA) on space situational awareness cooperation. In February, ESA hosted a technical meeting in Germany for U.S. and European technical experts to discuss standards for space object survey and tracking as well as cooperation in space weather monitoring. These discussions should not remain limited to Europe, of course, but should include U.S. friends and allies in other regions, such as Asia. As with other forms of security cooperation, sharing space situational awareness data will likely see expanding circles of trust—proceeding from the United Kingdom, Australia, and Canada, to NATO members, Japan and then other space-faring states, such as India.

As part of expanding cooperation, more formal steps could be envisioned such as banning any destructive testing in space that would create long-lived orbital debris—the kind of debris that pose a threat to all space activities. This would not necessarily means a ban on "space weapons" which would be unverifiable, nor would it ban space-based kinetic energy interceptors used for ballistic missile defense, or ground-based interceptors such as the SM–3. Priority should be placed on potential agreements that offer the best chance for an international consensus and verification.

Building international consensus can be a slow process but it should be kept in mind that there are risks in trying to be too comprehensive in approaches to space (e.g., creating a new treaty regime). There is a broad and flexible body of existing international space law that is sufficient for virtually anything we want to do in space. The development of new norms should start with our friends and allies that are active in space—in short, those with the most "skin in the game" and those willing to contribute new data sources or other capabilities.

Improving international space situational awareness is very feasible, in part because the information needed is quite basic and need not infringe on national security. The fundamental needs are to know where and when an object is located in space, a point of contact responsible for the object, plus knowledge of space weather and the Earth's atmosphere over time. There are many complex products and services that can be created with such basic information and space agencies and operators will do so. International cooperation should focus on sharing basic information using open standards while recognizing that proprietary "value-added" products will arise on their own in response to user needs.

Governance

It is an open question how international sharing of SSA data will occur. Several analogies come to mind in terms of governance models for international SSA data sharing. For example, sharing could evolve like the Internet, with a network growing based on common protocols. The CCSDS standards and rules of the road growing out of the IADC guidelines provide a starting point for this approach. A non-governmental, international, non-profit body modeled after ICANN (Internet Corporation for Assigned Names and Numbers) could encompass governments, non-governmental organizations, and private corporations that own and operate satellites to promote safer operations.

Another approach would be to expand the current Commercial and Foreign Entities (CFE) program by making high precision data more easily available for all reported objects. Sharing might initially be with other countries with security ties or space monitoring capabilities, similar perhaps to the U.S./Canadian sharing of warning information in NORAD, but on a much wider scale.

If expanded sharing via governments proves too slow, one might expect that geosynchronous (GEO) satellite operators (e.g., Intelsat, SES, J–Sat) will create their own data clearinghouse as a separate initiative. They would continue to use CFE-provided data but would share higher precision information from their satellites with other members.

It is hard to imagine the creation of a central international organization for SSA—what is sometimes called an "ICAO for Space" in analogy to the International Civil Aviation Organization. Similarly, it is hard to imagine expanding the role of the International Telecommunications Union (ITU) to include orbital debris. Both organizations have regulatory functions that work through sovereign states. They do not have direct operational roles. In the case of the ITU, it already has enough difficulties with managing the allocation of geosynchronous orbital slots due to the number of "paper satellites" in the pipeline already.

There are examples of mixing public and private data for common purposes, such as with weather predictions based on all sorts of international data. There are also examples where the government encourages non-government data sources, such as the International GNSS Service at the jet Propulsion Laboratory that monitors the GPS constellation through a voluntary federation of over 200 sites around the world. However, there is a clear line between awareness of data from open sources and using that data to operate the GPS constellation. In the case of space situational awareness, the benefits of sharing information have to be balanced against the risk of that same information being used to harm U.S. or allied assets. Another important policy question will be that of direct or indirect user fees. In general, international cooperation for the United States has worked best when not based on the exchange of funds, but the shared contributions to a common goal. The United States has opposed the charging of direct user fees for safety services in ICAO in order to not deter the use of those services. One might imagine similar treatment of orbital debris data as a safety service. While this might place a burden on the U.S. as the majority supplier of such data, our interests would not likely be served by trying to impose direct user charges that would lead to even more complex negotiations.

Summary

The issues that need to be addressed in keeping the space environment safe for civil and commercial users include:

1. **Protection of the space environment and mitigation of orbital debris.** Improving space situational awareness and reduction of the hazards posed by manmade orbital debris are both vital to the long-term sustainable use of space for all nations. Space-faring nations should adhere to consensus orbital debris mitigation standard practices recognized by the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. Improving space situational awareness should also be regarded as a promising area of international cooperation. In this context, proposals for voluntary "rules of the road" for space traffic need to be seriously considered.
2. **Protection of the radio spectrum used by space services from harmful interference,** with special attention to aviation safety services such as GPS and environmental services such as remote sensing. After space launch, communication is the most pervasive requirement for all space systems. Space-faring nations should work through the Space Frequency Coordination Group and within the International Telecommunications Union to achieve international support for necessary protections. Space agencies and industries should closely track the standards development work of terrestrial data communications standardization bodies in order to ensure compatibility of emerging commercial devices and services with current and future space needs.
3. **Promotion of open, inter-operable standards for space systems** and their associated mission operations systems to increase opportunities for international collaboration in space. Space-faring nations should support space standards developed by the International Standards Organization and

utilize the Consultative Committee for Space Data Systems and the Interagency Operations Advisory Group to strengthen capabilities for cross support across the international space community.

The core SSA policy problems are centered on data policy and information dissemination, followed by the assignment of appropriate roles and responsibilities to federal agencies and services. The primary data issue is to determine how much high precision information from U.S. Government sources can be made available in a timely manner and with whom. The second issue is how to most effectively promote international acceptance of CCSDS-developed standards for multilateral data exchange and to encourage non-proprietary propagation and interpolation models for conjunction analyses.

The United States should recognize the value of space sustainability as an international public good that also supports its own strategic interests. The United States needs to retain freedom of action in space while at the same time recognizing the presence of new actors in space and our own dependence on space systems. The most promising approach toward international norms aligned with our interests is to engage with other parties in creating a technically based consensus on reducing the hazards posed by orbital debris. We should avoid top-down prescriptive, legalistic or politically driven structures that do not allow for flexible evolution. Similarly, we should remain focused on mutual protection against common hazards found in the space environment and not be tempted to overreach, e.g., the creation of comprehensive space weapons bans or centralized space traffic management authorities.

If we actively support open technical standards and operational innovations based on real-world benefits, we will have the credibility necessary to establish new international norms that will add to our security and strengthen our economy.

If we focus on continuing to earn the trust of the billions of users worldwide that today rely on space systems, we will have the international support necessary to sustain the use of space for generations to come.

Thanks you for your attention. I would be happy to answer any questions you might have.

Biography for Scott Pace

Dr. Scott Pace is the Director of the Space Policy Institute and a Professor of Practice in International Affairs at George Washington University's Elliott School of International Affairs. His research interests include civil, commercial, and national security space policy, and the management of technical innovation. From 2005–2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA.

Prior to NASA, Dr. Pace was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy (OSTP). From 1993–2000, Dr. Pace worked for the RAND Corporation's Science and Technology Policy Institute (STPI). From 1990 to 1993, Dr. Pace served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Master's degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Dr. Pace received the NASA Outstanding Leadership Medal in 2008, the U.S. Department of State's Group Superior Honor Award, GPS Interagency Team, in 2005, and the NASA Group Achievement Award, Columbia Accident Rapid Reaction Team, in 2004. He has been a member of the U.S. Delegation to the World Radio communication Conferences in 1997, 2000, 2003, and 2007. He is a past member of the Earth Studies Committee, Space Studies Board, National Research Council and the Commercial Activities Subcommittee of the NASA Advisory Council. Dr. Pace is a currently a member of the Board of Trustees, University Space Research Association.

Discussion

Chairwoman Giffords. Thank you, Dr. Pace.

We are going to begin our rounds of questioning. We are going to try to keep to five minutes each, and I want to encourage Members if they haven't had a chance to read the written testimony, it was excellent, and there is a lot of detail, of course, that you can't get into in five minutes.

IRIDIUM-COSMOS COLLISION AND GOING FORWARD

I guess I would like to start off just fundamentally saying in terms of the Iridium-Cosmos collision in February, and I am going to start with you, General James, what went wrong, and how are we going to prevent it from happening again?

Clearly, we are not looking to assign blame, but we had a major problem, we have a program in place, we are looking for solutions of what we and the Congress can do, whether it is the public sector or the private sector, but this is a clear example of a problem that we haven't heard from the panelists yet. We are going to start with you, General, and then go to other members if we can get a clearer answer. Thank you.

General JAMES. Certainly, Madam Chairman. In terms of the Iridium collision, I would say that at the time we were not looking at the Iridium satellite to do conjunction analysis. We track, as we have said, 19,000 objects or so, but we only do a conjunction analysis or an assessment of whether they are going to come close to another body on a subset of that.

Primarily DOD payload, certainly manned payloads, the Shuttle, the International Space Station, and those payloads that support the U.S. Government in one form or fashion. So on the day that the Iridium collision happened, we were not looking at the Iridium satellite nor the Cosmos satellite to determine if there was going to be a close approach, if you will. So on that day there was no data that would have told the owner operators to any degree of precision whether there was a potential collision or not.

Certainly if you look to the future, you can define which particular spacecraft you want to assess for conjunctions, and we are ramping up to be able to ultimately do conjunction analysis on the 800 or so satellites that can maneuver. So obviously if a satellite can't maneuver, even if he knows that there is a piece of debris coming toward it, there is not a whole lot that that particular satellite can do. But for those that can maneuver, the intent is to do that conjunction analysis, provide that potential warning that says we have an analysis that says there will be a close approach within 100 meters, 200 meters, 300 meters, whatever the case may be, and then the owner operator of that particular system could take action.

So that is the path we are moving down in the near future to do that assessment on those 800 or so maneuverable spacecraft.

Chairwoman GIFFORDS. And do you have a timeframe for that, General?

General JAMES. Certainly within the next year and ideally before the end of the year.

Chairwoman GIFFORDS. Okay, and I know that you can't get too detailed, but do you believe that you will have the resources necessary in order to do the job?

General JAMES. Yes. We have been working with our headquarters to get additional processing capacity as well as personnel to implement that capability.

Chairwoman GIFFORDS. Okay. Would other panelists—yes. Dr. DalBello.

Mr. DALBELLO. Yes. I think this raises an important issue as to what we as a Nation want to happen, and we had this debate, was it maybe 10 or 15 years ago, when we decided what were we going to do with the GPS system. Were we going to have it as an exclusive system for the U.S. Government, or were we going to make it available globally? And recognizing at that time there were all sorts of people who were arguing that making GPS more generally available introduced significant risks, national security risks, in terms of our potential adversaries using the GPS system against us.

I think we are in a similar place now in trying to decide as a Nation where are we going with space traffic control. I think that Lieutenant General James and the JFCCS are doing a great job, but I also think that as a Nation we haven't decided whether we want to be in the space control business or not. Is this something that we want to take on, either alone or with other countries, for the world?

Inherent in your question was the assumption that someone should have been watching that Iridium satellite. The system today is not set up that way. The operators are, you are on basically your own. We have our own internal management system. Now, we operate in a different orbit, a less-cluttered orbit than the Iridium satellites do, but the operators are responsible for their own safety. So we actually request when we see a potential issue, we do make requests. Occasionally we do get comments and calls from the Joint Space Operations Center.

But you—but the situation we are in today is we do not have something that approaches an operational space traffic control system, and I think that is a policy decision that this Nation needs to make.

Chairwoman GIFFORDS. Speaking of policy, Dr. Pace.

Dr. PACE. Certainly. Well, and this is where analogies I think can be a dangerous thing. Everything that my colleagues said is quite correct, but, for example, you could imagine how the maritime world developed. There wasn't a central sea-control facility that was guiding and tracking, you know, every ship. Again, pardon the strange analogy, but operators both in the military and the civilian side developed rules and procedures for navigating with respect to each other. They adopted certain procedures about separation of ships based upon long operational experience and developed navigation aids. There became laws that arose through Admiralty Law in courts for adjudicating and handling liability in these environments.

So I think that when you are looking at the policy and governance for how space traffic might evolve in the future, I suspect you will see really two separate streams that will hopefully merge. One is expansion of the CFE Program to involve a number of our allies who are—we already have security relationships with, so it will become more capable and broader and more inclusive, including commercial input.

And the second part is the operators themselves are—have large investments at stake, and so you would imagine that they would be exchanging information in and amongst each other, and they would be watching out for each other. And so between the two of those, a bottoms-up sort of approach by the commercial community, which is increasingly at risk, as well as expansion and strengthening for the new environment of traditional military functions to involve greater number of civil and international actors, you will likely see. I don't think you will see a centralized master plan. I think you see growth and expansion in both areas.

Chairwoman GIFFORDS. Thank you.

Mr. Olson, please.

Mr. OLSON. Thank you, Madam Chairwoman.

COMMERCIAL AND FOREIGN DATA SHARING

And my first question is for General James. General, in your testimony you state that the long-term solution for the provision of high-fidelity orbital data includes integrating commercial and foreign entity advanced services in the joint space operations missile system, with the ability to ingest data directly from the entities on a voluntary basis. And what new resources will be required for you to provide this—to implement such a service? Has a concept been discussed with foreign and commercial operators, and do you have any concerns about the joint space operations missile system taking on an expanded role outside of its charter?

General JAMES. Well, thank you, sir. Looking at the resources required, in terms of ingesting data as Mr. DalBello said, we think that is a worthy goal. In other words, if there are data coming from the satellite owners themselves, we should have mechanisms to bring that data into our systems, and frankly, that frees up our sensors because we know where those satellites are, and I don't have to task a telescope or a radar to go look for a particular satellite.

Now, there are things we have to work there, because we have to verify that the data is valid. Before I put that into the Space Surveillance Network I have got to know that that is, indeed, good data. So there needs to be processes and procedures that allow us to do that.

But the resources to do that, I think, are not great, because it is more process, it is more taking the data that is, that they are putting together for the commercial entities and determining how to put that into the right formats and verify that it is good data. So from a resource perspective in that capability I think we can move down the path, but it will take some time.

I would say this is not necessarily outside the Joint Space Operations Center mission area, but it will require assessment in terms of manpower, in terms of processing, the things that I discussed earlier, to allow us to continue to improve these processes.

