# ISRO's NAVIC: Navigation Support to Civil and Military Segments

**Dr. Ranjit Singh,** FIETE
Department of Electronics Communication Engineering, Ajay Kumar Garg Engineering College,
27 Kmstone, Delhi-Meerut Expressway, Ghaziabad 201009 UP India
editor_journal@akgec.ac.in

*Abstract* -- **Satellite Navigation service is an emerging satellite based system with commercial and strategic applications. Modern weapon systems like guided missiles need navigation support for proper targeting and maximum lethality. Indian Space Research Organisation developed satellite based navigation system, NavIC, on which Army, Navy and Air Force can rely for assured positional data during hostilities on land, sea or air. A distance of 1,500 km from the Indian boundary is covered by this system and overcomes little-known limitationsof GPS in geographically-diverse terrains of India.**

**India, after US, Russia & EU is the fourth country in the world to have its independent regional navigation satellite system. The constellation of seven satellites is operational since April 2016.**

**NavIC provides drivers and other users in India with visual and voice navigation. Sensing huge market potential, manufacturers like Qualcomm and others entered the scene to launch NavIC¬compatible chipsets for use in mobile handsets.**

## I. INTRODUCTION

DURING 1999 Kargil war, India's request for use of U.S. owned GPS for information about positioning, timing & navigation of hostile forces was denied. Likewise, in 2009 and 2012, India's Brahmos missile failed to hit targets in trial operations as U.S. shut off GPS satellites without any warning, causing crippling of missile's guiding system, which failed to achieve its objectives. Such unsavoury incidents necessitated the need for an Indian Navigation Satellite System. Geopolitical vicissitudespoint out that some countries can deny us the service in times of conflict. Likewise, it's a way of arm twisting & we should protect against that.

In 2006, the government gave assent to the project called "Indian Regional Navigation Satellite System" (IRNSS) that requires seven satellites. ISRO launched nine satellites between 2013-2018: IRNSS-1A, IRNSS-1B, IRNSS-1C, IRNSS-1D, IRNSS-1E, IRNSS-1F, IRNSS-1G, IRNSS-1H & IRNSS-1I, Two extra satellites were launched due to failure of Rubidium atomic clocks on-board the first satellite, IRNSS-1A & also the failed launch of its replacement.

IRNSS, is an operational name of NavIC, which is the acronym for NAVigation with Indian Constellation. It also, denotes navik, "sailor" or navigator in Hindi.

IRNSS II was launched to finally complete NavIC's constellation. Additionally, two backup satellites are also available.

NavIC provides accuracies of 10 m throughout the Indian landmass and 20 meters over Indian Ocean, termed Standard Position Service (SPS). For defence applications, accuracy of 0.5 — 5 m is provided via encrypted version, termed Restricted Service (RS).

NavIC's primary operational range covers Bangladesh, Pakistan, Sri Lanka & parts of China besides India landmass and 1500 km distance from shore. On the other hand, GPS is a global tracking constellation, covering the whole earth. For common public, Interface Control Document (IC D Ver. 1.1) released by ISRO gives essential information besides facilitating R&D for commercial use.

Practical benefits of NavIC chipset receivers

- Makes possible navigation at sea, land and in air
- Help during disasters to track & manage a fleet
- Receivers provide users with a satellite-based navigation system
- Receivers support frequency bands for both GPS & NavIC systems
- Give location services on phone, maps etc
- Help trekkers/hikers/travellers in terrestrial navigation
- Creation of maps via capture of geodetic data
- Provide audio-visual navigation guide for drivers
- Accurate data creation with understanding of the local terrain.

## II. CIVIL AVIATION REQUIREMENTS

To meet Civil Aviation requirements, ISRO worked with Airport Authority of India (AAI) to establish the GPSAided Geo Augmented Navigation (GAGAN) system.GAGAN uses satellite-based navigation services with utmost accuracy & integrity needed for civil aviation applications in order to provide better Air Traffic management over Indian Airspace. Moreover, it is compatible with global systems, leading to

