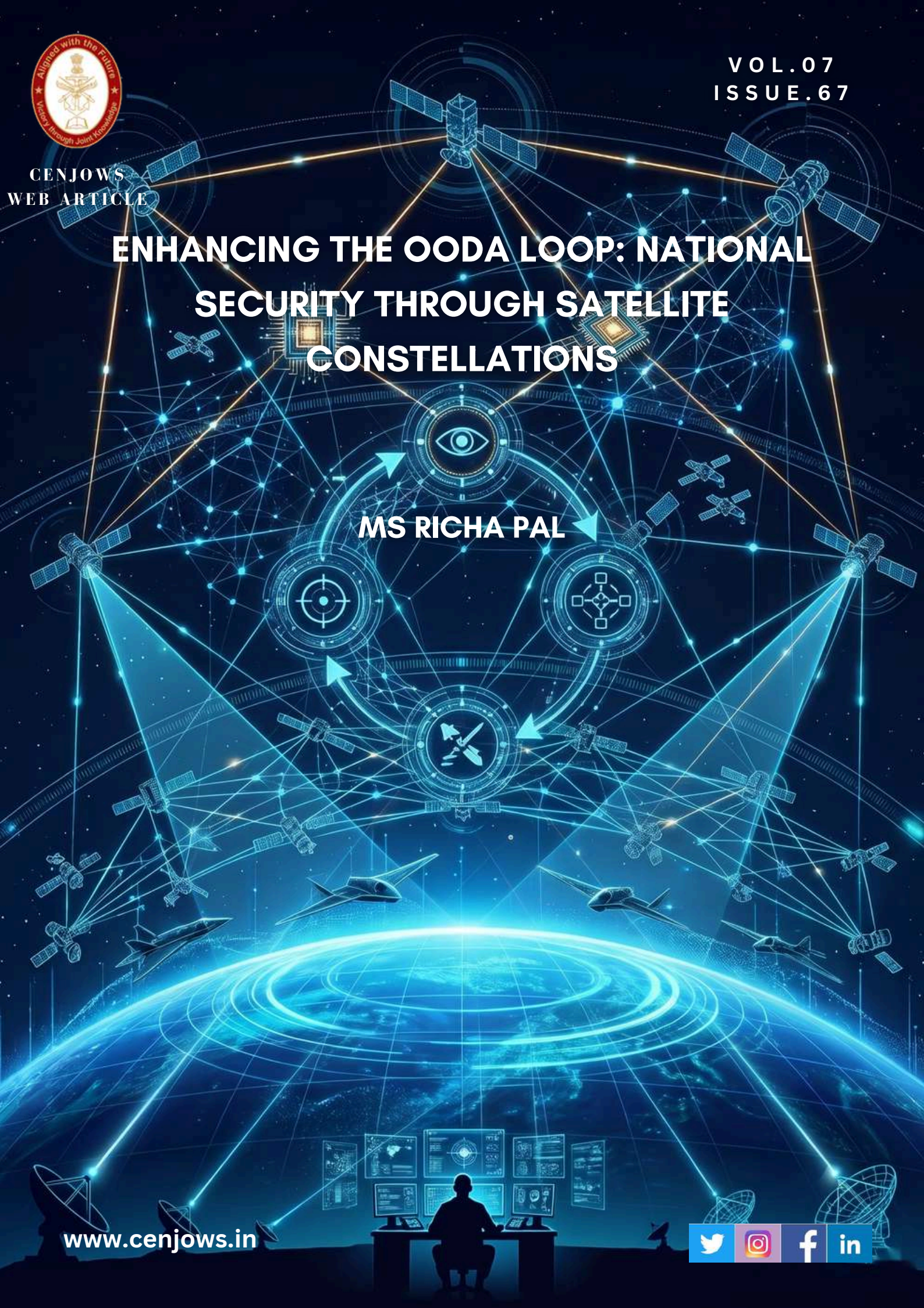
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ENHANCING THE OODA LOOP: NATIONAL SECURITY THROUGH SATELLITE CONSTELLATIONS

