Bharathidasan University

Tiruchirappalli, Tamil Nadu

Programme: M. Tech Geoinformatics

Course: Global Navigation Satellite System (GNSS)

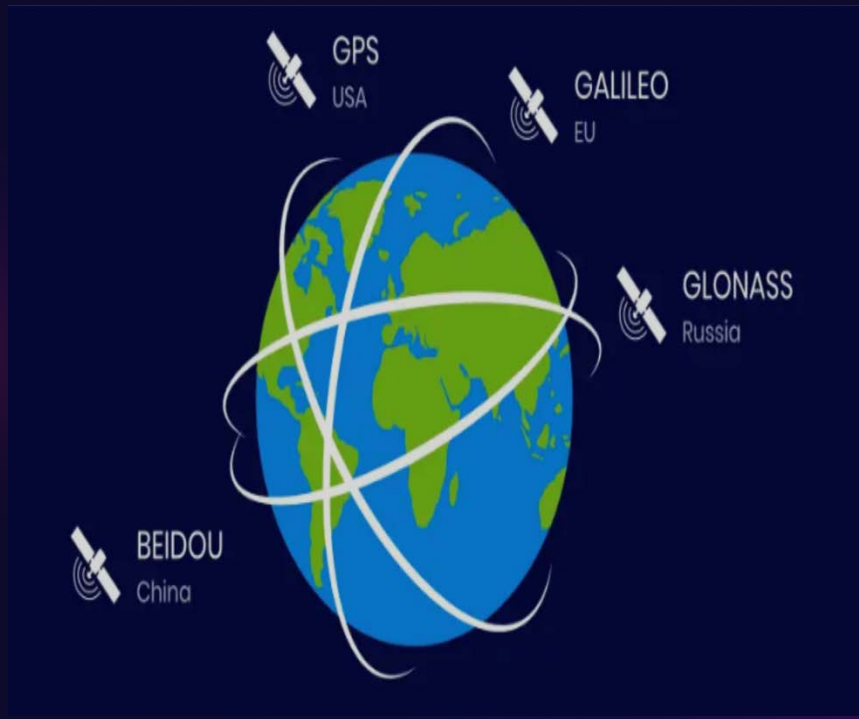
Title: Historical development, Global Navigation Satellite Systems and Regional Navigations Satellite Systems

Dr. C. Bhuvaneswaran, M.sc., M.Tech., Ph.D
Guest Faculty
Department of Geography
Bharathidasan University

Historical Development of GNSS

- Global Navigation Satellite Systems (GNSS) are a type of satellite-based navigation system that provides location and time information to user's on Earth.
- The most well-known GNSS is the United States' Global Positioning System(GPS), but other countries have developed or are in the process of developing their own systems as well, such as Russia's GLONASS, the European Union's Galileo, and China's
Bei Dou.
- The development of GPS began in the 1970s, when the U.S. Department of Defence started the project as a military navigation system.
- The first GPS satellite was launched in 1978, and the system became operational in 1995, with 24 satellites in orbit.
- Initially, the use of GPS was limited to the military, but in the 1980s, the U.S. government started to allow civilian access to the system, with some limitations.
- In 2000, the Clinton Administration announced that the military would no longer scramble the signal for civilians, greatly increasing the system's accuracy.
- GLONASS, the Russian counterpart to GPS, was first proposed in 1976, and began operation in 1993.
- The system struggled due to funding and technical issues, and at one point in the early 2000s, only had a few operational satellites.

- The Russian government has since invested in the system, and it is now fully operational with a similar number of satellites as GPS.
- The European Union's Galileo system was first proposed in the early 2000s, with the goal of having a independently controlled navigation system for European countries.
- The first Galileo satellite was launched in 2011 and it began partially operation in 2016 with a full system operational in 2020.
- China began developing its Bei Dou system in the 1990s, and launched its first satellite in 2000.
- The first generation of the system, called BeiDou-1, provided limited coverage and was primarily used in China.
- The second generation, called BeiDou-2, or Compass, was completed in 2011 and provided regional coverage. The current phase, Beidou-3, will provide global coverage by 2020.
- The development of GNSS technology has greatly increased the capabilities and accuracy of satellite-based navigation, and these systems have become essential tools for a wide range of applications including transportation, surveying, agriculture, and more.



