Development and Insights from the USSF Satellite Equipment for Space Objective Surveillance

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Abstract: The USSF attaches great importance to the research and development and acquisition of satellite equipment, especially in the area of space objective surveillance, to provide critical support for its control of other nations' space activities, real-time assessment of space security threats, space countermeasures, and the pursuit of space control. This paper provides an overview of the USSF' extensive surveillance network in terms of the next generation of the “Next Generation Overhead Persistent Infrared” (OPIR) satellite system, the continuing development of the SBSS, and the ongoing refinement of the SBIRS. It also systematically describes the characteristics of the USSF' satellite equipment space objective surveillance development from the aspects of space surveillance system technology focusing on integration and construction, more lethal GSSAP, and emphasis on missile tracking, and proposes inspirations for our military space objective surveillance.

1. Introduction

With the establishment of the USSF, the ambitions of the United States in the field of space are fully demonstrated. The purpose of this paper is to study the important deployment, development program, and various data of the satellite equipment of the USSF in recent years, and summarize the key development construction of the USSF satellite equipment to inspire our country in space objective surveillance.

2. Characteristics of USSF Satellite Equipment Space Objective Surveillance Development

Space objective surveillance is a necessary condition to seize the advantage of space confrontation, and only with a strong space objective surveillance capability can we ensure the effective development of subsequent space offensive and defensive operations. Space objective surveillance is an important basis for monitoring space equipment, space operations and space debris of other countries, and thus realizing space situational awareness, and its capability level is directly related to space confrontation ability.

Satellite equipment has gradually risen from a supporting position to an important new combat domain in military strategy. Since the establishment of the USSF, the integration of satellite equipment, to improve the organizational structure, the realization of inter-service joint as the main breakthrough, and the more obvious actual combat characteristics, are accelerating the integration of space forces into the conventional services modernization and transformation process, and accelerating the construction of space military forces with a distinctive combat-oriented.

In the area of space objective surveillance, the USSF attaches great importance to the research and development and procurement of its satellite equipment to provide key support for its control of other countries' space activities, real-time assessment of space security threats, attempted space confrontation, and seeking to control space.

2.1. Extension of a Large Space-Based Surveillance Network

The USSF has established a global and comprehensive surveillance system for space objective surveillance, and is continuously upgrading it to accomplish the goal of an all-orbit space objective surveillance system. These space-based surveillance systems are geographically unrestricted,

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operate in all-weather motion, provide wide coverage surveillance, and have the strong ability to detect and track tiny aerial objective in deep space.

According to the latest statistics in 2022, the USSF have 79 satellites in service (Table 1) [1]. It can be seen that the USSF weaves a space-based surveillance network in a comprehensive, high-density, and wide-ranging manner.

Table 1 Major USSF satellites in service over the years

System Model	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Advanced Extremely High Frequency Satellite	1	2	2	3	3	3	3	4	5	5	5	6
Advanced Technology Risk Reduction Satellite	0	1	1	0	0	0	1	1	1	1	1	1
Defense Meteorological Satellite	6	4	4	6	6	6	5	5	4	4	4	4
Defensive satellite Communication System	8	8	8	7	6	6	6	6	6	6	6	6
Global Positioning System	34	30	31	38	41	37	35	31	29	31	31	32
Geosynchronous Orbit Space Situational Aware Programming Satellite	0	0	0	2	2	4	4	4	4	4	4	6
"Military Satellite"	5	5	5	5	5	5	5	5	5	4	4	5
Space Rapid Response Operations-5(ORS-5) Satellite									1	1	1	1
Space-based Infrared System Satellite	1	1	2	2	2	2	3	7	6	6	6	7
Space-based Surveillance System Satellite	1	1	1	1	1	1	1	2	1	1	1	1
Broadband Global Communications Satellite		3	3	4	6	7	7	9	10	10	10	10
Total Satellites	59	55	58	70	73	71	72	77	77	73	73	79

2.1.1. The focus of Next-generation "next generation overhead persistent infrared" OPIR satellite system development

To objective future space operations in response to emerging and expected threats, the USSF has proposed the "next generation overhead persistent infrared, NG-OPIR" warning satellite program, which effectively reduces the operational objective value of missile warning satellites through the use of "mature satellite platforms + focused sensor technology" to achieve a higher probability of survival.