And, again, the CFE Program as we said, it is a pilot program. I mean, we are learning this year exactly, okay, what are the processes, how does a commercial entity need to request, what legal agreements do we need to have, and we are making great progress so that by October, November timeframe we will say, these are the processes, and we can transition this to the U.S. Strategic Command successfully.

Mr. OLSON. Thank you for that answer, General.

And this is a question for all of you, and we will start with Mr. DalBello, involving space traffic. Since all the space-faring nations and commercial entities have an interest in keeping the space environment as pristine as possible, what is impeding the widespread adoption of the data center concept that you mentioned in your testimony, and what is impeding nations and commercial entities right now from sharing orbital data today?

Mr. DALBELLO. I think when the space age started and up until very recently, I think most operators had an attitude characterized perhaps as the big sky approach, which is space is vast, and the odds of two objects intersecting in space, the odds are still quite low. So I think up until very recently there was a perception among operators that this wasn't something that they had to worry about. And we even find even today among smaller operators that they will say to us, well, if I am flying in my box, box being an assigned location in space from whatever regulator licensed your launch to space, if I am flying in my box, what do I have to worry about anyone else, which has really, I think, got it exactly backwards.

So one answer to your question is that we have—it is only recently that people have been worried about the complex interaction between debris, dead spacecraft that were not removed from orbit, and maneuvering spacecraft. And I think as we look out forward, it is clear that environment is going to get more complex rather than less.

So I think that the idea like the data center, which started out with one group of operators, the large operators in geostationary orbit, those operators who, all who were used to working with each other, could adopt a common set of protocols that they could use to exchange data.

There are still many other operators who do not—who are either in different orbits or who are not part of that group who don't perhaps yet see the overall value to it. And I think other people take an assumption that they shouldn't have to worry about, this is something the governments should worry about.

So I think a variety of reasons, and it is part of the maturing approach, I think it started out with Dr. Johnson's great work on space debris, what is it, almost a decade ago now? And it raised the awareness that we couldn't just do anything we wanted in space. And so we have taken baby steps since then, I think, to get to where we are today.

Mr. OLSON. Thank you. Dr. Pace, would you care to comment, sir?

Dr. PACE. Yeah. I would agree with that. I would also say that there—we are focusing on orbital debris, but I would say, though, there is a couple of other factors that need to be taken into account in terms of keeping with the hearing's title about keeping space sustainable and safe for civil and commercial operators, and we are not really probably going to spend a lot of time talking about it, but understanding of the space weather environment, which perturbs these satellites and which monitoring of that environment is sort of a long-term interest of all the operators. Better understanding of the radio frequency environment. I mean, part of the reason why satellites are spaced the way they are across the GEO synchronous arc is not just physically because space is vast but because of how they radiate and so how they radiate and potentially interfere with each other.

So radio frequency interference, space weather environment, better modeling of all of those characteristics and then getting standardized data to exchange with each other, those are things that are the foundation for any sort of future decisions. And so right now people I think are still working on the standards part. The awareness is there, the standards are still developing to even talk with each other, and people are trying to look at, okay, what are the right operational practices so we don't make hard and fast rules too early but that we get moving on it and not make them too late.

Mr. OLSON. Thank you for that answer.

Mr. Johnson, would you care to comment? You don't have to say yes.

Mr. JOHNSON. I don't think I have much to add. The situation in low-Earth orbit is dynamically different than geo, so we will have to find some other method of communicating data positions for low-Earth orbit.

Mr. OLSON. Thank you for that answer. I am out of my time. Thank you, Madam Chairwoman.

Chairwoman GIFFORDS. Thank you, Mr. Olson.

Congresswoman Fudge.

Ms. FUDGE. Thank you, Madam Chair.

INTERNATIONAL AGREEMENTS ON ORBITAL OBJECTS

I actually have two questions. The first one I would like to address to Mr. Johnson. You alluded to the whole concept of there being some international discussions about orbital debris. My question is do you believe—is there an international treaty on orbital debris, and if not, should there be one?

Mr. JOHNSON. We do have—the primary way of communicating with an international environment is through the Inter-Agency Space Debris Coordination Committee I mentioned earlier.

Ms. FUDGE. Uh-huh.

Mr. JOHNSON. We have been very successful. It is considered the preeminent world body for technical assessment of the debris environment. Now, we have provided information to the United Nations, which enabled them to adopt space debris mitigation guidelines in 2007. So they are guidelines only. They are not legally enforceable. It is not a treaty status, but what we are looking for is allowing the individual members of the United Nations to implement these guidelines through their national mechanisms and to watch their compliance. The current agenda in the United Nations is to review the implementation of these guidelines on an annual basis when we meet in Vienna every February.

Ms. FUDGE. Well, I guess that really is my question. Should there not be something that is enforceable?

Mr. JOHNSON. Yeah.

Ms. FUDGE. Internationally. Anyone can answer. If you would like to, Mr. Johnson, but any panelist can——

Mr. JOHNSON. Actually, it has been my experience over the last 25 years that talking with industry, and of course, operators, that they have always been very responsive. This has been one of those rare instances where legal requirements are not always necessary, and we have time. The environment is certainly degrading over time but at a very relatively low rate.

If we find that voluntary measures are not working to the extent that we would like, other options are certainly possible in the future, but so far we found very good reception at the voluntary level.

Thank you.

Mr. PACE. I would just simply add a particular example of that. Under the Outer Space Treaty in 1967, state parties are responsible for persons under their jurisdiction or control, which would include, for example, registered satellite operators or people licensed say by the United States, whether remote sensing or commercial satellites. And one of the ways the U.S. has responded or carried out that obligation to the Outer Space Treaty for things like these technical guidelines is to then write domestic regulation in place for how those regulations, those guidelines are enforced.

So for example, the Federal Communications Commission has part of its licensing requirement discussions about, well, how does a licensee propose to deal with the end of life of this satellite? How are they going to dispose with it? And they had a full regulatory review and hearing and public comment and so forth on that. So for FCC licensees when people go to the Commerce Department for a commercial remote sensing license, there is a section in there that deals with end of life disposal.

So the State Department when it reports back to the U.N. S&T Committees, it says here are the domestic regulations we have adopted in implementing these guidelines in our own way. And that—and then we encourage other countries to do that. So in lieu of a master, kind of one-size-fits-all treaty, the U.S. proposes that other sovereign administrations adapt the guidelines, you know, to their own environments. And so far, as I said, that has worked out I think fairly well without triggering a larger international treaty debate, which as you can imagine could be quite contentious.

Ms. FUDGE. Thank you. Mr. DalBello, I just want to follow up on our chair's question. You in your prepared statement indicated that there should be some dialogue on rules of the road, who we develop guidelines or protocols that would inform other operators when one of their spacecraft could potentially cause damage to another.

How do you propose we do that?

Mr. DALBELLO. Well, it is—this is the kind of issue where you are going to have to have a partnership between government and the commercial industry. I think we can do part of that ourselves. I think that we are—we routinely share information, we routinely discuss protocols and flight operations, procedures. We obviously, we can't do anything to instruct or to coordinate with governments or smaller companies flying from other countries.

So we—there is—part of the job can be done by large operators cooperating on a set of what you would just say would be common sense procedures, but there will be a role for governments, and I think it can look, that process can look something like the process that Dr. Johnson outlined with the IADC, the debris coordination, where you start out by saying, what are our best practices?

So if you are going to move a satellite or if you know that you will pass near a satellite as you are either putting a satellite in orbit or relocating a satellite, what are your obligations with respect to other operators? Those are issues that—those are the kind of issues that we can wrestle with, and there may be a process whereby beginning that international dialogue we can end up with something that looks like the debris mitigation guidelines.

Ms. FUDGE. Thank you, Madam Chair. I yield back.

Chairwoman GIFFORDS. Thank you. Mr. Rohrabacher.

IRIDIUM AND COSMOS COLLISION AND MILITARY CONCERNS

Mr. ROHRABACHER. Thank you very much, Madam Chairman, and I offer my praise as well to the Chairman or Chairwoman I should say, pardon me, for calling this hearing. It is a very important issue and has not been given the attention it deserves.

General, about the Cosmos and Iridium, you know, collision, we, of course, knew what the Iridium orbit was and did we—was the Cosmos one of the objects that had been traced before, or was that an unknown object to you?

General JAMES. No, sir. Both those objects were tracked and were in our space catalogue.

Mr. ROHRABACHER. Okay. Well, if they are in the space catalogue, have we not—did their orbit change in some way? Have we not run out the orbit so we know that after a certain number of years they are going to cross? Or do they change their orbit in space?

General JAMES. Sir, kind of a two-part answer. The Iridium constellation does maneuver their orbit occasionally, and in fact, they had done a maneuver as I understand it prior to the collision, but, again, in reality when we track something, all we do is we produce basically what we call an element set that says this is the characteristics of that orbit. We do not then for all objects do an assessment, is that orbit going to intersect with any other orbit. We only do that on a subset of objects.

Mr. ROHRABACHER. Let me suggest that in an era of computers that it is not that costly for us to simply task, maybe you could task an intern to go and put all these orbits into the—into your computer and find out if any of them are going to cross. It seems to me that that is not—let me put it this way. To be more responsible I think it would, that that would have been a responsible course of action if your office is, indeed, tasked with this issue.

About China, China intentionally demonstrated their great capabilities by blowing up one of their satellites in orbit. Now, of course, there is no one here to speak for the Administration, Madam Chairman, so I can't ask the question that should be asked today. So let us note that there is no one here from the Administration, and let us hope that perhaps the Administration will pay some attention to NASA and give us a new leader of NASA so that we can actually interact with them. I think that might be a good recommendation. I certainly would yield to the Chairwoman.

Chairwoman GIFFORDS. And, Mr. Rohrabacher, thank you for bringing up obviously a very important issue. We are hoping that the House Armed Services Committee will pick this topic up and also have a committee hearing, because there is a defense side to the problem as well, and we look forward to hearing from the Administration in the future.

Mr. ROHRABACHER. Right.

Chairwoman GIFFORDS. Yield back.

Mr. ROHRABACHER. And but it would help to have a new leader of NASA here or at least an official representative of that leader rather than someone who may or may not have the leader's ear whenever that administrator is chosen.

But let us just say that China intentionally created massive debris but yet the Administration from what I now understand is supporting permitting American satellites to be launched on Chinese rockets. I guess that is the way to prove to them how upset we are with their creating massive space debris.

RUSSIA'S POLICY ON ORBITAL DEBRIS

About cooperation in space, do—are any of you aware that the Russians have presented a plan to try to deal with space debris? What I have heard today is only ideas about how we track space debris. The Russians actually have presented something a few years ago of how we might be able to actually deal with it and take some of the space debris down. Are any of you aware of that proposal? Yes, sir.

Mr. JOHNSON. Yes, sir. The Russians, as well as several other individuals and organizations, have proposed different techniques for removing debris from orbit, either small debris or large debris.

Mr. ROHRABACHER. Uh-huh.

Mr. JOHNSON. As I said earlier, it is a challenge. It requires a substantial amount of research, and of course, later funding, and none of that has taken place.

Mr. ROHRABACHER. Yes. I would suggest, Madam Chairman, that this subcommittee might take a leading, play a leading role in let us say promoting cooperation with other countries to deal with this, not just to identify debris but perhaps in finding a real solution because the Russians have presented a plan. It would take international cooperation, international effort, and maybe this subcommittee might be able to play an important role in that.

Thank you very much.

Chairwoman GIFFORDS. Thank you, Mr. Rohrabacher, and I fully agree with you.

Next we are going to hear from Mr. Griffith.

Mr. GRIFFITH. Madam Chair, thank you for the opportunity, but my questions have been asked. Thank you.

Mr. OLSON. Thank you, Madam Chairwoman. I would like to ask another round of questions here, gentlemen, just a couple more for you, and this is for all of you, sort of building on some of the comments we have heard earlier today.

STATUS OF CURRENT DEBRIS CREATION

Implicit in the suggestion that the rules of the road need to be more uniformly-advocated and encouraged is that some nations that are commercial operators are not fully observing best practices, and is this the case, other nations and operators continuing to generate large amounts of debris with each new launch?

Mr. Johnson, you seem to be the one who raises the hand.

Mr. JOHNSON. I would say that on average most space-faring organizations and countries are creating very small amounts of orbital debris on each mission. Typically one debris or less, sometimes maybe three or four. It is the accidental explosions which are leading to a growth in the environment, and of course, the most recent collision.

Mr. OLSON. Dr. Pace, do you have a comment? It looks like you were going for the microphone.

Dr. PACE. Mr. Johnson can maybe correct me if I am wrong, as I recall the history of it, the Chinese initially were actually quite a bit dirty in their initial launches. They created a fair amount of debris, and they—some effort—they got involved in the IADC and got involved in these international technical discussions, and Chinese practices then improved over the years such that the amount of debris they wound up producing in their routine launches became noticeably less, and people felt this was a good example of technical cooperation.

That is why their—ASAT against their weather satellite was so shocking I think to many people was not simply the military capability but the fact that they intentionally created a large amount of orbital debris when their technical experts had been involved in the IADC and their operational practices had, in fact, improved over the years.

So it points out that there is a sort of an international norm side of it. I think the Chinese were somewhat surprised at the amount of international reaction that occurred as a result of that, in part because people recognized that an international norm about what was proper hygienic practices, if you will, in orbit had been violated.

And so these international discussions are really quite valuable, but they have to have—they have a political component as well as a technical component, and so that it one of the reasons why we should keep supporting them.

INCREASING SATELLITE STRENGTH

Mr. OLSON. Anybody else? Any other comments? Okay. One more question sort of coming at this problem from another angle in terms of hardening our satellites to prevent them from being damaged if they are impacted by orbital debris. What measures are currently out there being employed to harden satellites, and obviously this has to be very small debris, whether it is man-made or natural, and what are the limits, what is being done to do that, and what are the limits with hardening our satellites to protect themselves?

And that is for all of you. General James, if you would like to start, please.

General JAMES. Well, certainly as I think was mentioned earlier, as you look at the very small particles that we encounter, you know, quite often frankly, most satellites have sufficient protection against, you know, micro-meteor, micro-millimeter type objects. But as you get into the larger particles, one centimeter and larger, that is a more difficult problem. Certainly within the Air Force we are looking at that from a space protection program point of view to assess what needs to be done in the future to protect our systems from those type of objects.

But that is an ongoing work, and again, there is always tradeoffs between cost and weight and size and protection and probability. So all of that has to be weighed in the analysis as we look to the future.

