Bharathidasan University
Tiruchirappalli, Tamil Nadu

Programme: M. Tech Geoinformatics
Course: Global Navigation Satellite System (GNSS)
Title: Working Principles of GPS

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PRINCIPLES AND FUNCTIONING OF GPS/ DGPS /ETS

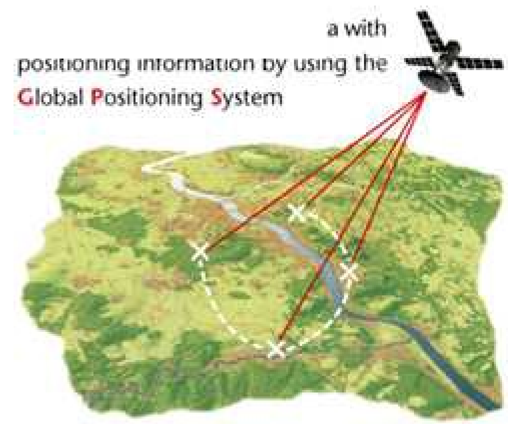
There are four GNSS systems in existence

GPS, GLONASS,Galileo & Compass

- The Global Positioning System (GPS) is also called NAVSTAR GPS (Navigational System with Time and Ranging)operated by United States Government.
- The GLObal NAvigation Satellite System (GLONASS) operated by the Russian Government.
- The Galileo Navigation Satellite System to be operated by European Union.
- The Compass Navigation Satellite System to be operated by Chinese Government.

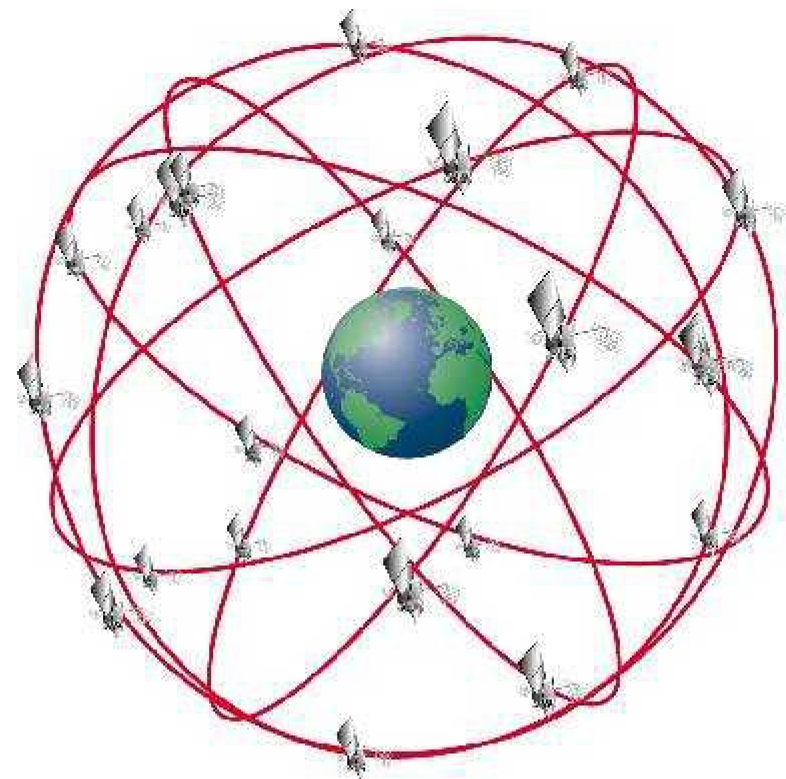
Receivers and Satellites

GPS units are made to communicate with GPS satellites (which have a much better view of the Earth) to find out exactly where they are on the global scale of things.



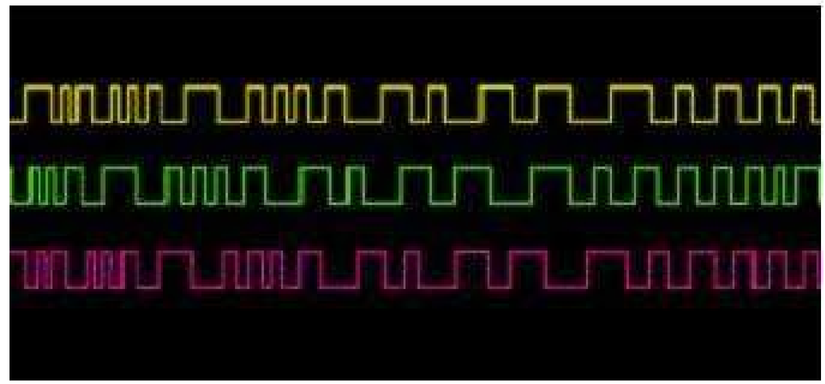
GPS Satellites

The GPS Operational Constellation consists of 24 satellites that orbit the Earth in very precise orbits twice a day. GPS satellites emit continuous navigation signals.



GPS Signals

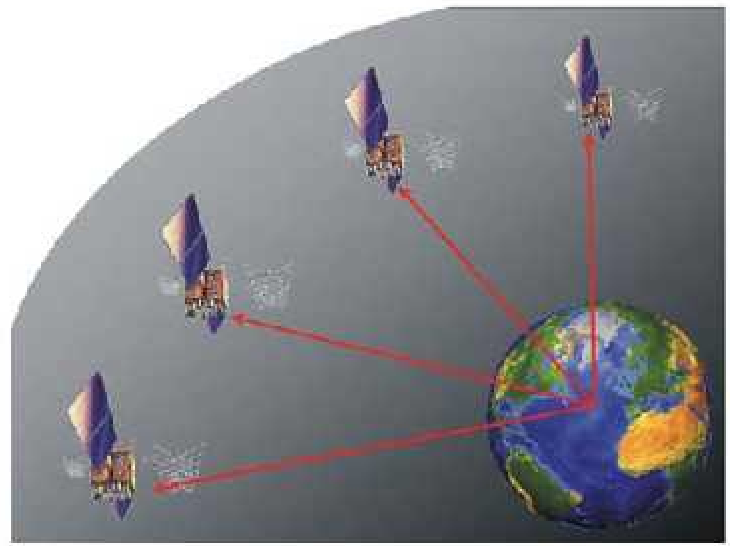
Each GPS satellite transmits data that indicates its location and the current time. All GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant.

