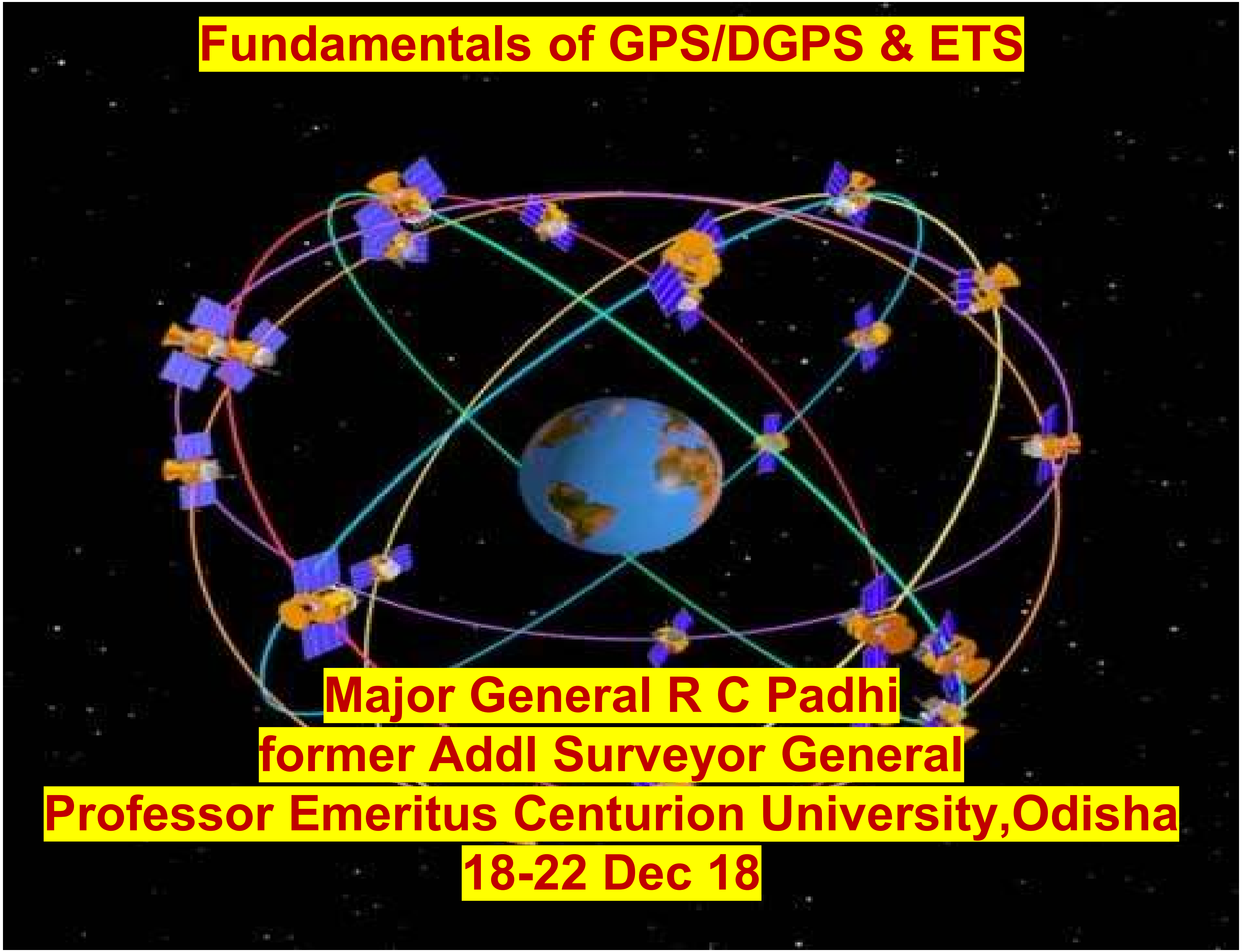
Fundamentals of GPS/DGPS & ETS



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INTRODUCTION:

