BENEFITS OF INDIAN SATELLITE NAVIGATION SYSTEMS

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The applications of Global Navigation Satellite System (GNSS) are rapidly increasing across various sectors and entered into our daily life in many ways that we might not think about and the values of those services are beyond monetary values. Yet, the future potential is still far reaching.

Realizing the enormous potential benefits and economic impacts of Navigation Satellite System providing position, navigation and timing services, India took early initiative and initiated GAGAN (GPS Aided Geo-Augmented Navigation) and IRNSS (Indian Regional Navigation Satellite System) or NAVIC (Navigation with Indian Constellation) projects.

The GAGAN system is a Space Based Augmentation System (SBAS) developed by the Indian Space Research Organization (ISRO), together with Airports Authority of India (AAI) to deploy and certify an operational SBAS for the Indian Flight Information Region (FIR), with expansion capability to neighboring FIRs. GAGAN provides a safety of life civil aeronautical navigation signal consistent with International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) as established by the Global Navigation Satellite System (GNSS) Panel. GAGAN system provides NPA (Non Precision Approach) services of RNP-0.1 over Indian FIR and PA(Precision Approach) services of APV-1.0/APV-1.5 (AProach with Vertical guidance) over Indian landmass on nominal days.

IRNSS project is a regional independent navigational satellite system using a combination of GEO and GSO spacecrafts and state-of-the-art ground systems. The IRNSS System provides navigation solution all time with position accuracy better than 20m during all weather conditions, anywhere within India and a region extending about 1500 km around India. IRNSS provides Standard Positioning Service (SPS) and Restricted Service (RS) to the users on dual frequencies in L5 and S band.

GAGAN and IRNSS will provide benefits to many user segments for land, sea and air applications such as intelligent transportation, agriculture, maritime, highways, railways, surveying, geodesy, security agencies, telecom industry, personal users of position location applications and timing applications etc, in the Indian subcontinent.

The application of GAGAN and IRNSS in a number of market segments will deliver enormous benefits to India's economy. The products and services create values for commercial and noncommercial users. For commercial users, the satellite navigation technology will make the production processes and operations to be easier, safer, and cost-effective. For noncommercial users, the technology will create monetary values of time and cost savings as well as nonmonetary values of safety and lifestyles. Like other innovative products and services, this technology is expected to create jobs and economic activities to support the economic growth.

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Introduction

Since the beginning of time, human beings have looked at SUN, star and other planets to determine their whereabouts. Constellations of manmade satellites are taking over their guidance currently.

The Word Navigation has been derived from the Sanskrit word "NAVGATH". Navigation is the science of charting one's own route from point 'A' to point 'B' with respect to known references both in terms of space and time. Finding out the position of an object is made possible by navigation.

Satellite-based navigation has become an integral part of human life in 21st century with pocket size GPS receivers used in vehicles, Global Navigation Satellite System (GNSS) enabled smart phones etc. Today, the GNSS has entered the society with its multi-facet applications through its remarkable presence in location based services, survey, GIS, agriculture, industry and service sectors, the core contributors towards any country's economy. The Socio-economic impact is a major predictor of success of a large scale technological venture in any country. In a nutshell, any new technological development and its value added services will have considerable social and economical impact on the livelihood of common man and the associated society, in addition to the industrial impacts. Satellite based navigation system is one such newly advancing technology which is offering modern navigation services and benefitting the users in terms of highly accurate position, velocity and timing solution economically all around the world.

Realizing the enormous potential benefits and economic impacts of GNSS providing precise position, navigation and timing services, India took early initiative and initiated GAGAN (GPS Aided Geo Augmented Navigation) and IRNSS (Indian Regional Navigation Satellite System) or NAVIC (Navigation with Indian Constellation) projects. GAGAN is the Indian SBAS-Satellite Based Augmentation System to offer safety of life navigation services over Indian airspace, while IRNSS is being realized to achieve self reliance in satellite navigation in the Asian region , to serve as an all weather system on a 24x7 basis.

This paper describes first, the two Indian Satellite Navigation Systems and then gives an overview of their applications.

Navigation

In the earlier days the elements of nature, the celestial bodies, the geographical landmarks etc guided him along his journeys. As the humans evolved, new guidance mechanisms evolved with him. Compass, cross-staff, sextants, light houses etc. were invented. Later began the times of radio navigation with systems like LORAN which paved way for the next generation of navigation systems the ***Satellite-based Navigation***.

The era of Satellite Based Navigation began with the Timation and Transit systems. This was followed by the more advanced and currently operational GPS by USA and GLONASS by Russia. The Chinese and Europeans are entering the arena with COMPASS and GALILEO constellations respectively.

According to a number of market studies and surveys Global Navigation satellite system- GNSS revenues are expected to grow at a double digit CAGR in the 2010 – 2020 periods. This growth will come from both new applications and expansion of current products and services. In terms of penetration, the biggest impact will come from Location Based Services since GNSS is still only in a small portion of today's mobile phones.

