Chapter 13

US Space-Based Intelligence, Surveillance, and Reconnaissance

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I wouldn't want to be quoted on this, but we've spent 35 or 40 billion dollars on the space program. And if nothing else had come out of it except the knowledge we've gained from space photography, it would be worth 10 times what the whole program cost. Because tonight we know how many missiles the enemy has and, it turned out, our guesses were way off. We were doing things we didn't need to do. We were building things we didn't need to build. We were harboring fears we didn't need to harbor. Because of satellites, I know how many missiles the enemy has.

—Pres. Lyndon B. Johnson
Remarks to educators in Nashville, TN
16 March 1967

Intelligence, surveillance, and reconnaissance (ISR) is the collection of data and information on an object or in an area of interest (AOI) on a continuing, event-driven, or scheduled basis. Collection over relatively continuous periods of time is called surveillance. Collection that is event-driven, is scheduled over shorter periods, is repeated, or occurs on a relatively brief one-time basis is generally referred to as reconnaissance. Orbital characteristics and numbers of systems applied to a target over time can determine whether reconnaissance or surveillance is conducted. The joint force commander (JFC) and the components have access to space systems that can collect diverse military, political, or economic information that can be valuable for planning and executing throughout the range of military operations (including peacekeeping) and humanitarian or disaster-relief missions. More specifically, information can be collected, processed, exploited, and disseminated on such diverse subjects as indications and warning (to include ballistic missile attack), targeting analysis, friendly course-of-action (COA) development, adversary capability assessment, battle damage assessment (BDA), or battlespace characterization. Types of data and information collected from space can include signals intelligence (SIGINT), imagery intelligence (IMINT), and measurement and signature intelligence (MASINT).

ISR and Space Systems

ISR capabilities allow commanders and decision makers to collect information to aid them in planning and decision making. Space systems are vital to the military's ISR functions.

Intelligence

Intelligence is the product resulting from the collection, processing, integration, analysis, evaluation, and interpretation of available information concerning foreign countries or areas. Space systems contribute to the development of intelligence through surveillance and reconnaissance activities.[1]

Surveillance

Space systems offer commanders continuous observation of space, air, surface areas, places, persons, or things by visual, electronic, photographic, or other means that provide situational awareness within a given area. Surveillance from space does not infer that a single satellite or "system" must be continuously collecting. Satellites that are able to provide a snapshot in time can be augmented by additional systems collecting in the same or even different areas of the electromagnetic spectrum. There will be short gaps in collection (minutes or a few hours), but systems will be concentrating on a target, which over time constitutes surveillance. These "following" systems can continue collecting on a target as the previous satellite moves out of the area of access in its orbit. Several satellites in low and medium Earth orbits can provide coverage of targets on the order of minutes. Geosynchronous satellites can provide true surveillance, as their orbits allow them to have continuous access to large portions of the earth. Collection from geosynchronous systems may, by necessity, be prioritized based on area of the world and where within the electromagnetic spectrum they can be tasked to collect. In many instances, the number of requirements levied against a system may also necessitate a prioritization of collection. Satellites may also be a contributor to an overall surveillance effort consisting of space, terrestrial, and airborne systems that together provide continuity in surveillance when space systems alone do not have continuous access or are unavailable.[2]

Reconnaissance

Single low and medium Earth orbiting systems or architectures that provide limited numbers of low or medium orbital systems are well-suited to the reconnaissance mission. Generally their access to specific targets are limited in time based on their orbits, such that data collected will be a "snapshot" of events in the portion of the electromagnetic spectrum where the systems can collect. Geosynchronous or geostationary satellites are capable of performing reconnaissance from space as well, focusing their collection efforts on a target or region for relatively short amounts of time before focusing on another area.[3]

Imagery Intelligence

Imagery intelligence is defined by the Department of Defense (DOD) as intelligence derived from the exploitation of collection by visual photography, infrared sensors, lasers, electro-optics, and radar sensors such as synthetic aperture radar, wherein images of objects are reproduced optically or electronically on film, electronic display devices, or other media.[4]

Background

Military reconnaissance was one of the first applications of space technology in the United States. The first attempted launch of an imagery collection satellite occurred in February 1959, but that launch failed. However, in August 1960 the first successful imagery launch took place under the CORONA program. In September 1961, the National Reconnaissance Office (NRO) was formed to execute the national reconnaissance program.[5] The CORONA program operated in secret from August 1960 to May 1972, collecting over 800,000 images from space. The existence of the NRO was declassified in 1992, and the CORONA program was declassified under executive order on 24 February 1995.[6] Although the CORONA program was the earliest pioneer in space-based IMINT, there have been many other programs since.

The NRO manages all data collection from national satellite systems. The NRO and National Geospatial-Intelligence Agency (NGA) work jointly to process this data. Data collected at the theater and tactical levels by airborne collection systems and through other methods are managed by the military services. The services are responsible for providing this data to national-level databases. The NGA is responsible overall for managing, disseminating, and archiving data.

