GPS UNIT-I ASSIGNMENT

1Q) Explain the trilateration method to estimate GPS receiver position in 3D.

There are many Global Positioning System (GPS) satellites orbiting the Earth. These are used to locate your position on the planet.

Trilateration is the first concept and it is based on finding the position of a GPS device from three distances.

The second idea is the relationship between the speed of the signal (speed of light, c), the time taken for the signal to travel and the distance travelled. All that is needed for this second concept is the equation:

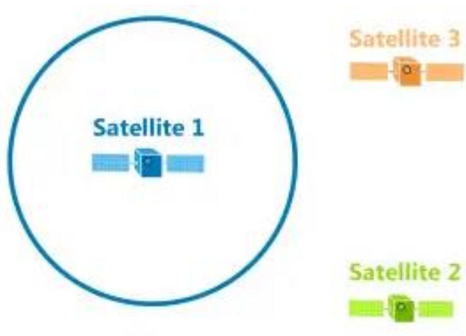
Distance travelled (m) = Speed (m/s) x Time (s)

Trilateration works by finding your position on Earth once the location of GPS satellites orbiting the Earth and their distance from your location are known. Since we cannot physically measure the distance of these satellites directly, we need to use the known speed of the signal sent by the GPS satellites and the time the signals were sent. Trilateration involves measuring distances.

Let’s imagine we have three GPS satellites each with a known position in space.Really, all that satellites do is broadcast a signal for your GPS receiver to pick up with a specific time and distance.

For example, the first satellite broadcasts a signal that eventually hits your GPS receiver. We don’t know the angle, but we do know the distance. That’s why this distance forms a circle equal in all directions.

This means that your GPS position could be **anywhere on this circle** at this specific radius.



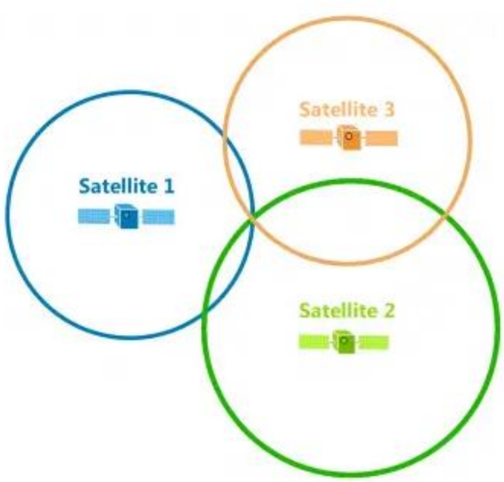
When a second satellite broadcasted the signal in all directions and it hits GPS receiver, GPS receiver is in the region of intersections of two spheres. This means that the distance could be anywhere on that circle.

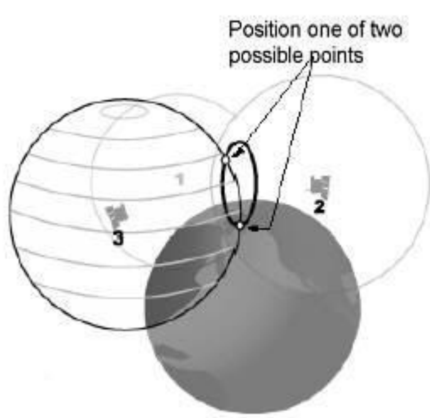
But this time, we have two known distances from two satellites. With two signals, the precise position could be any of the two points **where the circles intersect**.

Because we have a third satellite, it reveals your true location where all three circles intersect.

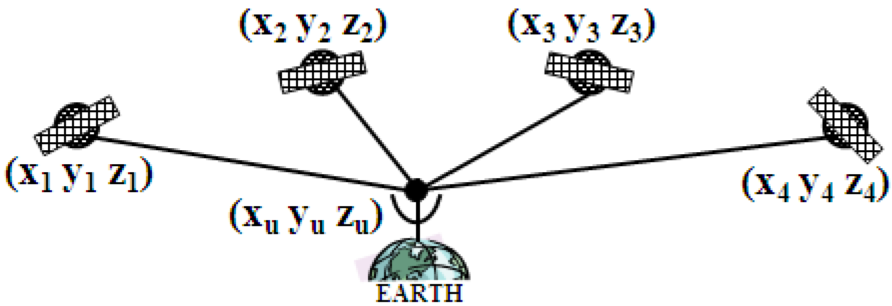
Using three distances, trilateration can pinpoint a precise location. Each satellite is at the center of a sphere and where they all intersect is the position of the GPS receiver.

