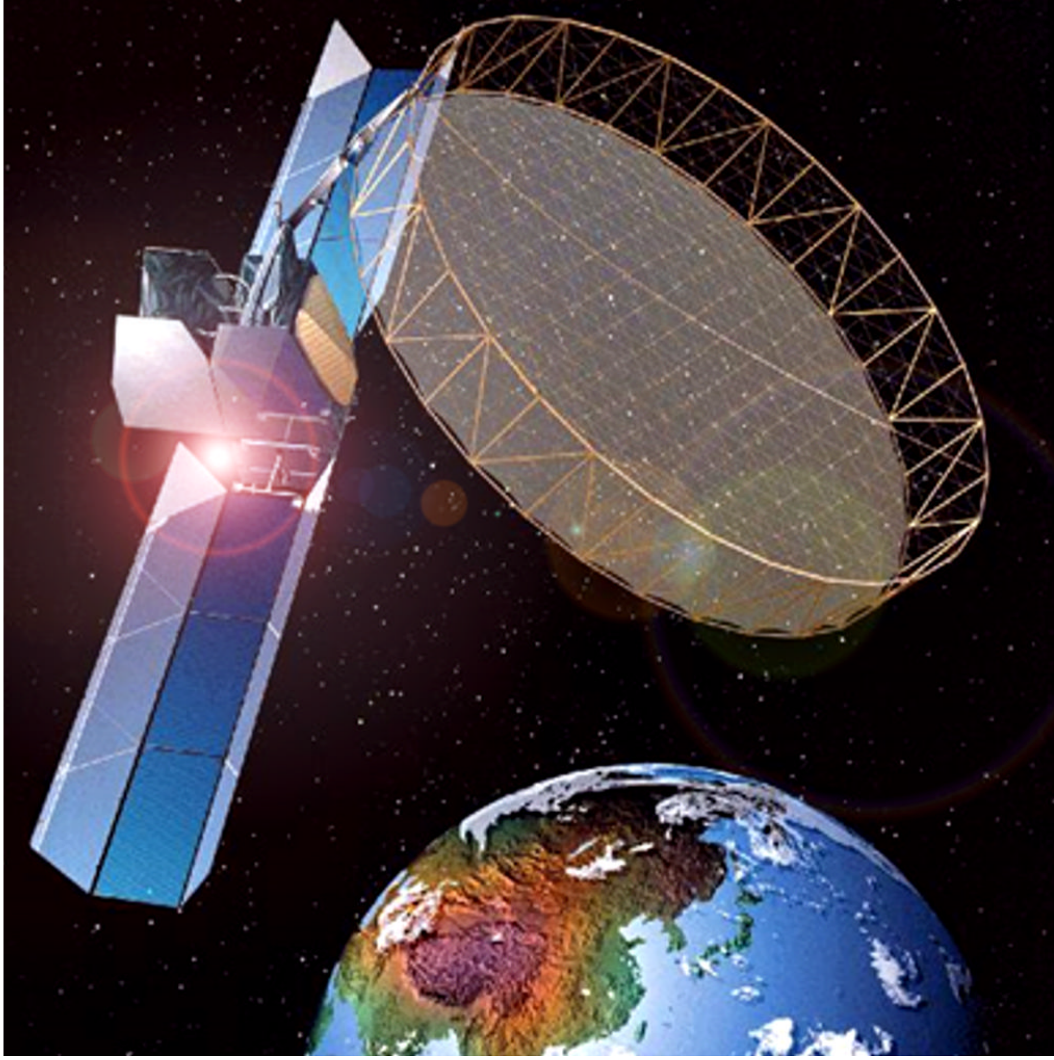

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Implications for U.S. Air and Naval Operations

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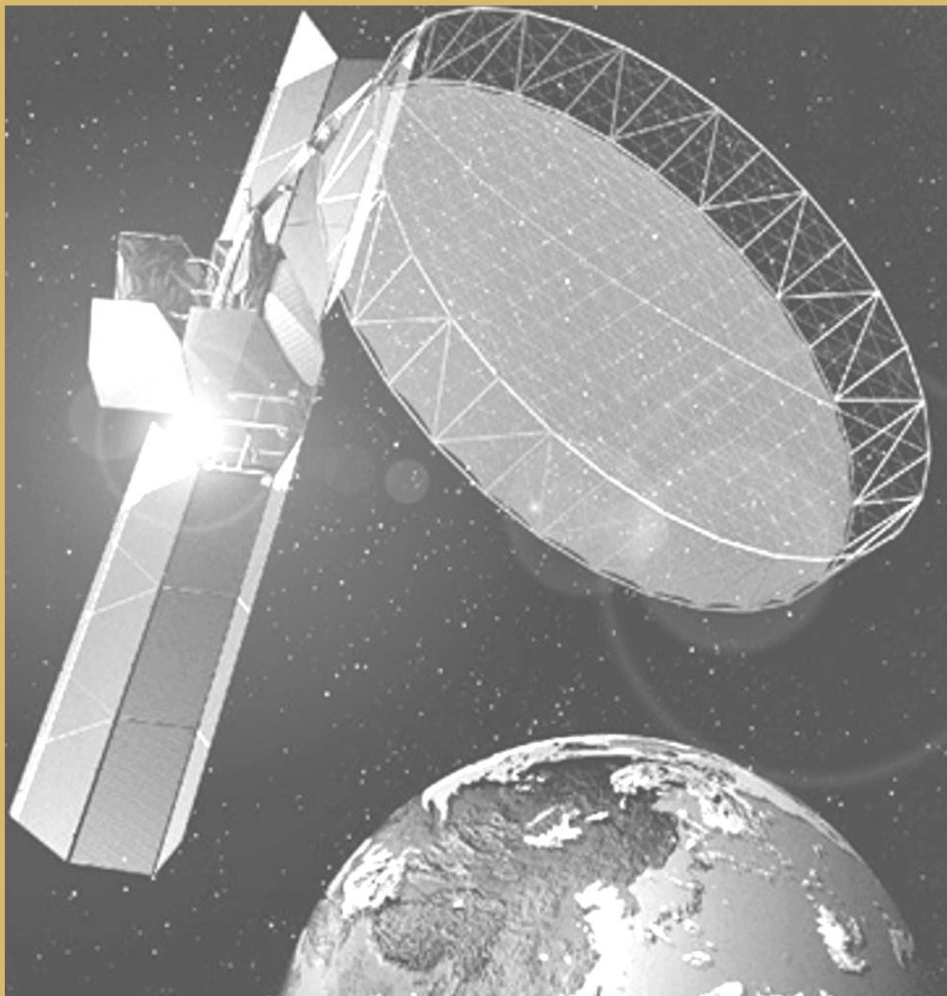
PROJECT 2049 INSTITUTE



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The Project 2049 Institute seeks to guide decision makers toward a more secure Asia by the century's mid-point. The organization fills a gap in the public policy realm through forward-looking, region-specific research on alternative security and policy solutions. Its interdisciplinary approach draws on rigorous analysis of socioeconomic, governance, military, environmental, technological and political trends, and input from key players in the region, with an eye toward educating the public and informing policy debate.

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Ian Easton & Mark A. Stokes

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Cover image: Telecommunications/SIGINT satellite in GEO Source: FAS

Contents

List of Abbreviations

AN/MPQ-53 - frequency-agile multifunction G/H-Band radar group which performs surveillance, Identification Friend-or-Foe (IFF), tracking and guidance, and Electronic Counter Measures (ECM) function entailed in the Patriot tactical air defense system

AN/SPS-48 - long-range, three-dimensional, air-search radar system that provides contact range, bearing, and height information to be displayed on consoles and workstations

AN/SPS-49 - long-range, two-dimensional (range, bearing) air search radar whose primary function is to provide target position data to a ship command and control system

AN/SPY-3 - 3-face X-band active phased-array radar designed to detect the most advanced low-observable anti-ship cruise missile (ASCM) threats and support fire-control illumination requirements for the Evolved Sea Sparrow Missile (ESSM), Standard Missiles (SM-2/SM-3), and future missiles required to support engagement of the most stressing ASCMs

AN/TPS-75 - mobile, tactical radar system capable of providing radar azimuth, range, height, and Identification Friend or Foe (IFF) information for a 240-nautical-mile area

ASBM - anti-ship ballistic missile

BICE - Beijing Institute of Control Engineering

C4ISR - command, control, communications, computers, intelligence, surveillance, and reconnaissance

CASC - China Aerospace Science and Technology Corporation

CASIC - China Aerospace Science and Industry Corporation

CAST - China Academy of Space Technology

CETC - Chinese Electronics Technology Group Corporation

CMC - Central Military Commission

COMINT - communications intelligence

ELINT - electronic intelligence

EO - electro-optical

EORSAT - ELINT Ocean Reconnaissance Satellites

ESM - electronic support measures

EW - electronic warfare

GAD - General Armaments Department

GBR-X - Ground-Based X-Band Radar

ISR - intelligence, surveillance, and reconnaissance

GEO - geosynchronous orbit

GSD - General Staff Department

HEO - highly-elliptical orbit

LEO - low earth orbit

NOSS - Naval Ocean Surveillance System

NWIEE - Northwest Institute of Electronic Equipment

PLAAF - People's Liberation Army Air Force

PLAN - People's Liberation Army Navy

RORSAT - Radar Ocean Reconnaissance Satellite

SAR - synthetic aperture radar

SAST - Shanghai Academy of Space Technology

SIGINT - signals intelligence

SJ - *Shijian*

SWIEE - Southwest Institute of Electronics Equipment

TDOA - time difference of arrival

UEWR - Upgraded Early Warning Radar

UHF - Ultra High Frequency

VLBI - Very Long Baseline Interferometer

VSAT - very small aperture terminal

Introduction

The People's Republic of China (PRC) has embarked upon an ambitious military modernization program. This concerted effort has been driven by the desire for an ability to use force against Taiwan decisively and in a manner that precludes U.S. and other foreign intervention. China also appears to be striving for an ability to enforce other sovereignty claims around its periphery. Along these lines, force projection—especially in the form of long range precision strike—is viewed as an important enabler.

The PLA's ability to conduct strategic and operational strike missions is likely to be restricted by the range of its persistent surveillance. To expand battlespace awareness, the PLA is investing in a number of command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) capabilities to monitor activities in the Western Pacific, South China Sea, and Indian Ocean.

Along these lines, space-based surveillance assets would serve as a critical component of a broader C4ISR architecture. China is investing heavily in electro-optical (EO), synthetic aperture radar (SAR), and electronic reconnaissance surveillance capabilities. A significant amount of data exists on China's EO and SAR capabilities. However, one of the most critical components of a space-based system for regional surveillance, especially monitoring of maritime activity, is electronic reconnaissance.[1]

Electronic Reconnaissance Satellites

For over 40 years, space-based signals intelligence (SIGINT) has been a critical component of U.S., former Soviet Union, and other countries' global and regional surveillance architecture. Within the broad domain of SIGINT, electronic intelligence (ELINT) has proven to be an effective means of assessing a foreign military's electronic order of battle, including ground-based air defense radars and maritime surveillance systems. While initially ground- and air-based, ELINT assets in space offer a wider field of view and broader geographical coverage. In a maritime context, notional targets could include radar systems such as AN/SPS-48, AN/SPS-49, Sea-Based X-Band Radar, and AN/SPY-3 emitters. Targeted land-based air surveillance radar systems could include Ground-Based X-Band Radar (GBR-X), PATRIOT AN/MPQ-53, AN/TPS-75, and Upgraded Early Warning Radar (UEWR) systems operating in UHF portion of the frequency spectrum.