MS RICHA PAL



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Room No 301, B-2 Wing, 3rd Floor
Pt Deendayal Antyodaya Bhawan,
CGO Complex, Lodhi Road
New Delhi –110003 (INDIA)
Telephone Nos: 011-24364881, 24366485
Fax: 011-24366484
Website: www.cenjows.in
E-mail: cenjows@cenjows.in

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301, B-2 Wing, 3rd Floor
Pt. Deendayal Antyodaya Bhawan CGO Complex, Lodhi Road
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Editor : Maj Gen (Dr) Ashok Kumar, VSM (Retd) (dg@cenjows.in)

Deputy Editor : Dr Ulupi Borah, Distinguished Fellow
(distinguishedfellow1@cenjows.in)

Editorial Board :

Brig K Ranjeev Singh, VSM (ddg@cenjows.in)
Col Ajay Kumar Rajak, SM
(secy@cenjows.in)
Gp Capt Ashish Kumar Gupta (Retd)
(seniorfellow2@cenjows.in)
Dr Ulupi Borah, Distinguished Fellow
(distinguishedfellow1@cenjows.in)
Dr Monojit Das, Senior Fellow, PRO (monojit.das@cenjows.in)

301, B-2 Wing, 3rd Floor
Pt. Deendayal Antyodaya Bhawan
CGO Complex, Lodhi Road
New Delhi-110003

Publication Head : Ms Vaibhavi Katal

All correspondence may be addressed to:

Editor

Centre for Joint Warfare Studies (CENJOWS) 301, B-2 Wing, 3rd Floor

Pt Deendayal Antyodaya Bhawan CGO Complex, Lodhi Road
New Delhi-110003
Telephone: (91-11) 24366485/Telefax: (91-11) 24366484 e-mails: cenjows@cenjows.in / cenjows@yahoo.com Website: http://cenjows.in

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ENHANCING THE OODA LOOP: NATIONAL SECURITY THROUGH SATELLITE CONSTELLATIONS

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CENTRE FOR JOINT WARFARE STUDIES

CENJOWS

ENHANCING THE OODA LOOP: NATIONAL SECURITY THROUGH SATELLITE



Author: Richa Pal, Research Intern, CENJOWS

Abstract

National security is shifting from the traditional domain of land, sea, and air to safeguarding a domain far away in Space. Space security is heavily dependent on surveillance, decision-making, and real-time action. Ongoing global conflicts have showcased the importance of the advancing operational use of satellite surveillance and intelligence. The global shift from Geostationary (GEO) satellite orbit to a multi-layer orbit spanning GEO, Medium Earth Orbit (MEO), and Low Earth Orbit (LEO), along with emerging technologies, can redefine modern warfare. India's latest liberalised space policies are expected to sharpen the nation's network-centric warfare capabilities. This paper argues that this multi-layered shift, paired with AI-enabled decision-making, can shrink the sensor-to-shooter timeline from hours to minutes, ultimately compressing the Observe-Orient-Decide-Act (OODA) loop. Automated cueing and triage of Intelligence, Surveillance and Reconnaissance (ISR) imagery can reduce cognitive fatigue and speed up decision-making but risks bypassing human oversight and raises concerns over accountability. The paper identifies five capacity gaps, i.e., surveillance revisit and spectrum limits, ground segment resilience, indigenous navigation, orbital safeguarding

and trust in AI. In addition, it recommends NavIC restoration, phase-wise expanding Space-based Surveillance-III (SBS-III) programme, onboard edge computing, GEO relay, and anchoring Explainable AI (XAI) with human-in-the-loop control.

Introduction

For centuries, one of the fundamental rules of defence has been that whoever holds a higher elevated point controls the battlefield below. Be it sea, land, or air. Advancing technologies have pushed national security upward towards space, i.e., the fourth domain of security. India's combat capabilities are compromised unless it prioritises the strategic necessity of safeguarding space. Advancing space-based assets and navigation capabilities could potentially reshape the global peace order.

