Space Domain Awareness: The Global Common

Lieutenant Colonel Amandeep Singh[@]

Abstract

Space as an operational sphere has arrived for good times to come. The earlier we appreciate it, the earlier and faster we will be prepared, equipped, skilled whilst organised to respond to any incident upsetting the access and management of our national space proficiencies. Satellite operational business has been becoming challenging day by day due to increased democratisation of space, which has taken leaps in this arena at both the international and national levels. This has resulted in making space more accessible and reachable to public and private players, however, that comes at a pricey value. Space Domain Awareness (SDA) means our capability to examine the space settings and securely function within it. SDA involves the tracking of space objects, understanding their actions, monitoring space weather actions, and detecting probable threats to space activities. SDA encompasses all of the information that is essential to provide a preparedness for the space environment. It is related to space weather conditions, natural phenomena that can disturb and disrupt satellites as well as the tracking and identification of orbiting space objects. Indian space capability is on dual verticals i.e., civil and military. The Indian SDA programme, NEtwork for space object TRacking and Analysis is an Indian Space Research Organisation's initiative intended to support India's autonomous space access and

[@]**Lt Col Amandeep Singh** is a serving Indian Army Officer with distinctive cross domain expertise. He has a Degree in Law (LLB), a Degree in Air and Space Law, an MBA in Finance and presently selected as a Research Scholar for PhD in Space Economy and Legislation. He has contributed through his articles and been invited a speaker in various panels at seminars/conferences and Military institutions.

Journal of the United Service Institution of India, Vol. CLIII, No. 634, October-December 2023.

utilisation through the timely and precise transfer of data concerning the space environment. SDA allows the monitoring of the space environment and empowers the attribution of space events affecting space systems. Establishing a process to regularly identify and evaluate commercial SDA capabilities could enhance ability to conduct important national security mission.

Introduction

Space as an operational sphere has arrived for good times to come. The earlier we appreciate it, the faster we will be prepared, equipped, skilled whilst being organised to respond to any incident upsetting the access and management of our national space proficiencies. These proficiencies with dual use applicability i.e., civilian/military are very expensive and exclusive, and are measured to be as both strategic and sovereign assets. Satellite operational business is becoming challenging day by day due to increased democratisation of space, which has taken leaps in this arena at both the international and national levels. This has resulted in making space more accessible and reachable to both public and private players, however, that comes at a pricey value.

Space debris is considered as a great risk to space assets as presently an estimated of 8,400 tonnes of space objects of varied sizes have found their way into the orbit around the earth with speeds up to approximately 7 km/sec (28,000 km/hr). At such speeds, one can very well envision the consequences of the impact of any object, no matter its size. The numbers of active satellites orbiting the earth are estimated to be around 2,000 which will significantly increase with the launches of new mega constellations within the next ten years. Most of these new satellites are strategically planned to be launched in the Low Earth Orbit, which is already the most crowded and polluted orbit. Consequently, the risk of collisions cannot be ruled out, and the risk of accidental collisions will be compounded by the knowledge that a satellite can be manoeuvred to impact another targeted satellite. These dangers are becoming serious security threats, and the number of passive control measures, such as collision avoidance manoeuvres, will surely strengthen and intensify.[1]

Space Domain Awareness

In general domain awareness and situational awareness, both arrive from very similar structures of actions which are 'knowing what is going on around us'. However, as space has become more congested, enhancement and change of posture regarding space was very much needed. Space is considered as a 'Domain of Warfare' like air, sea or land. Space Domain Awareness (SDA) means our capability to examine the space settings and securely function within it. SDA involves the tracking of space objects, understanding their actions, monitoring space weather actions, and detecting probable threats to space activities. SDA encompasses all of the information that is essential to provide a preparedness for the space environment. It is related to space weather conditions, natural phenomena that can disturb and disrupt satellites as well as the tracking and identification of orbiting space objects.

Establishing SDA is an indispensable part of any space activity. Meaningful knowledge of where space objects are positioned in orbit, their orbital courses and their status permits operators to commence missions securely, decrease the hazard of collisions, and avoid intrusive actions with the space activities of other entities or nations. SDA also means classifying potential destructive natural phenomena in space, such as electro-magnetic interference formed by astronomical conditions and threats posed to the spacecrafts by asteroids.[2]

SDA can be accomplished by utilising varied prevailing technologies, domain knowledge and services. Such technologies and services regularly comprise of tracking of space objects through ground stations, retrieving space object tracking catalogues, and the launching of space-based SDA hardware. These methods and procedures enable operative actions to realise varying levels of consciousness and alertness that are appropriate for their specific requirements and objectives.