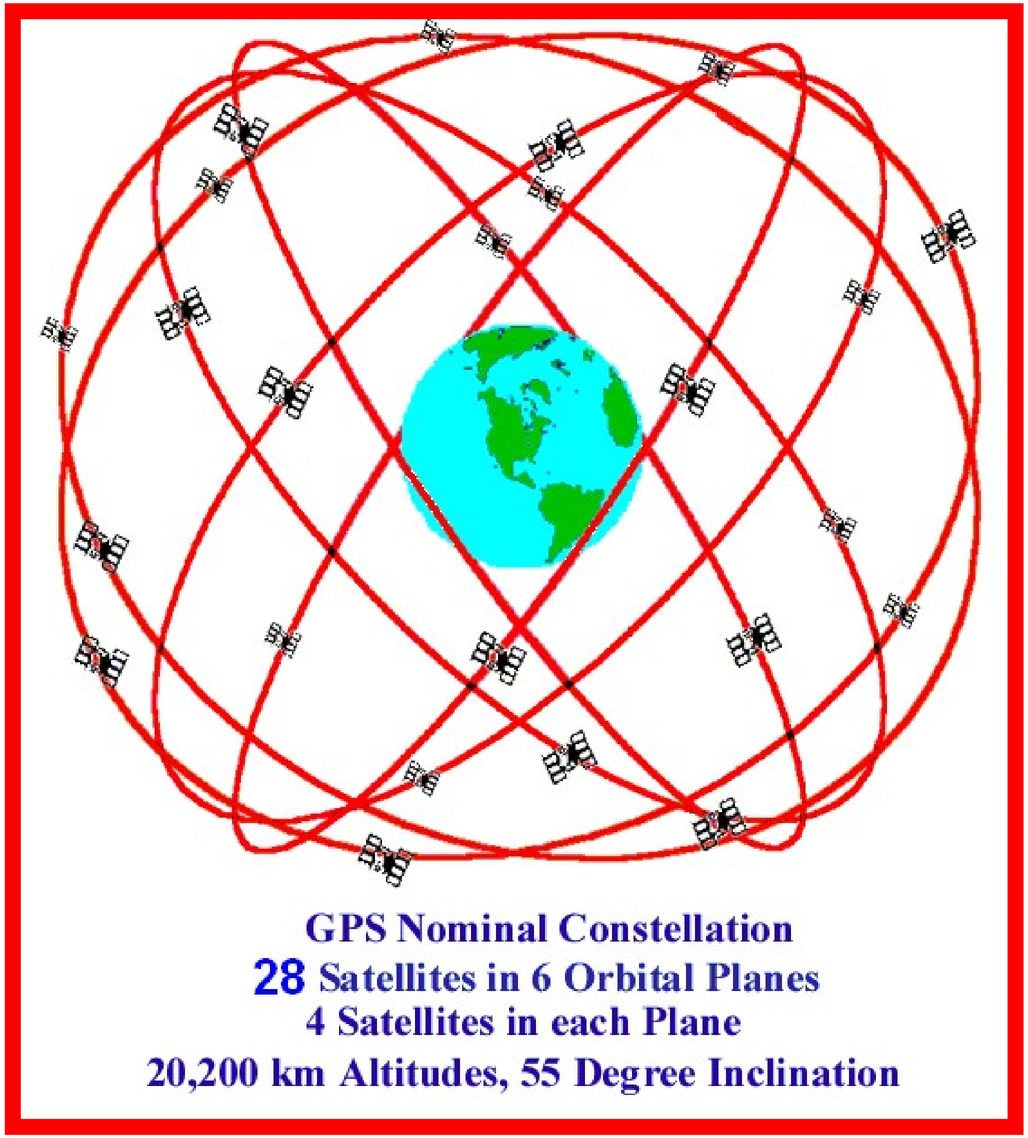
NAVSTARGPS (NAVigation System with Time And Ranging Global Positioning System)

- **Satellite based Positioning and Time transfer System**
- **Designed, financed, deployed and operated by US DoD**
- **Development work of GPS commenced within the DoD in 1973**
- **The objective was to design and deploy an all weather, 24 hour, global, satellite based navigation system to support the positioning requirement of US armed forces and its allies.**

