What is GNSS?

A global navigation satellite system (GNSS) comprises satellite constellations that offer worldwide or local positioning, navigation, and timing (PNT) services. While GPS is the most widely utilized GNSS, other nations are implementing their systems to provide supplementary and independent PNT capabilities. GNSS incorporates constellations of satellites orbiting the Earth, transmitting their positional information in space and time, networks of ground control stations, and receivers that determine ground positions using trilateration.

PRESENT:

As of 2024, there are four operational global navigation systems: the United States Global Positioning System (GPS), Russia's Global Navigation Satellite System (GLONASS), China's BeiDou Navigation Satellite System (BDS), and the European Union's Galileo. Supplementing these systems are satellite-based augmentation systems (SBAS) such as Japan's Quasi-Zenith Satellite System (QZSS) and the European EGNOS. Operational regional navigation satellite systems (RNSS) encompass earlier iterations of the BeiDou navigation system and India's Regional Navigation Satellite System (IRNSS) or NavIC.

FUTURE AND APPLICATIONS:

Upon full deployment of all global and regional Positioning, Navigation, and Timing (PNT) systems, users worldwide will access precise positioning, navigation, and timing signals facilitated by a network of over 100 satellites. These signals are indispensable for diverse applications, encompassing transportation (space stations, aviation, maritime, rail, road, and mass transit), telecommunications, land surveying, law enforcement, emergency response, precision agriculture, mining, finance, and scientific research. Furthermore, these PNT systems play a pivotal role in the governance of computer networks, air traffic, power grids, and more. Each system ensures global coverage through a meticulously coordinated satellite constellation comprising 18–30 medium Earth orbit (MEO) satellites distributed across distinct orbital planes. These satellites are situated in orbits with inclinations exceeding 50° and possess orbital periods of approximately twelve hours, orbiting at an altitude of approximately 20,000 kilometers or 12,000 miles.

PAST:

Ground-based radio navigation has a rich history spanning several decades. Notable systems such as DECCA, LORAN, GEE, and Omega utilized terrestrial longwave radio transmitters to emit a pulse from a predetermined "master" location, followed by pulses from various "slave" stations. By computing the interval between the reception of the master signal and the slave signals, receivers could accurately ascertain their distance from each slave, thereby facilitating precise location determination. The initiation of the first satellite navigation system, Transit, by the US military in the 1960s marked a significant development. This system operated on the principle of the Doppler effect, where satellites followed established paths and transmitted signals on known radio frequencies. By monitoring the frequency shift of the received signals over a brief period, receivers could determine their spatial position relative to the satellites. The identification and correction of errors caused by radio wave refraction, fluctuations in the gravitational field, and other related phenomena were undertaken by a skilled team led by Harold L. Jury of the Pan Am Aerospace Division in Florida from 1970 to 1973. By using real-time data and iterative estimation, the corrective actions helped reduce systematic and residual errors, allowing for more accurate navigation.

GPS:

The Global Positioning System (GPS) is a U.S.-owned service that provides users with positioning, navigation, and timing services. It consists of three segments: the space segment, the control segment, and the user segment. The system includes up to 32 medium Earth orbit satellites arranged in six orbital planes, with 31 operational satellites currently in orbit, providing L1 (1575.42 MHz), L2 (1227.60 MHz), and L5 (1176.45 MHz) frequency support.

GLONASS:

GLONASS, initially developed by the Soviet Union and now operated by Russia, is a satellite-based navigation system that provides civilian radio navigation-satellite service and is used by the Russian Aerospace Defence Forces. It achieved full global coverage in 1995 and currently has 24 active satellites. The GLONASS control segment includes the system control center and a network of command tracking stations across Russia. Similar to GPS, it monitors satellite health and uploads corrections twice a day. GLONASS satellites transmit at slightly different L1 and L2 frequencies, with P-code and C/A codes on both. This technique is known as frequency division multiple access (FDMA).

BeiDou:

The BeiDou Navigation Satellite System (BDS) is an independent system China operates to meet national security and development needs. It provides high-accuracy positioning, navigation, and timing services globally. The BDS has three generations, each with advanced features and improved capabilities. The system consists of multiple satellites in different orbits to ensure better performance and coverage, and it offers various services including navigation, communication, search and rescue, and precise positioning. BeiDou satellites currently transmit several signals, including B1I (1561.098 MHz), B1C (1575.42 MHz), B2a (1175.42 MHz), B2I and B2b (1207.14 MHz), and B3I (1268.52 MHz).

