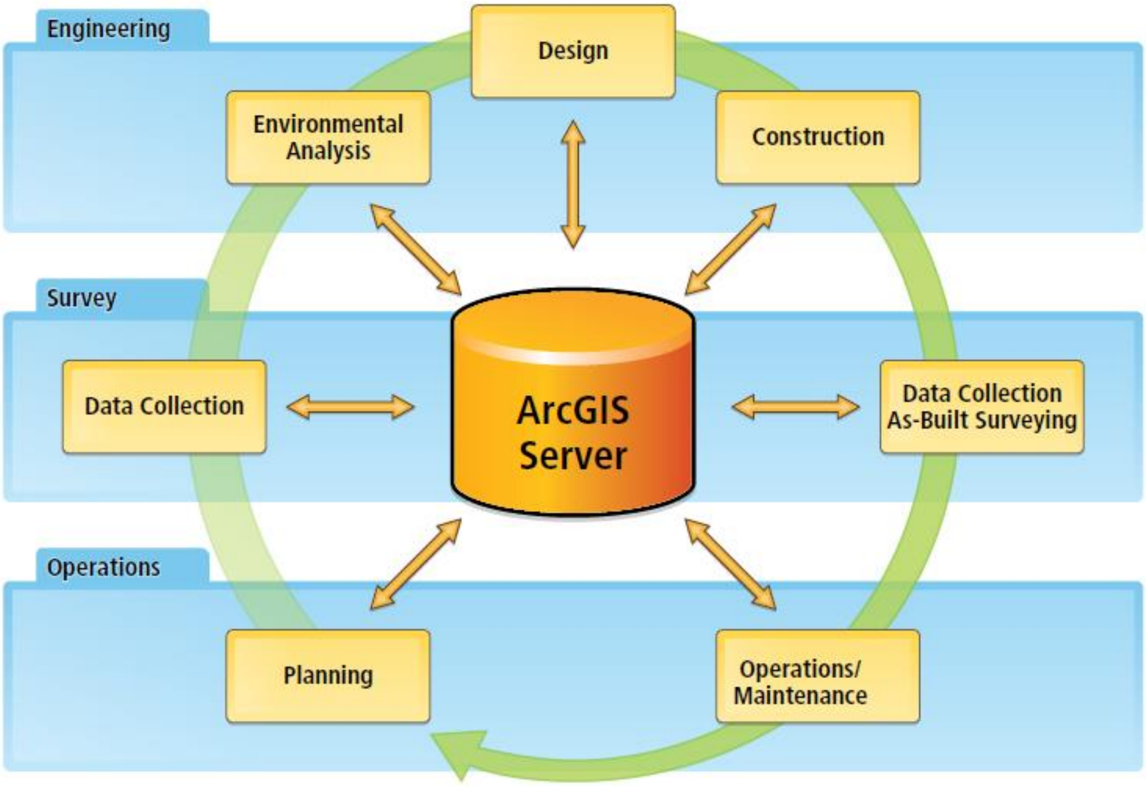
Applications of GIS in Civil Engineering:



1. Planning:

In planning its major contribution is to give us with an organized set of data which can help professionals to combat complex scenarios relating to :

- the selection of site,
- environmental impact,
- study of ecosystem,
- managing risk regarding the use of natural resources,
- sustainability issues,
- managing traffic congestion, routing of roads
- pipelines etc.

2. Data Collection:

It has specific functions to collect precise site data used for

- Pre-design analysis
- design

- calculations including field survey, topography, soils, subsurface geology, traffic, lidar, photogrammetry, imaging, sensitive environmental areas, wetlands, hydrology, and other sitespecific design-grade data.

3.Analysis:
Analysis is a method which supports our design. Some of the analyses that can be performed by GIS are:

- Water distribution analysis
- Traffic management analysis
- Soil analysis
- Site feasibility analysis
- Environment impact analysis
- Volume or Area analysis of catchment
- River or canals pattern analysis
- Temperature and humidity analysis

4.Design:
It allows creation of new infrastructure data for new civil works including

- grading,
- contouring,
- specifications,
- cross sections,
- design calculations,
- environmental mitigation plans,

5. Construction
It is the stage when all layout plans and paper work design come into existence in the real world.

- Timely usage of construction equipment.
- Working Hours
- Effects of seasonal fluctuations.
- Optimizing routes for dumpers and concrete trucks
- Earth filling and cutting
- Calculation of volumes and areas of constructed phase thereby helping in Estimation and Valuation.

6. Operations
GIS can help us to keep track of timely operations of activities.

Spatial selection and display tools allow you to visualize scheduled work:

- ongoing activities,
- recurring maintenance problems,
- historical information.

General Applications of GIS in Civil Engineering

- Transportation
- Watershed Analysis
- Environment Impact Assessment
- Target Site Selection
- Mineral mapping
- Resource management and disaster management
- Land use planning
- Urban Planning
- Water and Sanitation Mapping and many more.......