Mr. OLSON. Thank you, General, for that comment.

Mr. Johnson.

Mr. JOHNSON. The International Space Station is the most heavily protected vehicle currently in Earth orbit, and the best we can do is to guard against particles one centimeter and less. It is a technology issue. Actually, 10 percent of the entire mass of the International Space Station is devoted to shielding. Robotic spacecraft can't afford to do that. Most robotic spacecraft are vulnerable to particles three, four millimeters in diameter, and there any many, many of those.

Mr. OLSON. Thank you very much, Mr. Johnson.

Mr. DalBello.

Mr. DALBELLO. The—I think what Dr. Johnson pointed out is correct that the challenge of protecting something against anything but the smallest particles. We in the commercial satellite industry, we simply couldn't, we couldn't commit that amount of weight on the satellite for protection. Luckily our experience and where we operate our satellites, our experience has been that I don't think—there is no recorded loss of a satellite in geostationary orbit from debris.

So I guess I would have to answer is that we don't do anything on protection specifically other than the normal structure of the satellite that, you know, needs to be a certain robustness to survive launch. But other than that we don't take any extraordinary measures, and that is purely driven by our assessment of the risks and the realization that there really are no good technologies for protection.

Mr. OLSON. Thank you.

Dr. Pace.

Thank you very much, Madam Chairwoman. I yield my time back.

FUTURE OF CFE

Chairwoman GIFFORDS. Thank you, Mr. Olson. My apologies for getting a little bit out of order. We are starting the second round. I am going to go and then we are going to shoot over to Mr. Rohrabacher, then we are going to hear from Mr. Griffith.

So General James, I would like to get back to what you talked about with the CFE. In your prepared testimony you stated that the DOD intends to operationalize support to the commercial and foreign entities by the fall of 2009.

But I would like to hear in concrete terms what that means. If you are simply going to extend the current CFE Program, do you plan to expand it, its budget, or are you planning on making additional changes to it?

General JAMES. Yes, ma'am. The first piece of that is to, as I said earlier, work out the processes that we are currently doing to make sure that the commercial entities understand and the foreign entities understand how to engage in the system, what are the legal forms that have to be filled out, what are the agreements that have to be reached, and make sure that process is all in place. And that is where we are headed right now.

But we are looking to expand capabilities. One option that we are looking at is to push more out on the web, if you will, so that there is automatic information that is pushed out to those who signed up for the Commercial and Foreign Entities Program. We are also looking at additional capabilities, for example, if there is an anomaly on a spacecraft, if an operator comes in and says, hey, I need this potential support for end of life, those sorts of things, we would add that to the Commercial and Foreign Entities Program. And then, again, providing that high accuracy data that Mr. DalBello talked about, essentially those who signed the agreements today would get that high accuracy assessment of their satellite.

So we are continuing to look at ways to improve, ways to more automate the processes, ways to push the data out to the individual end users that have signed the agreements and make this a better program.

FUTURE OF CFE WITH COMMERCIAL INDUSTRY

Chairwoman GIFFORDS. Mr. DalBello, if you can please—you have heard what the General has said, you have heard the description for the plans for DOD and the CFE Program, but I am curious whether or not those plans address the commercial space sector's needs, and if not, what more is needed?

Mr. DALBELLO. I think they don't today, and, again, I don't mean that as a criticism but just a judgment on where we are as compared to where we would all like to be. I think as a first measure we need to do that simple things. You have hundreds of space objects from the commercial sector, and we know where all those objects are, because we are constantly ranging those objects with our ground antennas. So we know precisely where they are. So there should be a way to incorporate that data, and why is that important? Well, it is important because the Air Force network can't constantly monitor spacecraft. It sort of takes a picture of a particular point in time, and then it says, I think that object should be here based on where I last saw it.

We are actually constantly monitoring, and what you miss when all you are doing is taking a snapshot of the heavens is you miss maneuvers, and as General James pointed out, that may have been what resulted in the Iridium crash. So if someone maneuvers, then your past information is no longer accurate because it changes significantly.

So, number one, we need to incorporate the data from the operators that are willing to give it. We need to—and this goes to Congressman Rohrabacher's concern, we do need to develop the computer capacity to run what they call all against all, so we are running the data, the entire data set, and this is just purely a computer limitation issue. I mean, we need to have the computing power to run all against all on a regular basis.

We need to have the rules and procedures for getting high-accuracy data to the commercial sector at a minimum for those objects that are not maneuvering, and at a minimum for spent rocket stages and parts of—and components of dead satellites.

I understand there is sensitivity. We are trying to walk a line here that is somewhere between safe operations in space. On the other hand, we don't want to give away the store on what our military is doing in space on every single program.

So we are actually trying to do a complicated thing. We don't want complete transparency of the heavens, but we want them to be opaque in a safe direction. So it is a challenge, and, again, I think we aren't there yet. That is not meant as a criticism. I know there are a lot of folks working really hard at the JSpOC. I think it starts with a fundamental—with a national policy decision that we do intend to do this.

As Thoreau said, "In the long run, men only hit what they aim at."

Costs and Benefits of Monitoring

Chairwoman GIFFORDS. Following along those lines, we have heard a lot today about space situational awareness, but I am curious as the cost to monitor space debris increases. Who exactly should pay for the services provided to both commercial and also to foreign users? I am interested about pushing out more information on the web, but obviously this is going to cost U.S. taxpayers increasingly more money.

I would also like to hear whether or not the U.S. Government or the United States people derive sufficient benefits from the information and whether, again, we should be charging for the services, and if so, how much.

So, Mr. DalBello, if you can just make a stab there and——

Mr. DALBELLO. Yeah. Congresswoman Giffords, obviously this is something that we have spent a lot of time thinking about, because it is one of those 'be careful what you ask for' situations. We think that there is a good middle ground. What we are offering is to be able to explain where we are all the time, and that will reduce the U.S. or perhaps other countries' burdens substantially. So we are coming to the table with a lot of data as it is. So that is the first thing.

And secondly, we think if you are going to build out a total space situational awareness capability, you will want to go to space, and, again, we have offered and continue to offer to make our platforms available if the United States Government can define a simple, low-cost, low-weight sensor, we would be glad to take it to orbit. So we could become part of the network.

So my first answer is——

Chairwoman GIFFORDS. Mr. DalBello, do you find that that is the same with your counterparts or your competitors in the industry? Is that generally the position that——

Mr. DALBELLO. I can't speak for anyone other than Intelsat, obviously, but I know that in our dialogues I have heard very sympathetic comments from the largest operators; SES, Inmarsat. So some—many of the largest operators have expressed their enthusiasm for these ideas.

Chairwoman GIFFORDS. General, do you have any comments?

General JAMES. Yes, ma'am. A couple of things.

First on utilizing the data from the commercial vendors, we certainly as I said earlier, agree with that, and as we have the agreements that we build for the CFE Program, that is one of the things we discuss with those commercial operators is their willingness to provide their satellite positional data into our engine, if you will, and that allows us not to have to task our sensors as I said earlier.

So it is just a matter, I believe, of working out the procedures, the formats, and the processes until we can get that in place. But that is a dialogue we do have with those commercial satellite vendors.

In terms of payment for this, again, I think that is a national policy decision. The Authorization Act allows the DOD to request payment for these services. At this point we have elected not to do so, but, again, I think that has to be a dialogue at levels above us in terms of policy at OSD and above, in terms of do we want to change for this or not to offset some of the expenses of sensors and so on.

And then lastly, in my testimony I did point out that we are going to space with our sensors. The space-based surveillance system is a DOD-dedicated space surveillance sensor that should launch this summer that will allow us to much more actively track everything in the geo-belt, which we cannot always do today due to the telescopes being weathered out and had to be nighttime and so on.

So we do recommend the importance of space-based sensor capabilities, and we are launching one of those this summer.

PRIVATE INDUSTRY CHARGING FOR SATELLITE DATA

Chairwoman GIFFORDS. Thank you.

Mr. Rohrabacher.

Mr. ROHRABACHER. Let us note that we now have the capability of determining the course of a near-Earth object that is millions and millions of miles away to determine whether or not that object is a threat to hitting the Earth. Now, if we can chart an object that is in distant space and determine whether or not it will hit the Earth or come in this direction so it is a concern, certainly we can chart the course of objects that are in low-Earth orbit and determine whether they are going to hit each other and put them into the computer.

So I think if nothing else has come out of this hearing, it is our understanding that we haven't been doing something that we are very capable of doing that is not costly. So let us pay attention to that. Next time we have a hearing on that I hope to hear how we have made some progress on that.

I think the idea that we are missing a little bit here with the Chairwoman's suggestion of where perhaps someone can be charged for certain data. It is not necessarily the data from commercial operations, General. It is also the cataloguing, not just the, you know, actually obtaining of the data but the cataloguing of that and perhaps the actual dispersing of that for a charge.

Apparently that is—does the—do you have any suggestions or any reaction to the idea of having a commercial company open up shop and start charging people for information, especially satellite, people who will be launching commercial satellites will have to get—and perhaps the military as well would have to have the information approved and the course of their orbit charted by and approved by this or at least certify that it will not in some way run into an object that is already in space. This could be done by a private sector company, could it not, Mr. DalBello?

Mr. DALBELLO. Yes. It is something that we have thought through at the very beginning stage in our data center prototype, which is you certainly could set up—it is not technically challenging to do what you describe. The challenge you have is managing the national security issues, and what is the level of data, and this gets into who are your customers for this information. At some point you do want to have a dialogue with the Russians and the Chinese and everyone else who has got objects in space, because you wish to know not only where they are but where they are maneuvering and those issues.

So is it possible? Absolutely it is possible.

Mr. ROHRABACHER. What about the percentage of the—of what you are describing, the problematic part of it is only a small percentage. Aren't we talking about——

Mr. DALBELLO. Small percentage.

Mr. ROHRABACHER.—10 percent or 20 percent and——

Mr. DALBELLO. Yes.

Mr. ROHRABACHER.—the rest of what can be tracked and catalogued and made available so that we can actually start working at that—at least at that level. We are not talking about an overwhelming percentage, are we, when we say the national security issue?

Mr. DALBELLO. No. I think it is—it would be the smaller part definitely. Whether it is 10 pr 20, I don't know that I am competent today to answer, but it would be definitely the smaller portion. It would obviously be significant to those people.

Mr. ROHRABACHER. So we could make a significant difference without solving the whole problem. There is still a national security part of it that we may not be able to handle but a significant part of the challenge can get done, and we are capable of doing that.

I also might add I think that we are very capable of working with our international partners, with the Europeans and the Russians and others, to perhaps even go even further and bring down space debris. And if we chart it, if you are already charting the course, all we have to do is get something up there that will knock it down, and that doesn't have to be something very sophisticated, just a big bulldozer in the sky you might say and perhaps something like that would actually be, not be as expensive as we think, especially if we were doing it internationally.

So thank you very much for holding this hearing. There are very good ideas that we been talking about.

Chairwoman GIFFORDS. Thank you, Mr. Rohrabacher.

Mr. Griffith.

CHARACTERISTICS OF CURRENT DEBRIS

Mr. GRIFFITH. Thank you, Madam Chair. This is an interesting discussion. I think that I would have the opposite view of my colleague that I don't think there will be a reduction in space debris.

I think the idea that we are going to have a conversation with Iran, North Korea, or China and have them jeopardize their national security as they see it is maybe a little bit naïve.

So if that, if my premise is correct, what is the nature of space debris? Is it—are the particles charged? Do they travel in the same orbit as they find themselves in, or is it more of a Brownian movement as to you get into sub particle, and what is their electromagnetic nature? Because I think it is important for us to know their nature, the particles' nature, because it sounds like we are going to have to be our own BFI up there as far as our space vehicles are concerned. And if we are going to rely on Iran or North Korea to cooperate with us, it can change our cataloguing of debris in an instanct because the SC–19 missile 27 months ago that hit the decommissioned weather satellite created 25 percent more that day than we would have had if we had had a catalogue.

So it seems like we need to know what the nature of this debris is, and all I have heard so far is the physical size of it. Do we know anything else about it besides its size?

Mr. JOHNSON. Yes, sir. We actually spent a great deal of effort in trying to characterize the debris, not only by size but by density, its radar properties, its optical properties. It turns out, though, that even lightweight things moving at 10 kilometers per second can do a sufficient amount of damage should you run into it or it run into you.

So to answer your question about charging, actually there is a very modest charging effect which takes place. We have look at it in terms of maybe taking advantage of it, using some sort of electromagnetic field to perturb the orbit. That doesn't seem to be a very promising avenue.

Mr. GRIFFITH. Yes, sir.

General JAMES. Sir, just one other comment. As we look at tracking this debris, it is something that you can't track it and then, you know, two days later assume it is going to be exactly where you expect it to be, because there are various forces acting on it, you know, gravitational forces, solar wind, solar particles, atmospheric forces depending on where you are in the orbit. So over time, even though we track it and say, okay, six hours from now it should be here, generally it will be pretty close to that, but as you go out further and further there are forces acting on those particles, especially the smaller ones, one centimeter, five centimeters, 10 centimeters, that do, indeed, change that orbit, which require us then to go back and recalculate. That is why I can't give Intelsat a prediction a week away that says this thing will hit you within 20 meters——

Mr. GRIFFITH. Sure.

General JAMES.—because it is going to change fairly significantly over that period of time.

Mr. GRIFFITH. Good. Thank you very much. I appreciate that.

CFE RESOURCE AND PRIORITY CONCERNS

Chairwoman GIFFORDS. Okay. All right. Well, we have time so we are going to do another round, and I will start. We will see who can—who will hang in there.

This question is for General James. Retired Major General James Armor recently testified that the Space Surveillance Network is not sufficiently resourced to support civil and commercial operations. He said that the Air Force does not have the resources to carry out the CFE support and added that recent complaints by commercial operators about unwarned movement of DOD satellites and lack of support for moving commercial satellites at GEO were indications of inadequate resources and lower priority given to the CFE.

So I am curious about your views on General Armor's stated concerns regarding insufficient resources for the Space Surveillance Network.

General JAMES. Well, certainly as we have looked to the programs that we have in place, I believe we do have a reasonably good plan to address some of the shortcomings that we have. First, we—I talked about the space-based Space Surveillance System. That is addressing our ability to map the GEO belt with our satellites to a more accurate capability and more real-time capability. So that is in place.

