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POSTURING IN OUTER SPACE & CONTOURS OF AN INDIAN INTEGRATED SPACE DEVELOPMENT PROGRAM

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Capabilities take Time to Develop, Intentions can Change Anytime !
Whatever can be precisely defined, can be accurately designed and developed !
Geospatial data is the new oil, geospatial technologies are the new oil refineries !

Abstract

Indian Space Policy 2023 is iconic with a strong emphasis on international collaboration and technological advancements aiming for joint missions, knowledge sharing, capability and capacity building in satellite launches, scientific missions, space exploration, and technology transfers with an intent of the growth of the commercial space industry. The Policy aims to retain flexibility in addressing its national security concerns while maintaining strategic autonomy in outer space affairs and highlights India's achievements and future goals in the development of nano satellites, advanced launch vehicles, hypersonic glide vehicles, ASATs and ambitions for human spaceflight through public-private partnerships to stimulate economic growth, technological innovation, and job creation within the space sector. But the ambition is bereft with challenges. This calls for an Indian Integrated Defence Space Development Program, on the lines of IGMDP, to gain technology sovereignty in state of the art satellites and SLVs, Resilient PNT, and military assets - offensive, defence, hard kill, soft

kill based on, into and from, outer space platforms and Defence Space Technologies.

INTRODUCTION - EXPLORING OUTER SPACE AS A NATIONAL ASSET

India has been on the forefront in exploring outer space as a national asset encompasses multiple dimensions comprising scientific, technological, strategic, economic, and diplomatic facets. The space sector is a growing industry with opportunities in satellite communications, earth observation, remote sensing, space exploration and space based scientific and technological research. Engaging in space exploration has positioned India as one of the leaders in strategic and defence applications, hi-tech industries, enhancing its competitiveness on the global stage. Space capabilities are critical for national defence, including satellite-based navigation (GPS), communication, and surveillance. Satellites provide critical data for weather forecasting, climate monitoring, and disaster management, contributing to global safety and resilience. That said, space exploration initiatives contribute to the development of technologies that can enhance a country's security. Collaboration in space exploration can serve as a tool for diplomatic engagement, fostering partnerships and cooperation between countries. Joint missions and projects can build trust and reduce geopolitical tensions and foster international cooperation.

NavIC and Indian Space Policy 2023 are major milestone and have created reverberations among space agencies, institutions and industry alike to harness the opportunities in defence and dual use technologies. The policy is expected to institutionalise private sector participation in the space sector, with ISRO focusing on R&D of advanced space technologies and is likely to increase India's share in the global space economy substantially from 2 percent to 10 percent in the foreseeable future. It is envisaged that the boost in satellite manufacturing and launch capabilities will yield USD 3.2 billion by the year 2025 against USD 2.1 billion in 2020.

Navigation with Indian Constellation (NavIC)[1] is an autonomous Indian Regional Navigation Satellite System (IRNSS) that provides accurate real-

time positioning, navigation and timing services. NavIC is designed with a constellation of seven satellites initially and a network of ground stations. The NavIC receivers in the ground based systems are proliferating the employment of NavIC based systems. The coverage of the satellite system currently is effective in the equatorial belt, in India and regions extending approximately 1500 km with plans for further extension.

THE FUTURE OF SPACE WARFARE - TRYST WITH TECHNOLOGY

The future of space as a domain for warfare encompasses a range of potential developments shaped by technological advancements, geopolitical dynamics, military strategy and international regulations. Nations are likely to develop both offensive and defensive space capabilities. Defensive measures could include satellite hardening, manoeuvrability to avoid attacks, and the development of systems to track and neutralise threats. The international community's response to these developments, through regulations and agreements, will be crucial in shaping the nature and extent of militarisation in space. The Outer Space Treaty of 1967, which outlines that space shall be used for peaceful purposes, faces new challenges with the militarisation of space. Future conflicts may test the limits of current international law, leading to potential revisions or new treaties to address the realities of space warfare. Salient aspects in outer space based applications, speculative overview based on current trends and technological advancements: for consideration are given below:

- **Satellite Technology**. Satellites are critical strategic assets and play a crucial role in communication, navigation, surveillance and reconnaissance. With advanced materials, nanomaterials and nano energisers, there is a paradigm shift from the traditional large single satellites to multiple small constellations. Small, nano satellites and launch on demand satellites with a variety of payloads would be imperative for real time situational awareness. A number of dual use satellites '*RADARSAT*', '*CARTOSAT*' and other military satellites can be easy targets by an adversary and hence, multiple smaller satellites are

a preferred choice. There is requirement to have a fortified approach to protect our space based assets. In addition, drone based pseudo satellites with a variety of payloads, solar panels for higher endurance are popular for bridging surveillance gaps and launch on demand. In an overall analysis, there is immense technology upgrade to configure a '*zero trust secure architecture*' by infusing emerging critical technologies to include software on chips, software on platforms, quantum materials, quantum compute and quantum encryption, big data analytics, multi platform, multi sensor data fusion, to name a few big tickets, with an intent to enhance security of satellite communication data from space assets.

- **Satellite Communication Payloads**. Communication payloads are designed based on the specific needs of the service they are intended to provide, such as television broadcasting, internet services, mobile communications and military applications. The advancements in payload technology, such as higher frequency bands and digital signal processing, continue to improve the capacity, flexibility, and efficiency of satellite communications.[2] These payloads can include transponders, antennas, and other equipment that facilitate the transmission and reception of signals. The key elements and their functions are given below:
  - **Antennas, Amplifiers and Transponders.** Antennas on satellites are designed for specific frequency bands, C-band, S-band, Ku-band, Ka-band, critical for sending and receiving signals. These may be highly directional to focus on particular areas of the Earth or more omnidirectional for broader coverage. The transponders are the heart of the satellite's communication payload. A transponder receives signals from an Earth station, amplifies them, changes the frequency, and re-transmits them back to another Earth station. This process allows for efficient, long-distance communication across the globe. Amplifiers boost the strength of the incoming and outgoing signals.
  - **Beams Technology.** Modern communication satellites use beam technology to focus their signal on specific geographical areas. This can enhance signal strength and efficiency. Spot-beams, a more focused

version of beams, allow for even greater precision and positioning and are particularly useful in providing high-speed internet services. Laser communication beams are being used for data transfer with minimum latency.

- **On-board Processors**. Advanced communication payloads include on-board processing capabilities, allowing the satellite to perform geospatial data analytics, data manipulation, routing, and error correction, which can significantly improve the efficiency and quality of the communication service.

- **Satellite Surveillance Payloads**. Satellite based space situational awareness mission payloads are specialised equipment carried by satellites to perform surveillance from space. Each payload is tailored to its specific mission, which can range from environmental monitoring, disaster response, intelligence gathering and military functions.[3] The design and deployment of such payloads are highly sophisticated, involving cutting-edge technology to ensure reliability, accuracy, and efficiency in data collection and analysis.
  - **Electro Optical Imaging.** High-resolution cameras capture detailed images of the Earth's surface. These can be used for military reconnaissance, environmental monitoring, and mapping.
  - **Radar Surveillance.** Synthetic Aperture Radar (SAR) can penetrate cloud cover and work in all weather conditions, day or night. SAR is used for military surveillance, maritime monitoring, and to observe changes in the Earth's surface.
  - **Thermal Imaging.** Sensors that detect heat, including the heat emitted by vehicles, industrial activities, or geological phenomena. Useful in both military and environmental applications.
  - **LiDAR (Light Detection and Ranging)**. Uses pulsed laser light to measure variable distances to the Earth. This technology is used for mapping and analysing the Earth's surface, vegetation, and buildings.
  - **Signals Intelligence (SIGINT).** Equipment to intercept communications, electronic signals, and other types of information

transmission. This is primarily used for national security and intelligence purposes.