Application of SDA

Space is transforming into a more contested and disputed zone and this category of competition brings out a new theatre of operations with deliberate and intentional coercions to different national capabilities, turning them into easy targets and, therefore,

altering the nature of space. There is no singular end state of accomplishing SDA. The degree of awareness necessary for an operator to reach depends on the nature of their actions and what they hope to accomplish in outer space.

The security environment is multifaceted and complex and is expected to remain so. There are numerous space faring players and with space technologies and skills becoming progressively easier to attain, it is anticipated that this number will continue to see an increasing trajectory. Most actors are using space capabilities to better human existence and to improve the management of resources, but the intent of some other nations and organisations are based on self-centred missions which could be detrimental due to vested interests.[3]

Satellite systems are intrinsically fragile which makes them vulnerable and susceptible with a substantial dependence on space arrangements and the proliferation of space agents. With hostile intentions, such space agents, can create an unhealthy state of affairs that if comprehended could destructively influence the normal way of life. In other words, this combination produces a productive ground for hostile entities to contemplate space systems as targets for disruption resultantly causing disturbance. Contingent to the level of interference or damage created, it could have dire consequences. Deterring anyone from threatening to disrupt a country's space systems must be a national strategic objective.[4]

However, the significant positive potential in space gives a valid reason for the rising geopolitical competition on earth, it is bringing substantial risks for how expansions in space perform. Competition in space is being shaped by fragmentation and great power rivalry and has the potential to reshape the global power map. Adversaries which seek to exploit reliance on space and monopolise technologies and services for their own advantage might limit the geopolitical advancements of others. Space is also recognised as a potential warfare domain. The increasing militarisation of space and the development of counter space technologies is evolving rapidly. Space can be and is already being used as a tool of statecraft for enhanced surveillance and espionage.

At present, the mainstream space situational awareness data comes from external sensors. This may change in the future, with increasing amounts of space navigation data being collected by sensors such as Global Positioning Systems receivers on satellites themselves. Such a change will possibly generate another SDA warfare attack trajectory for a challenger by manipulating the navigation data reaching the satellite, a variety of effects might be achieved, extending from missed data group opportunities to complete misperception of the satellite's attitude and orbit regulator system. Similar confusion could be generated by deliberately inserting optical or infra-red objects into the star cameras or infra-red earth sensors used by the satellite to determine its orientation.[5]

Economic Aspects of SDA

Situational Awareness Platform market displays comprehensive evidence that is a valuable source of perceptive data for business planners. On the basis of historical data, Situational Domain Platform (SDP) market report affords key sectors, their sub-segments, revenue and demand and supply data. In view of technological innovations and breakthroughs of the market, SDP industry is expected to appear as a lucrative platform for emerging investors.

Successful commercial establishments that have shaped catalogues into government databases are doing so by triangulating observations from a system of many smaller telescopes and radar sites instead of depending on a handful of powerful telescopes. Commercial companies are able to automate and decrease the operational costs of these broad networks, and they can establish partnerships and position innovative new technologies at a quick pace. These fast innovation series recommend that commercial SDA operators may be able to comprehend gaps in SDA capabilities and services and address them at a faster rate than the governments.

Accelerating commercial innovation and a surge in international interest into tracking proficiencies emphasises the vital need for consistent and dependable SDA data. With an intensification in operators launching more assets into space, governments and private entities depend on SDA data to safeguard critical infrastructure in the space domain. The investment from an increasing number of nations and private companies involved

in SDA has seen a direct bearing on the capability to track smaller objects with more accuracy, decrease the size of sensors needed to make observations, and maintain a safe and predictable space domain.

The important trends like globalisation, growth, regulations and ecological concerns have been examined and the future projections are quite promising based on the subdivision of the market.