OPIR consists of space-based sensors and ground-based data processing stations that work in a cooperative network to continuously or nearly continuously collect visible, near-infrared, short-wave infrared, and mid-wave infrared energy from space and process it to produce infrared images to support missions in the areas of missile warning, missile defense, technical intelligence, and battlefield space awareness [2]. In 2021, Lockheed Martin Space Systems Company was awarded a USD 4.9 billion OPIR program change contract to support the manufacturing, assembly, integration, testing and delivery of the system's first three satellites, as well as the equipping of ground facilities. OPIR is the successor to the U.S. space-based infrared system, with the first satellites expected to be launched in FY 2025. OPIR will eventually include Lockheed's three GEO satellites, as well as two polar-orbiting satellites as part of Block 0. Under the contract, the first phase of development will be completed by the end of 2025, with the first satellite delivered in FY 2027 and all five initial satellites will be ready in 2029. The system will eventually replace the

space-based infrared system, also produced by Lockheed. "Next generation overhead persistent infrared" (OPIR) warning satellite is the successor to the Space-Based Infrared System (SBIRS) and will extend the range of the original SBIRS [3].

2.1.2. Continued development of space-based space surveillance systems

The "Space-Based Space Surveillance System (SBSS) satellite is designed to track, characterize, measure and collect optical signatures of Earth-orbiting objectives, including space vehicles and debris. The Missile Defense Agency initially launched the SBSS satellite as a technology demonstrator to classify and track in-flight ballistic missiles before transferring it to the Air Force Space Command in 2011. The "Space-Based Space Surveillance System" satellite uses primarily gyroscopic ground control and space-based visible light sensors to track objectives without repositioning. Sensing potential high-end and persistent dynamic space threats from China and Russia, the USSF has pushed orbital domain awareness to the top of the Air Force Space Command's priority list. Air Force Space Command is committed to extending the life of the Space-based Space Surveillance System satellites and having one of the experimental combat response space satellites fill a four-year coverage gap until the newly established Space Force can launch the follow-on spacecraft in 2022. The Combat Response Space-5 satellite was launched on August 26, 2017, and is equipped with optical sensors that allow for rapid and continuous scanning to detect movement in geosynchronous orbit. The Space-Based Space Surveillance System satellites work in concert with a range of networked land-based sensors, including the "Space Fence" wide-area search and surveillance system being built at Kwajalein in the Marshall Islands. Beginning in 2020, SSAS collision warning data was made available to the public with the goal of increasing domain awareness and orbital safety.

2.1.3. Refinement of the "Space-Based Infrared System" (SBIRS)

The "Space-Based Infrared System" (SBIRS) satellites provide advanced space surveillance and missile warning, battlefield spatial characterization and technical intelligence collection. This is the successor to the DSP satellites. The system includes an infrared sensor payload on the main Highly Elliptical Orbit (HEO) satellite, two infrared sensors on the dedicated Geosynchronous Orbit (GEO) satellite, and ground-based equipment. The HEO sensor detects submarine-launched ballistic missile (SLBM) launches from the Arctic and can perform other infrared detection missions. The GEO scan infrared sensor performs the initial phases of strategic missile warning missions, global technical intelligence, and strategic missile defense missions, providing two times the revisit rate and three times the sensitivity of the DSP satellites. The GEO-3 satellite was launched into orbit on January 20, 2017. The GEO-4 satellite was launched into orbit on January 19, 2018. GEO-5 and GEO-6 satellites will be based on modernized spacecraft and was launched in 2021 and 2022, respectively. These satellites will replace the two oldest satellites in orbit and are intended to consolidate control of multiple satellite systems. USSF Operations Command also awarded Raytheon Company a USD 197 million contract in 2020 for ground data processing modernization. USSF cancelled the contract for the last two GEO satellites and shifted the funds to develop the next generation OPIR system [4].

On May 18, 2021, the fifth SBIRS GEO satellite (GEO-5) was successfully launched from Cape Canaveral, and according to related information, GEO-6 has been sent into space in the first half of June 2022 [1]. As the last satellite to join the SBIRS constellation, the launch of GEO-6 marks the successful completion of the SBIRS development program.

2.2. The Special Attention to Integrated Construction on Space Surveillance System Technology

The U.S. space objective surveillance system, whose construction principle is unified programming and system advancement, the entire construction is completed in accordance with the division of labor and reasonable coordination. In the form of tasks to complete the corresponding collaborative use, implement the effective processing of data, and distribute uniformly. For organizational management, the U.S. further completes the jurisdictional division of each

department in the surveillance equipment system. For business management, in the relevant surveillance system, after completing the corresponding objective surveillance data, it shall be transferred to the space surveillance center in time to realize centralized processing.