Conventional Navigation :-

Conventional navigation in the context of GNSS (Global Navigation Satellite System) refers to the use of traditional navigation aids and methods alongside or as a backup to satellite-based navigation.

- ❖ Traditional Navigation Aids:- These aids have been the backbone of aviation navigation for decades.
- ❖ Integration with GNSS:-Conventional navigation aids are often used in conjunction with GNSS to provide redundancy and ensure reliability.

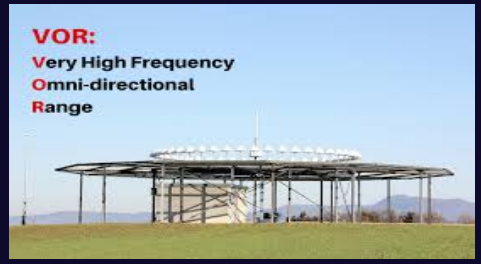
Example:-If GNSS Signals are Unavailable or Degraded pilots can revert Using VOR,DME Or ILS for Navigation

(a) VOR:-Very High Frequency Omni-Directional Range, Which is a ground Based Radio –Navigation system for aircraft.

(b) DME:-Distance Measuring Equipment , is a radio navigation technology that measures the distance between an aircraft and a ground station.

(c) ILS:-Instrument Landing System , is a precision radio navigation system that provides short-range guidance to aircraft to allow them to approach a runway.

- ❖ Historical Significance:-Conventional navigation systems have played a crucial role in the development of aviation safety and infrastructure.



VOR Antenna

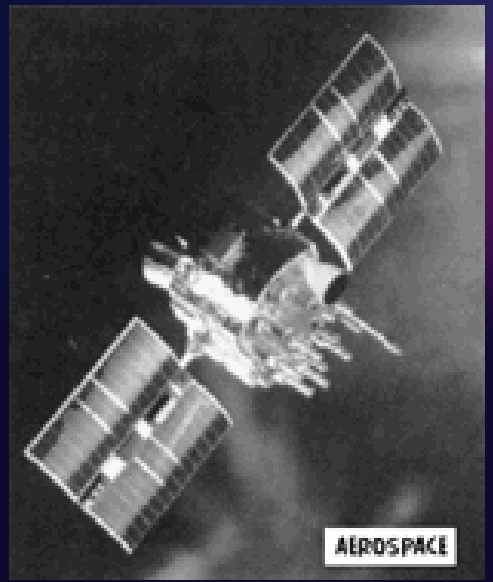
DME

ILS Antenna

Background:-

- The concept of using satellites for navigation date's back to the Cold War era when the Soviet Union and the United States both began developing their own satellite navigation systems.

- In 1978, the United States launched the first GPS (Global Positioning System) satellite, and in 1995, it became fully operational for military and civilian use.



First GPS Signal Receiver

Concepts:-

- Global navigation satellite systems (GNSS) use a network of satellites orbiting the Earth to provide precise location and timing information to users on the ground, in the air, or at sea.
- The signals from these satellites can be received by devices known as receivers, which can then use the information to calculate the user's position and other navigation data.

The Following Steps in Concept of GNSS :-

Step 1:- Satellites :

Orbit the Earth and broadcast their time and Ephemerides.

Ephemerides:- The Parameters that define their Orbit).

Step 2:- Propagation:

When GNSS signals travel from the satellite to the receiver, passing through the atmosphere and space.

Step 3:- Reception:

It involves the user equipment receiving signals from multiple GNSS satellites.