Galileo:

The European Union and European Space Agency introduced the Galileo positioning system as an alternative to GPS. It became operational on December 15, 2016. The full constellation consists of 24 active satellites, and the system is expected to be compatible with GPS, offering increased accuracy when combined. The main modulation used in the Galileo Open Service signal is the Composite Binary Offset Carrier (CBOC) modulation, transmitting along the L-Band spectrum at various frequencies.

NavIC:

The NavIC, or NAVigation with Indian Constellation, is a regional satellite navigation system developed by the Indian Space Research Organisation (ISRO). It consists of 7 navigational satellites providing precise positioning within and around India, with the goal of complete Indian control over the system. In 2018, the NavIC system became available for public use. NavIC provides a standard positioning service for civilian use and a restricted service for authorized users, including the military. The system is expanding to include 11 satellites and plans to become a global system with 24 MEO satellites. It offers services in L5 (1176.45 MHz) and S-band (2498.028 MHz) and covers India and a region up to 1500 km beyond the Indian boundary. The system also introduces a new civilian signal in the L1 band (1575.42 MHz) and all forthcoming satellites will broadcast SPS signals in the L1, L5, and S bands.

QZSS:

The Quasi-Zenith Satellite System (QZSS) consists of four satellites that provide regional time transfer and enhance GPS coverage in Japan and the Asia-Oceania regions. QZSS services were available on a trial basis starting from January 12, 2018, and officially started in November 2018. The first satellite was launched in September 2010. Additionally, an independent satellite navigation system with 7 satellites is planned to be launched in 2023.

IRNSS:

The Indian Regional Navigation Satellite System (IRNSS) is a state-of-the-art satellite navigation system owned and operated by the Government of India. It was meticulously developed by the renowned Indian Space Research Organization (ISRO) to provide precise navigation services over the expanse of India and its neighbouring countries. The system seamlessly transitioned into operational status with a constellation of seven active satellites perfectly positioned in their designated orbits. Researchers and scientists are privileged to dissect the intricate NavIC signals to conduct in-depth ionospheric studies and pioneer innovative algorithms for improved navigation accuracy. These signals encompass a Standard Positioning Service (SPS) and a Restricted Service (RS) transmitted through L5 (1176.45 MHz) and S-band (2492.028MHz) frequencies. Notably, three of the seven satellites majestically orbit the earth in the geostationary orbit (GEO), while the remaining four gracefully navigate in an inclined geosynchronous orbit (IGSO). In a bid to expand the system's global coverage, ISRO has presented a compelling plan to augment the satellite constellation by deploying twelve satellites in the Medium Earth Orbit (MEO).

The IRNSS system architecture mainly consists of:

* Space Segment
* Ground Segment
* User Segment

**SPACE SEGMENT:**

The IRNSS space segment consists of seven satellites. These satellites are designed around an I-1K bus with a dry mass of 600 kg and a launch mass of 1425 kg. They have a power generation capability of 1600 W. Highly stable Rubidium Atomic Frequency Standards (RAFS) are used on board to generate navigation signals. IRNSS is an independent regional navigation satellite system being developed by India. It is designed to provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary, which is its primary service area. An Extended Service Area lies between the primary service area and the area enclosed by the rectangle from Latitude 30 deg South to 50 deg North, Longitude 30 deg East to 130 deg East. IRNSS will provide two types of services, namely, Standard Positioning Service (SPS) which is provided to all the users and Restricted Service (RS), which is an encrypted service provided only to the authorized users. The IRNSS System is expected to provide a position accuracy of better than 20 m in the primary service area.

