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EVENT REPORT

DEFSAT 2023 : REPORT ON THE DELIBERATIONS

TEAM CENJOWS and SIA-INDIA

-Team CENJOWS & SIA-India

Introduction. The DEFSAT 2023 seminar was conducted jointly by CENJOWS-SIA on 27-29 April 2023. The seminar covered various facets of civil-military fusion in the Space Sector, focusing on the growing requirements of the armed forces. The participation of various foreign as well Indian private companies, DRDO, ISRO, PSUs and users would help the private players align their technology and capacity endeavours to match the requirements of the armed forces and CAPFs. Development of dual use technologies providing Intelligence, Surveillance and Reconnaissance (ISR), Positioning, Navigation, and Timing (PNT) and satellite communications are disruptive enablers for the armed forces.

Growth in Space industry. Emerging and Disruptive Technologies (EDTs) are leading to emergence of dual use applications in space. Commercialisation has made the Space domain more complex, blurring the lines of distinction between civil and military capabilities in space. Technological innovations and developments have brought about not only opportunities, but threats as well. The threats could be in, from and through space. While the country's space activities aren't at the level of China or the US, it has earned quite a few achievements by having a homegrown ability to launch spacecrafts to orbit. India's ISRO has built an industry supporting activities like remote sensing / Earth observation and has planned crewed missions. India has manufactured and launched rockets such as Geosynchronous Satellite Launch Vehicle (GSLV), Polar Satellite Launch Vehicle (PSLV) which is the most reliable lot, and the small satellite launch vehicle (SSLV). In addition, ISRO also manufactures all kinds of payloads, from remote sensing to navigation. The success of private players like Space X, Planet Labs, Astra and Rocket Labs have revolutionised the pitch for start-ups and India too, has success stories being scripted by Digantra, Sky Root, Pixel and many more. Any space-based asset, civilian or military is a national asset which can potentially disrupt information operations.

The broad requirements for the Military users are as under: -

(a) **Launch Capabilities**. Re-Launchable Vehicles (RLV), Launch on Demand (LoD), nuclear power for interplanetary missions, smart fuels and lower costs per Kg of launch.

(b) **Spacecraft**. Nuclear power/batteries for longer sustenance, CUBESATs, Nano-satellites, multi-sensor payloads, miniaturisation, robotic systems for on-orbit servicing, assembly and manufacturing (OSAM), high resolution Hyper-Spectral Imagery (HSI), edge-processing, Counter-ASAT capabilities, electronic hardening, plasma thrusters for maneuvers.

(c) **Ground Infrastructure.** Adequacy and geographical spread of ground stations, mobile ground stations, scaling up ground stations for LEO constellations.

(d) **Intelligence, Surveillance & Reconnaissance (ISR)**. Persistent coverage over select areas; precise, real-time and predictive ISR using AI/ML, change detection, mixed/multiple sensors/payloads like EO, IR, SAR, ISAR, SIGINT; missile launch detection & threat intelligence integration; dynamic target recognition with real time downloading of data to static and mobile ground stations; data interoperability with weapon systems for Long Range Precision Targeting (LRPT); AI/ML enabled Intelligentisation to filter fake/poisoned data; Sensors with a dynamic range of 120dB (presently 90dB). Capacity building for indigenous HSI technology requires immediate attention. Initially, the land forces need a revisit time of 1-2 hours over select critical areas, though combination of EO/IR and SAR capabilities.

(e) **Resilient Satellite Communications**. Current capability of 350 transponders and 111 leased transponders is inadequate for meeting future needs. Dis-aggregated, distributed and diversified capabilities are needed. LEO Satellite constellation based military internet; leveraging 5G/6G technologies for IoMT; software defined communications; high bandwidth laser/optical/ free space secure communications; Tactical Data Relay Satellites (TDRS), low latency; more exploitation of Ka, Ku, Q, V Bands; ELINT and COMINT with fingerprinting.

Antenna nulling and adaptive filtering technology are needed as anti-jamming and anti-spoofing techniques.

(f) **Position, Navigation & Timing (PNT)**. Resilient PNT, expanded IRNSS/NavIC coverage (3000 kms around the Indian sub-continent) and eventually global coverage; small receivers, precise guidance of missiles, aircraft and unmanned vehicles.