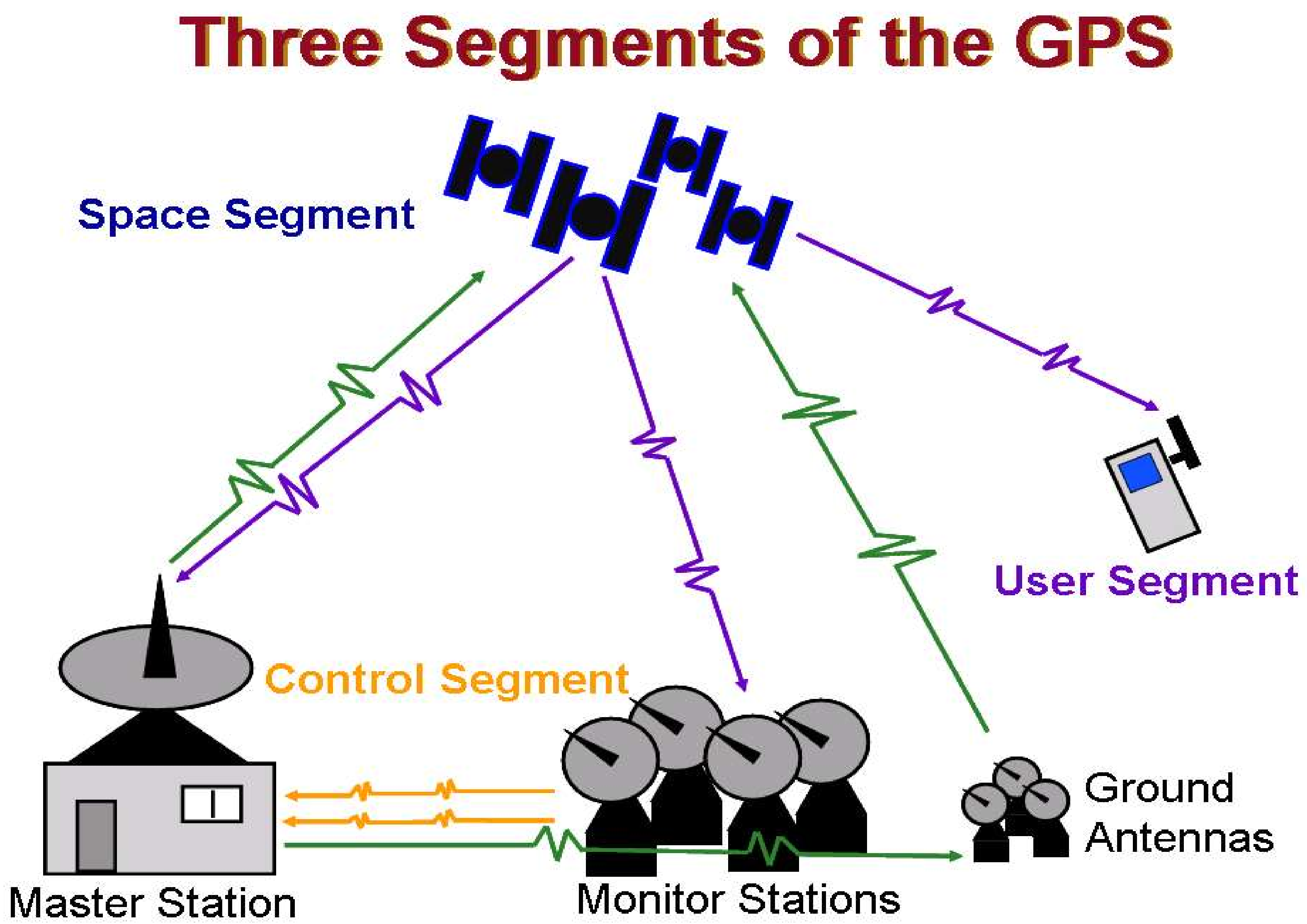
Advantages of GPS :

- Relatively high positioning accuracy, from meters down to millimeter level
- Capability of determining three dimensional position, velocity and time accurately
- No inter-station visibility is required for high precision positioning
- Results are obtained with reference to a single, global datum (WGS – 84)
- Signals are available to users anywhere on earth; in the air, on the ground or in the 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-dimension.

ORBITAL ARRANGEMENT OF GPS SATELLITES:



COMPONENTS OF GPS: (Continued)



Space Segment:

- The Space Segment consists of constellation of space craft and the signals that are broadcast by them
- The Signals allow user to determine position, velocity and time.
- The basic functions of the satellite are to:
- Receive and store data uploaded by control segment
- Maintain accurate time by means of onboard atomic clocks
- Transmit information and signal to user on two L-band frequency.

Space Segment: (Contd.)

- **Each GPS satellite transmits signals on two L-band frequencies of electromagnetic spectrum.**
- **L1 at 1575.42 MHz and L2 at 1227.60 MHz**
- **The satellite signal consists of the following components:**
  - **Two L-band carrier waves**
  - **Ranging code modulated on the carrier waves**
  - **Navigation message**

Control Segment:

The control segment consists of facilities necessary for

- **satellite health monitoring**
- **telemetry tracking**
- **command and control**
- **satellite orbit and clock error computations**

Control Segment: (Contd.)