Commercial and civil entities also contribute significantly to these databases.[7] Today, at least seven other countries and multinational organizations operate space-based imaging platforms.[8] In addition to state-owned and operated programs, there are numerous commercial space-based imaging programs in operation. The NGA is the executive agent for the purchase of commercial satellite imagery within DOD and has the capability to buy rights in two distinct forms. It can purchase imagery for immediate use, or it can purchase the rights to selected imagery for future distribution, depending on specific requirements. The Commercial Satellite Imagery Library (CSIL) contains an archive of all DOD-purchased commercial satellite imagery and is maintained by the Defense Intelligence Agency (DIA) for the NGA.[9]

Resolution

The detail discernible in an image is dependent on the spatial resolution of the sensor and refers to the size of the smallest possible feature that can be detected. Spatial resolution of passive sensors depends primarily on their instantaneous field of view (IFOV). The IFOV is the angular cone of visibility of the sensor and determines the area on the earth's surface that is "seen" from a given altitude at one particular moment in time. The size of the area viewed is determined by multiplying the IFOV by the distance from the ground to the sensor. This area on the ground is called the resolution cell and determines a sensor's maximum spatial resolution. To detect a homogeneous feature, its size generally has to be equal to or larger than the resolution cell. If the feature is smaller than this, it may not be detectable, as the average brightness of all features in that resolution cell will be recorded. However, smaller features may sometimes be detectable if their reflectance dominates within a particular resolution cell allowing subpixel or resolution-cell detection.

With current systems, resolution is usually referred to in meters, and each pixel will sample a square area on the ground in terms of meters. Most remote sensing images are composed of a matrix of picture elements, or pixels, which are the smallest elements of an image that can be detected. Image pixels are normally square and represent a certain area on an image. Reflected energy is received by a sensor array in the form of individual brightness values or picture elements (pixels). In a digital system, a pixel represents an area on the earth's surface. For example, the Satellite Pour L'Observation de la Terre (SPOT) panchromatic sensor has pixels that are the average of the light reflected from a 10-meter by 10-meter (10 m x 10 m) area on the ground.[10] Therefore, SPOT panchromatic imagery can be said to have 10 m pixels.

It is important to distinguish between pixel size and spatial resolution—they are not interchangeable. Spatial resolution is a measure of the smallest angular or linear separation between two objects that can be resolved by the sensor. More simply put, it is the smallest separation between two objects where the objects can still be detected as separate. This type of resolution is related to the ground sampling distance (GSD) of a system. GSD is defined as the distance between centers of pixels or, in other words, the centers of areas sampled on the ground. An image from the LANDSAT Thematic Mapper (TM) sensor, for example, which has a GSD of 28.5 m, will not normally allow for detection of an object that is 5 m.[11]

If a sensor has a spatial resolution of 20 m and an image from that sensor is displayed at full resolution, each pixel represents an area of 20 m x 20 m on the ground. In this case, the pixel size and resolution are the same. However, it is possible to display an image with a pixel size different from the resolution. Many posters of Earth satellite images have their pixels averaged to represent larger areas, although the original spatial resolution of the sensor that collected the imagery remains the same.

Images where only large features are visible are said to have coarse or low resolution. In fine- or high-resolution images, small objects can be detected. Military sensors, for example, are designed to view much greater detail and therefore have very fine resolution. Commercial satellites typically provide imagery with resolutions varying from a few meters to several kilometers. Generally speaking, the finer the resolution, the less total ground area can be seen. See figures 13-1 through 13-4 for examples of GSD.

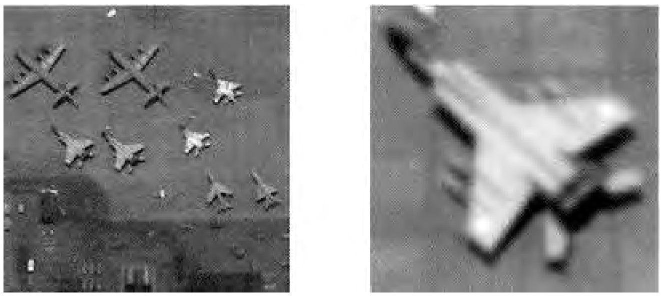

Figure 13-1. 48-inch GSD. (*Reprinted from* Jeffrey J. Hemphill, "ITEK Optical Reconnaissance Camera System: Comparing Resolution and Area Coverage," http://www.geog.ucsb.edu/~jeff/115a/militaryintelligence/itek.html [accessed 5 April 2008].)

