Satellite positioning

Global Positioning System (GPS)

The concept of satellite position fixing commenced with the launch of the first Sputnik satellite by the USSR in October 1957. This was rapidly followed by the development of the Navy Navigation
Satellite System (NNSS) by the US navy. This system, commonly referred to as the Transit system, was to provide world-wide navigation capability for the US Polaris submarine fleet.
System was made available for civilian use in 1967. However, as it required very long observation periods and had a rather low accuracy, its application was limited to geodetic and navigation uses.
In 1973, the US Department of Defense commenced the development of NAVSTAR (Navigation
System with Time and Ranging) global positioning system (GPS), and the first satellites were launched in 1978. These satellites were essentially experimental, with the operational system scheduled for 1987. Now that GPS is fully operational, relative positioning to several millimetres, with extremely short observation periods of a few minutes, has been achieved. For distances in excess of 5 km GPS has been shown to be more accurate than EDM traversing. It therefore has a wide application in engineering surveying, with an effect even

greater than the advent of EDM. Apart from the high accuracies attainable.

GPS advantages:

(1) Position is determined directly in an X, Y, Z coordinate system.

(2) Intervisibility between ground stations is unnecessary.

(3) As each point is fixed discretely, there is no error propagation as in networks.

(4) Survey points may therefore be selected according to their required function, rather than to produce a well-conditioned network configuration.

(5) Low skill required by the operator.

(6) Position may be fixed on land, at sea or in the air. This latter facility may have a profound effect in aerial photogrammetry.

(7) Measurement may be carried out, day or night, anywhere in the world, at any time and in any type of weather.

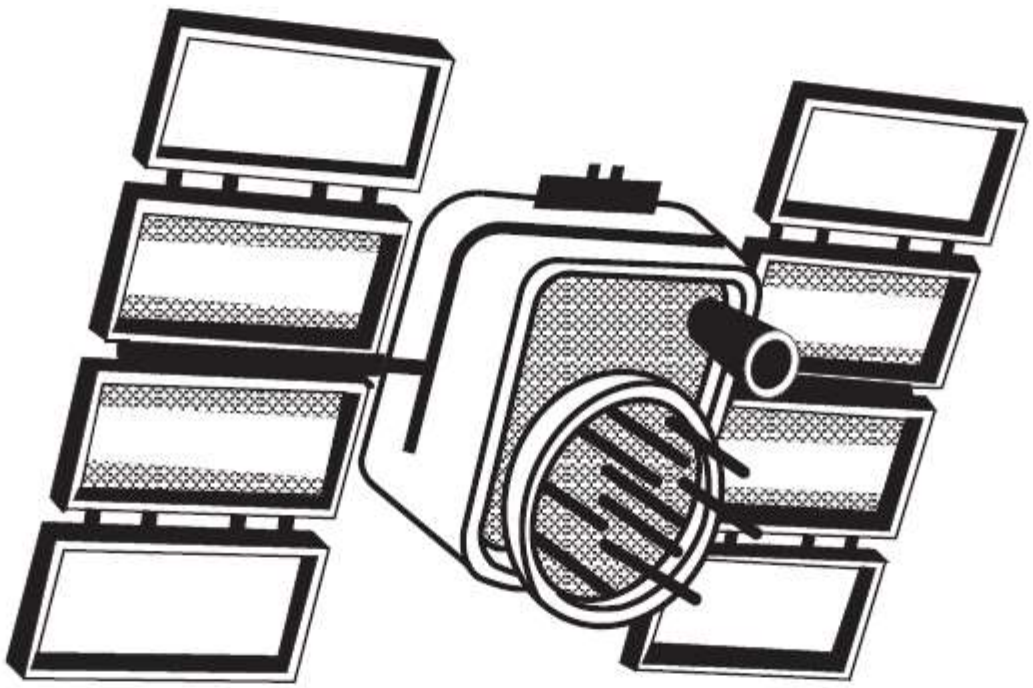
(8) Continuous measurement may be carried out, resulting in greatly improved deformation monitoring.