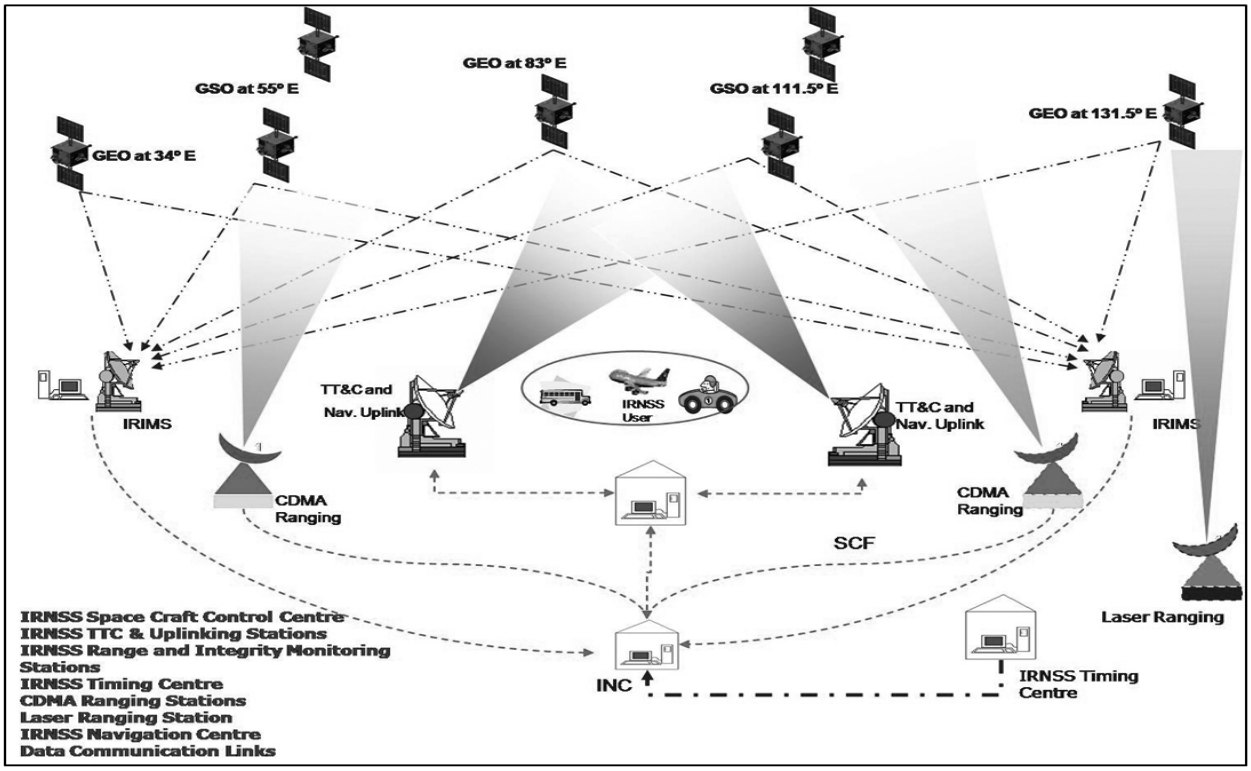


Figure 1. IRNSS schematic diagram.

