Fact Sheet

SPACE SITUATIONAL AWARENESS

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SUMMARY

Space situational awareness (SSA) is the ability to accurately characterize the space environment and activities in space. Civil SSA combines positional information on the trajectory of objects in orbit (mainly using optical telescopes and radars) with information on space weather. Military and national security SSA applications also include characterizing objects in space, their capabilities and limitations, and potential threats.

SSA is an inherently international and cooperative venture. It requires a network of globally distributed sensors as well as data sharing between satellite owner-operators and sensor networks. SSA also forms the foundation of space sustainability as it enables safe and efficient space operations and promotes stability by reducing mishaps, misperceptions, and mistrust.

TYPES OF SSA SENSORS

Sensors and systems used to provide SSA information are commonly optical telescopes or radar, and can be either space-based or ground-based. Increasingly other sensor types, including radio frequency monitoring, non-Earth imaging (NEI), and infrared sensing, are being incorporated into SSA networks.

Ground-based radars have historically been the backbone of SSA. Radar consists of at least one transmitter and receiver. The transmitter emits radio waves at a specific frequency, some of which reflect off the target and are measured by the receiver, which can then calculate the location of the target in relation to the radar. The primary advantages of radars are that they can actively measure the distance to a target and some types of radars can accurately track many objects at once. Some radars can also detect the motion of an object and construct a representation of its shape. The main disadvantages of radars are their cost, size, and complexity.

Optical telescopes are also widely used for SSA. Telescopes collect light or other electromagnetic (EM) radiation emitted or reflected by an object and focus it into an image using lenses, mirrors, or a combination of the two. The main advantages of using optical telescopes for SSA are their ability to cover large areas quickly and, in particular, to track objects above 5,000 km (3,100 mi) altitude. Some telescopes can create high-resolution images of space objects. The main disadvantage of optical telescopes is that they require specific light conditions and clear skies to see an object, although space-based optical telescopes eliminate some of these limitations.

Other types of sensors can be used for SSA, including sensors that detect radio frequency (RF) or other types of signals from satellites, lasers that measure the distance or range to a satellite very accurately, and infrared sensors that detect heat. Non-Earth imaging capabilities, in which satellites are used to image other space objects, can also be integrated into advanced SSA systems. Combining data from many different types of sensors, both ground- and space-based, that are also distributed around the globe provides a much more complete picture of the space environment and of activities in space.

SSA CAPABILITIES AND INITIATIVES AROUND THE GLOBE

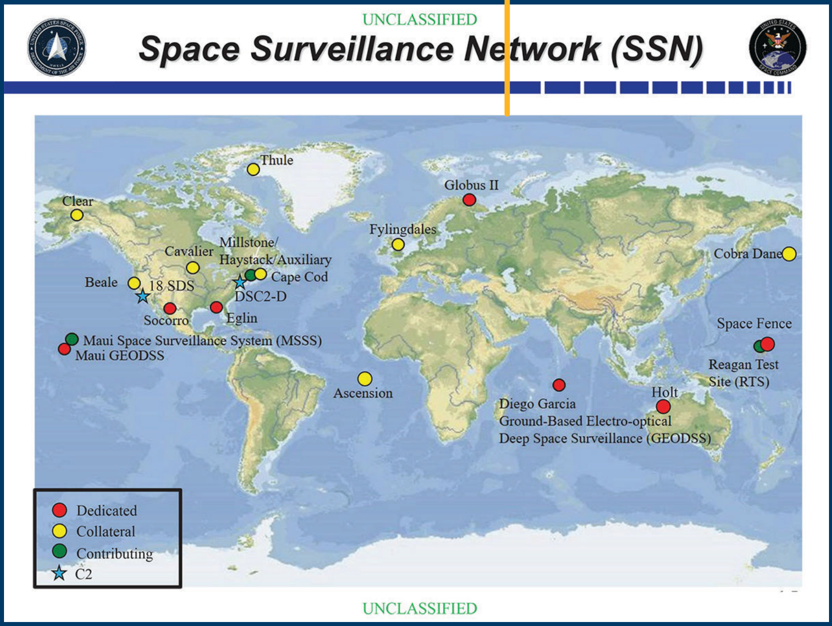
The United States of America

The United States government operates the largest network of sensors and maintains the most complete catalog of space objects, although there are gaps in its coverage and catalog. The U.S. system is known as the Space Surveillance Network (SSN) and is managed by the United States Space Force (USSF). The SSN consists of multiple phased array radars that are primarily used for missile warning along with a few dedicated phased array and mechanical tracking radars, dedicated ground-based electro-optical telescopes, and dedicated space-based optical telescopes. Several of the SSN sensors are located outside of the continental United States and some of those are operated by NATO allies. The SSN also includes several space-based sensors, including