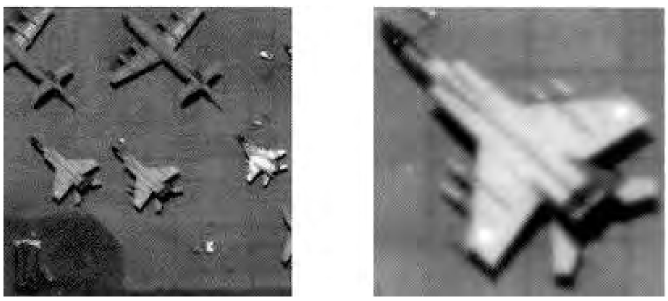

Figure 13-2. 24-inch GSD. (*Reprinted from* Jeffrey J. Hemphill, "ITEK Optical Reconnaissance Camera System: Comparing Resolution and Area Coverage," http://www.geog.ucsb.edu/~jeff/115a/militaryintelligence/itek.html [accessed 5 April 2008].)

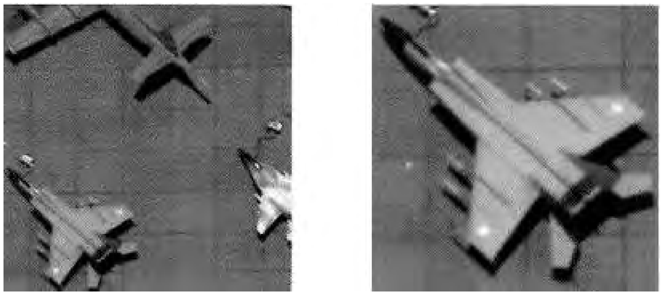

Figure 13-3. 12-inch GSD. (*Reprinted from* Jeffrey J. Hemphill, "ITEK Optical Reconnaissance Camera System: Comparing Resolution and Area Coverage," http://www.geog.ucsb.edu/~jeff/115a/militaryintelligence/itek.html [accessed 5 April 2008].)

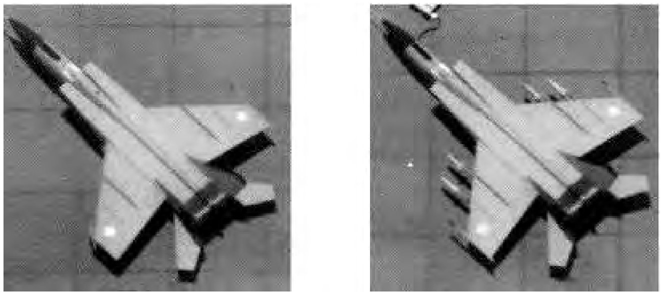

Figure 13-4. **6-inch GSD**. (*Reprinted from* Jeffrey J. Hemphill, "ITEK Optical Reconnaissance Camera System: Comparing Resolution and Area Coverage," http://www.geog.ucsb.edu/~jeff/115a/militaryintelligence/itek.html [accessed 5 April 2008].)

Types of Space-Based Imagery Systems

There are several types of spaced-based imagery systems that collect IMINT.

Film Return Capsule. The CORONA program operated as a film-return capsule system (fig. 13-5). Photographs were taken on a film roll system stored within the satellite. Film canisters were then ejected from the satellite and returned to Earth. Once the capsule had penetrated Earth's atmosphere, a small parachute would open, and the capsule would fall slowly over the ocean until it was recovered in mid-air by a US Air Force C-119 aircraft.[12]

This method of collecting film capsules from space is quite challenging and not very timely. Several IMINT programs from around the world still use film-return capsule systems to access and process imagery data. Another good example of a film-return

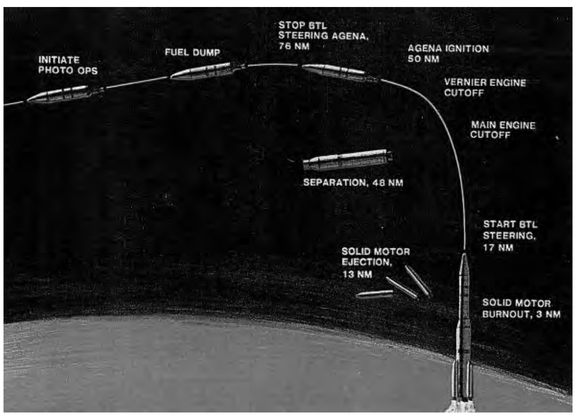

Figure 13-5. CORONA film capsule recovery sequence. (*Reprinted from* NRO, "Corona System Information," http://www.nro.gov/corona/sysinfo2.html [accessed 5 March 2008].)