(g) **Space Situational Awareness (SSA)**. Though SSA control centre, NETRA, was set up by ISRO in Dec 2020, more ground (radars and telescopes) and space-based systems (satellite based sensors) are needed to enhance SSA and Space Surveillance & Tracking (SST) capabilities to monitor and protect assets in space.

(h) **ASAT and Counter-ASAT Capabilities**. Kinetic (Direct Ascent, Co-Orbital) and Non-kinetic (EW, Laser, HPM, chemical sprays and EMP) capabilities be developed to deter adversaries.

(j) **International cooperation** address gaps in technology, sharing of SSA information and evolution of inclusive regulatory / policy frameworks. NATO has proposed a real time analysis and sharing of military and commercial satellite imagery called NATO APSS 2023. Indian armed forces too could explore such collaboration.

(k) **Availability of trained pool of manpower**. Large pool of professionals is required for AI/ML applications for imagery analysis and decision support systems.

(l) **Need for Defense Space Policy, Strategy and Joint Defence Doctrine.** In addition to the building capabilities to use civil-military space assets optimally, there is a need to evolve a space strategy, joint space doctrine and importantly greater cyber-space integration.

(m) **Synergy between Govt and Private players**. Need to remove the disconnect between the military and private entities to ensure that the Indian ecosystem provides the desired space services. There is a need to define and streamline the roles of all stakeholders for capability building by adopting a systems approach.

Challenges. Technological advancements have enabled countries to develop space assets to achieve superiority in space and terrestrial situations awareness. Besides the challenges of space weather, solar phenomenon and space debris, Space has become increasingly more contested, congested and competitive due to a spurt of satellites, especially in LEO. Currently, there are 29 countries which are using space for weather, command and control (C2), communications, sensors/detectors (IR detectors for submarines), SAR, platform tracking (ADS-B for aircrafts, AIS for ships), ballistic missiles and cruise and hypersonic missiles. This is no international treaty or binding regulations on weaponisation of space and ASAT, ASAT mines, co-orbital warfare, EW and directed energy weapons. In future, particle beams may also be weaponised. In order to develop Defence Acquisition Policy and Defence Procurement Procedure in the space segment, there is a need to establish a structured and consultative approach involving relevant stakeholders to develop and update acquisition policies regularly, by taking into account industry inputs and future requirements. There is a need to foster greater collaboration between civil, military, industry and academia to achieve technological spin-offs

Space Vision and Policy. In April 2023, Govt of India released the Space Policy 2023, which has an overarching, composite and dynamic framework to implement the reform vision approved by the Cabinet. The Vision of the Government is to augment space capabilities; enable, encourage and develop a flourishing commercial presence in space; use space as a driver of technology development and derived benefits in allied areas; pursue international relations, and create an ecosystem for effective implementation of space applications among all stakeholders, for, the **nation's socio-economic development and security,** protection of environment and lives, pursuing **peaceful exploration of outer space,** stimulation of public awareness and scientific quest.

Strategy. In pursuance of the vision set out for the space sector, Government seeks to pursue a holistic approach by encouraging and promoting greater private sector participation in the entire value chain of the Space Economy, including in the creation of space and ground-based assets. Thus, Indian consumers of space technology or services (such as PNT, communication, remote- sensing, data-services, launch-services, etc), whether from public or **private sectors, shall be free to directly procure them from any source**, whether **private or public**. The focus is on: -

(a) Encouraging advanced Research & Development to sustain and augment the space program.

(b) Providing public goods and services for national priorities,

(c) Creating a regulatory framework to provide a level playing field to Non-Government Entities (through IN-SPACe), SIA, ISpA etc.

(d) Promoting space-related innovation, including support to space-sector start-ups, and

(e) Using space as a driver for overall technology development and nurturing scientific temperament.

Non-Governmental Entities. **NGEs** shall be allowed to undertake end-to-end activities in space sector through establishment and operation of space objects, ground-based assets and related services, such as communication, remote sensing, navigation, etc.