The U.S. initiated its first experimental ELINT satellite series with the successful launch of two "GRAB" satellites equipped with small collection antennas in 1960 and 1961. These were followed by numerous second, third, and fourth generation SIGINT/ELINT satellites between 1968 and 2003. Throughout this period, the U.S. Air Force and Navy developed a variety of sophisticated ELINT satellites for capturing and recording ground- and ship-based radar emissions and locating the position of the emitters. These satellites provided intelligence about the distance of the transmitter and signal characteristics, including the radar systems' operating frequencies, pulse repetition frequency, and antenna rotation speeds. The collected data were used to study air defense networks and shipping movements for operational and targeting purposes. The U.S. is now launching and operating a number of fifth generation satellites for the gathering of electronic and signals-derived intelligence.[2] Chinese analysts estimate that the U.S. currently operates nine to 11 ELINT satellites.[3]

The U.S. Naval Ocean Surveillance System (NOSS) satellite constellations evolved from the U.S. Air Force "Ferret" ELINT satellite program that began gathering intelligence on air defense radars in the 1960s. The first experimental U.S. NOSS constellation was launched in 1971 aboard a Thorad-Agena rocket that conducted multiple retro-rocket firings to place three 123kg small satellites in orbit. From 1976 to 1980 three first generation NOSS constellations were deployed, with five improved variant constellations launched between 1983 and 1990. These NOSS constellations were used to detect, indentify, and precisely locate foreign warships, relying on time difference of arrival (TDOA) triangulation techniques. This intelligence was relayed to command centers in real-time for target designation with over-the-horizon cruise missile attacks in times of conflict and to gather intelligence on foreign naval tactics in peacetime. Later generations of the system also proved useful for seeking mobile, ground-based air defense systems, as the frequencies of such emitters were essentially the same as their seaborne equivalents. Aside from ELINT packages, these satellites were believed to have carried infrared and radar sensors for a variety of Navy and Air Force missions by the 1990s.[4]

One detailed Chinese study on the U.S. "White Cloud" system described the concept of a NOSS satellite constellation as such:

> *Naval Ocean Surveillance System [NOSS] satellites primarily work through the detection of a ship's unique radar signals and radio signals to monitor ship activity at sea. They can effectively detect and identify ships at sea, and accurately judge a ship's location, speed, direction and other such information…There are two types [of NOSS]: active, which can*

obtain information on a ship's size, best represented by the Russian [NOSS] satellites; and passive, which can provide information on the state of a ship's electronic equipment, these work in groups and are best represented by the American [NOSS] satellites.[5]

The U.S. NOSS satellites reportedly operated on a band between 555 MHZ and 10 GHZ, with an accuracy of two to three kilometers, and an ability to detect radar transmissions out to 3,218km. It was all-weather and also employed satellite infrared detection sensors and millimeter wave emitters for the detection and tracking of nuclear submarine wakes, as well as low flying missiles.[6] The system was controlled by the Navy Space Command, with signal processing conducted at the Naval Information Center in Suitland, Maryland, as well as naval intelligence centers in Spain, England, Japan and Hawaii. Ground stations supporting the constellations were located in Blossom Point, Maryland; Winter Harbor, Maine; Edzell, Scotland; Guam; Diego Garcia; and Adak, Alaska.[7]

The former Soviet Union launched over 200 ELINT satellites from 1967 to 1991. This highly active program, conducted a variety of missions, included nuclear-powered SAR satellites and conventionally powered passive ELINT satellites working in tandem to track U.S. and allied carriers and other warships. Underscoring their importance, Russia maintained at least two ELINT satellite programs after the fall of the Soviet Union, albeit at a scaled-down level, despite massive cutbacks and cancellations elsewhere across the space and missile sectors of the defense industry.[8]

China's ELINT Developments

Historical Chinese ELINT Efforts

As U.S. and Soviet space-based ELINT efforts proceeded, China's answer appears to have been the 701 Program initiated in the late 1960s. The 701 Program was managed by the Shanghai Bureau of Astronautics to augment China's ground-based ELINT collection capabilities and was afforded high-level attention. The resources allocated to the 701 Program in terms of talent and treasure led to some impressive initial gains. An unconfirmed Chinese source indicates the country's first experimental ELINT satellite—the *Shijian*-1 [实践一号]—was launched in March 1971. The SJ-1 satellite served on orbit for over eight years, and was hailed for its breakthroughs in power, control, telemetry, and sensors.[9] Three ELINT satellites were launched as part of a follow-on "technical experiment satellite" [技术试验卫星] series from July 1975 to August 1976.[10] These satellites were launched aboard the *Fengbao*-1 "Storm-1" [风暴一号] launch vehicle which was specifically designed to meet the various requirements of ELINT satellite platforms.[11] In September 1981, China achieved a significant breakthrough, launching three *Shijian*-2 [实践二号] satellites aboard one carrier rocket, something observers saw as further adding to its ELINT satellite portfolio.[12] However, the initial high-level party leadership interest in the ELINT program waned and nearly a decade followed with no known follow-on capability being launched.[13]

Modern Chinese Electronic Reconnaissance Satellite Development

Building on the foundation established under the 701 Program, the PRC appears to have resurrected efforts to develop and deploy a space-based ELINT capability as part of a broader surveillance and reconnaissance architecture for tracking and targeting U.S. and allied maritime assets. ELINT technology is designed to intercept electromagnetic radiation, and works in tandem with imagery sensors–especially space-based SAR–for strategic and naval reconnaissance. China has long enjoyed Asia's most extensive SIGINT capability. However, most of its assets have been land-based and airborne, and not in space.[14] A surge of recent military space launches and a number of authoritative Chinese writings suggest that this may be changing. China has begun deploying a robust network of ELINT and imagery satellites in order to locate and track large warships, mobile air defense systems, and other critical defense systems.

This section first addresses key organizations that may be involved in development of ELINT-related operational and technical requirements, acquisition management, and research, development, and manufacturing. The section also includes a review of possible ELINT-related programs.

Operational Management Issues

The People's Liberation Army (PLA) appears to have a distinct organizational structure for managing and satisfying its space-based surveillance architecture, and in particular its ELINT program. Key PLA organizations within this structure include the General Staff Department (GSD) and the General Armaments Department (GAD).

General Staff Department: The PLA GSD plays a key role in developing operational requirements for space-based surveillance. While previous works done by Dr. David Finkelstein, Dr. Desmond Ball, and others have made significant contributions, it admittedly remains a speculative endeavor to assess which specific GSD organization is responsible for space-based ELINT and ground-based receiving and processing stations.[15] However, this section reviews possible candidates:

- *First Department Surveying Bureau*. The GSD First Department Surveying Bureau appears to operate the ground segment of China's satellite navigation system and a Very Long Baseline Interferometer (VLBI) network of radio telescopes that support China's space tracking system.[16]

- *Second Department*. The GSD Second Department appears to play a role in the development of space-based sensor operational requirements, and perhaps operation of ground stations. More specifically, the key organization is the GSD Second Department Technology Bureau, also known as the Beijing Institute of Remote Sensing Information [北京遥感信息研究所] or GSD Space Technology Reconnaissance Bureau [总参航天技术侦察局]. Based in the northern Beijing suburb of Qinghe, the GSD Space Reconnaissance Bureau appears to be primarily focused on EO and SAR remote sensing operations.[17]

- *Third Department*. The GSD Third Department [解放军总参三部] appears to be China's primary SIGINT collection and analysis agency. Its management of a foreign language training center in Luoyang implies a communications intelligence (COMINT) mission. The Third Department, which formerly functioned as a direct reporting agency under the Central Military Commission (CMC), maintains its headquarters in the Xianghongqi [厢红旗] area of Xishan, specifically Hongshankou [红山口].[18] Organized into at least 12 and perhaps as many as 16 regional and functional bureaus, the GSD Third Department manages a large bureaucracy for SIGINT collection and analysis.[19] The GSD Third Department 12th Bureau (61486 Unit), headquartered in Shanghai's Chabei District, supports China's space surveillance network and appears to maintain a close linkage with the Second Department's Beijing Institute of Remote Sensing Information. Its subordinate divisions operate facilities in Taicang (Jiangxi Province), Fuqing (Fujian Province), and Kunming (Yunnan Province).[20] It is reported that the GSD Third Department currently employs some 130,000 people.[21]

- *Fourth Department.* The GSD Fourth Department [总参四部; or 电子对抗与雷达部] is responsible for radar and electronic countermeasures.[22] Established in 1990, the Fourth Department holds the overall responsibility for electronic warfare (EW), including ELINT and tactical electronic support measures (ESM). The Fourth Department may also operate ground receiving stations and channel data, for targeting and operational purposes, to the Second Artillery and various other PLA units through an intelligence support cell within a Joint Theater Command.[23] The Fourth Department not only plays a leading role in joint force planning and the development of requirements, but also oversees one or possibly two direct reporting ECM units. The first is a brigade-level organization based in Langfang with subordinate elements in Anhui, Jiangxi, and Shandong. The other, located on Hainan Island, appears to have either operational or experimental satellite jamming responsibilities.[24] The Fourth Department also oversees the PLA Electronic Engineering Academy [解放军电子工程学院], an institution for professional military education and technical training.[25]

General Armaments Department: The General Armaments Department (GAD) appears to be the key organization responsible for managing the acquisition of China's space-based surveillance system and satellite tracking and control, most likely including electronic reconnaissance satellites. Within GAD, the Electronics and Information Infrastructure Department [总装电子信息基础部] Aerospace Equipment Bureau [航天装备局] appears to be responsible for developing the technological requirements of the space-based sensor infrastructure supporting missile operations. It appears that the GAD may also manage the satellite tracking and control infrastructure supporting ELINT satellites.[26] Indications of this include the GAD's specialized unit for studying means of effective satellite launch preparation and applications.[27]

Research, Development, and Manufacturing

Two state-owned defense industrial establishments—the China Aerospace Science and Technology Corporation and China Academy of Space Technology—support the GSD and GAD in research, development, and manufacturing of space-based surveillance systems, including electronic reconnaissance satellites.

The primary organization is the China Aerospace Science and Technology Corporation (CASC). Within CASC, the Shanghai Academy of Space Technology (Eighth Academy) and the China Academy of Space Technology (Fifth Academy) are key business divisions involved in the ELINT program.

Shanghai Academy of Space Technology: Central to ELINT satellite development is the Shanghai Academy of Space Technology (SAST), also known as the Eighth Academy.[28] As the successor to the 701 Program's "workshop," the SAST 509th Research Institute appears to have inherited the responsibility of the lead systems integrator for ELINT satellites. The SAST 509th Institute falls under the CASC Eighth Academy and works with the CASC Fifth Academy to integrate satellite payloads.[29] A number of institutes may support the SAST 509th Institute with sub-systems, such as receivers. For example, the SAST 804th Research Institute (Shanghai Institute of Electronic and Communications Equipment; 上海航天电子通讯设备研究所) appears to conduct R&D on space-based radar antenna systems.[30] The Chinese Electronics Technology Group Corporation (CETC) Southwest Institute of Electronics Equipment (SWIEE) in Chengdu, also known as the 29th Research Institute, is closely affiliated with the GSD Fourth Department and is likely China's premier entity engaged in ELINT sensor R&D.[31] The CETC 36th Institute in Jiaxing may also play a role in supporting the SAST 509th Institute by producing various onboard ELINT support systems.[32] In addition, the Northwest Institute of Electronic Equipment (NWIEE) has conducted a number of studies on large space-based antenna arrays for SIGINT satellites.[33]

China Academy of Space Technology: In cooperation or perhaps in competition with SAST, the China Academy of Space Technology (CAST), also known as the Fifth Academy, is likely involved in ELINT satellite R&D and possibly production. The Fifth Academy's 501st design department—the Beijing Institute of Control Engineering (BICE)—functions as CAST's overall systems engineering organization. Established in 1975, BICE designs, researches and develops satellite attitude and orbit control systems, including jet propulsion and various guidance, navigation and control sub-systems. Another CAST organization—the 508th Research Institute—designs and develops EO and other satellite sensors.