TRIANGULATION

The horizontal positions of points is a network developed to provide accurate control for topographic mapping, charting lakes, rivers and ocean coast lines, and for the surveys required for the design and construction of public and private works of large extent. The horizontal positions of the points can be obtained in a number of different ways in addition to traversing. These methods are triangulation, trilateration, intersection, resection, and satellite positioning.

The method of surveying called *triangulation* is based on the trigonometric proposition that if one side and two angles of a triangle are known, the remaining sides can be computed. Furthermore, if the direction of one side is known, the directions of the remaining sides can be determined.

A triangulation system consists of a series of joined or overlapping triangles in which an occasional side is measured and remaining sides are calculated from angles measured at the vertices of the triangles. The vertices of the triangles are known as *triangulation stations.* The side of the triangle whose length is predetermined, is called the *base line.* The lines of triangulation system form a network that ties together all the triangulation stations (Fig. 1.1).

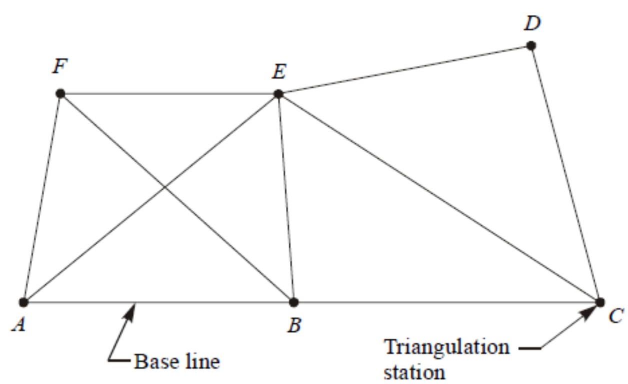


Fig. 1.1 Triangulation network

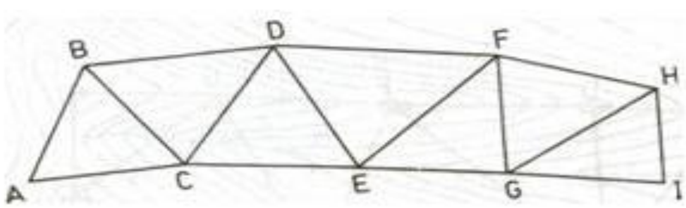
Objective of Triangulation Surveys:

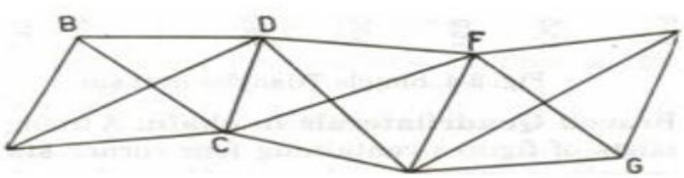
The main objective of triangulation survey is to provide a number of stations whose relative and absolute positions, horizontal as well as vertical, are accurately established. More detailed location or engineering survey are then carried out from these stations.

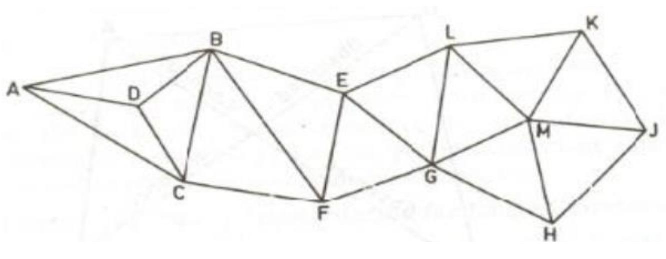
The triangulation surveys are carried out

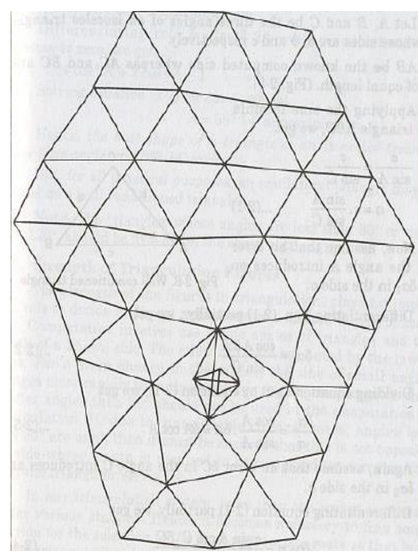
(*i*) to establish accurate control for plane and geodetic surveys of large areas, by terrestrial methods,
(*ii*) to establish accurate control for photogrammetric surveys of large areas,
(*iii*) to assist in the determination of the size and shape of the earth by making observations for
latitude, longitude and gravity, and
(*iv*) to determine accurate locations of points in engineering works such as :
(*a*) Fixing centre line and abutments of long bridges over large rivers.
(*b*) Fixing centre line, terminal points, and shafts for long tunnels.
(*c*) Transferring the control points across wide sea channels, large water bodies, etc.
(*d*) Detection of crustal movements, etc.
(*e*) Finding the direction of the movement of clouds.