Towards reaping the anticipated benefits, India through the Indian Space Research Organization (ISRO) and Airports Authority of India (AAI) have implemented the GAGAN project as a Satellite Based Augmentation System (SBAS) for the Indian Airspace. The objective of GAGAN to establish, deploy and certify Satellite based augmentation system for safety-of-life civil aviation applications in India has been successfully completed. Together with this, IRNSS**,** the Indian Regional Navigation Satellite System, is an ISRO initiative to design and develop an independent satellite-based navigation system to provide positioning, navigation and timing services for users over Indian region

GAGAN

The GAGAN system is a Space Based Augmentation System (SBAS) developed jointly by ISRO and AAI to deploy and certify an operational SBAS for the Indian Flight Information Region (FIR), with expansion capability to neighboring FIRs. GAGAN provides a civil aeronautical navigation signal consistent with International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) as established by the Global Navigation Satellite System (GNSS) Panel. GAGAN system provides NPA (Non Precision Approach) services of RNP-0.1 over Indian FIR and PA (Precision Approach) services of APV-1.0/APV-1.5 (AProach with Vertical guidance) over Indian landmass on nominal days.

Although primarily meant for Civil Aviation, the GAGAN signal can be used by a vast majority of users like private and public vehicles, railways, shipping, surveys etc. It is to be noted that India is the 4th country in the world to implement the SBAS system for navigation after US WAAS, European Union's EGNOS and Japan's MSAS. India has become the third country in the world to have APV-1 precision approach capabilities. GAGAN system is interoperable with other SBAS systems and will offer seamless navigation in the region bridging the gap between Europe and Japan.

The GAGAN system presented by Ganeshan et al[1] consists of the following elements for the effective implementation of SBAS over India.

1. Indian Reference Station (INRES)- at 15 locations across India
2. Indian Master Control Centre(INMCC) – 2 at Bangalore
3. Indian Land Uplink Station(INLUS)- 3 ; 2 at Bangalore, 1 at New Delhi
4. Geo Stationary Satellite (GSAT8/GSAT10) in the orbit and one on orbit spare in GSAT-15(to be launched)
5. Data Communication Sub-system- 2 OFC circuits, 2 VSAT circuits, Total 4 circuits

The data collected by each the INRES across the country are transmitted to INMCC in real time (every second) and processed for the generation of correction and integrity parameters, in the form of SBAS messages. The generated SBAS messages are sent to INLUS for further processing.

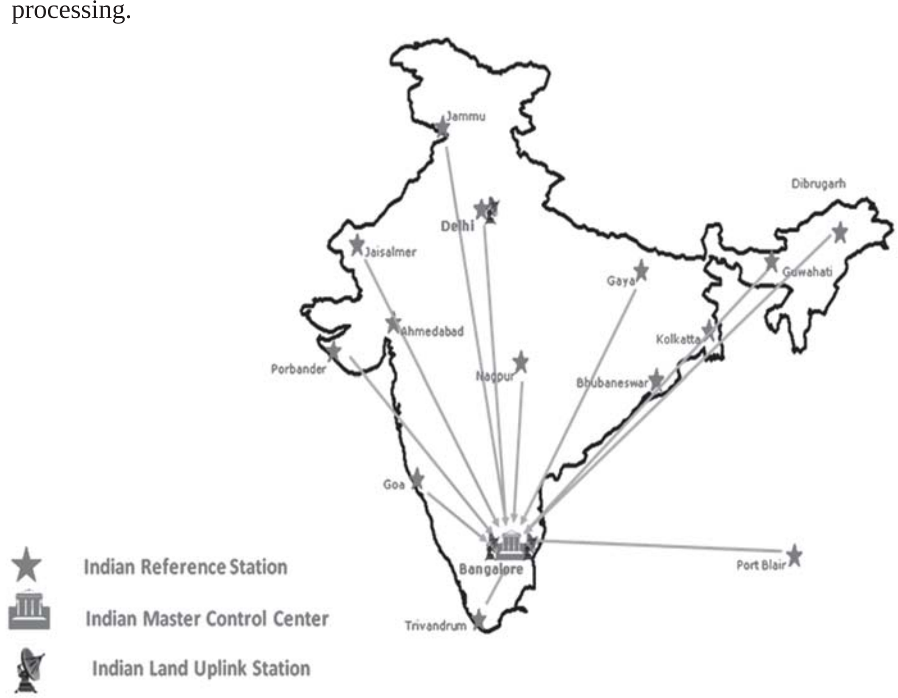


Fig. 1 : GAGAN ground segment

The INLUS receives the SBAS messages from INMCC, formats them for GPS compatibility and uplinks the SBAS messages to GEO Stationary satellite for broadcast to the user community. The SBAS messages contain information that allows SBAS receivers to remove errors in the GPS position solution, thereby allowing for a significant increase in location accuracy with reliability. Along with the corrections, the confidence parameters (integrity) are also computed and provided to the users as messages. Three GEO satellites GSAT-8, GSAT-10 and GSAT-15 carry GAGAN payload. GSAT-8(55 deg East) and GSAT-10(83 deg East) are already transmitting GAGAN SIS (Signal in Space) with PRN127 & 128.

In addition to the above hardware elements, ISRO has developed a region specific ionospheric model called ISRO GIVE Model-Multi Layer Data Fusion (IGM-MLDF) with Raytheon which is well suited for Indian ionospheric conditions. This model is incorporated into the main operational software to compute and provide iono corrections and integrity factors to meet the APV requirements. This model was chosen for implementation into the operational software after evaluation of algorithm based on performance and ease of certification.