Chinese Theoretical Writings

China's defense-industrial complex has established a strong theoretical foundation for the development of a space-based electronic reconnaissance architecture. A central PLA figure in systems architecture development appears to be the GAD Aerospace Bureau director Wu Weiqi [吴炜琦].[34] Wu Weiqi has published detailed research on linking EO, SAR, and ELINT satellite sensors for targeting ships at sea.[35] He has also conducted evaluations on the effectiveness of a space-based information system in supporting ballistic missile operations and long-range precision strike.[36] Wu Weiqi's research is supported by other detailed studies on an integrated space surveillance architecture's potential to support an anti-ship ballistic missile (ASBM) program. For example, one study states:

> *During the tactical process of ASBM attack/defense the support of space-based satellite information is highly required for target reconnaissance, missile early-warning, global communications, precision guidance, battle damage assessment and the digitalized construction of the battlefield…When compared to long-range, precise missile attacks on land targets, ASBM assaults on long-range sea [targets] are very different…For example, when attacking land [targets] long-range cruise missiles use terrain contour matching, using the geographical references such as mountains or rivers to aid guidance; but ASBMs have few or no references when flying over water, and cannot use this method…Thus, an ASBM requires military satellite support at every stage of the attack process.*[37]

In discussing the role that ELINT satellites would play in China's ASBM program, this study goes on to emphasize the importance of C4ISR sensor fusion:

> *During the process of planning [to use] the fire power of an ASBM, [there is a need] for obtaining reliable target intelligence information for guiding the missile attack. This could be achieved by integrating EO imaging satellites, SAR imaging satellites, electronic reconnaissance satellites, naval ocean surveillance system satellites, mapping resource satellites, and highly accurate commercial remote sensing satellite imagery, which could be purchased on the international market. Through the integration of the data obtained via a number of different satellites, and with the addition of processing and data fusion, [one could] guarantee missile guidance requirements for all types of target information for a long-range ASBM strike.*[38]

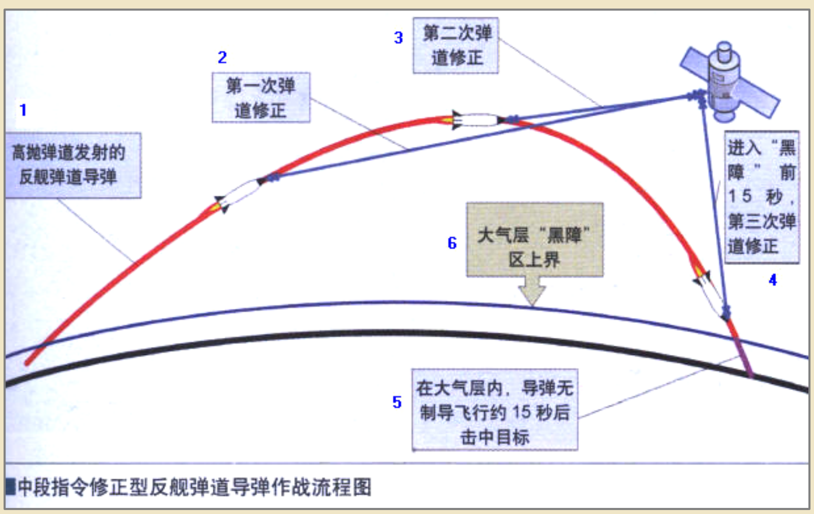


Image: ASBM being guided to target through direct communication with reconnaissance satellite

Caption reads: Operational flow chart of a mid-course order correction anti-ship ballistic missile

1. Launch of high parabolic trajectory anti-ship ballistic missile
2. First trajectory correction
3. Second trajectory correction
4. Third trajectory correction, 15 seconds prior to entering "blackout"
5. Back in the atmosphere, the missile flies unguided for around 15 seconds, then hits target
6. Upper limit of atmospheric "blackout" zone

Source: Modern Ships (Xiandai Jianchuan)

Chinese writings have also advocated linking satellite sensors to ground-based early-warning radars, modeling the "obvious improved" ability of the radars to detect, track, and calculate targets with satellite support.[39] Studies have been conducted on employing space sensors for early-warning and missile defense operations.[40] Chinese technical writings indicate that advancements made in operating satellites in highly-elliptical orbit (HEO) could contribute to this mission.[41]

In years past, China's sporadic space-based ELINT capability, working in tandem with ground, air, and sea-based ELINT sensors, most likely provided for a capable, regionally-focused program. Periodic satellite coverage would have enabled a population of GSD electronic orders of battle. A database of such information would likely include maritime radar systems as well as ground-based air and missile defense systems. This database would be updated when new signals were detected, and intelligence analyzing new developments was produced.[42]

Chinese writings have indicated that while the numbers of ELINT satellites are increasing, they have been unable to meet the demand from different intelligence consumers. One study described the nature and the challenges facing ELINT satellites:

> The military applications [of electronic reconnaissance satellites] are very numerous. Although the numbers of electronic reconnaissance satellites are increasing, they are still far from meeting various departments' needs for electronic reconnaissance. The limited numbers of satellite resources are extremely valuable. Thus we need to conduct research on how to optimize electronic reconnaissance satellites' broad-area coverage planning systems in order to optimize target reconnaissance to the greatest extent possible and maximize satellite efficiency.[43]

This highlights the importance of developing a robust ground-based satellite support system to help integrate space-based ELINT into a broader C4ISR system. It also underscores the challenges in prioritizing missions as demand for ELINT collection capabilities come from an expanding number of intelligence consumers. Authoritative sources suggest that China has made considerable progress in this area.

Chinese technical writings indicate investment into multiple satellite constellations using time difference of arrival (TDOA) direction finding or geolocation techniques. One study on a three-satellite TDOA system for precise geo-location was published in March 2010, the same month that one suspected electronic reconnaissance system, the *Yaogan*-9, was launched.[44] Organizations most likely responsible for space-based electronic reconnaissance, such as SAST's 509th Institute and SWIEE, have published detailed assessments of how to most effectively track and target aircraft carriers and other large naval ships.[45] For example, one senior Chinese engineer identified as working on ELINT system technologies wrote:

> *A three satellite TDOA [system] for geo-location has the advantages of high precision, broad-area coverage, and long-surveillance times. It is very suitable for ocean surveillance, for example in [conducting] continuous surveillance against aircraft carrier groups, and submarines. It enables real time understanding of the threats coming from the sea.*[46]

While many Chinese studies have focused on three-satellite electronic reconnaissance architecture, breakthroughs in advanced algorithm processing could allow China to construct a two-satellite constellation.[47] Chinese sources suggest substantial progress has been made in this direction.[48]

As a signal of intentions, recent PLA-affiliated technical writings indicate a focus on utilizing ELINT sensors in conjunction with radar networks.[49] Such a system, if based in space, would parallel the former Soviet Union's development of NOSS constellations. According to Chinese reports, the Soviets launched the world's first NOSS platform, the Cosmos-198, in December 1967. In the years following, the Soviets launched a series of "RORSAT" (Radar Ocean Reconnaissance Satellite) and "EORSAT" (ELINT Ocean Reconnaissance Satellites) systems which operated in co-planer pairs and co-orbital constellations from 1974.[50] PLA-affiliated authors researching U.S. and Russian NOSS systems strongly advocated in 2007 that China should develop its own NOSS system. They stated:

In light of the Naval Ocean Surveillance System [NOSS] satellites' importance and the facts of our nation's situation, we should work hard to reference other countries advanced technologies, carefully following dynamic developments, and with great effort develop our own [NOSS] so that we may possess an operational [NOSS] system as early as possible; contributing to the nation and the people's economic development and guaranteeing national security.[51]

China's ELINT Satellite Downlinks

China's expanding space-based surveillance network has placed a greater burden on the country's terrestrial space support infrastructure. Developments underway suggest that China is working to improve its ability to quickly download, process, and disseminate the intelligence gathered from space, including that from ELINT satellites. One recent study described the developments as such:

As electronic reconnaissance satellites develop, the requirement to obtain military intelligence from the satellites increases. The issue at hand is how to (from the ground) quickly, effectively set and decide satellite system mission tasking for effective, appropriate ground application of satellite resources…Satellite ground stations combine and use six systems for linking up with electronic reconnaissance satellite signals: 1) Antenna systems: responsible for uploading and downloading satellite signals; 2) Emitting systems: responsible for ordering satellite signal modulations, encryption, etc. post-processing, these work through antenna systems; 3) Receiving systems: receiving signals from the satellites, and after processing then send to terminal station system; 4) Terminal station systems: responsible for reconnaissance data processing, satellite command and mission arrangement; 5) Monitoring and control systems: monitor satellites and downlink operation status and monitor overall ground station; 6) Power supply system: providing power for all ground station equipment. In short, an electronic reconnaissance satellite ground station is an integrated system for receiving, processing and managing data.[52]

One authoritative source indicated that a system linking ELINT satellites to a ground network for wide area coverage and multiple object targeting (including those at sea) has been operationally tested for effectiveness, and was found to perform well.[53] The GSD Fourth Department may be a leading candidate for managing ELINT downlink sites. Space-related units that have been associated with the GSD Fourth Department are located in Beijing, Hainan, and Shandong areas. For example, one source notes that GSD Fourth Department initiated a project in 1999 for the construction of 10 coastal stations in the area of Shidao in Shandong Province.[54]

While speculative, GSD Second Department, Third Department, First Department Surveying Bureau, or civilian downlink facilities could also host ground-based support architecture for ELINT satellite constellations. China utilizes shared facilities to support a number of satellites along with its maritime observation *Haiyang*-series satellites. Ground stations supporting these satellites are located in Beijing, Sanya, Hangzhou, and Mudanjiang. The director of China's National Ocean Satellite Application Center, Jiang Xingwei [将兴伟], has stated that China also has a ground station in Antarctica supporting these satellites.[55] China is reported to operate at least three other ground stations abroad. These are located in Swakopmund, Namibia; Malindi, Kenya; and Karachi, Pakistan.[56] China is also constructing a space antenna facility Argentina, and evaluating sites for further antenna facilities in Argentina as well as in Chile.[57] China's operational headquarters and data processing center for remote sensing satellites is located in Beijing, with three main ground stations supporting the network located in Miyun, near Beijing; Kashgar, in Xinjiang; and Sanya on Hainan Island.[58]

These ground stations could be conceivably used in conjunction with China's fleet of *Yuanwang* [远望] space tracking ships to support electronic reconnaissance satellite constellations. China's *Tianlian* [天链] data relay satellites could also be expected to help pass data from ELINT satellites to ground stations, particularly when the constellations are above a target but not within line-of-sight of a receiving station.[59] It is also possible that the People's Liberation Army Navy (PLAN) could install receivers on their warships to receive ELINT from space transmitted from data processing centers at the joint theater command level via military/dual-use communications satellites such as the *Zhong Xing* 20A "China Sat 20A" [中星-20A].[60] Data from China's ELINT satellites could also be transmitted from data processing centers to Second Artillery and People's Liberation Army Air Force (PLAAF) units via the *Qu Dian* [区电] C4ISR system as a part of China's ASBM program.[61]

As part of a broader effort to build a robust satellite communications infrastructure, China has invested considerable resources into its mobile satellite communications and small mobile satellite ground station technologies for the integrated transmission of voice, imagery, and numerical data. These systems are linked by very small aperture terminal (VSAT) technology and cyber networks. China has deployed mobile satellite communications platforms in military and security roles for at least a decade.[62]

Image: Mobile Remote Sensing Satellite Ground Station
Source: CAST

Chinese Interest in Sensors in Geosynchronous Orbit

While it appears that China has experienced a lag in developing a robust electronic signals collection capability, there is another possibility one could posit. It is possible that the Chinese strategic leadership has long benefited from unidentified ELINT sensors attached to other satellite payloads, and recent launches simply represent an increase in dedicated systems. It is possible that SIGINT/ELINT sensors have piggybacked aboard Chinese remote sensing satellites in LEO and communications satellites in geosynchronous orbit (GEO) for many years. Authoritative Chinese writings have explored the utility of GEO for SIGINT/ELINT sensors, stating:

> *In the information age, the utilization of electronic reconnaissance satellites to obtain intelligence has become an important method [of doing so]. Geostationary electronic reconnaissance satellites provide unique advantages and are being increasingly emphasized…Using geostationary satellite platforms to engage in electronic reconnaissance is useful for the large coverage ranges available for obtaining electronic information in the air, including terrestrial and other radar signals, communications signals, satellite telemetry, etc. It also allows for the continuous, long-term surveillance of target areas; obtaining intelligence in real-time to provide rapid electronic intelligence for diplomatic and strategic military decisions.*[63]