The recent global conflicts like the Russia-Ukraine war and the June 2025 Israel-Iran 'Twelve-Day War' have demonstrated that modern warfare is not just about fireworks but also speed in decision-making. Any nation's military must conduct continuous surveillance to understand the emerging threat, make a decision, and act first. Former United States Air Force (USAF) fighter pilot and military strategist John Boyd formulated a framework known as the Observe, Orient, Decide, and Act (OODA) loop. Boyd's framework was not merely based on speed but on paralysing the enemy's mind and command structure. While Boyd brings a framework for cognitive and decisive superiority, executing this in modern warfare requires transitioning from single-layered to multi-layered orbital architecture to address necessary hardware and operational demands.

For India, catching up with this high-speed advantage is an urgent priority. Linking smart LEO satellites into a broader multilayered network could shorten India's military response time. However, it introduces key capacity gaps and ethical dilemmas, demanding a clear line of accountability.

Orbital Architecture: GEO, MEO, LEO

Historically, this loop was bottlenecked by single-layered space architecture, which heavily relied on Geostationary (GEO) satellites. While GEO satellites provide immense strategic

geographic area coverage for early warning, it suffers from high vulnerability, a small number high in value, and can be an easy target for jamming and anti-satellite (ASAT) weapons, also have high latency. So, we should shift our focus from single-orbit reliance to multi-orbit space architecture.

Features	**Geostationary Earth Orbit (GEO)**	**Medium Earth Orbit (MEO)**	**Low Earth Orbit (LEO)**
Altitude	35,786 km	2,000-35,786 km	160- 2,000 km
Latency (round trip)	541 ms (transparent payload); 271 ms (regenerative payload) [1]	93.45 ms at 10,000 km (transparent payload) [2]	25.77 ms (transparent payload); 12.89 ms (regenerative payload)[3]
Coverage per satellite	Almost ⅓ of the Earth at practical elevation angles; poor coverage above 75-80 degree latitude.	Regional coverage	Highly focused tactical footprint
Cost per satellite	₹ 2,563 crore for GSAT-7C.[4]	$104 Million per satellite (O3b mPOWER, commercial broadband)[5] to $ 650 million per satellite (GPS IIIF, for GNSS/PNT).[6]	₹ 100 crore (Light Earth observation satellite)[7] to ₹ 351.16 (Cartosat 3) satellites.[8]
Military Role	High bandwidth command links, early warning	PNT and advanced satellite communications (SatCom)	Rapid ISR, low latency, Earth observation, onboard Edge AI

Source: Compiled by the author from 3GPP (2021); NGMN (2019); Akashvani News (2026); Selding (2020); Machi (2018); Satnews (2026); and Government of India, Department of Science (2021)

In a multi-layered architecture, GEO satellite-based constellations maintain strategic global beam coverage, while Medium Earth Orbit (MEO) satellites focus on global navigation satellite systems (GNSS) like GPS and Galileo, also communications satellite like O3b mPOWER. India's regional navigation system, the Navigation with Indian Constellation (NavIC) system, uses GEO and inclined geosynchronous (GSO) orbit.[9]

The Low Earth Orbit (LEO) satellite constellations act as a catalyst to reduce the OODA loop. As it provides several benefits such as lower latency and through proliferation, distributed beamforming has greater resilience to jamming than a small constellation of high-value GEO satellites.[10]. To ensure rapid revisit rates requires a large constellation across multiple orbital planes. Finally, adding artificial intelligence (AI) directly into the satellite's payload enables real-time analysis of complex datasets. This will improve geospatial and space situational awareness.

Understanding Space Control and Operations

The space-based command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) structure draws on space situational awareness (SSA) tracks orbital traffic to command operational tasks.