That's pretty much how GPS works except that GPS is in 3D and we are dealing with spheres instead of circles. We would also end up with two points instead of a single point with the third satellite but you can eliminate the other point as it's not on the surface of the earth as the illustration shows.





A fourth range measurement from fourth satellite determines which point is our true location and also gives the GPS time.



Solving of four independent equations leads to estimation of user location and time offset :

$$(x_u-x_1)^2 + (y_u-y_1)^2 + (z_u-z_1)^2 = C^2\ (t_{u1} - t_{sv1} + t_{bias})^2$$

$$(x_u-x_2)^2 + (y_u-y_2)^2 + (z_u-z_2)^2 = C^2\ (t_{u2} - t_{sv2} + t_{bias})^2$$

$$(x_u-x_3)^2 + (y_u-y_3)^2 + (z_u-z_3)^2 = C^2\ (t_{u3} - t_{sv3} + t_{bias})^2$$

$$(x_u-x_4)^2 + (y_u-y_4)^2 + (z_u-z_4)^2 = C^2\ (t_{u4} - t_{sv4} + t_{bias})^2$$

Where (Xu,Yu,Zu) is the GPS Receiver(User) Position Co-ordinates, and (Xi,Yi,Zi) , i=1,2,3,4 are satellite position Co-ordinates.

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2Q) Explain in detail about GPS Segments

The GPS configuration comprised of 3 segments, which are the operational elements of the GPS (Figure 2.6):

- Space Segment
- Control Segment
- User Segment

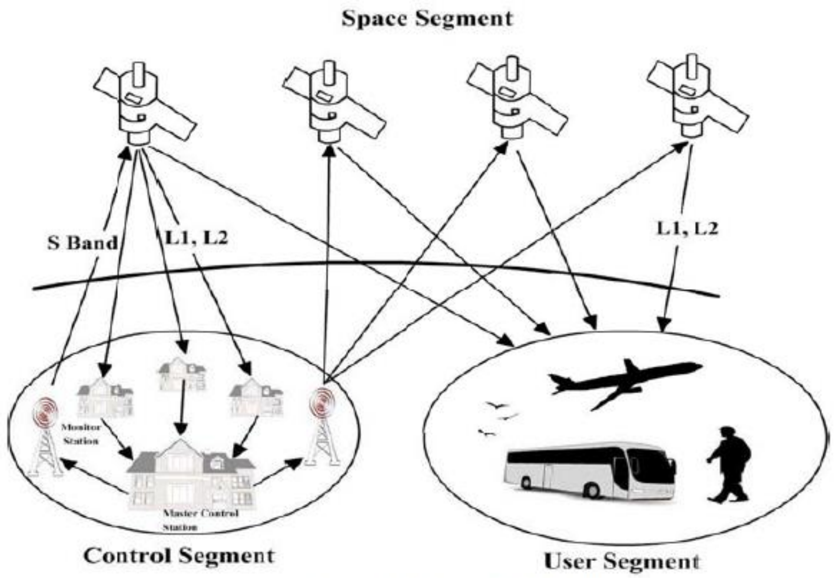


Figure 2.6: Segments of GPS

.1 Space Segment (GPS Satellite Constellation or GPS Satellites orbiting the Earth)

- U.S Air Force has launched first GPS satellite in 1978. Later on more satellites were launched to complete the GPS satellite constellation to total 24 satellites orbiting the earth at an altitude of about 20,200 km above the surface of Earth. The high altitude insures that the satellite orbits are stable, precise and predictable, and that the satellites' motion through space is not affected by atmospheric drag.