Chinese writings also discuss deploying large antenna structures for SIGINT/ELINT collection, predicting they "will certainly obtain increased utilization aboard large electronic reconnaissance satellites, mobile communications satellites, and earth observation satellites as…technologies continue to improve and quickly mature."[64] In what could have implications for the clandestine use of telecommunications satellites in geostationary orbits for SIGINT/ELINT purposes, one Chinese aerospace electronics engineer at a research institute closely associated with the Chinese military analyzed the use of airborne telecommunications systems for the collection of SIGINT, and found it to be possible to combine both the telecommunications and the SIGINT missions on one hardware platform.[65] Another authoritative Chinese source described the technology trends involved in SIGINT gathering satellites and the Chinese requirements as such:

> *The developing trend in signals intelligence satellites is to go from deployment in lower orbits to medium and geostationary orbits; from single satellites to multiple satellite networks; from ground-based data processing to onboard data processing; and from unitary to joint satellite missions. These developments require higher data processing, data compression, real-time transmission capabilities, and extremely large antenna technologies. We must actively explore and work diligently towards overcome challenges posed by satellite reconnaissance equipment and technology.*[66]

Chinese engineers have conducted detailed studies to model large mesh deployable antenna technologies for satellites in GEO, including those deployed on previous U.S. SIGINT/ELINT satellites.[67] Studies have also been conducted to explore the relative advantages and disadvantages of operating SIGINT/ELINT satellites in GEO as opposed to LEO, exploring economic factors and precision variables in coverage. Ultimately, Chinese writings advocate combining sensors in both orbital realms to optimize effectiveness, concluding that:

> *As the geo-location requirement indicators continually increase for electronic intelligence satellites, presently high orbit satellites' geo-location technology has difficulties satisfying requirements for precision and low orbit satellites' wide-area coverage capability is clearly insufficient. As such, a low-orbiting satellite network for geo-location…and low orbiting constellations (i.e. three satellites or two satellites for geo-location based on time difference of arrival) would provide for special requirements for high precision systems…while at the same time advancements in exploring new high-orbit…high-level passive geo-location techniques for simultaneously satisfying precision and wide-area coverage requirements should be considered.*[68]

This literature suggests, at very minimum, a strong Chinese interest in utilizing a number of different orbital environments and technologies for the collection of SIGINT/ELINT. This would go well beyond the limited LEO capabilities believed to have been deployed in orbit by the Chinese since the 1970s. While recent launches demonstrate an on-going effort to deploy two- and three-satellite ELINT constellations in LEO, a considerable number of writings also indicate a commitment to deploying co-orbital satellite formations in GEO. This has clear implications for China's ability to use GEO for SIGINT/ELINT collection.[69]

Possible On-Going Programs

Over the last 15 years, technical writings offer strong indications of a resurrected R&D program for electronic reconnaissance satellites. At least two possibilities exist for an initial space-based ELINT capability: one associated with launches of four pairs of *Shijian*-6 satellites, first launched in 2004, and the other with the *Yaogan*-9, launched in 2010.

The launch of the two co-orbital *Shijian*-6 Group-04 [实践六号 04 组卫星] satellites in October 2010 was reported to have included "electronic intelligence technology tests" as part of the mission.[70] A number of the *Shijian* (SJ) "Science Experiment" or "Practice" series of satellites have characteristics of ELINT satellites, and observers suspect that their true mission involves signal collection because of their orbital characteristics.[71] Unlike other Chinese scientific satellites, no scientific research on their missions has been published in the public domain.[72]

An overview of key institutions, personnel, and technology supporting these two programs suggests that they are deeply connected. Chinese writings also suggest that both satellite formations could have a key role in China's ASBM and other long-range precision strike programs.

While official Chinese confirmation as to the military nature of these spacecrafts' respective missions is unlikely given the extreme secrecy surrounding such capabilities, PLA and affiliated technical literature strongly indicates significant interest in ELINT satellites as part of a broader space-based sensor network for maritime surveillance.[73] Such a capability could be critical for cueing China's ASBM system.[74] An effective ASBM capability targeted towards U.S. carrier strike groups operating in the Western Pacific would most likely require a persistent surveillance capability out to a range of several thousand kilometers off China's coast.

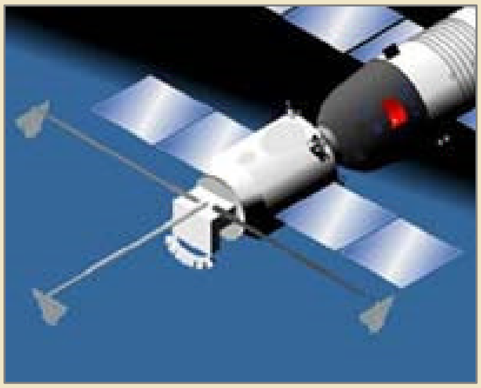


Image: Notional Image of ELINT System Deployed by Shenzhou Modules
Source: Space Daily

While a network of land, air, and sea-based sensors exist for this mission, each is limited by the challenges of range, precision, and timeliness.[75] Chinese writings indicate that, barring unexpected breakthroughs in near-space surveillance technologies in the near to mid-future, only a dedicated space-based sensor architecture would be able to overcome the challenges inherent in a naval surveillance mission. Therefore, ELINT satellites represent a powerful force multiplier in China's growing spaced-based intelligence, surveillance, and reconnaissance (ISR) network. In the absence of near real-time precision cueing, an ASBM would struggle to find its target.

Shijian Series

With a history dating back to the 701 Program, R&D on the *Shijian*-6 series of satellites began in July 2001 under the technical leadership of the veteran satellite designer Shen Cong [沈琮]. Responsible for the A satellite, Shen Cong had previously worked on the *Chang Kong*-1 "Long Space" [长空一号] satellite launched in July 1975 as part of the 701 Program. The *Shijian*-6A and Shijian-6B satellites were launched in tandem in September 2004. A second pair of *Shijian*-6 satellites (SJ-6C and SJ-6D) was launched in October 2006. A third pair (SJ-6E and SJ-6F) was launched in October 2008; and a fourth pair (SJ-6G and SJ-6H) was launched in October 2010. Each satellite pair has a service life of two years.[76] SAST (CASC Eighth Academy) led the R&D and manufacturing of the SJ-6A, while CAST (CASC Fifth Academy) took the lead for the SJ-6B.[77]

Yaogan Series

With at least 13 satellites launched since April 2006, the *Yaogan* remote sensing satellites appear to be key military space platforms for EO and SAR imaging missions.[78] Indications exist that the *Yaogan*-9 [遥感九号卫星], launched in March 2010 from China's *Jiuquan* Satellite Launch Center, may be a first generation Chinese electronic reconnaissance system, similar in nature to the U.S. NOSS.[79] The initial indication came from amateur astronomers who reported that the *Yaogan*-9 mission saw the launch of not one, but rather a constellation of three satellites that are now orbiting together in a highly choreographed triangular formation.[80] This formation is orbiting in a 1080 km x 1100 km x 63.4 degree position,[81] strikingly reminiscent of earlier generations of the U.S. "White Cloud" NOSS satellite triplets described in detail by Chinese writings.

The CASC Fifth Academy's Fifth Design Department, the Chinese Space Technology Research Institute General Department [中国空间技术研究院总体部], had overall responsibility for the *Yaogan*-9 satellite program, and worked with other elements within CASC to finalize pre-launch production.[82] The director and chief designer of the *Yaogan*-9 was Li Yandong [李延东]. The China space industry's flagship publication reported that Li Yandong's innovative leadership resulted in the completion of the *Yaogan*-9 program in only four years despite the high level of technical difficulty involved in production.[83] Li Yandong also served as the director and chief designer of one of the two Shijian-6 Group-04 satellites, and was previously involved in China's *Haiyang*-1 [海洋一号] maritime surveillance satellite program.[84]

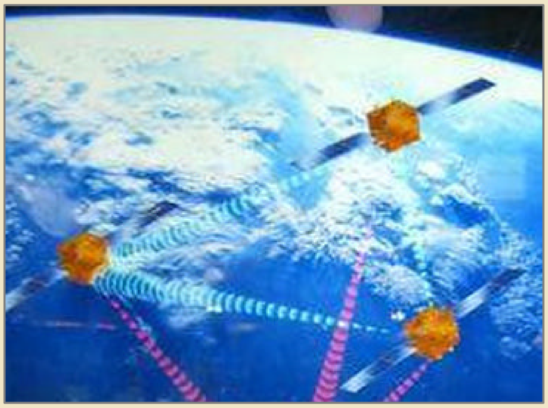


Image: Notional Image of Yaogan-9 Satellites
Source: Gunter's Space Page

Other common personnel also link the *Yaogan* satellite series to the 701 Program and the SAST 509th Institute, suggesting that a number of *Yaogan* satellites may carry ELINT sensors piggybacked onto the main EO/SAR platforms. For example, Zhu Hongchang [朱鸿昌] was a deputy chief director of the *Yaogan*-1 and then the chief director of the *Yaogan*-3.[85] Likewise, Wei Zhongquan [魏钟铨] served as the chief designer of the *Yaogan*-1 satellite,[86] and may have previously played a key role in designing the *Shijian*-6 Group-01 (SJ-6A/B) satellites.[87] Both men spent their careers in the SAST 509th Institute and were deeply involved in the 701 Program.[88]

The CASC Fifth Academy, which played a role in building both the *Shijian*-6 Group-04 and the Yaogan-9 satellite constellations, specializes in developing small and micro satellite buses,[89] and would be a logical candidate for building multi-satellite electronic reconnaissance satellite buses. Bolstering its ocean surveillance satellite portfolio, the CASC Fifth Academy has a working relationship with the State Key Laboratory of Satellite Ocean Environment Dynamics in Hangzhou.[90] Thus, China's ELINT satellites are linked at the personnel as well as the institutional levels.

Parallels between the *Yaogan*-9 and previous U.S. NOSS satellites go beyond shared orbits and constellation formations, and extend to the launch on the *Yaogan*-9 itself. It is significant that the *Yaogan*-9 was launched from the *Jiuquan* Satellite Launch Center on a Long March 4C with a restartable third stage to improve payload performance. This was in contrast to all previous *Yaogan* launches from *Jiuquan* which used the less powerful Long March 2D booster.[91] Drawing from Chinese literature on NOSS, this upgraded booster would have allowed for a series of highly choreographed maneuvers that released co-orbital sub-satellite units (SSU) into orbit where they will orbit in a triangular formation with the "mother" satellite.[92]

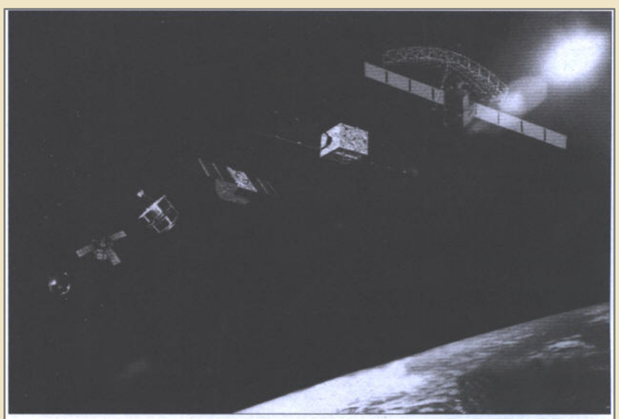
A Chinese media report released soon after the launch of the *Yaogan*-9 indicated that a "certain satellite" launched in 2010 executed a series of high-risk orbital changes directed by an advanced GAD satellite control base. These "multiple retro-rocket firings saved fuel on this precious satellite and effectively extended the satellite's lifetime."[93] According to the report, this GAD base indigenously developed an "Aerospace Command and Tracking Network Multiple Mission Management Center" [航天测控网多任务管理中心] and an "Automated Satellite Management System" [卫星管理自动化系统], both of which have contributed to the base's ability to "guarantee highly effective, safe, 24-7 satellite operations."[94] The base has also conducted highly successful technical research projects on "constellation tracking" [星座测控] and "co-positional satellite" [多星共位] operations.[95] It can be inferred from the article that the "unnamed satellite" in question is the *Yaogan*-9.[96] As a final comment, it is conceivable that the *Shijian*-6 Group-04 program may have built upon technology acquired in the *Yaogan*-9 program for the development of a smaller two-satellite NOSS constellation. This would mirror previous Soviet (and later Russian) advancements in deploying two-satellite NOSS constellations.