Emerging Trends in Militarisation of Space. Counter space operations aim at enabling own forces to exploit space capabilities while negating adversary's ability to exploit space capabilities. In order to maintain desired degree of space control/superiority, salient emerging trends are as under: -

- **Anti-Satellite (ASAT) Weapon Systems.** Some leading counties including China have developed ASAT weapons, which include direct ascent as well as Space based capabilities. Some countries are reportedly developing the technology to melt satellites. ASAT capabilities provide another rung of conflict escalation between conventional and the nuclear thresholds.
- **Rocket, Missile and Aircrafts.** Long range rocket systems with varying warheads capable of self-acquisition of targets, precise engagement and

assured destruction are becoming the norm. Hypersonic missiles can avoid detection and countermeasures. Countries are developing missile systems as well as aircrafts which can engage aerial threats as well as satellites. These capabilities rely heavily on space-based capabilities.

- **High-Altitude pseudo-Satellite (HAPS) Systems.** HAPS are being used in the “Near Space” threshold. Drones, swarms, HAPS, and their counter measures rely heavily on space-based capabilities for C2, surveillance and targeting.

- **Electronic Warfare.** Space based services and capabilities are entirely dependent on the Electro-Magnetic Spectrum (EMS) for C2/communication links and streaming of data. Space based assets are being leveraged for SIGINT, offensive dazzling using high energy lasers using miniaturised electronics technology.

- **Cyber Warfare**. Banks, financial institutions, health infrastructure, power grids and other critical national infrastructure use space-based services both during peace and war. Cyber-attacks can target satellites and ground infrastructure to deceive, disrupt, deny, degrade, destroy space based as well as ground-based assets. Besides cyber-defence and resilience, legal regulations are needed for tackling such attacks on critical information infrastructure.

Key Takeaways From the Deliberations

Communications. Networks and information-based power projection plays a dominant role in warfighting and space-based communications are a major pillar. Flexible routing, channelisation, redundancy, usage of smart antennae and quantum communications will enable secure communications. Edge computing, data clouds and data centres also create new vulnerabilities.

- **Software Defined Radios**. Space qualified SDRs need to be developed. Alternately, commercially available COTS electronics component and system be developed with fault tolerance systems to reduce the cost and develop systems faster.
- **Quantum Communication.** Real time communications and data collection is the need of the hour, and the future lies in high throughput satellites, for higher bandwidth data collection and communications. The industry should not only provide secure 5G/6G networks, but use of Quantum technology needs to be leveraged to enable secure communications. Currently, India's terrestrial quantum communications capability is at an experimental stage. However, the country needs to develop and launch quantum satellites and exploit Quantum Key Distribution (QKD) technology. In addition, there is a need to develop quantum data teleportation.
- **AI Driven Spectrum & Power Management**. Growth of Space based assets have made spectrum a critical asset. Therefore, communication networks using Ku Band, Ka Band, V Band, 5G/6G, optical and Free Space communications are required for providing high bandwidth and resilient links. Exploding space usage is leading to unprecedented spectrum congestion and competition. Therefore, dynamic, AI driven spectrum and power management are needed.
- **Tactical Data Relay Satellites.** GEO satellites are strategically positioned at a fixed point above the Earth's equator, ensuring that they always remain stationary relative to ground. GEO satellites are preferred for communications, broadcast and banking, but they are costly to launch and operate, and suffer from higher latency of communications. India's GSAT series communication satellites have data transfer capabilities up to 48 Gbps capacity. However, the growth of LEO satellites is inevitable primarily due to advantages arising out of lower latency and global footprint. Therefore, the need for relay functions for LEO satellites will grow as the numbers keep increasing.

