162-175

SPACE BASED ELINT - A CHINESE CASE STUDY: MEASURES TO DEVELOP CAPABILITIES IN INDIAN CONTEXT

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"The doctrinal imperative to gain the higher ground for tactical advantage, in the military domain, has manifested in us seeking capabilities in air and now in space, and utilisation of space-based assets has revolutionised warfare by enhancing our capacities in intelligence gathering, surveillance and reconnaissance, communications, early warning, weather forecasting and navigation."

Chief of the Air Staff
Air Chief Marshal VR Chaudhari
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Abstract

Significance of ELINT in modern multi domain operations (MDOs) cannot be overemphasised. Surveillance of Electromagnetic Spectrum (EMS) is vital to gain advantage in symmetric, asymmetric and hybrid conflicts. It is accorded highest priority during peacetime operations. Knowledge of adversaries of EMS is vital for Indian armed forces. ELINT systems provide the armed forces with effective means to intercept, classify and localise any type of air and surface RF emitters. Indian armed forces have a robust ELINT collection mechanism from ground-based sensors and a few airborne platforms; however, the intervening ground/ obstructions and limited line of sight issues constitutes a great drawback. Space based ELINT gathering

by virtue of its elevated character overcomes these limitations. This article explores the way ahead for development of Space based ELINT system for Indian armed forces using a real world case study of the Yaogan satellite constellation of the Chinese People's Liberation Army Strategic Support Force (PLA SSF).

INTRODUCTION

China has been steadily ascending as a global space power, it is now a full-fledged space power in all respects and is ready to compete with any nation across the spectrum of space capabilities. Space power seems to be critical component of its aspiration to emerge as a global power at the regional and global level.

China has been leaping forward in enhancing its space capabilities. Last year alone it undertook 67 orbital launches, including 17 by its private entities, thereby putting more than 200 satellites in various orbits. Prior to that, it has undertaken 64 launches in 2022, 54 in 2021 and 45 in 2020, despite the Covid pandemic. At the global level, space activities have increased, there are more than 5200 active satellites today, owned by 80 countries, in 2023 itself, some 675 satellites were launched.

Chinese President Xi Jinping in his 20th Party Congress address in October 2022 emphasised the need to enhance the space infrastructure as a critical component to Chinese Communist Party's legitimacy to power.[1] Enhancing situational awareness about adversary's disposition of assets, especially mobile assets, constitutes a significant component of this capability. Having a set of reliable ISR, EO and SAR constellation of satellites is one of the most reliable asset in providing near real time situational awareness about the adversary.

Of the launches by China in 2023, 9 launches specifically augmented China's reconnaissance and strike capabilities, these included, Yaogan 37 on January 13; Yaogan 41 (YG 41)[2] a geostationary SIGINT satellite on December 15 and a set of seven triads between July and October last year.

This paper characterises the development of Space based ELINT system for Indian armed forces using a real world case study of the Yaogan satellite constellation of the Chinese PLA SSF (People's Liberation Army Strategic Support Force).

ELINT: AN IMPORTANT ARM OF WAR FIGHTING

Electronic Warfare (EW) has tremendous importance in modern multi domain operations (MDOs). In all the phases of a multi domain operations, EW encompasses military actions involving the use of electromagnetic (EM) energy to determine, exploit, reduce or prevent hostile use of EM spectrum and the actions, which retain friendly use of the EM spectrum.

ELINT gathering is of prime importance for all competing forces. Surveillance of Electromagnetic Spectrum (EMS) is vital to gain advantage in symmetric, asymmetric and hybrid conflicts. It is accorded highest priority during peacetime operations.

ELINT relies on the passive detection of emissions from radar systems (RF Emitters) and can be used to classify as well as geolocate radar systems operated by an adversary. ELINT is responsible for supplying intelligence and threat recognition.

The objective of ELINT, is to achieve high sensitivity & direction finding (DF) accuracy with accurate RF emitter parameters with an ultimate aim to create EW threat databases that are used to update the Electronic Order of Battle (EOB) which is concerned with location updates, movements and the readiness status of adversary emitters.