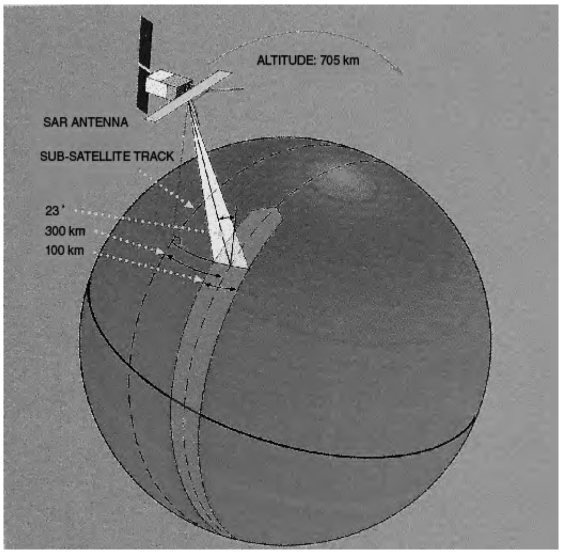

Figure 13-6. SAR satellite. (*Reprinted from* NASA, "What Is SAR, Anyway?" http://southport.jpl.nasa.gov/polar/sar.html [accessed 5 March 2008].)

capsule system is the Russian Resurs-F system. Russia flew 42 space missions with the Resurs-F system from May 1986 to September 1999 conducting remote sensing work. Each mission lasted less than 30 days and carried a film camera system, which returned to Earth in a 2.2 m spherical descent capsule. The capsules were reused an average of three times, and some camera systems were also refurbished and reflown.[13]

Electrical-Optical Imagery. Today most space-based imagery is collected by space-based camera systems and transmitted electronically to Earth. Electro-optical imagery is imagery collected from the portion of the electromagnetic spectrum visible to the human eye. The Indian Remote Sensing (IRS) P-5, or CARTOSAT-1 satellite system, is an example of an electro-optical imagery satellite. CARTOSAT-1 carries two panchromatic (PAN) cameras that take black and white stereoscopic pictures of the earth in the visible region of the electromagnetic spectrum. It also carries a solid state recorder to store the images taken by its cameras. The stored images can be downlinked when the satellite comes within the visibility zone of Shadnager Ground Station and processed and distributed by India's National Remote Sensing Agency.[14]

With an electro-optical imagery system, images can be transmitted to Earth electronically whenever in view of a receiving station. Those images can then be processed and distributed almost instantly. This provides imagery in a much more timely fashion than film-return capsule systems, with which it took weeks or months to view an image taken from space. With electro-optical systems that timeline can be reduced to minutes.

Space-Based Radar Imagery. Space-based radar systems rely on synthetic aperture radar (SAR) systems (fig. 13-6). Using SAR, a space-based radar sends out a pulse of radio waves which bounces off the object to be depicted. The scattered pulses then return to the radar, where they are captured by the receiving antenna. The antenna is the radar's aperture—its opening on the world. SAR antennas are a type of radar antenna designed to take advantage of their satellite's movement, thus creating a "synthetic" aperture or opening.[15]

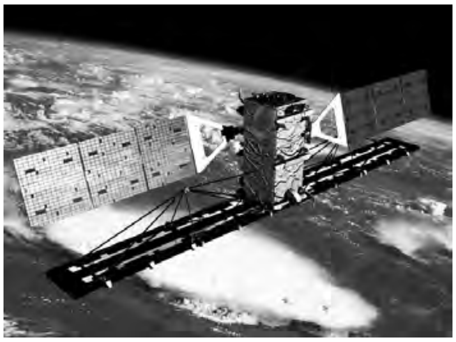

Figure 13-7. RADARSAT-2. (*Reprinted from* Canadian Space Agency, Web site, http://www.asc-csa.gc.ca/images/recherche/.)

SAR images, which resemble photographs, are actually maps in which the brightness shown is a measure of the radar energy reflected back to the antenna. Water droplets in fog and clouds are transparent to radio waves of the proper frequency just as window glass is to light waves of the visible frequency. Hence, a SAR instrument can gather data in conditions where optical sensors would be useless, that is, it can provide excellent images of what the radar detected even in fog, clouds, or darkness.[16]

The Canadian Space Agency designed, constructed, launched, and now operates the RADARSAT. RADARSAT-2, launched on 14 December 2007, is the world's most powerful commercial radar remote-sensing satellite totally dedicated to operational applications (fig. 13-7).[17]

Infrared Imagery. Some imaging satellites contain sensors that collect images in the infrared (IR) portion of the electromagnetic spectrum. Infrared light lies between the visible and microwave portions of the electromagnetic spectrum. Infrared light has a range of wavelengths, just like visible light has wavelengths that range from red light to violet.[18] IR sensors on satellites are used to determine temperature variations of the object being imaged. This capability is useful in a number of situations. Due to temperature variations in an image, it is possible to determine if oil is running through a pipeline, if a nuclear reactor is active, or if a vehicle is operating or not. These are just a few obvious applications, but a more common use for IR sensors on a satellite is weather monitoring.

Many weather satellites have IR sensors to monitor temperature differences on Earth. Some of these sensors can be extremely sensitive to temperature variations. The French-owned and operated SPOT-4 Earth observation satellite has an additional sensor which can image objects in the shortwave infrared (SWIR) band. This information is used to discriminate between different types of crops and plant cover.[19]

Multispectral Imagery. Multispectral imagery (MSI) is steadily growing in popularity within DOD as a digital means for a variety of important taskings to include mission planning, thermal signature detection, and terrain analysis. Presently, it is frequently used as a map substitute when standard mapping, charting, and geodesy (MC&G) products are outdated or inadequate. The ability to record spectral reflectances in different portions of the electromagnetic spectrum is the main attribute of MSI, which can be useful in a number of applications. MSI typically provides such things as terrain information over broad areas in an unclassified format. This attribute make MSI convenient to share with personnel and organizations that are not usually privileged with controlled information from "national" assets. Multinational forces, news media, and civil authorities can all share the benefits of MSI.