- **Operating in Denied and Degraded Environment and HAPS**. Satellites should be able to figure out the jamming conditions and be able to tackle these conditions by switching frequencies. The ground-based infrastructure should also be able to handle these conditions. Therefore, the use of Near Space Assets like HAPS-Pseudo Satellites should be developed for providing support up to several months and have the ability of processing of data independently. HAPS is becoming more real due to availability of new lightweight material, advanced avionics, advanced and lightweight batteries, tech miniaturisation, low costs of production. It can be a bridge between unmanned systems and satellites and can be brought down for undertaking maintenance and repairs. There is a need to have an integrated approach using IoT. ISRO is currently developing a HAPS solution.
- **Satellite Connectivity for Leveraging** IoMT (Internet of Military Things) and IoBT (internet of Battlefield Things) will enable full spectrum communications interoperability. Interconnection of network of sensors and IoT devices at scale and offers game-changing capabilities, using cloud and edge computing to create a cohesive and efficient fighting force. IoMT and IoBT technology can range from battlefield assets like ships, tanks, drones or even soldiers, data analysis centres, secure Satcoms, integration of existing and new devices, direct sensor-to shooter systems, and low power consumption devices for CubeSats, nano-satellites which form a part of a concept of IoST (Internet of Space Things). There is a need to explore different used cases using different Service Level Agreements. A network sharing framework is vital of IoST. The connectedness requires different standards for its architecture for ensuring that communication between sensor to sensor and sensor to ground stations are robust. However, IoBT and IoMT are vulnerable to cyber-attacks. The challenges will come from bugs within the systems, along with hardware problems associated with IoBT and IoMT devices. Low latency is required forthese applications and LEO and MEO combinations will provide 100% connectivity across vast regions. However, there is a need to design failsafe systems to face EMP burst, solar storms and incorporation of AI systems to enable quick detection of intrusions. Conducting Blackbox testing will help

better testing to avoid intrusions, except when brute force is used for intrusions. Small form factor and low energy requirement demands of consumer creates challenges for the manufacturer and hence lightweight robust IOT devices along with security protocol must be developed.

- **Nano, Micro, VLEO Satellites** (200-350kms**)** will require constellations of satellites some of which will relay data while not flying over the sub-continent, and provide very high resolution in EO and SAR for providing battle space transparency. A large number of assets will be needed to ensure redundancy and contingency planning for the worst-case scenarios. These satellites should have a real time self-fault reporting system. CubeSAT satellites are light and hence poor payload stabilisation due to vibrations results low quality imagery, which needs to be addressed. **ASAT Capabilities and Countermeasures**. Hard kill using direct ascent ASAT is not a desired option, due to the debris generated. High power laser and HPM, whether ground, air or space based, using miniaturised electronics components, are better options.
- **EMP Hardening and Shielding** for the onboard sensors will become a key issue, more so where edge computing built-in.
- **Cyber hardening** needs to be improved. India's Space sector should closely work with the software companies to develop indigenous solutions for jamming as well as spoofing. Data intercept/monitoring, data corruption as well as seizing the control of satellites are some the cyber-attack threats for which the designers must find solutions like Host Based Intruder Detection System (HIDS). Space and Cyber have to be integrated more closely.
- **Thrusters**. Plasma thrusters are needed to enable manoeuvring of small satellites and co-orbital assets- capability which has been exploited minimally, so far.
- **Non-Kinetic ASAT.** Lasers, EMP weapons and High-Power Microwave technology having power up to 1 GW would need to be developed.
- **Space-based Ports/ hubs** will enable longer and safer missions. Launch on demand (LoD) capabilities will require quick launches and ground infrastructure

to sustain these capabilities. Hence, the funding, storage and servicing ecosystem for these payloads, till such time they are launched needs to be evolved. The fact that such payloads need 5-7 days post launch, before activation and optimal utilisation, must also be factored.

ISR. Situational awareness helps identify the threats, both natural as well as man-made**.** Hence, the development of an indigenous, world class image processing, remote sensing and survey software is an urgent necessity. In an event of a satellite becoming in-operative, there is a need to have quick replacements by Launch on Demand (LoD) or by developing redundancy**.** Precise, real time and predictive ISR using AI/ML will assist armed forces to develop common operating picture for all three services**.**