ELINT provides radar operating parameters, waveform details, geo-location and other pertinent information. ELINT involves in-depth signal analysis of RF emitters, accurate characterisation, analysis and tracking by employing sophisticated software tools for RF pulse and most importantly the intra pulse detailed analyses. An efficient ELINT system is required to have a capability to detect and measure the angle of arrival (AOA) of any RF emitter. Systems employ obtain geo-location of emitters by triangulation algorithms.

ELINT undertakes accurate measurement and analysis of parameters of RF emitters and powerful correlation with known-emitters reference database.

Database storage is a repository of all detected waveforms and elaborated information, accurately time stamped. Integration and assessment of the acquired data to generate the Electronic Order of Battle (EOB) of friendly and hostile radar emitters is another significant facet of ELINT.

During peacetime, the quest for knowing enemy's EOB is high on priority so that during hostilities, own forces are able to decipher the electronic signatures and exploit the EMS to the best advantage.

ELINT Requirements for Indian Armed Forces

Knowledge of adversary's of EMS is vital for Indian armed forces to gain advantage in a symmetric, asymmetric or hybrid conflicts. ESM and ELINT systems provide the armed forces with effective means to intercept, classify and localise any type of air and surface RF emitters. Normally, frequency coverage is 0.5 to 18 GHz, where most of radars work is considered essential, with an additional option of keeping tab on extremely high frequency radars, like the air defence tracking radars of up to 40 GHz.

ELINT Collection Mechanism

Indian armed forces have a robust ELINT collection mechanism from ground based sensors. Besides, all three armed forces are also employing certain drones and airborne platforms to acquire ELINT through an elevated observation concept.

Ground Based ELINT System (GBES) are required for fulfilling strategic EW requirements. GBES comprises of a Control Station and a triad of three Receiving Stations integrated to search, detection, monitor, record and process the hostile emissions as well as to find the location of the emitter.

Ground based ELINT systems work on the principle of line of sight wherein the intervening ground/ obstructions constitutes a great drawback. Such systems do not meet the operationally essential requirement of covering

larger areas and perseverance over time. India faces threat on western and northern front, at the same time modern day threat environment is fast evolving with most of the RF emitters becoming highly mobile and versatile in modifying its RF parameters as part of its ECM features. The EM spectrum too is getting highly contested. In such an operational scenario, a ground based ELINT system suffers from the drawback of lack of persistent coverage, limited to a small area. Space based ELINT gathering by virtue of its elevated character overcomes these limitations.

ELINT gathering process within the armed forces is essentially being carried by Electronic Warfare (EW) units/sub-units and Wireless Experimental Units (WEU) of the three services. The effort is supplemented by agencies under the Cabinet Secretariat such as National Technical Research Organisation (NTRO) and Aviation Research Cell (ARC).[3] Integral UAV/ drones and airborne platforms further supplement these efforts. While the overall ELINT gathering and dissemination can be made more efficient by synergising efforts of all these organisations at the national level, the limitations of line of sight, ground obstructions, persistence coverage and limited area can be overcome by employing space based mechanisms.

ELINT THROUGH SPACE: TECHNICAL FEASIBILITY

In view of evolving EM spectrum threat of modern days, Indian armed forces need to upgrade to ELINT gathering from space to be able to exploit the knowledge of EOBs in a dynamic tactical and strategic battle ground for its armed forces. Space based ELINT offers unique advantages and is a great game changer.

Space based ELINT gathering has its own sets of challenges like housing the antennas in the space craft, especially wide frequency band needs different types of antennas of varying shapes and sizes. Other issues like fast moving spacecrafts, of approximately 7 to 9 kms per second, gathering RF emissions from LEO (typically from approximately 400 to 600 kms) comes with its own sets of challenges of gathering enormous amount of data in each millisecond, of multiple radar characteristics, RF sensors requiring highly

sensitive antennas, limited field of view available for signal gathering due typical beam patterns of RF emitters and reduced radar horizon for gathering emissions. Added to all this is the challenge of expeditiously analysing data and passing the information to ground station.

Newer problems and challenging operational environment demand technologically sound solutions. Indian space sector is evolving, new private space companies are emerging. Consequent to space sector reforms in 2020, the whole of the Indian space ecosystem is highly catalysed. The challenge of gathering ELINT from space can be technically addressed. The same is discussed later in the paper.