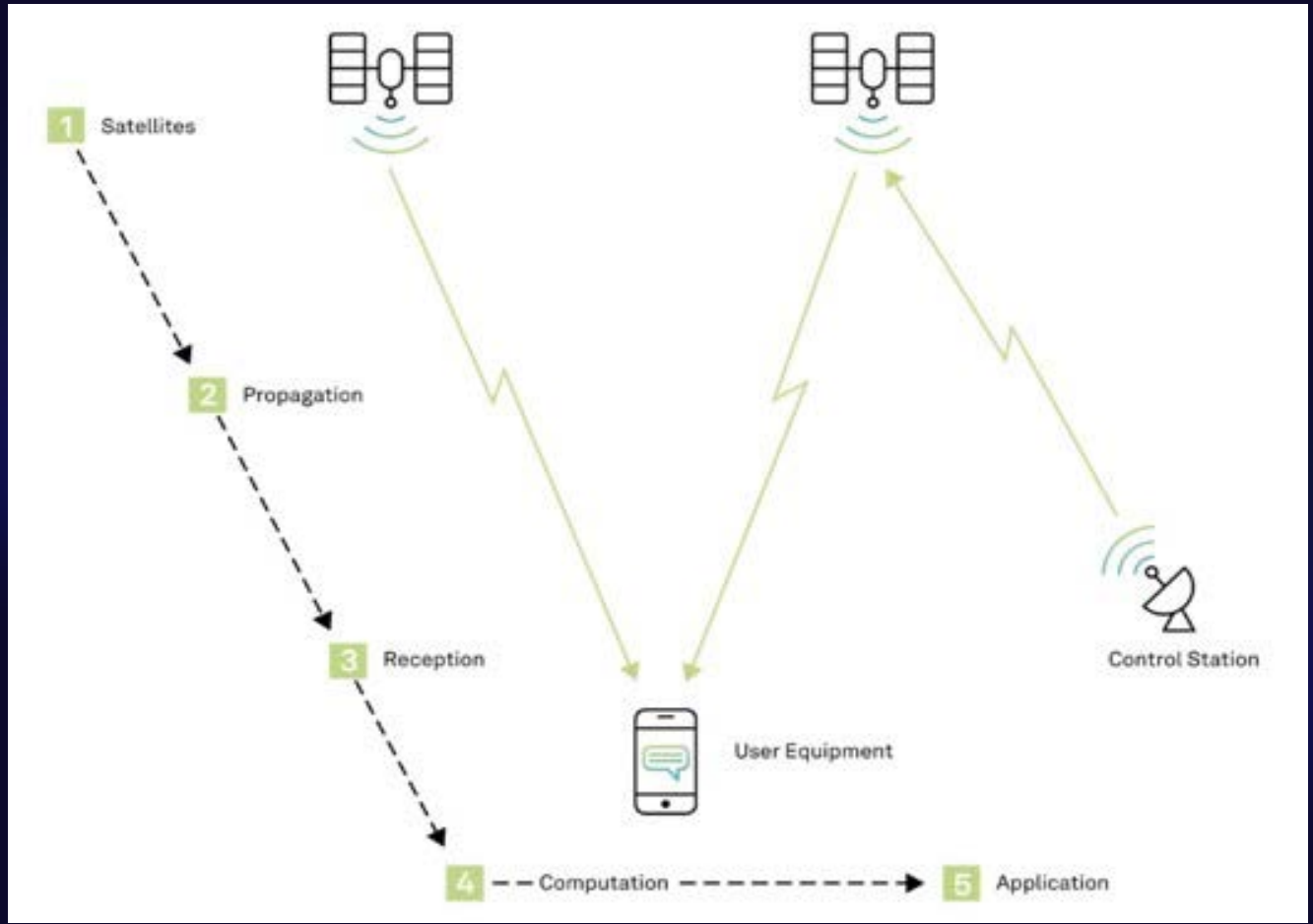
Step 4:- Computation:

When the GNSS user equipment uses the information it's received to calculate its position and time

Step 5:-Application

GNSS used equipment provides the computed Position and time to the end-used application for use in

Navigation, Surveying, Mapping & Planning etc.