Initially, Director General of Civil Aviation (DGCA) certified GAGAN for enroute operations (RNP 0.1) on December 30, 2013 and subsequently on April 21, 2015 for precision approach services (APV 1). APV1 Certified GAGAN signals are being broadcast with effect from May 19, 2015.

The accuracy of position solution given by standalone GPS is more than 10m, whereas the SBAS system improves the accuracy to better than 5m by providing various correction signals to the user. Typically the horizontal accuracy provided by GAGAN is better than 1.5m (95%) and the vertical accuracy realized is better than 2.5m (95%) of the time.

Also, in standalone GPS, the integrity is not guaranteed as all GPS satellites are not monitored at all times. In case of any fault, the time-to-alarm is from minutes to hours. The quality of the service is not indicated. The SBAS provides integrity information about all the GPS satellites in view and protect the user

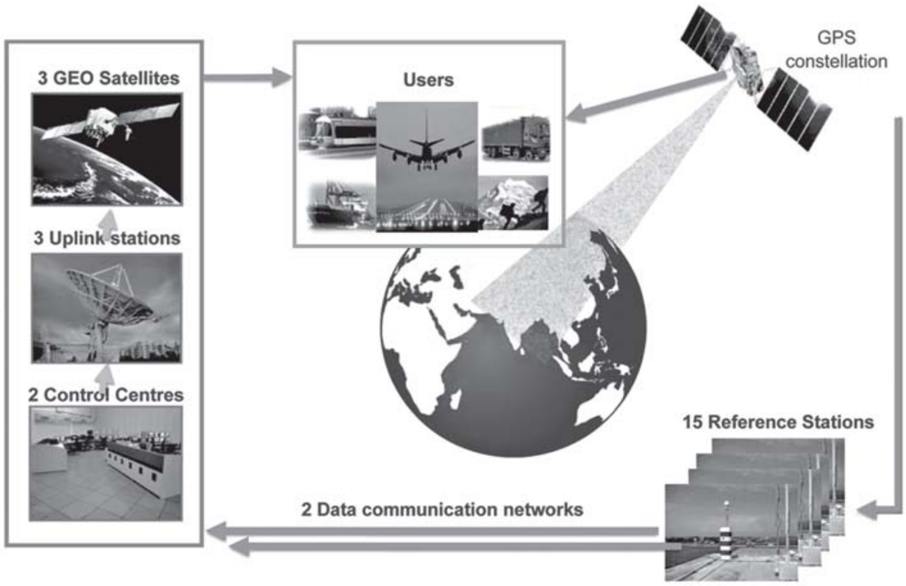


Fig. 2 : GAGAN Architecture

from using unreliable/unmonitored satellite. Thus SBAS has the ability to protect the user from inaccurate information in a timely manner.

By adopting GAGAN for aviation, flight delays, diversions and cancellations (DDC) will be minimized, while minimizing Controlled Flight into Terrain (CFIT) incidents by 75%. In addition, it enables direct flight paths and reduction of separation minima, which reduce the workload for pilots and controllers. Further, GAGAN facilitates enhanced oceanic air traffic control facility, where ground-based navigation system is unavailable. Also, shorter direct flight paths enabled by GAGAN, leads to time and fuel saving. Consequently, decrease of emission of green house gases due to shortened flight paths, results in reduction of air pollution. At the same time, flexible flight paths enabled by SBAS makes weather deviation uncomplicated and also enables reduction of noise in noise sensitive areas.

GAGAN is an enabler for low cost regional airports (green field and brown field airports) and usher in greater connectivity to the fast growing aviation in the country.

Although primarily meant for Civil Aviation, the GAGAN signal can be used by a vast majority of civilian and non-aviation users. GAGAN will provide benefits beyond aviation to many other user segments such as intelligent transportation, maritime, highways, railways, surveying, geodesy, security agencies, telecom industry, personal users of position location applications etc in the Indian subcontinent. GAGAN can be utilized for sending short service messages with suitable changes in the message structure.

It is to be noted that India is the 4th country in the world to implement SBAS system for civil air navigation after US WAAS, European Union's EGNOS and Japan's MSAS. India has become the third country in the world to have APV-1 precision approach capabilities and the first SBAS system in the world to serve the equatorial region. GAGAN system is interoperable with other SBAS systems and will offer seamless navigation in the region bridging the gap between Europe and Japan.

IRNSS (NAVIC – Navigation with Indian Constellation)

The Indian Regional Navigation Satellite System (IRNSS) marks India's entry into the realm of independent satellite-based navigation systems. The Indian Space Research Organization (ISRO) is the nodal agency for the realization, operation and maintenance of the system. This involves building, launching and operating the navigation satellites, establishing the ground support systems,

