Paper CC12
Unit 2 Topic 3

GLOBAL NAVIGATION SATELLITE SYSTEM

(GNSS)

SATNAV

- A **satellite navigation** or **satnav** system is a system that uses satellites to provide autonomous geo-spatial positioning.
- It allows small electronic receivers to determine their location (longitude, latitude, and altitude/elevation) to high precision (within a few centimeters to metres) using time signals transmitted along a line of sight by radio from satellites.
- The system can be used for providing position, navigation or for tracking the position of something fitted with a receiver (satellite tracking).
- The signals also allow the electronic receiver to calculate the current local time to high precision, which allows time synchronisation. These uses are collectively known as Positioning, Navigation and Timing (**PNT**).
- Satnav systems operate independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the positioning information generated.

GNSS

- A satellite navigation system with global coverage may be termed a **global navigation satellite system** (**GNSS**).
- As of June 2020, the United States' Global Positioning System (GPS), Russia's Global Navigation Satellite System (GLONASS) and China's BeiDou Navigation Satellite System (BDS) are fully operational GNSSs, with the European Union's Galileo scheduled to be fully operational by 2020.
- Japan's Quasi-Zenith Satellite System (QZSS) is a GPS satellite-based augmentation system to enhance GPS's accuracy, with satellite navigation independent of GPS scheduled for 2023.
- The Indian Regional Navigation Satellite System (IRNSS) plans to expand to a global version in the long term.

Geostationary Earth orbit
Graveyard orbit (GEO+300 km)
Orbital period
20 hours
15 hours
10 hours
5 hours
Galileo
GPS
BeiDou
MEO satellites
GLONASS
Inner Van Allen belt
Iridium
Hubble
Radius of orbit
Height above sea level
40000
30000
20000
10000 km
10000
20000
30000 km
20000
10000 mi
10000
20000 mi
ISS
15000 mph
25000 km/h
20000 km/h
10000 mph
15000 km/h
Orbital speed
Outer Van Allen belt
7000 mph
11000 km/h

GPS

- First Launch year: 1978
- The United States' Global Positioning System (GPS) consists of up to 32 medium Earth orbit satellites in six different orbital planes, with the exact number of satellites varying as older satellites are retired and replaced. Operational since 1978 and globally available since 1994, GPS is the world's most utilized satellite navigation system.

GLONASS

- First launch year: 1982
- The formerly Soviet, and now Russian, ***Glo****bal'naya* ***Na****vigatsionnaya* ***S****putnikovaya* ***Si****stema*, (GLObal NAvigation Satellite System or GLONASS), is a space-based satellite navigation system that provides a civilian radionavigation-satellite service and is also used by the Russian Aerospace Defence Forces. GLONASS has full global coverage since 1995 and with 24 satellites.

BeiDou

- First launch year: 2000
- BeiDou started as the now-decommissioned Beidou-1, an Asia-Pacific local network on the geostationary orbits. The second generation of the system BeiDou-2 became operational in China in December 2011. The BeiDou-3 system is proposed to consist of 30 MEO satellites and five geostationary satellites (IGSO). A 16-satellite regional version (covering Asia and Pacific area) was completed by December 2012. Global service was completed by December 2018. On 23 June 2020, the BDS-3 constellation deployment is fully completed after the last satellite was successfully launched at the Xichang Satellite Launch Center.

Galileo

- First launch year: 2011
- The European Union and European Space Agency agreed in March 2002 to introduce their own alternative to GPS, called the Galileo positioning system. Galileo became operational on 15 December 2016 (global Early Operational Capability (EOC)) At an estimated cost of €10 billion, the system of 30 MEO satellites was originally scheduled to be operational in 2010. The original year to become operational was 2014. The first experimental satellite was launched on 28 December 2005. Galileo is expected to be compatible with the modernized GPS system. The receivers will be able to combine the signals from both Galileo and GPS satellites to greatly increase the accuracy. Galileo is expected to be in full service in 2020 and at a substantially higher cost.