- The GPS satellites comprise of sun seeking solar panels having NiCad batteries providing secondary power. The system consists of 24 satellites (21 + 3 active spares) nominally orbiting the earth in MEO i.e. Medium Earth Orbit at an altitude of 20,200 Km approximately also named as GPS Operational Constellation. Each satellite takes 12 hours in completing one full orbit and repeat the same ground track each day. The satellites are arranged in 6 orbits with 4 satellites in each orbit, as shown in figure 2.7A and 2.7B. At present there are 27 operational GPS satellites orbiting the earth as new ones are replacing older one.

- The GPS satellite orbits are designed in such a manner that they ensure the availability of minimum 4 satellites whose visibility is above a 15° cut off angle anywhere on the earth's surface irrespective of day and night. The satellites send radio signals from space, which are received by the GPS receivers. Data from minimum four satellites are required for positioning computations. 15° cut-off angle is taken to compensate for ground undulations. Normally for an open ground, with fewer obstructions (undulating topography, high rise buildings etc.) there are 6 or 7 satellites visible quite often.

- A very accurate atomic clock having a fundamental frequency of 10.23 MHZ is a very special characteristic of each GPS satellite. On board each GPS satellite are four atomic clocks, only one of which is in use at a time. These highly accurate atomic clocks having accuracy of better than 10^{-10} seconds enable GPS to provide the most accurate timing system that exists. These clocks are generating the signals via broadcasting from the satellite.

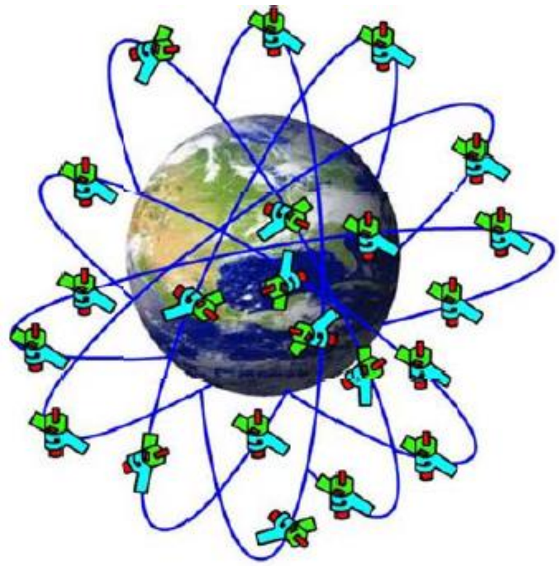


Figure 2.7A: GPS satellite constellation

Figure 2.7B: GPS satellite

.2 Control Segment (U.S. DOD Monitoring or The control and monitoring stations)

- The U.S. Department of Defense manages a master control station at Falcon Air Force Base in Colorado Springs, CO. There are four other monitor stations located in Hawaii, Ascension Island, Diego Garcia and Kwajalein. Figure 2.8 shows the locations of Control Segment stations. The DOD control stations measure the satellite orbits precisely. These are classified according to 5 locations approx. on the earth's equator and used to measure signals from SVs (Satellite Vehicles) incorporation with orbital model which enables the computation of orbital data i.e. ephemeris & SV clock correction for each satellite.

- The main function of Master Control Stations is to upload ephemeris and clock data into SVs which then send their subsets to GPS receivers via radio signals.

- The control segment is used in tracking stations, updating GPS satellite position located around the world with calibration and synchronization process of their clocks.

- It monitors and predicts the orbital path of satellite for the next 24 hrs. It also works to successfully locate the expected position of each satellite via GPS receiver. Monitor stations easily observe the satellite signals. Any discrepancies between predicted orbits and actual orbits are subsequently uploaded and broadcasted to each satellite. The satellites can then broadcast these corrections, along with the other position and timing data, so that a GPS receiver on the earth can precisely establish the location of each satellite it is tracking.