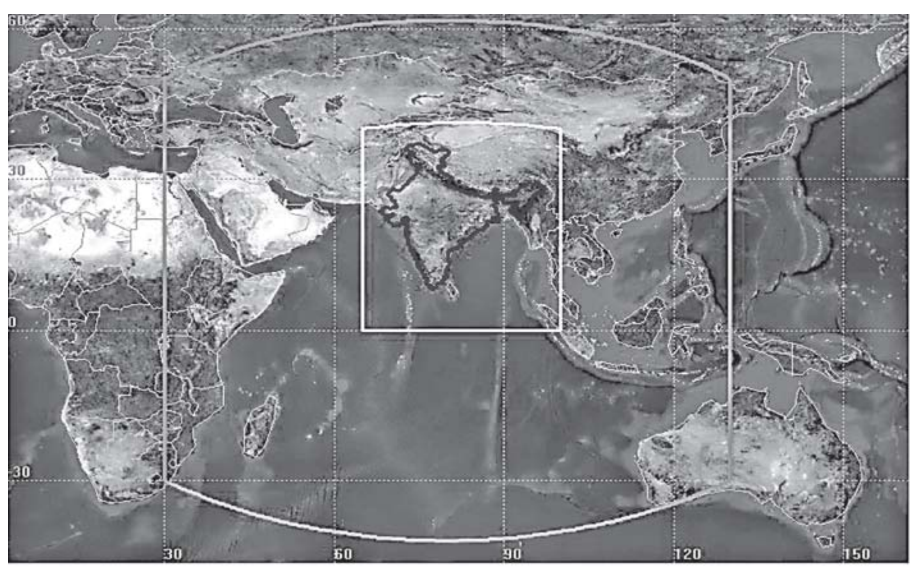


Fig. 3: IRNSS Service Area

replenishing the spacecrafts and augmenting the ground systems from time to time. The IRNSS is established with an objective of offering Positioning, Navigation & Timing services to the users in its service area. The system is designed to provide its users with a position accuracy of less than 20m (2ó) in its primary service area.

The IRNSS classifies its service areas broadly in to two regions. The primary service area of IRNSS encompasses the Indian landmass and a region lying within a distance of 1500km from its geo-political boundary and the secondary service area is extends between 30^0S and 50^0N Latitudes and 30^0E to 130^0E Longitudes (as shown in Figure 3).

IRNSS provides two types of navigation services, the Standard Positioning Service, which is an unencrypted service, provided to all the users within the IRNSS service area and a Restricted Service which is an encrypted service provided only to the authorized users in the service area.

Similar to GAGAN, the IRNSS navigation infrastructure as described by Ganeshan et al[2,4] can be divided into three segments

i. Space Segment : consisting of the seven space vehicles that broadcast the IRNSS navigation signals to its users.

ii. Ground Segment : consisting of the various ground stations that provide all the necessary ground support to operate the IRNSS system. This includes the precise timing system, the spacecraft ranging mechanisms, the navigation software, the communication networks and spacecraft telemetry, tracking & command network.

iii. User Segment: consisting of the civilian and authorized users of IRNSS employing various types of IRNSS receivers.

The figure[4] below depicts the general architecture of the IRNSS architecture:

IRNSS space segment consists of a constellation of seven satellites, three satellites in GEO and four satellites in GSO with inclination of 29° to the equatorial plane as given in Ganeshan et al[3] and Pal et al[5]. The 3 GEO satellites located at 32.5° E, 83° E and 129.5° E and the 4 GSO satellites have their longitude crossings 55°E and 111.75° E (two in each plane). All the satellites will be visible in service region for 24 hours. The satellites as seen from the IRNSS service areas are depicted in the figure below. The footprint of a GSO satellites form a figure of 8 (It has to be noted that the spacecrafts move in a circular orbit and do not move along figure of 8 orbits)

The IRNSS spacecraft is configured around I1K Bus i.e. a 1-ton class bus. The I1K bus is selected because the weight of the payload and all the sub systems required for IRNSS can be accommodated in the structure, and also falls within the payload capacity of the PSLV (Polar Satellite Launch Vehicle), the workhorse of Indian space program. The I1K bus structure is also optimum in terms of the structural weight to payload weight and volume, and meets the propulsion requirement of the satellites. All the satellites for GEO and GSO are similar. The similar design has been chosen in order to manufacture the satellites in a production mode which enabled deployment of constellation in a fast track mode. The stowed view of IRNSS spacecraft is shown below:

IRNSS satellites have two types of payloads, viz. the navigation payload and the ranging payload as described by Parimal et al[6]. The navigation payload of IRNSS is a broadcasting type of payload which transmits navigation service signals to the users. This payload operates in S and L5 bands.