We also have a program in place called the Space Fence, which addresses one of our shortcomings, which is the Southern Hemisphere. We don't have a lot of sensors in the Southern Hemisphere, and one of the components of the Space Fence will put a very accurate radar system in the Southern Hemisphere to allow us to get more tracking capability in the Southern Hemisphere.

So we are also looking, as I said, at increasing our processing capability that Representative Rohrabacher talked about. We should be able to do that, and we are moving down that path. When you talk about doing conjunction assessment on everything that is up there, that is 19,000 objects against 19,000 objects roughly. That is a lot of calculations, a lot of time, and a lot of effort to do that.

And the other piece of that is that you can automate a lot of that but where it gets tricky is that when the analysts with the computer says, I now have a potential close conjunction, then an analyst has to get involved, he looks at the data, he then says, well, the data that that was based on is 48 hours old. So now I have to go task a sensor to look at that data again and rerun the analysis. I then have to talk to the owner operator potentially and say, can you give me any additional information? Do you plan to maneuver, et cetera?

So it is not just the computing power. Once it identifies something, then the person has to get involved to do some additional assessment. So all those things we are addressing, as I said. I think we are on a good path to get to 800 and then 1,300, but 19,000 versus 19,000 is something I think, frankly, again, we have to decide is that what the U.S. wants to do for the world.

CFE COMPUTER ANALYSES

Chairwoman GIFFORDS. And following up on that, obviously, I am not an expert in orbital mechanics, but, you know, I have heard what was said today, and you know, I heard Mr. DalBello talk about the all-against-all computer analysis. I know that Mr. Rohrabacher has had to leave and with all due respect to our incredible interns that we all have, I am a little concerned, again, about the complexity and the cost associated with these computer analyses.

So perhaps, General, you could talk about that a little bit more in-depth.

General JAMES. Well, again, I don't know how much more in-depth I can go, but as I said, getting to the active payloads, roughly 1,300, and doing an conjunction assessment with those payloads against any of the debris that is, you know, around the Earth is doable, and that is the path we are headed down.

But if I want to take debris piece X and look at it for—is it going to hit debris piece Y, number one, do we want to do that? I mean, is there any value in that because they are both just pieces of debris? And then if I do, you know, there is a fair amount of processing and computational capability that is required to do that.

And while we have not made that decision yet that is that the path we want to go down. But it is doable. It is just—requires resources.

Chairwoman GIFFORDS. Thank you.

DEBRIS RISKS

Let me shoot over to Dr. Pace. You indicated in your prepared statement that the Air Force does not have the resources to look at everything, and that some risks will not be addressed until it is too late.

Well, that certainly got our attention, so can you talk a little bit more about these risks?

Dr. PACE. Well, I think that you have actually heard a description of that. There is going to be a spectrum of these risks. Obviously the highest-priority items is going to be for human space flight and looking at national security payloads, and that is appropriately what the Air Force does. The question is is how far down that list are you going to go. Plainly the Iridium and the Cosmos collision fell below the resource line in terms of what people could go look at.

Now, the problem is if you go all the way over to say, well, I want everything on everything, on orbital mechanics every object has roughly ten orbital elements associated with it, so 20,000 objects times 20,000 objects, each with ten orbital elements, we quickly come up with 40 billion numbers that you are worrying about. Maybe $40 billion. So 40 billion things that you are now going and tracking, and then that changes with time, because, again, the things don't move in static orbits, but the weather, how—whether there were any maneuvers and so forth. So it is a very, very dynamic model.

So you are going to be drawing a line somewhere, and the question is is can you do things that mitigate the chances of there being something bad occurring? Now, some of the IADC practices mentioned or things like venting your tanks after you are done so that there isn't a chance of accidental explosion, putting catchers on bolts so that you don't blow them off into space. Pretty common sensical sorts of things.

So with good operational practices, with people not doing things like creating large debris at high altitude as the Chinese did, but if you do create debris as the U.S. did in the case of USA 193, I guess, there is the case that system cleaned itself out in the space of a few days.

So there are proper and improper ways of engaging with space objects and in bringing them down. Establishing those operational norms is sort of the first thing. Making sure that you don't get any worse is the next thing.

I think that there are some interesting ideas about mitigating debris out there, and as Congressman Rohrabacher mentioned and actually some of the French proposals include things like ground-based lasers against small debris items. Now, of course, there is a fine line between a ground-based laser cleaning orbital debris and a weapon system. And so you would have to have an amount of international discussion as to whether or not that makes any sense.

Let me pause right there.

Chairwoman GIFFORDS. Okay. Thank you, Dr. Pace.

Mr. Olson.

TIMELINE FOR DEBRIS WARNING

Mr. OLSON. Thank you, Madam Chairwoman, and I will be brief with the questions. First of all, I want to thank you for holding this hearing again. The first time this topic has been heard from in this committee. I think it is critically important. I also want to thank your witnesses. I have learned a lot today, and I appreciate your time and expertise.

And General James, my last question is for you. Building on your conversation with the Chairwoman, when you go through that analytical process, how long does it typically take or how much advanced notice can you determine that there is going to be a threat of a conjunction?

General JAMES. Generally speaking about four days out is where we feel that the data is reasonably accurate and won't change very much over that period of time. So that is when we do an assessment, and if we get something that says there is a potential conjunction let us say within a kilometer, then, again, we will normally go task our sensor system to give us more updated data. We will run the assessment again and see if that is still valid, and we will continue to march that down all the way up to really the point of conjunction.

So certainly, for example, on the International Space Station we are very aware of that. We run those analyses every four to six hours if there is a potential conjunction. We have two NASA orbital analysts that reside at the JSpOC and are in close communication with NASA constantly whenever we get into those scenarios, and we move forward from there.

But, again, there can be very small objects that may suddenly have changed from the last time we looked at them and create a conjunction that is only 12 hours, 24 hours out, and then we have to do those assessments fairly quickly.

Mr. OLSON. And one more follow-up question, General. When the—what was the timeframe, the warning for the last sort of conjunction with the Space Station, remember when the astronauts had to go into the hardened area of the station in the event of an impact.

General JAMES. And, sir, I will have to give you the exact time for the record, but again, and you can probably add to this, but that was a scenario where the object was fairly small. The data we had was fairly old and then when we did an updated data set, it essentially said we have a predicted conjunction coming up fairly quickly, which did not give NASA the time to actually conduct a maneuver on the spacecraft.

And I don't know if you want to add to that at all but——

Mr. JOHNSON. The other contributing factor was that that particular particle was in a relatively elliptical orbit, which means you had fewer opportunities to track it. It was also more susceptible to perturbations in the atmosphere, and so its orbit was actually changing pretty rapidly every time it went around the world. And so it was much more of a challenging situation than we normally are faced with.

Mr. OLSON. Thank you very much for those answers.

Madam Chairwoman, I yield my time back. Thank you all again.

Chairwoman GIFFORDS. Thank you, Mr. Olson.

Mr. Griffith.

Mr. GRIFFITH. I just wanted to thank the panel and then—you guys are great. Kind of reminds me of your next science question. If a two-centimeter particle hits a five-centimeter particle, is it Wednesday or Thursday? And so I thank you all for being here. Thank you very much.

Chairwoman GIFFORDS. Thank you. Obviously I want to thank the witnesses for coming today, and before we bring the hearing to a close, I especially want to recognize General James, and we were just speaking earlier before, and there are some models out in the entry room, and the fact that you have seen Saturn, the Space Shuttle, Delta IV all launch really speaks to your history in space and aviation. We appreciate your service.

And to our other Members that spoke today on our panel, thank you for your service. We only touched on just the brief cursory beginning of what will be an importantly—increasingly important issue for all of us, and I am pleased that, Mr. Olson, we had a good discussion today. This is just the beginning. We have a lot more to cover, but I thank the Subcommittee Members for being here. The record will remain open for two weeks for additional statements from the Members and for answers to any follow-up questions that the Subcommittee may ask of our witnesses.

The witnesses are excused, and the hearing is now adjourned. Thank you very much.

[Whereupon, at 3:30 p.m., the Subcommittee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Lieutenant General Larry D. James, Commander, 14th Air Force, Air Force Space Command; Commander, Joint Functional Component Command for Space, U.S. Strategic Command

Questions submitted by Chairwoman Gabrielle Giffords

Q1. In your prepared testimony you state that "the DOD intends to operationalize the support to commercial and foreign entities in the Fall of 2009." You also indicated during the hearing that you were ramping up to ultimately do conjunction analysis on a greater number of satellites and that you are working with your headquarters to get additional processing capacity as well as personnel. You also said that you were looking to expand capabilities, and looking at ways to automate processes and ways to push the data out to the individual end users that have signed agreements with you. Now that the President's budget for FY 2010 has been released, please provide more details on the "operationalized" CFE follow-on program, projected costs in executing that program, costs of planned improvements to space surveillance capabilities, and projected milestones associated with the aforementioned actions.

A1. Provided we remain on track for guidance publication as well as the delivery of information technology and human capital resource improvements, we anticipate being able to provide daily safety of flight screenings for all active, maneuverable payloads by the end of 2009. If there are significant delays in the delivery of any of the aforementioned we will see a continued delay in being able to take on this vital mission set.

The Joint Space Operations Center (JSpOC) Mission System (JMS) will incrementally deliver additional advanced services. CFE capability depends on the collaboration of multiple space situational awareness and command and control systems used by operators to collect data, process and analyze it, and to handle CFE requests and reports. Costs and activities specifically associated with CFE improvements include:

- Additional data processing equipment and associated support equipment will directly increase the ability to handle larger volumes of data for calculations, and provide backup capability in case of equipment failures: $7.6M (ECD: 15 Jun 09)
- Migration of CFE processing from legacy system to new net-centric JSpOC Mission System: $9.9M (ECD: 2013). In the interim, AFSPC will deliver a basic Conjunction Assessment (CA) capability to USSTRATCOM 1 Oct 2009 by delivering additional computing power, personnel, and processes to bridge the gap until delivery of JMS.
- Additional personnel to handle CFE operations: $1.2M per year (ECD: 2009)
- Prototype system to improve data from existing sensors by filtering data to find more objects at the limits of detection: $4.5M (ECD: 2009)
    - Recurring costs estimated at $5M per year
- 24 civilian billets (ECD: 2010)
- AFSPC developed a three-tier solution to delivering CA capability: short-term, mid-term, long-term solution
    - Short-term delivery is to build out current capability (described above) by expanding legacy systems with additional computing power, personnel, and procedures to meet CFE needs. Allows for CA services for 800 active maneuverable versus all cataloged objects
    - Mid-term addresses the gap between now and the 2013 JMS delivery. AFPSC engaged with the SPO to evaluate commercial or government owned solutions to enhance CA services until JMS delivery.
    - Long-term solution is the 2013 JMS

Q2. You state in your prepared statement that the relationship between DOD and commercial space operators is sound but that challenges remain, such as sharing of SSA data. Your statement references a recent round table discussion with owner/operators sharing the short- and long-term goals of the CFE Program. Was there a meeting of the minds on how commercial users' information and analysis needs could be better met?

A2. We have made great strides in developing relationships and beginning to understand CFE requirements. There have been two round table discussions between the

DOD and Commercial and Foreign Entities (CFE). The first was conducted on 2 April 2009 during the National Space Symposium and the second was held 14 May 2009. We have gained tremendous insight into CFE needs by closely working with the entities we already have support agreements with. The goal of our interaction with CFE is to set expectations, understand CFE needs, and explain to CFE what data and services the Joint Space Operations Center can provide consistent with National Security interests and on a non-interference basis. This dialogue will continue with the resurrection of the Flight Dynamics Task Force Working Group, which will serve as a focused, technical forum comprised of system experts from industry and government.

The Flight Dynamics Task Force (FDTF) is a task force established by the Mission Assurance Working Group (MAWG). The FDTF was established in 2006 to address commercial SATCOM industry concerns over CFE Program. The FDTF surveyed the industry to gather technical information from industry and determine their desires for the CFE program which was provided to AFSPC in 2007. The current stand-up of the FDTF will be to update the information from the previous study and will include more commercial SATCOM participants as our numbers have increased along with the commercial Remote Sensing operators.

The DOD Executive Agent (EA) for Space, with CDRUSSTRATCOM and ASD (NII) meet at least annually with the commercial SATCOM CEOs to discuss issues relevant to the commercial SATCOM operators—one of the primary topics is CFE. The National Security Space Office (NSSO), as the staff for the DOD EA for Space, leads the MAWG. The FDTF is an appropriate forum as the NSSO has an established relationship with the commercial SATCOM operators through the aforementioned forums. At present, it is the best forum as the Air Force and USSTRATCOM work to determine how best to engage with industry on matters such as this.

Q3. According to a March 9, 2009 article in Space News, *the Air Force is planning on producing a new space traffic management policy before the beginning of June which would "provide wider access to its high-accuracy catalog showing the whereabouts of orbital debris and operational satellites as part of an effort to enable commercial and non-U.S. government satellite operators to better avoid in-orbit collisions." Is such a policy going to be implemented? And if so, what are the details of this policy?*

A3. There are currently no plans for the Air Force to conduct a space traffic management role. The Federal Aviation Administration's Office of Commercial Space Transportation has regulatory oversight of launch and reentry operations conducted by U.S. citizens or in the U.S. There is currently no authority to regulate commercial on-orbit operations. The Air Force does publish basic catalog data on the *Space-Track.org* web site, which can be accessed after registration approval, but has no plans to publish any high accuracy space catalog data to Commercial and Foreign Entities (CFE) satellite operators.

However, in an effort provide crucial conjunction assessment support to CFE, the CFE may enter into a legal agreement with Air Force Space Command. Once approved, the CFE will be able to receive conjunction assessment and space support information based on the Air Force's high accuracy catalog through a future release on the Air Force Space Command sponsored *Space-Track.org* web site.

Q4. Your prepared statement notes that "the global diffusion of space technologies, especially the availability of small spacecraft technologies and providers, will lead to a larger and more diverse population of active spacecraft" What does a potential increase in small satellites mean for estimated debris growth and potential collisions in the future? What actions are needed to address any questions about an increase in the use of small satellites?

A4. The smaller a satellite gets, the harder it is to track. With less tracking data the positional accuracy degrades and so too does our ability to provide accurate conjunction assessments. Ensuring that we bring new capabilities on line such as the Space Fence and Space Surveillance Telescope will be essential in improving our ability to track these smaller spacecraft and keep up with small spacecraft technology trends.