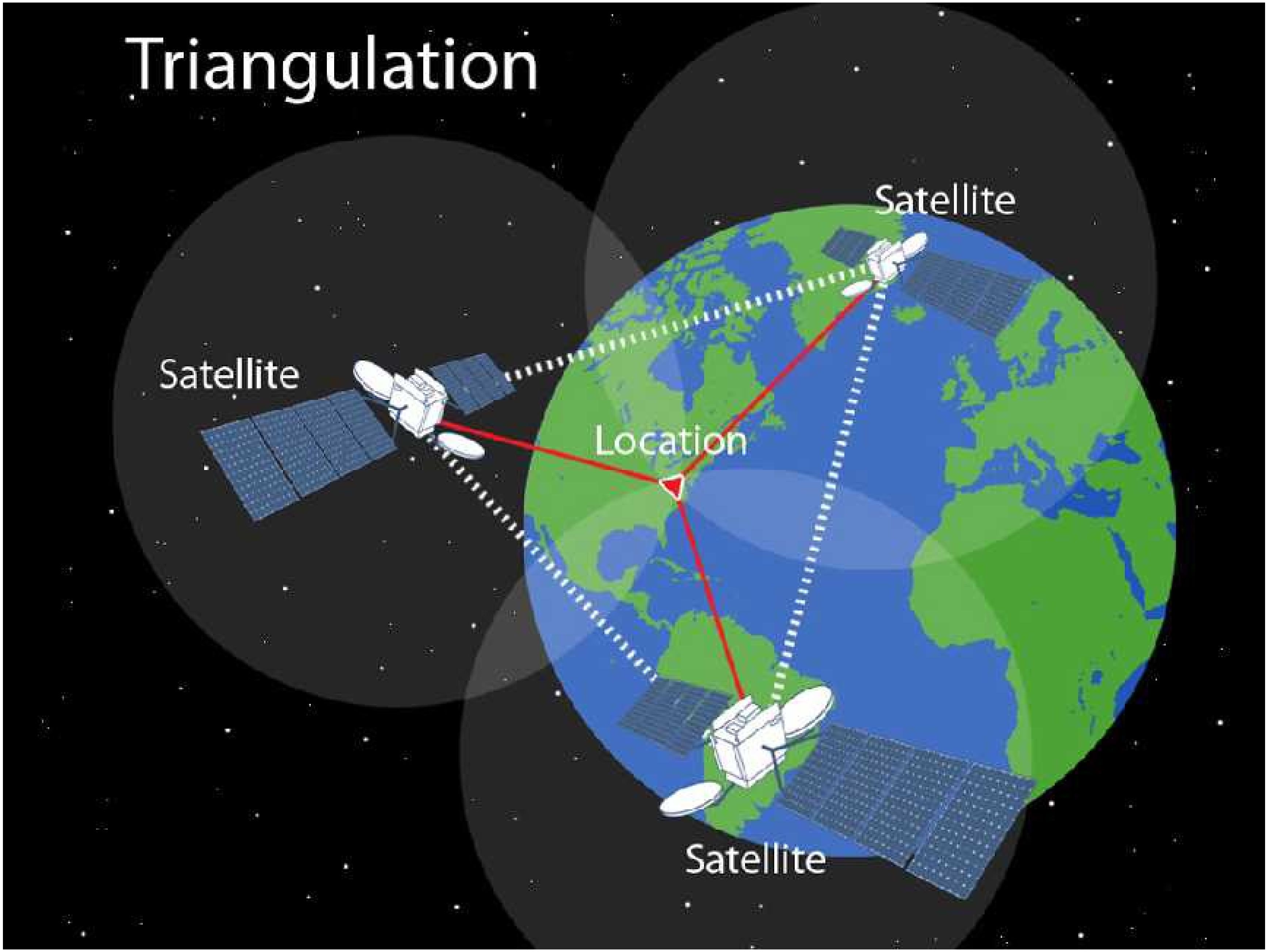


Physically the signal is just a complicated digital code, or in other words, a complicated sequence of "on" and "off" pulses.

Time Difference

The GPS receiver compares the time a signal was transmitted by a satellite with the time i was received. The time difference tells the GPS receiver how far away th satellite is.




Triangulation
Satellite
Satellite
Location
Satellite

Measurement of GPS Satellites Signals and position determination

- Measurement of Travel time of the signals from a constellation of GPS Satellites orbiting the earth for enabling the position in the earth.

The GPS satellites are in orbits such that one can be able to receive signals from at least four satellites to enable for the determination of latitude, longitude,

altitude and time.

Calculating Distance

Velocity x Time = Distance

Radio waves travel at the speed of light, roughly 186,000 miles per second (mps)

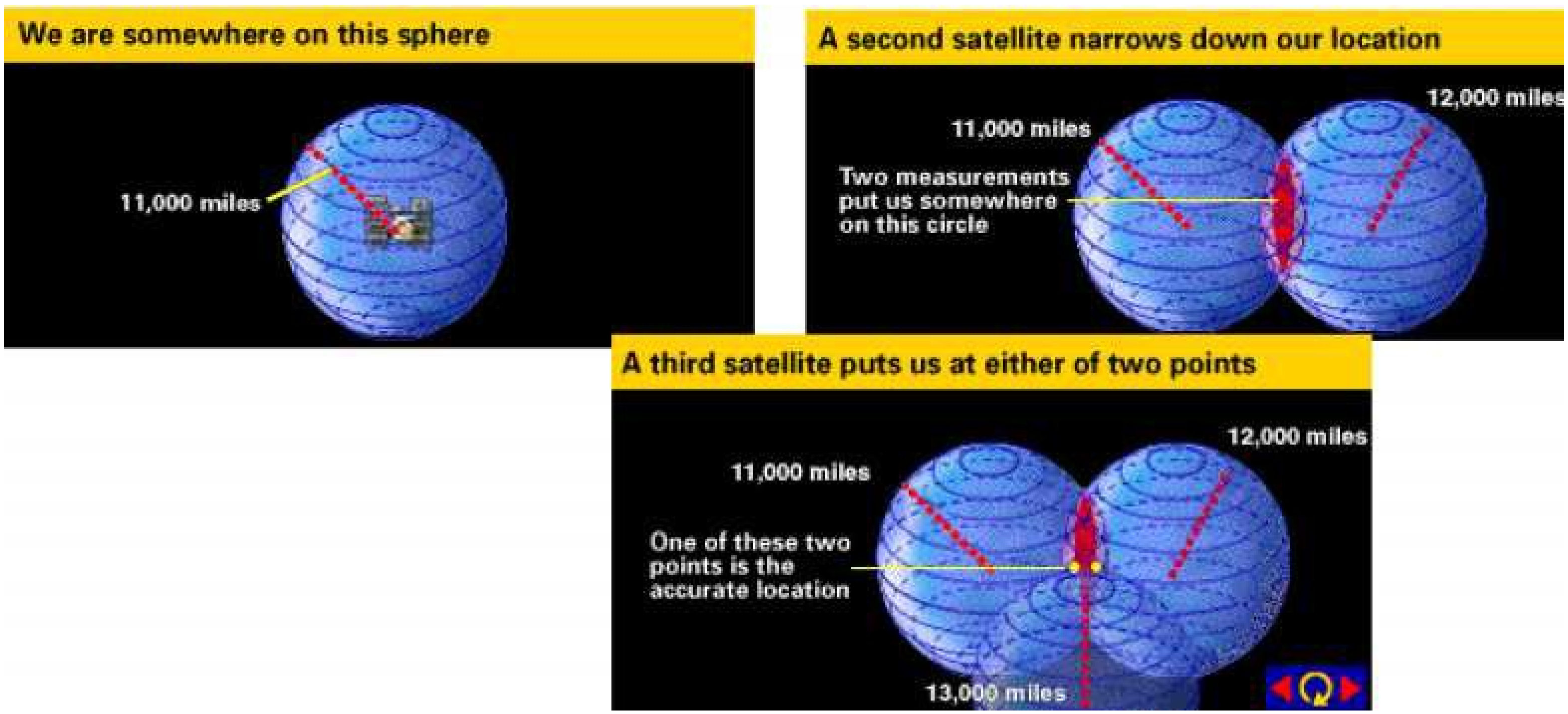
If it took 0.06 seconds to receive a signal transmitted by a satellite floating directly overhead, use this formula to find your distance from the satellite.