There are five ground facilities stations:

- **Hawaii**
- **Colorado Springs**
- **Ascension Island**
- **Diego Garcia**
- **Kwajalein**

All are operated by US Department of Defense

Functions of Monitor Stations:

- **All the five monitor stations, equipped with GPS receiver to track the satellites.**
- **The resultant tracking data is sent to Master Control Station (MCS)**
- **Colorado Spring is the MCS, where tracking data are processed in order to compute the satellite ephemeredes (or coordinate) and satellite clock error parameters.**
- **The station initiates all operations of Space Segment, such as**
  - **space craft maneuvering**
  - **signal encryption**
  - **satellite clock-keeping etc.**
- **Three of the stations (Ascension Island, Diego Garcia and Kwajalein) are upload stations through which data is telemetered to the satellite.**

What's the Differential?

Until 2000, civilian users had to contend with Selective Availability (SA). The DoD intentionally introduced random timing errors in satellite signals to limit the effectiveness of GPS and its potential misuse by adversaries of the United States. These timing errors could affect the accuracy of readings by as much as 100 meters.

- With SA removed, a single GPS receiver from any manufacturer can achieve accuracies of approximately 10 meters. To achieve the accuracies needed for quality GIS records from one to two meters up to a few centimeters requires differential correction of the data. The majority of data collected using GPS for GIS is differentially corrected to improve accuracy.

- Differential GPS (DGPS) is a relatively simple technique to improve positional accuracy and integrity. This technique was developed in the early 1980s, and it is widely used in various forms.

DGPS is a method of improving the accuracy of your receiver by adding a local reference station to augment the information available from the satellites. It also improves the integrity of the whole GPS system by identifying certain errors.

- Differential GPS uses one unit at a known location and a rover.
  - The stationary unit compares its calculated GPS location with the actual location and computes the error.
  - The rover data is adjusted for the error.

- The underlying premise of differential GPS (DGPS) is that any two receivers that are relatively close together will experience similar atmospheric errors.

- DGPS requires that a GPS receiver be set up on a precisely known location. This GPS receiver is the base or reference station.

- The base station receiver calculates its position based on satellite signals and compares this location to the known location.

- Differential correction techniques are used to enhance the quality of location data gathered using global positioning system (GPS) receivers.

- Differential correction can be applied in real-time directly in the field or when post-processing data in the office. Although both methods are based on the same underlying principles, each accesses different data sources and achieves different levels of accuracy. Combining both methods provides flexibility during data collection and improves data integrity.

Real-Time DGPS

- Real-time DGPS occurs when the base station calculates and broadcasts corrections for each satellite as it receives the data. The correction is received by the roving receiver via a radio signal
- As a result, the position displayed and logged to the data file of the roving GPS receiver is a differentially corrected position.