Q5. Mr. DalBello's prepared statement notes that "there is no single standard for representing the position of an object in space. Different operators characterize the orbital position of their satellites differently, depending on the software they use for flight operations." Is a standard for characterizing the position of an object in space needed? If so, what entity or entities would develop the standard?

A5. Since different satellite operators have different mission requirements, it would not be practical to require one standard for all space flight operations. However, within a user community where it is necessary to exchange satellite positional information, it is crucial to maintain inter-operability. AFSPC currently does this by providing inter-operable orbit prediction models to users of JSpOC orbital products. Another approach for ensuring inter-operability would be to provide a common data exchange format. This format should spell out the coordinate systems and time standard for a series of predicted satellite positions (this is often referred to as "satellite ephemeris"). However, limitations of legacy communication systems and limited bandwidth have made this difficult to implement on a large-scale basis.

Q6. What are the challenges associated with fusing data from different sources such as radar and optical systems?

A6. The challenge is not in fusing the data but acquiring enough high quality satellite tracking from either source for the fusion process, especially on small pieces of debris. The current Space Surveillance Network has not been optimized for small debris tracking but with programs like the Space Fence and Space Surveillance Telescope (SST) our ability to track small debris will be greatly enhanced.

The current legacy Command and Control system (SPADOC) does have some throughput limitations in high volume observation correlation processing for "angles only" data on newly discovered unknown satellites (the type you could get from future optical systems like Space-based Space Surveillance and SST). The correlation activity occurs at the front end of the observation processing flow prior to the data fusion process. These capacity limitations should to be addressed in the SPADOC replacement system known as the JSpOC Mission System (JMS).

Typically radars focus more on LEO orbits and optical systems more on GEO and HEO, although we can get data on all three orbit classes from both types of sensors. As new space based optical satellite tracking capabilities become available this mix of data may change somewhat. However, the two types of data are complementary and we are able to readily fuse them and obtain excellent results when we have the data.

Q7. If conjunction analysis and other warning activities could be out-sourced without infringing on national security considerations, what would be the limitations you see as having to be established?

A7. The DOD performs CA and other warning activities for satellites conducting DOD mission requirements [i.e., United States Government (USG) satellites and non-USG satellites supporting DOD missions]. Protection of DOD assets/missions is inherently and should remain a government responsibility. Space situational awareness data is critical to the security of our DOD assets/missions, characterized by very tight decision and maneuver timelines to preserve national assets from debris or maneuvering objects.

Outsourcing poses challenges regarding duplication of effort, forcing competition over resources, protection of data, and data release control. In light of these challenges it does not seem feasible to out-source to a commercial entity other than through government contract. However, a government contract poses its own set of challenges.

Contractors would likely have to be collocated with the Joint Space Operations Center (JSpOC) for effective comparisons and notifications. Appropriate clearances would have to be obtained for the contractors. Assurances would have to be made that requested services are appropriately screened, securely delivered, and safeguarded by the receiver. Finally, with a government contract, upon renewal it may turn over to another company, and with it its expertise.

The space control community is small, experienced operators are rare, and continuity is critical. The ideal model to meet the increasing need for CA and other warning activities would be to keep these functions within government and hire government civilians to work in the JSpOC. This would maintain continuity and create a centralized, stable location to keep and grow CA/warning expertise.

Questions submitted by Representative Pete Olson

Q1. During our hearing, you stated that the Air Force is increasing its ability to process orbital data, which will eventually lead to broadening the system's ability to do conjunction analysis for up to 1,300 objects. How does the Air Force plan to manage the distribution of this data to civilian satellite operators? Will satellite operators be charged a fee?

A1. The Air Force is extensively engaged with allies and partners with respect to the sharing of SSA data. Through DOD and Air Force international cooperation strategies, the DOD details its goals with respect to SSA cooperation, data sharing, and plans for future expansion of these capabilities.

AFSPC leads the pilot program for Commercial and Foreign Entities (CFE) allowing expanded sharing of space track data.

- This program is generally considered successful, but not without concerns. The pilot program has identified legal and policy issues which must be addressed to allow expanded data services.
- Effective 1 October 09, this pilot program will be taken over by USSTRATCOM, who will continue to work closely with other entities (government and commercial), and when appropriate share data of higher accuracy.

The DOD and Department of State are leading discussions on SSA cooperation with key allies. AFSPC experts support such discussions.

- These discussions provide a foundation for expanded SSA cooperation in support of common civil, commercial, and military requirements.
- These discussions serve as a model for developing SSA cooperation with our space partners in other regions.

Bilateral SSA Engagements are addressed on a case-by-case basis. Each interaction is governed by delegation guidance and DOD and AF International Engagement strategies.

Q2. To what extent is the Air Force coordinating orbital surveillance and tracking efforts with other governments? Are there plans to work more closely with other governments to share data and increase its accuracy?

A2. The Air Force is extensively engaged with allies and partners with respect to the sharing of SSA data. Through DOD and Air Force international cooperation strategies, the DOD details its goals with respect to SSA cooperation, data sharing, and plans for future expansion of these capabilities.

AFSPC leads the pilot program for Commercial and Foreign Entities (CFE) allowing expanded sharing of space track data.

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Bilateral SSA Engagements are addressed on a case-by-case basis. Each interaction is governed by delegation guidance and DOD and AF International Engagement strategies.

Questions submitted by Representative Dana Rohrabacher

Q1. When a commercial user asks the Air Force to provide satellite data, is there a standard set of data and a standard published price list that is publicly available? Is the typical data set that you provide sufficient, or do most commercial users require additional information?

A1. The most commonly requested data, two line element sets, are provided on the AFSPC *Space-track.org* web site to registered users free of charge. The two line element sets provide basic orbital parameters, based on general perturbations, and the level of accuracy is sufficient for the majority of registered users; however, commercial operators often require/request data with a higher accuracy level. The Joint Space Operations Center (JSpOC) can provide high-accuracy data and conjunction assessment based on special perturbations; however, this is done only for commercial users who enter into an agreement with the U.S. Government.

Commercial operators can request special perturbations data and advanced services by registering on the *Space-track.org* web site, and then submitting a Space Support Request (SSR) to AFSPC. AFSPC will review the SSR to ensure security and legal requirements are met. If the SSR is supportable, a legal agreement is signed, and the SSR then goes to the JSpOC. The JSpOC works directly with the commercial users to deliver high-accuracy information (based on the special perturbations) and advanced services free of charge. Since we do not charge for services, this is no published price list.

Q2. Although we have not yet seen widespread commercial human space flight, it is clear that within a few years there will be several commercial entities capable of regular sub-orbital, and possibly orbital, service. In the planning for future programs, is any consideration being given to this industry? Is there concern that these entities might present further dangers to civil and commercial users?

A2. The space situational awareness support required for any future commercial human space flight is the same as the orbital safety and anomaly resolution support provided today for NASA human space flight. The services include launch conjunction assessment, on-orbit conjunction assessment, on-orbit anomaly resolution, positional data, and reentry support. Our planning for future systems such as JSpOC Mission System includes requirements to deliver these services and is scalable to handle the future growth of new customers who need these types of services. DOD policy related to CFE support would need to be modified to include language covering the commercial human space flight needs and priorities.

Q3. What are the hurdles in expanding our international agreements beyond debris mitigation to include debris remediation? Are there nations or commercial operators who would be against such an expansion?

A3. Directing debris remediation efforts for international governments and CFE are beyond DOD authorities. Initiatives would need to be coordinated with the DOS and FAA.

Debris remediation is one potential approach to increasing the safety/security of both manned and unmanned space systems. AFSPC is prepared to examine such options as a part of the larger space protection suite of capabilities.

There are several hurdles that must be addressed before debris remediation can be become operationally feasible, these include: policy/legal challenges, technological challenges, and fiscal challenges.

- U.S. Policy and international law will need to be addressed prior to developing and employing a U.S. capability, or agreeing to support any foreign/cooperative effort to remediate space debris.
    - The Outer Space Treaty provides that the State of registry of a space object retains "jurisdiction and control" while the object is in outer space. This provision applies equally to active satellites and to debris. Therefore, a State could only take remediation measures for its own debris unless there is an international agreement in place.
    - If a remediation capability were developed that permitted the return of an object to Earth, the U.S. Government would need to be aware of the possibility of technology transfer of our sensitive satellites in violation of the International Traffic in Arms Regulations.
- Studies by NASA and Industry allude to the technological feasibility of debris remediation. However, such systems are beyond the scope of current technology development programs. As AFSPC continues to examine the realm of space protection and situational awareness, we will actively seek any technology that will allow us to protect and maintain our space capabilities.
- Fiscal hurdles will also limit the ability of the U.S. to field a space remediation capability. Any system capable of providing a remediation of debris will be expensive, and beyond the current ability of the MAJCOM to budget for without reduction in some other space capability. A joint U.S.–Allied approach might be more fiscally tenable.

Other nations might be against a debris remediation capability. Each nation will have its own political and technological reasons for either supporting or not supporting debris remediation. Until the U.S. begins to discuss this concept with our allies and partners we will not have a true sense of what other nations views are on this issue. It seems unlikely that commercial entities will have any issues with a government agency expending resources to provide a safer domain for their commercial enterprises.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Nicholas L. Johnson, Chief Scientist for Orbital Debris, Johnson Space Center, National Aeronautics and Space Administration (NASA)

Questions submitted by Chairwoman Gabrielle Giffords

Q1. In 1995, NASA was the first space agency in the world to issue a comprehensive set of orbital debris mitigation guidelines. It took until 2002 for a consensus set of guidelines to be adopted by major space agencies. And the U.N. General Assembly endorsed a set of voluntary orbital debris mitigation guidelines finally in December 2007. Why did it take so long to gain global acceptance of urgently needed guidelines? What does this bode for the universal endorsement of other needed agreements, such as reaching consensus on a space surveillance awareness system and code of conduct for space operations?

A1. In January 1998, the "U.S. Government International Strategy on Orbital Debris" was drafted. This strategy, which was updated numerous times, envisioned a multi-year, three-step process: (1) development and adoption of U.S. Government Orbital Debris Mitigation Standard Practices; (2) development and adoption of orbital debris mitigation guidelines by the Inter-Agency Space Debris Coordination Committee (IADC); and, (3) adoption of orbital debris mitigation guidelines by the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS). All three steps in the process required considerable discussion within the domestic aerospace community, and then across the principal foreign aerospace communities to inform them of the threat of orbital debris and means to mitigate that threat.

Step (1) was completed in February 2001, and step (2) was completed in October 2002. In February 2003, the IADC Space Debris Mitigation Guidelines were formally presented to the Scientific and Technical Subcommittee (STSC) of UN COPUOS. The hope was that the STSC, and then the full COPUOS, would adopt or endorse the IADC guidelines by 2004. However, after two years of discussion, the STSC decided to develop an independent set of guidelines, but one which would be based upon the IADC guidelines. Two additional years were required for the completion and adoption of the guidelines.

The groundwork, including the development of organizational and personal relationships, established during the process of creating international orbital debris mitigation guidelines should facilitate future efforts related to space surveillance awareness systems and potential codes of conduct for space operations. However, these topics involve complex issues of technology and policy, and it is difficult to predict how long either would take to reach an initial consensus.

Q2. Your office's April 2009 issue of Orbital Debris Quarterly News *indicates that debris caused by the February 10 collision between the Iridium satellite and a defunct Russian Cosmos spacecraft were observed by a pair of radars at Goldstone, CA because they were too small to be seen by the Space Surveillance Network.*

Considering the heavy workload the aging radars of the Deep Space Network already perform for NASA's Science missions, what is the likelihood similar space debris observations will continue to be made in the future? Do you know if this particular use has been incorporated by NASA in establishing the requirements of the future Deep Space Network?

A2. Orbital debris observations made with the radars at Goldstone are carried out on a non-interference basis with the principal missions being tracked by the facility. Typically, about 100 hours are available annually. The Goldstone data fill in a relatively narrow gap between one mm (about the largest size of debris found in returned spacecraft surfaces) and five mm (smallest debris size normally seen by the Haystack radar). While generally helpful to NASA orbital debris environment assessments, these data are not critical. NASA is currently reviewing requirements for the Deep Space Network's future capabilities, including orbital debris tracking, as part of the 70 m antenna replacement study.

Q3. Dr. Pace's prepared statement notes that radio astronomy telescopes could possibly be used to aid space situational awareness efforts. Has NASA taken any steps to explore the potential use of radio astronomy telescopes for this purpose or engaged the international scientific community on this question?

A3. In 1989, the Arecibo radio telescope was used successfully in a pioneering effort to detect small orbital debris. This exercise led to the ongoing work with the Goldstone radars noted in the NASA response to Question for the Record number two immediately above. To date, NASA has not identified a need to employ radio astronomy telescopes to support the characterization of orbital debris populations. The use of the U.S. Space Surveillance Network and the Haystack, Haystack Auxiliary, and Goldstone radars, and the examination of spacecraft returned surfaces span the entire size regime of orbital debris.

Q4. Mr. DalBello's prepared statement notes that "there is no single standard for representing the position of an object in space. Different operators characterize the orbital position of their satellites differently; depending on the software they use for flight operations." Is a standard for characterizing the position of an object in space needed? If so, what entity or entities would develop the standard? Do you envision this to require international involvement?

A4. Since the 1960s, the U.S. Government, through the U.S. Space Surveillance Network, has established standards for representing the position and trajectory of objects in space. These standards are widely used domestically and in the international community and have evolved as needs have arisen and technology has permitted. The Department of Defense, as the operator of the U.S. Space Surveillance Network, is best-suited to maintain and, if required, improve these standards.

Q5. You were recently quoted in a National Geographic *article that it may be time to think about how to remove orbital debris from space. While recognizing that current technology makes it neither technically feasible nor economically viable to do so at present, you equated this to an environmental problem. What are the steps that need to be taken before any sort of active debris removal strategy can be established? Are there any technology R&D efforts that should be undertaken to give us future options for debris removal?*

A5. The International Academy of Astronautics (IAA) is nearing the completion of a multi-year assessment of concepts for remediating the near-Earth space environment, i.e., the removal of orbital debris. This report will be the first comprehensive look at the problem with respect to both small and large debris and for debris at low and high altitudes. NASA plans to take advantage of the work done by the IAA in addressing how best to proceed. In addition, NASA and the Defense Advanced Research Projects Agency have recently begun discussions on joint work with the U.S. aerospace and academic communities to investigate possible cost-effective means of removing hazardous orbital debris.

