Lecture-1
CHAPTER 2 INTRODUCTION TO GPS

2.1 History of GPS

- GPS is a global navigation satellite system (GNSS). It is the commonly used acronym of **NAVSTAR** (NAVigation System with Time And Ranging) GPS (Global Positioning System) operated by US DOD (Department of Defence). It helps the user to know his position anywhere on the earth by giving solution to the problem-"Where on earth am I?"

- Four GPS coded satellite signals make possible the computation of position in 3- dimensional form, velocity and time offset via receiver clock.

- It could be contributed on ease of use and cost reduction in hardware simultaneously.

- GPS surveys provides following advantages:-

  • 3- Dimensional with no need of site Intervisibility.
  • All weather and day or night operation.
  • Data processing with high speed having Common Reference System.
  • High quality control with achieving high precision.
  • Less labor but skilled persons are needed.

- A new beginning in new project of GPS has been proposed by US Department of Defense in the starting day of 1970's. This new concept found success in fulfilling all requirements related to position determination accurately at any time in any weather conditions for US government.

- After Post processing the data , following values would be possible to visualize:-

  - State Plane coordinates with latitude, longitude, geodetic height.
  - Cartesian Coordinates X, Y, Z.
  - Forward & backward geodetic azimuth with geodetic or slope distances of baselines for eliminating the use of Laplace correction for conversion of astronomic to geodetic azimuth.
  - Point to point varying vertical angle.

- Accuracy depends upon the quality of known points having baseline components in survey.

- There are two other Global systems for determination of positions, GLONASS and GALILEO.

- **GLONASS (Russian Navigation Satellite System):** Global Navigation Satellite System by Russian Aerospace Defence Forces is a space-based satellite navigation system. It provided an alternative to the NAVSTAR GPS of U.S., during the cold war time of last decades of twentieth century. At present, it is complementary as well as alternative option for operational navigation system with related precision and full coverage. The modern age GPS receivers are compatible to both NAVSTAR and GLONASS, thus providing more flexibility of positioning and better accuracy.

- GLONASS was conceived in erstwhile Soviet Union in 1976. The launching of satellites started in 1982 until the constellation was completed in 1995. After the division of Soviet Union, the system was not operational for few years due to non-maintenance which was resulted by economic melt-down of Russia. The life cycle of GPS satellites are 5-7 years and the new satellites are to be launched after a specific time interval in order to fill the gap due to ageing satellites. It will make the satellite constellation complete and will prevent the non-availability of requisite number of satellites for ranging created by one or two non-operational satellites in the orbits. During the late 2000s, the restoration of the system was started. It is most expensive program as seen in third budget of Russia in 2010. GLONASS proves very beneficial for Russia's territory by 2010. In 2011, restoration of system is improved to enabling full global coverage. Many upgrades of GLONASS has been launched i.e. GLONASS-K.

- **GALILEO (European Navigation Satellite System):** Galileo is a €20 billion project developed by collaboration of European Union and European Space Agency. Apart from Russian GLONASS, US GPS, high precision has been achieved in this positioning system.

  - The system is not fully operational yet. However, the operation center nearby Munich in Germany may be used when the system will be fully operational. The satellites which are being launched are controlled by Galileo Control Centre in Germany. The headquarters of Galileo project is in Prague, Czech Republic.
  - The system is expected to be completed by 2019. On completion, it will have 30 satellites in the orbit (27 operational and three active spares). The launching of satellites has been started since October 2011. Additional satellites will be launched after In-Orbit Validation phase (IOV) to achieve IOC (Initial Operational Capability). Galileo will give position measurement i.e. horizontal & vertical having the range of 1 meter precision. This positioning service even at high latitudes proves more efficient than other relatively positioning systems. Salient features of Galileo satellites and Galileo system are shown in figures 2.1A and 2.1B.
  - Global Search and Rescue (SAR) function is a unique feature of Galileo. Rescue operation is initiated via relaying signals from user's transmitter to preventing from coordination center which will possible by equip with transponder via satellites. The users will also receive a signal from the system at the same time, including location detection information that helps rescue team.