The IKONOS satellite (fig. 13-8) is the world's first commercial satellite to collect black-and-white images with 1 m resolution and multispectral imagery with 4 m resolution. Imagery from the panchromatic and multispectral sensors can be merged to create 1 m color imagery (pan-sharpened). Commercial and governmental organizations rely on high-resolution IKONOS imagery to view, map, measure, monitor, and manage global

Figure 13-8. IKONOS satellite. (*Reprinted from* Colorado State University, Environmental Observing Satellites, http://www.cira.colostate.edu/cira/RAMM/hillger/Ikonos_image.jpg.)

activities. Applications range from national security and disaster assessment to urban planning and agricultural monitoring.[20]

Signals Intelligence

Signals intelligence is the collection of broadcast transmissions from communication systems, as well as radars and other electronic systems. The SIGINT arena is comprised of three sub-areas—electronic intelligence (ELINT), communications intelligence (COMINT), and foreign instrumentation signals intelligence (FISINT)—which are differentiated based on the type of analysis to be performed and the nature of the emitter.

Background

The Soviet Union's launch of *Sputnik*, the world's first orbiting artificial satellite, impelled the United States to explore the concept of a space-based reconnaissance program. Along with the CORONA imagery system, President Eisenhower approved the development of a SIGINT satellite system in August 1959 called the Galactic Radiation and Background (GRAB) satellite, referring to its unclassified cover mission (fig. 13-9).[21] After the shootdown of Francis Gary Powers' high-altitude U-2 spy plane in May 1960, President Eisenhower cancelled all further U-2 overflights of the Soviet Union, cementing America's need for satellite reconnaissance. Along with its imagery cousin CORONA, GRAB and its successor, Poppy, became the original cornerstone of satellite reconnaissance in the 1960s and 1970s.[22]

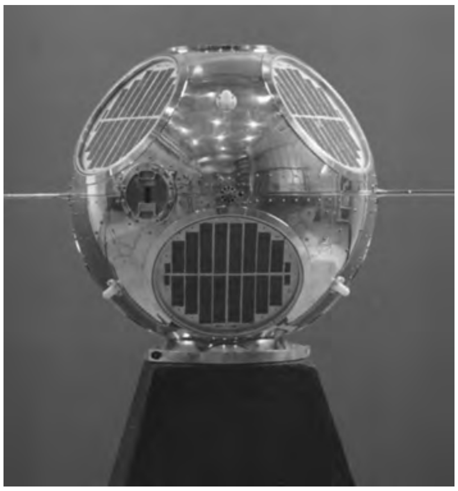

Figure 13-9. GRAB satellite. (Photo provided courtesy of the Naval Research Laboratory)

GRAB and Poppy were ELINT satellites developed by the Naval Research Laboratory (NRL) and were designed to intercept Soviet radar emissions. The GRAB satellite was a 20-inch diameter metal ball packed with electronic equipment and antennas that provided reception of signals. It also featured a larger and separate turnstile antenna that received commands and transmitted telemetry and ELINT data.[23] The GRAB system included two successful satellite launches, failing twice at a third.[24] Following the conclusion of *GRAB 2's* mission, the United States launched the first of six GRAB successor satellites, *Poppy 1*, in 1962. The early Poppy spacecraft had a stretched spherical shape, while later satellites featured a 12-sided

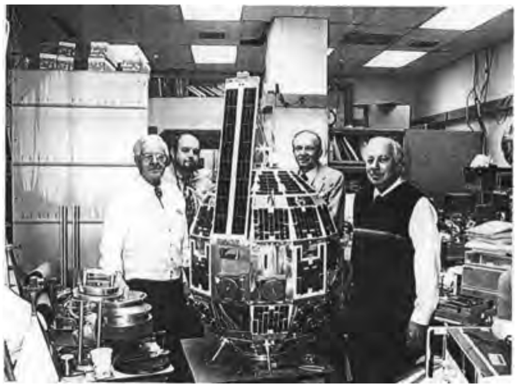

Figure 13-10. Poppy satellite with multiface design. (Photo taken by the NRL and provided courtesy of the NRO)

multiface design (fig. 13-10).[25] As Soviet terrestrial radars emitted their signals above the horizon, GRAB and Poppy satellites collected each radar pulse in a specified bandwidth and sent a corresponding signal to NRL ground stations. Personnel at the ground stations then transmitted the data to NRL, Air Force Strategic Air Command, and the National Security Agency (NSA) to exploit the data and generate technical intelligence about the Soviet radars.[26]

Intelligence derived from the GRAB and Poppy systems supported a wide range of applications during the Cold War. It provided cues to locations and capabilities of Soviet radar sites, characteristics and locations of Soviet air defense equipment, ocean surveillance information for Navy commanders, and a more complete picture of the actual Soviet military threat.[27] The GRAB and Poppy satellite systems were declassified in 1998 and 2004, respectively. They created the critical operations and exploitation paradigm for signals collection that established the foundation of the current overhead SIGINT reconnaissance architecture.