- **Space-Based Weapons Platforms.**[4] An ever increasing pursuit in the space domain has led to the design and development of new weapon platforms and systems. Space weapons may be characterised by earth to space, space to space and space to earth both kinetic and non-kinetic. Earth to space weapons have been of immense interest to include anti satellite (ASAT) weapons, directed-energy weapons and jammers. The US, Russia, China and India have all tested ASATs. Space to space based combat systems are satellites and similar assets which are deployed in the outer space to attack, destroy and disrupt other satellites through direct hit, use of directed energy and EM waves. Space to Earth weapons are now on the anvil of R&D and include satellite based kinetic or non-kinetic weapons for soft and hard kills to disrupt/destroy terrestrial targets.. Ballistic Missiles Defence (BMD) is yet another space controlled land based guided missiles weapon platform system. Further, the idea of intercepting missiles while they are in space or shortly after launch is not new, but advancements in sensor technology, interceptors, and directed energy weapons could make space-based missile defence systems more viable and effective in the future. The capability to conduct soft kill and hard kill based on the emerging technology landscape may result in reinterpretation of Outer Space 1967 Treaty and could change the legal landscape.
- **Cyber Warfare in Space.** As satellites and other space assets rely heavily on digital technologies, they are vulnerable to cyberattacks. Future space warfare could see a rise in cyber operations aimed at disrupting, hijacking, or disabling space-based systems. Hacking or jamming satellite communications could disrupt enemy operations without physical destruction.
- **Space Debris and Its Implications.** The destruction of satellites, either through anti-satellite weapons or other means, can generate significant space debris, posing risks to other satellites and space activities. This

issue might lead to an international push for more regulated conflict management in space to prevent unsustainable levels of debris.

- **Technological Innovations.** Emerging technologies, such as autonomous drones capable of operating in space, laser-based communication and weapon systems, and advanced propulsion technologies, could significantly alter the dynamics of space warfare, making it more sophisticated and potentially more destructive. Space drones and unmanned autonomous vehicles deployment in space for surveillance, repair, or even attack missions could become more common. These could range from small CubeSats[5] for espionage to larger drones capable of performing a variety of missions autonomously. That said, with the increasing presence of commercial and civil entities in space, the distinction between military and non-military targets could become blurred in conflicts, raising ethical and legal concerns.
- **On-Orbit Servicing and Space Manufacturing.** Technologies enabling on-orbit servicing, repairing, refuelling satellites and manufacturing[6] could significantly extend the lifespan and capabilities of space assets. This would also allow for the construction of advanced spacecraft and structures directly in space, potentially including weapons systems.

THE DEFENCE SPACE PROGRAM DELIVERABLES

General. Satellites offer huge intelligence, information, surveillance and communication advantages. Military and other application based satellite systems have the potential of being the centre of gravity of military operations planning and execution. In fact the Tri Services requirements of 24x7 real time situational awareness and common operating picture can be realised by invoking satellite systems for military perspective planning. Further, as the need for monitoring EEZ and maritime domain awareness expands, weaknesses in Indian space security eco system need to be addressed by building up the present small number of military satellites. There are major opportunities in Defence Space Technologies to carry out

realistic scenario building in this fourth dimension for invisible cyber space based warfare. Salient deliverables are given in the succeeding paras.

IGMDP – The Flagship R&D Program. The Indian Integrated Guided Missiles Development Program (IGMDP), envisioned development of five Guided Missiles, Prithvi as SSM, ATGM Nag, Akash and Trishul as SAMs and Agni as technology demonstrator. The Program is a case study in technology sovereignty. Motivated by the overwhelming accomplishments of ISRO in satellite launch vehicles (SLV) project, despite dependencies on imports of key space technologies, IGMDP was planned to gain self reliance in the Guided Missile Technologies. The challenges compounded in 1987 when Missile Technology Control Regime (MTCR) was slapped to restrict proliferation of missiles components, sub systems and systems. India demonstrated a robust political resolve and organised a concerted whole of Nation approach to with academia for basic TRL 1-6 research, developed PSUs, and private Indian industry and R&D agencies. The key payoffs accrued include advance materials for airframes, gyros – accelerometers – servo systems for guidance control systems hardware and software, inertial measurement units, launch pad & onboard computers, solid and liquid propellants, liquid propulsion engines, precision technologies in hydraulics and pneumatic actuators, to name a few big tickets. The momentum has continued into large number of variants of Agni with multiple warheads, Brahmos, MRSAM and many more. Given the present Government impetus and whole of Nation approach with Aatmanirbhar Bharat, Make in India, Startup and Skill India Missions, India is well poised to be a global leader in the Defence – Space Technology Program.