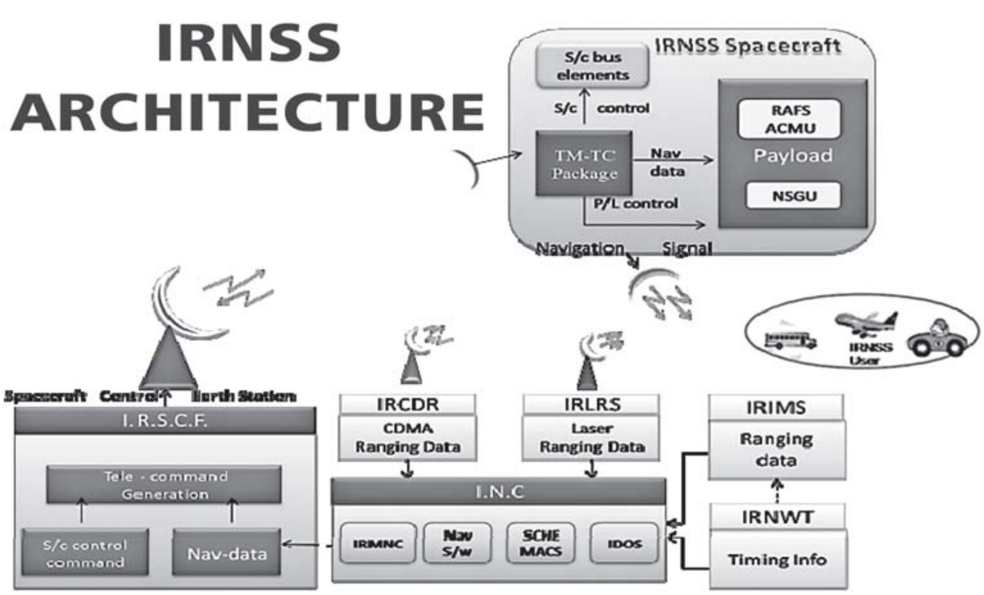


Fig 4. IRNSS (or NAVIC) Architecture.

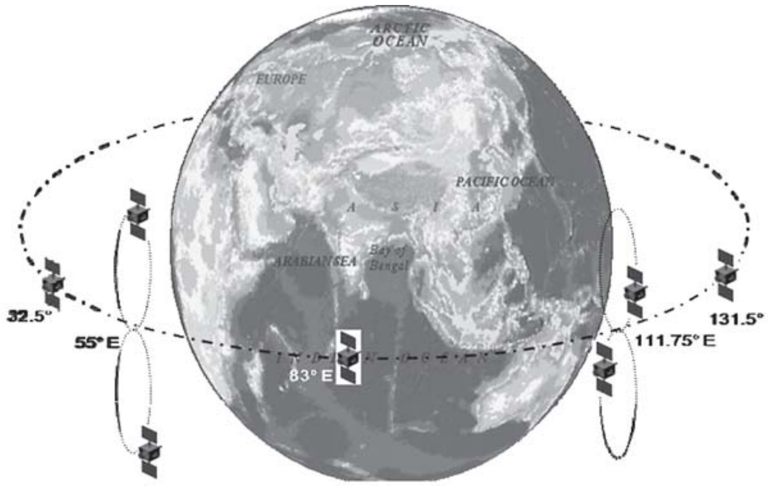


Fig 5: IRNSS constellation as seen from Indian region

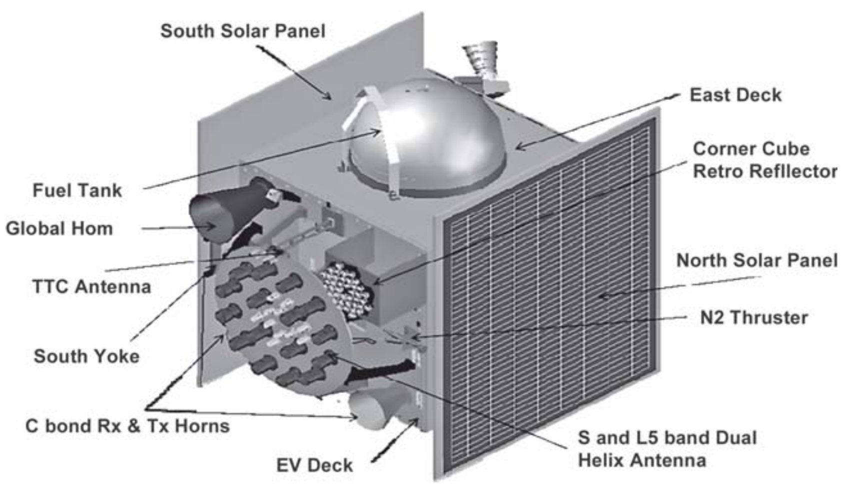


Fig. 6: IRNSS satellite – stowed view

The ranging payload supports the CDMA ranging of the IRNSS spacecrafts.

The Ground Segment constitutes of several components that provide all the necessary ground support to operate the IRNSS system. Ground segment comprises of:

- Spacecraft Control Facility (SCF)
- Range and Integrity Monitoring Stations (IRIMS)
- Network Timing Facility(IRNWT)
- Navigation Centre (INC)
- CDMA Ranging Stations(CDMA)
- Laser Ranging Stations(ILRS)
- Data Communication Network (DCN)

IRNSS System Operations Concept : Once the IRNSS spacecrafts are launched and declared fit for operations, the various ground segment elements step in to action. The activities commence with the orbit and clock estimation of the spacecraft. The on-board clock is synchronized with respect to the highly precise and stable IRNWT timescale. The ranging of the satellite is carried out by means of 1-way ranging and CDMA ranging. The laser ranging of the IRNSS spacecrafts are carried out in a campaign mode in coordination with the International Laser Ranging Stations (ILRS) located across the globe. The laser ranging provides precise range measurements thereby validating the orbit estimations carried out by the regular one-way and two-way range measurement systems.

The orbit and clock estimation is carried out by the Navigation software hosted at INC. The software predicts the orbital parameters from one-way and two-way range measurement data. Also, the on-board clock is characterized and the clock parameters viz. clock offset, clock drift and drift rate are predicted. The orbit and clock parameters constitute the primary navigation data that is uplinked to the spacecraft and finally reaches the user. Generally, the orbit and clock parameters are predicted in advance for 24 hours and uplinked to the spacecraft. In order to cater contingency situations resulting in a communication breakage from ground system to the spacecraft Autonav data are also uplinked to the spacecraft. Satellites store 7 days ephemeris and clock parameter sets as AutoNav data sets and support broadcast of primary navigation parameters.