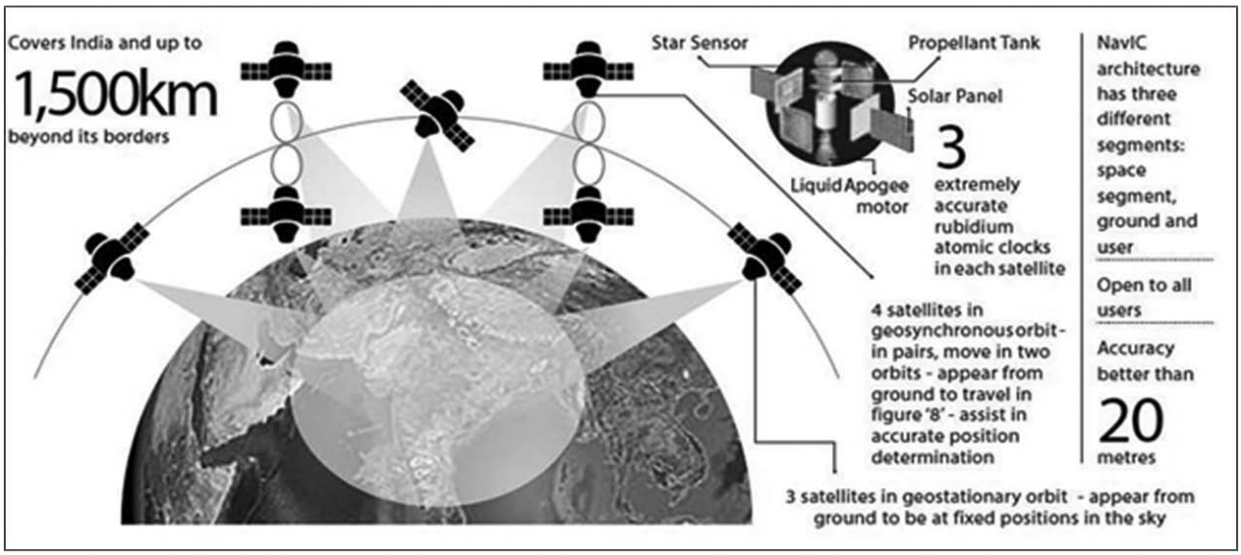


Figure 2. Seven sisters in space: The NavIC receiver developed by SAC can receive signals from both IRNSS and GPS satellites.

seamless navigation across regional boundaries. GAGAN navigation payloads were launched on May 21, 2011 and Sep 29, 2012 aboard GSAT-8 and GSAT-10.

Benefits of induction of GAGAN include:
Flight safety, high position accuracy,fuel saving, saving in equipment cost, efficiency, increased air space capacity, enhancement of reliability, reduction in work load for operators, coverage of oceanic area for air traffic control, etc.

Additionally, GAGAN benefits other sectors like:

- Navigation and Safety Enhancement in Railways, Roadways, Ships, Spacecraft
- Geographic Data Collection
- Scientific Research for Atmospheric Studies
- Geodynamics
- Natural Resource and Land Management
- Location based services, Mobile, Tourism, etc.

## III. GLOBAL ENDORSEMENT

The global wireless communications standards body 3GPP has accepted the interface specifications of NavIC, which implies it can be integrated into devices like snart phones and tablets. It also received recognition by the International Maritime Organization (IMO) as part of the World Wide Radio Navigation System for operation in the Indian Ocean Region. IMO is the United Nations' agency responsible for safety and security of shipping and prevention of marine and atmospheric pollution by ships.

International Maritime Organization urges individual countries for developing own navigation systems for reducing their reliance on other navigation systems.

These recognitions impart big boost to India's mobile telecom industry while encouraging use of NavIC throughout the Asia-Pacific region.

At present, all merchant vessels including small fishing vessels are authorized to use the IRNSS. The vessels having transponders installed in them are tracked by satellite navigation showing their accurate position in the Indian Ocean region. At least 2,500 merchant vessels are there in the Indian waters which are authorized to use this system.

Outcome will be that Smart phones and IoT devices using location information will start using the NavIC system, which will enable mass market usage in 4G, 5G and IoT. Accordingly, domestic entities have opportunities to design chips and ICs based on NavIC. This will create market for these chipsets and products for exports.

With this, India became the fourth country in the world to have its independent regional navigation satellite system developed to provide accurate position information service to assist in the navigation of ships in the Indian Ocean region. Glonass from Russia using 26 satellites, Galileo from the European Union using 30 satellites besides US-owned GPS, employing 32 satellites.

## IV. FREQUENCY BANDS

NavIC uses dual frequency bands, L5 (1.17GHz) & S band (2.5 GHz). On the contrary, GPS uses a single frequency band, namely L band. Now, when microwave signals travel through the atmosphere, it gets affected due to atmospheric disturbances. Therefore, GPS relies on atmospheric model to assess any frequency error. The model requires updating from time to time, to assess & correct any error. While in NavIC, error is assessed by measuring the differences in the delay of the dual frequencies (L5 & S bands), making NavIC more reliable & accurate in comparison to GPS.


Figure 3. Launch dates and weight of IRNSS satellites.

## V. ACCURACY

All the satellites of GPS revolve in a Semi-Geosynchronous orbit. Additionally, GPS's satellites take 11 hours (almost 1/2 of earth's rotation time) to complete one revolution. This makes acquiring position of an object more tedious. The fast velocity provides for relatively inaccurate positioning. The user will keep on jumping around from one satellite to another (for signal) increasing the acquisition time frame. Therefore, for densely built areas GPS lacks reliability.

Contrary to this, NavIC provides a pin-point accuracy. This is due to the direct line of sight maintained between the satellites (in Geosynchronous orbit) and the user (all the time). Also, NavIC's satellites take 23hr, 56min & 4 sec out (exact earth's rotation time) to complete one revolution. This makes the accuracy more precise and reliable.