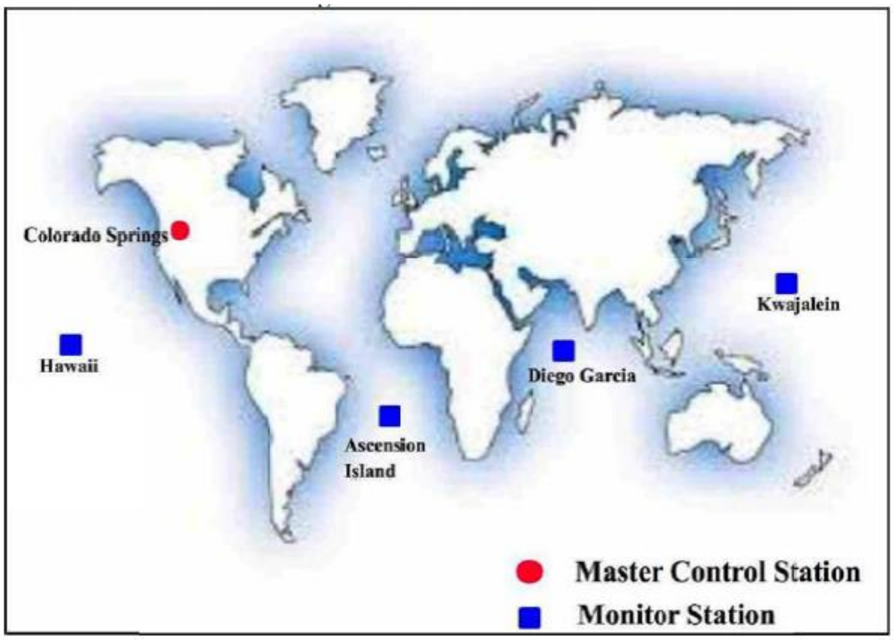


Figure 2.8: Locations of Control Segment stations

.3 User Segment (Military and Civilian GPS Users)

- It comprises of anyone who wish to determine his position and/or time. The user should be equipped with a GPS receiver to receive the GPS signal. Various applications which can be performed in the user segment are surveying and navigation including marine, aerial, machine control, vehicle etc.