In 1976, Boyd formulated the OODA loop derived from 'Pattern of Conflict' briefings and expanded the idea in his later work 'The Essence of Winning and Losing'(1995).[11] He expanded the OODA loop into strategic and operational decision-making. One of the important points is that the OODA loop is not a linear sequence, but a multi-directional loop where each phase can influence the others. This can be seen as a web instead of a linear chain reaction.[12] The focal point is the 'Orient' phase, which has multilayered and multidimensional aspects, including moral and mental dimensions. According to Boyd, strategic superiority is not just speed, but the capability to destabilise orientation, causing a cascading effect into "uncertainty, doubt, mistrust, confusion, disorder, fear, panic, and chaos".[13]

The evolution of the OODA Loop can be seen in three stages:

First, Traditional OODA Loop- Earlier, the OODA loop relied on human-driven, manual, limited radio communication, and visual observation. Boyd described "orientation as the centre point, which is shaped by genetic code, cultural traditions and previous experiences, new information, analysis and synthesis."[14]The orient phase is shaped by institutional norms, prior experience, and human intuition. The human cognitive burden of decision-making, as well as human reaction time and command chain latency, constrained military operations. This period was heavily dependent on the level of training and human intuition.

Second, Technology-Augmented OODA loop-

The present stage of the OODA loop is already using advanced technologies with a fusion of AI. India is reaching this stage gradually. The Indian government started the Indian Space Programme in 1962, as INCOSPAR (Indian National Committee for Space Research), primarily focused on civilian applications. The Strategic turning point was the aftermath of the Kargil War, due to intelligence information inadequacies. Following the military success of Operation Sindoor, Lt Gen VP Singh (Retd) noted that the decisive edge for future conflict, "the sensor-to-shooter loop must be closed within seconds rather than hours."[15] The real-time coordination and unified command and control marked the tactical and strategic success.

Following the operational success, the modern OODA loop is observing a technology-driven approach as follows:

- **Observe-** Data collection and real-time multi-domain battlespace awareness.
- **Orient-** identifying a unified concept of operations using digital data, RF signals and Signal Intelligence (SIGINT), and automated threat assessment.
- **Decide-** by shrinking the command chain: Unified C4I Networks, Algorithm-Assisted Options, Integrated Theatre Commands.
  Example: Indian Air Force's **IACCS (Integrated Air Command and Control System)**
- **Act-** Strike: compressing sensor-to-shooter timeline.
  Example: Akashteer, India's fully indigenous Air Defence Control and Reporting System, which intercepts incoming drone or missile threats and neutralises.[16]

***Third*, the Super-OODA loop,** Assistant Professor Michael Raska, from the RSIS Military Transformations Programme, describes a futuristic, highly autonomous AI-driven, fast-paced, and high-intensity operational "Super-OODA loop".[17] It is a sharp shift from real-time data

collection from multiple sources to predictive AI-native surveillance, autonomous decision-making, and decentralisation with minimal human interference.

Michael Raska presents three major developments predicting the upcoming future OODA loop:

- Real-Time Data Integration and Predictive Observations: Raska describes it as AI-enhanced surveillance, edge computing, and cyber intelligence to process vast data into adversarial action.[18] Military application: Synthetic Aperture Radar (SAR), Signal Intelligence (SIGINT), and on-orbit optical imagery, enabling predictive observation.

- Adaptive Orientation Through Machine Learning: Raska explains this by using machine learning to observe complex patterns and adapt dynamically to potential threats.[19] Military application: Onboard Edge AI can perform Automated Target Recognition (ATR), data prioritisation and compression. This reduces heavy raw imagery into small, low-bandwidth data pockets, strategically improving situational awareness before the data touches the ground.

- Autonomous Decision-Making and Immediate Action: Raska relies on pre-defined protocols that bypass human approval for speed. He acknowledges this raises ethical and accountability concerns. His vision is that the Super OODA loop will progressively minimise human reliance in decision-making.[20]

  Military application- Raska points to UCAVs (unmanned combat aerial vehicles) and other AI-enabled self-directing platforms, which act on pre-set protocols at machine speed, reducing human reliance.[21]

The Super OODA loop reduces the human cognitive burden by compressing latency in decision-making. But Raska's own analysis identifies critical concerns like cyber vulnerability (e.g., adversaries spoofing), ethical and legal concerns about accountability, integrating the Super OODA loop into existing infrastructure, and AI may data dump paralysing decision making.[22]