- **Missile & Launch Detection.** Space is the ideal domain for detection of cruise/ballistic as well as Hypersonic Missiles. In future, the capability to destroy hypersonic threats using soft kill will help in neutralising the threats of speed and manoeuvrability while flying at lower altitudes. There is a need to have overhead persistent infra-red detection capability to monitor ballistic, cruise and hypersonic missiles. Space based sensors will require sensors to detect, another set to process and counteroffensive systems to tackle such threats during the glide phase where the weapons is skimming space before it reenters the atmosphere-the longest phase of flight between launch and terminal phase.
- **Data Fusion & Edge Processing.** Increase in space assets has generated unprecedented volumes of a very critical product-"Data" and therefore, AI and ML are used to process the information dynamically, in real time. Data collection, cataloguing and dissemination is a critical capability. Leveraging AI/ML for fusion of data for change detection would enable commanders and practitioners to identify their targets correctly and timely. Archival storage and processing on the edge needs to be developed to shorten the OODA loop. In the Indian context, advancements in AI and ML have not impacted the space domain fully. AI standards are needed to ensure that all sensors and ground segments are interoperable, since most agencies in every country work in silos. However, the training data for AI is very important and 'poisoned' or 'biased'

data can lead to catastrophe. Currently AI is being used for support functions. However, in the future, increased use of AI in the space domain may end up controlling main functions, which may potentially be a risky situation. Hence, the human element in the loop should not be removed. In addition, satellites must have self-healing capability, especially for critical operations related functions. Algorithms should be able to predict better, work with multi-domain system of systems, be scalable to provide better targeting solutions.

- **ISAR, Hybrid & Hyper-spectral Imagery (HSI).** Sensors with spatial and spectral resolution is an important need for military. These applications are under export restrictions for military applications, though are available for academic and agriculutral use. Higher resolutions facilitate correct assessment of the threats. Armed Forces needs to monitor changes at the millimetre level. Differential interferometry can be used for predicting natural disasters. IPB is a geospatial perspective of the terrestrial area and a geospatial profile helps identify targets using space-based and aerial data. HSI provides characterisation and material identification, enabling change detection. HSI-SAR fusion minimises false detection and confirms target location. This capability needs to be developed indigenously, with an accuracy of 5 meters. Similarly, indigenous HSI-LiDAR fusion capability is a must for aerial and space-based applications, along with the capability to tip and cue by RF sensing. Blue-Green Laser technology is needed for satellite communications with submarines.

- **Software Development Strategies.** Backdoors in processors and software is a major concern during the development cycle. Agile software development model in the military sector faces several challenges. Hence, agile, along with waterfall methodology may be adopted for space related facilities.Secure waveforms and encryption techniques should be employed to safeguard communications

- **Software Defined Satellites**. This essentially means replacing traditional hardware components with software, this implies that the mission can be reconfigured throughout life, based on changing requirements. Eutelsat Quantum (launched 30 July 2021) is an example, whose beams can be reshaped and redirected to provide information to people on planes and cars in real time.

- Pseudo satellites like balloon, blimp and airships, collaborating with UAVs need to be deployed for ISR roles and as communication hubs.

Meteorology. Space weather can create anomalies and problems akin to denial of Space Situational Awareness (SSA). Nations with SSA capability will be able to identify and track space weather events. Geomagnetic storms induce large currents in LEO and GEO leading to satellites getting damaged due to shorting. Geo-magnetic storms can also affect ground infrastructure in many ways. Recently, Star Link lost 32 satellites due to a Geomagnetic storm. There is a need to have meteorological sensors on every satellite as a standard feature, which can detect and navigate space weather.

Use of AI and ML to calculate and track solar weather events like solar flares including Coronal Mass Ejections is something which all nations are exploring to protect their space assets. ISRO, DoD and the private sector must work together to develop and use technology, sharing real-time information using various sensors.

PNT. PNT for space and ground segment can be rendered resilient by having multiple signals and services including multiple GNSS. IRNSS constellation of ISRO provides PNT over the Indian region with an accuracy of 20 m on 4G and 5G phones. IIT Tirupati is engaged in the development of PNT products like atomic clocks, NavIC system etc.

At the system and device level, the industry needs to build resilient PNT capability through other means at the RF, Digital and processing level. IRNSS footprints need to be enhanced to 3000km around the Indian Subcontinent, and finally become global. Elena Geo Systems has launched the first composite dual band (L1, L5) NavIC chips with orders from the Indian Army. Besides IRNSS, it uses signals from GPS and GLONASS.

Launch, Ground Stations & Maintenance.