Global SDA Capabilities and Initiatives

The United States (US) operates the largest network of sensors and keeps the most comprehensive register of space objects, though there are gaps in its coverage and database. The system is known as the Space Surveillance Network (SSN) and it is regulated and controlled by the military. It comprises primarily of phased array radars mainly used for missile warning and optical telescopes, along with a few tracking radars and a large space fence located along the southern US. There are also two space-based tracking telescopes as part of the SSN, the US Space Based Space Surveillance satellite and the Canadian Sapphire satellite.[6]

Russia operates the second largest network of sensors and preserves a relatively complete catalogue of space objects. The Russian system is identified as the Space Surveillance System (SSS), which also comprises of phased array radars used primarily for missile warning, along with some dedicated radars and optical telescopes. Several of the SSS sensors are in former Soviet republics and are operated by Russia under a series of mutual arrangements with the host countries. Russia is also in the process of upgrading and modernising its SDA capabilities with the Automated Space Danger Warning System to track space debris and sustenance of national security.[7]

Over the last few years, the private sector has commenced evolving its own SDA capabilities. The Space Data Association, a not-for-profit organisation shaped by commercial satellite operators, uses data provided by members to provide improved combination assessment and radio frequency interference services. More than a few commercial companies are now offering commercial SDA data services from their own radars and telescopes and others

have formed their own operations centres to fuse information from multiple sources and provide commercial SDA services. Private sector SDA capabilities are getting refined and improving rapidly and are expected to surpass those of the governments in the near future.

India's Capability in SDA

Ever since the beginning of India's space programme, space-based assets have played a fundamental role in the nation's growth story by contributing to the vital services in the field of weather monitoring, communications, resource monitoring, navigation etc. However, the ever increasing space object population, including that of operational satellites, orbital debris and the allied collision risks pose a danger to the safe and sustainable use of outer space. The cumulative overcrowding of earth's orbit poses an impending threat of collisions among larger fragments of debris that could trigger a self-sustained cascading process of further collision, known as Kessler Syndrome. This could considerably intensify the density of space debris population, rendering outer space inaccessible for future generations.[8]

Operational management of safe and sustainable operations in outer space involves an all-inclusive approach regarding multiple areas related to observation and monitoring of space objects and space environment. Additionally, examination of development for space environment, risk assessment, data exchange and collaboration. The multi domain awareness platform will bring prompt, accurate and efficient information on the on-orbit collision, fragmentation, atmospheric re-entry risk, cataloguing of observational data, hazardous asteroids and space weather forecast. Accurate orbital information from ground-based sensors is a pre-requisite for mitigation of any collision threats to an operational space threat from other objects.[9]

India's approach to space defence and security, like many other countries, has a purpose to enter this new theatre of operations. As India has a very progressive space programme, the need to safeguard and defend the space assets i.e., military, civilian, or dual has always been of paramount importance. Being a 'question of sovereignty', the objective is to maintain a positive level of self-sufficiency to assure the strategic autonomy. Indian defence forces policy considers operations in high ground i.e.,

pace, integrated with no clear dividing grounds, from the ground, through the air until outer space. Space oriented service from its origin and having units providing intelligence, surveillance and reconnaissance, command and control, up until geostationary earth orbit, are interrelated.

Indian space capability is on dual verticals i.e., civil and military. The Indian SDA programme, NEtwork for Space Object TRacking and Analysis (NETRA) is an Indian Space Research Organisation (ISRO) initiative intended to support India's autonomous space access and utilisation through the timely and precise transfer of data concerning the space environment. It also focuses on the data pertaining to threats to both in orbit and ground infrastructure. SDA programme also provides a segment of Space Surveillance and Tracking designed to track active and inactive satellites and space debris.[10]

In view of the ever-growing population of space objects and the recent trend towards mega constellations, SDA has become an integral and indispensable part of safe and sustainable space operations. For the last five decades, ISRO has been carrying out SDA activities with main focus towards safeguarding India's space assets. Recognising the need for dedicated efforts to tackle the emerging challenges of operating in an exceedingly crowded and contested space domain, Directorate of Space Situational Awareness and Management has been established at ISRO. The Directorate engages in developing upgraded operational mechanisms to defend and protect Indian space assets through effective coordination among ISRO Centres, other space agencies and international bodies. To establish necessary supporting infrastructures, such as additional observation facilities for space object monitoring, and a control centre for centralised SDA activities. NETRA project is initiated as a first step towards meeting this goal, its main elements include radar, an optical telescope facility, and a control centre.[11]

Recently, Government of India released the Space Policy 2023, which conveys a fused and dynamic framework to implement the reform vision. The Space Vision Policy is aimed at augmenting space capabilities, enabling, encouraging and developing a flourishing commercial presence in space, derive benefits in allied areas and create an ecosystem for operative applications of space

operations among all stakeholders. As a result, the SDA gets more involved and promises to be an indispensable part.

