**Aerospace Control**

In 1988 Gen Larry D. Welch stated that "space power will assume as decisive a role in future combat operations as airpower has today."(31) Aerospace control includes the ability to control the combat environment. Aerospace control is the ability to assure the use of space systems during conflict while denying the enemy the use of his space systems.(32) The mission is called counterspace and embodies the idea of space superiority over the battlefield. The ability to achieve and maintain aerospace control has been and continues to be a critical mission of the US Space Command.

Aerospace control is comprised of three mission elements:

space surveillance--the ability to surveil and monitor continuously all significant military activities in space. The surveillance mission is necessary to execute one or both of the following two missions.

protection--the ability to protect friendly space assets. This mission is also referred to as defensive counterspace.

negation--the ability to negate any hostile space asset. This mission is referred to as offensive counterspace.(33)

**Space Surveillance**

Space surveillance is essential to the space control mission and involves the functions and ability to monitor, assess, and inform. The nerve center of United States Space Command's (USSPACECOM) space surveillance mission is the Space Surveillance Center (SSC) located deep inside Cheyenne Mountain AFB, Colorado. A computer network in the SSC keeps a constant record of the movements of thousands of man-made objects orbiting the Earth. These objects include satellites (active and inactive) and pieces of space debris. The SSC computers receive a steady flow of information from the elements of the space surveillance network (SSN). The SSN consists of radars and optical tracking devices located around the world. Specific SSC responsibilities include:

1. Providing operational command and control of the SSN. These activities include tasking of sensors to provide tracking support for routine space catalog maintenance, space object identification, and special events monitoring.

2. Maintaining a catalog of orbital characteristics of all observable man-made space objects for position prediction.

3. Providing routine space operations information.

4. Providing orbital data to many users and informing the Space Defense Operations Center of any contributing factors affecting any degradation of performance within the SSN.(34)

When a sensor acquires a piece of orbiting hardware, it sends the information to the SSC computers. The SSC tracks the present position of these objects and predicts their future orbital paths. The SSC compares the observation with the predicted location of cataloged objects. Observed information which the SSC cannot verify or match with a known object may be an indication of a new or previously uncatalogued object in space. It often takes several hours to accumulate enough information to form an accurate mathematical description of an object's orbit. Orbital elements describe this mathematical model. This set of figures includes the period, inclination, eccentricity, and orientation of the satellite's orbital plane about the equator.(35)

The SSC generates a Project TIP (tracking and impact prediction) to predict when and where a larger decaying satellite or object will reenter the Earth's atmosphere and then forwards this information to several users. The Missile Warning Center, inside Cheyenne Mountain AFB, uses this information along with other sensor information to assess the potential threat from the object. Many factors make it difficult to predict precisely where and when a satellite or other object will come down. Gaps in the space surveillance network's coverage prevent total surveillance coverage, while atmospheric drag and solar radiation can also influence both the speed and course of an object returning to Earth.(36)

The center's catalog dates back to 1957 with the Soviet Union's launch of Sputnik I. Since that time, the center has cataloged more than 21,000 objects. Currently, over 7,000 of these objects remain in Earth orbit.(37) While the SSC is primarily interested in satellite vehicles (or payloads), it also keeps track of space debris. This includes items such as spent rocket bodies, launch hardware, and other objects from operating satellites. It also includes fragments resulting from in-space breakups of larger objects. In fact, the vast majority of objects now in space are pieces of debris. Although the SSC has the ability to track and monitor thousands of pieces of debris, many go undetected because of their minute size. It is possible that tiny pieces of debris, the size of paint flecks, may actually number in the millions.

The SSC also has a backup operations center, the Alternate SSC or ASSC. The ASSC is part of the Naval Space Surveillance (NAVSPASUR) system in Dahlgren, Virginia. The ASSC maintains the satellite catalog when the computational capability or the command and control capability of the SSC fails to function properly.

**Space Surveillance Network**

The USSPACECOM uses a worldwide network of sensors, collectively called the SSN, to perform the mission of keeping track of space objects orbiting the Earth. (The SSN is a network separate from the AFSCN. The SSN supports the space control mission, while the AFSCN supports the space support mission.) The SSN reports to the Space Defense Operations Center and is comprised of three different types of sensor systems: dedicated sensors, collateral sensors, and contributing sensors.(38)

**Dedicated Sensors.** Dedicated sensors support the space surveillance mission. They include three unique optical systems, a combined radio frequency (RF) and optical system, a phased array system, a mechanical tracker radar, and a "radar fence" operated by the Navy.