**GROUND SEGMENT:**

The ground segment plays a crucial role in keeping the IRNSS constellation operational. This segment is responsible for the maintenance and operation of the constellation. The ground segment consists of:

* IRNSS Spacecraft Control Facility (IRSCF)
* ISRO Navigation Centre (INC)
* IRNSS Range and Integrity Monitoring Stations (IRIMS)
* IRNSS Network Timing Centre (IRNWT)
* IRNSS CDMA Ranging Stations (IRCDR)
* Laser Ranging Stations
* IRNSS Data Communication Network (IRDCN)

The Indian National Centre for Space-based Positioning, Navigation and Timing (NCSPNT) facility located in Byalalu is responsible for conducting remote operations and data collection with all ground stations. Currently, 14 IRIMS (Indian Regional Navigational Satellite System Range and Integrity Monitoring Stations) are operational and are actively contributing to the operations of the IRNSS (Indian Regional Navigation Satellite System). The four IRCDR (Indian Regional CDMA Ranging) stations regularly perform Code Division Multiple Access (CDMA) ranging for the IRNSS satellites. The IRDCN (Indian Regional Data Communication Network) has established both terrestrial and VSAT links between the ground stations. Furthermore, seven 7.2m Fixed Cassegrain Antennas (FCA) and two 11m Fixed Mobile Antennas (FMA) of IRSCF (Indian Regional Satellite Control Facility) are currently in operation to support both the Launch and Early Orbit Phase (LEOP) and the on-orbit phases of the IRNSS satellites.

**USER SEGMENT:**

The User segment mainly consists of:

* A single-frequency IRNSS receiver can receive an SPS/RS (Standard Positioning Service/Radio Station) signal at either the L5 frequency or the S-band frequency.
* A sophisticated dual-frequency IRNSS receiver designed to receive both SPS (Standard Positioning Service) and RS (Restricted Service) signals in the L5 and S-band frequencies, enabling high-precision positioning and navigation capabilities.

APPLICATIONS:

* Terrestrial, Aerial and Marine Navigation
* Disaster Management
* Vehicle tracking and fleet management
* Integration with mobile phones
* Precise Timing
* Mapping and Geodetic data capture
* Terrestrial navigation aid for hikers and travelers
* Visual and voice navigation for drivers

TIMELINE:

[IRNSS-1A](https://www.isro.gov.in/IRNSS_1A.html)

Jul 01, 2013

The Polar Satellite Launch Vehicle, PSLV-C22, successfully launched India’s first dedicated navigational satellite, IRNSS-1A, from the First Launch Pad (FLP) of Satish Dhawan Space Centre, Sriharikota. This marked the fourth flight of the ‘XL’ version of PSLV. IRNSS-1A is the first satellite in the Indian Regional Navigation Satellite System (IRNSS) and is part of the seven-satellite IRNSS space segment. IRNSS-1A has a navigation payload that transmits signals in L5-band and S-band and includes a Rubidium atomic clock. It also features a ranging payload with a C-band transponder for precise satellite range determination, with Corner Cube Retro Reflectors for laser ranging.

**PSLV-C26/IRNSS-1C**

Oct 16, 2014

The PSLV-C26 launched the third satellite, IRNSS-1C, of the Indian Regional Navigation Satellite System (IRNSS) from the First Launch Pad (FLP) of Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota. This mission used the ‘XL’ version of PSLV, marking its seventh flight in this configuration. IRNSS-1C is the third of seven satellites in the IRNSS space segment. It follows IRNSS-1A and IRNSS-1B launched in July 2013 and April 2014, with a lift-off mass of 1425.4 kg. IRNSS-1C was completed in less than six months after its predecessor's launch. IRNSS-1C is powered by two solar arrays generating up to 1,660 watts of power, with a lifespan of ten years. It carries navigation and ranging payloads, including a highly accurate Rubidium atomic clock and Corner Cube Retro Reflectors for laser ranging.

**PSLV-C27/IRNSS-1D**

**Mar 28, 2015**

The PSLV-C27 successfully launched the IRNSS-1D, the fourth satellite of the Indian Regional Navigation Satellite System, from the Second Launch Pad of the Satish Dhawan Space Centre. This marks the eighth time the ‘XL’ configuration has been used. IRNSS-1D is the fourth navigation satellite in the IRNSS space segment. It has a lift-off mass of 1425 kg and a configuration similar to its predecessors, IRNSS-1A, 1B, and 1C. The satellite was developed less than four months after the launch of its predecessor. The two solar panels of IRNSS-1D, each with Ultra Triple Junction solar cells, generate about 1660 Watts. Sun and star sensors, along with gyroscopes, provide orientation reference. Special thermal control schemes are in place for critical elements such as atomic clocks. The Attitude and Orbit Control System (AOCS) uses reaction wheels, magnetic torques, and thrusters to maintain satellite orientation. Its propulsion system includes a Liquid Apogee Motor (LAM) and thrusters. IRNSS-1D was initially launched into a sub-Geosynchronous Transfer Orbit (sub-GTO) with specific orbit parameters and inclination. After deploying its solar panels, the satellite used its Liquid Apogee Motor (LAM) to maneuver into its final circular geostationary orbit.