The SIGINT satellites of today are developed and launched jointly by the USAF and the National Reconnaissance Office, with support from the National Security Agency. The NRO's relationship with the NSA for the SIGINT mission mirrors the relationship it has with the National Geospatial-Intelligence Agency for the IMINT mission. The NRO collects signals from overhead satellite systems and delivers the data to the NSA for processing, analysis, dissemination, and exploitation.[28]

Signals Intelligence Types

Unlike imagery satellites, the United States deploys SIGINT spacecraft in all orbits—geosynchronous orbits to pick up ultra-high frequency (UHF) and very high frequency (VHF) communications, and low to medium Earth orbits to collect signals from air defense and early warning radars.[29] Highly elliptical orbits give satellites both long dwell times at high altitudes and short dwell times at low altitudes, maximizing signals collection over multiple regions for specific and repeating durations or frequencies.[30] The type of SIGINT collected often dictates which orbit will be used for a particular satellite.

Electronic Intelligence. ELINT involves the collection and analysis of intercepted signals by other than the intended recipient. It involves the exploitation of signal "externals," referring to the characteristics of the actual transmitted signal (including frequency of carriers and subcarriers, modulation, bandwidth, power level, etc.), beam footprint parameters, and emitter location and motion. A collection signal parameter can be used to obtain a radio frequency (RF) fingerprint for each emitter/emitter platform, which can then be used to locate and rapidly identify the specific emitter or emitter type in subsequent intercepts. Generally, ELINT requires the least amount of analysis of the three SIGINT sub-areas. Typically, systems that are designed to perform ELINT collection may also be capable of performing COMINT and/or FISINT activities.

Traffic analysis is an ELINT technique applicable to COMINT targets wherein the level and timing of activity associated with a specific communication or data-transmission system is assessed by determining whether or not data is present in the link. This determination is based on an examination of the actual RF signal; it is not necessary to actually demodulate the signal and recover the raw data (although this would be more reliable). Because of this, the technique is useful against encrypted links in which it is not possible to recover the raw data. Traffic analysis can be used for indications and warning purposes. Combined with emitter location data, traffic analysis can be used to specify users and user locations (by examining, over time, signal up and down times and assessing visibility between the targeted emitter and the list of potential users).

Communications Intelligence. COMINT involves the collection and analysis of intercepted signals used in communication systems by other than the intended recipient. Generally, the intercepted signal is demodulated, and the original data streams are extracted (voice, electronic messages, computer data, facsimile, etc.), which can then be processed by computer or analyzed by human analysts. For encrypted communication systems, it may not be possible to extract the original data streams, but traffic analysis techniques can still be used to extract some useful intelligence data. COMINT thus involves the exploitation of signal "internals," where *internal* is a reference to the actual data contained in the signal. COMINT analysis is more apt to provide information about the users of the communication link and their activities and is less apt to provide information about the communication system itself. COMINT is routinely used to meet other intelligence requirements and generally requires more analytical effort than ELINT but less than FISINT. Typically, systems that are designed to perform COMINT collection may also be capable of performing ELINT and/or FISINT activities.

Foreign Instrumentation Signals Intelligence. FISINT involves the collection and analysis of intercepted signals used in noncommunication data-transmission systems (telemetry systems, tracking/fusing/arming/command systems, beacons, certain video transmission systems, etc.). Generally, the intercepted signal is demodulated, and the original data streams are extracted. For encrypted communication systems, it may not be possible to extract the original data stream(s), but traffic analysis techniques can still be used to extract some useful intelligence data. Like COMINT, FISINT thus involves signal internals. However, unlike COMINT, FISINT can be used to determine the configuration, characteristics, and capabilities of the emitter and, more importantly, the overall system of which the emitter is a part. Generally, FISINT requires the most analytical effort of the three SIGINT sub-areas. Typically, systems that are designed to perform FISINT collection may also be capable of performing COMINT and/or ELINT activities.