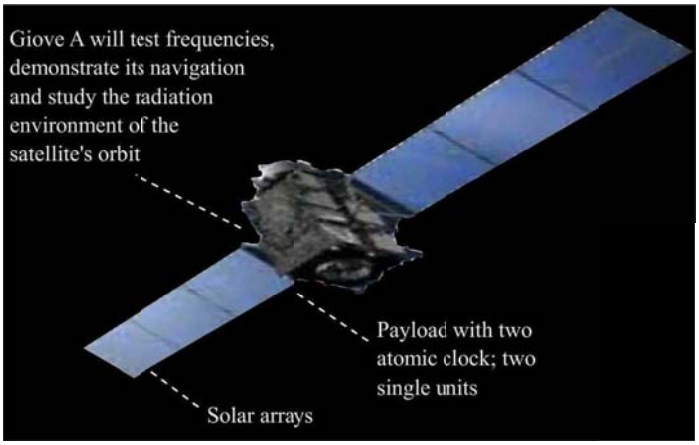

Figure 2.1A: Salient features of Galileo satellites

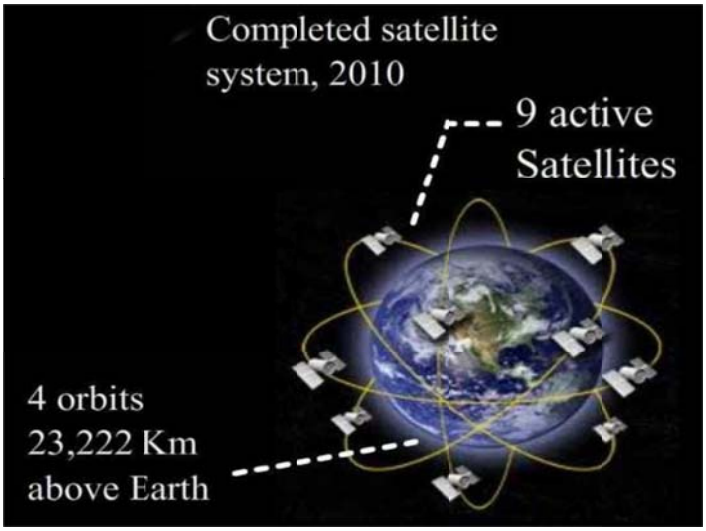

Figure 2.1B: Salient features of Galileo system

- Apart from above there are few others regional satellite navigation systems

- **BEIDOU (Chinese Navigation Satellite system):** It comprises of two separable satellites constellations i.e. limited test system operating since 2000 and under construction full scale navigation system.

  - BEIDOU Satellite Navigation Experimental System or BeiDou-1 offers limited coverage and applications. It consists of three satellites and basically famous for users of china and their neighbored countries.
  - It is official termed as a second generation of system or COMPASS. It will prove global satellite navigation system after all 35 satellites. It proves operational and fully successful with 10 satellites in orbit in China in December, 2011. After that, the Asia-Pacific region was shoeing interest in those services in December, 2012. After the completion of 2020, it would be available all global customers. The salient features of Beidou system are shown figure 2.2.

Figure 2.2: Salient features of BEIDOU system

- **QUASI ZENITH – QZSS (Japan Navigation Satellite System)** is a proposed three-satellite (now expanded to four satellites) regional time transfer system and Satellite Based Augmentation System (SBAS) for the GPS that would be receivable within Japan. Full operational status is expected by 2013.

  - QZSS is targeted to achieve communication related services i.e. audio, video & data with location information. It is also useful in mobile applications.
  - QZSS also termed as GNSS Augmentation service, is not planning for standalone mode based work on the basis of its positioning service due to the reason of providing only limited accuracy. MTSAT (Multifunctional Transport Satellite) of Japan is used by geostationary satellites that are presently under development, benefits in positioning accuracy improvement. Similar functionality have been provided by WAAS (Wide Area augmentation System) owned by U.S. Federal Aviation Administration.