The OODA loop in Russia-Ukraine War: A Case Study

The Ukraine operational manoeuvre- the Kill Zone and Satellite Constellation. During the opening phase of the Russia-Ukraine war (February 2022), Russia's destructive wiper malware called 'AcidRain' attacked Viasat's KA-SAT network, disrupting Ukraine's military communication networks.[23] The intervention of Starlink LEO satellites gave Ukraine crucial leverage in resilience against jamming, restoring communication systems. Currently, Ukraine-led tactical drones are responsible for over 80% of enemy targets among Russian forces.[24] These drones are equipped with Starlink's stable, high-bandwidth communication for effective command and control.[25]

Moving forward, the Russia-Ukraine frontline is evolving towards a 25 km kill zone on each side, and expecting 30 km by end of the year 2026, within which movement is restricted by drone surveillance.[26] ICEYE's Synthetic Aperture Radar (SAR) capability provided persistent, all-weather surveillance day and night, with cloud-penetrating capabilities, with rapid revisit gaps.[27] Ukraine's "GIS Art for Artillery" with Starlink connectivity has managed to reduce call-to-fire from 20 minutes to 30 seconds, giving a measurable highlight for network-centric warfare.[28]

Vulnerability of LEO constellations

Russia has reportedly developed a ground-based uplink jammer, known as "Volna Kupol Garant" or "Wave Dome Guarantor", reportedly described as a system using multiple trailer-mounted antennas to directly interfere with Starlink's satellites.[29] This device targets satellites in orbit, temporarily disabling Starlink service and locally impacting Ukraine's war efforts. This system relies on narrow, high-power radio frequency beams which temporarily interfere with a specific satellite to serve ground stations, but cannot block completely.[30] A key operational issue is that this system can disrupt one satellite at a time within a megaconstellation of Starlink. The weaker point for Starlink lies outside the satellite, which is GPS. In January 2026, the Iranian government reportedly jammed GPS instead of jamming Starlink, which seemed to have to practically disable Starlink for a while, which is well needed for precision timing and location.[31]

As discussed above, the satellite capability can be denied using non-kinetic methods, which are usually cost-effective and reversible, unlike kinetic methods, which carry a long-term risk of cascading effects of orbital debris called Kessler Syndrome. India should codify a counterspace doctrine to clearly specify escalation thresholds and mandate exhausting non-kinetic means (like cyberwarfare) before authorising kinetic (ASAT) response.

The New Reality: Building Proliferated Satellite Constellation

China's aggressive expansion goal

China reportedly set to build Guowang ('National Net') megaconstellation operated by the state-owned China SatNet. Roughly planned 12,992 filed with the ITU.[32] Simultaneously, the Shanghai-backed Qianfan ('Thousand Sails') megaconstellation is aiming for a full system of 14,000 satellites.[33] As of mid 2026, Guowang had around 168 operational satellites in orbit while Qianfan had deployed 126 satellites.[34]

India's Space-based Surveillance-3 programme (SBS 3)

In October 2024, India's Cabinet Committee on Security (CCS) approved an indigenous 52-satellite surveillance constellation, proliferating the LEO and GEO both with the small-satellite constellations through public-private partnership. It is a mix of SAR and optical sensor payload-based surveillance, throughout day and night, to ensure resilient "eyes in the sky" for the Indian Armed Forces.[35]

AI in Space

The European Space Agency (ESA) launched the small satellite named Phi-Sat-1 (2020), the first European AI-integrated satellite launched for Earth Observation[36]. Later in 2022, Satellogic launched the NewSat-27 spacecraft carrying Palantir's EdgeAI platform to run multi-model processing directly in space.[37]

Indian startups Pixxel and Sarvam AI are also planning to launch India's first orbital data centre satellite, named Pathfinder, carrying the data-centre-grade Graphics Processing Unit (GPU).[38] Together, these shifts from satellite only collecting data to collecting and analysing show a shift already started towards the super-OODA loop.

Is Speed Everything?