Regional navigation satellite systems

NavIC

- The **NavIC** or **NAVigation with Indian Constellation** is an autonomous regional satellite navigation system developed by Indian Space Research Organisation (ISRO). The government approved the project in May 2006, and consists of a constellation of 7 navigational satellites. 3 of the satellites are placed in the Geostationary orbit (GEO) and the remaining 4 in the Geosynchronous orbit (GSO) to have a larger signal footprint and lower number of satellites to map the region. It is intended to provide an all-weather absolute position accuracy of better than 7.6 meters throughout India and within a region extending approximately 1,500 km around it.
- The constellation was in orbit as of 2018, and the system was available for public use in early 2018. NavIC provides two levels of service, the "standard positioning service", which will be open for civilian use, and a "restricted service" (an encrypted one) for authorized users (including military).
- There are plans to expand NavIC system by increasing constellation size from 7 to 11.

QZSS

- The Quasi-Zenith Satellite System (QZSS) is a four-satellite regional time transfer system and enhancement for GPS covering Japan and the Asia-Oceania regions.
- QZSS services were available on a trial basis as of January 12, 2018, and were started in November 2018.
- The first satellite was launched in September 2010.
- An independent satellite navigation system (from GPS) with 7 satellites is planned for 2023.

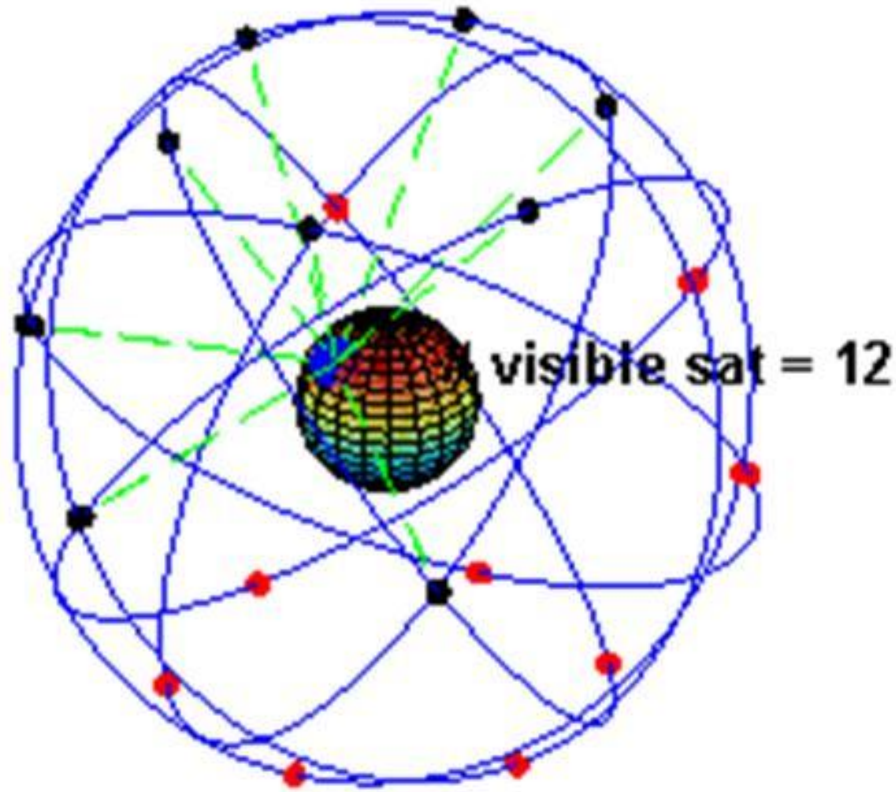
GPS is a satellite – based navigation system started for the US Department of Defense

Components of GPS :

- Space Segment
- Control Segment
- User Segment

Space segment

- Composed of satellites that transmit signals from space, on the basis of which time and position of the user is measured.
- Set of satellites is called as constellation.
- GPS uses two satellite constellations i.e. NAVSTAR and GLONASS.
- NAVSTAR (Navigation satellite timing and ranging)
- NAVSTAR composed of 24 satellites, arrayed in 6 orbital planes, inclined 55 degrees to the equator and with a 12 hours period.
- They orbit at altitudes of about 20,200km each.
- Each satellite contains four precise atomic clocks, only one of which is in used at a time.


visible sat = 12

Control segment

- Control segment consists of a group of 5 ground based monitor stations, three antennas and a master control station.
- The Master Control facility is located at Schriever Air Force Base (formerly Falcon AFB) in Colorado.
- The monitor stations measure signals from the SVs continuously and provides data to the master control station.
- The master control station calculates satellite ephemeris and clock correction coefficients and forwards them to an antenna.
- The antenna transmit the data to each satellite at least once a day. The SVs then send subsets of the orbital ephemeris to GPS receivers over radio signals