Triangulation systems:









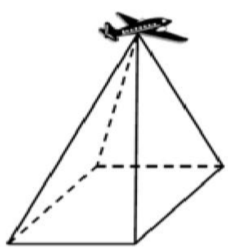
PHOTOGRAMMETRY

Definition of Photogrammetry: Photogrammetry is defined as the art and science of obtaining reliable measurements, by the use of photographs, in order to determine characteristics such as size, shape and position of photographed objects.

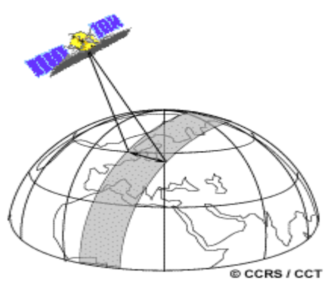
Classification of Photogrammetry:

1.Terrestrial Photogrammetry: photographs taken on the ground with the camera usually pointing in a horizontal

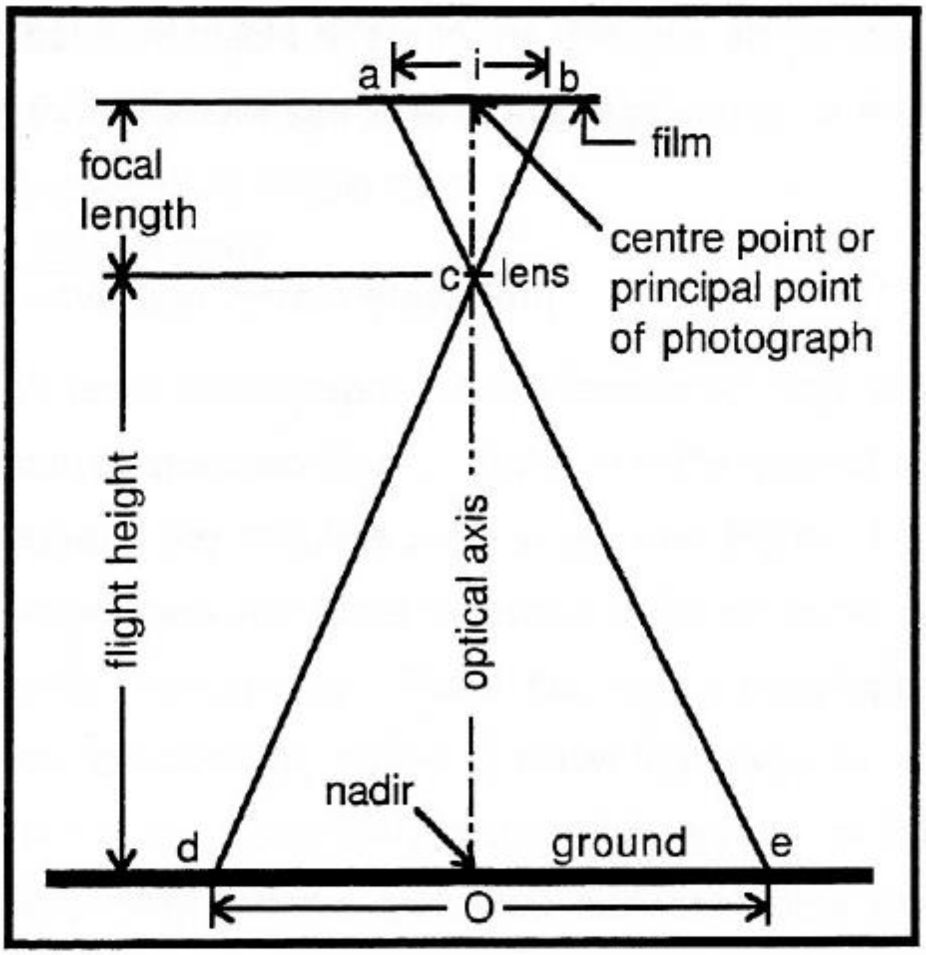

2. Aerial Photogrammetry: photographs taken from the air with the camera usually pointing vertically downwards




3.Space Photogrammetry: photographs taken from the space with the camera usually pointing vertically downwards



Geometry of the single aerial photograph:



The geometry of a single vertical aerial photograph is illustrated in above Figure. In a vertical aerial photograph the optical axis of the camera is vertical and the plane of the photograph (film) is horizontal. The point where the optical axis intersects the photograph is termed the centre point or principal point of the photograph. This can be located on an aerial photograph as the intersection of lines drawn between opposite fiducial marks in the margins of the print. In a perfectly vertical aerial photograph the principal point also represents the plumb point or nadir point which is the photographic position representing the point on the earth's surface vertically beneath the camera lens at the time of exposure. In practice a vertical aerial photograph, Geometry of a single vertical aerial photograph is rarely absolutely vertical and the nadir point and the centre point do not coincide exactly, the usually small difference being the result of tilt. The distance between the camera lens and the ground represents the flight height of the aircraft and the focal length is the distance between the camera lens and the film.