Integrated Defence Space Development Program (IDSDP). There is a dire need to launch a major *Indian Integrated Defence Space Development Program (IDSDP) akin to IGMDP*. Policy, structure and strategy are three quintessential macros for launch of a successful IDSDP. The three structures comprise space sector PSU New Space India Limited (NSIL) for oversight on strategic and operational activities in the Space Sector, Indian Space Research Organisation (ISRO) with focus on developing new technologies and new

systems, Indian National Space Promotion and Authorisation Centre (IN-SPACe) as an interface between ISRO and private entities. There is a dire need to create and develop an overarching structure comprising subject matter experts (SMEs) for providing long term strategy and management oversight through an Integrated Defence Space Development Program akin to Integrated Guided Missiles Development Program to prepare a cogent strategy, plan, direct, coordinate and monitor, short, medium and long term deliverables to ensure that the policy's efforts are carried forward as a joint effort with academia and industry stakeholders. This would provide velocity to a well orchestrated hub and spoke wheel to the Indian National Space Development Program. The success of IGMDP to a great measure is attributed to the Technology Wizard and Charismatic Leader, late Dr APJ Abdul Kalam, ably supported by hand picked project directors, system directors and SME veterans as advisors. In a similar endeavour, IDSDP calls for a cogent Program Structure suitably led by a Space Technology SME as a Program Director. Salient pre-requisites for this are given below and would need deliberation to create a thesis and a baseline document for the next 23 years to Viksit Bharat:

- **Project Structure.** Configure at least ten Project Verticals in the Program comprising Project LEO, Project MEO, Project Nano Satellites, Project Pseudo Satellites, Project ASAT, Project Hypersonic Glide Vehicle, Project Surveillance Payloads, Project Communication Payloads, Project Satellite Launch on Demand Systems, Project Ground Control Platform System, led by a Project Director each. Obviously each project would have their roadmaps and milestones clearly defined.
- **Technology/Systems Verticals.** At least eleven systems verticals led by a Technology Director each comprising Advance Materials, Smart manufacturing, SAR, Laser, Semiconductor, advanced electronics manufacturing with software on chips and platforms, robot refuelling and in orbit repair, hypersonic systems, guidance and control systems, propulsion systems and emerging & critical technologies big data analytics, AI and Info Decision Support Systems etc.

- **User Advisory Interface.** It would be imperative that the Tri Services Space Command be suitably integrated with SMEs as technology managers to value add the program with user inputs.
- **Public Private Partnership (PPP).** This calls for a cogent *'whole of nation approach'* with collaboration for developing niche technologies by DRDO, ISRO and other R&D Organisations, DPSUs, private players and startups and a synergy with academia, technology innovation hubs and centres of excellence.IDSDP will integrate & synergise efforts of this PPP Defence Space Ecosystem. At present the system is working in silos and needs to be vectored for a well directed outcome and impact.
- **Defence and Space Industrial Corridors.** The scope of Defence Industrial corridors could be enhanced with inbuilt space development clusters of startups, MSMEs and OEMs duly supported by International Collaborations through Strategic Partnerships and Joint Ventures under the aegis of the IDSDP. This would give the necessary filip to the short, mid and long term strategies of the program.
- **Strategic Oversight Committee.** A Program of this magnitude requires a strategic structure under the Office of The Honorable Prime Minister. The proposed structure may comprise Union Ministers of MoD, Department of Space, Department of Science, Chairman ISRO, Chiefs of Staff Committee and special invitees for a quarterly update. The Strategic Oversight Committee could assess the needs of Integration of Civil Space and Military programs, International cooperation for technology development, budget requirements including FDIs and review of Space and Geospatial Policies in National interest. The success of the space missions and security of space assets depends on building a resilient Defence Space Technology and a skilled Workforce which could be organised under the IDSDP and given a strategic oversight.