- **IRNSS (Indian Regional Navigation Satellite System):** It is defined as a regional satellite navigation system being developed by ISRO (Indian Space Research Organization).

  - The IRNSS would comprise of two services i.e. Standard Positioning service for civilian users and restricted service for authorized military users. Both services will be worked on L5 and S band having 1176.45 MHz and 2492.08 MHz frequencies respectively. SPS (Standard Positioning Service) will be modulated by a BPSK signal having 1 MHz.
  - The proposed navigation system would have a constellation of 7 satellites & a supported ground segment. 3 satellites from constellation will be kept in geostationary satellites. Continuous radio visibility and Indian control stations would have features of 7 satellites. Atomic clocks and electronic equipment would consist by satellite payloads for generating the navigation signals.
  - GPS with aided augmented navigation system is initiated in India with the collaboration of ISRO and AAI (Airport authority of India) which is termed as GEO Augmented System (GAGAN).This system is used to enhance the accuracy of a GNSS receiver on the basis of reference signals. When GAGAN will be fully operational, it will fulfill the requirements of three geostationary satellites. The Indian subcontinent (India and the neighbouring countries) will be covered with the

help of footprint of its signal. The operational SBAS implemented by AAI's efforts tends to a step in the field of modern communication, air traffic control & management and navigation. To save operators time and money of airlines, a flight management on the basis of GAGAN will play a very important role by climb, descent and engine performance management of aircrafts.

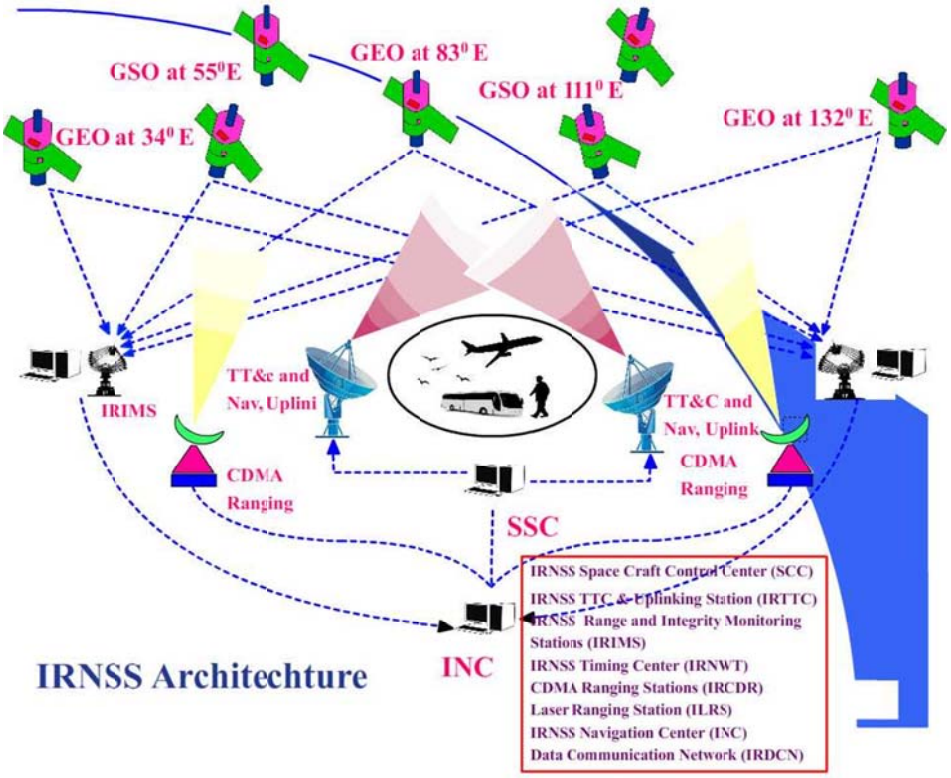

Figure 2.3: IRNSS Architecture (source: www.spacealliance.ro, 2015)