186,000 mps **x 0.06** seconds **= 11,160 miles**

POSITION CONCEPTS OF GPS

- Latitude
- Longitude
- Altitude

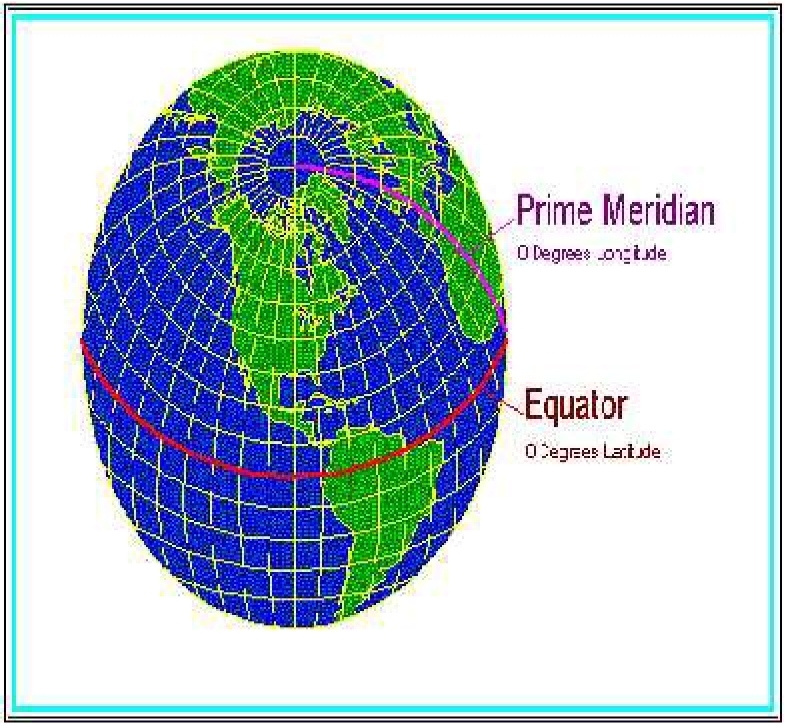
Sphere Concept



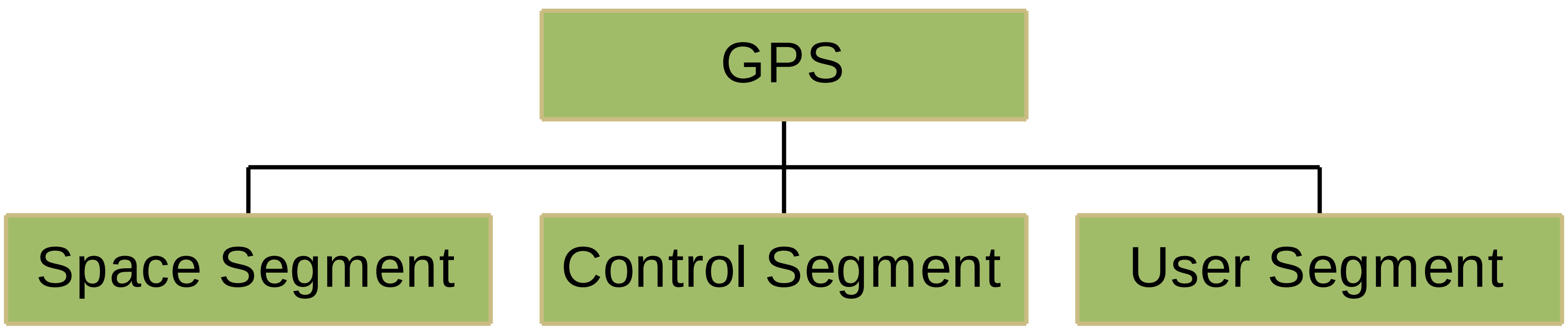
A fourth satellite narrows it from 2 possible points to 1 point

Latitude and Longitude

Latitude and Longitude are *spherical coordinates* on the surface of the earth. Latitude is measured North or South of the Equator. Longitude is measured East or West of Greenwich. GPS uses Latitudes and Longitudes to reference locations.

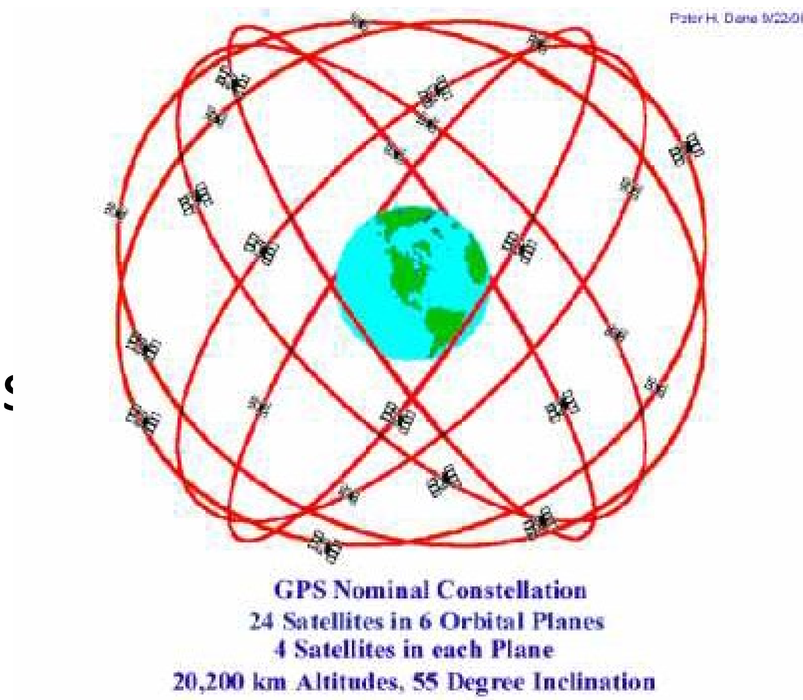


Components of the GPS



Space Segment:

- 24 GPS space vehicles(SVs).
- Satellites orbit the earth in 12 hrs.
- 6 orbital planes inclined at 55 degrees with the equator.
- This constellation provides 5 to 8 SVs from any point on the earth.



Control Segment:

Global Positioning System (GPS) Master Control and Monitor Station Network

- The control segment comprises of 5 stations.
- They measure the distances of the overhead satellites every 1.5 seconds and send the corrected data to Master control.
- Here the satellite orbit, clock performance and health of the satellite are determined and determines whether repositioning is required.
- This information is sent to the three uplink stations

Control Segment

The tasks of Control Segment is as follows:

- To monitor and control the satellite system continuously
- To predict the satellite ephemerides and the behaviour of satellite clocks.
- To update periodically the navigation message for each satellite

User Segment:

- It consists of receivers that decode the signals from the satellites.

- The receiver performs following tasks:
  - Selecting one or more satellites
  - Acquiring GPS signals
  - Measuring and tracking
  - Recovering navigation data

User segment (Contd.)

- Precision Oscillator
- Power Supply
- User Interface ,Command and Display Panel
- Memory data Storage

User Segment(Contd.)

Functions of Antenna :

- Detection of the electromagnetic waves arriving from the satellites
- Convert the wave energy into Electric Current
- Amplifies the signal strength
- Hands the Signals over to the Receiver Electronics

GPS service and civilian users

- Available of basic GPS service to civilian users with an accuracy of 100 meters.

- Removal of selective availability to improve the accuracy of a few meters

Satellite Transmission signals

- L1 Carrier signals 154x 10.23 M Hz =1575.42 MHz (Wave length 19.05 cm)

- L 2 Carrier signals 120x 10.23 M Hz =1227.60 MHz (Wave length 24.45cm)

Differential GPS

Differential GPS(DGPS) is a system in which differences between observed and computed co-ordinates ranges(known as differential corrections) at a particular known point are transmitted to users(GPS receivers at other points) to upgrade the accuracy of the users receivers position.

Types of Antenna

Monopole or Dipole

Quadrifilar Helix

Spiral Helix

Microstrip Antenna

Choke Ring

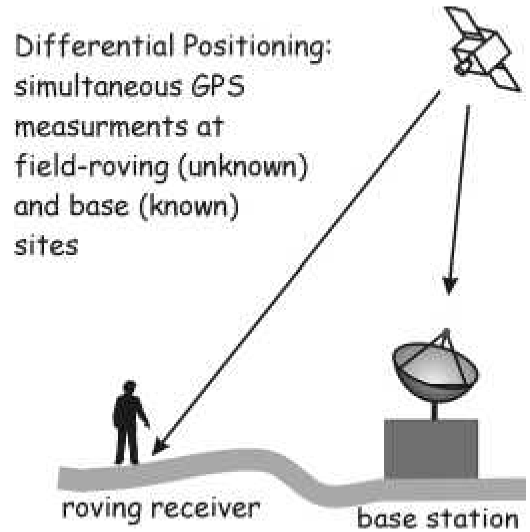
Differential GPS Positioning

Differential positioning user finds the point position derived from the satellite signals and applies correction to that position. These corrections, difference of the determined position and the known position are generated by a Reference Receiver ,whose position is known and is fed to the instrument and are used by the second Receiver to correct its

internally generated position. This is known as Differential GPS positioning.