1 Satellites
2 Propagation
3 Reception
User Equipment
Control Station
4 Computation
5 Application

Evolutions of Global Navigation Satellite System's:-

There are 2 types of Constellation system in GNSS they are,

1. Global Constellation:-

- GPS: The US-based Global Positioning System (GPS) is one of the oldest and most widely used GNSS in the world. It has been continuously updated and improved, with the latest version, GPS III, offering increased accuracy and security.

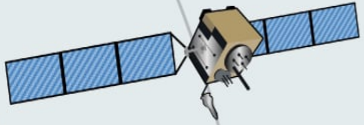
- GLONASS: The Russian-based Global Navigation Satellite System (GLONASS) was developed as a rival to GPS and has similar capabilities. It has also undergone upgrades, with the latest version, GLONASS-K, offering improved accuracy and a larger number of satellites.

- Galileo: Developed by the European Union, Galileo is a new GNSS that offers even higher accuracy than GPS and GLONASS. It is also designed to be more secure and resistant to jamming.

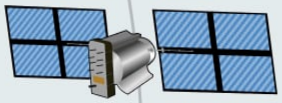
- Beidou/COMPASS: Developed by China, Beidou (also known as COMPASS) is a regional GNSS that is gradually becoming a global system. It offers similar capabilities to GPS, GLONASS, and Galileo and is designed to work with them to provide even more accurate location information.

Updated April 2023

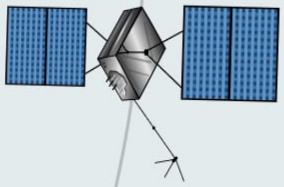
EOS Positioning Systems



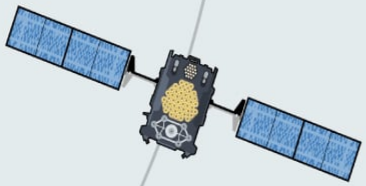
31 GPS (31 operational satellites)



25 GLONASS (24 operational satellites)



28 Galileo (24 operational satellites)



29 BeiDou (27 operational satellies*)

*not including 20 geostationary satellites

1.GPS (Global Positioning System):-

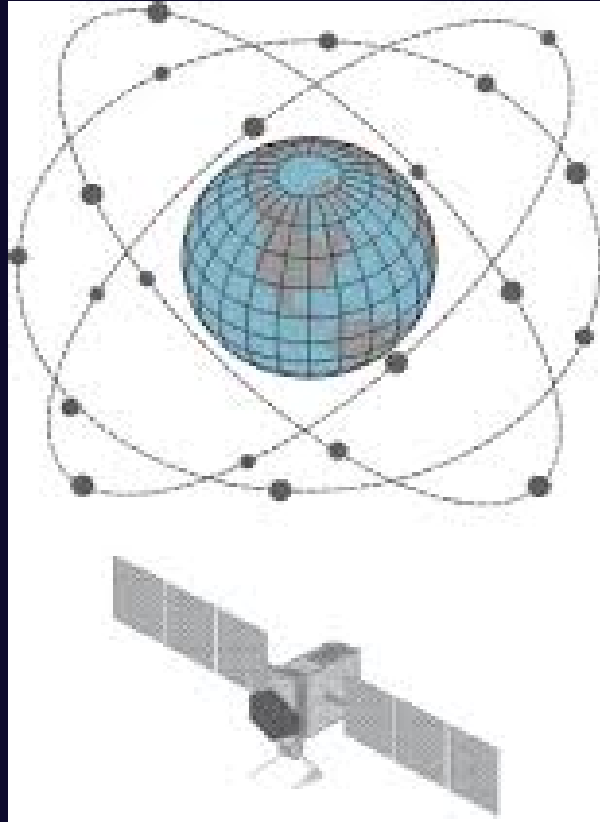
- US –Owned utility that provides users with positioning, navigation and timing (PNT) Services.
- Maintains availability of at least 24 operational GPS satellites 95% of the Time.
- 31 operational GPS Satellites .
- Flies in medium earth orbit at an altitude of approximately 20,200 km.
- Each satellite circles the Earth twice a day.
- There are 6 Equally –spaced orbital planes with4 slots occupied by baseline satellites.
- This 24-slot arrangement ensures users can view at least 4 satellites from virtually any point of the planet.
- The next launch is GPS III SV07, originally scheduled for June 2024, currently January 2025.