- **Smart Propellants, Launch on Demand (LoD), Mobile, Off-Shore, Reusable Launch.** Electric thrusters are under development specially if the satellite is launched in the lower atmosphere. They will have better maneuverability and can last longer without fuel. A reusable space launch platform will reduce the average cost of launch. Also, there is a need to reduce the size and weight of payloads so that the cost of launch reduces. In addition, quick launch of satellites can be done using different mobile ground stations which will provide flexibility of launch on demand during conflicts. Finally, there is a need to develop advanced propulsion systems and mission planning algorithms to optimize spacecraft trajectories and reduce fuel consumption.

- **Robotics, 3D Printing, Self-healing Satellites, On-Orbit Servicing, Assembly and Manufacture (OSAM).** Nations need to repair and maintain their space-based assets using these technologies. Research into self-repairing satellites using nanotechnology, launch of dummy/loitering satellites, quick replacement of damaged space assets and other actions like deployment of redundant hubs need to be undertaken. On-orbit repairs and refueling capabilities using space-based hubs needs to be harnessed.
- **Ground Stations**. Satellite-based detection, including that by commercial nano-satellites calls for several ground stations, which collect and distributedata, the most critical asset. The footprint of these technologically sophisticated ground stations would enable real time download of imagery (electro-optical, radar, Infra-red, SAR). LEO slots in space are getting increasingly crowded. Although technology for ground stations for the larger GEO satellite class is well developed, the same needs to be done for multiple LEO satellites as the demand for simultaneous tracking and command of many LEO satellites creates more demanding requirements for pointing and tracking. Multiple communication bands will need to be used by the ground stations. Therefore, adequate and regionally/globally spread ground stations would be needed.
- **Inter-Planetary Space Programs**. ISRO missions to moon “Chandrayaan-3” followed by “Aditya-L1” to the Sun are likely to take place in July 2023. Chandrayaan-3 consists of an indigenous lander module and a rover and will demonstrate new technologies required for interplanetary missions. These

capability demonstrators are needed to keep India abreast with the leading spacefaring nations.

SSA

- **Space based SSA Sensors**. This capability needs to be augmented at the earliest. Better optical surveillance and resolution enhancement capabilities are needed. The US has SSA systems which can achieve miss distance and probability of collision to the probability of 10^{-6}.
- **Ground-Based Radar & Optical Assets**. More Phased Array Radars are needed to bolster the SSA capabilities. The feasibility of merging Air Defence (IACCS program) and SSA infrastructure could be examined to strengthen integrated Air and Missile Defence.
- **Collaboration for SSA** with partner countries, like a recent dialogue with the US, needs to be explored since the round the clock surveillance of impending natural as well as man-made space emergencies are beyond the capabilities of any one nation.
- **Space Debris.** Space surveillance and SSA capabilities involves monitoring, tracking, cataloguing, analysing and informing the users to help obviate damage due to space debris**. Many collisions in space are either reported late or not reported, highlighting the lack of space-based asset tracking.** It is estimated that out of 15430 satellites launched, 10290 are still in orbit and 7600 are still operational. There are about 36500 debris still in orbit whose size is bigger than 10cm, which travel at very high speed (32,000km/hr), which can render satellite inoperable. **As on Jan 2023, India has 111 payloads,105 space debris and has undertaken 21 collision avoidance manoeuvres in 2022.** The 830-900 km altitude band is saturated with derelict, non-maneuverable space assets, most of them dating back to the cold war. This underscores the importance of **Active Debris Removal**. Satellite laser ranging can be done only if the satellite is built for this purpose. Having redundant systems which can independently verify, and track space objects is a necessity, to ensure uninterrupted operational capability in space. The commercial sector