The number of operational satellites will be increased to 11 in the future to further expand coverage & enhance accuracy.

## VI. DEFENCE FORCE-MULTIPLIER

Services provided by NavIC multiplies Indian armed force's strength. The Army, Navy and Airforce can rely on assured positional data during hostilities on land, sea or air. Most modern weapon systems like guided missiles, bombs, defence systems use navigation systems for proper targeting and maximum lethality. An indigenous system like the NavIC will ensure reliable development and execution of such capabilities. Although, the civilian side service of both NavIC& GPS is equal (accuracy wise), NavIC will improve everything that GPS lacks in terms of navigating in Indian environment. It is the best option for geographically diverse terrains of India.

## VII. MANUFACTURING ECOSYSTEM

ISRO's NavIC is supported by mobile chipset manufacturers like Qualcomm, MediaTek and Broadcom across various chipset platforms. For instance, Smartphones with the latest Qualcomm chipsets can now latch on to NavIC. It will provide a Standard Positioning Service to all users and an encrypted Restricted Service to authorized users. NavIC will provide drivers and other users in India with visual and voice navigation. Its primary beneficiaries will be Indian mariners and fishermen, who are being provided with NavIC handsets.

Qualcomm has launched several NavIC compatible chipsets — Snapdragon 865, Snapdragon 765, Snapdragon 720G, Snapdragon 662, and Snapdragon 460. The first phone in India with NavIC support is Realme X50 Pro 5G. Qualcomm claims that ISRO's navigation will have a more accurate location tracking in dense urban environments, where normally geolocation accuracy has a tendency to degrade.

## VIII. ARCHITECTURE

*Space Segment:* Satellites are positioned in both geostationary as well as geosynchronous orbits. Of the seven satellites, three are geostationary orbits located at 32.5° East, 83° East and 131.5° East longitude while the other four are located 550 East and the other two at 111.75° East (two satellites in each plane). Life span is 9.5 years of GEOs while GSOs have a life span of 11 years.

An Extended Service Area lies between primary service area and area enclosed by the rectangle from Latitude 30 deg South to 50 deg North, Longitude 30 deg East to 130 deg East.

*Ground Segment:* The IRNSS Ground Segment consists of the following:

1- IRNSS Spacecraft Control Centre
2-IRNSS Navigation Centre
3- IRNSS TTC & Uplinking Stations
4- IRNSS Range and Integrity Monitoring Stations
5- IRNSS Timing Centre
6- IRNSS CDMA Ranging Stations
7- Laser Ranging Station
8- Data Communication Network.

*User Segment:* The IRNSS User Segment consists of dual-frequency IRNSS receivers (L5 and S-band frequencies) or the single frequency IRNSS receivers (L5 or S-band frequency). Total cost of the project is Rs.14.2 billion, of which ground segment costs Rs.3 billion, each satellite costs Rs. 1.5 billion and the PSLV-XL version rocket costing around Rs.13 billion.

**Dr Ranjit Singh,** FIETE (b. 17 Aug 1948) obtained B.Tech, M.Tech. and Ph.D degrees from Indian Institute of Technology, Kanpur in 1969, 1971 and 1975 respectively specializing in the area of Electronic circuits and devices. Has abiding passion for research and innovative approach to teaching. Guided BTech, MTech and PhD scholars. He is founding Editor-in-Chief of the '*AKGEC International Journal of Technology*', which is running in thirteenth volume.

Earlier served IETE as Editor during 1975-1987; Technical Editor at *Telematics India* during 1987-2001 and Editor of *Industrial Purchase* journal during 2002-2008.

From September 2008 to February 2015, he taught at Ajay Kumar Garg Engineering College where, he was a Professor in the EC department. Thereafter served as Head of the ECE and EI departments, IEC Engineering College, Greater Noida from April 2015 – May 2016, where he supervised setting up of e-Yantra lab.

Delivered Keynote address in the Seminar on 'Mobile Computing' in 2014 and Guest Lectures on:

- Security Issues in Wireless Communications ( Nov 2016)
- Big Data: Challenges and opportunities (Feb 2017)
- Smart Cities (April 2017)
- Lure of ISM Band (July 2017)
- Lithium Ion Batteries: Answer to Communications Energy Crunch (May 2018).

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