- *The U.S. Space-Based Space Surveillance (SBSS) satellite, which is an optical sensor;*
- *The U.S. Geosynchronous Space Situational Awareness Program (GSSAP) satellites in geosynchronous orbit (GEO), which can provide up-close imaging and characterization of other space objects;*
- *The Canadian Sapphire satellite (an optical sensor); and*
- *Several classified and/or technology development sensors.*

The SSN historically has little to no coverage in the Southern Hemisphere or in South America, Africa, and Asia, but that is improving. Efforts are also being made to improve the ability of the SSN to track smaller objects. In March 2020, the new S-Band Space Fence radar in the Marshall Islands entered operations; it is capable of tracking objects in LEO as small as a marble in diameter. However, as this system is only a single site, it is not capable of continuously tracking those objects. In May 2023, the Space Force started construction in Australia on the first of three sites for the Deep Space Advanced Radar Capability (DARC) program with the goal of completing that first site's construction by the end of 2025; the two additional sites are planned for the United States and the United Kingdom. DARC will focus on tracking of objects in GEO and will also augment the Space Fence capabilities. The USSF has also been working to place SSA telescopes in other sites around the globe, including for example, the installation of a half-meter class telescope at Chile's Cerro Moreno Air Base in March 2023.

Data from the SSN flows to the central command and control center called the Combined Space Operations Center (CSpOC), located at Vandenberg SpaceForce Base in California. There, the 18th Space Defense Squadron maintains a catalog of the orbital trajectories of more than 45,000 space objects (as of June 2024), which is used to perform a variety of analyses to support commercial and civil spaceflight safety along with military and intelligence applications.



Key sites of the Space Surveillance Network (as of 2022)

Image credit: U.S. Space Force.

These services include providing conjunction assessment (CA) warnings to all satellite operators as part of the Space Situational Awareness information sharing program. The United States has negotiated a significant number of data-sharing agreements with more than 185 commercial sector, academic, foreign government partners, and intergovernmental organizations.

The United States is also in the midst of establishing a civil space traffic coordination system operated by the Department of Commerce, under Space Policy Directive-3 (issued by the Trump Administration in 2018 and maintained by the Biden Administration). Under this policy, the Office of Space Commerce (OSC) will be responsible for space safety information and services for public safety (including commercial space operators) while the Department of Defense will continue to maintain the authoritative catalog of space objects. OSC is developing the Traffic Coordination System for Space (TraCSS) to provide SSA services to civil and private space operators.

Russia

Russia also operates a large network of SSA sensors and maintains a relatively comprehensive catalog of space objects. The Russian Space Surveillance System (SKKP) consists of phased array radars used primarily for missile warning, along with dedicated radars and optical telescopes. Several of the SKKP sensors are located in former Soviet republics and are operated by Russia under a series of bilateral agreements with the host countries. In 2016, a new civil SSA monitoring center called Automated Warning System on Hazardous Situations in Outer Space (ASPOS OKP) began operations under contract to Roscosmos. ASPOS OKP utilizes data from ISON and other Russian SSA assets to detect and track objects in GEO, HEO, and MEO orbits and provide a range of SSA services, including conjunctions, and tracking of fragmentations and reentries, as well as national security uses. Sensors contributing to ASPOS have been installed in Russia, Armenia, Brazil and South Africa. Intent has been announced to install additional sites in Chile and Mexico., Roscosmos, the Russian state space agency, has announced plans to create what it calls the 'Milky Way' system to share SSA information, based on ASPOS, amongst members. This will likely initially focus on BRICS countries.

In addition to these state-managed systems, the International Scientific Optical Network (ISON) is a partnership of scientific and academic institutions around the world organized by the Russian Academy of Sciences in Moscow. ISON is a heterogeneous mix of telescopes of various sizes and capabilities, but as a network, it can track a wide range of object sizes across several orbital regimes while providing a significant number of observations. ISON collaborates with the Russian government, including with ASPOS, and with the Vympel Corporation, which provides a public portal to access the catalog maintained by ISON.

European Union

In Europe, the European Union Space Surveillance and Tracking (EU-SST) service is a network of ground-based and space-based sensors capable of surveying and tracking space objects managed by the European Union Agency for the Space Programme (EU-SPA) as a cooperative endeavor of 15 member states. Based on sensors operated by its member countries, EU-SST provides collision avoidance, re-entry analysis and fragmentation analysis services on-request and free of charge. National SSA centers in France, Spain, Italy, and Germany provide operations for various aspects of the EU-SST system. The EU-SST maintains a database that shares information between the various national operating centers contributing to the system, and plans to expand that database into a common EU-SST Catalog of space objects. Beyond EU-SST, several individual European countries operate space tracking systems of varying capabilities.