The ground-based electro-optical deep space surveillance system (GEODSS) is an optical system that uses a low-light-level TV camera, computers, and large telescopes. GEODSS tracks objects in deep space, or from about 3,000 NM out to beyond geosynchronous altitudes. GEODSS requires nighttime and clear weather tracking because of the inherent limitations of an optical system. There are currently four operational GEODSS sites with coverage areas as follows: Socorro, New Mexico (165W-050W); Maui, Hawaii (140E-010W); Choe Jong San, South Korea (070E-178E); and Diego Garcia, Indian Ocean (010E-130E). Each site has three telescopes, allowing GEODSS to track three objects simultaneously. All three telescopes are linked to video cameras. Two of the three telescopes are 40-inch aperture main telescopes, which are used primarily to search the deep sky for faint, slow-moving objects. The other, a 15-inch telescope, does wide searches of lower altitudes where objects travel at higher relative speeds.

The only exception to this configuration is the Diego Garcia site, which has three 40-inch telescopes. The television cameras feed their space pictures into a computer that drives a display device. The computer automatically filters stars from the night sky backdrop, and the satellites appear on the display screen as streaks of light. GEODSS can transmit position and identification signature data to the SSC (in Cheyenne Mountain) in seconds. GEODSS sensors are responsible for over 65 percent of all deep space object tracking and surveillance, and provide almost worldwide coverage of the equator. Any sustained loss of a GEODSS sensor would have dramatic impact on the deep space surveillance mission and maintenance of the space catalog.(39)

The second optical system is the Maui Optical Tracking and Identification Facility (MOTIF) in Hawaii. MOTIF is a dual 1.2-meter telescope system on a single mount. One telescope primarily does infrared and photometric collection. The other performs low-level light tracking and imagery. MOTIF can track space objects in near-space and deep-space orbits and represents AFSPACECOM's sole long-wave infrared imaging capability. Like GEODSS, MOTIF is limited to night operations. MOTIF is also hindered by high winds, high humidity, cloud cover, and a bright Moon.(40)

The third and final optical system under the dedicated sensors of space surveillance is the combined RF/optical surveillance system (CROSS). CROSS is located at San Vito, Italy, and replaced the previous Baker-Nunn system. CROSS improves eastern hemisphere deep space coverage. Like its optical counterparts, CROSS is a passive sensor and is constrained by weather, field of view, and daylight. However, unlike its optical counterparts, it benefits from its capability to use radio frequencies to search out active satellites in deep space. (For additional information on CROSS and other passive RF sensors, such as the deep-space tracking system and the low-altitude surveillance system, see annex B.)

The remaining dedicated sensors are all radars: a phased array system and a continental United States (CONUS) radar fence operated by the US Navy. The Air Force has one phased array radar (UHF, FPS-85) located at Eglin AFB, Florida. This radar operates in the 437-447 megahertz (MHz) frequency range and has the capability to track both near-earth and deep-space objects simultaneously with extreme sensitivity. In fact, the Eglin AFB radar can provide 10,000 observations per day on space objects--the equivalent of 14 mechanical trackers or three PAVE PAWS sensors. Eglin AFB also maintains the radar cross section catalog for the SSN. The four PAVE PAWS sensors use the Eglin radar's observations to assist in tracking space objects.(41)

The final dedicated sensor is the NAVSPASUR system. Operated by the Navy, NAVSPASUR is an electronic "fence" stretching 3,000 miles across the southern United States from Georgia to California and extending 1,000 miles off each coast.

The fence consists of three powerful transmitters and six receivers. The transmitters are located at Lake Kickapoo, Texas; Gila River, Arizona; and Lake Jordan, Alabama. The receivers are in San Diego, California; Elephant Butte, New Mexico; Red River, Arizona; Silver Lake, Mississippi; and Hawkinsville and Tattnall, Georgia.