Q6. If conjunction analysis and other warning activities could be out-sourced without infringing on national security considerations, what would be the limitations you see as having to be established?

A6. At this time, out-sourcing conjunction assessment analyses and other warning activities would be extremely challenging. In addition to inseparable national security issues, only the U.S. Space Surveillance Network (SSN) has the raw data and the expertise necessary to perform these operations. Moreover, conjunction assessments and other warning activities involve interactive processes, such as realtime tasking of individual space surveillance sensors to acquire new data, which cannot be accomplished via out-sourcing. Conjunction assessments currently performed by some using publicly available data from the SSN are of insufficient accuracy upon which to base collision avoidance decisions.

Questions submitted by Representative Pete Olson

Q1. During our hearing, it was suggested that one solution to mitigate the likelihood of future orbital collisions would be the provision of high-accuracy data to the commercial sector for those objects that are not maneuvering. Were the Air Force to provide such data, would civil operators have the capability to generate their own conjunction analysis for their satellites? Instead of relying on the Air Force to perform conjunction analyses for the universe of operators, is it more effective to rely on operators (or coalitions of operators) to do their own analysis based on raw data provided from multiple sources, including the Air Force?

A1. At this time, out-sourcing conjunction assessment analyses and other warning activities would be extremely challenging. Conjunction assessments and other warning activities involve interactive processes, such as real-time tasking of individual space surveillance sensors to acquire new data, which cannot be accomplished via out-sourcing. In addition, the U.S. Space Surveillance Network (SSN) uses a set of validated software which is designed to work specifically with the raw data provided by the SSN sensors. Further, national security issues prevent the release of information needed to provide the most accurate conjunction assessments.

Q2. You stated that "the international aerospace community has already made significant strides in the design and operation of space systems to curtail the creation of new orbital debris, but more can be done." Please explain what additional steps could be taken?

A2. First and foremost is to continue to improve compliance with the recently established United Nations space debris mitigation guidelines. This is done primarily via reporting and discussions at the annual meeting of the Scientific and Technical Subcommittee of the United Nations' Committee on the Peaceful Uses of Space and via the various major international space conferences, e.g., the annual International Astronautical Congress and the biannual Scientific Assembly of the Committee on Space Research Some spacecraft and launch vehicle design changes could also reduce the risk of the inadvertent generation of debris. For example, not all pressurized vessels are designed to be vented when no longer needed.

Questions submitted by Representative Dana Rohrabacher

Q1. Although we have not yet seen widespread commercial human space flight, it is clear that within a few years there will be several commercial entities capable of regular sub-orbital, and possibly orbital, service. In the planning for future programs, is any consideration being given to this industry? Is there concern that these entities might present further dangers to civil and commercial users?

A1. Member States of the United Nations (UN) are expected to implement the 2007 UN Space Debris Mitigation Guidelines in their national regulations of future commercial human space flight operations. Human space flight is currently conducted at low altitudes where the orbital debris population is low and where the inadvertent creation of new orbital debris is mitigated by short orbital lifetimes. The vast majority of civil and commercial spacecraft operations take place above the regime used for human space flight.

Q2. What are the hurdles in expanding our international agreements beyond debris mitigation to include debris remediation? Are there nations or commercial operators who would be against such an expansion?

A2. The principal hurdle is to identify practical and affordable means of removing debris from orbit. The International Academy of Astronautics has been conducting a survey of many concepts during the past few years. In general, the concepts are either not technically feasible or are too costly. At this point, it would be premature to judge whether there would be opposition to the development of practical, affordable debris removal systems; as such systems have not yet been identified.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Richard DalBello, Vice President, Legal and Government Affairs, Intelsat General Corporation

Questions submitted by Chairwoman Gabrielle Giffords

Q1. At the hearing you urged DOD to be creative in the development of data sources in recognition of the high costs associated with upgrading the Space Surveillance Network. You suggested, as a potential alternative to utilizing expensive terrestrial infrastructure, that DOD place sensors on every commercial platform going into orbit. How big an impact would making provision for such sensors be on your commercial satellite operations?

A1. Making provisions for the accommodation of sensors on every commercial satellite need not create an operational burden for industry. If the sensors were relatively small and consumed a modest amount of power, they could be accommodated without a significant impact to the commercial mission. Multiple classes of sensors may be needed to match various commercial satellite configurations. The government would need to play a role in the development and coordination of these devices. Specialized, larger, or 'single mission' sensors could also be flown, but, the bulk of the program should probably be built around common and relatively inexpensive units. The communication component of the mission (returning the sensor data to Earth) could be handled easily through the use of the satellites commercial transponders.

In order to routinely add space surveillance sensors to commercial satellites, the private sector would need:

- A clear statement of government objectives and requirements;
- Government provided or designed low-cost, sensors;
- Well-defined and common technical interfaces to reduce cost and allow the package to be 'designed in' at the start of the programs;
- A commitment that the government would have 'insight, not oversight' of the commercial program;
- Contracts that are simple, are based upon commercial terms, and are for a sufficient length of time to justify commercial sector efforts.

Q2. Commercial space users have indicated concern about inadequate funding. An article in Aviation Week and Space Technology *reported on a satellite communications official's concern that there is a question on "whether there will be enough money to get more than the two-line elements currently available." The article added that industry analysts say existing data sets do not satisfy operators' accuracy needs. Do you believe inadequate funding will translate to your industry not receiving data that is as accurate as it needs?*

A2. It is our current understanding that DOD intends to expand significantly the resources available to its Space Situational Awareness Program. How much of this funding will eventually be allocated to the CFE program is unclear. Our current conjunction monitoring systems depend on the two-line elements provided through CFE for initial screening. Should future funding constraints result in limitations on our access to the current two-line elements, or further degrade their accuracy, satellite operators would lose the ability to perform initial screening. The current accuracy of two-line elements does not support reliable conjunction monitoring. However, because this is the only means available for providing the orbital elements for the objects in the catalog, operators rely on it for initial screening only. Once a potential alert is detected, operators typically request assistance from JSpOC via the CFE Form-1 process. If the two-line elements are unavailable or their accuracy is degraded, operators will need to rely more on the direct aid of JSpOC which will increase the workload and expense of this operation. Alternatively, if higher accuracy data are made available to the public, operators could tighten the collision thresholds in their initial screening and thus reduce false alarms and unnecessary requests of assistance from JSpOC for second screening. This would reduce the unnecessary workload on JSpOC and allow for optimal use of its resources.

Q3. In your prepared statement, you advocate beginning an international dialogue on "Rules of the Road" for space to develop guidelines such as protocols for informing other operators when one of their spacecraft could potentially cause damage to other space objects. How would you initiate such a dialogue and what do you consider the major obstacles to agreeing on such Rules of the Road?

A3. An international dialogue on "Rules of the Road" should be pursued through both government and non-government channels. The United States Government should take a leadership role in discussions on space traffic management in international bodies such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), the Consultative Committee for Space Data Systems (CCSDS), and the Inter-Agency Space Debris Coordination Committee (IADC). Leadership and engagement in these fora will be instrumental in efforts to develop a common international understanding of definitions and standards. In addition to these activities, significant attention should be paid to current operational practices. Specific "'best practices'" should be developed by the appropriate communities currently engaged in space operations. The commercial industry's proposal to create a Data Center for the coordination of space traffic information would be one mechanism to engage the participation of commercial satellite operators. Other space actors, such as the science community and the human space flight community, will also need to engage to capture their own unique "best practices." The U.S. Government can play a meaningful role in coordinating the sharing of information between and among these various communities. It is important that the development of "Rules of the Road" be based on practical, experienced-based lessons. Attempts to create a top-down, treaty-based approach or an approach that emphasizes the creation of new international bureaucracies is unlikely to be productive.

Q4. Your prepared statement notes that "there is no single standard for representing the position of an object in space. Different operators characterize the orbital position of their satellites differently, depending on the software they use for flight operations." What are some concrete examples showing how this lack of standard is affecting the ability of some operators to share information on close approach monitoring?

A4. Different operators represent the orbital position and velocity of their spacecraft in different reference frames, time systems and formats based on the flight dynamics systems they use for flight operations. The table below illustrates some examples of the different systems that Intelsat must accommodate when we exchange orbital elements with other operators based on our experiences.

Operator	**Reference System**	**Representation**
Intelsat	ECI and True of Epoch	Cartesian
Inmarsat	ECEF – Earth Center Earth Fixed	Cartesian
EchoStar	ECI and J2000	Cartesian
Eutelsat	ECI and Quasi Equator Mean Equinox	Cartesian
SES	ECI and True of Date	Keplerian
JSPOC	ECI and Mean of J2000	Cartesian
CFE – TLE	ECI and True Equator Mean Equinox	Mean Keplerian

** (ECI - Earth-Centered Inertial (ECI) is the name given to a group of coordinate frames with their origins at the center of mass of the Earth. ECI frames are called inertial in contrast to the Earth-centered, Earth-fixed (ECEF) frames which rotate in inertial space in order to remain fixed with respect to the surface of the Earth. It is convenient to represent the positions and velocities of terrestrial objects in ECEF coordinates such as latitude and longitude. However, for objects in space, the equations of motion that describe orbital motion are simpler in a non-rotating frame such as ECI. The ECI frame is also useful for specifying the direction toward celestial objects.)*

The problem is further complicated due to inconsistent use of terms and definitions. There are many subtle differences even if the "same" reference frames are used and if not carefully accounted for will lead to errors of a few of kilometers in the satellite positions.

Q5. Given that the need for and benefit of space surveillance awareness is worldwide and cuts across military, civilian government, and commercial lines, what are the prospects for establishing a cost-sharing approach to the provision of the space surveillance function? Does the U.S. derive sufficient benefits from the information that it should provide the services free of charge, or should users pay a fee? What are the pros and cons of establishing user fees?

A5. It may be more immediately productive to characterize space traffic management as a "burden sharing" rather than a "cost sharing" opportunity. The commercial industry stands ready to provide valuable information to the U.S. Government by sharing with the government its satellite ephemeris data based on their its dedicated ranging systems. This high quality data will provide better accuracy than the special perturbation orbital data derived from DOD's space surveillance network. In addition, the industry ephemeris data contains the maneuver information which is essential for predictions in the future and for reliable close approach analysis. By sharing this high quality data with the government, operators also free up the government resources so they it can focus on monitoring the high priority targets. This will result in cost savings to the government. We believe, therefore, in exchange for the industry ephemeris data, that the government should provide the close approach monitoring services for free. Since any collision in space will create more debris and thus impact the operation safety for all others sharing the same space, it is important to encourage as many satellite operators as possible to participate in the close approach monitoring. If a fee is imposed on the service, it may discourage some operators from participating.

Q6. If conjunction analysis and other warning activities could be out-sourced without infringing on national security considerations, what would be the limitations you see as having to be established?

A6. Intelsat believes that it would be feasible to out-source the space traffic management function to a private entity or to a consortium of operators. To successfully carry out the space traffic management task, it is essential that the designated entity have access to high quality information on all space assets. Such information would likely be derived from U.S. and foreign observations and from data sharing between commercial and government entities. Obviously, the sharing of information on the location and maneuver of government space assets can raise important security concerns. Initially, an out-sourced space traffic entity might have to segregate its information into "open" and "restricted" categories. "Open data" might reasonably be accessible by all, whereas "restricted data" might be limited to a pre-designated group of entities. Such segregation would be complicated by the need to include non-U.S. entities in the data sharing plan. Over time, as more nations develop the ability to monitor space activities and space is rendered increasingly transparent, the difference between "open" and "restricted" data sources is likely to diminish.

Questions submitted by Representative Pete Olson

Q1. During our hearing, it was suggested that one solution to mitigate the likelihood of future orbital collisions would be the provision of high-accuracy data to the commercial sector for those objects that are not maneuvering. Were the Air Force to provide such data, would civil operators have the capability to generate their own conjunction analysis for their satellites? Instead of relying on the Air Force to perform conjunction analyses for the universe of operators, is it more effective to rely on operators (or coalitions of operators) to do their own analysis based on raw data provided from multiple sources, including the Air Force?

A1. If the Air Force were to provide the high quality data for non-active satellites and debris, the industry would be able to use this data to conduct conjunction monitoring with respect to those objects. One of the goals of the Data Center initiative is to enable operators to provide close approach monitoring for as many space objects as possible. One of the limitations in our effort is the lack of high quality data for non-active objects and non-cooperative operators. Provision of high quality data regarding non-operational objects would not be sufficient to perform conjunction analysis in all cases, since operators would still have to account for active government and non-cooperating satellites. Nonetheless, such a sharing approach would enhance commercial operators' assessment capabilities, while reducing the burden on the Air Force JSpOC.

Over time, it would be possible to use raw data provided from multiple and disparate sources to substitute for the services currently provided through the CFE program. However, such sharing arrangements—particularly between different nations—are not yet in place. Even if countries and companies were committed to data sharing, there are still important data format and data validation issues to resolve. So, in short, it is not today more effective to rely on data from coalitions of operators and multiple sources to perform conjunction analysis; however, we hope and expect that it will be in the future.

Questions submitted by Representative Dana Rohrabacher

Q1. Although we have not yet seen widespread commercial human space flight, it is clear that within a few years there will be several commercial entities capable of regular sub-orbital, and possibly orbital, service. In the planning for future programs, is any consideration being given to this industry? Is there concern that these entities might present further dangers to civil and commercial users?

A1. For Intelsat's part, the expansion of commercial human space flight should have no impact on its operations. Typically, human space flight activities take place within a few hundred miles of the surface of the Earth. Intelsat's satellites are in geostationary orbit at approximately 22,000 miles from the Earth.

Our interests notwithstanding, there are many commercial operations in communications and imagery that will have to share 'low-Earth orbit' with future commercial human space flight activities. It is my understanding that currently NASA, working with DOD's JSpOC, pays very close attention to the safety of the space station. As other human space flight activities proliferate, the JSpOC, or other future space traffic management entity, will need to add these activities to its list of actively monitored objects. The number of objects represented by future commercial human space flight activities is likely to be small and therefore should not challenge our state-of-the-art computational capabilities for space traffic management. So, in short, increased human space flight activity does add another set of challenges for space traffic management, but these challenges should be well within our technical competence.

Q2. What are the hurdles in expanding our international agreements beyond debris mitigation to include debris remediation? Are there nations or commercial operators who would be against such an expansion?