The scale of a vertical aerial photograph:

One of the most significant geometric relationships of above Figure is that equal angles are subtended at a camera lens by an object and by its photographic image. In other words, the triangles abc and cde are similar and it follows that the ratio of object size (O) to image size (i) is the same as the ratio of focal length (f) to flight height (H), or

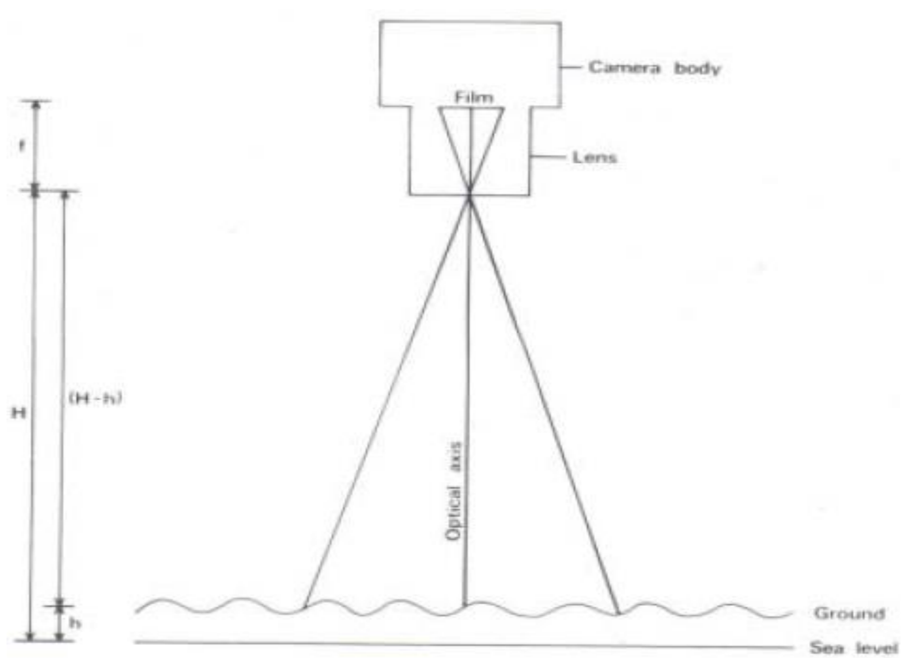
$$\frac{f}{H} = \frac{i}{O}$$

The ratio of image to object size is the general scale of the aerial photograph and it follows that the scale may be determined if the camera focal length and flight height are known:

$$Scale\ (s) = \frac{focal\ length}{flight\ height} = \frac{f}{H - h}$$

So ground distance can be calculated by using

$$\text{Scale of photograph} = \frac{Photo\ Distance}{Ground\ Distance}$$



An aerial photograph has the following advantages over a line map:

1. It is a pictorial representation of the ground that shows far greater detail than a line map. This distinction is greatest in wilderness areas where there are few or no cultural features.

2. Because aerial photographs are much more cheaply produced than maps, most areas are photographed more frequently than they are mapped and aerial photographs thus are usually more current.

3. Related to (2) is the fact that a sequence of aerial photographs can provide a more detailed account of landscape change over time than is available from topographic maps.

APPLICATIONS OF PHOTOGRAMMETRY

- Topographical Mapping
- Regional geological mapping
- Regional soil mapping
- Forestry Resources
- Military intelligence
- Large Scale Plans
- Cadastral Plans
- Land use maps
- Hydrographic Maps and Charts
- Exploration and Reconnaissance
- Archaeology and civil engineering studies

GLOBAL POSITIONING SYSTEM

Introduction:

The Global Positioning System (GPS) is a satellite-based navigation and surveying system for determination of precise position and time, using radio signals from the satellites, in realtime or in post-processing mode. GPS is being used all over the world for numerous navigational and positioning applications, including navigation on land, in air and on sea, determining the precise coordinates of important geographical features as an essential input to mapping and Geographical Information System (GIS), along with its use for precise cadastral surveys, vehicle guidance in cities and on highways using GPS-GIS integrated systems, earthquake and landslide monitoring, etc. In India also, GPS is being used for numerous applications in diverse fields like aircraft and ship navigation, surveying, geodetic control networks, crustal deformation studies, cadastral surveys, creation of GIS databases, time service, etc., by various organisations.

GPS is primarily a navigation system for real-time positioning. However, with the transformation from the ground-to-ground survey measurements to ground-to-space measurements made possibly by GPS, this technique overcomes the numerous limitations of terrestrial surveying methods, like the requirement of intervisibility of survey stations, dependability on weather, difficulties in night observations, etc.. These advantages over the conventional techniques, and the economy of operations make GPS the most promising surveying technique of the future. With the well-established high accuracy achievable with GPS in positioning of points separated by few hundreds of meters to hundreds of km, this unique surveying technique has found important applications in diverse fields.