- **GPS SEGMENTS**

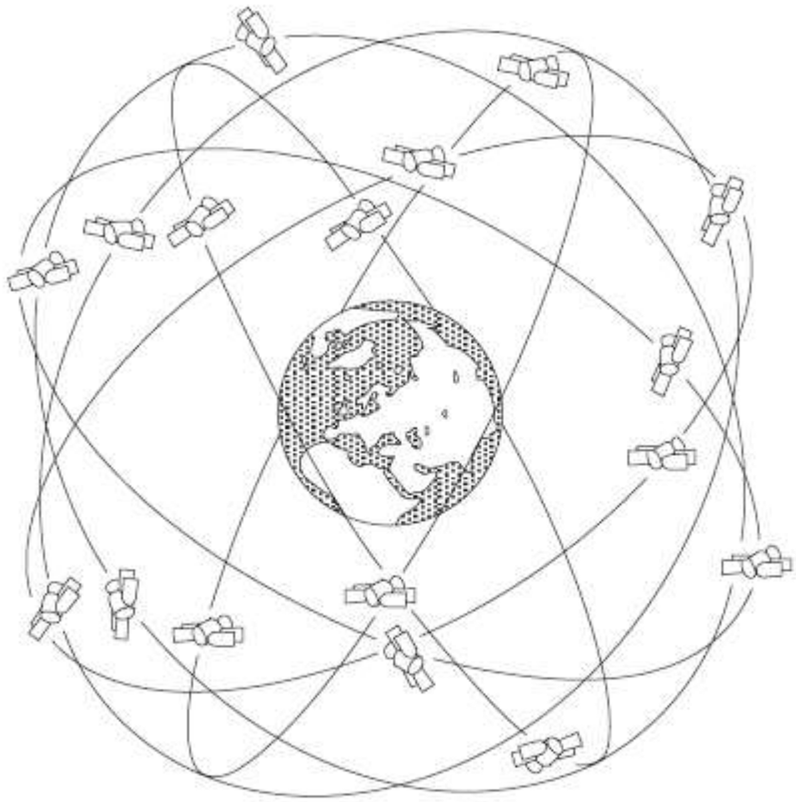
The GPS system can be broadly divided into three segments: **the *space* segment**, **the *control* segment** and the ***user* segment**.

i- ***Space segment***

The space segment is composed of satellites weighing about 400 kg and powered by means of two solar panels with three back-up, nickel-cadmium batteries that as shown in (Figurembelow). The operational phase consists of 28 satellites, at the present time, with three spares. They are in near-circular orbits, at a height of 20 200 km above the Earth, with an orbit time of 12 hours (11h 58 min).



The six equally spaced orbital planes illustrates in (Figure below), are inclined at 55° to the equator, resulting in five hours above the horizon. The system therefore guarantees that at least four satellites will always be in view.



ii- control segment

The control segment has the task of supervising the satellite timing system, the orbits and the mechanical condition of the individual satellites. Neither the timing system nor the orbits are sufficiently stable to be left unchecked for any great period of time.

The satellites are currently tracked by five monitor stations, situated in Kwajalein, Hawaii, Ascension and Diego Garcia, with the master control in Colorado Springs.

As the basic principle of position fixing using GPS is that of a resection, using distances to three known points (satellites), the position of the satellites (in a known coordinate system) is critical.

