6th SEMESTER (MAJOR)

PAPER 604: PRINCIPLES AND APPLICATION OF REMOTE SENSING, GIS AND GPS

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GLOBAL POSITIONING SYSTEM (GPS)

The NAVSTAR Global Positioning System (GPS) is a satellite-based radio-positioning and time transfer system designed, financed, deployed, and operated by the US Department of Defense. GPS has also demonstrated a significant benefit to the civilian community, who are applying GPS to a rapidly expanding number of applications.

"The NAVSTAR Global Positioning System (GPS) is an all-weather, space based navigation system development by the U.S. Department of Defense to satisfy the requirements for the military forces to accurately determine their position, velocity, and time in a common reference system, anywhere on or near the Earth on a continuous basis. "

The attractions of GPS are:

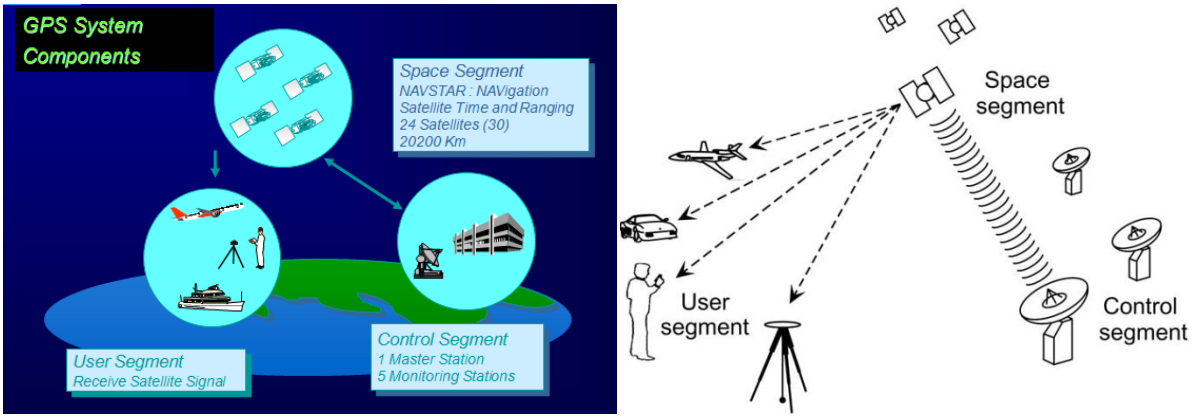
- Relatively high positioning accuracy, from meters down to the millimeter level;
- Capability of determining velocity and time, to an accuracy commensurate with position;
- No inter-station visibility is required for high precision positioning;
- Results are obtained with reference to a single, global datum;
- Signals are available to users anywhere on the earth: in the air, on the ground, or at sea;
- No user charges, requiring only relatively low-cost hardware;
- An all-weather system, available 24 hours a day;
- Position information is provided in three-dimensions.

Since its introduction to the civilian community in the early 1980s GPS has revolutionized geodesy, surveying and mapping. GPS technology is increasingly addressing the precise positioning needs of cadastral, engineering, environmental, planning and Geographical Information System (GIS) surveys, as well as a range of new machine, aircraft and ship location applications. Development work on GPS commenced within the US Department of Defense in 1973. The objective was to design and deploy an all-weather, 24 hour, global, satellite-based navigation system to support the positioning requirements of the US armed forces and its allies.

Components of GPS:

GPS technology and applications starts with the identification of the three components:

- **The space segment**: the satellites and the transmitted signals
- **The control segment**: the ground facilities carrying out the task of satellite tracking, orbit computations, telemetry and supervision necessary for routine operations.
- **The user segment**: the applications, equipment and computational techniques that is available to the users.



The space segment: The space segment consists of the constellation of spacecraft, and the signals that are broadcast by them, which allow users to determine position, velocity and time. The basic functions of the satellites are to:

- Receive and store data uploaded by the control segment
- Maintain accurate time by means of onboard atomic clocks, and
- Transmit information and signals to users on two L-band frequencies

At an altitude of approximately 20,200 km, a constellation of 24 functioning GPS satellites, located in six orbital planes inclined at about 63° to the equator, is sufficient to ensure that there will be at least four satellites visible, at any unobstructed site on the earth, at any time of the day. As the GPS satellites are in nearly circular orbits:

- Their orbital period is approximately 11 h 58 min, so that each satellite makes two revolutions in one sidereal day (the period taken for the earth to complete one rotation about its axis with respect to the stars).
- At the end of a sidereal day the satellites are again over the same location on the earth.
- Reckoned in terms of a solar day (24 h in length), the satellites are in the same position in the sky about 4 min earlier each day.

