Strategic Imperatives Towards Upgrading NavIC (IRNSS)

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INTRODUCTION

Mankind has inhabited the Earth for millions of years, but its tryst with the space domain has been very recent in the chronology of important events which have changed human life forever. Space has represented the final frontier of human scientific accomplishment and discovery. With man's foray into space, he has naturally carried his practices of domination and denial into the new frontier.

India has established itself as a prominent spacefaring nation. It is among the few countries that have the capability of launching satellites and using them effectively for remote sensing, communications, disaster management, natural resources management, navigation, etc. The commercialisation of space has opened up a resource domain to the nations that are technologicaly capable of exploiting it. Space is the future colony for mankind.

Protection of space assets and future colonies would be one of the bigger security challenges in the latter part of the 21st

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century. Without the backing of a comprehensive military space programme, combat enabling assets like satellites would always be vulnerable to denial and degradation by the adversary. While the 20th century saw warfare being changed with the exploitation of the 'third dimension'(i.e. air), it is possible that it would be changed again in the 21st century as space becomes the high ground to be seized and either commanded or denied to potential adversaries. India needs to develop critical technologies as part of a comprehensive military space programme to protect its space-based assets and prevent denial, disruption and degradation of its armed forces through the medium of space.

With this background and in the quest for strategic autonomy in Satellite Navigation Systems (SNS), India launched its Indian Regional Navigation Satellite System (IRNSS) between 2013 and 2018. India is one of the few countries that have established an independent satellite navigation system in space. There are four global navigation systems in place: US Global Positioning System (GPS), Russia's GLONASS (in the Russian: GLObalnaya NAvigatsionnaya Sputnikovaya Sistema), China's Beidou, and the European Galileo. Japan's Quasi-Zenith Satellite System (QZSS) is the only other regional satellite navigation system in the world and its covers the Asia–Oceania region.

IRNSS: A GAME-CHANGER CONCEPT TOWARDS STRATEGIC AUTONOMY

The impetus for a strategic space programme was felt very early by the Indian policy-makers. The Indian Regional Navigation Satellite System (IRNSS), operationally called NavIC (Navigation with Indian Constellation), has been developed and is maintained by the Indian Space Research Organisation (ISRO). The project was launched in response to strategic vulnerabilities exposed during the Kargil War. IRNSS is designed to provide precise Positioning, Navigation, and Timing (PNT) services over India and a region extending roughly 1,500 km around the country.[1] Though the project was approved in 2006, it became operational only in 2018. With the launch of the 7th satellite, the IRNSS-1G, in 2016, Prime Minster Narendra Modi renamed IRNSS as NavIC. The term NavIC is adapted from the Hindi word *'navik'* which means 'sailor' or 'navigator'.[2]

NavIC provides two types of services:

- Standard Positioning Service (SPS) for civilian applications.
- Restricted Service (RS), an encrypted signal reserved for military or strategic users.

NavIC, like any other navigation satellite system, consists of three segments:

- **Space Segment:** Consisting of a constellation of satellites.
- **Ground Segment:** Consisting of a network of ground stations that generate navigation data to be uplinked to the satellites, and subsequently, to be used by the user receiver for aiding in position computation.
- **User Segment:** Consisting of the users utilising the navigation signals for the purpose of PNT.

NavIC has been conceived and built mainly with the aim of having an independent navigation satellite system for India to eliminate the dependence on foreign satellite systems for navigational requirements, especially for the strategic sector. It is a novel approach towards space-based regional domination of a highly contested domain. It is not built for the purpose of revenue generation.[3] However, many civilian applications are possible

1. http://timesofindia.indiatimes.com/home/science/How-Kargil-spurred-India-to-design-own-GPS/articleshow/33254691.cms
2. https://indianspacetechnology.com/navic-indias-powerful-gps-like-system/
3. www.isro.gov.in

using free-to-air navigation signals broadcast from satellites. The industry can produce receivers capable of receiving NavIC signals and use these for various applications in several areas. Thus, economic benefit will accrue to the Indian economy by the usage of position and navigation technologies.