Each transmitter station sends out a continuous wave of radio energy in a fan-shaped pattern, with a very narrow north-south dimension and a wide east-west spread. This creates the fence, an overall vertical east-west fan of radio energy extending thousands of miles into space. An object passing through the beam reflects energy back to the receivers. The receiver stations then measure the reflected satellite signal and send their data to the NAVSPASUR Operations Center at Dahlgren. The center processes the data to determine the object's precise location and relays this information to the SSC.(42)

**Collateral Sensors**. Collateral sensors have a primary mission other than space surveillance, but still provide support to the space surveillance mission. Collateral sensors include the following systems:

**System Type Site**

1. BMEWS Phased Array Radar Thule AB, Greenland
2. Phased Array Radar RAF Fylingdales Moor, UK
3. Mechanical Tracking Radar Clear AFB, Alaska
4. PAVE PAWS Phased Array Radar Cape Cod, Massachusetts
5. Robins AFB, Georgia
6. Eldorado, Texas
7. Beale AFB, California
8. PARCS Phased Array Radar Cavalier AFS, North Dakota
9. RADINT Phased Array Radar Shemya, Alaska (Cobra Dane)

Mechanical Tracking Radar Pirinclik, Turkey

The ballistic missile early warning system (BMEWS) sensors contribute to the space surveillance mission. These sensors are somewhat limited in the performance of the space surveillance mission since planners designed each radar primarily to perform a missile warning mission as opposed to the space track and identification mission.

Each radar is unique in its ability to contribute to the space surveillance mission. For example, the perimeter acquisition radar attack characterization system (PARCS) sensor currently contributes over 15 percent of the observations used to maintain the space track catalog. However, due to the geographic location and positioning of its one-face phased array radar, PARCS does not play a significant role in new foreign launch (NFL) processing, nor is it able to track a significant portion of deep-space objects.

Unlike the other collateral sensors, Cobra Dane and Pirinclik have primary missions of intelligence data collection. Cobra Dane is a single-faced phased array radar (AN/FPS-108) at Shemya AFB, Alaska. Located on the far end of the Aleutian Island chain and less than 500 miles from Kamchatka Peninsula, Cobra Dane is perfectly situated for its primary mission of collecting technical radar intelligence (RADINT) data on intercontinental ballistic missile (ICBM)/submarine-launched ballistic missile (SLBM) test launches into the Kamchatka Peninsula and the Pacific Broad Ocean Area.

Cobra Dane's corollary mission is to provide tactical warning and attack assessment of ICBM/SLBM attacks on the CONUS and southern Canada. As a space surveillance sensor, Cobra Dane is the most important NFL ground sensor and is usually the first US radar to track Soviet space launches. Operating in the L-band range, Cobra Dane uses both a wideband (1,175-1,375 MHz) and a narrowband (1,215-1,250 MHz) frequency to provide better accuracy and sensitivity than PAVE PAWS sensors. Its wideband capability is well suited for mission payload assessment.

Cobra Dane is currently undergoing a system modernization program to update its hardware and software. Scheduled for completion in the fall of 1993, this upgrade will improve its data collection and replace aging data processing equipment.(43)

The Pirinclik, Turkey, RADINT site operates both a detection radar (AN/FPS-17) and a mechanical tracking radar (AN/FPS-79). Both radars operate at an UHF (432 MHz) frequency. Although limited by their mechanical technology, Pirinclik's two radars give the advantage of tracking two objects simultaneously in real time. Its location close to the southern Soviet Union makes it the only ground sensor capable of tracking actual deorbits of Soviet space hardware. In addition, the Pirinclik radar is the only 24-hour-per-day eastern hemisphere deep-space sensor.

Finally, another set of collateral sensors include three mechanical tracking C-band radars: Antigua, British West Indies, Kaena Point, Hawaii, and Ascension Island in the Atlantic Ocean. These radars are located on islands and primarily support test and evaluation of US ICBM and space launches. The three radars spend approximately 128 hours per week supporting the space surveillance mission. Antigua's position in the northern hemisphere near the equator allows accurate coverage of all low-Earth orbits; however, as a tracking radar, Antigua's FPQ-14 radar (operating between 5,400-5,900 MHz) has a limited search capability. Kaena Point's radar is nearly identical to Antigua's (operating in the same frequency range with a narrow beam width) providing accurate data with limited search capability. The final C-band radar, a TPQ-18, located on Ascension Island in the southern hemisphere near the equator, provides accurate coverage of all low-Earth orbits.