2.GLONASS:-

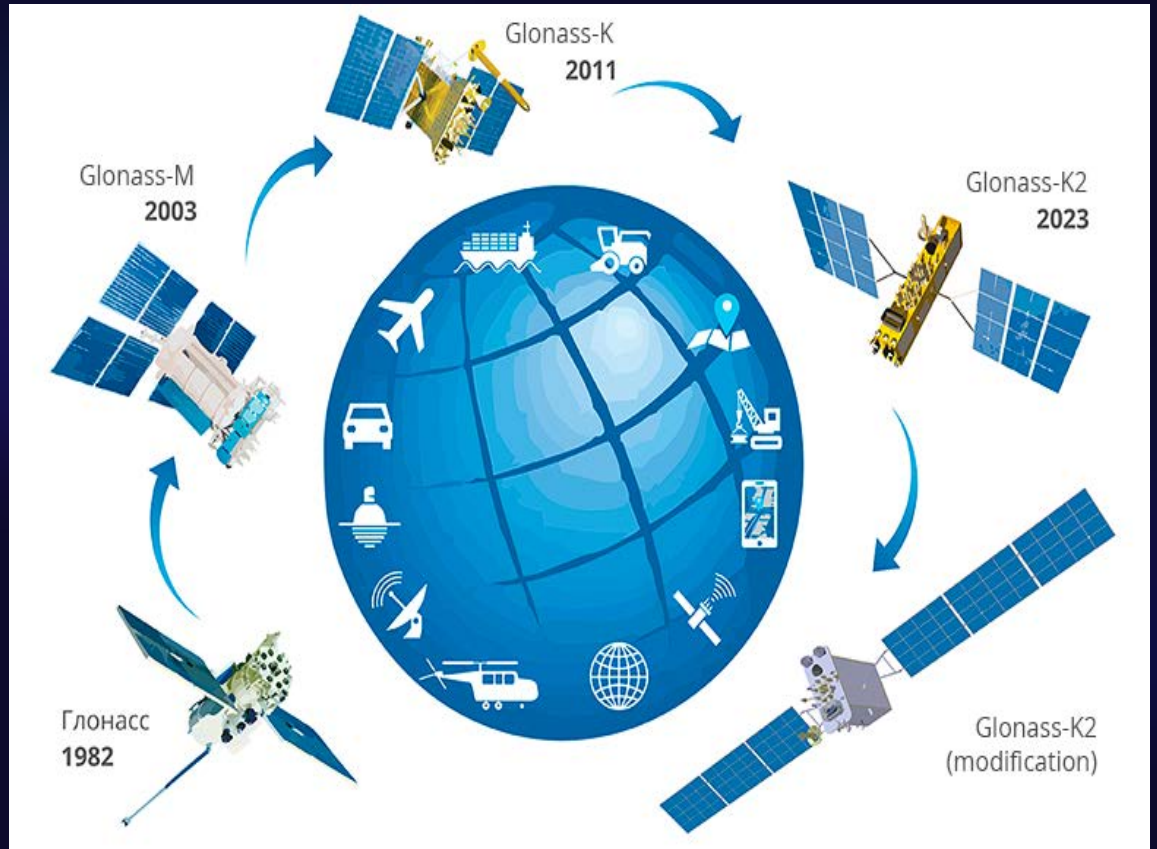
- Owned and operated by Russia.
- Consists of 25 Satellites equally distributed in 3 orbital planes inclined at 64.8 degree to the equator with nominal altitude of 19,100 km and an orbital period of 11 hours 15 minutes 44 seconds.
- Better suited for usage in the Northern Hemisphere than in the Southern Hemisphere , due to a higher number of Ground stations in these locations.
- As of August 2023, 145 GLONASS Navigation Satellites have been launched, of which 133 reached the correct orbit and 24 are currently operational.
- Differences with GPS