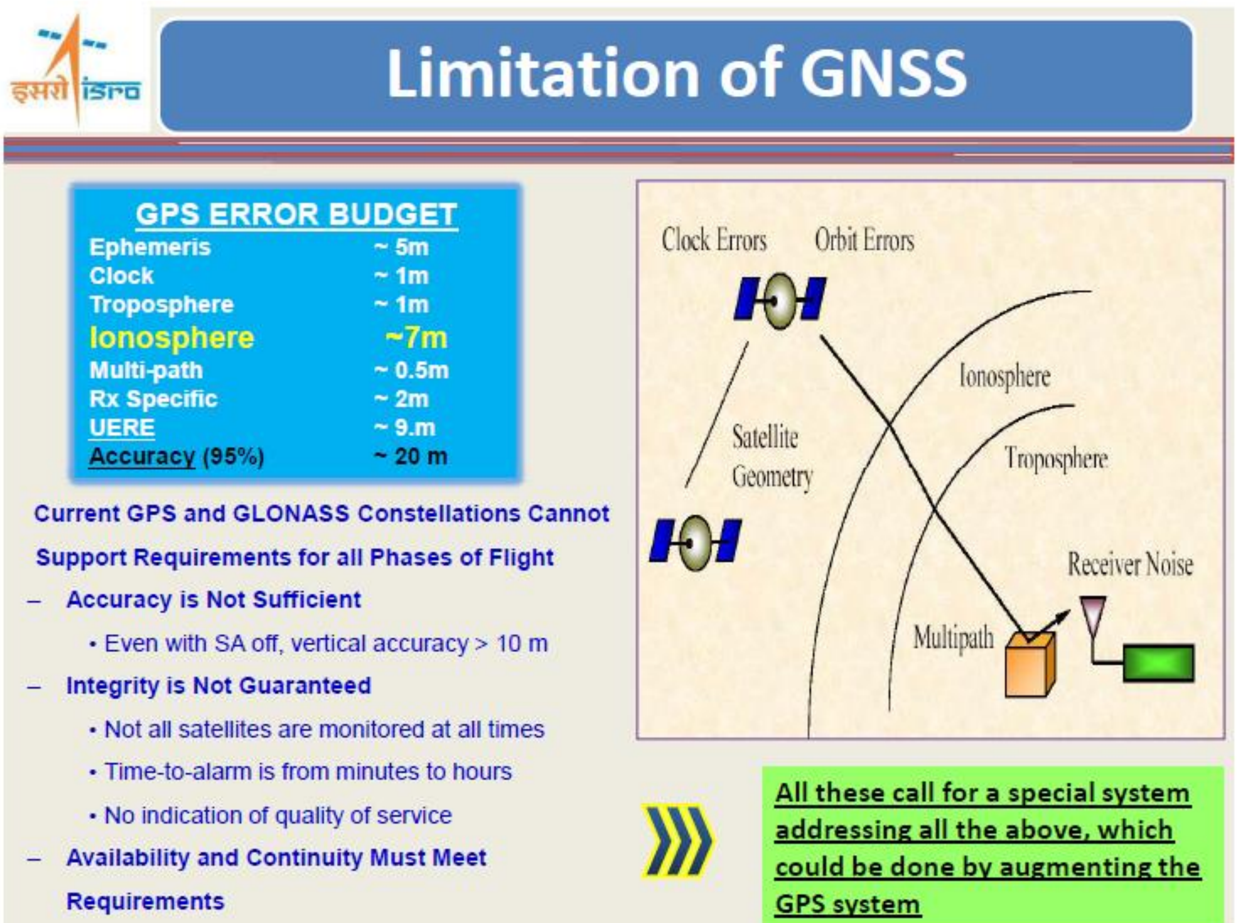
- GPS has been used by U.S. Military for the purpose of reconnaissance, navigation & missile guidance. Civilian use of GPS developed at the same time as military uses were being established, and has expanded far beyond original expectations. There are civilian applications for GPS in almost every field, from surveying to transportation to natural resource management to agriculture. Most civilian uses of GPS, however, fall into one of four categories: navigation, surveying, mapping and timing. Figure 2.9 shows various types of GPS receivers as well as their uses in various fields.

- User Segment comprises of the user group equipped with GPS receivers. The GPS receiver receives the signals from SV and converts these into position, velocity, and time estimates. Minimum four satellites are required to compute the positional dimensions of X, Y, Z along with Time. GPS receivers are mainly used for navigation and precise positioning.