Implications of China's ELINT Program

Looking ahead, it appears that China is laying the foundation for what could be a robust space-based network of satellites dedicated to ELINT collection. It could also be developing clandestine piggybacked sensors that could work with other space and terrestrially-based ISR sensors to enable a truly *informationalized* [信息化] network for global SIGINT/ELINT collection in near real-time. This development may hold serious implications for the Asia-Pacific region, especially for U.S. and regional actors' naval and air operations, air defense systems, communications security, counterspace requirements, and nuclear deterrence.

Naval and Air Operations: The most immediate implication of China's evolving ELINT capability is its ability to accurately track and target U.S. carrier strike groups in near real-time from lower earth orbit as part of China's ASBM system.[97] Technological and organizational advancements in the space-based sensor network supporting the ASBM system would bolster China's rapidly evolving long-range missile programs directed against warships operating on China's periphery, as well as U.S. and friendly air bases in Japan, Guam, Taiwan, the Philippines, Singapore, Thailand, India, and beyond. A robust space-based ELINT capability would also enable Chinese strategists and war planners to monitor adversary naval and air operations as well as peace time exercises, providing highly useful intelligence for war planning.

Air Defense Systems: A robust ELINT capability allows for the locating and monitoring of air defense systems, and enables the precise cataloging of air defense orders of battle. This knowledge, when combined with sophisticated TDOA techniques, could be leveraged by China for the targeting of mobile air defense systems with electronic attack and anti-radiation cruise missiles. Furthermore, static missile defense early warning sites may also be vulnerable to strikes by China's short and medium-range ballistic missiles. Without an assured air defense system, a nation would be exposed to follow-on waves of missile, rocket, and air strikes.



■我国小卫星群，从右到左依次为："环境" 卫星、"海洋" 1A、"实践" 5、"实践" 4、"实践" 2、"实践" 1。

Image: Small Satellites

Caption reads: A group of small Chinese satellites. In order from left to right: Huanjing [Environment] satellite; Haiyang-1A [Maritime]; Shijian-5 [Practice]; Shijian-4; Shijian-2; Shijian-1

Source: Modern Ships (Xiandai Jianchuan)

Communications Security: China's interest in developing and deploying SIGINT platforms in GEO could be affected by gains made in ELINT gathering technology, given the technological overlap that the two fields enjoy.[98] A robust SIGINT collecting sensor network in GEO could enable China to monitor global communications with a small number of platforms, providing it with intelligence vital for military and strategic decision making. China's rapid gains in supercomputing technology and computer code writing could allow for significant breakthroughs in cryptanalysis with potentially damaging implications for communications security.[99]

Counterspace Requirements: The demonstration of an operational ASBM system could compel U.S., and its allies and friends, to develop counterspace systems to temporarily blind, disable or permanently destroy China's space-based ELINT and imagery sensors in times of conflict. Recent U.S. studies have called for the development of a counterspace capability to offset China's evolving anti-access/area denial capabilities.[100] In the event of a war, it would be critical for the U.S. to deny China the ability to target carrier strike groups. Advances in high-powered energy and cyber technologies could provide the U.S. with a non-kinetic means of doing so while mitigating the threat of space debris. Chinese literature shows that substantial resources have been dedicated to counterspace capabilities. As part of its anti-satellite (ASAT) effort, China has conducted detailed studies on defending reconnaissance satellites from counterspace operations.[101]

Nuclear Deterrence: Chinese interest in developing ELINT and SIGINT gathering platforms in GEO, suggests that China may also deploy satellites and sensors in this orbital domain for other missions. Available research suggests an interest in utilizing space for missile defense purposes. If pursued, this capability could eventually allow for worldwide missile launch surveillance and early warning capabilities, strengthening China's nuclear deterrent and missile defense posture.[102]

Conclusion

Many unknowns remain, but it is probable that China has now deployed at least two different ELINT gathering satellite constellations, one comprised of two and another comprised of three co-orbital satellites in LEO. Strong indications exist that these dedicated ELINT platforms are augmented by ELINT sensors piggybacked on other satellites platforms in LEO, and perhaps in GEO. Technical writings suggest that China is committed to expanding its SIGINT/ELINT capabilities in GEO. These evolving capabilities are likely to greatly improve the PLA's ability to track and target moving carrier strike groups and undermine regional air defense systems in the coming years. Chinese literature suggests a substantial amount of resources has been dedicated to its evolving space-based ELINT capabilities, and operational tests of a system linking those assets to ground-based C4ISR network for the targeting of terrestrial targets have been successfully conducted.

The bulk of Chinese sources discussing ELINT satellites link them to the broader maritime surveillance mission, and specifically to the ASBM system. As such, China's ELINT satellite program appears well-placed to strengthen China's asymmetric regional aerospace campaign strategies, complicating the ability of the United States and allies to conduct air and maritime operations in the West Pacific. Indeed the launch of these satellites comes at a crucial time in U.S.-Chinese strategic relations, accompanying as it does official announcements that China has been testing an ASBM system of systems, and set against the backdrop of the rapid Chinese build-up of space assets for the exploitation of the space domain for its strategic and tactical military utility.

At the same time, Chinese writings indicate a significant interest in developing a space architecture of ELINT and SIGINT satellites and sensors in a number of orbital environments, including higher orbits. This has implications for worldwide military and strategic communication security as well as for missile defense. China's utilization of space assets for tactical missions also has implications for counterspace operations and ASAT weapons development programs.

Therefore, while the *Shijian*-6 Group-04 and the *Yaogan*-9 satellite constellations represent but one facet of an increasingly complex integrated network of systems enabling China's build-up of long-range conventional strike capabilities, their respective launches have created strategic effects that could reverberate well into the future.

References

[1] Signals intelligence (SIGINT) is often divided into functions: electronic intelligence (ELINT) and communications intelligence (COMINT). However, Chinese writings offer less distinction, with a vague term "electronic reconnaissance" generally being used to refer to SIGINT, ELINT and COMINT. However, individual authors tend to define "electronic reconnaissance" slightly differently, and for the purpose of this study we translate electronic reconnaissance based on the context of each individual article. For example, many of the authors noted in this study define electronic reconnaissance as ELINT, something they view to be separate from SIGINT/COMINT, while others refer to it more in western terms, sometimes translating them directly from English into Chinese.

[2] For an excellent Chinese overview of U.S. programs see: Liu Xing [刘兴], *Air Defense and Space Defense Information Systems and Other Integrated Technologies* [防空防天信息系统及其一体化技术] (Beijing: National Defense Industry Press, 2009), pp. 34-36. See also Desmond Ball, "Information Warfare (IW) in Asia: Signals Intelligence (SIGINT), Electronic Warfare (EW), and Cyber-Warfare," Paper presented at Canadian Association for Security and Intelligence Studies (CASIS) 2002 Conference, Ottawa, September 26-28, 2002, p. 32.

[3] These join the ranks of some six or seven classified imaging satellites and are supported by 38 military-run ground stations. See Yu Ling, Wang Chun, and Rong Hui (eds.), *Counter Space* [太空对抗] (Beijing: Military Friendship Publishing, 2010), p. 272. Note that this book won the PLA's 6th annual book award.

[4] Song Yanping, "American SIGINT Reconnaissance Satellites" [美国的信号情报侦察卫星], *Space Electronic Technology* [空间电子技术], No. 1, March, 1999, pp. 49-50. See also Mei Guobao and Wu Shilong, "Development, Application and Challenges Confronted with Electronic Reconnaissance Satellite" [电子侦察卫星的发展，应用及其面临的挑战], *Shipboard Electronic Countermeasure* [舰船电子对抗], August 2005, pp. 28-31. For an excellent English-language source (translated from Russian) see Major A. Andronov, "The U.S. Navy's 'White Cloud' Spaceborne ELINT System," *Foreign Military Review* (ISSN 0134-921X), No. 7, 1993, pp. 57-60, translated by Allen Thomson, at http://www.fas.org/spp/military/program/surveill/noss_andronov.htm.

[5] Su Jianwei, Song Yuan, Xu Linzhou, "Electronic Reconnaissance Effectiveness Analysis of Ocean Surveillance Satellite to Surface Ship" [海洋监视卫星对水面舰艇电子侦察效能分析], *Shipboard Electronic Countermeasure* [舰船电子对抗], August 2009, p. 51.

[6] Ibid. p. 52.

[7] Song, 1999, p. 47.

[8] Ball, September 26-28, 2002, p. 33-34.

[9] "'SJ'Scientific exploration and technological experiment satellite series" ["实践" 科学探测与技术试验卫星系列], *Huanqiu*, October 20, 2010, at http://mil.huanqiu.com/weapon/2010-10/1185243.html.

[10] "Imagery Reconnaissance and Electronic Reconnaissance Satellite Series" [照相侦察与电子侦察卫星系列], *Anhui News*, January 22, 2007, at http://mil.anhuinews.com/system/2007/01/22/001656523.shtml.

[11] Mark A. Stokes, *China's Strategic Modernization: Implication for the United States* (Carlisle, PA: Strategic Studies Institute, 1999), p. 34.

[12] These were the *Shijian*-2, *Shijian* 2A, and the *Shijian* 2B satellites launched aboard the "Storm-1" [风暴一号] launch vehicle into a 59.4 degree, 1600km x 200km elliptical orbit. See National Aeronautics and Space Administration (NASA), "Shijian 2B," *National Space Science Data Center*, at http://nssdc.gsfc.nasa.gov/nmc/masterCatalog.do?sc=1981-093A.

[13] James A. Lewis, "China as a Military Space Competitor," *Center for Strategic and International Studies*, August 2004, at http://csis.org/files/media/csis/pubs/040801_china_space_competitor.pdf.

[14] Ibid.

[15] For an excellent overview of the General Staff Department, see David Finkelstein, "The General Staff Department of the Chinese People's Liberation Army: Organization, Roles, & Missions," in James C. Mulvenon and Andrew N.D. Yang, eds. *The People's Liberation Army as Organization: Reference Volume v1.0*, Santa Monica, CA: RAND, CF-182-NSRD, 2002, pp. 122-224. See also Mark A. Stokes, 1999; and Desmond Ball, "Signals Intelligence In China," *Jane's Intelligence Review*, Vol. 7, No. 8, August 1995, pp. 365-370. Also see Desmond Ball, "China's Signals Intelligence (SIGINT) Satellite Programs," Australian National University Strategic and Defence Studies Centre Working Paper #382, December 2003.

[16] VLBI sites track space objects simultaneously via telescopes that are combined, emulating a telescope with a size equal to the maximum separation between the telescopes. Using ELINT methodology, VLBI measures the time difference of arrival (TDOA) of radio waves at separate antennas. Therefore, the GSD First Department Surveying Bureau likely has a close relationship with the GSD Fourth Department. VLBI sites, presumably subordinate to the brigade or regimental-level 61540 Unit, are in Shanghai Sheshan, Kunming, Guizhou Qiaodongnan [黔东南] Huangping County, Wulumuqi Nanshan, and Beijing Miyun. See "PLA 61540 Unit Successfully Joins Moon Satellite Tracking and Control" [解放军 61540 部队成功参与探月卫星测控], China Surveying and Mapping

Yearbook [中国测绘年鉴编], July 29, 2008, at http://zgchnj.sbsm.gov.cn/article//ljnjll/lbnj/tz/zdsj/200807/20080700039517.shtml. Other key GSD Surveying Bureau ground stations are located in Hainan.