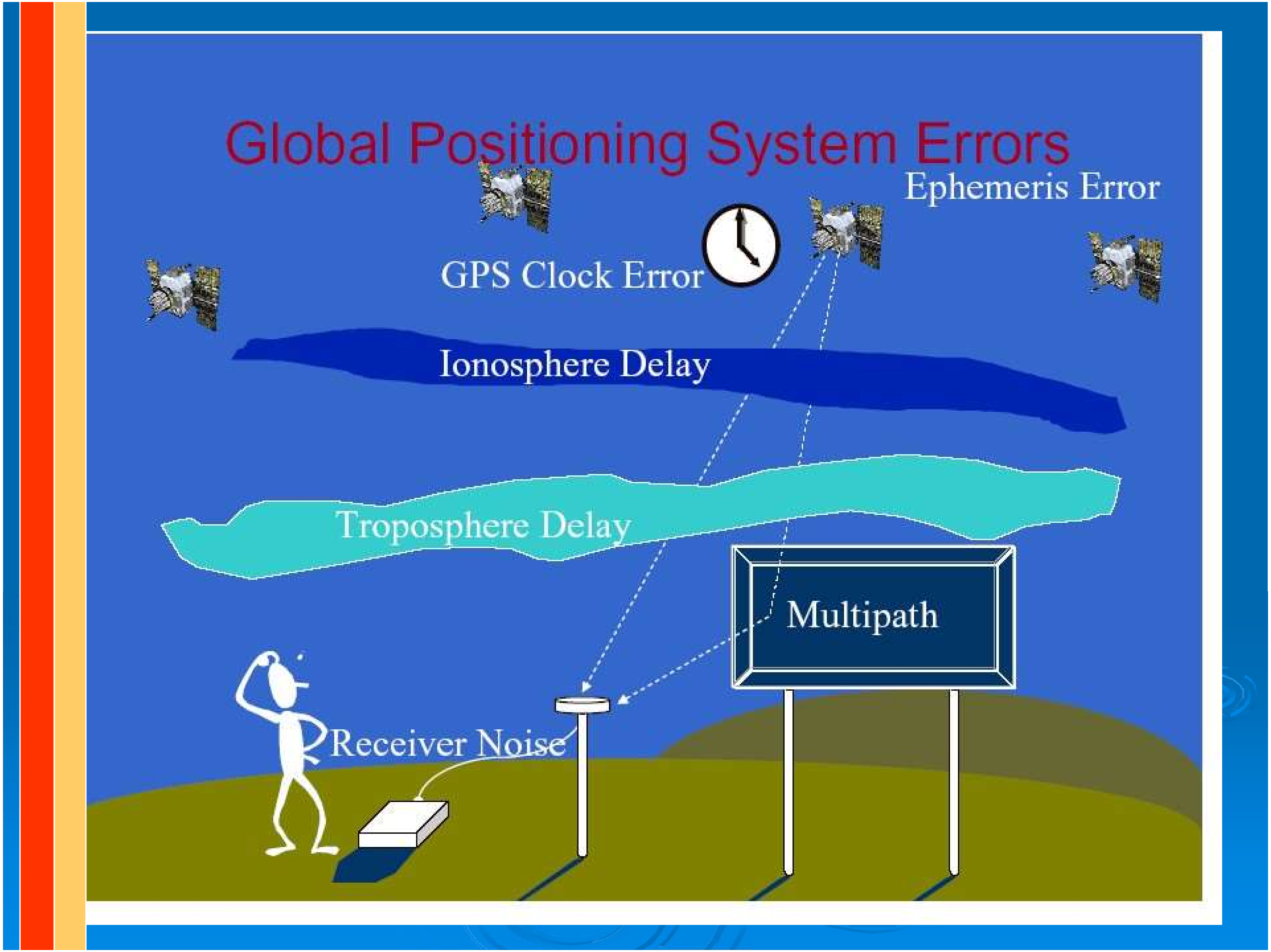
Satellite Differential Services

- Another method for obtaining real-time differential correction data in the field is by using geostationary satellites. This system obtains corrections from more than one reference station, sends the information to a geostationary satellite for verification. The verified information is sent to the roving GPS receiver to ensure it obtains GPS positions in real time.

Errors in GPS

Errors in GPS

- The receiver is not synchronized with the atomic clock in the satellite
- The estimate of the position of the satellite
- Speed of light is only constant in vacuum
- ”Multi path errors” : Ghost signals from reflected radio waves
- ”Selective availability (SA)” :Added noise from department of defense
- No free sight to enough satellites
- Noise in the receiver


Global Positioning System Errors
Ephemeris Error
GPS Clock Error
Ionosphere Delay
Troposphere Delay
Multipath
Receiver Noise

BUDGETING OF GPS ERRORS

Error	Value
Ionosphere	4.0 meters
Clock	2.1 meters
Ephemeris	2.1 meters
Troposphere	0.7 meters
Receiver	0.5 meters
Multipath	1.0 meter
Total	**10.4 meters**

Errors compansated by DGPS

- Eliminates/ reduces clock errors, path errors, ephemeris errors and ionospheric effects

- Reason: The errors are almost the same for two receivers close to each other
    - Place a fixed receiver on a well defined location.
    - Compute the error in the position
    - Estimate from the satellites
    - Calculate backwards to find the time error
    - Broadcast it by radio to other receiver

Noise Error

- Noise errors are the combined effect of code noise (around 1 meter) and noise within the receiver (around 1 meter).

BIAS ERROR

- Selective Availability (SA)
  - SA is the intentional degradation of the SPS signals by a time varying bias. SA is controlled by the DOD to limit accuracy for non-U. S. military and government users.
  - Selective availability is turned off.
- Ephemeris data errors: 1 meter
  - Satellite orbits are constantly changing. Any error in satellite position will result in an error for the receiver position.

- SV clock errors not corrected by Control Segment can result in one meter error.
- Tropospheric delays: 1 meter.
  - The troposphere is the lower part (ground level to from 8 to 13 km) of the atmosphere that experiences the changes in temperature, pressure, and humidity associated with weather changes.
  - Complex models of tropospheric delay require estimates or measurements of these parameters.