To meet the rapidly changing challenges of battlefield space situational awareness, SBIRS team proposed a modular, hierarchical and adaptive OPIR system ground application development framework to support multi-mission and multi-sensor battlefield situational awareness missions based on open system architecture (OSA) in 2016. On January 28, 2020, Raytheon Company was awarded a five-year, USD 197 million contract by the USSF to design the OPIR ground data processing system, a project known as the “future operationally resilient ground evolution (FORGE) program”, it replaces the SBIRS ground data processing system and is scheduled to be operational in FY 2024. FORGE is an open architecture that is scalable, extensible, and flexible, allowing for the development of specific applications based on the platform whose primary mission is to provide missile warnings to the Pentagon and national command agencies, and to support civilian application development.

The SBIRS team believes that the mission domain of OPIR is expanding; the expansive demand for OPIR data and the dynamic nature of the battlefield space situational awareness mission are driving significant changes to the ground processing system. Under the traditional framework, specific interfaces need to be designed between different components, developed, tested, and then integrated into the larger system; whereas the OSA framework uses an open, standard unified programming interface that does not require the development of component-specific interfaces and has portability and tailor ability characteristics that can facilitate rapid deployment of new operations. The OSA-based framework not only enhances missile defense and early warning, but also enables rapid response to changes in operational requirements and allows efficient deployment of operational systems for data processing.

2.3. Further Improvement of Geosynchronous Space Situational Awareness Program (GSSAP)

The "Geosynchronous Space Situational Awareness Program" is a constellation of high-orbiting space objective surveillance satellites developed by the U.S. Army to perform geosynchronous orbit objective patrol reconnaissance missions with high precision orbital maneuvering capabilities, enabling rendezvous and docking, close accompanying flight, close observation of objectives, and precise positioning and tracking of geosynchronous orbit objectives.

GSSAP satellites are deployed in drifting orbits above and below the GEO orbit, and are capable of reviewing communications and surveillance satellites, etc. GSSAP satellites operate in pairs, one slightly above and one slightly below the GEO orbit; GSSAP satellites have the distinct advantage of reviewing resided space objectives (RSOs) at this orbital position, and are not subject to weather and atmospheric aberrations as the limitations of ground-based systems. In addition, GSSAP satellites are capable of performing RPO. RPO enables satellites to maneuver to the vicinity of the "objective of interest" and reportedly reach a position 10 km from the objective. GSSAP satellite approaches the objective satellite when it is in the Earth's shadow, so that GSSAP activity is not visible through ground-based telescopes. GSSAP can characterize space objectives to a very fine level, and GSSAP data can be used for accurate and timely orbit prediction, enhance understanding of the GEO orbital environment, and further realize spaceflight safety, including satellite collision avoidance.

Two new satellites launched by the USSF have unveiled a mysterious U.S. program to monitor other countries' satellites in orbit, according to the latest information [4]. The two satellites, built by Northrop Grumman, will expand the USSF’ capability for geosynchronous space situational awareness and improve the accuracy of tracking other satellites in orbit.

The two situational awareness program satellites launched by U.S. in 2022 can also be seen in Table 1 above. GSSAP is part of the "Orbital Warfare" program, which is used to destroy satellites that U.S. considers dangerous to others. GSSAP satellites can not only conduct surveillance activities to track the activities of other spacecraft and hazardous junk in geosynchronous orbit, but

can also approach enemy satellites and assess their functions, according to USSF commander John Raymond. GSSAP is part of the "Orbital Warfare" program, is used for the mission that destroys satellites of other nations that U.S. considers dangerous "to protect U.S. space assets and deter threats from space enemies. Russian experts point out that GSSAP 5 and GSSAP 6 have a variety of weapons, including radio jamming, laser blinding and cyber-attacks, and that this is a commercial satellite, so even if an attack is launched on another country's satellite, U.S. can say it is a commercial operation [5].

2.4. Emphasis on Missile Tracking

According to the U.S. financial budget of 2023, the USSF highlights significant investments in missile warning and tracking and the service desires to make data transmission and space-based intelligence, surveillance and reconnaissance a major part of its 2024 requirements, with the U.S. Department of the Air Force releasing a detailed "J-book" document at the week of April 18, 2022 [6]. It requests USD 24.5 billion for Space Force, an increase of USD 6.5 billion over the USD 18 billion set by Congress for FY 2022. The USD 24.5 billion for Space Force occupies 12.6% of the U.S. Department of the Air Force's USD 194 billion requests for 2023 [7].

USD 4.5 billion of the increase in Space Force will be for research, development, test and evaluation, including USD 1 billion for new programs in resilient missile warning and missile tracking [8].

Under Air Force Secretary Frank Kendall's first "order of battle" - defining "the resilient and effective operational order and architecture for space" - the Department of Defense requests USD 1 billion in new program tracking for "the resilient missile warning missiles. This includes funding for a low Earth orbit "tracking layer" of the Defense Space Architecture already bid by the Space Development Agency; and for another "layer" of missile warning and tracking in medium earth orbit.