Integrated Space Domain & Situational Awareness Capabilities.[7] Space is a congested, contested, and competitive domain with a highly dynamic and rapidly evolving environment. More than 10000 satellites have been placed into Earth orbit and the number is expected to increase in advanced

small satellites, LEO, MEO, pseudo satellites and myriad of satellite launch capabilities. That said, Space Situational Awareness (SSA) and Space Domain Awareness (SDA) become a vital space capability. SDA is the capability to detect, identify, track and characterise space objects including space debris and the space environment with an intent to support safe sustainable space activities. Consistent with SDA, Space Situational Awareness (SSA) is fundamental to the deportment of all space-based operations based on important ingredients of space domain capabilities and capacities. SSA comprises technologies to detect and track objects in space so as to establishing their orbits, comprehend the environment they are operating in, and predicting their future positions and threats to their operations. In fact, SDA and SSA are two sides of the same coin for military, civilian and dual use. Space surveillance and tracking systems detect space objects and classify them as friendly, hostile or debris and predict their orbits. On the other hand, space intelligence plays a fundamental role to coordinate, command and control space ISR based ground data in support of military commanders, thereby ensuring that space services driven right info is available at the right place and right time.

Designing a Satellite Constellation for Space Situational Awareness (SSA). SSA and Intelligence, Surveillance, and Reconnaissance (ISR) with a focus on terrain info mapping with rapid revisit times, involves a complex interplay of technological, orbital, and mission-specific factors. To achieve a significant reduction in revisit time for terrain mapping to at least 4 hours, as a revisit time, and to incorporate advanced capabilities like Hyperspectral Imaging (HSI), Synthetic Aperture Radar (SAR) including bistatic configurations, and Multi-Spectral Imaging (MSI), requires salient strategic considerations as given below:

- **Types of Satellites**. Nano and Small Satellites are preferred for creating a cost-effective, responsive constellation. Nano-satellites typically weigh 1-10 kg, while small satellites may weigh up to 500 kg. Theses are discussed in details ahead. Micro, Nano & Software Defined Satellites,[8] comprise

the nextgen satellites based on advanced materials, nano materials and energisers. These miniaturised satellites have resulted in proliferation of LEO and MEO satellites and launch on demand satellites given the ease of their launch with smaller launchers and cheaper launch vehicles. Software defined satellites are the next disruption. A large number of surveillance devices are deployed, but given the porosity and the sheer length of the borders and areas of interest and influences, for round the clock surveillance, India must develop capability to launch nano - tech enabled LEO satellites, drone based pseudo satellites and a number of ground stations enabled by big data analytics with a GIS platform duly integrated for real time situational awareness.

- **Hybrid Constellation.** Incorporating a mix of satellites with different sensing capabilities (ELINT, SAR, MSI, HSI, Optical) ensures comprehensive surveillance and intelligence gathering. Alternatively, satellite systems may be designed with multiple payload features.
- **Advanced Payloads.** As discussed above, an array of communication and surveillance payloads may be deployed singly or as a hybrid constellation with SAR, Optical, Laser, Electro-optical, ELINT, and others, for effective Image Intelligence. The following spectrum of payloads would be important:
  - **Hyperspectral Imaging (HSI)** would be essential for detailed information across a wide range of wavelengths for precise identification of materials and objects.
  - **Bi-Static and Tandem SAR** facilitates dem-data for objects of military importance, 3D mapping and enhanced imaging regardless of weather or lighting conditions.
  - **Multi-Spectral Imaging (MSI)** for a wide range of applications to include military applications, agriculture to combatting climate change.
- **Multi Platform, Multi Sensor Data Fusion (MPMSDF).** It is imperative to configure a ground command and control platform for giving decision makers and stakeholders real time situational awareness and a common

operating picture. Given the myriad of surveillance platform and sensors, space satellite based, Medium Earth Satellites MEO, Low Earth satellites LEO, psuedo satellites, AWACs and aerial platforms, ground based sensors, there is a dire need to get the true picture through *meshed intelligence*. This involves the integration of data from various sources (satellites, drones, ground stations) to create a comprehensive intelligence picture. It necessitates advanced data processing and communication capabilities and a MPMSDF integrated unified platform.