needs to be an active player, besides international cooperation in space. Space debris analysis calls for automation and prediction using AI/ML. SSA networks of assets like radars and telescopes lack interoperable architecture. There are gaps in coverage and sensor capabilities. The capability to detect space debris measuring 1mm-1cms is inadequate. Currently, micro-satellites are denied permissions because they cannot be easily detected, tracked and cannot be maneuvered to safety, if needed. Countries like the US have catalogued space debris, and the data is shared online. Russia, France, Asia Pacific Space Co-operation Organisation and EU also maintain this data. Indian Institute of Astrophysics is working with many nations to build a 30-meter diameter telescope to monitor GEO satellites. Advanced ground radar systems can look into the lower edges of space. Space Data association and International Scientific Optical Network are also engaged in surveillance of space debris in addition to commercial SSA providers based in US, Canada, Germany and Digantra in India. There are issues related to incomplete catalogues in any SSN. This requires data standards to be devised and interoperability amongst various agencies to ensure that the data is shared between satellite operators. ISRO has set up a directorate of SSA and Management and a SSA Control Centre has been established at Bangalore, foe debris identification, modelling and removal.

Incentivising the Industry-Roadmaps and Patents. Patent regulations must ensure that those who do the research keep their IPs. The Indian ecosystem should encourage local patent by enabling quick orders by govt and private players to the patent holder thereby increasing its business potential. This will enable the holder to earn money without much delays and thereby discouraging the Indian companies from filing patents abroad. Space capability roadmap of the armed forces needs to be shared under the Officials Secrets Act. The DAP 2020 does not provide clear metrics to measure indigenization level in technology, and it still allows significant purchase from foreign vendors. There is a need to define measurable indigenisation metrics and gradually increase the requirement for indigenous production to reduce dependence on foreign vendors, encouraging self-reliance in the space industry. There is a need to allocate higher funding for Research and Development initiatives.

Standards. There is a need for IN-SPACe to prepare Standards for ecosystem so that the private and Government systems are interoperable and help Quality Assurance agencies accept the equipment for military applications. Components being produced by private vendors should meet the space grade standards for use in military as well civil space sectors. Lightweight, low energy consumption, robust IoT and IoBT devices along with security protocols are needed for achieving excellence. ISRO should take the lead in formalising Standards.

Space Diplomacy. Space is important from both strategic as well as economic point of view. International cooperation is the key to successful space operations. Space cooperation could be driven by shared corporate interests, as these players will continue to set the rules for space-based activities. There is a need to establish mechanisms for sharing best practices, lessons learnt, technical knowledge amongst space agencies, industry stakeholders, and academia. Large number of LEO satellites would lead to congestion and the probability of close encounters in space are likely to grow. These shared vulnerabilities call for greater collaboration between nations to address the risk of inadvertently exacerbating tensions and potentially triggering diplomatic or military conflicts. Secondly, Indian membership of export control regimes helps avoid technology denial. ISRO has signed more than 275 MoUs with 40 plus nations and NISAR satellite with the US is an example. In addition, ISRO has launched satellites made by various nations and enjoys high standing with other space agencies. India needs partners to collaborate for material assistance and technology. Therefore, MEA and the embassies must leverage their outreach. African Space Agency, Latin American and Caribbean Space Agency and Arab Space coordination group are examples of organisations where nations have come together to form multi-national space organisations. Similarly, Asia-Pacific Space Cooperation Organisation, which includes many South and South East Asian countries, is funded by China to ensure that their Beidou and other services flourish. There is a need to strengthen mechanisms for resolving disputes and managing conflicts in the space domain through diplomatic channels by encouraging dialogues, mediation. Thirdly, strengthen existing international treaties, such as Outer Space Treaty, COPUS (Committee on the peaceful use of Outer Space) and Moon Agreement, by encouraging more countries to ratify and abide by their provisions. MEA must promote dialogue and diplomatic negotiations to address emerging challenges and enhance the effectiveness of space governance frameworks. India must support United Nations Office for Outer Space Affairs and other international organisations in their efforts to coordinate space related activities and facilitate information exchange.

Defence Space Strategy and Doctrine.