The position of the satellite is obtained from data broadcast by the satellite and called the 'broadcast ephemeris'. The positional data from all the tracking stations are sent to the master control for processing. These data, combined with the satellite's positions on previous orbits, make it possible to predict the satellite's position for several hours ahead. This information is uploaded to the satellite, for subsequent transmission to the user, every eight hours. Orbital positioning is currently accurate to about 10 m, but would degrade if not continuously updated.

iii- User segment

Basically, a receiver obtains pseudo-range or carrier phase data to at least four satellites. As GPS receiver technology is developing so rapidly, it is only possible to deal with some of the basic operational characteristics. The type of receiver used (Figure below) will depend largely upon the requirements of the user. For instance, if GPS is to be used for absolute as well as relative positioning, then it is necessary to use pseudo-ranges. If high-accuracy relative positioning is the requirement, then the carrier phase would be the observable involved. From this initial consideration it can be seen that, for real-time pseudo-range positioning, the user would need access to the navigation message

(Broadcast Ephemerides). If carrier waves are to be used, the data are post-processed and an external precise ephemeris may be used. Thus, where the navigation message is essential, a code-correlating receiver would be used. If carrier phase and post-processing are the requirement, a codeless receiver may be preferred.

The user segment consists essentially of a portable receiver/processor with power supply and an omnidirectional antenna as shown in (Figure below). The processor is basically a microcomputer containing all the software for processing the field data

Figure illustrate GPS antenna and receiver

Figure illustrate GPS receiver

A receiver generally has one or more channels. A channel consists of the hardware and software necessary to track a satellite on the code and/or carrier phase measurement, continuously.

- **SATELLITE ORBITS**

The German astronomer Johannes Kepler (1571–1630) established three laws defining the movement of planets around the Sun, which have been applied to the movement of satellites around the Earth:

(1) Satellites move around the Earth in elliptical orbits, with the center of mass of the Earth situated at one of the focal points (***G***) as illustrate in (Figure 1). The other focus ($\bar{G}$) is unused.

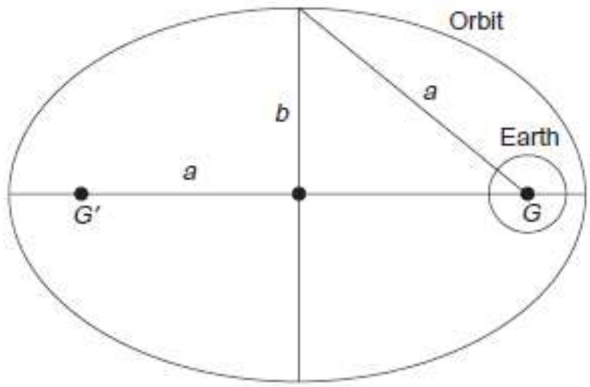


Figure 1

(2) The radius vector from the Earth's center to the satellite sweeps out equal areas at equal time intervals (Figure 2).

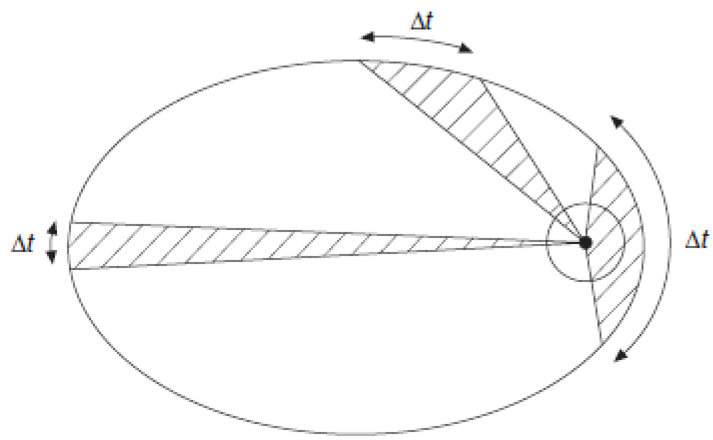


Figure 2

(3) The square of the orbital period is proportional to the cube of the semi-major axis ***a***, i.e. $\boldsymbol{T}^2 = \boldsymbol{a}^3 \times$ constant.

These laws therefore define the geometry of the orbit, the velocity variation of the satellite along its orbital path, and the time taken to complete an orbit.