Figure 2.9: User segment

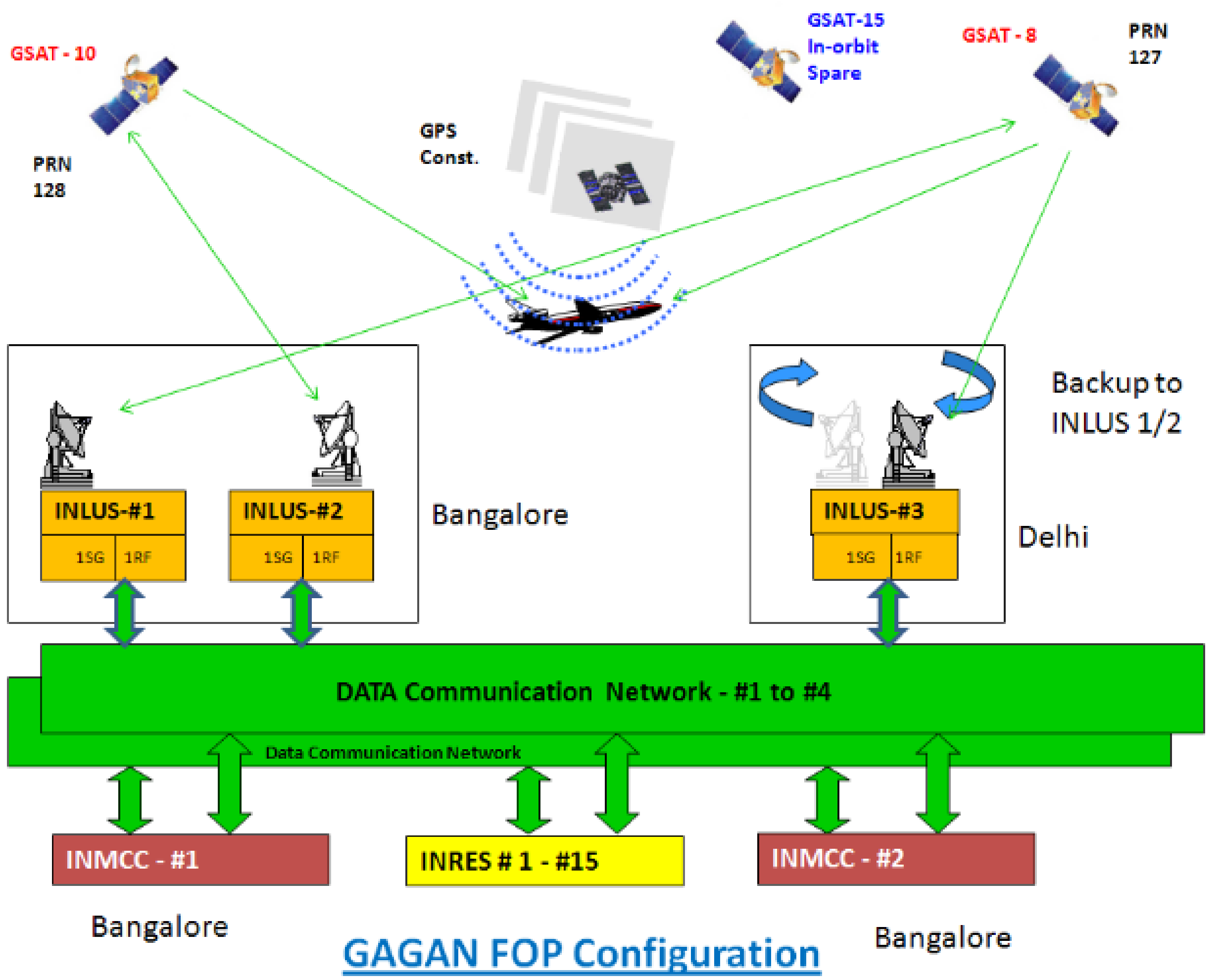
3Q) Discuss briefly about GAGAN.

- GAGAN is an acronym for GPS Aided GEO Augmented Navigation.
- It is a Space Based Augmentation System (SBAS) jointly developed by ISRO and AAI
- Provides the best possible navigational services over Indian FIR (Flight Information Region)
- GAGAN is a system of satellites and ground stations that provide GPS signal corrections, giving you better position accuracy.
- GPS alone does not meet the ICAOs navigational requirements for accuracy, integrity and availability.
- GAGAN corrects for GPS signal errors caused by Ionospheric disturbances, timing and satellite orbit errors and also it provides vital information regarding the health of each satellite.



The Key elements of GAGAN

- 15 Indian Reference Stations (INRESs)
- 2 Indian Master Control Centers (INMCCs)
- 3 Indian Lank Uplink Stations (INLUSs)
- 4 chains of Data networks (OFC and VSAT)
- 3 GEO satellites with GAGAN payloads



GAGAN Working

1. GAGAN consists of set of ground reference stations positioned across various locations in India called Indian Reference Station (INRES), which gathers GPS satellite data.
2. A master station, Indian Master Control Centre (INMCC) collects data from reference stations and create GPS correction messages.
3. The corrected differential messages are uplinked via Indian Uplink Station (INLUS) and then broadcasted on a signal from three geostationary satellites (GSAT-8, GSAT-10 and GSAT-15).
4. The information on this signal is compatible with basic GPS signal structure, which means any SBAS enabled GPS receiver can read this signal

GAGAN Services

- Aviation,
- Forest management,
- Railways signaling,
- Scientific Research for Atmospheric Studies,
- Natural Resource and Land Management,
- Location based services,
- Mobile,
- Tourism.

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