**PSLV-C31/IRNSS-1E**

Jan 20, 2016

In its 33rd flight, the Polar Satellite Launch Vehicle launched IRNSS-1E, the fifth satellite of the Indian Regional Navigation Satellite System, using the ‘XL’ version of PSLV for the eleventh time. IRNSS-1E, with a lift-off mass of 1425 kg, is the fifth navigation satellite of the seven satellites comprising the IRNSS space segment. Its predecessors, IRNSS-1A, 1B, 1C, and 1D, were launched between July 2013 and March 2015. The configuration of IRNSS-1E is similar to that of IRNSS-1A, 1B, 1C, and 1D. IRNSS-1E carries two payloads - navigation and ranging. The navigation payload operates in L5-band and S-band, transmitting navigation signals and containing a Rubidium atomic clock. The ranging payload consists of a C-band transponder and Corner Cube Retro Reflectors for laser ranging. IRNSS-1E is the fifth navigation satellite in the IRNSS space segment. It was launched by PSLV-C31 on January 20, 2016. The satellite carries navigation and ranging payloads and has a lift-off mass of 1425 kg. It is similar in configuration to its predecessors and operates in L5-band and S-band.

**PSLV-C32/IRNSS-1F**

Mar 10, 2016

The PSLV-C32 launched IRNSS-1F, the sixth satellite of the Indian Regional Navigational Satellite System, from the Second Launch Pad of Satish Dhawan Space Centre in Sriharikota. This is the thirty-third consecutively successful mission of PSLV and the twelfth in its 'XL' configuration. IRNSS-1F is the sixth navigation satellite in the Indian Regional Navigation Satellite System (IRNSS). Its predecessors, IRNSS-1A to 1E, were successfully launched between July 2013 and January 2016. All five satellites are currently operating satisfactorily from their designated orbital positions. IRNSS-1F has a lift-off mass of 1425 kg and features two solar arrays generating about 1660 Watts of electrical power. Its Attitude and Orbit Control System (AOCS) maintains orientation using reaction wheels, magnetic torques, and thrusters, with a propulsion system consisting of a Liquid Apogee Motor (LAM) and thrusters. IRNSS-1F carries two payloads: navigation and ranging. The navigation payload transmits signals in L5-band and S-band and includes a Rubidium atomic clock. The ranging payload consists of a C-band transponder for accurate range determination. It also carries

**PSLV-C33/IRNSS-1G**

Apr 28, 2016

On April 28, 2016, PSLV-C33 launched IRNSS-1G, the seventh satellite of the Indian Regional Navigation Satellite System, into a Sub-Geosynchronous Transfer Orbit. The launch took place at the Satish Dhawan Space Centre in Sriharikota using the PSLV-XL version. The 'XL' variant of the PSLV has been utilized for the thirteenth time. In addition to deploying six IRNSS satellites, PSLV-XL has overseen the successful launch of various other spacecraft, including India’s Mars Orbiter spacecraft, the multi-wavelength observatory ASTROSAT, Radar Imaging satellite RISAT-1, and the Communication satellite GSAT-12Furthermore, the PSLV-XL successfully placed five satellites from the United Kingdom into orbit during a single commercial mission. PSLV has completed 34 successful missions, proving its reliability. IRNSS-1G is the seventh navigation satellite in the IRNSS space segment, with the same configuration and mass as its predecessors. IRNSS-1G, like its predecessors, carries two types of payloads: navigation and ranging. The navigation payload transmits signals in L5-band and S-band and includes a Rubidium atomic clock. The ranging payload consists of a C-band transponder for accurate range determination.