- **Revisit Time & Quantification of Satellites.** The primary goal of achieving a revisit time of 4 hours or less requires a carefully designed constellation. This involves calculating the optimal number of satellites and their orbital parameters to ensure global coverage with the desired temporal resolution. The exact number of satellites required would depend upon depends on several factors, including orbital altitude and inclination in that Lower Earth Orbit (LEO) satellites which have shorter orbital periods would necessitate more satellites for continuous coverage; sensing capabilities based on different types of sensors (SAR vs optical) having varying swath widths and resolutions, affecting how many satellites would need to be deployed and constellation design which may be Walker Delta or Star constellations for global coverage, with the specific design impacting satellite numbers.
- **Estimation of Number of Satellites.** Based on the above and assuming a mix of SAR and optical satellites in LEO (altitude around 500-600 km), achieving 4-hour revisit times globally might require a constellation of over a hundred satellites, as a part of limited coverage of India's areas of interest and influence, considering the need for different payloads and redundancy. This assessment provides a broad overview, and detailed constellation design would necessitate more precise calculations and considerations tailored to the specific mission requirements and technological capabilities.
- In an overall analysis, incorporating advanced technologies like AI for data analysis and autonomous satellite management systems can also

enhance the efficiency and responsiveness of the constellation, potentially reducing the required number of satellites.

Space Based Surveillance Network Systems.[9] There is a dire need to configure a network of varied space surveillance systems space radar systems, phased array and synthetic aperture radars, thermal infrared spectrometers, multi spectral imagers, glimmers, rolling mirror space telescopes with varying resolution on ground and in space. This shall generate info for space situational awareness and debris status and ground based geospatial data for military applications and National Missions/ SDGs of India.

Secure Space Communication Systems. Space Communication systems is a two way communication in uplink and down link which need to be secured to convey signals and geospatial data in real time. Satcom Association of India is an Agency which is tasked to identify areas of research, design and development in seamless secure satellite communication systems. There is a need to proliferate NavIC based satellite receivers for mobile handsets, drones and myriad of applications.

Research Centre of Big Data for Nation Mission & Defence.[10] A unified secure cloud (Space Data Centres) for storing big data that will get generated would need to be created. This Research Centre would be the most important repository of the humongous amount of data for defence and National Missions /SDGs and would be a strategic asset of National Importance. This Data Platform would aim to integrate Big Earth Data, data from multiple Tri Services platforms and other agencies for collation, synthesis & monitoring data to create business analytics., augmented intelligence and predictive analytics. Big Data Platforms, Multi Platform Multi Sensor Data Fusion and AI platforms would need to be created for generating an *Integrated Information, Actionable Intelligence and Decision Support System.*

Global Navigation Satellite System (GNSS) -NavIC. A system of GEO and Medium Earth Orbit (MEO) and LEO satellites would need to launched to configure a robust NavIC as a reliable global positioning system (GPS).

This would need to be hardened for a robust global positioning, navigation and timing.

Resilient Positioning Navigation and Timing (PNT) Systems. PNT is the critical mass of all space based systems. In the digital world, it is a National level problem but can affect Armed Forces at the time of crisis and war. The Indian Satellite Based Systems are dependent on Global Navigation Satellite Systems to include US based Global Positioning System (GPS). The ability of USA or an inimical Nation degrading GPS and affecting PNT will have serious implications on e-Governance and decision support systems and can be disastrous in war. There is need to design, develop and deploy three layers of systems for assured PNT:

- **A terrestrial system for PNT.** This shall help in getting geospatial data from in premise infrastructure so important in management of information, resources and autonomous systems
- This terrestrial grid must be layered with low earth orbit (LEO) satellite-based systems which are ready to launch on demand for real-time situational awareness.
- **Tethered/solar based drones as quasi satellite as eye in the sky,** on demand for localised PNT support up to 30 Km above the mean sea level.