Requirements

Although exact requirements vary with the emitter being targeted and its capabilities, a basic SIGINT system is comprised of a receiving antenna, a preamplifier, a receiver, and demodulation equipment. The quality of the SIGINT components will be dictated by the nature of the intercepted link (effective radiated power, bandwidth, beamwidth, etc.). Normally, the SIGINT antenna should be in the footprint of the emitter; that is, the SIGINT receiver must be physically located at a site which has access to the main beam of the emitter transmit antenna. With the trend of using increasingly smaller antenna beamwidths, this could mean being physically close to the intended receiver site. However, if sufficient receiver gain is available, then it may be possible to collect from a location which is in a sidelobe of the emitter transmit antenna, greatly increasing the allowable distance between the SIGINT systems and the intended receiver. Also, it is usually necessary to be within the physical line of sight of the emitter. However, for some lower frequency (high frequency [HF]) links, the beam will alternatively bounce off the atmosphere and the ground, allowing over-the-horizon (not within line of sight) collection.

Targets for SIGINT collection include space system components which emit electromagnetic waves—either uplink, downlink, or crosslink transmitters. Such emitters may be located at ground facilities and/or on satellites. In some situations, it may also be possible to collect signals of interest as they are reflected off of another object. For example, it may be possible to collect an uplink signal as it is reflected off of the satellite containing the uplink receiver. This is called a bistatic collect. Bistatic collection is very difficult because the power of the received signal is typically very low. Another potential target would be COMINT emitters not directly related to an operational space system, but which convey information related to a space system. One example would be the communications at a launch range that occur before, during, and after a new satellite launch.

Timeliness is an important quality of any intelligence operation. ELINT and COMINT (for relatively simple unencrypted systems) can be conducted in real time by trained personnel. FISINT, however, requires significant amounts of time. For example, a limited understanding of what is in a telemetry signal might be gained in a period of days or weeks. However, a thorough assessment of what each telemetry channel represents (there may be hundreds) may require years and would likely involve fusion of data from the other kinds of intelligence. In all cases, the amount of time required to answer a specific intelligence question is a function of the skill and experience of the analysts involved.

Locating an Emitter

A major goal of any SIGINT operation is to precisely locate the source of a signal. This is the direction finding (DF) process. Such data can be used to target weapons against the emitter and the platform to which it is attached (either a ground facility or a satellite). Generally, SIGINT systems can only provide bearing information (based on the direction of arrival of the intercepted signal), not the range to the emitter (bearing and range together would uniquely locate the emitter). However, by combining a single bearing fix with bearing fixes from SIGINT systems located elsewhere, it is possible to locate the emitter. It may also be possible to obtain range data from a single SIGINT collector using interferometric (superimposing or comparing multiple signals to detect differences) techniques. Finally, single bearing data, coupled with data from other intelligences, could be used to pinpoint an emitter, assuming the other intelligences can provide a list of potential emitters.

The most widely used DF technique is to vary the SIGINT antenna pointing angles and look for the point of maximum received signal. A very narrow-beam antenna must be used for an accurate measurement. With a broad-beam antenna, the signal variation is slight as the antenna is rotated off boresight or DF. Therefore, it is sometimes necessary to estimate the point of maximum signal. The directional antenna technique has the advantage of relatively high gain because the DF is taken on the peak of the antenna beam.

A somewhat more accurate method of DF is to use an antenna with one or two nulls in its radiation pattern. The antenna is rotated until the received signal strength is minimal. This technique is more accurate than the previous because the signal variation around the null is more rapid than the signal variation around the beam maximum (for most antennas). The disadvantage of this technique is that DF is done at a point of very low gain in the antenna pattern. If the signal is weak, it may be lost around the null, eliminating any DF capability.

Probably the best DF technique is lobe comparison. Two antennas are placed near one another so that their patterns overlap. When the two antennas receive equal strength signals, the antennas are both pointed at the target emitter. Another way to use this system is to take the difference between the two antenna outputs. When the antenna is on boresight, the difference should be zero so that the combined antenna pattern has a deep null. The two techniques are generally used together and called sum and difference direction finding. The high-gain sum pattern is used to pick out the approximate DF. Then the difference pattern is used for exact DF.

In the phase method, the phase difference between two separated antennas is measured to determine direction of arrival of the incoming signal. The antenna type consists of at least two antenna elements physically separated in space by some portion of a wavelength of the received signal. In general, the more antennas used to accomplish DF, the more accurate the resulting bearing measurement.

Identifying the Emitter

Identification of the emitter (name and mission) and the platform on which it is located is another major goal of a SIGINT program. The amount of effort required to identify the emitter will depend on the fidelity of the result. It may be possible to characterize the type of emitter from a few basic ELINT parameters (radar, communication systems, telemetry system, etc.). On the other hand, identifying the specific emitter and developing a detailed assessment of its mission may require COMINT/FISINT analysis of the data contained in the signal (for data transmission systems). It is also possible (even likely) that a single platform will have multiple emitters, providing additional data for the construction of an RF signature.