In the USD 1 billion for resilient missile warning and missile tracking in FY 2023, USD 499.8 billion is for a tracking layer in low earth orbit, or LEO [8]. Kendall spoke about the programs in April during a speech at a space symposium in Colorado Springs, saying the new programs would "be able to track objects like China's hypersonic weapons systems or potential Chinese orbital bombing systems." [9]

3. Inspiration for Our Space Objective Surveillance

3.1. Satellite Construction Emphasizes Data Fusion and Information Sharing

Take the U.S. space objective surveillance system as an example; its construction principle is unified programming and system advancement. The entire construction is completed in accordance with the division of labor and reasonable coordination. In the form of tasks to complete the corresponding collaborative use, implement the effective processing of data, and distribute uniformly. For organizational management, the U.S. further completes the jurisdictional division of each department in the surveillance equipment system. For business management, it completes the corresponding objective surveillance data in the relevant surveillance system.

In addition to using space surveillance systems to collect data, the U.S. military also focuses on traditional intelligence resource means to obtain information on the characteristics, capabilities, and intentions of other countries' satellites, and achieve a large fusion of space situational awareness data based on specialized multi-source data fusion processes, algorithms, and systems [10].

In addition, emphasis is placed on the integration of space situational awareness and missile warning capabilities for application. Missile warning and space situational awareness have many commonalities, so the U.S. military actively uses the capabilities of missile warning systems to compensate for the lack of space situational awareness capabilities.

3.2. Develop a Resilient Space-Based Warning System

Through the study of the "Next generation overhead persistent infrared" warning satellite, for the

future development and planning of China's missile warning satellites, first, we must build a resilient and decentralized space architecture, adopt a combination of high and low orbit deployment, deploy large satellites in GEO and HEO high orbit, and make full use of commercial satellites in low orbit. Second, focus on the development of search and tracking integrated large planar array payload technology, research on high-performance processing algorithms for wide-field mission data, build high-quality, scalable objective infrared image data sets, improve the timeliness of on-satellite data processing under strong confrontation conditions, achieve discovery that is tracking, and respond to new threats; Finally, in order to enhance the wartime survival capability of high-orbiting warning satellites, we shall actively develop satellite near-field sensing and maneuver avoidance. In short, when building a warning system, we shall focus on specific needs and try to build a space-based warning system that takes into account strategic and tactical requirements and focuses on tactical applications.

3.3. Accelerate Research on Spatial Situational Awareness Capabilities

Space situational awareness is an important means of implementing space deterrence and a prerequisite and foundation for implementing space offensive and defensive confrontation. The possession of high-level and subversive space situational awareness capabilities is of great strategic importance for seizing the right to control the sky and the right to control information, and is one of the important signs of a strong military power. The U.S. has the most advanced situational awareness system in the world, which has been developed over the years and is now capable of accomplishing many missions based on it. In addition, it also gives full play to the advantages of "civil-military integration" and combines with commercial satellites, construct the civil-military integration construction pattern with the U.S. military and intelligence community as the main construction force and complementing by other civilian, commercial and foreign agencies [5]. China should continuously strengthen the research and construction of space situational awareness technology, and pay close attention to the hot technologies of future space situational awareness system development such as big data technology, artificial intelligence, and multi-source data integration processing.

3.4. Space Threat Detection and Alerting Technologies are Hot Spots for Development

Overall, the space threat detection and warning tools being developed by the U.S. military include: first, the use of space objective surveillance systems to determine objectives that may pose a threat to space systems and form threat forecasts. This requires a range of powerful ground-based and space-based surveillance equipment to provide comprehensive surveillance of all space objectives (including debris). Second, the use of satellite itself that equipped with detection equipment to realize the sensing of enemy RF, infrared, and laser interference, forming threat forecasts and issuing warning messages. This requires the satellite system itself to have the ability to monitor space objectives to detect and identify threats. Third, the comprehensive use of space objective surveillance system and the detection equipment equipped by the satellite itself, through the comprehensive monitoring and identification classification of all space objectives and the sensing of enemy RF, infrared, laser interference situation to analyze and determine objectives that may pose threats to space systems and form complete threat warning and issue alert messages. Its characteristic is to realize the integration processing of multi-source information to form a complete threat forecast.

4. Conclusion

The space "high frontier" competition is becoming more and more intense, the USSF since its establishment, has accelerated the construction and development of the space domain, and has gradually brought many hidden dangers to the international security situation. In the development of the space domain, space objective surveillance is the foundation, and only by mastering the initiative of space objective surveillance can other operations be carried out. Therefore, vigorously developing of our space objective surveillance technology is an important direction for future space

construction and one of the important factors for protecting our security.

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