Differential Correction

Differential correction is a technique that greatly increases the accuracy of the collected DGPS data. It involves using a receiver at a known location - the "base station“- and comparing that data with DGPS positions collected from unknown locations with "roving receivers."



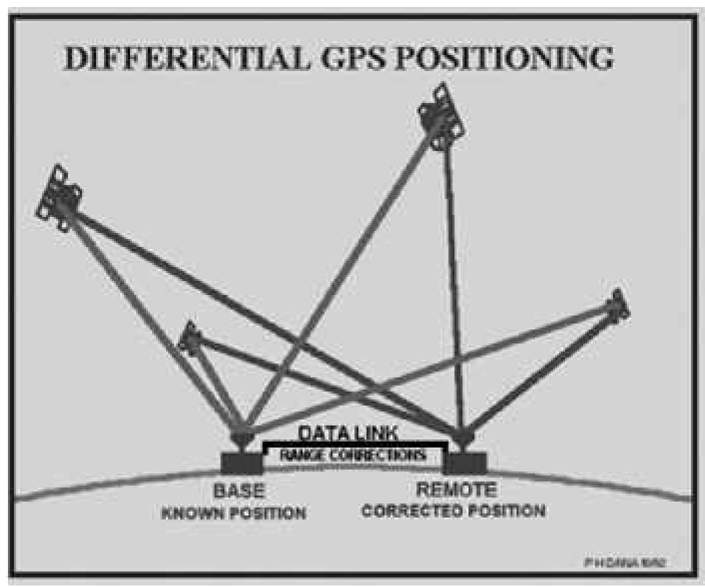
Geodetic/ High Precision Applications

- To use the carrier phase as observables
- To use both the frequencies(L_1,L_2)
- To have access to the P-code

(For long distances and geographical regions with strong ionospheric disturbances)

Differential GPS survey

Differential GPS Positioning



Limitation & Errors of GPS/DGPS

a) International Limitation of Accuracy
b) Receiver Independent Exchange Format
c) Reference System Co-ordinates

DUAL FREQUENCY DGPS RECEIVER

Dual-Frequency receivers receive signals from the satellites on two frequencies simultaneously. Receiving GPS signals on two frequencies simultaneously allows the receiver to determine very precise positions.

Classification Criteria

GPS receivers can be classified into different groups according different criteria. One such classification depending upon available data type (signal structure)yields receiver with :

- C/A code
- C/A code + L_1 Carrier Phase
- C/A code + L_1 Carrier Phase + L_2 Carrier Phase
- C/A code + P code +L_1 ,L_2 Carrier Phase

Broad Classification of GPS receiver

1. Code dependant Receiver
2. Code free receiver

Classification of GPS receivers as per use

- Military Receiver
- Civilian Receiver
- Navigation Receiver
- Timing Receiver
- Geodetic Receiver

Selection of DGPS observation Mode

- Static
- Rapid Static/PPK
- Real Time Kinematic (RTK)

DGPS survey

Establishment of Ground Control Points :

- Primary Control Points (PCPs)
- Secondary Control Points (SCPs)

ALMANAC DATA

The Almanac data tell the GPS receiver where each GPS satellite should be at any time through out the day. Each satellite transmits the almanac data showing the orbital information for that satellite and every other satellite in that system.

Ephemeris

A GPS ephemeris is the predictions of current satellite positions. Accurate GPS planning is only accomplished when a current ephemeris is used for the GPS planning.For precise navigation information,ephemeris data is used by GPSs.Every navigation satellite broadcasts have its own ephemeris data only.

Sources of GPS signal errors

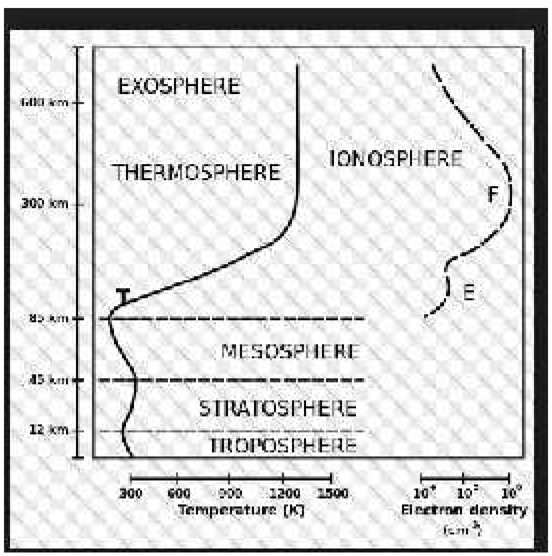
Factors that can affect the GPS signal and thus affect accuracy includes as follows :

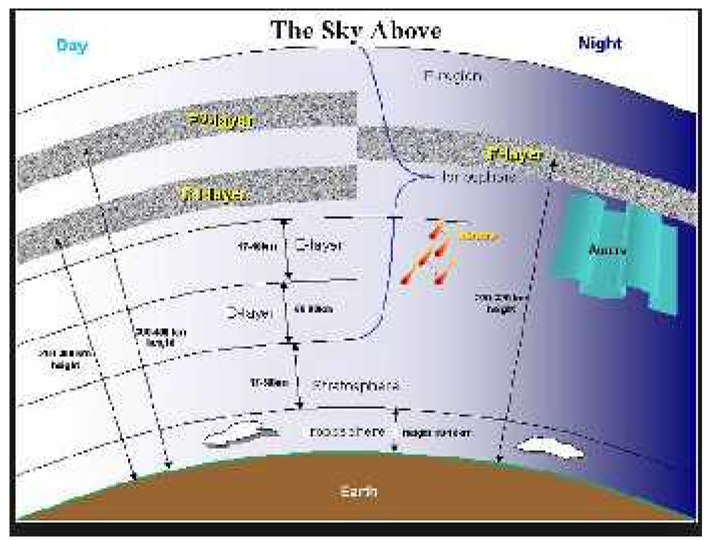
1. Ionospheric and Troposphere Delays
2. Signal Multipath
3. Receiver clock Errors
4. Orbital errors/ Ephemeris errors
5. Satellite Geometry / Shading

Sources of GPS signal errors

Ionospheric and Troposphere delays :

The satellite signal slows as it passes through the atmosphere. The GPS system uses a ‘built in model’ that calculates an average amount of delay to partially correct for this type of error.