**PSLV-C41/IRNSS-1I**

Apr 12, 2018

India's PSLV-C41 in XL configuration launched the IRNSS-1I satellite from SDSC SHAR, Sriharikota. This was the twentieth time the 'XL' configuration was used. IRNSS-1I is the eighth satellite in the NavIC navigation constellation. IRNSS-1I is the eighth navigation satellite in the IRNSS space segment. It has a lift-off mass of 1425 kg and a configuration similar to its predecessors, IRNSS-1A, 1B, 1C, 1D, 1E, 1F, and 1G. PayloadsIRNSS-1I carries a navigation payload transmitting signals for position, velocity, and time determination, equipped with Rubidium atomic clocks. Its ranging payload includes a C-band transponder for accurate range determination and Corner Cube Retro Reflectors for LASER Ranging.

RESEARCH:

Research areas:

* Research is going on in the comparative studies between IRNSS and other GNSS constellations, IRNSS band, ionospheric studies, solar radiation pressure, GDOP, HDOP and VDOP estimation for IRNSS constellation, Kalman filter, Standard Positioning Signals, Analysis of parameters of L5 and S1 NavIC signals,

**1. Satellite Design and Development**

* **Next-Generation Satellites**: Improving the design and technology of future IRNSS satellites to enhance their lifespan, reliability, and performance.
* **Payload Optimization**: Research on optimizing payloads for better signal strength, accuracy, and coverage.

**2. Signal Processing and Algorithm Development**

* **Signal Integrity and Authentication**: Ensuring the signals are robust against interference, spoofing, and jamming. Developing authentication mechanisms to verify signal authenticity.
* **Error Correction Algorithms**: Enhancing algorithms to reduce errors in positioning data, including ionospheric and tropospheric correction models.

**3. Navigation and Positioning Applications**

* **Precise Positioning Services**: Research on improving the accuracy of positioning services, targeting sub-meter or even centimeter-level accuracy.
* **Time Synchronization**: Ensuring high-precision time synchronization for critical applications like telecommunications and financial transactions.

**4. Integration with Other GNSS Systems**

* **Multi-GNSS Integration**: Combining IRNSS/NavIC with other Global Navigation Satellite Systems (GNSS) like GPS, GLONASS, Galileo, and BeiDou for improved accuracy and reliability.
* **Hybrid Positioning Systems**: Developing hybrid positioning systems that use a combination of satellite navigation, inertial navigation, and other technologies for enhanced performance.

**5. Environmental and Disaster Management**

* **Disaster Monitoring and Response**: Using IRNSS/NavIC data for real-time monitoring and management of natural disasters like earthquakes, tsunamis, and floods.
* **Environmental Monitoring**: Research on applications for tracking environmental changes, pollution levels, and weather patterns.

**6. Vehicular and Fleet Management**

* **Navigation for Autonomous Vehicles**: Developing applications for autonomous vehicle navigation and control using IRNSS/NavIC.
* **Fleet Management Systems**: Enhancing systems for tracking and managing fleets of vehicles, improving logistics and transportation efficiency.

**7. Agriculture and Rural Development**

* **Precision Agriculture**: Using IRNSS/NavIC for precision farming techniques, optimizing the use of resources like water, fertilizers, and pesticides.
* **Rural Development**: Applications in rural areas for land surveying, resource management, and infrastructure development.

**8. User Equipment and Receivers**

* **Low-Cost Receivers**: Developing affordable and efficient IRNSS/NavIC receivers for mass-market use.
* **Mobile Integration**: Integrating IRNSS/NavIC capabilities into smartphones and other mobile devices for widespread accessibility.

**9. Academic and Industrial Collaboration**

* **Collaborative Research**: Partnerships between academic institutions, research organizations, and industry to foster innovation and practical applications of IRNSS/NavIC technology.
* **Pilot Projects**: Implementing pilot projects to test and demonstrate the capabilities and benefits of IRNSS/NavIC in real-world scenarios.

**10. Standardization and Policy Development**

* **Standards for Integration**: Developing standards and protocols for integrating IRNSS/NavIC with other systems and services.
* **Regulatory Framework**: Establishing policies and regulations to support the deployment and usage of IRNSS/NavIC in various sectors.

Ongoing research endeavours seek to amplify the capabilities and broaden the applications of IRNSS/NavIC, positioning it as a crucial element of India's strategic and technological infrastructure.

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