GPS Segments / GPS Components:

The Global Positioning System basically consists of three segments: the Space Segment, The Control Segment and the User Segment.

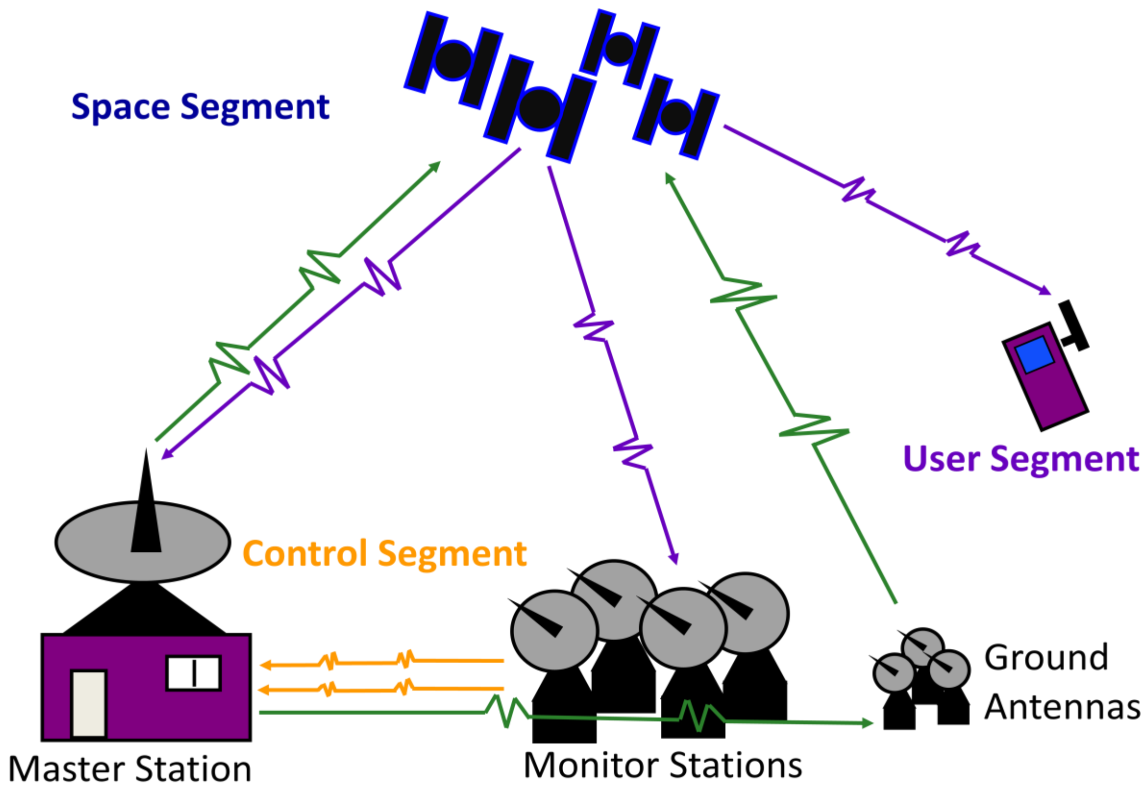
1.Space Segment: The Space Segment contains 24 satellites, in 12-hour near-circular orbits at altitude of about 20000 km, with inclination of orbit 60 degree. The constellation ensures at least 4 satellites in view from any point on the earth at any time for 3-D positioning and navigation on world-wide basis.

2.Control Segment: This has a Master Control Station (MCS), few Monitor Stations (MSs) and an Up Load Station (ULS). The MSs are transportable shelters with receivers and computers; all located in U.S.A., which passively track satellites, accumulating ranging data from navigation signals. This is transferred to MCS for processing by computer, to provide best estimates of satellite position, velocity and clock drift relative to system time. The data thus processed generates refined information of gravity field influencing the satellite motion, solar pressure parameters, position, clock bias and electronic delay characteristics of ground stations and other observable system influences. Future navigation messages are generated from this and loaded into satellite memory once a day via ULS which has a parabolic antenna, a transmitter and a computer. Thus, role of Control Segment is:

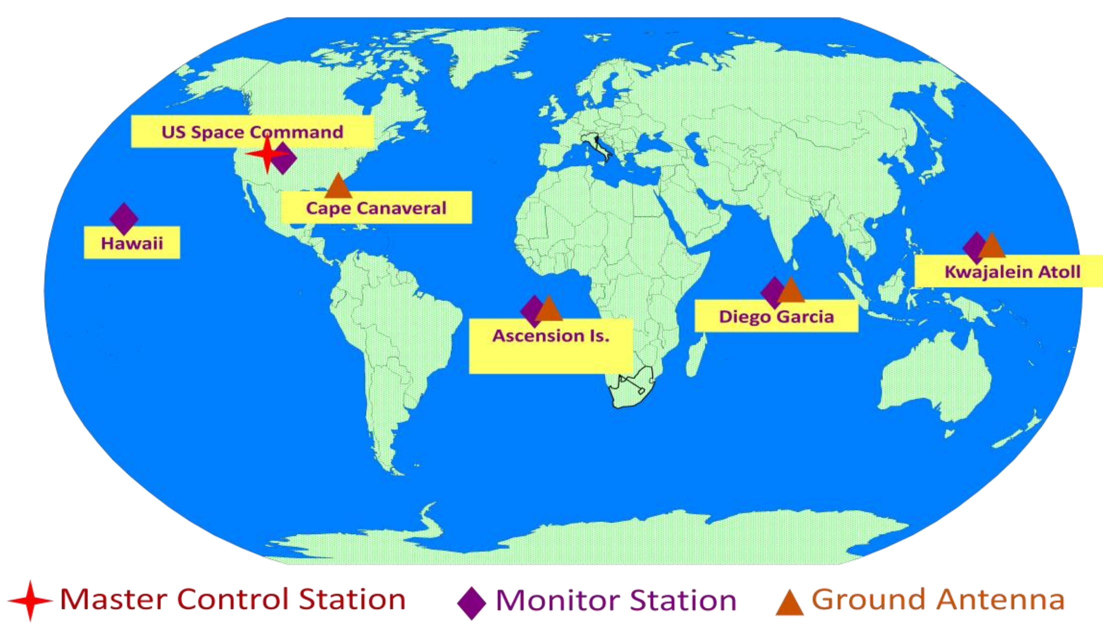
- To estimate satellite [space vehicle (SV)] ephemerides and atomic clock behaviour.
- To predict SV positions and clock drifts.
- To upload this data to SVs.

3.User Segment: The user equipment consists of an antenna, a receiver, a data-processor with software and a control/display unit. The GPS receiver measures the pseudo range, phase and other data using navigation signals from minimum 4 satellites and computes the 3-D position, velocity and system time. The position is in geocentric coordinates in the basic reference coordinate system: World Geodetic reference System 1984 (WGS 84), which are converted and displayed as geographic, UTM, grid, or any other type of coordinates. Corrections like delay due to ionospheric and tropospheric refraction, clock errors, etc. are also computed and applied by the user equipment / processing software.

Three Segments of the GPS



Control Segment



Applications of GPS and DGPS in Civil Engineering:

GPS can be used to Prepare

- Contour Maps,
- Longitudinal Section Of Roads
- Alignment of Roads, Bridges etc.
- All most all surveying applications

GPS for Construction Industry

The ability of GPS to provide real-time sub-metre and centimetre level accuracy has significantly changed the construction industry. Construction firms are using GPS in many applications such as road construction and earth moving, fleet management and other civil engineering applications (see Figure 1). In road construction and earth moving, GPS, combined with wireless communication and computer systems, is installed on board the earth-moving machine. Designed surface information, in a digital format, is uploaded into the system. With the help of the computer display and the real-time GPS position information, the operator can view whether the correct grade has been reached.

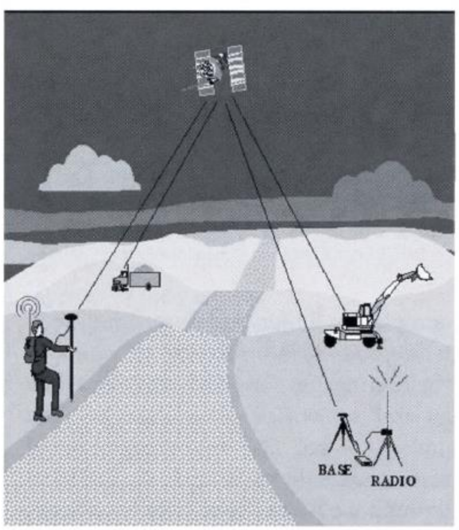


Figure 1.
GPS for Construction Applications

GPS for Mining and Tunnelling Surveys

Until recently, conventional surveying was the only method available for staking drill patterns and other mining surveying. As a result of the harsh mining environment, however, stakes were often buried or displaced. In addition, drill operators had no precise way of determining the actual bit depth. Likewise, there was no way of monitoring the drill performance in the various geological layers or monitoring the haul trucks in an efficient way. More recently, however, the development of the modern positioning systems and techniques, particularly the real-time kinematic GPS, has dramatically improved the various mining operations. In open-pit mines, for example, the use of real-time kinematic (RTK) GPS has significantly improved several mining operations such as drilling, shoveling, vehicle tracking and surveying. RTK GPS provides centimeter-level positioning accuracy, and requires only one base receiver to support any number of rovers.