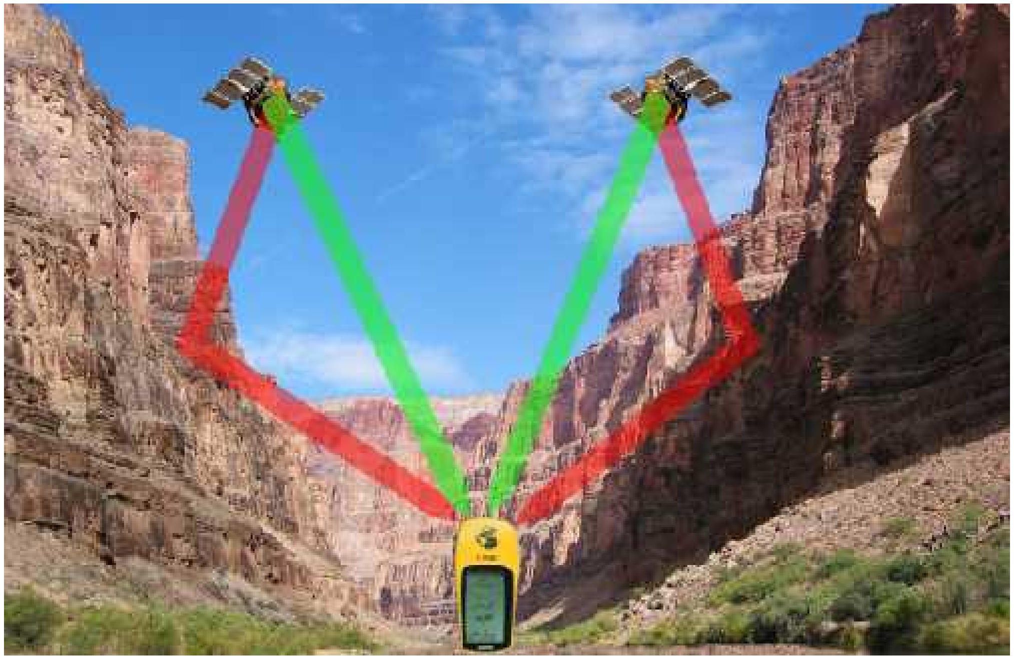




Sources of GPS signal errors

Signal Multipath

This occurs when the GPS signal is reflected off objects such as tall buildings ,large rock surfaces etc. before it reaches the receiver. This increases the travel time of the signal thereby causing errors.



Sources of GPS Signal errors

Receiver Clock Errors

A receiver's built –in clock is not as accurate as the atomic clocks on board the GPS satellites. Therefore, it may have very slight timing errors.

Sources of GPS Signals

Orbital Errors

Also known as ephemeris errors.These are inaccuracies of the satellite reported location.

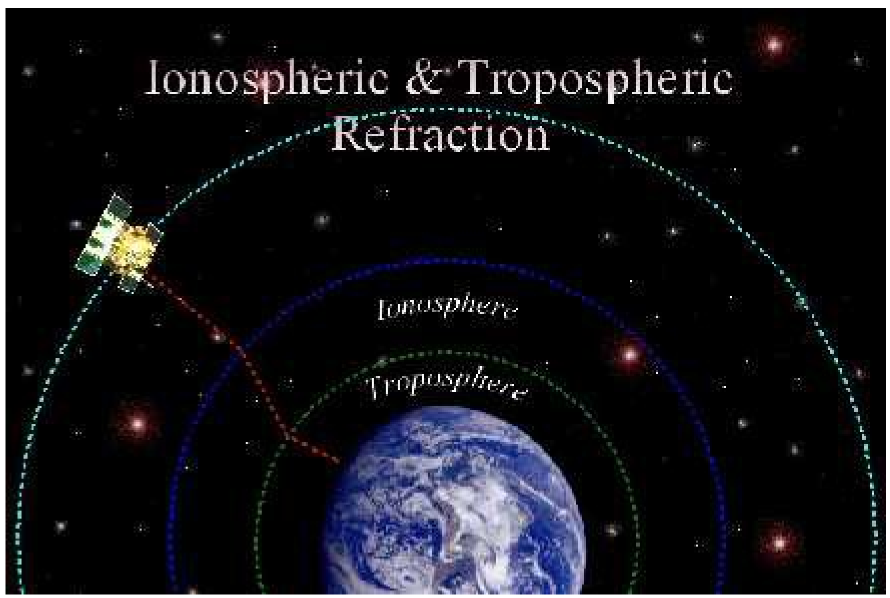
Light Refraction

Sometimes the GPS signal from the satellite doesn’t follow a straight line.

Refraction is the bending of light as it travels through one media to another.

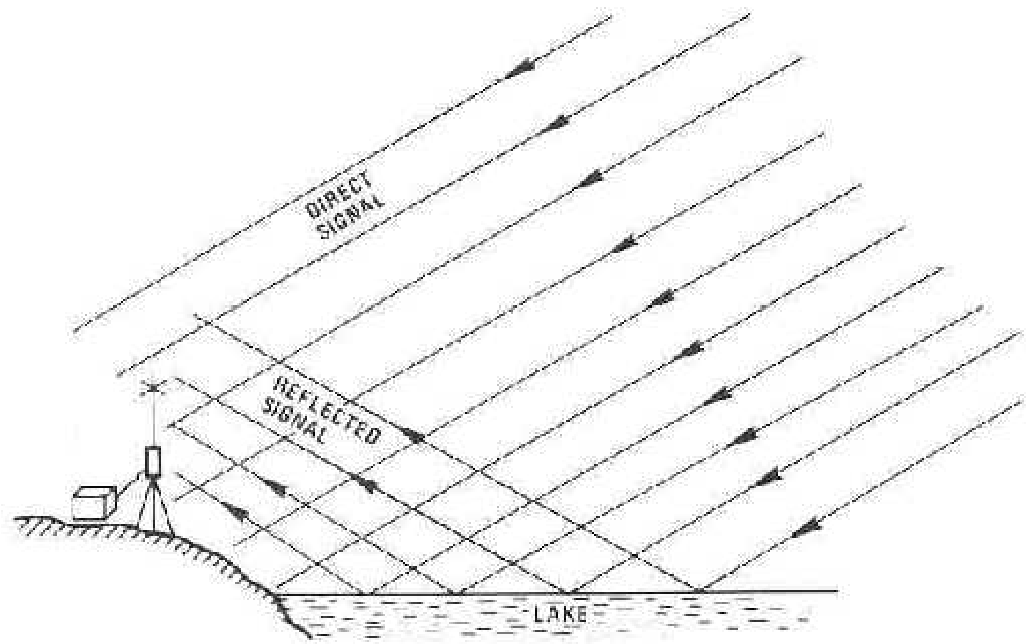
Signal Refraction

Signals from satellites can be like light. When they hit some interference (air patterns in the atmosphere, uneven geography, etc.) they sometimes bend a little.



Signal Interference

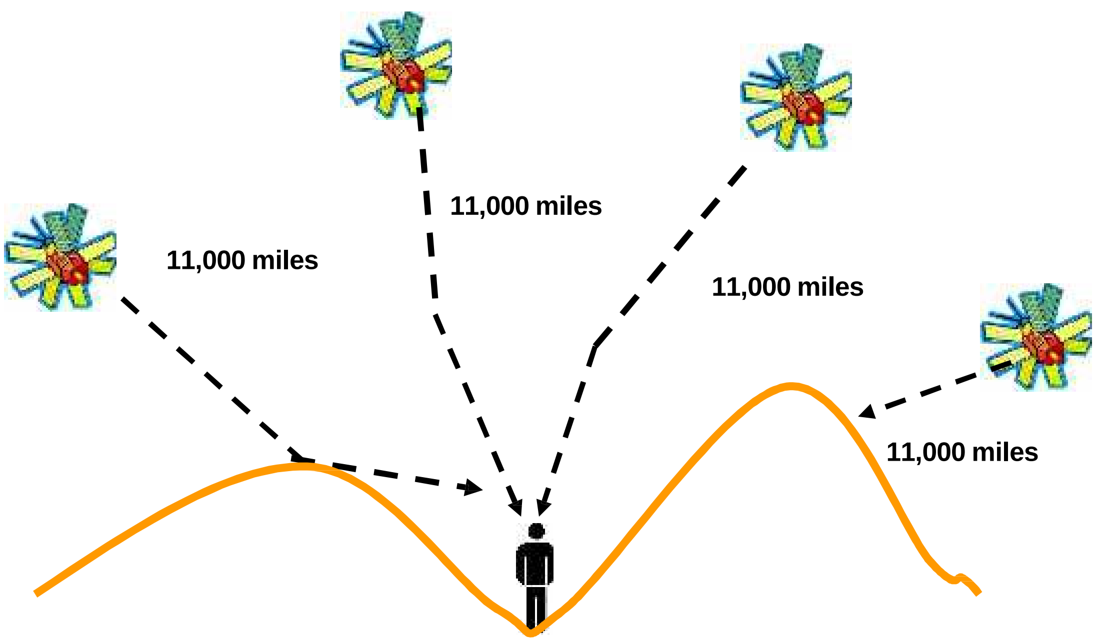
Sometimes the signals bounce off things before th the receivers.