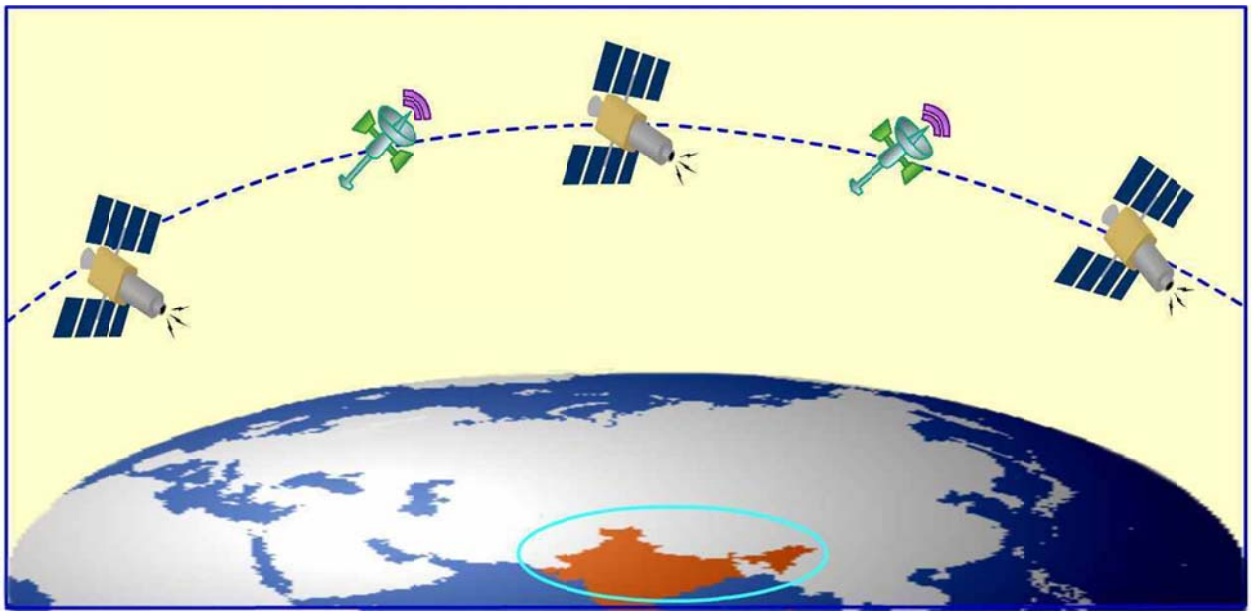

Figure 2.4: Satellite constellation of IRNSS

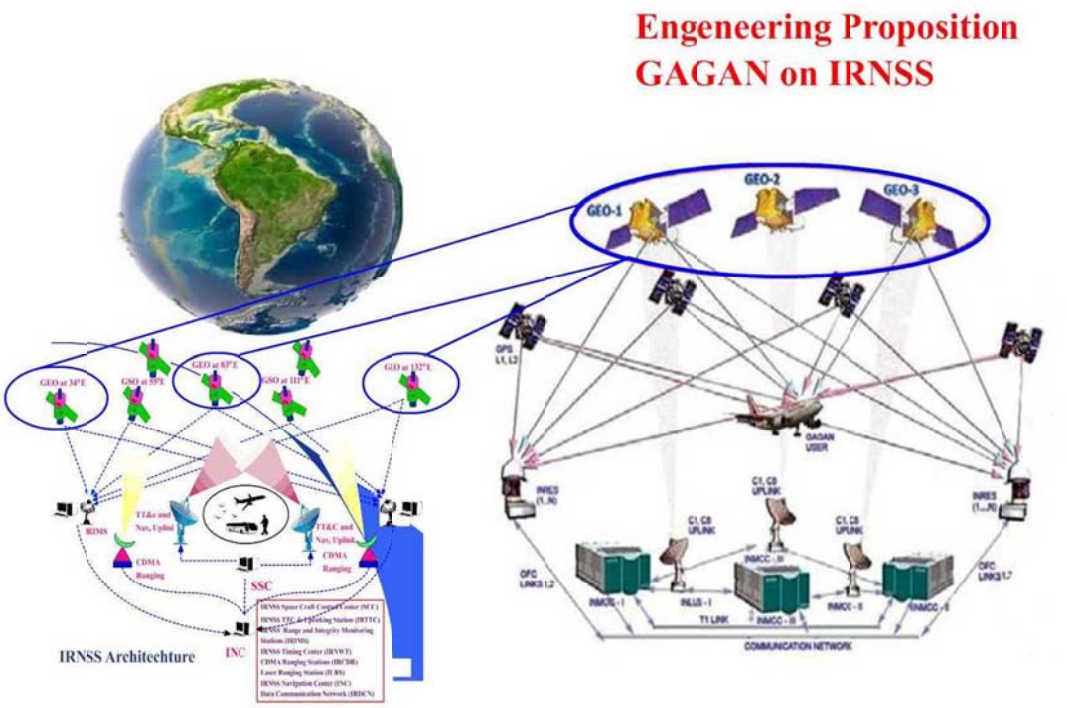

Figure 2.5: Control and Space segment architectures of GAGAN and IRNSS (Rao & Lachapelle, 2013)

All the navigational satellite systems have their specific constellations and other characteristics. Owning a navigational satellite by a country gives it advantage of independence as well as availability of the system in all conditions. It may be noted that navigational satellite systems are initially designed for military use, later the applications are extended for civilian use, but still the country controlling the system can shut done the service over a specific region as well as can use encrypted signal having conditional access to authorized users only. Therefore availability of services of the system at crucial times including warfare and calamity are a major concern. A comparison of global navigation satellite systems of the world is given in Table 2.1.

Table 2.1: Comparison of global navigation satellite systems of the world

Name	Country	No. of Satellites	Altitude/ Orbits	Global/ Regional	Other information
NAVSTAR	U.S.	24	20,200 km in 6 orbital planes	Global	Project is operational. Most widely used.
GLONASS	Russia	24	19,100 km in 3 orbital planes	Global	Project is operational.
Galileo	Europe	27	23,200 km in 3 orbital planes	Global	Project not operational yet.
Beidou	China	35	5 satellites in geostationary orbit at 36,000 km;	Global	Project is operational in

			3 satellites in inclined geosynchronous orbit at about 36,000 km; 27 satellites at 21,500 km in 3 orbital planes		regional mode.
QZSS	Japan	3	3 satellites in elliptical orbit at about 40,000 km t 32,000 km in different orbital planes	Regional	Project not operational yet.