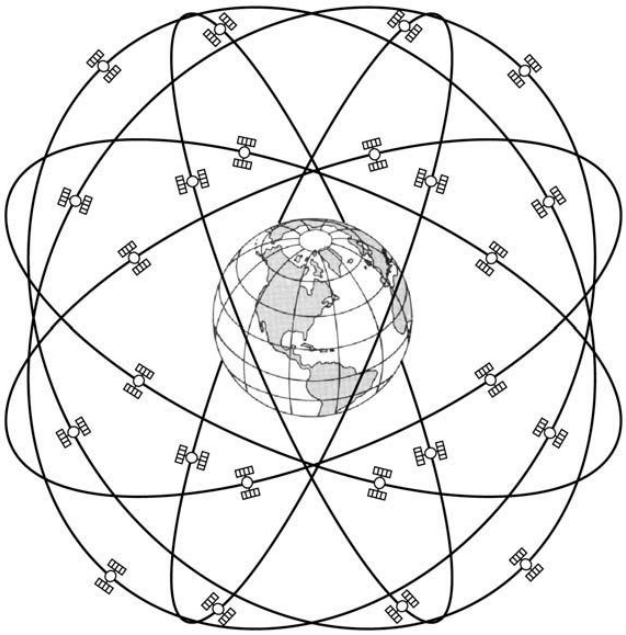


Fig: The GPS constellation 'birdcage' showing the 24 orbiting satellites

Each GPS satellite transmits unique navigational signals centered on two L-band frequencies of the electromagnetic spectrum: L1 at 1575.42 MHz and L2 at 1227.60 MHz. At these two frequencies the signals are highly directional and can be reflected or blocked by solid objects. The satellite signal consists of the following components:

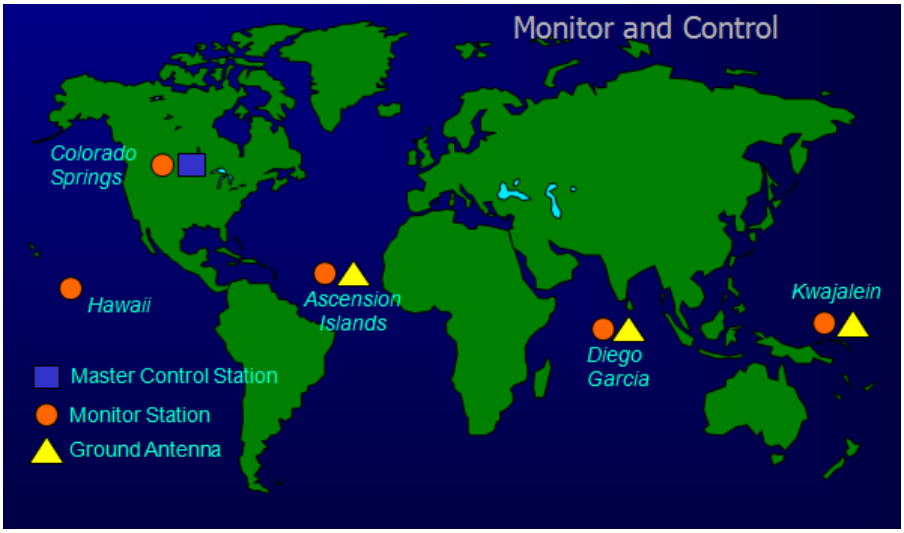
- Two L-band carrier waves
- Ranging codes modulated on the carrier waves
- Navigation message

The primary function of the ranging codes is to permit the signal transit time (from satellite to receiver) to be determined. The transit time when multiplied by the speed of light then gives a measure of the receiver-satellite 'range'. The navigation message contains the satellite orbit (or ephemeris) information, satellite clock error parameters, and pertinent general system information necessary for real-time navigation to be performed.

The control segment: The control segment consists of facilities necessary for satellite health monitoring, telemetry, tracking, command and control, and satellite orbit and clock error computations. There are currently five ground facility stations: Hawaii, Colorado Springs, Ascension Island, Diego Garcia and Kwajalein. All are operated by the US Department of Defence and perform the following functions:

- All five stations are Monitor Stations, equipped with GPS receivers to track the satellites. The resultant tracking data is sent to the Master Control Station (MCS).
- Colorado Springs is the MCS, where the tracking data are processed in order to compute the satellite ephemerides (or coordinates) and satellite clock error parameters. It is also the station that initiates all operations of the space segment, such as spacecraft maneuvering, signal encryption, satellite clock-keeping, etc.
- Three of the stations (Ascension Is., Diego Garcia, and Kwajalein) are Upload Stations through which data is telemetered to the satellites.

The computation of each satellite's ephemeris, and the determination of the each satellite's clock errors, is the most important tasks of the control segment. The first is necessary because the GPS satellites function as 'orbiting control stations' and their coordinates must be known to a relatively high accuracy, while the latter permits a significant measurement bias to be reduced.



The user segment: This is the component of the GPS system with which users are most concerned the space and control segments are largely transparent to the operations of the navigation function. While military R&D has concentrated on achieving a high degree of miniaturization, modularization and reliability, the commercial equipment manufacturers have, in addition, sought to bring down costs and to develop features that enhance the capabilities of the positioning system. Civilian users have, from the earliest days of GPS availability, demanded increasing levels of performance, in particular higher accuracy, improved reliability and faster results. Another major influence on the development of GPS equipment has been the increasing variety of civilian applications. Although it is possible to categorize positioning applications according to many criteria, the most important from the perspective of geospatial applications are:

- Accuracy, which leads to a differentiation of the GPS user equipment and techniques into several sub-classes.
- Timeliness, whether the GPS results are required in real-time, or may be derived from post-mission data processing.
- Kinematics, distinguishing between static receiver positioning, and those applications in which the receiver is moving (or in the so-called 'kinematic' mode).

It is used by everyone from Merchant, Navy, Coast Guard vessels to commercial airliners, civil pilots, surveyors, commercial truckers, hikers, mountain climbers, backpackers, cars now being equipped, even communications and imaging satellites and any system requiring accurate timing.

Advantages of GPS:

1. Weather Independent
2. Does not require line of sight
3. Gives high Geodetic Accuracy
4. Can be operated day and night
5. Quicker and requires less manpower
6. Economical advantages
7. Common Coordinate System
8. Wide Range of Applications
9. Competitively Priced