- A 2020 RAND wargame implied that autonomous systems are particularly worse at de-escalation than humans, and the sheer speed of unmanned autonomous systems could lead to crisis instability.[39]
- Black Box behaviour means we cannot see AI internal logic; instead, it commands. Hence, the inability to determine whether an output is a glitch or a correct assessment.[40]

"Raska warns AI-amplified output questions how decisions are justified, without clear human understanding, can trigger unintended escalation."[41] While outpacing an adversary is important, concluding speed as the only metric to outplay in modern warfare is a mistake. Speed is better seen as a diagnostic tool to keep decision-making well aware. At the highest level, the right goal is situational awareness, diplomacy, collaboration, and long-term strategy.

India's Emerging Startups and Contributions

Drawing from these global lessons, India is actively incentivising its domestic startup ecosystem to fortify national security. An emerging example of this strategic pivot is Sanyark Space Technologies, a space-tech startup founded by former ISRO scientists. Sanyark Space is actively addressing the vulnerability of current GNSS systems like GPS by building a unified Low Earth Orbit (LEO) constellation that fuses resilient Positioning, Navigation, and Timing (PNT) with secure communications (IoT-NTN and 5G NR-NTN).

This would give India a single LEO satellite constellation having both centimetre-level navigation and ubiquitous direct-to-device communication capabilities, which enables several strategic applications for the Indian armed forces. This indigenous, dual-use infrastructure

directly addresses the GNSS dependency vulnerability this article raises. This builds the sovereign capability required to sustain the high-speed OODA loop in future conflicts.

India's Capacity Gap: its Operational Requirement with Recommendations

- Capacity Gap 1- **Observe: Continuous Surveillance and Restocking Capability**
  India's satellite surveillance faces a revisit gap of approximately two hours, compared to China's estimated 30 minutes revisit time.[42] . This latency restricts India's military decision cycle.
  International Telecommunication Union (ITU) spectrum rights grants on a first-come, first-served basis, also filing lapse unless deployment milestones are met. So, early filing with actual deployment is needed. China's reported filing for nearly 193,000 satellites in December 2025 is one of the largest such filings.[43]
  Operational requirement- All-weather continuous day-and-night surveillance and capacity to replace lost or outdated satellite surveillance quickly. Also secured orbit and spectrum rights to allow the possible phased extension.

  Recommendations-
  - Prioritise SBS-III completion as scheduled and then extend the programme in a phased manner, to restock and cover, if any loss happens.
  - High Altitude Pseudo Satellite (HAPS), an unmanned stratospheric platform (approx. 20-25 km altitude), can act as an intermediate bridge until SBS-III is completed. [44]
  - Lieutenant General Raj Shukla, former General Officer Commanding-in-Chief of the Army Training Command (ARTRAC), has proposed a long-term vision for India to prioritise a 10,000-satellite LEO constellation. It will enable real-time remote coverage and direct-to-device connections, and thereby safeguard national security against China's aggressive Guowang and Qianfan megaconstellation projects.[45]
  - India must prioritise early filing with the ITU and plan a phased extension. In July 2026, the government extended its regulatory backing with IN-SPACe and the

Department of Telecommunications (DoT), clearing Reliance Jio's proposed 1,600 LEO satellites with 4.5-5 Tbps capacity, which sought to file with the ITU.[46]

- Capacity gap 2- **Observe to Act: Navigation Over-Reliance on GPS**

  Iranian authorities reportedly disabled Starlink via jamming GPS, which is needed for timing and positioning.

  NavIC is a regional satellite navigation system and needs at least four functioning satellites; as of March, 2026, only three are fully operational.[47]Group Captain Dr Ajey Lele (Retd) argues the planning gaps in satellite replacement, also gaps in constellation planning, reliance on imported components, and limited redundancy.[48]

  The atomic clock failure in IRNSS-1A and IRNSS-1F undermines precise positioning.[49]

  Operational requirement- Accurate, independent real-time positioning and timing for crucial military operations.