ISRO launched the original constellation of first-generation IRNSS satellites between 2013 and 2018. More recently, ISRO has begun deploying the second-generation NVS-series (NavIC Very Small/Next-Gen NavIC Satellites); the NVS-01 (IRNSS-1J) was launched in May 2023, and NVS-02 (IRNSS-1K) was launched in January 2025.

Despite its strategic importance, IRNSS/NavIC faces significant technical, operational, and adoption challenges, which threaten its long-term viability and utility. With proper course correction, these can be addressed to fulfil NavIC's promise of strategic autonomy and broad-based industrial/economic benefits.

KEY CHALLENGES FACING IRNSS/NAVIC

Atomic Clock Failures

One of the most critical challenges comprise the repeated failures of the Rubidium Atomic Frequency Standards (RAFS) onboard the IRNSS satellites. These clocks are the heart of any navigation satellite, because they provide the extremely precise timing necessary for triangulation of position. Several first-generation IRNSS satellites saw their atomic clocks malfunction or stop altogether. IRNSS-1A, for instance, lost functionality when all three of its rubidium atomic clocks failed by 2016. Other satellites—such as the IRNSS-1C, 1D, 1E, and 1G—also developed clock issues over time. Several satellites are now defunct, primarily due to clock failures. These persistent clock failures undermine the reliability and accuracy of the NavIC constellation. Without healthy atomic clocks, the navigation signals degrade, affecting both civilian and strategic services.[4]

Satellite Launch and Orbital Deployment Failures

NavIC's first-generation deployment had setbacks, and even the second generation has experienced issues. The IRNSS-1H, launched in 2017, to replace the 1A, failed to reach the intended orbit because its heat shield did not separate properly during launch. The NVS-02 (IRNSS-1K), launched in January 2025, suffered an engine failure and remains in a suboptimal orbit, rendering it unable to fully serve its navigation purpose. The reliance on launch vehicle performance and orbital insertion precision means that failures or partial failures directly erode the constellation's robustness and redundancy. These deployment hiccups delay the replenishment of ageing or defunct satellites, leaving gaps in coverage and reducing the overall resilience of the system.

Ageing Constellation/Operational Lifespan Risks

Several of the first-generation IRNSS satellites are nearing or have exceeded their design life. Currently, only a small sub-set of satellites remain fully operational. The constellation, if not replenished in a timely manner, risks losing the minimum required operational geometry for accurate positioning. This makes the continuity of NavIC's PNT service precarious: if more satellites fail or are decommissioned without replacements, the system could degrade significantly or even become non-functional.[5]

4. https://www.indiandefensenews.in/2025/08/indigenous-clocks-delay-isros-plans
5. https://www.gpsworld.com/indias-navic-constellation-in-jeopardy-as-majority-of-satellites-become-defunct

Supply Chain and Indigenous Technology Bottlenecks

While ISRO has made strides in developing indigenous rubidium atomic frequency standards, some critical sub-components remain dependent on imports. Procurement delays for these imported components are slowing down the deployment of second-generation satellites. Such reliance on foreign technology for core sub-systems reduces the system's self-reliance and introduces geopolitical and supply risk. The inability to fully indigenise essential satellite technology (especially atomic clocks) constrains NavIC's *"Make in India"* promise and may hamper future sustainment.

Limited Device Adoption and Commercial Use

NavIC's adoption among consumer devices and commercial users has been slower than expected. Historically, major chipset manufacturers have hesitated to include NavIC support in their equipment. Only recently did Qualcomm begin to integrate NavIC in some of its processors (post-2023), helping smartphone manufacturers to support NavIC signals.[6] Even with chipset support, many device manufacturers, especially globally, may not prioritise NavIC in their designs because its coverage is regional, not global. Without strong device adoption, the user base (civilian, commercial) remains limited, which, in turn, limits the commercial case for NavIC. Thus, despite having a capable PNT system, NavIC's full potential remains under-leveraged because of slow integration into end-user devices.