In order to mitigate the ionospheric errors for a single frequency user, IRNSS utilizes a specially devised Grid-based ionospheric model in addition to the conventional Klobuchar model. The ionospheric grid parameters computed by the navigation software and uplinked to the spacecraft form the major part of the secondary navigation data. The time offsets with respect to other GNSS service providers are also computed and uplinked as a part of secondary navigation parameters. These time offset parameters facilitate time correlation between different systems in multi GNSS receivers.

The spacecraft control facility performs the navigation data uplink routine in addition to its regular telemetry, tracking and command operations. As a GEO- GSO combination of satellites are chosen to support the regional service, regular operations on satellite called station keeping operations are required to be carried out periodically in order to maintain specific orbits. The station keeping maneuvers cause a short outage of service for a given satellite. On completion of the station keeping maneuver the ranging and orbit determination of the satellite are again carried out and the new set of orbit and clock parameters are uplinked before the satellite is again declared operational. The processes are highly automated and the outage time is kept very minimal.

The User segment mainly consists of: a Single frequency IRNSS receiver capable of receiving SPS signal at L5 or S band and a dual frequency IRNSS receiver capable of receiving both L5 and S band frequencies.

The IRNSS Network Timing facility is operational since June 2012. The offset between UTC (IRNWT) and UTC is being generated using the common-view measurement with National Physical Laboratory(NPLI), New-Delhi. The IRNWT (Timescale-A) is maintained within the specification of 50ns for 95% of the time in a year.

With the IRNSS constellation being fully realized, it was possible to estimate the position at reference station locations with known clock bias. The position error obtained is better than 10m across all the reference stations over a day.

GNSS Applications

GNSS applications use GNSS Receivers to collect position, velocity and time information for their functionality. The GNSS-based applications introduced great benefits in surveying, timing, aviation, maritime, agriculture, mining and logistic market industry, as well as other fields such as construction or oil offshore platforms. The GNSS-based applications for fleet management market are also expanding due to decreasing device prices and increasing accuracy of systems at a very low cost as projected by Nam[7].

The GNSS Applications range from non-critical to highly critical applications. The different criticality of GNSS applications leads to different performance requirements from the GNSS systems as indicated by Bone[8]. GNSS applications are categorized into:

- Civil Applications
- Surveying, Mapping and GIS
- GNSS-based Products
- Space Applications
- Scientific Applications
- Military Applications
- Autonomous Applications and Other applications

Civil Applications : Even though the GNSS systems (GPS and GLONASS) were developed for military purposes, later on they were made freely available for civilian users.

Different types of civil applications which use GNSS are:

- Personal navigation for travelers
- Railways
- Maritime Applications
- Vehicle navigation
- Aviation Applications
- Automated vehicle navigation in industries
- Search & Rescue operations etc

Given the easy availability of GNSS positioning in consumer products the use of GNSS positioning for personal applications has become customary and new uses such as pedestrian navigation, outdoor navigation for hiking, social networking, photography geo-coding etc., keep emerging.

In many places, Rail systems are beginning to use GNSS to track the movement of locomotives, rail coaches, maintenance vehicles, and wayside equipment in real time. The technology helps reduce accidents, delays and operating costs while increasing track capacity, customer satisfaction and cost effectiveness. The railway domain could considerably profit from the implementation of autonomous on-board positioning systems[13].

GNSS technology brought innovation and progress in navigation and many other marine activities such as fishing, oceanography and oil and gas exploitation. Satellite navigation benefits all maritime applications, including leisure boats, commercial vessels, and unregulated and Safety of Life at Sea (SOLAS) regulated ships. Each application will take advantage of the new characteristics offered by GNSS augmentation: increased accuracy and integrity, certified services and high availability and GNSS is being used in every phase of marine navigation: ocean, coastal, port approach and port maneuvers, under all weather conditions.

The road sector is a major potential market for GNSS applications. Satellite navigation receivers are now commonly installed in new cars as a key tool for providing new services to people on the move: electronic charging, real-time traffic information, emergency calls, route guidance, fleet management and Advanced Driving Assistance Systems. Satellite navigation will help regulate road use and minimize traffic jams and It could be used to charge motorists for using a stretch of road, to restrict access to congested roads, or to inform drivers of congestion and suggest alternative, quieter routes etc.,

The development of GNSS has provided a supplementary positioning service for many flight phases, in leisure flying as well as commercial air transport. Refining and improving satellite navigation through augmentation systems will assist pilots in all flight phases, from taxing, to take-off, en-route flying, and landing in all weather conditions, reaching the level of safety that will be required to cope with the continuous increase in the number of flights.

Industry uses heavy machinery for many purposes. Satellite navigation and GNSS augmentation techniques can guide these machines precisely to perform their work. The same technique can be used for automated guidance of machines working in dangerous areas or simply to save manpower in repetitive work. The computer compares the GNSS position with the desired work profile and provides visual guidance to the operator for maneuvering the vehicles. The use of satellite-based machine guidance systems in surface mines is becoming common with very positive results in productivity and costs.