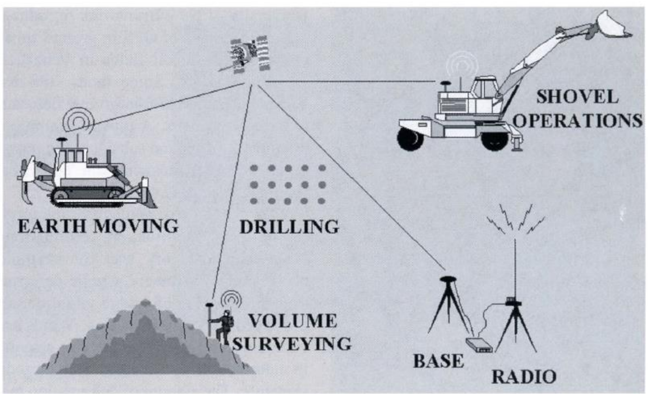


Figure 3. GPS for Open-Pit Mining

GPS for Monitoring Structural and Ground Deformations

Monitoring of structural deformations requires the highest possible accuracy of measurements. Here, one should distinguish between the slow motion deformations such as dam deformations, and cyclic structural deformations produced by effects of fast changing loads, such as bridge vibrations due to changeable traffic loads or TV towers vibrations due to wind gusts. GPS has found many applications in both cases. Here, however, one should give a word of warning to those who overemphasize the use of GPS as a stand-alone tool. Generally, structural deformations, for instance deformation of concrete dams, require millimetre and, sometimes, even sub-millimetre accuracy of displacement monitoring. This is still not achievable with GPS in an economical way. Besides, GPS requires good visibility to the satellites and is susceptible to errors arising from the signals reflected from the structural surfaces (so-cajled multipath effect). Nevertheless, when combined with other high precision monitoring techniques, GPS becomes a valuable tool in implementing.

DIFFERENTIAL GPS (DGPS)

Differential GPS is essentially a system to provide positional corrections to GPS signals. DGPS uses a fixed, known position to adjust real time GPS signals to eliminate pseudorange errors.

An important point to note is that DGPS corrections improve the accuracy of **position data only**. DGPS has no effect on results that are based on speed data, such as brake stop results.

What are Pseudorange errors?

GPS signals coming from satellites down to the ground have to travel through layers of the earth's atmosphere, so they are subjected to delays. This affects the time taken for the signal to travel from any given satellite to a GPS receiver, which introduces slight error into the GPS engine, causing an error in the measured position.

Differential GPS - How Does DGPS Work?

Differential GPS (DGPS) gets around the accuracy problem by relying on a number of fixed points on the earth whose GPS coordinates are well-known. Base stations or reference stations are located at these fixed points. The DGPS system works as follows:

1. Base stations constantly measure the accuracy of the GPS signal received from each of the satellites that it has a Line-of-Sight (LoS) or direct visibility to.
2. The base station calculates how much of a correction (compared to the known accurate position) is required per satellite and broadcasts this information to DGPS units in its vicinity.
3. Using the original signal received from the satellite and the correction information received from the nearest fixed point (or points) the DGPS unit can then establish a more accurate estimate of its current position.

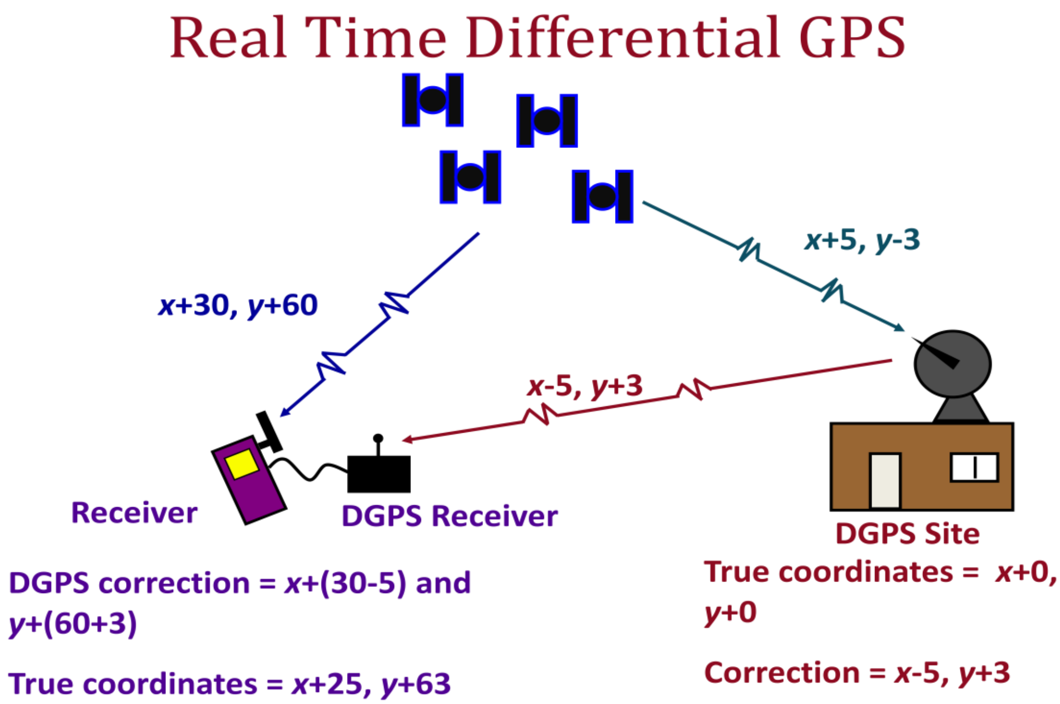
The basic assumption is that GPS receivers that are close to each other suffer from similar atmospheric effects, and so in all likelihood the base station and the closest DGPS unit will experience the same amount of error. Clearly, the accuracy of DGPS will depend on the distance from the closest base station. A DGPS unit, thus, needs to have the additional capability of receiving the signal from base stations) and carrying out the post-processing.