Signal Propagation and Geophysical Challenges

Ionospheric irregularities, especially over low-latitude regions like India, affect NavIC's signal reliability. Studies show that during

6. https://www.qualcomm.com/news/releases/2023/12/qualcomm-announces-support-for-india-s-navic-satellite-navigation

geomagnetic storms, NavIC signals suffer scintillation, degrading signal strength and accuracy. Such environmental vulnerabilities are inherent in any Global Navigation Satellite System (GNSS) system, but regional constellations like NavIC, with limited satellites, may be more sensitive to such disturbances.[7] These geophysical challenges must be carefully managed through better system design, error correction, and ground infrastructure.

THE LONG WAIT: MISSED OPPORTUNITIES IN THE STRATEGIC DOMAIN

Having earned a rightful slot in the exclusive club of spacefaring nations, India made a significant technological leap by launching the NavIC project. As has been brought out earlier, the push was towards strategic autonomy. PNT comprises the future navigation and has permeated into every sphere of human activity. However, certain technological glitches and long procurement delays have brought immense pressure on the project, questioning its viability in the future.

NavIC is India's attempt to secure the skies and provide an indigenous alternative to the GPS dominated SNS segment. From a strategic perspective, India cannot just rely on the fight towards control of air—there is a need for dominating the air waves—which can be done by achieving self-reliance in the PNT segment.

Somewhere, in the quest for an advanced space programme during the last decade or so, we have underestimated the full potential of the IRNSS project in future military and civil aviation scenarios. This can possibly be attributed to a *milestone-based approach* to our space programme wherein the strategic priorities and the military needs have not got the desired impetus. As a major

7. "On the Low-Latitude Ionospheric Irregularities under Geomagnetically Active and Quiet Conditions using NavIC Observables: A Spectral Analysis Approach", https://arxiv.org/abs/

space power, we need to be fully conscious of the vulnerabilities and technological gaps existing in the NavIC project and address them on priority. The long-term vision of ISRO needs to be aligned to the spectre of increased militarisation of space and future contestations in the 'commons'.

Denial of service can have a major impact on critical infrastructure, and disruptions can lead to potentially disastrous situations. Reports of suspected GPS interference near the New Delhi airport in early November 2025 have drawn public and policy attention toward a threat that, until recently, was largely confined to the military. GPS jamming occurs when powerful radio frequency signals are transmitted within the GPS spectrum, affecting the extremely weak signals received from satellites orbiting thousands of kilometres above the Earth.[8]

Recent conflicts only prove the heavy reliance of modern weaponry on PNT solutions. The spectrum can be spoofed or jammed as this has a direct influence on the targeting outcomes. All precision weapons rely on GNSS signals for navigational guidance. The recent conflicts have highlighted the dependence on the PNT segment to direct weapons to designated impact points.

NavIC has been designed with the advantage of spread spectrum utility. The transmission frequencies are in the L-Band (L1-1575.42 MHz & L5-1176.45 MHz) and S Band (2492.028 MHz) providing jamming redundancy.[9] The new generation of satellites support the L1 frequency for increased commercial adoption. Restricted code and improved anti-spoofing techniques need to be strengthened so as to counter the threats in both military and civil domains.

8. https://indicrf.org/article/cyber-security-ai-and-defense/mystery-behind-gps-jamming-and-spoofing-a-practitioners-view
9. https://www.isro.gov.in/media_isro/pdf/SateliteNavigation/irnss_sps_icd_version1.1-2017.pdf

POLICY, FUNDING AND STRATEGIC PRIORITISATION

The government must formalise a long-term NavIC roadmap. Military imperatives should dominate the future shaping of the project, with commercialisation, though important, being the secondary objective. This should cover satellite replenishment, expansion, indigenisation, market adoption, and international cooperation. There is an urgent need for sustained funding for the project, along with a clear vision for the future. The government must allocate a dedicated, predictable budget line for NavIC maintenance, replacement, ground infrastructure upgrades, and research. ISRO can explore Public Private Partnership (PPP) models for downstream use (apps, receivers, augmentations), ground-station operations, and possibly even satellite financing. An overarching regulatory framework can be made to establish standards, certifications, and procurement guidelines so that public sector agencies adopt NavIC in mission-critical applications (defence, railways, civil aviation, disaster management).