A2. In Intelsat's opinion, there are no practical technologies available today that could be used to provide low risk, cost effective, and reliable debris remediation. Intelsat closely monitors progress in this field and is routinely briefed by entrepreneurs and innovators regarding emerging debris remediation techniques. For example, we recently reviewed several "space tug" concepts that would be designed to remove whole satellites from the geostationary orbit. Intelsat would support government and industry efforts to advance the state-of-the-art in this important field.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Scott Pace, Director, Space Policy Institute, Elliott School of International Affairs, George Washington University

Questions submitted by Chairwoman Gabrielle Giffords

Q1. Your prepared statement advocates international cooperation focusing on sharing basic information using open standards while recognizing that proprietary "value-added" products will arise on their own in response to user needs." Can you elaborate on what basic information should be shared and what open standards you envision?

A1. The basic information that should be shared is the object's location and enough data to be able to estimate (or "propagate") the object's position forward in time with sufficient accuracy to do conjunction analysis. In addition, there should be a "point of contact" for that object if possible (i.e., who to call regarding maneuvers or impending collisions).

The two-line elements (TLE) put out by the Commercial and Foreign Entities (CFE) pilot program are a common means of representing an orbit. They contain position information, orbital characteristics, and time information about each object in a comprehensive catalog of space objects. "Orbital characteristics" are represented by parameters such as the orbital period, inclination, apogee, perigee, eccentricity, semi-major axis, longitude of the ascending node, argument of periapsis, mean anomaly, etc. With information about an object at a particular time (or epoch), the future orbit can be calculated. Realistically, this means taking into account complex perturbations including, among other effect, atmospheric drag, solar radiation pressure, gravity field variances, third-body effects due to the Moon and Sun, and spacecraft maneuvers.

The International Standards Organization (ISO) has two subcommittees (ISO/TC20/SC13 and ISO/TC20/SC14) which between them develop the full body of international space standards. In cooperation with these ISO subcommittees the international Consultative Committee for Space Data Systems (CCSDS) has developed a recommended standard for "Orbit Data Messages" which provides a common framework for the interchange of orbit data across the international space-faring community. There are three general types of messages: 1) Orbit Parameter Message which specifies the position and velocity of an object at a specified epoch or time; 2) Orbit Mean-elements Message which specifies the orbital characteristics of a single object at a specified epoch or time; and 3) Orbit Ephemeris Message in which the position and velocity of a single object is specified at multiple epochs within a specified time range. For a given object, analysts may use all three types of messages to get an accurate ephemeris (or description of the object's behavior).

In addition, scientific information about the space and Earth environment, such as space weather, models of the Earth's gravity and atmosphere, are needed to accurately predict orbital behavior over time. The basic framework of required standards needs to be more comprehensively defined and their development responsibility assigned to the appropriate standards organizations. Once the basics are agreed via open international standards, value-added augmentations from the private sector will follow. One way to establish the basic framework could be to assign its definition as a joint working activity between the two existing ISO subcommittees.

Q2. Some European space agencies have signed the European Code of Conduct for Space Debris Mitigation. Is there a need for a code of conduct to be followed by all space-faring nations?

A2. A goal of having a code of conduct followed by all space-faring nations is a worthwhile one. The current EU-proposed code is a starting point but other nations such as the United States, Russia and China, need to be part of the shaping of any code if voluntary adherence is to be effective. The code of conduct can be expected to evolve as countries gain more space experience. It should be kept in mind that this proposal Is separate from the current *Space Debris Mitigation Guidelines.* The Inter-Agency Space Debris Coordination Committee (IADC) that includes all the major space agencies produced these guidelines.

Q3. What are the main challenges associated with active debris removal? What research should be undertaken to better understand the technical, policy, and cost issues associated with such removal?

A3. There are complex technical, cost, policy, and legal issues associated with active debris removal. At a technical level, the challenge is how to accurately impart sufficient energy to create a change in an object's velocity to de-orbit or put it into intersection with the Earth's atmosphere so it will reenter. For object too high for atmospheric reentry (e.g, MEO and GEO orbits), the challenge is to put the satellites into stable disposal orbits and vent residual propellant to mitigate the possibility they disintegrate into a cloud of debris. The energy may be imparted by ground-based systems (e.g., lasers) or by in-space devices through collision, manipulation, or propulsion. For physical contact, it is unclear how one would rendezvous with a spinning, potentially unstable object.

The technical options are all costly with low economic incentives to remove any particular piece of debris. What objects would be targeted for removal first? Would we target the most massive objects or the objects most likely to disintegrate or those in the most crowded orbits? Further, it may be difficult to tell the difference between intentional and unintentional debris removal and thus the actions of a space weapon. From a legal perspective, objects in space still belong to States and there is no "salvage law" for space to deal with what are effectively abandoned objects. This raises policy questions such as whether States should only remove their own objects or those whose removal has been specifically consented to. Some small objects may be both unidentified and unidentifiable as debris below certain sizes are very difficult to track if costs of debris mitigation are to be shared, then agreement will be needed on which objects should be given prior for removal based on some common understanding of potential risk.

Q4. Your prepared testimony also refers to the increasing deployment of small satellites. Can you comment on how this might complicate things?

A4. Small satellites typically have little to no internal Delta V capability (i.e., ability to change their orbit) for end of mission life disposal. Countries, companies, and academic institutions may deploy small satellites into uncoordinated orbits or fail to follow operational practices developed for larger satellites. This may be a particular concern for polar orbits where many satellite orbits intersect above the poles. On the other hand, if deployed into very low orbits, they wall tend to have low orbital lifetimes and need not be a persistent threat: For small "swarms" of nano- or pico-satellites, their optical or radar cross-sections may be so small as to render direct observation difficult, In those cases, small satellites may be required to have optical or radar reflectors or radio transponders to ease and tracking. Passive reflectors would likely be preferable as they would not require satellite power.

Q5. Your testimony refers to the need for "a common understanding of definitions, standards, operating procedures, and practices for space operators to communicate with each other." What mechanism do you believe is appropriate for developing this "common understanding" nationally and internationally?

A5. The two ISO subcommittees mentioned previously seem to provide a viable and easily activated mechanism for developing a common international framework of definitions and open standards. ISO/TC20/SC13 (the parent of the CCSDS) develops data communications and exchange standards for space systems and ISO/TC20/SC14 develops electromechanical and process standards. A joint working group could be quickly established between these subcommittees to parse the problem and to develop the common operating standards and practices to accommodate different locations and conditions, e.g., GEO communications satellites, environmental monitoring satellites in polar orbits. With the necessary standards under development, discussions would then occur among IADC members with recommendations incorporated into air evolving code of conduct. This avoids premature constraints that may be created by a top-down treaty approach while including all space-faring nations into a common, fact-based process. Consensus will likely be slow but it will also be more reliable and effective than attempts at mandates. For this approach to be truly useful to the United States, however, strong interagency coordination for a national position and active agency support for the international discussions will be needed, e.g., in the ISO space standards subcommittees and the IADC.

Q6. What are the challenges associated with fusing data from different sources such as radar and optical systems?

A6. I am not an expert in fusing data from optical and radar systems and identifying the problems would seem to be another task that might be assigned to the joint ISO working group suggested above. I would note however that the CCSDS in particular is already defining the necessary basis of information architecture, information packaging and associated XML-based data interchange standards that provide a common platform for the rapid sharing and fusion of multi-source data across the international space community.

Radar and optical systems have advantages and disadvantages so data from both are important to have, especially in geographically dispersed areas. Radars are useful for finding and ranging objects very quickly and they can track multiple objects at once. Unfortunately, radars are also expensive and thus there will be relatively fewer sites in use. Radar wavelengths can often be greater than really small objects and thus not useful for tracking them. Optical tracking is less expensive but slow with the need for multiple sightings. Tracking lasers cannot find objects but they can be very fast and accurate given optical and radar cuing information. At a minimum, it would seem that standardized exchange of calibration agreement and verification would be vital as the same object can have very different optical and radar cross-sections and thus verification that data from two systems actually concerns the same object can't be assumed.

Q7. Given that the need for and benefit of space surveillance awareness is worldwide and cuts across military, civilian government, and commercial lines, what are the prospects for establishing a cost-sharing approach to the provision of the space surveillance function? Does the U.S. derive sufficient benefits from the information that it should provide the services free of charge, or should users pay a fee? What are the pros and cons of establishing user fees?

A7. The United States is especially dependent on space to support its national security and economic interests. We have a Navy to protect our interests and dependencies on the sea and in a similar way, the United States needs to have a leading role in capabilities like SSA to protect our interests and dependencies in space. The fact that the benefits of SSA are international and cross all space sectors (and the ground systems that depend on space), would argue that SSA is a public good. In peacetime, one nation's use of SSA does not reduce the benefit of another nation's use of SSA and both may benefit from the positive externalities of sharing information. Thus cost sharing is not quite the right question to be asking. International space cooperation has long been based on the principle of 'no-exchange of funds" and the pooling of efforts for shared objectives.

We should be asking how each space sector and space-faring nation could make efforts that improve common SSA. For example, commercial firms can share information about their systems and data exchanges with each other and they can do independent conjunctions analysis. The same is true for civil agencies that may also be able to contribute data from ground-based radars and optical tracers. Both industry and civil agencies could create opportunities for hosting payloads on their satellites to improve SSA from sensors in space. There can be international contributions of data from geographically distributed optical and radar sources that would otherwise be difficult and expensive for the United States to create alone.

The 1996 National Space Policy (now superseded by the 2006 National Space Policy) contained some guidance if fees of any sort were considered:

> (a) Prices charged to U.S. private sector, State and local government space activities for the use of U.S. Government facilities, equipment; and services will be based on costs consistent with federal guidelines, applicable statutes and the commercial guidelines contained within the policy. The U.S. Government will not seek to recover design and development costs or investments associated with any existing facilities or new facilities required to meet U.S. Government needs and to which the U.S. Government retains title.

Improved but still limited SSA services such as those provided by the CFE pilot program, should be provided freely to all who contribute to stronger SSA capabilities for the United States. This includes civil agencies, allied countries, commercial operators with data sharing agreements, and even NGOs. If fees were charged, there would be incentives to not use safety services and thus increase risk to others. Fees would also creates incentives for separate SSA systems and could undermine data sharing with common standards which would in turn reduce the public good afforded by SSA. Finally, there would be the transaction cost associated with the task of calculating and collecting the fees.

Q8. If conjunction analysis and other warning activities could be out-sourced without infringing on national security considerations, what would be the limitations you see as having to be established?

A8. If conjunction analysis and other warning activities were out-sourced, regulatory guidance would have to be in place to define quality standards for analyses and standards of liability for warnings. As with other safety services, the government can provide them or allow the private sector to provide them, but four the latter approach, government requirements for public safety would need to be defined. At present, it is too soon to set such requirements.

The government should be wary of out-sourcing its intellectual capability to produce conjunction analyses and warnings. Even though the government relies on expert contractors, the existence of a substantial fixed cost government capability results in a relatively low marginal cost for doing an additional analysis. Thus it is hard to see how paying another contractor to serve non-government customers would save significant resources. For national security purposes, the government may not wish to discuss particular space objects or detection capabilities. If the United States doesn't reveal some information and an incident occurs, it would be likely held responsible for any consequences. Again, this creates a practical problem for out-sourcing.

Questions submitted by Representative Pete Olson

Q1. During our hearing, it was suggested that one solution to mitigate the likelihood of future orbital collisions would be the provision of high-accuracy data to the commercial sector for those objects that are not maneuvering. Were the Air Force to provide such data, would civil operators have the capability to generate their own conjunction analysis for their satellites? Instead of relying on the Air Force to perform conjunction analyses for the universe of operators, is it more effective to rely on operators (or coalitions of operators) to do their own analysis based on raw data provided from multiple sources, including the Air Force?

A1. With high precision data, many commercial operators (e.g., GEO comsat firms) should be able to generate their own conjunction analyses. Such analyses may be more challenging for commercial firms operating communication satellites and remote sensing satellites in LEO due to the faster moving nature, and stronger orbital perturbation effects in the LEO environment.

As stated elsewhere, conjunction analyses can only be performed against objects the satellite operators are told about. A pilot effort could be started with the major satellite operators in GEO by sharing high accuracy information with them try return for hosted space sensors on some of their satellites and routine information on the precise location of the commercial GEO satellites. The Air Force, in cooperation with other government agencies, should remain responsible for conjunction analyses in LEO for now.

Questions submitted by Representative Dana Rohrabacher

Q1. What are the hurdles in expanding our international agreements beyond debris mitigation to include debris remediation? Are there nations or commercial operators who would be against such an expansion?

A1. Leaving aside technical and cost difficulties, there are policy and legal issues associated with debris remediation. It may be difficult to tell the difference between intentional and unintentional debris removal and thus the actions of a space weapon. Thus some countries might object remediation fearing the creation of a means for hostile actions on still operational satellites and spacecraft.

From a legal perspective, objects in space still belong to States and there is no "salvage law" for space to deal with what are effectively abandoned objects. This raises policy questions such as whether States should only remove their own objects or those whose removal has been specifically consented to. Some small objects may be both unidentified and unidentifiable. If costs of debris mitigation are to be shared, then agreement will be needed on which objects should be given prior for removal based on some common understanding of potential risk. One approach to developing an international agreement on debris remediation could be the clarification of any permissible salvage rights for man-made objects in space. Some countries may object to this as a modification to the 1967 Outer Space Treaty.

Q2. Although we have not yet seen widespread commercial human space flight, it is clear that within a few years there will be several commercial entities capable of regular sub-orbital, and possibly orbital, service. In the planning for future programs, is any consideration being given to this industry? Is there concern that these entities might present further dangers to civil and commercial users?

A2. I am not aware of specific regulatory considerations being given Lo the commercial human space flight industry. I am aware of an FAA licensing requirement for collision avoidance as part of flight safety analyses for commercial space launches. The requirement is to maintain a distance of at least 200 km from any habitable orbiting object, e.g., the International Space Station and perhaps other commercial human space flights. It is unclear how that requirement will be met, what would constitute an acceptable analysis, and how potential collisions would be addresses. Should commercial launch operators be required to pay for conjunction analysis by the government, private third parties, or will their own work be acceptable? At this stage, it would seem prudent for the government to remain flexible and encourage use of non-proprietary collision avoidance models that allow independent verification of a collision avoidance analysis.