Working of DGPS:

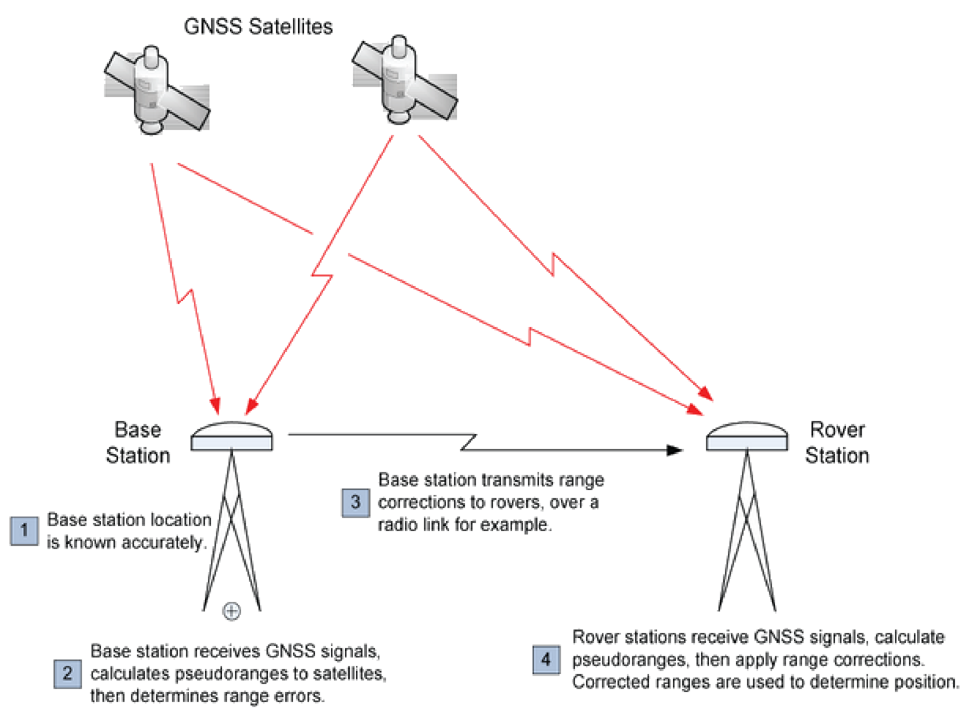
A typical DGPS architecture is shown in below Figure. The system consists of a Reference Receiver (RR) located at a known location that has been previously surveyed, and one or more DGPS User Receivers (UR). The RR antenna, differential correction processing system, and datalink equipment (if used) are collectively called the Reference Station (RS). Both the UR and the RR data can be collected and stored for later processing, or sent to the desired location in real time via the datalink. DGPS is based on the principle that receivers in the same vicinity will simultaneously experience common errors on a particular satellite ranging signal. In general, the UR (mobile receivers) use measurements from the RR to remove the common errors. In order to accomplish this, the UR must simultaneously use a subset or the same set of satellites as the reference station. The DGPS positioning equations are formulated so that the common errors cancel. The common errors include signal path delays through the atmosphere, and satellite clock and ephemeris errors.

Types of DGPS System

1) **Real-Time DGPS**
2) **Satellite Differential Services**



Satellite Differential Services



Advantages and disadvantages of DGPS:

Advantages

- It helps to survey with many times greater Precision.
- It helps to complete a Survey with lesser time and thus helps to cut down the Completion Period.
- It Reduces the Difficulty of taking manual measurements to great extent.
- With GPS there is a very less chances of error. And this error may come only due to the Instrument malfunction.
- DGPS helps to know perfect location on the earth.
- Provide accurate data within a minute.
- GPS is quite accurate; however, using DGPS pushes its accuracy even further.

Disadvantages

- The main Disadvantage is that, it requires high initial investments.
- To conduct such High End Survey works and to operate such Electronic Equipments much skilled persons are required.
- The coverage area to take advantage of DGPS is limited.
- To ensure greater coverage area more DGPS stations need to be added.