EXPANSION OF SATELLITE CONSTELLATION AND IMPROVED REDUNDANCY

Currently, NavIC has a small constellation, and technical failures in the past have reduced the availability of the satellites. Additional reserve satellites need to be launched to build in redundancy in the system. There is a need to launch Next Generation Satellites (NVS) to replace the first generation satellites. Needless to say, future launches need to have high mission assurance: improved propulsion, testing, integration to avoid failures like the NVS-02.[10]

10. https://orbitaltoday.com/2025/02/03/a-100-million-problem-isros-nvs-02-navigation-satellite-stuck-in-orbit

At present, NavIC works on signals in the L5, S-band, and short-code to provide positioning data, However, most mobile and wearable Systems on Chips (SoCs) support the L1 band signals (the L1 frequency is the mostly used frequency in the GPS ecosystem). To overcome this drawback, ISRO has planned L1 frequencies in the NavIC 2.0 generation of satellites.[11]

IMPLICATIONS AND BENEFITS OF UPGRADING THE NavIC PROJECT

The NavIC project has entered Phase II of its operation with the launch of the new series of satellites. NavIC 2.0 should focus on reliability and expanded coverage for maintaining its future viability. The benefits of upgrading NavIC and making it more resilient are as follows:

- **Strategic Autonomy:** A robust and modern NavIC ensures that India does not rely solely on foreign systems (like the GPS or GLONASS) for critical navigation and timing, especially for the defence, security, and strategic infrastructure.
- **Economic Impact:** Improved PNT services can benefit agriculture (precision farming), transportation (fleet management), railways, maritime, aviation, disaster response, and more. Its widespread adoption could foster new business ecosystems.
- **Technological Leadership:** By developing indigenous clocks, next generation receivers, and augmentation techniques, India can showcase homegrown innovation. This can also support exports to other nations wanting regional constellations.
- **Resilience and Redundancy:** A well-maintained NavIC system adds redundancy to the global PNT infrastructure, contributing to national and even international resilience.

11. https://indianspacetechnology.com

- **Scientific Advancements:** Deeper understanding of space weather, ionospheric behaviour, and satellite technologies will emerge from continued research, positioning India as a contributor in fundamental space science.
- **Global Diplomacy:** As NavIC matures, India can offer PNT services regionally (or even globally) through partnerships. This can enhance its geostrategic influence and soft power in the space domain.

Policy support for NavIC is crucial—in terms of long-term vision financial backing and regulatory push—to ensure that NavIC remains a critical strategic tool, along with avenues for commercially exploitation. Given the limited space budget, ISRO must balance NavIC against other priorities (e.g., Earth observation, exploration, interplanetary missions). There is strong justification for greater military insight into the project. A game-changer technology is available indigenously with the country, however, strategic vision is required for its future sustenance and development.

CONCLUSION

The IRNSS / NavIC project embodies India's ambition of strategic autonomy, technological self-reliance, and socio-economic impact through space technology. However, after more than a decade after its first satellite launch, the system still grapples with serious challenges, from atomic clock failures and launch mishaps to limited device adoption and regional constraints. Addressing these challenges, demands a multi-pronged approach: accelerate indigenisation of critical sub-systems, maintain a steady tempo of replacement and new satellite launches, expand coverage (in terms of both geography and ground infrastructure), and build stronger linkages with device manufacturers and commercial users. Complementing these, policy commitment, sustainable funding, and innovation in emerging technologies will be indispensable.

If India can execute this roadmap, NavIC has the potential not only to secure its strategic PNT needs but also to become a globally significant navigation service, contributing to military prowess, economic growth, scientific progress, and geopolitical strength.