

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

HEARING CHARTER

***Keeping the Space Environment Safe
For Civil and Commercial Users***

**Tuesday, April 28, 2009
2 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 (ISS) 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 nongovernmental 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 3-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) website 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 of Defense (DOD) for costs the Department 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 DOD's 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 space 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 communications satellites that orbit at 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 4 accidental collisions resulting in the generation of debris (there has been only 1 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 outpaced the removal rate, leading to a net growth in the debris population in low Earth orbit at an average rate of approximately 5 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 1 cm in size or greater. Of that number, there are more than 18,000 objects that are 5 cm or greater in size. Objects that are between 1 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 than 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 1 cm can potentially destroy a satellite, while an object less than 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% 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 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 Shuttles 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% 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 micrometeoroid 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 way 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 6%. 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 spaceflight and at the time, accounted for more than 25% of cataloged objects in LEO. The estimated debris population larger than 1 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

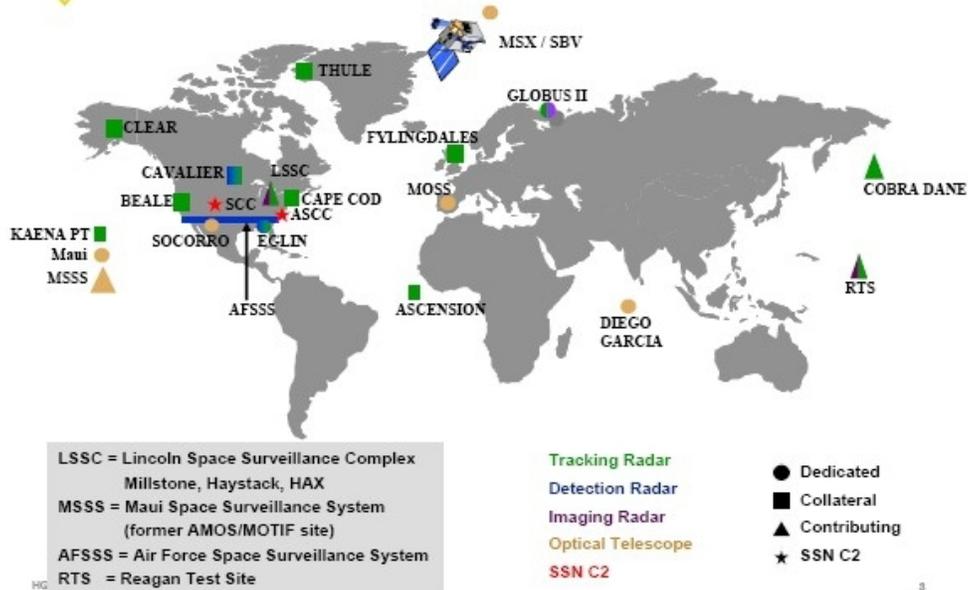
Although the U.S. has the most capable space surveillance system in the world, other countries also utilize radars and telescopes to perform similar tracking activities. Limited in their space surveillance capabilities, other nations must use information generated by the U.S. system to supplement their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



Space Surveillance Network (SSN) Map



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 cm in LEO, and only objects 30 cm 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 5 cm 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, 7 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 5 cm in diameter, compared to the 30 cm 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 FY-20.*"

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 website, 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 website says, TIRA can detect debris and determine “*coarse orbit information for objects of diameters down to 2 cm at 1,000 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 nongovernmental 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 (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 3-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 website, 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* website to replace the NASA OIG website. 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 transitional one where the CSO activated the *Space-Track* website offering a limited subset of the NASA OIG website functionality. During Phase 2, the NASA OIG website 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 website 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 37,000 users and 110 countries 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 website, 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 website 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'Etudes Spatiales); CNSA (China National Space Administration); DLR (German Aerospace Center); ESA; 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 website, 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 website 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 research and development 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. Dr. Pace, a witness at today’s hearing, will discuss some of the policy issue implications of keeping the space environment safe for civil and commercial users, such as the ramifications of enhanced sharing of space situational awareness information.