1.Satellites motion is described using fundamentally different Mathematical Models.

2.With GPS , satellites use the same radio Frequencies but have different codes for communication , while GLONASS satellites have the same codes but use different frequencies , allowing satellites on the same orbital plane to communicate with one another.



An Modification of GLONASS Satellite (1982-2023)



3. Galileo:-

- Europe owned under civilian Control.
- Total Satellites 30 in Medium Earth Orbit.

- Operational Satellites 24 including 6 In – orbit Spares.

- 3 circular MEO Planes at 23,222 km altitude 56 degree Inclination.

- As of September 2024, 32 Galileo (4 IOV "In Orbit Validation" and 28 FOC "Full Operational Capability") satellites have been launched.

- Currently, 25 satellites are operational, 2 are undergoing commissioning, 4 are not usable, and 1 is decommissioned.
- Provides a global Search and Rescue (SAR) function. Satellites are equipped with a transponder, which is able to transfer the distress signals from the user transmitters to regional rescue Co-ordination centres, which will then initiate the rescue operation.
- At the same time , the system will send a response signal to the user, informing him that his situation has been detected and that help is on the way.

4. BeiDou Navigation Satellite System:-

- Owned and operated by the People's Republic of China.
- First Launch 30 October 2000
- 62 satellites had been launched.
- 44 satellites are operational.
- 7 in Geostationary Orbit (GEO).
- 10 in Geosynchronous Orbits (IGSO).
- 27 in Medium Earth Orbits(MEO).
- Furthermore, 8 satellites (4 in Medium Earth orbit, 2 in geostationary orbit and 2 in inclined geosynchronous orbit) are undergoing testing or commissioning.
- Last Launch 26 December 2023
- Major functions :- Real time Navigation , Rapid Positioning , Precise timing ,Location reporting and short message communication Services.

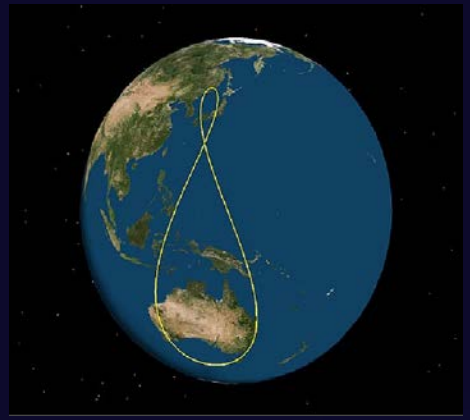
2. Regional Navigation Satellite System:-

Regional Navigation Satellite Systems (RNSS) are satellite systems that provide navigation services to a specific region, rather than global coverage. The Indian Regional Navigation Satellite System (IRNSS) and the Quasi-Zenith Satellite System (QZSS) are two examples of RNSS.