  Recommendations-

  - Restore NavIC with deep policy planning and develop indigenous atomic clocks.
  - Accelerate launch of NVS-02/03/04/05 satellites with L1 band signals (NVS-01 already carries) to widen mass market compatibility .[50]
  - Deeper integration of startups, research institutes, and companies to build resilience towards LEO-PNT, integrative AI-based satellite systems, and LEO megaconstellations.

- Capacity gap 3- **Observe to Orient: To strengthen the ground segment**

  As satellite sensors produce more data, LEO satellites interact with a single ground station only briefly for 5-12 minutes, a few passes per day per station, so more ground stations are needed for data downlink. This raises operational costs.

  Simply targeting a single ground terminal via jamming or a low-cost drone strike can neutralise communication, making it a highly vulnerable single point of failure.[51]

  Operational requirement- A secure ground segment with backup stations and requires limited satellite contacts and low bandwidth.

  Recommendations-

- Edge computing- processing data on the satellite itself, enabled by a high-performance, space-qualified processor architecture like CPU-GPU-FPGA. It will enable smart data handling and ensure mission-oriented information is transmitted over limited downlink bandwidth.[52]
- As proposed by the Defence Space Agency (DSA), India should deploy a GEO data relay satellite with high-speed optical inter-satellite link capability with a LEO satellite, at over 1.5 Gbps.[53]The LEO satellite views the ground station briefly, but the GEO satellite remains visible to the ground station at all times. So, the relay can carry data when no ground station is overhead. This allows the relay to carry data when no ground station is overhead.
- The need to harden and disperse ground terminals reduces vulnerability to a single point of failure.
- Institutionalise regular audits of the ground segment, cybersecurity, and AI system performance. This is to ensure transparency and accountability, and to mitigate risk.

- Capacity gap 4- **To protect the loop: Awareness and safeguarding orbit.**

  India presently has limited capability for detecting, tracking, and monitoring satellite/space debris. The DSA proposed to integrate optical and radar sensors with AI-based analytical systems.[54]

  Operational requirement- Timely detection and characterising suspicious interferences, real-time response.

  Recommendations-

  - Space situational awareness- Project NETRA (Network for Space Object Tracking Analysis) by ISRO, for safe and sustainable space operations.[55] Extend Project NETRA with optical and radar sensor AI-based trajectory analytics and real-time monitoring.
  - India is reportedly planning AI-enabled bodyguard satellites to protect key satellites.[56]

- To drive universally accepted space governance mechanisms and binding laws. Diplomatic collaboration among nations to protect sovereign assets and safeguard global space.

- Capacity gap 5- **Decide: Trust in AI decisions**

  To mitigate the risks highlighted by the 2020 RAND wargame and the black-box behaviour. Raska warns of a "digital fog of war" in which humans cannot validate machine-based decision-making in real time.[57]

  Operational requirement: AI-based decisions that a human can understand, audit, and hold strictly accountable.

  Recommendations-

  - Fund Explainable AI (XAI), which allows humans to understand and trust the results and outputs created by machine learning algorithms.[58]
  - Meaningful Human Control: Human-in-the-loop integration is much needed to ensure accountability, safety, and ethical decision-making.
  - Institutional AI literacy to overcome automation bias- The Armed Forces should be equipped with AI knowledge and skills.

Conclusion

This paper has argued that transitioning the worldview from single-orbit to a multi-orbit GEO-MEO-LEO architecture, paired with AI-enabled technology, can compress the OODA loop for India's space security. This requires consistent improvement in the capacity gap as surveillance revisits capacity, restoring NavIC, ground segment resilience, orbit safeguard and trust in AI-assisted decisions. While speed is important, yet not enough, it requires human judgement and accountability. India is stepping forward with the SBS-III programme to the emerging startups building India's first data centre satellite. India remains at an early stage relative to China's megaconstellations and Starlink's progress. Closing these gaps will determine whether India's OODA loop in space can keep pace.

Declaration

I declare that this manuscript is being submitted exclusively to CENJOWS for publication consideration, is original, and has not been published or submitted elsewhere. I further certify that it contains no classified, restricted, or sensitive information and is based entirely on open-source material suitable for publication in the public domain.

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