Surveying, Mapping and GIS : One of the most evident uses for GNSS is the realization of surveys and production of maps. Although a simple standalone GNSS Receiver might not have the required precision for some survey requirements, most of these requirements can be fulfilled using high-end dual frequency multi-constellation receivers built specifically for surveying and by using GNSS Augmentation techniques. The use of GNSS techniques in geodesy have revolutionized the way geodetic measurements are made. An increasing number of national governments and regional organizations are using GNSS measurements as the basis for their geodetic networks.

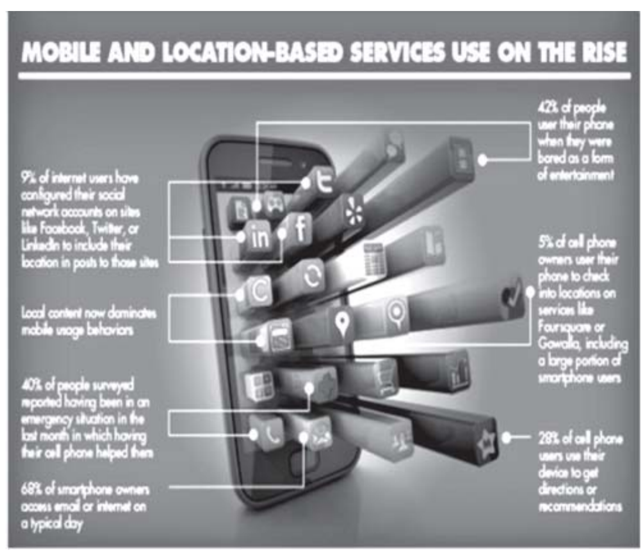
Space Applications : Even though the GNSS systems were originally designed for earth-based positioning and navigation, real-time spacecraft navigation based on space borne GNSS receivers is becoming a common technique for low-Earth orbits and geostationary orbits, allowing satellites to self-determine their position using GNSS, reducing dependence on ground-based stations. The different launch vehicles also use GNSS-based ranging systems for the launch and initial orbit phase.

Scientific Applications : GNSS systems offer important contributions to variety of scientific research work. New and improved data analysis techniques, jointly with a growing variety of available measurements encouraged development of more and more scientific applications in various fields. It is expected that evolving new systems such as Galileo and BeiDou, will contribute to further improvements in the current available applications as well to promote new applications in the areas of earth sciences and space science meteorology etc.,

Military Applications : Since the first GNSS systems (GPS and GLONASS) were primarily developed for military purposes, the military applications are one of the drivers for these systems. For instance GPS offers encrypted Precise Positioning Service which is available only to the US military and its allies. GNSS is used for different types of Military Applications such as Military Navigation and Target Acquisition.

Autonomous Applications : Autonomous vehicles technology is a multidisciplinary technology where different engineering areas, such as Navigation, are required. GNSS plays the pivotal role in the development of driverless car technology. With precise positioning, GNSS can be used for lane or track determination (for road and rail vehicles) and attitude determination by using multiple antennas.

Autonomous vehicle technology is still at its infancy but currently the first laboratory prototypes are being tested and demonstrated. GNSS has been one of the key drivers



for the recent developments in the area of Autonomous Driving and Autonomous Flying.

Location Based Services : Location Based Services (LBS) include applications that depend on the user location to provide a service/information that is relevant to the user at that location. LBS normally use mobile devices with positioning ability to provide the service or information to the user.

LBS can be used for personal or professional purposes such as:

- Location based Information Streams
- Tourist Information, Games
- Carpooling and Transport on Demand etc.

Other Applications : The main objective of GNSS systems is to provide positioning but by design other information is available from the measurements gathered by GNSS receivers. This led to less conventional uses of the technology in application areas that were not initially envisioned. By design GNSS systems deliver precise time along with the position and velocity of the user. This capability has been used to provide a precise time reference in different areas such as financial transactions power grid , stock markets etc.

One other example of a less conventional use of GNSS technology is the use of the measured interference of the atmosphere on the GNSS signals to do atmospheric sensing.

Safety-of-Life (SOL) Services : In addition to the above regular applications, GNSS also provide safety-of-life services. To provide SOL services such as aviation, maritime etc., navigation systems must satisfy several stringent performance requirements such as

- Accuracy – The information that they give must be close to the actual value.
- Integrity – If the system cannot give sufficiently accurate information, it must notify the user of this in time.
- Availability – It may not occur that the system is unexpectedly unavailable.
- Continuity of service – If the system stops working after, for example, 2 years, it's not really useful.

A GNSS system, on its own does not possess these features. The GNSS system is then augmented using a ground-based (GBAS) or space-based (SBAS) system in order to meet the safety of life performance requirements. The various SBAS systems in place are: WAAS in USA, EGNOS in Europe, GAGAN in India and QZSS by Japan.

Benefits of IRNSS and GAGAN

All the benefits described in the earlier sections can be derived with GAGAN and IRNSS. Satellite based navigation systems used in mobile phones play an important role in our daily lives. People use various types of navigational devices and smart phones to help them locate and route their travel destinations, to identify the different places they move around in and also get the information they seek. The availability of many applications in the smart phones has led to an increased popularity and demand for them. Though a bit on the expensive side, considering the safety and benefits they offer to the user, it is well worth paying this extra amount for the devices.