Space Sustainability and Security - Role of SDA

SDA warfare integrates a series of procedures which a space actor might follow to attain information dominance. SDA warfare might involve three key principles.[12]

- To maintain the accuracy of own SDA information.
- To degrade the accuracy of the adversary's SDA information.
- To avoid collateral threats.

SDA warfare activities that permanently degrade the overall SDA capability would reduce the effectiveness of the overall catalogue of space objects. As a result, the commercial satellites operators would have less assurance in corroborating the warning messages they receive, and the possibility of an inadvertent collision would increase. In view of the many applications that satellites presently support, any reduction in capability in the areas of navigation, communications, meteorology, etc. could result in the loss of life of non-combatants external to the theatre of operations which is considered illegal under the rules of armed conflict.

One of the significant issues associated with SDA dominance is the geographic location of the sensors. It is not difficult to find information on the locations of the US tracking networks that are likely to be subject to surveillance.

The Way Ahead - Integration is the Way to Go

As the North Atlantic Treaty Organisation has declared Space as an operational domain, it has initiated the preliminary steps to intensify the cooperation, collaboration and coordination of all allies and the space capabilities they own. As SDA being a global domain autonomous subject, it becomes necessary to take into account the interests and prerogative of nations to maintain operational command and control of their assets.

New tactics, techniques, and procedures for space are making incremental advancements towards evolving new SDA tactics, techniques, and procedures to achieve better upstream, midstream and downstream capabilities for operations. The completion of the new formats depends on a variety of factors, including the modernisation of outdated hardware and software. Integration, more than coordination, will offer the best standards to advance the domain of security, solidity and sustainability of space. However, the challenge is how that level of integration is implemented.[13]

Conclusion

As part of the development progress, we have refined sophisticated procedures for monitoring the health, position, and operational status of space vehicles. However, the growth and setting up of sensors to caution and detect attacks on them were to some extent neglected. The rapid rise in the importance and challenges of operating in space necessitates enhancements to SDA capabilities, including consideration of commercially available data and tools. Significant challenges remain unaddressed with respect to consistent and systematic assessment of commercial capabilities for space operations. In particular, while there has been periodic evaluation and use of some commercial capabilities, these efforts have been limited.

SDA allows the monitoring of the space environment and empowers the attribution of space events affecting space systems. Establishing a process to regularly identify and evaluate commercial SDA capabilities, could enhance the ability to conduct an important national security mission. SDA therefore becomes a key element for space deterrence. SDA is an area that has received increased international attention in the last decade due to the space environment becoming increasingly congested, contested and competitive. The next 10 years will likely see further improvement in the accuracy and timeliness of SDA services, including reducing the size of the object that can be detected and how frequently the location of objects in space can be monitored and updated.

Endnotes

[1] nasa.gov/mission_pages/station/news/orbital_debris.html

[2] spacelaws.com/articles/laws-relating-to-space-situational-awareness-ssa/

[3] carnegieendoement.org/2022/09/01/india-s-space-priorities-are-shifting-toward-national-security-pub-87809

[4] United States Space Systems : Vulnerability and Threats, Section 3, Federation of American Scientists

[5] The Global Risks Report 2022, 17th Ed, World Economic Forum

[6] Brian Weeden, www.swfound.org, Space Situational Awareness Fact Sheet May 2017

[7] Globalsecurity.org/space/world/Russia/space-surveillance.htm

[8] BN Suresh, Diverse Space Applications for National Development, Indian National Academy for Engineering& Chancellor, Indian Institute of Space Science and Technology

[9] isro.gov.ib/IS4OM.html

[10] idrw.org/isros-project-netra-indias-leap-into-space-situational-awareness/

[11] isro.gov.in/ISRO/SSA/Control/Centre.html

[12] Aerospace.csis.org/wp-content/uploads/2019/03/20190101_ChallangestoSecurityinSpace_DIA.pdf

[13] McKinsey &Company, McKinsey Technology Trends Outlook Report, 2022