IRNSS	India	7	3 satellites in geostationary orbit at 36,000 km; 4 satellites in inclined geosynchronous orbit at about 36,000 km	Regional	Project not operational yet.

2.2 GPS Design Objectives

- GPS (NAVSTAR) is a satellite based navigation system that provides accurate positioning on the basis of constellation of 24 satellites and navigational facilities to the users.

- Initially GPS was designed for military use for US Department of Defense to give positioning information at any weather conditions and anywhere on the surface portion of earth. Later it was made available for civilians use also.

- **GPS Positioning Services according to Radio Navigation Plan:-**

  - **PPS (Precise Positioning Service)**:- This service can use by approved U.S. Government agencies and specified civil users.

    Estimated Accuracy:-

    - 22 m & 27.7 m Horizontal & Vertical accuracy respectively.
    - UTC accuracy of 200 ns time.

  - **SPS (Standard Positioning Service)**:- This service has been used by civilians without any restrictions but accuracy has been degraded by DOD for Selective Availability.

    Estimated Accuracy:-

    - 100 m & 156 m Horizontal & Vertical accuracy respectively.
    - UTC accuracy of 340 ns time.

- The requirements of accuracy may be different for various users-

  - Moving vehicle, accuracy of about 50 m.
  - Soldier or hiker based users in desert, accuracy of about 15 m.
  - Ship based users in coastal waters, accuracy of about 5 m.
  - Land surveying based users, accuracy of about 1 cm or less.

- Different level of above accuracy can be achieved by using different types of receivers with different positioning methods.

- Initially most of civilian applications were in marine navigation and surveying. But in modern era, applications e.g. truck fleet management via car navigation, and automation of machinery via construction etc. has become very popular.