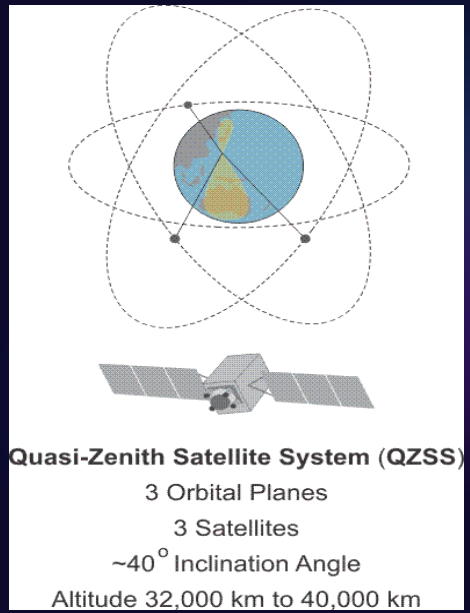
IRNSS (Indian Regional Navigation Satellite System)

- The Indian Regional Navigation Satellite System (IRNSS), with an operational name of NavIC.
- Owned by INDIA
- Operator ISRO
- First Launch 1st July 2013
- The IRNSS is provides navigation services to the Indian subcontinent, as well as a region extending up to 1500 km around it. The system consists of 7 satellites, with 3 of them in Geostationary orbit and 4 in Geosynchronous orbit.
- It provides navigation services such as position, velocity, and time information to users on land, sea, and air.
- The satellite that was launched on May 29, 2023 was the NVS-01 navigation satellite.

QZSS (Quasi-Zenith Satellite System)



- Country of Origin :- Japan
- Operator :- Quasi-Zenith Satellite System Services
- First Launch 11th September 2010
- Nominal Satellites 7
- Usable Satellites 4
- The QZSS is provides navigation services to the Asia-Oceania region. The system consists of four satellites, with one of them in a geostationary orbit and the others in inclined geosynchronous orbits.
- It provides navigation services such as position, velocity, and time information to users on land, sea, and air.
- Last Launch 26th October 2021



Comparison of GNSS with other Navigation System's

GNSS (Global Navigation Satellite System) is a type of satellite-based navigation system that uses a network of satellites to provide precise location and time information to users on the ground, in the air, or at sea. There are several other navigation systems available in the world, each with their own unique characteristics and capabilities. Here are a few comparisons of GNSS with other navigation systems:

1.GPS (Global Positioning System):

GPS is a type of GNSS that is operated by the United States government. It consists of a network of 31 satellites orbiting the earth and provides precise location information to users around the world. Compared to other navigation systems, GPS has the widest coverage and is the most widely used navigation system in the world.

2.GLONASS (Global Navigation Satellite System):

GLONASS is a type of GNSS that is operated by the Russian government. It consists of a network of 24 satellites orbiting the earth and provides precise location information to users in Russia and other parts of the world. Compared to GPS, GLONASS has a slightly smaller coverage area but provides similar precision in location information.

3.Galileo:

Galileo is a type of GNSS that is operated by the European Union. It consists of a network of 30 satellites orbiting the earth and provides precise location information to users in Europe and other parts of the world. Compared to GPS, GLONASS, and BeiDou, Galileo is still in the process of being fully deployed and is not yet fully operational.

4. BeiDou (Compass):

BeiDou is a type of GNSS that is operated by the Chinese government. It consists of a network of 35 satellites orbiting the earth and provides precise location information to users in China and other parts of the Asia-Pacific region. Compared to GPS and GLONASS, BeiDou has a smaller coverage area but is rapidly expanding its coverage to other parts of the world.

Conclusion:-

GNSS is a type of satellite-based navigation system that provides precise location and time information to users around the world. GPS, GLONASS, BeiDou, and Galileo are all types of GNSS, each with its own unique characteristics and capabilities. GNSS systems are becoming more prevalent in today's world, with all four systems working together to provide even more accurate and reliable navigation services.

1. http://www.unoosa.org/pdf/icg/2013/Ed_GNSS_eBook.pdf
2. https://www.ion.org/publications/online-tutorial-intertial.cfm
3. https://www.novatel.com/an-introduction-to-gnss/
4. https://serc.carleton.edu/getsi/teaching_materials/high-precision/unit1.html
5. https://www.e-education.psu.edu/geog862/node/1407