PDOP

PDOP = Positional Dilution of Precision

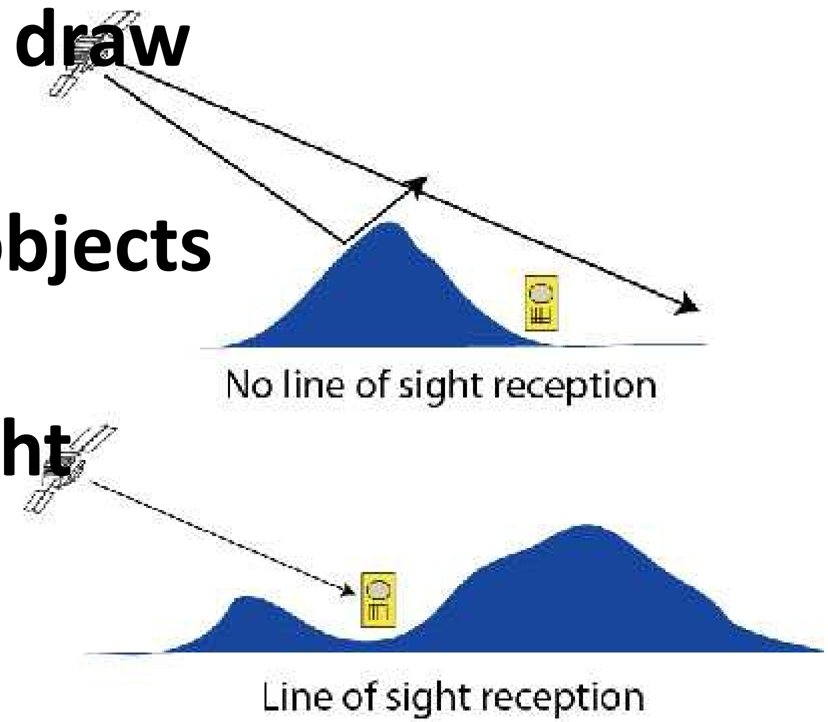
All of this combines to make the signal less accurate, and gives it what we call a high "PDOP."



- ***A PDOP of <4 is excellent***
- ***A PDOP of 4-8 is good***
- ***A PDOP of >8 is poor***

Line of Sight Transmissions

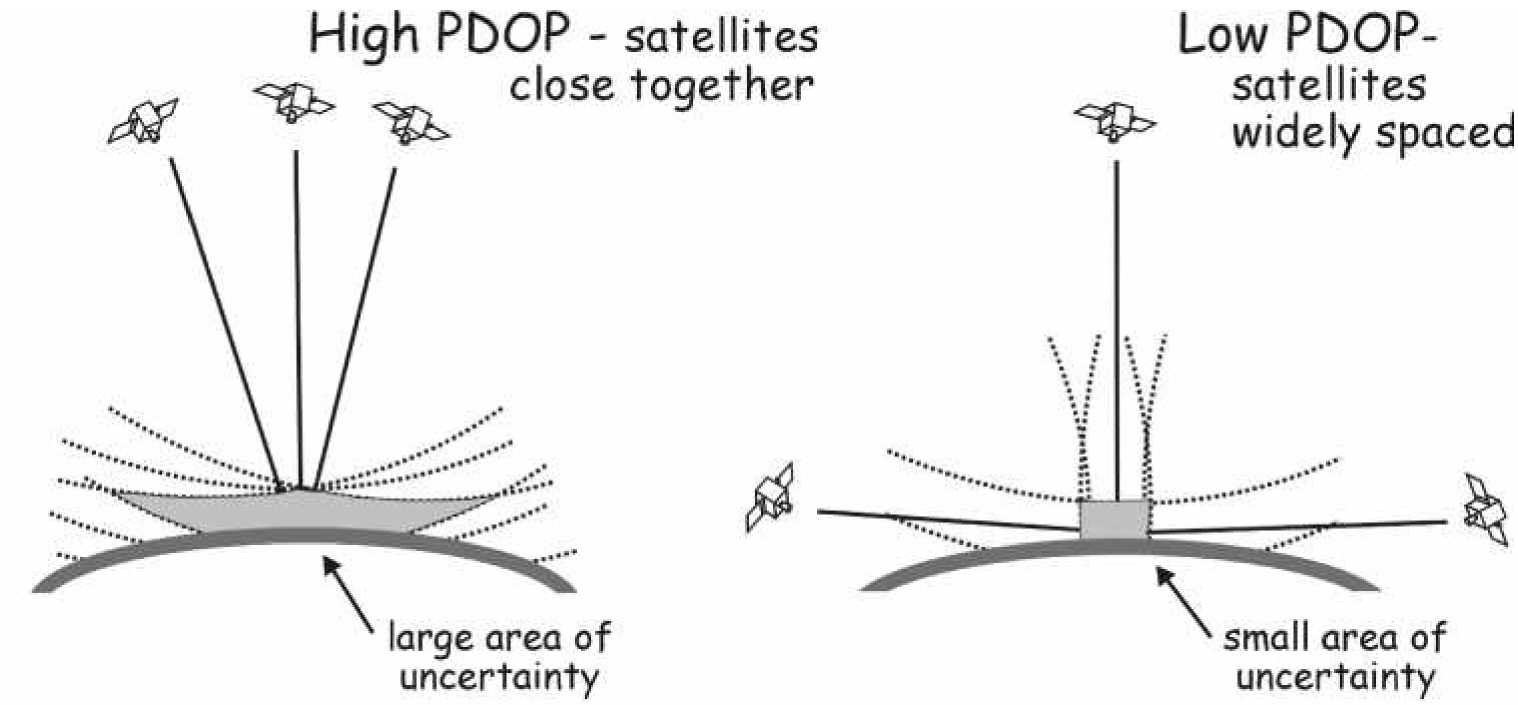
Line of sight is the ability to draw a straight line between two objects without any other objects getting in the way. GPS transmission are line-of- sight transmissions.



Obstructions such as trees, buildings, or natural formations may prevent clear line of sight.