Appendix 2:

Additional Material for the Record

STATEMENT OF MARION C. BLAKEY
PRESIDENT AND CEO
AEROSPACE INDUSTRIES ASSOCIATION

Introduction

Chairwoman Giffords, Ranking Member Olson and distinguished Members of the Committee, thank you for holding this important hearing on space debris and space environment safety. I appreciate the opportunity to submit this testimony for the record.

I represent the Aerospace Industries Association—we are an association of nearly 300 aerospace manufacturing companies and the 657,000 highly-skilled employees who make the satellites, space sensors, spacecraft, launch vehicles, and the ground support systems employed by NASA, NOAA, and the DOD. I welcome the opportunity to provide testimony on the major challenges and risks associated with debris in the space environment.

First, let me thank the Committee for its foresight and dedication needed to ensure the U.S. maintains our leadership in space, and we are grateful for your recognition of the role our nation's space programs play in both our economic strength and national security. The stimulus package was an excellent first step in providing the necessary support our space and aeronautics programs need to keep up with the demands of space exploration, aeronautics research and development, Earth observation, scientific research, and critically important manufacturing technology programs.

Current Threats Facing Our Crowded Space Environment

Just recently astronauts aboard the Space Shuttle Discovery and International Space Station (ISS) were forced to engage in maneuvers to avoid a small piece of debris that put their lives at risk. Crew aboard the ISS have also taken shelter in their Soyuz spacecraft as a precaution against possible collisions several times in the past. These incidents highlight a stark reality: space is becoming increasingly crowded. Over 60 nations are engaged in space efforts, and tens of thousands of man-made objects—including debris orbit the Earth. As the number of nations placing objects in space grows, risks to U.S. space systems and our ability to operate in space also increases. Space technology is a critical infrastructure that contributes to a strong and secure America. It needs to be adequately protected. This includes additional funding for space protection and space situational awareness efforts, better data-sharing with our international allies to limit space debris and maintain a safe environment, and improvements to government-industry partnerships.

From the early days of the Space Age, space systems have grown to become critical components of the modern U.S. economy, our national defense, and our preeminence in science. Today, U.S. satellites provide early warning when nations like Iran or North Korea launch a missile. They allow secure global communications and provide bandwidth for unmanned aerial vehicles used by our troops in isolated battlefields like Afghanistan. NASA's Science Directorate provides a better understanding of our Earth, and the universe. NASA's Aeronautics Research and Development endeavors tie the use of space systems into the completion of the NextGen air transportation modernization program and continued efforts to reduce aviation's environmental impact. Weather satellites give us warnings of storm fronts, deep freezes, and hurricanes. Space systems are also an important part of the modern U.S. economy; providing business communications, navigation through OPS handsets, remote sensing, and digital television and music for millions of consumers. In 2008 space system industry sales topped $33 billion providing thousands of high-wage, middle class jobs.

Yet we are not adequately protecting or ensuring the safety of our space assets. The Defense Department currently acts as the de facto Federal Aviation Administration (FAA) for space—responsible for providing space situational awareness for over 18,000 man-made objects in the Earth's orbit. This is no easy task. Remember, it's not just military satellites the Pentagon has to worry about; multiple systems from NASA, the intelligence community, commercial providers, and international assets are all circling the Earth at speeds of thousands of miles per hour.

Debris is a major concern. When an airplane accident occurs here on Earth, the associated debris does not impact future flights. In space however, debris can orbit the Earth for years, decades, or even centuries. if debris interacts with additional man-made objects, the problem can be compounded and result in the creation of even larger debris fields. In January 2007, a Chinese ballistic missile destroyed an aging weather satellite, which created a massive debris field that will orbit the Earth well into the future. In February 2009, the Pentagon's job became even more difficult when a commercial U.S. satellite and a defunct Russian satellite collided. Recent reports by NASA have detailed multiple debris threats to the Space Shuttle and ISS—endangering lives and billions of dollars of space infrastructure. Since we don't yet have the ability to clean up space, debris fields present a very real impediment for future uses of space by the U.S. and our international allies.

With its current minimal budget for space situational awareness, the Defense Department is forced to prioritize what objects it tracks. Limited resources force it to track space objects that could interfere with humans in space or military satellites as its top priorities. Tracking of commercial assets gets an even lower priority. To its credit, the Defense Department recently created, along with the National Reconnaissance Office, a Space Protection Program that supports interagency collaboration on space threat assessments and collaboration on space protection strategy. This is an important step forward for the military and intelligence community. Yet when compared with the FAA, which is provided billions every year for air traffic control and safety, our national space situational awareness efforts are lagging far behind.

Investment in Space Protection and Space Situational Awareness is Critical

Given our reliance upon military, intelligence, civil, and commercial space systems, and growing threats including debris and other satellites, the U.S. needs to provide robust funding for space situational awareness and the protection of our space assets. This funding should not only maintain current capabilities, but advance them towards significant improvement. This includes funding modernization programs for space systems to harden satellites from attack, and establishing contingency plans to ensure redundancy of space capabilities. Important initiatives like Operationally Responsive Space seek to develop systems that can be rapidly deployed and help improve space system redundancy, but with more systems in orbit we will need to increase the fidelity of tracking items in space. We also need to do a better job of sharing information with our international partners and between government and industry.

Space systems are no longer the dreams of rocket scientists of the early 20th Century; they have arrived and are part of our way of life. The space industry supports thousands of high-tech jobs and billions of dollars in economic activity. But without increasing resources for the protection of our space systems, we are putting our security and economic competitiveness at significant risk. Now, as the Administration puts the final touches on its Fiscal Year 2010 budget, is the right time to make the right investment in this critical infrastructure by providing significant resources to space protection and space situational awareness. Interagency partnerships and government partnerships with industry should be strengthened to provide robust protection of our critical space assets. It will also be important to take the steps necessary to work with our international allies to prevent additional collisions and the proliferation of debris in the global space environment.

STATEMENT OF THE
SECURE WORLD FOUNDATION

Secure World Foundation is pleased to provide this written statement to the Subcommittee on Space and Aeronautics in its consideration of the role of space situational awareness in supporting the long-term sustainability of activities in outer space. In order to continue to reap the substantial benefits provided by activities in Earth orbit, the United States will need to find a satisfactory way to enhance space situational awareness.

The current space environment and the value of space situational awareness

On February, 10, 2009, the communications satellite Iridium 33 was passing over Siberia on its way up over the North Pole and then southwards, a journey that had taken place without incident every one hundred minutes for the past eleven years, four months, and twenty-seven days of its mission providing satellite telephone services. That day, it experienced a sudden, violent shock and then fell silent. Iridium operators later learned that Iridium 33 had collided with another space object, a Russian communications satellite that had ceased operation years earlier. The two spacecraft had approached each other at speeds faster than any human eye could have ever followed.

If we desire to continue to reap the immense benefits that space can provide, we must take steps to preserve the Earth's orbital environment. A key concern is the threat of loss of utility of key orbits because of a proliferation of space debris. The unavoidable first step to this preservation is to determine what is in Earth orbit and where it is going: space situational awareness (SSA). Space situational awareness is not a new concept—it has been an important part of military space activities for many years. But like many other space applications, such as global positioning data and satellites communications, there is also a growing need for SSA in the civil world.

The fundamental difference between civil SSA and military SSA is in the types of information that it provides. Civil space situational awareness only needs to focus on the location of an object in Earth orbit and a point of contact for that object, along with environmental information about space weather. The additional military requirements of determining function, intent, and capabilities and limitations are not necessary for civil uses.

Imagine that you are in a car, driving down the road on a clear and sunny day. In this situation, the driver has excellent situational awareness and has all the information needed to operate the vehicle in a safe and efficient manner. However, if the windows are blacked out the situation becomes much different. Even if the driver is using a GPS device to display the car's position on the road the driver has no information about either the locations or movements of the other cars.

This environment of highly limited information is the same in which many of the satellites in Earth orbit are operated today. The owner or operator of a particular satellite usually has excellent knowledge about the position of that satellite in space, but little to no information about the locations of other objects around them. This situation was the root cause behind the collision of two satellites in February—the owner of the Iridium satellite, which could have potentially maneuvered it out of the way, did not know about the impending close approach.

This collision produced close to one thousand pieces of space debris larger than four inches, which are currently being tracked by the U.S. military. Although still a serious incident, this number could have been significantly higher had the two satellites collided with more than what seems to have been a glancing blow.

The debris generated by the February 10th collision is just a small fraction of the overall debris population. Over 18,000 pieces of debris are being tracked in Earth orbit by various militaries, scientists, and amateur observers around the globe. Much of this population will stay in orbit for decades and even centuries. This debris, which is the result of placing and operating objects in orbit, will pose an ever more challenging threat to our continued use of space, including for commercial benefit and exploration.

Space is a vast domain, yet there are only a few regions from which we derive the majority of the scientific and economic benefits. These regions are limited natural resources, and our use of them can have long lasting negative effects on their utility. SSA is crucial not only to understanding the effects of humanity's activities in space but also in minimizing the costs those effects have on future space activities.

The value of space situational awareness to human space flight and use of outer space for scientific and commercial benefit

Globally, outer space provides many services that are crucial to both the US and global economy and to increasing our scientific knowledge. Collisions between objects in orbit not only lead to potential disruptions in these services but also leave debris in orbit. This debris raises the economic costs of future operations in space by increasing the measures satellite operators must take to protect their assets. These measures include more frequent maneuvers, which expend fuel and can cause service outages as well as potentially increasing manufacturing and launch costs.

Space situational awareness is also crucial for the safety of human space flight. On March 12th, 2009, the crew of the International Space Station (ISS) was forced to prepare for an emergency evacuation inside the Soyuz spacecraft in response to an unexpected close approach by a piece of debris from the 1993 US launch of a Global Positioning Satellite. This was followed by another close approach by a piece of debris from an expired Russian satellite on March 16th. On March 22nd, the docked Space Shuttle Orbiter and ISS were forced to change orbit to avoid an extremely close piece from a Chinese rocket booster launched in 1999.

The remote sensing satellites that make up NASA's primary Earth observation A–Train constellation and provide invaluable data for climate and resource management also have dealt with the issue of satellite collisions. In June of 2007, the $1.3 billion Terra satellite was forced to change its orbit to avoid a piece of Chinese debris and in July 2007 the CloudSat satellite maneuvered to avoid a near miss with an Iranian remote sensing satellite.

Likewise, operators of commercial satellites in geostationary orbit 22,000 miles above the Earth are on a constant lookout for debris. Their satellites must stay within a fairly narrow assigned slot, both to maintain a fixed position for their customers on Earth and to prevent possible collisions with other satellites operating nearby. Natural forces continually pull these satellites in different directions, forcing all geostationary satellite operators to perform periodic maneuvers to maintain their precise positioning. Many times these maneuvers are made without precise knowledge of the location of neighboring satellites.

For U.S. strategic, commercial, civil and scientific objectives, improved space situational awareness of all parties is essential to ensure the viability of U.S. interests in space in the long-term.

The importance of increasing SSA capacity

As the number of actors in space has risen dramatically in recent years, there is a pressing need for space situational awareness information for all space-faring States. The fallout from a hypothetical on-orbit collision between the satellites of two emerging space states with limited access to SSA information will unavoidably place US space assets at risk. Access to SSA information, along with the capacity to interpret it for all space actors, both emerging and developed, can significantly enhance the safety of U.S. space assets. Improved operational practices through SSA will hopefully help to prevent future collisions and other debris causing incidents.

Unfortunately, most actors in space do not have the resources or capacity to provide their own space situational awareness information necessary to make safe and secure decisions regarding activities in space. The few States that do have the resources to provide this information are often limited by national security or military restrictions from sharing it with other actors.

Accurate tracking of all objects in Earth orbit from the ground requires a geographically distributed network of both radar and optical telescopes. Such a network is very expensive to create and maintain. The United States military currently has the world's best SSA network, but it still has significant limitations as a result of the lack of coverage in areas where the United States does not have a presence. Additionally, from an organizational perspective, this network does not currently have the financial resources, capacity or requirement to provide the necessary SSA data and resources for civil and commercial purposes globally Upgrades to this network are planned and underway by the U.S. military but are subject to fiscal constraints that may cause delays or reductions in desired capabilities.

The United States is not alone in its capacity to provide SSA data. Many other States possess a limited SSA capability, usually not more than a few radar or optical telescopes. Taken separately, these sensors only provide spot coverage and very limited capacity. However, if the data from these existing sensors were combined, they would provide a large fraction of the capabilities necessary for global coverage. Thus, some level of international data sharing would increase SSA capacity without the expense of building additional sensors.

In addition to global sensor coverage, space situational awareness must include data from commercial satellite owner-operators, as they have positional data on their satellites that is more accurate than any ground-based sensor could obtain. These commercial operators have very precise information about the locations of their own satellites, but little to no information about other satellites, dead satellites and other pieces of debris that float through their slots. Their positional data complements the ground-based tracking of debris and also reduces the workload requirements for the tracking networks, freeing up capacity to focus on inactive satellites and debris.

Concluding Thoughts and Summary of Key Points

Secure World Foundation's main goal is to improve SSA for all space actors as a matter of safety and long-term sustainability of outer space activities for all actors. In this regard, we do not necessarily support any specific means of accomplishing this goal over another. Nevertheless, Secure World Foundation believes that the long-term sustainability of outer space activities will in time require a broad international approach to space situational awareness.

To sum up our key points:

- SSA is vital to the continued long term use and sustainability of Earth orbit
- There are civil and commercial requirements and uses for SSA data, the U.S. military currently does not have the resources to provide this service
- An SSA system needs to combine multiple data sources, including ground and space-based sensors, satellite owner-operators, and space weather data
- While some elements of the SSA system can and should be done unilaterally, there are multiple options for international participation and engagement
- The key benefit to international participation in SSA is greater capability for relatively low cost, by combining existing sensors and data sources

About Secure World Foundation

Secure World Foundation (SWF) is headquartered in Superior, Colorado, with offices in Washington, D.C. and Vienna, Austria. SWF is a private operating foundation dedicated to the secure and sustainable use of space for the benefit of Earth and all its peoples.

SWF engages with academics, policy-makers, scientists and advocates in the space and international affairs communities to support steps that strengthen global space security. It promotes the development of cooperative and effective use of space for the protection of Earth's environment and human security.

The Foundation acts as a research body, convener and facilitator to advocate for key space security and other space related topics and to examine their influence on governance and international development.

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