China

China is developing a network of ground-based optical telescopes and radars for detecting, tracking, and characterizing space objects. In June 2015, China launched the Space Debris Monitoring and Application Center (part of the China National Space Administration) to collate SSA data from various sensors and help protect Chinese satellites from on-orbit collisions. While China lacks an extensive network of SSA tracking assets outside its borders, it is developing relationships with countries that may host future sensors, in particular through the Asia-Pacific Space Cooperation Organization (APSCO). China's main optical SSA capabilities are operated by the Purple Mountain Observatory (PMO), which operates multiple telescopes in seven separate locations that can track satellites throughout all orbital regimes. Few details are known about China's radar SSA capabilities as they are primarily operated by the People's Liberation Army (PLA). The PLA operates at least six large phased-array radars that likely have a primary mission of ballistic missile warning but could also support an SSA mission. Within the PLA Strategic Support Force (SSF), a unit known as "Base 37" has recently been established with a mission to both improve the accuracy of China's domestic space object catalog and to conduct identification and tracking of foreign space objects.

COMMERCIAL SPACE SITUATIONAL AWARENESS CAPABILITIES

Private sector SSA services and analysis is a growing segment, in particular in the United States and Europe. Several companies have been established specifically in this area, such as ExoAnalytics (U.S.), LeoLabs (U.S.), Slingshot Aerospace (U.S.), and are now offering commercial SSA data services from their own radars and telescopes while other firms, such as Look Up Space (France) and Aldoria (France) are just beginning to deploy sensor networks. Additional firms such as COMSPOC (U.S.) and Digantara (India) have created their own operations centers to fuse data from multiple sources and provide commercial SSA services. Advanced software capabilities, machine learning, and automation approaches are being developed by firms such as Kayhan Space (U.S.) and Neuraspace (Portugal) to offer automated space traffic coordination platforms. Larger, established aerospace companies are also developing SSA-related services and software, often building on existing roles they had operating or developing government sensor networks.

Commercial SSA data is used to support and augment government catalogs, and to provide services in support of public space traffic coordination services under development in governments, such as TRaCSS and EU SST. Services are also provided to spacecraft operators to augment their own satellite positional data and to support conjunction avoidance efforts, including automated collision avoidance systems being developed by large constellation operators. The Space Data Association (SDA), a not-for-profit created by commercial satellite operators, uses data provided by its members and other available SSA information to provide enhanced conjunction assessment and radiofrequency interference (RFI) services through its Space Data Center. The Space Data Center is operated by COMSPOC, a commercial entity itself. Commercial SSA data is also a key enabler for novel in-space activities such as satellite servicing and active debris removal. National security agencies may also use commercial SSA data to augment analytical capabilities for intelligence purposes.

AMATEUR SPACE SITUATIONAL AWARENESS CAPABILITIES

There are also many amateur satellite observers around the globe who use telescopes, binoculars, and other equipment to track satellites. Some amateurs have the capability to image satellites or detect radio frequency transmissions. Although they are only loosely organized through the Internet, the amateur observing community presents a non-trivial independent global SSA capability. In particular, they have demonstrated the ability to routinely track classified national security payloads from several countries.

ROLE OF SSA IN IMPROVING SPACE SUSTAINABILITY AND SECURITY

SSA also plays a role in the ongoing political initiatives aimed at tackling space sustainability and security. The United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) included a number of provisions related to SSA information as part of the 21 Guidelines on the Long-Term Sustainability of Outer Space Activities which were adopted in 2018.

There is ongoing discussion at the national and international level about a related issue: space traffic management (STM) and coordination. Space traffic management refers to operational, policy, and regulatory measures taken to minimize or mitigate the negative impacts of the increasing physical congestion in space. The goal of STM is to try to eliminate future collisions and other incidents in space that could create additional debris or other safety risks for space activities and to increase the safety and efficiency of space activities. Improved global SSA capabilities are a prerequisite to a future STM system, whatever form it takes. SSA data also plays a key role in the tracking and verification of space security activities, by serving as an important transparency and confidence-building measure (TCBM) for space activities. SSA in general can help both in identifying patterns of normal space activities and when space objects diverge from those normal patterns, as well as verifying that behaviors agreed to as part of legally binding arms control discussions are being followed. Broadly speaking, SSA is good for verifying whether something has or has not happened in space; determining why that did or did not happen is not a job for SSA, but rather for analyses that pull in a wider set of data from different sources.

B. Safety of space operations

Guideline B.1	Provide updated contact information and share information on space objects and orbital events
Guideline B.2	Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects
Guideline B.3	Promote the collection, sharing and dissemination of space debris monitoring information
Guideline B.4	Perform conjunction assessment during all orbital phases of controlled flight
Guideline B.5	Develop practical approaches for pre-launch conjunction assessment

LTS Guidelines Related to SSA Information

ENDNOTES

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