Launching of Satellite Systems on Demand. There is a void in real time satellite imagery. The present system of terrain mapping in the areas of interest and influence need to be reduced to at least four hours. This calls for a concerted effort to launch more defence payload satellites. These may be nano and small LEO satellites on demand. There is also a need to develop software defined satellites for muti payloads. As a fallout, resilient PNT can also be achieved by developing launch on demand satellites.

Weaponising Space Systems.[11] Hypersonic glide vehicles, hypersonic missiles, Anti Satellite Systems based on Ground based launchers for hard kill and soft kill systems in the space is in the realms of technology demonstration and a void. There is a need to design, develop and deploy anti satellite missile systems. Also, space based hard kill guided missile

systems, jamming, directed energy weapons and electromagnetic pulse systems need to be developed for use from space to earth. There is a need to create soft and hard kill systems including jammers and directed energy weapons (DEWs) for Outer Space Warfare. The scope of such capabilities include ground to space warfare, space to space warfare (satellites destroying hostile satellites, space to ground warfare. These technologies include EM spectrum, laser based DEWs and hard kill missile ASAT systems.

Space Force Development. Several countries have already established or are in the process of establishing dedicated military branches for space, recognizing the strategic importance of space dominance. These space forces would comprise manned unmanned technology based teams which, in future, may drive the development of doctrines, technologies, and strategies for space warfare. While this overview is speculative, the rapid pace of technological advancement and the increasing strategic importance of space suggest that the future of space warfare will be shaped by a combination of innovation, international policy, and the evolving nature of conflict.[12] The challenge will be in balancing the aggressive capabilities for space warfare with the need for cooperation and peaceful use of outer space, as it remains a global commons crucial for the entire benefit of humanity.

Value Addition Space Based Projects. That said, there are two key drivers of Defence Space Program – Technology and Data. Technology comprises space technologies and supporting emerging technologies AI, AR, VR, nano materials and energisers, quantum technologies, communication tech, cyber and electronics warfare tech, directed energy tech[13] to name a few big tickets. Data comprises geospatial data and all forms of unstructured data from various sensors and devices tied into big data analytics. There is a need to create enabling technologies and space based projects for 24/7 situation awareness:

- AI platform for satellite and other imagery interpretation and identification of military objects and combat groupings of interest.
- Integrated Battlefield Management System (IBMS) for Blue and Red Force Tracking, intelligence collection in real time including tracking key

enemy military targets of interest for int preparation of the battlefield (IPB) and effective IFF to ensure RTSA and COP, so important for integrated Tri Services theatre operations.

- All weather surveillance and satellite communication.
- Tri Service Platform for Electronic Warfare – electronics surveillance, electronics counter /counter-counter measures.
- Cyber defensive and offensive systems.
- Weather and met data for artillery and long range vectors though autonomous space based met data software systems.
- Effective disaster management, precision agriculture and defence through MPMSDF based proactive forecasting and follow up actions.

CONCLUSION

C7I2S2R DSS.[14] The paradigm of future warfare is invisible warfare and cyber warfare is a good example. The same would be true for information and Space Based Warfare. Given the emerging technology landscape and the primacy of space warfare with time, there is a need to develop a major Integrated Space & Aerial Systems Development Program to create a Command, Control, Communications, Computers, Cyber, Cognition (C6) Intelligence, Info, Surveillance, Security, Reconnaissance Big Data Decision Support System for National Missions/SDGs and add Combat (C7) systems for defence. This should be the ultimate intent for exploitation of Space Mission in National Strategic interest. In an ultimate analysis the IDSDP would create the platforms for C7I2S2R DSS and foster development of weapons to "degrade, disrupt, destroy or deceive an adversary's space capabilities". Opportunities beckon!

Lt Gen (Dr) Anil Kapoor, AVSM, VSM (Retd) superannuated as Director General Electronics and Mechanical Engineers on 31 December 2020. He was also the Director General Info Systems.

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