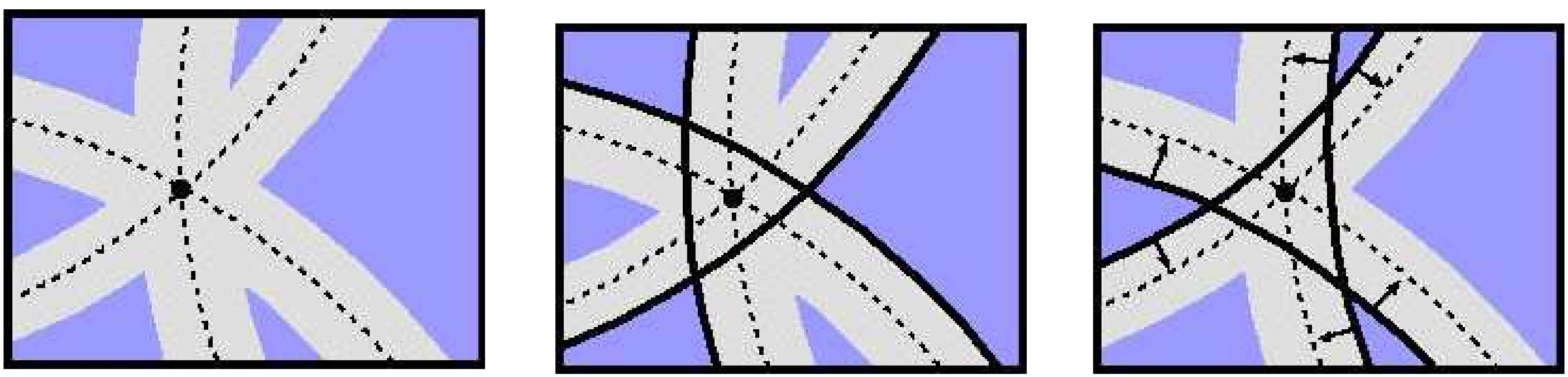
Satellite Distribution

When the satellites are all in the same part of the sky, readings will be less accurate.



Atomic Clocks

GPS satellites use Atomic Clocks for accuracy, but because of the expense, most GPS receivers do not.



Networks

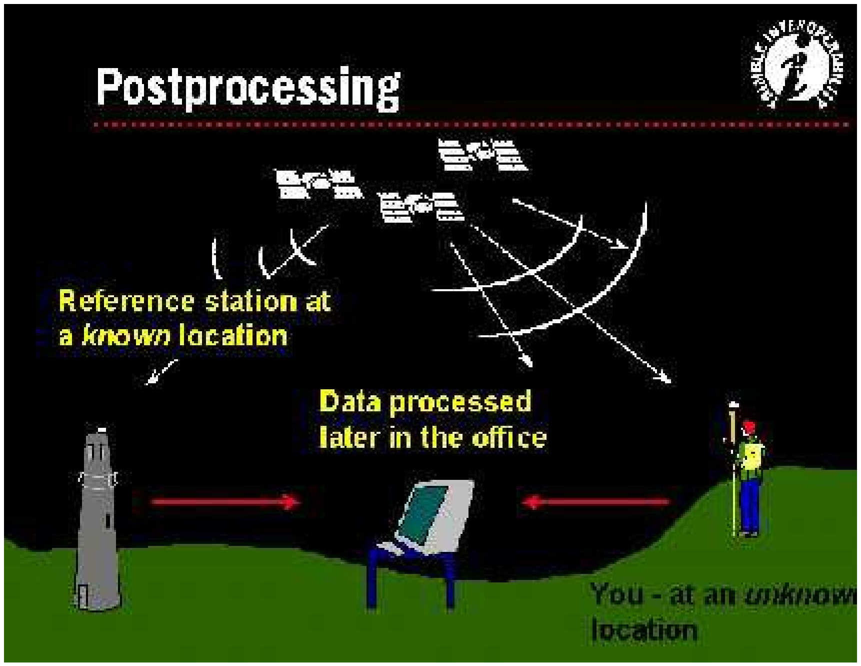
Networks shall only contain closed loops. Each station in a network shall be connected with at least two different independent baselines. Avoid connecting stations to a network by multiple baselines to only one other network station. First-order and second-order GPS control networks shall consist of a series of interconnecting closed-loops & geometric figures.

GPS Survey Specifications (Loop closure & Networking)

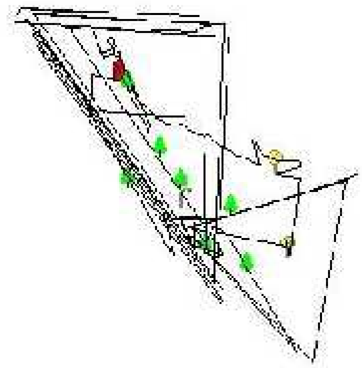
Loop

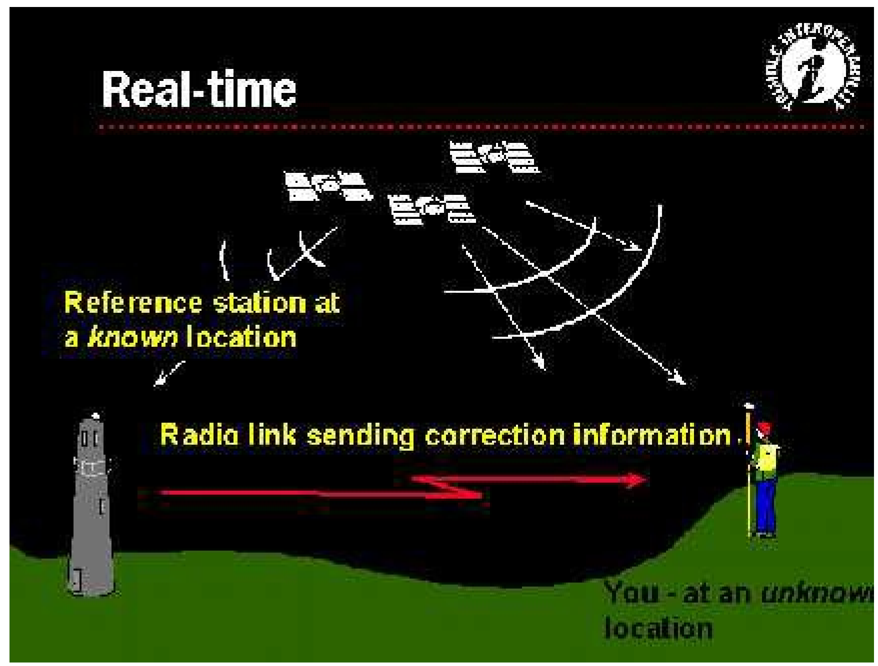
- A loop is defined as a series of at least three independent, connecting baselines, which start and end at the same station. Each loop shall have at least one baseline in common with another loop.