[17] The military unit cover designator may be 61646 (e.g., the 61646 部队). See Mark Stokes, "China's Quest for Joint Aerospace Power: Concepts and Future Aspirations," Project 2049 Institute Occasional Paper, (forthcoming). The institute manages a R&D center, which is directed by Zhou Zhixin [周志鑫]. For reference to Zhou, see [杜善义院士、曲久辉、栾恩杰和周志鑫校友获 2009 年度何梁何利奖], Harbin Institute of Technology Today, at http://today.hit.edu.cn/articles/2009/11-11/1115372591.htm. For reference to Zhou with the Second Department's Space Remote Sensing, see http://www.ciomp.cas.cn/jgsz/kyxt/klomt/sysgk_klomt/xswyh_klomt/. For reference to Zhou as 61646 Unit Deputy Bureau Director, see [胡锦涛签署通令给军队 1 个单位 22 名个人记功], at http://www.wpeu.net/html/china/2010/1225/18703.html. The institute is also known as 总参航天侦察局 or 总参二部航侦局 for short. Also see "Earthquake Prediction Institute Summary of Research on Emergency Respond to Yushu, Qinghai 7.1 Earthquake" [地震预测研究所应对青海玉树 7.1 级地震应急研究工作综述], China Earthquake Administration, May 11, 2010, at http://www.cea.gov.cn/manage/html/8a8587881632fa5c0116674a018300cf/_content/10_05/11/1273544138348.html. For reference to the 61646 Unit ground station (presumably an imagery downlink site), see [2007 年度首都文明单位候选名单 (1908 个)], at http://jbhg.bjwmb.gov.cn/public/info_selinfo.asp?Info_ID=27680&Bar_ID=123.

[18] See "Ascend Toward the Colored Evening" [朝花夕拾], *Shijiazhuang News Network*, January 14, 2011, at http://yzlnb.sjzdaily.com.cn/html/2011-01/14/content_305413.htm.

[19] The Third Department's primary military unit cover designator is 61195 [61195 部队].

[20] The 61486 Unit Commander, Senior Colonel Ju Qiansheng [巨乾生], has been affiliated with both the GSD Second Department Remote Sensing Institute and GSD Third Department's 12th Bureau. See "District Standing Committee, Deputy Mayor Yan Jianping Visits 61486 Unit for a Social Visit" [区委常委、副区长颜建平率队赴驻区 61486 部队开展军地互动联谊活动], February 8, 2010, at http://www.shmzj.gov.cn/gb/mzzbq/mzxw/zxxw/userobject1ai486.html. For reference to a presence in Taicang, see "Pu Rong'gao Pays Respects to Units in Taicang" [浦荣皋慰问立功受奖的驻太部队官兵], Taicang City website, September 30, 2010, at http://mz.taicang.gov.cn/art/2010/9/30/art_1187_93979.html. Also see "District Leaders Zhou Ping, Cao Liqiang Meet with 61486 Unit Leaders" [区领导周平、曹立强会见 61486 部队领导], Chabei District website, July 14, 2010, at http://zb.shmzj.gov.cn/gb/mzzbq/mzxw/zxxw/userobject1ai637.html. For reference to the Taicang remote sensing ground station (61728 Unit), see "City First Hospital Pays Visit to Ludu Reserve Artillery and 61728 Units" [市一院赴陆渡预备役高炮团、61728 部队表示节日的问候], Taicang Health Information Network, July 24, 2009, at http://www.tcws.cn/pro/news_view.asp?newsid=1142 or http://www.tcsyy.cn/Newsinfo.asp?id=148.

[21] Note that the author did not source the origins of this number, and it therefore remains unverifiable. See: Wen Dongping [聞東平], *The Spy War Underway* [正在进行的谍战] (New York: Mirror Books, 2009), p. 276.

[22] As of mid-2010, GSD Fourth Department Director is Major General Wan Xiaoyuan [万晓援]. Born in December 1952, Wan previously directed the Fourth Department's Technology and Equipment Department, served as the department deputy director, and Deputy Commander, 1st Group Army. He was promoted to Major General in July 2004. Former GSD 54th Research Institute Director Senior Colonel Hao Yueli [郝叶力] was promoted to Fourth Department Deputy Director in 2010.

[23] Finkelstein, 2002, pp. 160-168.

[24] Director of the Hainan GSD 4th Department Regiment [61764 Unit] is Jin Guodong [靳国栋], as of 2009. One indication of the unit having satellite jamming responsibilities is the number of articles published by its members. See, for example, Li Bin and Jin Guodong, "Analysis on GPS Jamming" [浅析 GPS 干扰技术], *Electronic Countermeasures*, January 2009, pp. 39-42; Jin Guodong and Li Suoku, "On Broadband Communications Satellites [宽带卫星通信探析], *Electro-Optical Systems*, April 2008, pp. 16-31; and Zhang Ming and Li Suoku, "Space Information Warfare and International Space Law [空间信息作战与国际空间法], *Armament Command and Technology Academy Journal*, February 2003; and Xiang Hanfei, Li Suoku, and Han Honglin, "Analysis of GPS System Countermeasures," [GPS 系统对抗若干分析], *Tracking and Communications*, October 2008.

[25] For an example of research supporting the Fourth Department ELINT mission, see Wu Shilong, Luo Jingqing, and Liu Youjun "Passive Location by Single Reconnaissance Satellite Based on Spatial Spectrum Estimation" [基于空间谱估计的单星侦察无源定位], *Shanghai Aerospace*, June 2005, at http://www.lw23.com/pdf_9588991b-8dd2-441a-baeb-3e576ca77a2f/lunwen.pdf. Gong Liangliang, Wang Yunliang, and Luo Jingqing, "Radar Electromagnetic Environment Simulation in Satellite Reconnaissance" [基于卫星侦察的雷达电磁环境仿真], *Modern Defense Technology* [现代防御技术], 2008 36(3), at http://d.wanfangdata.com.cn/periodical_xdfyjs200803031.aspx. The authors are from the GSD Fourth Department's Electronic Engineering Academy in Hefei. The Fourth Department oversees the GSD 54th Research Institute, which most likely provides engineering support, and also maintains close links with a number of China Electronic Technology Corporation (CETC) entities, including the 29th Research Institute in Chengdu, the 36th Research Institute in Jiaxing, and the 38th Research Institute in Hefei.

[26] "Certain GAD Base Makes Breakthrough: Controls Two or More Satellites Simultaneously" [总装某基地破难题 同时对两颗以上卫星实时测控], *Huanqiu*, March 18, 2010, at http://mil.huanqiu.com/china/2010-03/749024.html.

[27] See GAD Professional Unit for Effective Satellite Loading and Applications [总装备部位卫星有效载荷及应用技术专业组], *Current Satellite Applications and Developments* [卫星应用现状与发展] (Beijing: China Science Technologies Publishing, 2000).

[28] SAST Director is Zhu Zhisong [朱芝松]. Born in 1969, Zhu rose through SAST ranks and was appointed director in late 2008, replacing Yuan Jie [袁洁]. The 509th Institute [509 所] is also known as the Shanghai Institute of Satellite Engineering (SISE) [上海卫星工程研究所].

[29] See Yuan Xiaokang [袁孝康], "Satellite Electronic Reconnaissance, Anti-jamming," *Shanghai Hangtian*, October 9, 1996, pp. 32-37, in *FBIS-CST*-97-011; and Yuan Xiaokang, "Some Problems of Space Electronic Reconnaissance," *Hangtian Dianzi Duikang*, March 1996, pp. 1-5, in *CAMA*, Vol. 3, No. 4. Yuan is a key engineer involved space-based antenna systems design, including both ELINT and SAR, from the SAST 509th Research Institute (Shanghai Institute of Satellite Engineering).

[30] See Wang Jixue, "Satellite-Based SAR Antenna Engineering Design" [星载合成孔径雷达天线的工程设计], *Shanghai Aerospace*, February 2003, at http://www.cnki.com.cn/Article/CJFD2003-SHHT200302001.htm. The author is from the 804th Research Institute. Also see Zhang Fenghui and Yao Chongbin, "Spaceborne Electronic Reconnaissance and Countermeasures" [星载电子侦察与电子对抗], *Aerospace Electronic Countermeasures* [航天电子对抗], 2006(22) 4, at http://d.wanfangdata.com.cn/Periodical_htdzdk200604007.aspx. The authors also are from the 804th Research Institute.

[31] For one example of research, see Xiong Xiaoli [熊小莉], "Signal Interception Equipment Technology of SIGINT Satellite" [星载侦察接收技术], *Telecommunication Engineering*, 2010 (50)8, at Accessible online at http://www.teleonline.cn/ch/reader/create_pdf.aspx?file_no=201008004&year_id=2010&quarter_id=8&falg=1. Xiong is a SWIEE [西南电子设备研究所] engineer specializing in aerospace TT&C and reconnaissance payloads. The 29th Institute also manages a national defense lab on electronic warfare [电子对抗国防科技重点实验室]. Jiang Dao'an [姜道安], Deputy Director of the 29th Research Institute, was reportedly the chief designer of the sensor sub-system on the four pairs of SJ-6 satellites first launched in 2004. He also is credited with sensor development on the Shenzhou 2 spacecraft. See "Introduction of Candidates for the Sichuan Outstanding Innovation Award" [凝聚创新人才 推进"两个加快"第五届"四川杰出创新人才奖"20 名候选人简介], *Sichuan Online*, January 14, 2010, at http://news.163.com/10/0114/06/5SVI1B02000120GR.html.

[32] See Mark A. Stokes, 1999, p. 63. See also: "Foreign Military Observers' Interpretations: China's ELINT Satellite Plans" [外国军事观察家另类解读-中国电子情报卫星计划], *Sina*, November 15, 2004, at http://mil.news.sina.com.cn/2004-11-15/1112243166.html; and Rafael Smith, "Report from the 2010 Chinese Defense Electronics Exhibition (CIDEX): Growing Industry- Advancing Technology," *International Assessment and Strategy Center*, October 3, 2010, at http://www.strategycenter.net/research/pubID.230/pub_detail.asp. The assertions made in this section are also based on an assessment of which institutes are publishing the results of their research and development on ELINT satellites in authoritative journals – many of which can be seen in the following endnotes. For example, see Lin Jinshun, Lu Shengjun, and Wu Xianzhong, "Study on Overall Technology Of Integrated Electronic Reconnaissance Satellite Payloads" [一体化电子侦察卫星载荷总体技术研究], Aerospace Electronic Warfare, 2008 24(6), at http://d.wanfangdata.com.cn/Periodical_htdzdk200806005.aspx. The authors are from the 36th Research Institute in Jiaxing.

[33] See, for example, Wang Yuanchao, "A General View of Structures of Large Deployable Antennas on SIGINT Satellites" [大型星载电子侦察天线结构概述], *Radar and Countermeasures* [雷达与对抗], April 2006, at http://www.cqvip.com/qk/95518X/200604/23667480.html. Wang is from the Xian Institute of Electronic Equipment (NWIEE; 西北电子设备研究所).

[34] Liu Peixiang (ed.), "Our University Participates in Formal Establishment of Shenzhen Aerospace Dongfanghong Development Ltd." [我校参与组建的深圳航天东方红海特卫星有限公司正式成立], *Harbin Industrial University News*, March, 4, 2009, at http://news.hit.edu.cn/articles/2009/03-04/03163743.htm, accessed December 27, 2010.

[35] See Wu Weiqi and Zhang Yulin, "The Preliminary Study of General Effectiveness Model of the Ocean Target Detection Satellite System" [海洋目标探测卫星的通用效能模型初探], *Journal of Astronautics* [宇航学报], Vol. 27, No. 4, 2006; Wu Weiqi and Zhang Yulin, "Agent-based Simulation Method for Performance Evaluation of Satellite System" [基于 Agent 的卫星体系效能评估仿真方法], *Computer Simulation* [计算机仿真], Vol. 24, No. 7, 2007; Wu Weiqi and Zhang Yulin, "Analysis on the Probability of Target Detection with Photo-reconnaissance Satellite" [光学侦察卫星的目标探测概率分析], *Journal of National University of Defense Technology* [国防科技大学学报], Vol. 28, No. 4, 2006; and Wu Weiqi and Zhang Yulin, "SAR Satellite Baseline Mean Direction Optimization and Design" [星载 In SAR 空间基线指向优化与设计], *Chinese Journal of Space Science* [空间科学学报], Volume 26, No. 3, 2006. Major General Zhang Yulin is former Commander, Jiuquan Satellite Launch Center and a senior GAD authority on space and space launch systems.