Colorado
Springs
Hawaii
Ascension
Diego Garcia
Kwajalein
Master Control Stations
Monitoring Stations

User segment

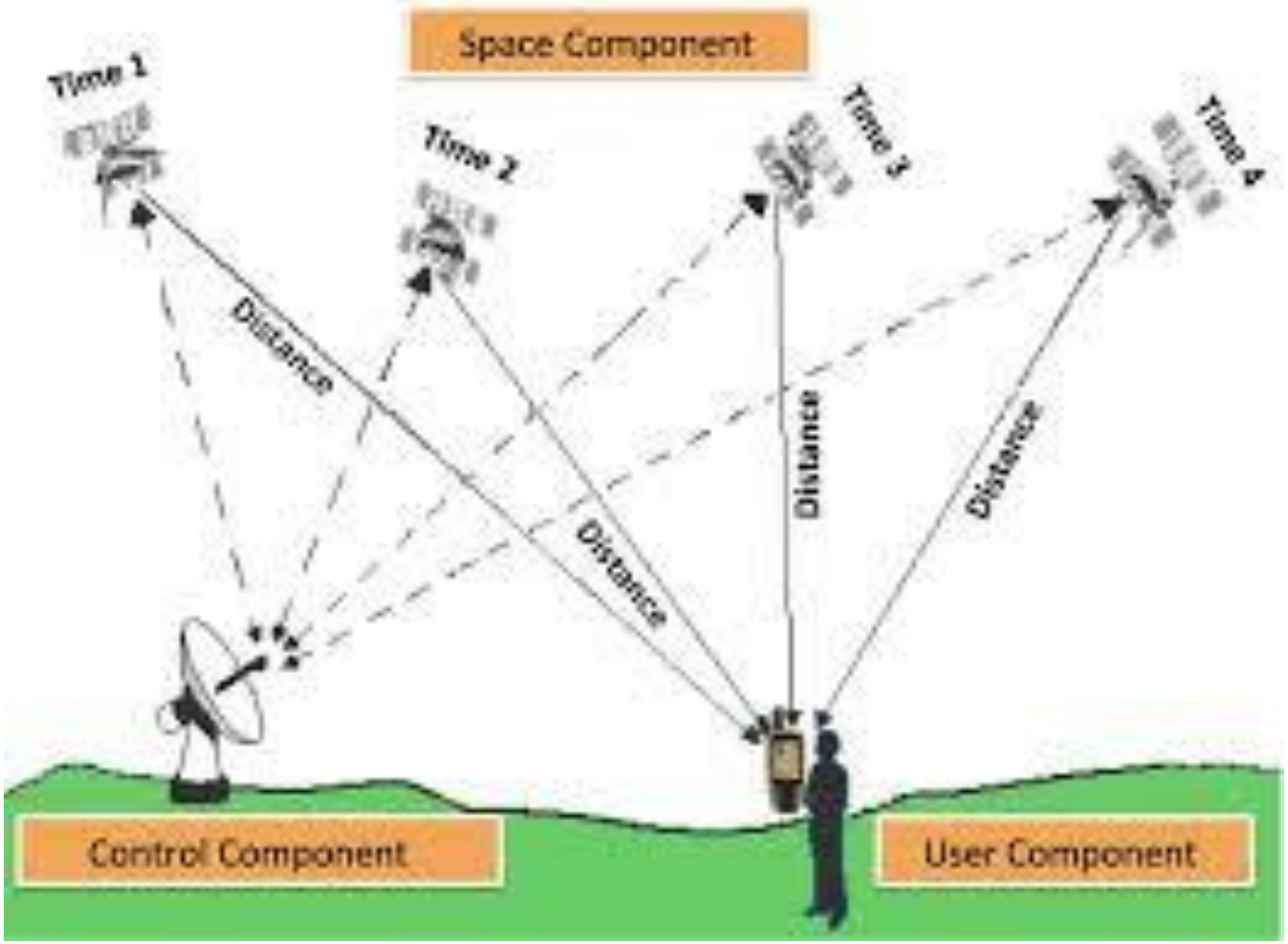
- GPS User Segment consists of the GPS receivers and the user community.
- The typical receiver is composed of an antenna and pre-amplifier, radio signal microprocessor, control and display device, data recording unit, and power supply.
- GPS receivers convert SV signals into position, velocity, and time estimates.
- A minimum of four satellites are required to compute the four dimensions of X, Y, Z (position) and Time.