In addition to common man there are also many others like fishermen, cyclists, sailors, hikers, travellers and those working with emergency services who benefit by these hand held devices. In fact, the usage of smart devices with the host of new apps, has grown so universal now that these devices have become a regular necessity for most people, just like wrist watches.

Fishermen go fishing with GNSS receiver to know his current location and identify the direction of his destination. The information from remote sensing data and navigation information from receivers help quite a lot. Based on this information they can plan their day's fishing, and decide if it is safe to go fishing.

We are no longer at the mercy of unexpected weather patterns that kill hundreds of people, as the location based services could warn us of impending disasters. Farmers and foresters benefit from satellites, as they receive location information about river flooding and forest fires.

Navigation satellites allow positions at sea to be determined with an accuracy of about 10 m, and they also aid navigation by locating ice and mapping ocean currents.

Those in emergency services benefit from the satellite navigation services as they provide more accurate and reliable information that can be used to take precautionary measures and plan relief operations. Moreover, the smart phones with navigation applications, help those people who are affected by unprecedented floods, earth quakes and winter storms as it could provide relief and information.

Though expensive, well worth it, Hikers and cyclists covering long distances do not have to worry about getting lost with a mobile navigation device in hand. The satellite navigation system in the hand held receivers not only provides them with navigational tools but also helps authorities track, monitor and reach them in case they meet some emergency situations.

The maps on mobile through **B**huvan, the satellite Navigation services through **I**RNSS and **G**AGAN, (**BIG**) will be highly beneficial to common man.

With several of the flagship programs of Government of India such as Digital India, Smart cities, Amrudh etc., the need for satellite based navigation services is very critical and central to their development. Together with this the other stake holders like the chip set manufactures, application developers, content providers and the user community will see rapid and large scale changes in the market. This will give rise to greater employment opportunities and consequently the socio-economic benefits of satellite based navigation will be tremendous. With the expected market projections to raise to about 7billion GNSS receivers in the world by 2022, the development and benefits will create a great opportunity. The usage of satellite based navigation in the forth coming years will be phenomenal[9-12].

The Socio-economic impact is a major predictor of success of a large scale technological venture in any country. In a nutshell, any new technological development and its value added services will have considerable social and economical impact on the livelihood of common man and the associated society, in addition to the industrial impacts. Satellite based navigation system is one such newly advancing technology which is offering modern navigation services to the users in terms of highly accurate position, velocity and timing solution economically all around the world on a 24x7 basis.

The utilization of space based services and applications has created new markets; helped save lives by warning us of natural disasters, expediting search and rescue operations, and making recovery efforts faster and more effective; made agriculture and natural resource management more efficient and sustainable; expanded our frontiers; and provided global access to advanced medicine, weather forecasting, geospatial information, financial operations, broadband and other communications, and scores of other activities worldwide.

Space systems allow people and governments around the world to see with clarity, communicate with certainty, navigate with accuracy, and operate with assurance. The satellite navigation program of India will redefine navigation over Indian region through self reliance and persistent development.

Conclusion

India has deployed two major satellite Navigation system – GAGAN and IRNSS. Benefits of satnav (Satellite Navigation) is enormous. The need of the hour is to create more awareness among the common man about the availability of such service and facility at minimal cost. Also there is an urge to identify and develop new applications based on user requirements. Once this is met, we can see a boom in the usage of satnav based services.

The application of Satellite Navigation technology in a number of market segments will deliver enormous benefits to global economy. The products and services create values for commercial and noncommercial users. For commercial users, the satellite navigation technology will make the production processes and operations to be easier, safer, and cost-effective. For noncommercial users, the technology will create monetary values of time and cost savings as well as nonmonetary values of safety and lifestyles. Like other innovative products and services, this technology is expected to create jobs and economic activities to support the economic growth.

Like any other manufacturers, manufacturers of satellite navigation products also create additional economic activities for upstream and downstream business entities. The manufactures purchase intermediate goods and services from upstream vendors to produce hardware, chipsets, etc. For downstream companies who rely on the technology the GNSS generates additional economic activities in the form of applications and services. The downstream business entities include satellite navigation device vendors, service and content providers, original equipment manufacturers, application developers and retailers. Commercial users utilize this technology to increase productivity which in turn has positive impacts on cost-savings, that include savings on labor, capital, and time. Noncommercial users enjoy Satellite Based Navigation technology for their daily life activities, like visual navigation for drivers for an instance. Altogether, satellite navigation systems will impart value for personal and business consumers.

Even though satnav is popular in US and Europe for some time, in India it is still in growing stage. The GAGAN system is deployed and operational and its outreach to user segment and application developer segment is progressing positively. More and more private, public and government departments are using GAGAN for variety of applications. The maps on mobile through **B**huvan, the satellite Navigation services through **I**RNSS and **G**AGAN, (**BIG**) will be highly beneficial to common man.The availability of low cost user receivers and satnav solutions through smart phones will take Indian satnav industry to the new heights in the forthcoming years. Technological advancement is considered as an important determinant of economic environment.

Acknowledgements

The author wishes to thank contributions from ISRO, AAI, DGCA, Raytheon Engineers, MITRE and other industry partners who have worked for realizing the GAGAN system. A special word of appreciation to Mr. G. Ramesh, Senior Manager, AAI for his efforts in brining out this article. ❐

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