Determining Characteristics of Emitter and Emitter Platform

SIGINT can significantly contribute to an overall understanding of the configuration, capabilities, and characteristics of the emitter and the emitter platform. All sub-areas can contribute to this analysis. ELINT can provide overall emitter characteristics and power requirements. COMINT can provide more detailed emitter characteristics. (COMINT might also provide, indirectly, a number of other system details.) FISINT is probably the most useful technique, especially the analysis of unencrypted telemetry signals. Telemetry systems are intended by the system owner/operator to provide the ability to monitor many aspects of system operation. Telemetry can be used by the SIGINT analyst to identify system components and their characteristics; identify sensors, their characteristics, and sensor event timing; identify the status or health of individual components; identify the interconnections between various components;

and determine the criticality of individual components. Data signals are also useful; the exploitation of data signals can provide very detailed sensor parameters.

Analysis of SIGINT (ELINT, COMINT, and/or FISINT where applicable) can also determine the status or health (active, inactive, reduced capabilities, etc.) of emitters and their platforms and, in some cases, system users. This capability would be useful just prior to a counterspace operation (ground segment attack, space segment attack, or electronic attack), so as to avoid needlessly conducting an operation against a nonfunctioning or improperly identified/misidentified target. The ability to determine systems/user status would also be useful just after a counterspace operation, to assist in performing kill assessment.

SIGINT is also crucial to the successful conduct of any electronic attack (EA). SIGINT will provide RF characteristics of the target link so that the EA systems can be selected or developed. SIGINT would also likely be used to monitor the effects of an attack while it is occurring (as in a counterspace operation).

Identifying the Users

COMINT exploitation of communication signals transponded through a communication satellite can be used to identify the users of the communication system (by the association of can signs, etc.). Also, it is possible to assess, based on the identity of the users or by looking at the data itself, how critical the communication system is to a country's overall military activities.

Measurement and Signature Intelligence

Measurement and signature intelligence is defined as "intelligence obtained by quantitative and qualitative analysis of data (metric, angle, spatial, wavelength, time dependence, modulation, plasma, and hydromagnetic) derived from specific technical sensors for the purpose of identifying any distinctive features associated with the emitter or sender, and to facilitate subsequent identification and/or measurement of the same. The detected feature may be either reflected or emitted."[31] MASINT basically covers technical intelligence derived from the rest of the electromagnetic spectrum plus other measurable "signatures" that can reveal information about an adversary. Together, MASINT, IMINT, and SIGINT provide full-spectrum technical intelligence of an adversary system or action.

While IMINT targets externals and SIGINT targets internals, MASINT targets distinctive features not previously exploited by the former two disciplines.[32] These distinctive features include other information that can be derived from collected raw data of IMINT and SIGINT sensors as well as signatures (changes in characteristics) from acoustic, magnetic, nuclear, radar, multi- and hyper-spectral, electro-optic, and other measurable phenomena.[33]

MASINT is described in terms of its six subdisciplines: radar, radio frequency, geophysical, nuclear radiation, materials, and electro-optical. However, the difficulty in defining MASINT in this manner is that the sensor platforms of each of these subdisciplines can be owned and controlled by different entities with different objectives. Thus, a single integrated intelligence picture is difficult to draw.[34]

Another way of describing MASINT is as a family of systems. Under this construct, a loose collection of signature sensors is employed with a single purpose of discerning adversary capability or intent.[35] By processing and comparing various measurements and signature data, additional complementary information beyond the capability of IMINT and SIGINT sensors can be gleaned. For example, a simple visual-spectrum image can reveal the external characteristics of an adversary weapon system. MASINT sensors could use the raw visible-light data along with other sensor data to reveal the material composition of the weapon (e.g., metal or composite material).

Space-based MASINT capabilities (technically) are thus any space-based remote sensing capability other than IMINT and SIGINT that can be employed individually or collectively to derive technical intelligence on an adversary capability or intent.

Block IIR GPS systems have onboard optical, x-ray, dosimeter, and electromagnetic pulse (EMP) sensors referred to as the Nuclear Detection System (GPS/NDS). This sensor array measures light, infrared, gamma, atomic, and electromagnetic signatures. The data is fused and analyzed to determine the location and yield of a nuclear detonation.[36] Note that the system is a collection of different sensors analyzing different phenomenology or signatures for a common purpose of providing the location and yield of a nuclear detonation. This is categorically a MASINT operation.

Similarly, the Defense Satellite Program (DSP) system and its follow-on systems (e.g., SBIRS) also perform MASINT-like functions. DSP satellites are equipped with two different infrared sensors and nuclear signature sensors. The infrared sensors measure changes and characteristics in infrared signatures and can determine if a ballistic missile has been launched and its probable impact point. The nuclear sensors, like the GPS/NDS system, are designed to provide the location and yield of a nuclear detonation.[37] These platforms look for distinguishing features, not necessarily externals or signal internals, in order to determine action or intent, making them inherently MASINT.

In short, MASINT is an ISR discipline, though not necessarily an ISR platform. Space-based remote sensing systems can derive MASINT by measuring and analyzing various phenomenologies or signatures to extract distinguishing characteristics. These sensors can reside on single or multiple space platforms. They need only be employed for a common purpose of deriving additional technical intelligence beyond traditional SIGINT and IMINT capabilities.

Notes

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