- The National Space Policy has been promulgated. The Defence Space Policy, Defence Space Strategy and Defence Space Doctrine need to be formulated and promulgated earliest, to ensure inter-ministerial, inter-agency and inter-service coordination and unity of effort towards delivering the desired commercial and defence capabilities that reinforce and compliment each other. This will bolster India's capabilities to enhance regional and global peace and cooperation, through international cooperation.
- Space assets play a critical role in ensuring Economic growth and National Security. This dependence on space is a critical vulnerability for all Nations, which is increasingly being threatened by adversarial nations, through growing kinetic and non-kinetic capabilities
- **In concert with DoS, ISRO, IN-SPACe and NSIL, DSA** is spearheading the strategy and doctrinal development endeavour. The doctrine must clearly articulate the salience of space domain, integration of space with physical and information domains and the roles and capabilities needed for resilient and robust Space support, Space Situational Awareness and Space Services ISR, PNT, SatCom and Space Counter-measures. Space infrastructure and roadmap needs to be elucidated.

Civil-Military Fusion In Space Capability Development. Civil military integration would require a national strategy and plan that defines a mechanism that facilitates implementation through top-down centralised governance structure and bottom -up commercial led development. Great strides have been taken by ISpA (Indian Space Association) and Satcom Industry Association (SIA-India), besides pathbreaking steps by IN-SPACe. However, all efforts need to be synergised, harmonised and much more needs to be done to incentivise the private sector to meet military space capability requirements. The development of indigenous technology for civil as well as military for the space industry will require following actions-

- Armed Forces, regulators and other Government agencies need to collaborate with private partners, both start-ups and bigger industries, to develop future technologies to enable holistic development of space assets. The private industry should preferably focus its efforts on downstream capabilities like space applications.
- Standards for data and AI needs to be developed and implemented between the govt and private sector to ensure security and interoperability.
- Need to create demand for the growth by promulgating long-term and short-term roadmaps. If the demand is low, the development will be slow. iDEX and TDF are two initiatives by MoD to reach out to the industry to participate in the growth of the defence space sector. The start-ups, are critically dependent on funding and PLI. There is a need to optimize sharing of R&D and production facilities.
- ISRO has developed large number of supporting Indian industries for the development and production of space parts, which ISRO integrates. Hence, an ecosystem is in place to produce satellites, launch and other related systems. There is a need to develop expertise in re-usable systems; AI /ML, robotics to enable remote maintenance, reduce human error and keep astronauts safe. The civil and govt partners should collaborate with each other, working synergistically for a better and efficient space ecosystem. There has to be trust between government and private players.
- Training of professional for skill development in the space segment and ground processing of data for military as well as civil partners will help the industry to thrive.

- Reusable Launch Systems (RLV) will help in achieving reduction in cost and development time, especially on the launch side
- Invest in R&D organisations so that the development time taken to deliver a product is reduced. i.e technology should be readily available to address a problem faced during the development process through collaborative efforts.
- There is a need to create a National Technology Commission to oversee the growth and facilitate dialogue, collaboration and sharing of information and expertise between the different players.
- There is a need to build civil-military redundant hub systems as a backup to keep space systems resilient during any adverse contingency.
- There is a need to develop mission planning algorithms jointly.
- Develop Space corridors along with defence corridors being developed in UP and Tamil Nadu so that technological collaboration is facilitated through subsidies and tax benefits.
- Continuous vigilance on vendors to ensure that cyber-attacks on all parts of the supply chain are mitigated.
- On April13,2022, Bangalore based Bellatrix Aerospace achieved a milestone by successfully testing India's first high performance green propulsion system which is a greener alternative to conventional hydrazine-based satellite propulsion systems. However, the development of Electric propulsion is the way forward.
- In order to provide small form factor integration of diverse sensors in IoT, India needs to develop gateways like LoRaWAN, which is a low-power, wide area networking protocol built on top of the LoRa radio modulation technique. It wirelessly connects devices to the internet and manages communication between end-node devices and network gateways.
- Strengthen cooperation between space agencies and regulatory bodies to harmonise licensing, funding mechanisms, authorization, and supervision process for commercial space activities.

- Promote open data policy to facilitate the sharing of space -related data and encourage cross disciplinary research collaborations between space and other scientific fields like nano-technology, agriculture, biology, energy etc.
- Advances in Hyperspectral and thermal band sensors need to be accelerated along with manpower to use and analyse the data sets.
- **Indigenisation of Critical Sub-Assemblies/Components.** A few critical sub-assemblies/components for satellites are still import dependent and the process takes over one year in certain cases. These items need to be identified and prioritised for indigenisation by the Private Industry.