PLA'S SPACE BASED ELINT CAPABILITIES: A CASE STUDY

China has been launching its electronic surveillance satellite under the Yaogan series- a combined military surveillance constellation of electro-optical (EO), imagery intelligence (IMINT), synthetic aperture radar (SAR) and electromagnetic intelligence (ELINT) satellites.

Yaogan constellation is essentially intended to enhance China's anti-access and anti-denial (A2AD) capabilities. Today, China is involved in conflicts with a number of nations, including Taiwan, Philippines, India and most importantly, with the US in the South China Sea (SCS). China feels that it needs to keep its vast neighbourhood under continuous surveillance, to be able to locate, identify and reliably track the US Aircraft Carrier Groups in the Western Pacific, before it comes consequently close to be able to threaten its own freedom of operation in its area of interest.[4]

Electronic Intelligence (ELINT) satellites pick up the electronic emissions from the RF Emitters from ground or Aircraft Carrier Group in the Ocean with a relatively coarser spatial resolution; thereafter, Synthetic Aperture Radar (SAR) satellites are cued by the ELINT satellites inputs once an object of interest has been spotted; and Electro Optical (EO) satellites that are cued to identify and locate the RF Emitter to accurately identify, locate and track an RF emitter on the ground or an Aircraft Carrier Group (ACG) on the high seas.[5]

Yaogan-class satellites are used for military intelligence purposes and are controlled by the Strategic Support Force of the Chinese People's Liberation Army (PLA SSF), which is responsible for space, cyberspace, and electronic warfare. PLA SSF came into being on 31 December 2015.

To keep the entire area of interest (for China, its concern would be the western Pacific Ocean) under surveillance the constellation will need three kinds of satellites: Electronic Intelligence (ELINT) satellites that pick up the electronic emissions from the Aircraft Carrier Group and locate it in the Ocean with a relatively coarser spatial resolution; Synthetic Aperture Radar carrying satellites that are cued by the ELINT satellites or by other satellites in the constellation that have located the object of interest; and Electro-optical satellites that are cued by the ELINT satellites or by other satellites in the constellation that had located the aircraft carrier earlier.[6]

China operated 136 reconnaissance satellites in 2022, as compared to 66 in 2019. According to the Military Balance report published by the London based International Institute for Strategic Studies, China has significantly increased its reconnaissance satellite capabilities. Additionally, China is expanding its fleet of electronic intelligence (ELINT) and signals intelligence (SIGINT) satellites, which are capable of intercepting electronic information.[7]

China embarked upon its Yaogan project with the launch of its first military EO satellite (Yaogan-1 from Taiyuan Satellite Launch Centre) on April 26, 2006 in a sun synchronous orbit with 97° inclination. Yaogan means "remote sensing" in Chinese. With the launch of Yaogan-9, an ELINT triad, on March 05, 2010 from Jiuquan Satellite launch Centre (JSLC),[8] the constellation became fully operational in 2010. Yaogan-9 had all three satellites 120° apart, in the same plane of 63° inclination to the equator. China further kept adding a few more EO and SAR satellite under the Yaogan-series name.

A detailed study of the architecture of ELINT, EO and SAR satellites deployed by the PLA forces over the past 17 years brings out certain significant aspects, important for Indian space agencies to draw lessons and craft our own ELINT satellite deployment plans.[9]

Yaogan constellation scan a large area over land and sea by acquiring electromagnetic signatures of various RF emitters, leading to optical acquisition by EO or SAR satellites, thereby ascertaining their precise location. This methodology or template is termed as tipping and cueing model, simply put, tipping about the presence of an RF emitter is made available by space based ELINT and the same is ascertained to a high degree of geo-location accuracy through an EO/SAR satellite. Thereafter, if required the RF emitter and its associated assets can be targeted through a proper targeting cycle at a time and weapon of its choosing.

Yaogan constellation scan a large area over land and sea by acquiring electromagnetic signatures of various RF emitters, followed by optical imaging by EO or radar imaging by SAR satellites, thereby ascertaining the precise location of source of RF emitter. This methodology or template is termed as tipping and cueing model, simply put, tipping about the presence of an RF emitter is made available by space based ELINT and the same is ascertained to a high degree of geo-location accuracy through an EO/SAR satellite. Thereafter, if required the RF emitter and its associated assets can be targeted through a proper targeting cycle at a time and weapon of choosing.