[36] See Wu Weiqi and Zhang Yulin, "Effectiveness Evaluation Approach for Space-based Information Support System of Missile Operations" [支持导弹作战的天基信息系统效能平估方法], *Journal of the Academy of Equipment Command & Technology*, [装备指挥技术学院学报], Vol. 17, No. 2, 2006; and Wu Weiqi and Zhang Yulin, "Space Information System Optimization for Long-range Precision Strike" [远程精确打击天基信息支持系统体系优化], *Journal of the Academy of Equipment Command & Technology*, [装备指挥技术学院学报], Vol. 17, No. 3, 2006.

[37] Pan Changpeng, Gu Wenjin and Chen Jie, "An Analysis on the Capabilities of Military Satellites to Support an ASBM in Offense and Defense Operations" [军事卫星对反舰导弹攻防作战的支援能力分析], *Winged Missiles Journal* [飞航导弹], 2006, No. 5, p. 12. Note that the authors are affiliated with the PLA Navy Aerospace Engineering Academy.

[38] Ibid. p. 13.

[39] Chen Langzhong, Guo Zhanglong, Wu Tao, and Li Weimin, "An Analysis on Accuracy of Ground-based Early-warning Radar Under Conditions of Space-based Information Support" [天基信息支援下地基预警雷达工作精度分析], *Journal of Projectiles, Rockets, Missiles, and Guidance* [导箭与制导学报], Vol. 26, No. 2, 2006.

[40] Zhao Chenguang and Zheng Changwen, "Analysis on Space-based Ballistic Missile Early Warning and Detection Means" [弹道导弹天基预警与探测手段分析], *Aerospace Electronic Warfare* [航天电子对抗], Vol. 24, No. 4, 2008; and Wang Rui and Xiong Wei, "Study on the Methods of Locating Ballistic Target in Coast Phase by Space-based Infrared LEO System" [天基红外低轨卫星系统对自由段空间目标定位方法研究], *Journal of the Academy of Equipment Command & Technology* [装备指挥技术学院学报], April 2008, pp. 71-75.

[41] See Zhang Yinsheng, Shen Zhen, and Yi Dongyun, "Estimate on Single Passive HEO Satellite Detection of Ballistic Missile Course Heading" [基于大椭圆单星无源探测弹道导弹射向估计], *Journal of Spacecraft TT & C Technology* [飞行器测控学报], Vol. 29, No. 3, 2010.

[42] Steven A. Smith, "Chinese Space Superiority? China's Military Space Capabilities and the Impact of Their Use in a Taiwan Conflict," *Air War College*, February 17, 2006, at http://www.au.af.mil/au/awc/awcgate/awc/smith.pdf.

[43] Wang Huilin, Huang Wei, Ma Manhao, and Zhu Xiaomin, "Design and Implementation of Area-Covering Electronic Reconnaissance Satellite Planning System" [面向区域的电子侦察卫星规划系统设计与实现], *Computer Engineering and Applications* [计算机工程与应用], Vol. 46, No. 26, 2010, pp. 209. Note that the authors are affiliated with the National University of Defense Technology's National Key C4ISR Technology Laboratory in Changsha. Their research was conducted as part of the 973 Program.

[44] Li Wenhua, "Research on Configuring Three-Satellites and Time Difference of Arrival for Precise Geo-Location" [三星构型设计与时差定位精度研究], *Journal of Astronautics* [宇航学报], March 2010, pp. 701-705. The author is affiliated with the Jiangnan Electronic Communication Institute in Jiaxing.

[45] Huang Hanwen, "Maritime Target Surveillance Satellite System Analysis and Development Assumptions" [卫星海洋目标监视系统分析与发展设想], *Journal of the Academy of Equipment Command & Technology* [装备指挥技术学院学报], October 2004, pp. 44-48, at http://d.wanfangdata.com.cn/periodical_zhjsxy200405011.aspx. The author is affiliated with the Shanghai Institute of Satellite Engineering, or SAST 509th Research Institute. Also see Gao Fei, Hu Xujie, Gao Lingyuan, and Liu Xiangmin, "An Analysis on the Influence of Military Satellite Information Systems on Missile Operations" [军事卫星信息系统对导弹作战的影响分析], *National Defense Science and Technology* [国防科技], Vol. 29, No. 4, 2008; Hu Xujie, Liu Zhiyuan, Wang Mo, Sun Yu, and Qiao Tian, An Analysis on the Effectiveness of Space-based Information to Support Missile Offense and Defense Operations" [天基信息支援对导弹攻防作战的效用分析], *Spacecraft Engineering* [航空器工程], Vol. 18, No. 1, 2009; and Huang Xuan, Zeng Jiayou, Zhao Xu Ming, and Niu Liyong, "Graph Modeling Influence of Space-based Information Supporting Aerospace Force Anti-ship Missile Assault" [天基信息支援下航空兵对海导弹攻击的影响图模型], *Tactical Missile Technology* [战术导弹技术], Vol. 2, 2007.

[46] Li Jianjun, "Research on Four-Satellite TDOA Location Algorithm" [四星时差定位算法研究], *Electronic Warfare Technology* [电子对抗技术], July 2004, p. 3. The author is affiliated with the Southwest China Research Institute of Electronic Equipment (29th Research Institute) in Chengdu.

[47] For example see Gao Qian, Guo Fucheng, Wu Jing, Jiang Wenli, "A Correcting Algorithm of Single Source Reference Source for Three-Satellite TDOA Location System" [一种三星时差定位系统的校正算法研究], *Aerospace Electronic Warfare* [航天电子对抗], Vol. 23, No.5, 2007. The authors are affiliated with the National University of Defense Technology. Also see Wu Shilong, Zhao Yongsheng, and Luo Jingqing, "Performance Analysis of Two-Satellite Joint FDOA and TDOA Location System" [双星时差频差联合定位系统性能分析], *Aerospace Shanghai* [上海航空], No. 2, 2007, p. 47. Wu and Zhao are affiliated with GSD Fourth Department 61541 Unit in Beijing, and Luo is affiliated with the PLA Electronic Engineering Institute in Hefei. The 61541 Unit is said to be located in "Space City" [航天城] north of Zhongguancun section of Beijing, appears to serve as an information fusion and R&D center, focusing on phased lock loop (PLL) receiving technology among other issues.

[48] Wei Hewen, Xia Changxiong, and Ye Shangfu, "Dual Satellite Geolocation System Moving Target Acquisition and Simulation" [双星定位系统中目标移动性检测与仿真], *Journal of System Simulation* [系统仿真学报], June 2007. pp. 2543-2546. The authors are affiliated with the University of Electronic Science and Technology in Chengdu and the Southwest Institute of Electronics and Communications Technology in Chengdu. See also Wang Ding, Lin Sichuan, and Li Changsheng, "A Nearly Unbiased Passive Location Algorithm for Two Stations Based on Direction of Arrival and Time Difference of Arrival Measurements" [双站基于角度和时差的近似无偏定位算法], *Radar Science and Technology* [雷达科学与技术], Vol. 6, No. 5, 2008.

[49] Zhen Jun, Zhang Jianhua, Yuan Jiansha, Zhou Tao, and Zhang Dongpo, "Semi-physical Simulation of Integrated Reconnaissance System of Radar and Communications Signals" [雷达与通信信号一体化侦察系统半实物仿真], *Shipboard Electronic Countermeasure* [舰船电子对抗], February, 2010, pp. 56-64. The authors are affiliated with CSIC's Ship System Engineering Department, CETC's 54th Research Institute, and CETC 36th Research Institute, respectively. See also Zeng Hao, Shao Xijun, and Wang Bo "Research on ELINT and Radar Information Networking Methods" [基于电子侦察和雷达组网的信息协同方法研究], *Electronic Engineer* [电子工程师], December, 2008, pp. 1-3. Zeng Hao is affiliated with PLA Unit 92232 in Beijing, and Shao Xijun and Li Changsheng are affiliated with the Nanjing Research Institute of Electronics Technology.

[50] Li Wei, Zhang Gengxin, and Jiang Hongbin, "Naval Ocean Surveillance Satellite" [海洋监视卫星], *Satellite Salon* [星座论坛], June 2007, p. 55. Note Li Wei and Zhang Gengxin are affiliated with the PLA University of Science and Technology's Communications Engineering Academy [解放军理工大学通信工程学院]. Jiang Hongbin is affiliated with the Sino Satellite Company [鑫诺卫星公司], founded by CASC and other state run industries in 1994.

[51] Ibid., p. 57.

[52] Wang Lei, Zhou Qi, and Chen Peiqun, "LEO Electronic Reconnaissance Satellite Ground Station Mission Tasking and Decision-Making Methods" [低轨电子卫星地面站任务调度决策方法], *Communication Countermeasures* [通信对抗], No.1, 2010, pp. 48-49. Note the authors are affiliated with CETC's 36th research institute in Jiaxing. For a Chinese perspective on the current state of the broader ELINT enterprise see Wei Ping, "Architecture for Signal Processing Technology Used in Electronic Reconnaissance [电子侦察中的信号处理方法体系], *Communication Countermeasures* [通信对抗], Vol. 101, No. 2, 2008, pp. 3-7.

[53] Wang Huilin, Huang Wei, Ma Manhao, and Zhu Xiaomin, "Design and Implementation of Area-Covering ELINT Satellite Planning System" [面向区域的电子侦察卫星规划系统设计与实现], *Computer Engineering and Applications* [计算机工程与应用], Vol. 46, No. 26, 2010, pp. 209-213. The authors are affiliated with the National University of Defense Technology's National Key C4ISR Technology Laboratory in Changsha. Their research was conducted as part of the 973 Program.

[54] For reference to the GSD Fourth Department ground stations in Shandong, see Yuan Zuzheng, "Ceng Weihua's Story – The Director's 'Hard Headedness'" ["曾卫华故事集——部长的 '执着面'"], Renminwang, September 21, 2009, at http://military.people.com.cn/GB/8221/71065/169352/169355/10091206.html. Ceng Weihua was former Jinan Military Region Communications Department Director. Other candidates include the GSD Fourth Department 96714 Unit in Beijing and Hainan; 61764 Unit in Hainan, 61276 Unit in Beijing and Hainan, or 61541 Unit in Beijing.

[55] "Haiyang Satellite Ground Station Established in Antarctica" [海洋卫星接收站布局南极], *Space Exploration* [太空探索], No. 1. 2010, p. 12.

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[61] Erickson, April 2010, p. 40.

[62] Guo Nairi [郭乃日], "The Invisible War in the Taiwan Strait" ["看不見的台海戰爭"] (Xizhi, Taiwan: Gaoshou Publishing, 2005), pp. 99-106. See also Zhang Jianguo, "Land Observing Satellite Control System Ground Station Constructed in Kashgar" [陆地观测卫星地面系统喀什站的建设], *Aerospace China* [中国航天], June 2010, p. 15.

[63] Dong Qiaozhong and Zhu Weiqiang, "Research on ELINT Satellite Techniques in GSO" [静止轨道电子侦察卫星技术研究], *Electronic Warfare* [电子对抗], July 30, 2009, p. 13. Note that the authors are affiliated with CASIC's 8511 Research Institute in Nanjing.

[64] Wang Yuanchao, 2006, p. 48.

[65] Mao Cheng, "Design of RF Receiver System for Multi-Mission Payload [多任务载荷中共用接收射频前端设计], *Telecommunications Engineering* [电讯技术], July 2009, p. 68. The author is affiliated with the Southwest China Institute of Electronic Technology in Chengdu.

[66] Xiong, August 2010, p. 22.

[67] Zhou Zhicheng and Qu Guangji, "Nonlinear Finite Element Analysis of Large Mesh Deployable Antenna on Satellite" [星载大型网状天线非线性结构系统有限元分析], *Spacecraft Engineering* [航天器工程], November 2008, pp. 33-34. Note that Zhou Zhicheng is the director of the Institute of Telecommunication Satellite, part of CAST, in Beijing; and Qu Guangji is affiliated with the Beijing Institute of Spacecraft System Engineering. Their study was funded by the Major National Science and Technology Engineering Program for Special Projects.

[68] Lu An'nan, "Thoughts on Developmental Problems of ELINT Satellite Passive Geo-location Techniques" [对电子侦察卫星无源定位技术发展问题的思考], *Communications Countermeasures* [通信对抗], March 2008, pp. 19-20. The author is affiliated with the 36th Research Institute of CETC in Jiaxing, Zhejiang.