In addition to this radar on Ascension, the US Navy is currently upgrading an FPQ-15 radar. When completed, this new radar will function in the X-band (8,000-12,500 MHz) frequency range and provide more accurate coverage.(44)

**Contributing Sensors**

The final group of sensors are referred to as contributing sensors. These sensors are not under USSPACECOM's operational control; however, they provide observation data on satellites to USSPACECOM on a contributing basis. There is a total of five contributing sensors: four mechanical tracker radars and one electro-optical sensor. One mechanical C-band tracker, located at Kwajalein Atoll, Marshall Islands, tests and evaluates US ICBMs. The ALCOR radar, one of two radars located on Kwajalein Atoll, provides wideband imagery data at 5,672 MHz and can be used for near-Earth surveillance to meet USSPACECOM requirements. Also located on Kwajalein Atoll, is the ALTAIR A-B band radar (415-450 MHz). USSPACECOM uses this radar about 128 hours per week.(45)

There are two contributing sensors located at Tyngsboro, Massachusetts. The Haystack radar, an X-band radar, operates at 10 gigahertz and is the only wideband radar in the western hemisphere able to image in deep space. Haystack operates eight scheduled five-day sessions and two recalls per year. (A recall requires four to eight hours to reconfigure equipment.) The other contributing sensor at Tyngsboro, is the Milistone L-band radar, operating at 1,295 MHz Milistone is contracted by the USAF for about 80 hours per week.

The final contributing sensor is the Air Force Maui Optical Station (AMOS). AMOS has an electro-optical system collocated with MOTIF and GEODSS on Maui, Hawaii. AMOS, with a 63-inch telescope, is a test bed for new surveillance systems and provides an infrared signature data base for space objects. Like other optical systems, AMOS is limited to night operations and is hindered by adverse weather conditions.(46)

**Protection**

In addition to the ability to protect friendly space assets, often referred to as space defense, is another mission--defensive counterspace. Currently, such passive means as electronic hardening of satellites and addition of fuel for potential avoidance maneuvering are used to protect space-based assets. The mission is characterized by an extensive battle management (BM)/command, control, and communications (C3) capability to direct the space defense of friendly space assets and thereby achieve space control. The principal component of the BM/C3 capability is the Space Defense Operations Center.(47)

The Space Defense Operations Center (SPADOC) is located in Cheyenne Mountain and serves as a fusion center for the space control mission. SPADOC is responsible for protecting DOD, US civilian, and allied nation space systems. SPADOC fulfills its mission responsibilities primarily through monitoring space and space-related activities, informing members of the space community of unique space-related events, and planning possible defensive countermeasures.(48) To achieve its objectives, SPADOC specifically monitors and reports abnormal or unusual space activity, and recommends the necessary follow-on steps to specific organizations. SPADOC also analyzes possible threat attack information, determines the time and location of the attack, and identifies both the space system under attack as well as the method and type of attack taking place.

Finally, SPADOC advises specific organizations of which US space systems are vulnerable to attack or are likely to be targeted for attack.

SPADOC communicates with organizations owning or operating space-based systems through various secure and unsecure communications means. SPADOC, a key center of operations under USSPACECOM, routinely communicates with other USSPACECOM operations centers and component commands for routine status information. In the event of a space threat, SPADOC will communicate directly with specific satellite system owners/operators to preclude delay in transmission of critical warning messages.(49)

The primary method of secure connectivity between SPADOC and all space system owners/operators is the Space Defense Command and Control System (SPADCCS). SPADCCS is a communications network using hard copy messages to and from SPADOC and space system owners/operators.

**Negation**

The final space control mission--offensive counterspace--is categorized by the term negation. The ability to negate or destroy any hostile space system includes the use of an antisatellite (ASAT) system. The US does not currently operate a functional ASAT system. Any future system will serve as an integral part of USSPACECOM's plan to achieve total space control.

An operational ASAT force would fulfill many objectives of space control. Operational ASATs would encourage the right of free passage through space, increase the options available to US commanders--especially during major war-fighting operations--and provide the capability, if required, to attack enemy military space assets to ensure space superiority and control of the high frontier. A comprehensive ASAT system would most likely consist of directed energy weapons, kinetic energy weapons, and possibly electronic warfare systems.