GPS Working Mechanism

- Each of the 24 satellites emits signals to receivers that determine their location or range by computing the difference between the time that a signal is sent and the time it is received.
- The signal contains data that a receiver uses to compute the locations of the satellites and to make other adjustments needed for accurate positioning.
- The receiver must account for propagation delays, or decreases in the signal's speed caused by the ionosphere and the troposphere. GPS satellites carry atomic clocks that provide extremely accurate time. The time information is placed in the codes broadcast by the satellite so that a receiver can continuously determine the time the signal was broadcast. With information about the ranges to three satellites and the location of the satellite when the signal was sent, the receiver can compute its own three-dimensional position. An atomic clock synchronized to GPS is required in order to compute ranges from these three signals. However, by taking a measurement from a fourth satellite, the receiver avoids the need for an atomic clock. Thus, the receiver uses four satellites to compute latitude, longitude, altitude, and time.

MEASUREMENTS OF DISTANCE

- Satellites broadcast radio signals (EM radiation)
- Simple distance calculation $d = v * t$
- Velocity = velocity of light 186,000 miles per seconds
- time is known (difference between send & receive)
- distance is calculated


Space Component
Time 1
Time 2
Time 3
Time 4
Distance
Distance
Distance
Distance
Control Component
User Component

Waypoint

- A **waypoint** is an intermediate point or place on a route or line of travel, a stopping point or point at which course is changed, the first use of the term tracing to 1880.
- In modern terms, it most often refers to coordinates which specify one's position on the globe at the end of each "leg" (stage) of an air flight or sea passage, the generation and checking of which are generally done computationally (with a computer or other programmed device).
- Hence, the term connotes a reference point in physical space, most often associated with navigation, especially in the sea or air—e.g., in the case of sea navigation, a longitudinal and latitudinal coordinate or a GPS point in open water, a location near a known mapped shoal or other entity in a body of water, a point a fixed distance off of a geographical entity such as a lighthouse or harbour entrance, etc.

Waypoints with GPS

- GPS systems are increasingly used to create and use waypoints in navigation of all kinds.
- A typical GPS receiver can locate a waypoint with an accuracy of three meters or better when used with land-based assisting technologies such as the Wide Area Augmentation System (WAAS).
- Waypoints can also be marked on a computer mapping program and uploaded to the GPS receiver, marked on the receiver's own internal map, or entered manually on the device as a pair of coordinates.
- If the GPS receiver has track-logging capabilities, one can also define waypoints after the fact from where one has been. For example, marine GPS receivers often have a "man overboard" function, which instantly creates a waypoint in the receiver for the boat's position when enabled and then begins displaying the distance and course back to that position.

- In GPS navigation, a "route" is usually defined as a series of two or more waypoints.
- To follow such a route, the GPS user navigates to the nearest waypoint, then to the next one in turn until the destination is reached.
- Most receivers have the ability to compute a great circle route towards a waypoint, enabling them to find the shortest route even over long distances, although waypoints are often so closely spaced that this is not a factor.
- Many GPS receivers, both military and civilian, now offer integrated cartographic databases (also known as *base maps*), allowing users to locate a point on a map and define it as a waypoint.
- Some GPS systems intended for automobile navigation can generate a suggested driving route between two waypoints, based on the cartographic database. As one drives along the route, the system indicates the driver's current location and gives advance notice of upcoming turns. The best of these systems can take into account traffic restrictions such as one-way streets and intersections where left or right turns are prohibited when computing the suggested driving route.

- Most GPS receivers allow the user to assign a name to each waypoint.
- Many models also let the user select a symbol or icon to identify the waypoint on a graphical map display from a built-in library of icons.
- These include standard map symbols for marine navigation aids such as buoys, marinas and anchorages, as well as land-based landmarks such as churches, bridges, shopping centers, parks and tunnels.

Applications of GPS:

- Military (accurate targeting of weapons)
- Navigation using TomTom Software (automobiles, aircraft, boats & ships, heavy equipment, bicycles, hikers, spacecraft, equipment for visually handicapped)
- Surveying & Mapping
- Precise Time Reference
- Mobile Satellite Communications
- Emergency & Location-based services
- Tracking
- Weather Prediction Improvements

THANK YOU