[69] For example see: Li Hengnian, Gao Yijun, Xu Peijun, Li Jisheng, and Huang Yongxuan, "The Strategies and Algorithms Study For Multi-GEO Satellites Collocation" [地球静止轨道共位控制策略研究], *Journal of Astronautics* [宇航学报], Vol. 30, No. 3, 2009. Also see Dong Qiaozhong and Zhu Weiqiang, "Study on Electronic Reconnaissance Satellites in Geostationary Orbit" [静止轨道电子侦察卫星技术研究], *Electronic Countermeasures*, June 2009, at http://www.cqvip.com/qk/91679x/200906/32557007.html. The authors are from the China Aerospace Science and Industry Corporation (CASIC) 8511 Research Institute in Nanjing. The 8511 Institute is responsible for missile-borne ECM, and missile defense technical countermeasures.

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[72] For an excellent overview of the rendezvous mission of the SJ-12 and SJ-6E, see Brian Weeden, "Dancing in the Dark: The Orbital Rendezvous of SJ-12 and SJ-06F," *The Space Review*, August 30, 2010, at http://www.thespacereview.com/article/1689/1; and Peter J Brown, "A Secret Rendezvous for China in Space, *Asia Times*, September 21, 2010, at http://www.atimes.com/atimes/China/LI21Ad03.html.

[73] Unconfirmed Western sources assert that China also deployed nose-mounted ELINT payloads on its *Shenzhou* "Divine Vessel" [神舟] missions 1 through 4, as part of its manned orbital module tests launched from November 1999 to December 2002. These platforms each stayed in orbit for as long as eight months with the capability to collect UHF emissions between 300 and 1100 MHZ. See Mark Wade, "Shenzhou – Devine Military Vessel," *Space Daily*, October 2, 2003, at http://www.spacedaily.com/news/china-03zd.html.

[74] Andrew Erickson and Gabe Collins, "China Deploys Worlds First Long-Range, Land Based 'Carrier Killer': DF-21D Anti-Ship Ballistic Missile (ASBM) Reaches 'Initial Operational Capability' (IOC)," *China Sign Post*, December 26, 2010, at http://www.andrewerickson.com/2010/12/china-deploys-world%E2%80%99s-first-long-range-land-based-%E2%80%98carrier-killer%E2%80%99-df-21d-anti-ship-ballistic-missile-asbm-reaches-%E2%80%9Cinitial-operational-capability%E2%80%9D-ioc/#_edn9, accessed December 27, 2010. For an excellent analysis on ASBM testing see Andrew S. Erickson, "China Testing Anti-Ship Ballistic Missile (ASBM); U.S. Preparing Accordingly," December 1, 2010, at http://www.andrewerickson.com/2010/12/china-testing-anti-ship-ballistic-missile-asbm/.

[75] These include sky and sea wave over the horizon (OTH) radars, manned airborne ELINT platforms, ship and submarine-based ELINT platforms, seabed sonar networks, and unmanned aerial vehicles (UAVs). In the future, these could eventually be augmented by near-space platforms such as airships. For details see: Mark A. Stokes and Ian Easton, "Evolving Aerospace Trends in the Asia-Pacific Region: Implications for Stability in the Taiwan Strait and Beyond," *The Project 2049 Institute*, May 27, 2010, at http://project2049.net/documents/aerospace_trends_asia_pacific_region_stokes_easton.pdf. For more on China's UAV programs see Wendell Minnick, "China Developing Armed /Recon UAVs," *C4ISR Journal*, November 24, 2010, at http://www.c4isrjournal.com/story.php?F=5101428.

[76] Chen Xingquan, "Shen Cong: Trial and Hardships on the Road to Space" [沈琮：风云程巡天路], *China Aerospace Science and Technology Corporation (CASIC)*, at http://www.spacechina.com/qywh_htrw_Details.shtml?recno=36670.

[77] China SpaceSat Company appears to serve as a CAST commercial front. See "Shijian-6 Tandem Twin Launch Successful" [实践六号双星发射成功], *China Spacesat Company* [中国东方红卫星股份有限公司], October 8, 2010, at http://www.spacesat.com.cn/newdfh/xwzx/ArticleShow.asp?ArticleID=260. Also see "Foreign Military Observers' Interpretations: China's ELINT Satellite Plans" [外国军事观察家另类解读-中国电子情报卫星计划], November 15, 2004.

[78] "Yaogan series (China), Spacecraft – Defense," *Jane's Space Systems and Industry*, August 18, 2010, at http://www.janes.com/articles/Janes-Space-Systems-and-Industry/Yaogan-series-China.html.

[79] "China's Yaogan-9 may be ocean surveillance satellite," *Jane's Defense Weekly*, March 11, 2010, at http://www.janes.com/articles/Janes-Defence-Weekly-2010/China-s-Yaogan-9-may-be-ocean-surveillance-satellite.html.

[80] For example see: "Yaogan 9A, 9B, 9C," *Gunter's Space Page*, undated, at http://space.skyrocket.de/doc_sdat/yaogan-9.htm; "Yaogan Weixing-9 CZ-4C launch March 5, 2010," *NASA Spaceflight.com*, March 5, 2010, at http://forum.nasaspaceflight.com/index.php?topic=20567.30, accessed December 9, 2010; and Robert Christy, "Space Events of 2010," *Zarya*, undated, at http://www.zarya.info/Diaries/2010.php.

[81] "Yaogan Weixing 9," *Jonathan's Space Report*, No. 625, April 6, 2010, at http://planet4589.org/space/jsr/back/news.625.

[82] "Warm Celebrations: 'Yaogan-9' Successfully Launched" [热烈庆祝："遥感九号"成功发射], China Spacesat Company [中国东方红卫星股份有限公司], March 9, 2010, at http://www.spacesat.com.cn/newdfh/xwzx/ArticleShow.asp?ArticleID=240.

[83] Li Guanjiao et al., "Open Doors to Success: Behind the Yaogan-9 Satellite Launch Success" [叩开成功之门—遥感卫星九号发射见闻], *China Space News*, March 10, 2010, at http://www.china-spacenews.com/n435777/n435778/n435783/66907.html.

[84] Li Yandong is a three-time National Defense Science Progress Award recipient, and has received awards from COSTIND and the State Council, amongst others. See: Xing Wen, "Li Yandong: Overcoming Difficulties and Dreams of Small Satellites" [李延东 攻坚克难 逐梦小卫星], *China Aerospace Science and Technology Corporation* (CASC), October 29, 2010, at http://www.spacechina.com/zt_chxzy/dyfc_Details.shtml?recno=71056, accessed December 9, 2010. See also: "Li Yandong" [李延东], *Xinhua*, October 10, 2007, at http://www.gs.xinhuanet.com/jdwt/2007-10/10/content_11364907.htm.

[85] Zi Mo (ed.), "A Conversation with the Shanghai Aerospace Bureau's Zhu Hongchang, Chief Director of the Yaogan-3" [对话上海航天局遥感卫星三号总指挥朱鸿昌], Changsanjiao City Net, September 9, 2009, at http://www.cncsj.net/a/2009/9/9/content_68714.html. Note that along with earlier ELINT satellites in the mid-1970s, Zhu Hongchang was also intimately involved in the Fengyun-2 meteorological satellite in GEO, the CBIRS "Resource Satellite-1" remote sensing satellite program, and the DFH-3 Communications Satellite in GEO.

[86] You Benfeng, "Wei Zhongquan: A Lifetime Infatuated with Satellites"[魏钟铨一生痴情伴卫星], *CASC News*, November 17, 2009, at http://www.spacechina.com/qywh_htrw_details.shtml?recno=57787, accessed January 27, 2011. Note that like Zhu Hongchang, Wei Zhongquan was intimately involved in the early ELINT satellites in the mid-1970s, as well as the Fengyun-2 program.

[87] This assertion stems from his winning of the National 863 Breakthrough Award the year the SJ-6A/B program was established, his winning of the Shanghai Model Worker award in 2004 (the year the SJ-6A/B satellites were launched), prominent gaps in his professional portfolio around the time of the program, and the mystery surrounding the origins of the awards.

[88] You, November 17, 2009; and Zi Mo (ed.), "A Conversation with the Shanghai Aerospace Bureau's Zhu Hongchang, Chief Director of the Yaogan-3" [对话上海航天局遥感卫星三号总指挥朱鸿昌], September 9, 2009.

[89] "Brief Company Introduction" [公司简介], *China Spacesat Company* [中国东方红卫星股份有限公司], undated, at http://www.spacesat.com.cn/newdfh/Article/Index.asp, accessed December 9, 2010.

[90] Gong Fang, "China Spacesat Company's First Research Visit to our Experimental Lab" [航天东方红卫星有限公司等一行来我实验室调研], *State Key Laboratory of Satellite Ocean Environment Dynamics* (SOED), July 13, 2007, at http://www.soed.org.cn/news_show.asp?id=720.

[91] Stephen Clark, "Military Reconnaissance Satellite Launched by China," *Spaceflight Now*, March 5, 2010, http://spaceflightnow.com/news/n1003/05longmarch/index.html.

[92] Li, et al., June 2007, p. 56.

[93] "Unnamed GAD Base Makes Breakthrough: Controls Two or More Satellites Simultaneously" [总装某基地破难题 同时对两颗以上卫星实时测控], *Huanqiu*, March 18, 2010, at http://mil.huanqiu.com/china/2010-03/749024.html.

[94] Ibid.

[95] Ibid.

[96] Note that the Yaogan-9 was one of only two Chinese satellite launches that had taken place in 2010 at the time of article's writing, and the other, a *Beidou*-2/*Compass* series navigation satellite, is referred to by name in the article.

[97] See Pan, et al., 2006. See also Gao Fei, et al., 2008; Hu Xujie, et al., 2009; and Huang Xuan, at al., 2007.

[98] Xiong, 2010, p. 19.

[99] Matthew Luce, "China Eyes 'Dual Use' Applications for its Supercomputers," *China Brief*, November 19, 2010, at http://www.jamestown.org/programs/chinabrief/single/?tx_ttnews[tt_news]=37195&tx_ttnews[backPid]=414&no_cache=1.

[100] Jan van Tol, Mark Gunzinger, Andrew Krepinevich &Jim Thomas, *Air-Sea Battle: A Point of Departure Operational Concept* (Washington D.C.: Center for Strategic and Budgetary Studies, 2010), p. 58.

[101] Yao Yuesong and Guo Fengyu, "An Analysis on Electronic Reconnaissance Satellites' Methods of Countering Electronic Interference" [电子侦察卫星反电子干扰措施分析], *Aerospace Electronics Technology* [空间电子技术], No. 4, 2010. The authors are from the 61541 Unit Information Receiving Office in Beijing; and Yao Yuesong, "Analyzing Effectiveness of Satellite Reconnaissance Under Conditions of Complicated Electromagnetic Interference" [卫星侦察在复杂电磁环境下的感知效果影响分析], *Spacecraft Environment Engineering* [航天器环境工程], August 2010, 444-446. See also: Chen Zhiqiu, Zhang Bo, Jiang Hong, and Wang Bing, "Modeling and Simulation of 'Hard Kill' Attack in Aerospace Electronic Warfare" [航天电子对抗"硬杀伤"建模与仿真], *Electronic Warfare* [电子对抗], Vol. 127, No. 4, 2009, pp. 29-33; Huang Hanwen, "Design of Satellite Electronic/Information Countermeasure System" [卫星电子/信息对抗系统设想], *Aerospace Electronic Warfare* [航天电子对抗], Vol. 21, No. 4, 2005, pp. 41-43. Huang is from the Shanghai 509th Research Institute. Also see Yang Ming and Yuan Bin, "Analysis on Infrared Radiation from Space Solar Cell Arrays of Satellite" [卫星太阳电池帆板的红外辐射分析], *Electronic Warfare* [电子对抗], Vol. 133, No. 4, 2010, pp. 37-40.

[102] See Zhao and Zheng, 2008; and Wang and Xiong, 2008, pp. 71-75.