Postprocessing / Real-time

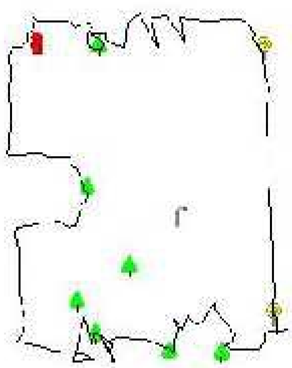


Before

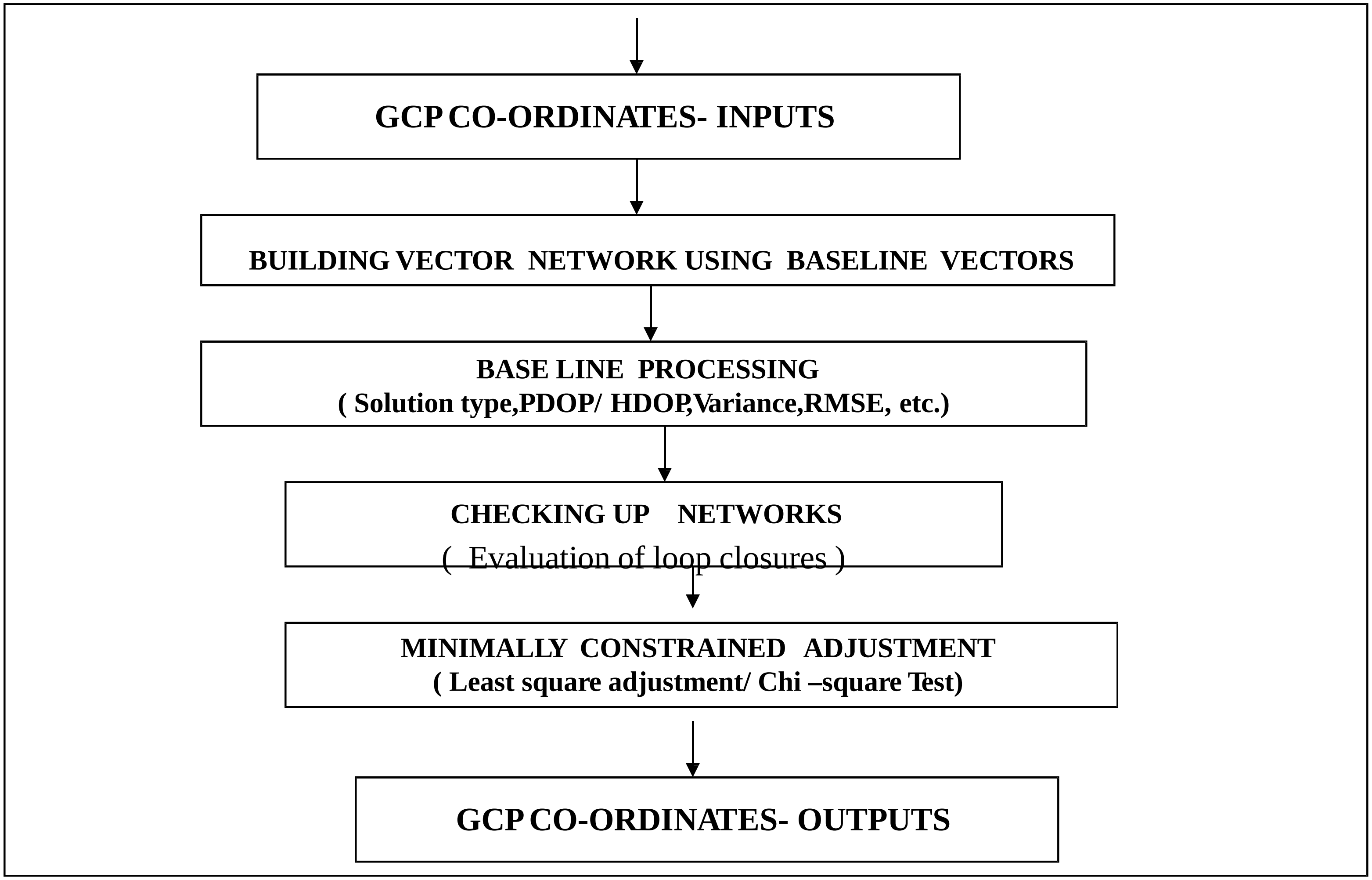




After



NETWORK ADJUSTMENT



A minimally constrained or free adjustment acts as one quality control check on the network.
This adjustment helps to identify bad observations in the network.
If an observation does not fit with the rest of the observations
, it is highlighted as an outlier.

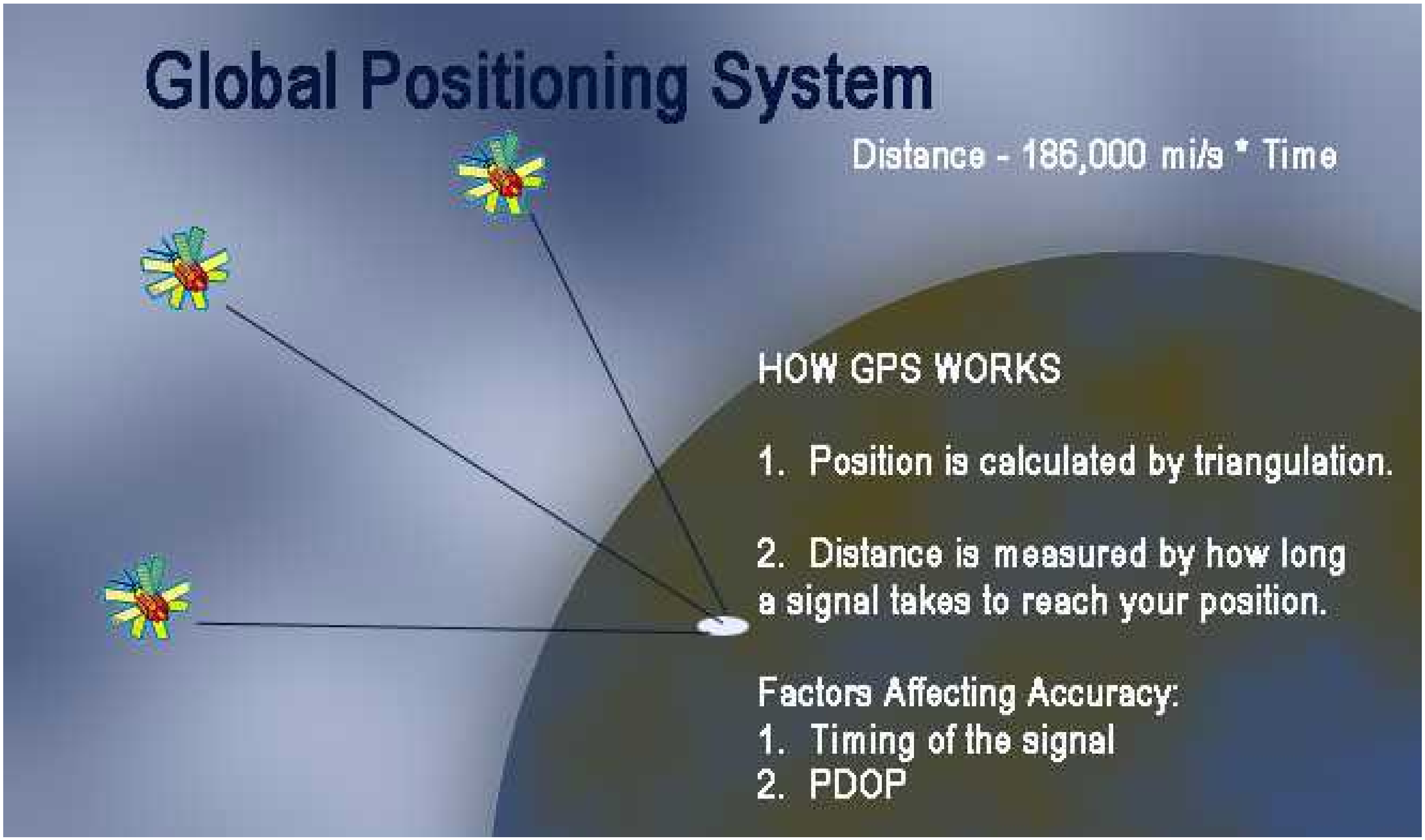
The minimally constrained or free adjustment also checks
on how well the observations hold together as a cohesive unit.

All minimally constrained adjustments must be performed in the WGS-84 datum.

Since all GPS observations are made
on the WGS-84 datum, the adjustment of the observations should be
tied closely to the WGS-84 datum.

Realistic error estimates for tribrach centering and H.I. measurement should
also be factored into the minimally constrained adjustment

In a Nutshell



DGPS / ETS survey

- DGPS Survey
- ETS survey

In Obscure /Crown cover Transmission line, Microwave tower areas etc , the Geo-co-ordinates for the point (s) has to be determined through Integrated ETS

Electronic Total Station (ETS)

- **The total station** is an electronic/optical instrument used in modern surveying.

The total station is an electronic theodolite integrated with an electronic distance meter (EDM) to read slope distances from the instrument to a particular point

Distance Measuring (Electronic Distance Meters)

- *In the early 1950's the first Electronic Distance Measuring (EDM) equipment were developed.*
- *Primarily consisted of electro-optical (light waves) and electromagnetic (microwave) instruments.*
- *Bulky, heavy and expensive.*
- *The typical EDM today uses the electro-optical principle. They are small, reasonably light weight, highly accurate, but still expensive.*

Electronic Total station & Prism

Thank You