In order to shorten the OODA loop, China has strengthened the Yaogan constellation by adding more ELINT triad satellites, coupled with a combination of EO and SAR satellite at various equatorial crossing times so as to keep the AoI under near continuous surveillance by ELINT and EO/SAR satellites. The People's Liberation Army (PLA) today has a network of the ELINT, SAR and EO satellites in orbit, enabling the integrated system of tip-and-cue to sweep vast target area once in less than 30 to 40 minutes, thereby enabling rapid target identification with precision.[10]

The concept has been evolving over the last two decades, based on the experience gained by Chinese forces in operating these satellites, new technological advances and operational thinking based upon tactical scenarios that armed forces are likely to encounter.

As far as the EO/SAR satellites are concerned, all of them have continued to be in sun synchronous orbits with inclination of 97° to 100°. Initially, the

resolution expected was of the order of 3-10 metres, over a period of time the accuracy has improved to sub-metric levels. Also improved satellite bar (CAST-100 and CAST-2000[11]) has made the satellite stabilise in an earlier time frame and has made the system of transmission of data more efficient and robust, thereby reducing the time gap between acquiring the data and dissemination to the ground station. At the same time the number of these satellites has kept on increasing.

Interestingly, it is the employment and exploitation of data from ELINT satellites that has witnessed the maximum evolution, essentially with the understanding of keeping the Taiwan and SCS region under better surveillance and the whole concept has further evolved especially after the formation of PLA SSF.[12]

The ELINT triads in early 2010s were all in 63.4° inclined, approximately 1200 km altitude orbit, with all three satellites displaced 120° in the same plane.

On December 31, 2015, against the backdrop of broader structural reforms, the PLA took a major institutional step to integrate its previously disaggregated space, communication network, and electronic warfare elements by creating the Strategic Support Force as a fifth service of PLA, named as PLA SSF. This clearly signifies Chinese military leaders' belief that "achieving information dominance and denying adversaries the use of the EMS is necessary to seize and maintain the strategic initiative in any conflict."[13]

Coincidentally, from September 2017 onwards (with Yaogan-30 A,B,C), China started launching ELINT triad of Yaogan satellites in a new configuration. Unlike the earlier triads their altitude was brought down to 600 Km with inclination of 35° and saw satellites being maneuvered to fly in a six spot configuration in the same orbital plane, thereby increasing the number of ELINT satellites to 18 in this 35° orbital plane. The relative angles were observed to be 260°, 140°, 20°, indicating that these triads were themselves displaced by 120°.

Reducing of inclination to 35° and having six set of satellites in each orbit was possibly to bring the areas of Taiwan and SCS under enhanced

surveillance. This pattern has continued to be observed in subsequent ELINT satellite launches as well.

A well stabilised constellation of Yaogan has given China a revisit time of approximately 30 minutes over a vast area of Indian territory and Indian Ocean area, thereby providing its armed forces a close watch over Indian strategic assets. This imposes a great limitation on conduct of operations to the Indian armed forces, in equal measure for its Army, Navy and the Air Force, as it denies them a great deal of flexibility of operations, thereby impeding the momentum of operations, considered so very essential for success of any military campaign.

Space-based ELINT has the potential to provide timely and accurate intelligence on potential threats from adversaries, a critical aspect of national security for formulating defence strategies for India. Thus, India need to accord highest priority amongst all the space capabilities.

SPACE BASED ELINT FOR INDIA

EMISAT, the lone ELINT Satellite

EMISAT is an ELINT satellite developed jointly by DRDO and ISRO, under Project Kautalya, Defence Electronics Research Laboratory (DLRL) Hyderabad, under DRDO is the lead developing agency for payload development. EMISAT is a satellite built around ISRO's Mini Satellite-2 bus weighing about 436 kg, with solar panels providing 800 watts of power to the satellite.

It was launched on April 01, 2019 onboard India's PSLV-C45 launcher from Satish Dhawan Space Center (SDSC), Sriharikota and successfully injected EMISAT and 28 international satellites from four countries- Lithunia, Spain, Switzerland and the US, into their designated orbits. It placed EMISAT in a sun-synchronous orbit, with 98.4° inclination and an apogee of 749 km. This is expected to give the satellite enough dwell time for picking up RF emissions from a specific area on the ground and recording them. The height of 749 km provides the EMISAT with a sufficiently large footprint and a 6

to 8 revisit per day, translating into a capability to be over the same point every second day.[14]

ELINT being a highly secretive and sensitive subject, not much information is available about the forthcoming projects in the open domain. Just having a single space based ELINT platform is not sufficient as it does not meet the most essential requirement of triangulation. It also has a limitation of very high revisit time that does not enhance the overall surveillance capability.

The fact remains that requirement to have a constellation on the same technical capability that the PLA SSF possess is the need of the hour for Indian armed forces. No nation is known to share niche intelligence gathering technology to any other nation, India would have to depend space based ELINT gathering capability by harnessing indigenous technology. Indian armed forces and ISRO are to do much more to design and develop space based ELINT capability, which may involve investing in research and development to design and develop satellite based RF sensors and other related capabilities.

Drivers for Indian Space Based ELINT: Path Ahead

Developing and operationalising Space based ELINT capability requires mastering certain high end technologies and developing efficient software based solution. Major building block technologies or components required for the same are covered in subsequent paragraphs.

In order to triangulate the location of RF emitter, a triad based satellite constellation would be required in the space also. To offer increased dwelling time over the area of interest (AoI), the complete constellation would have to be in inclined orbit. The exact angle of inclination would depend upon our AoI.

Considering the sensitivity of antennas onboard the satellite and strength of RF signals available and other peculiarities of EM emissions, a triad in LEO orbits would be able to provide an ideal solution. Also, placing more number of triad satellites in each planar orbit would help increase the number of observations in each orbit, thereby improving the accuracy of observation. A well knit constellation would also demand that each satellite communicates

with the other members of the constellation, requiring inter satellite links (ISL), imposing more power and system management challenges.

Amount of data getting accumulated at a fast-moving satellite (approx 7 km per second in LEO) would demand more dwell time for undertaking a focused search on intra pulse parameters. This could only be achieved by edge computing by employing latest AI and ML models and related processing technologies of software on chip (SoC) or Field Programmable Gate Array (FPGA) in which Integrated Circuits (ICs) can be programmed to perform a customised operation for a specific application related to ELINT processing, lets say specific to a particular geographic area, for a certain intra-pulse characteristic, as the case may be.

Inclined orbit has their own peculiar challenge of limited solar charging time availability. At the same time heavy computing and processing demands and ISL-link requirements would be placed on the satellite bus, thereby, imposing high power requirements. There is thus a need to consider designing a light weight agile satellite that is small, light and power efficient system. These systems need to be SWaP optimised with highly efficient algorithms to extract accurate radar parameters. Designing of such a system is a persistent challenge due to the limited availability of space graded components and associated tools.[15]

Also, space radiation effects on electronic devices are an important system design consideration. They can cause problems ranging from operational malfunctions to severe physical damage to the devices and possibly a catastrophic mission failure. Integrated Circuits (ICs) are susceptible to two types of space radiation effects viz. caused by electrons and protons trapped in the terrestrial magnetic field.[16] The system needs to be hardened to meet these standards.

RECOMMENDATIONS

Space-based ELINT capabilities have significant implications for national security, as they provide insights into adversary's activities, intentions and capabilities. Since 2020, the Indian space sector has been opened up to

private sector participation, amongst the various space based capabilities that are being sought by the Indian armed forces, these need to be prioritised and space based ELINT capability needs to be accorded highest priority. Maximum amount of investment in terms of resources and effort needs to be invested in this domain on an urgent basis. Gaps in the space based ELINT capability can be addressed by purchasing data from foreign friendly countries and simultaneously developing indigenous capability to gather RF emissions from ELINT satellites.

The issue may be taken up at the highest level to steer space based ELINT design and development on a mission mode by ISRO or by Indian private space companies or both together as a joint project. This capability building presently is being steered under iDEX challenges by the armed forces as well as under the aegis of ISRO as a further to EMISAT, Project Kautilya. This two-prong approach should continue to expeditiously strengthen national security posture. Acquiring such a versatile capability should be a national security endeavour, hence, a whole of nation approach and more resources needs to be accorded towards acquiring space based ELINT capability.

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