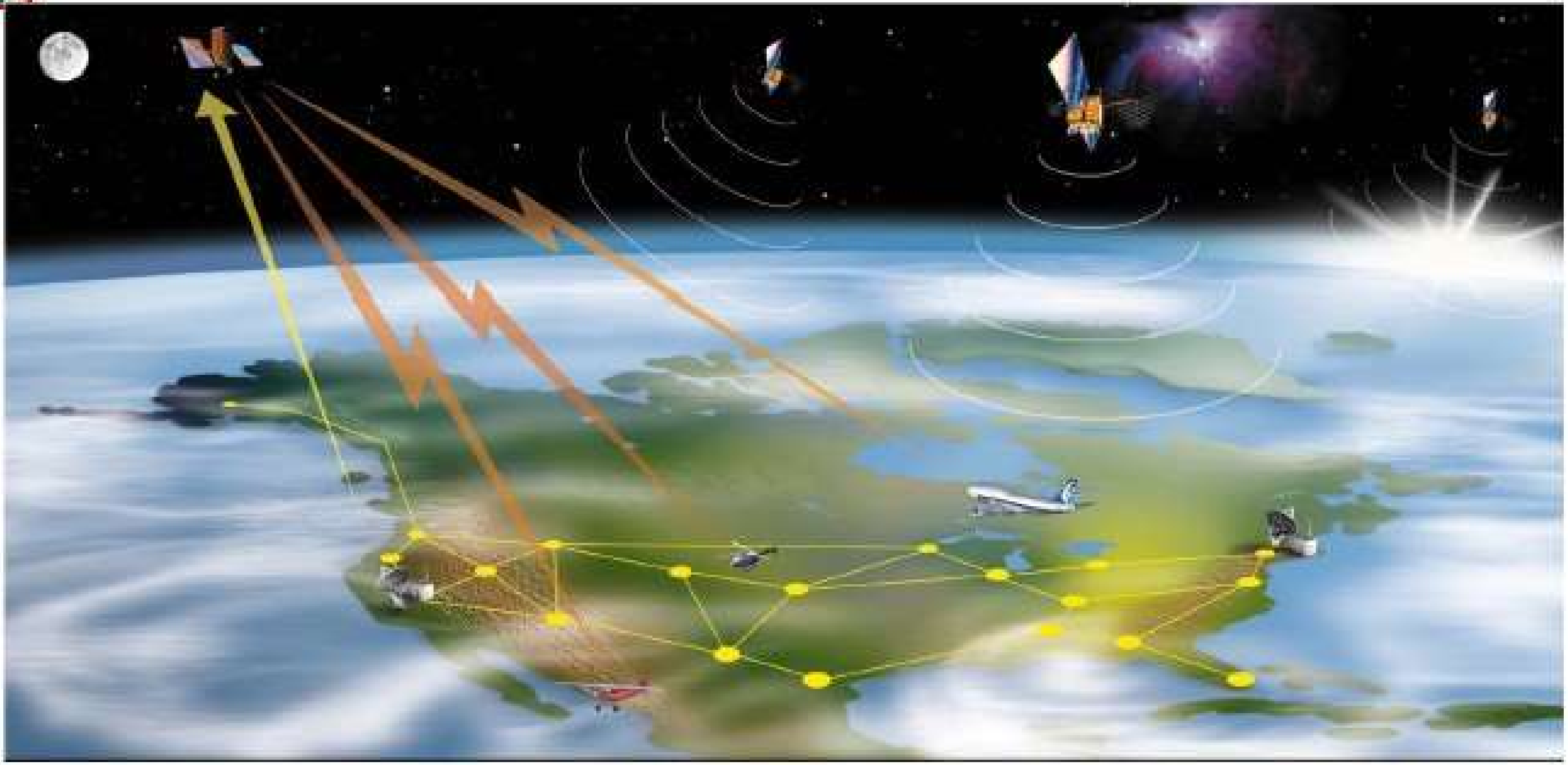
Bias Error--cont.

- Unmodeled ionosphere delays: 10 meters.
  - –The ionosphere is the layer of the atmosphere from 50 to 500 km that consists of ionized air. The transmitted model can only remove about half of the possible 70 ns of delay leaving a ten meter un-modeled residual.
- Multipath: 0.5 meters.
  - –Multipath is caused by reflected signals from surfaces near the receiver that can either interfere with or be mistaken for the signal that follows the straight line path from the satellite.

Blunder

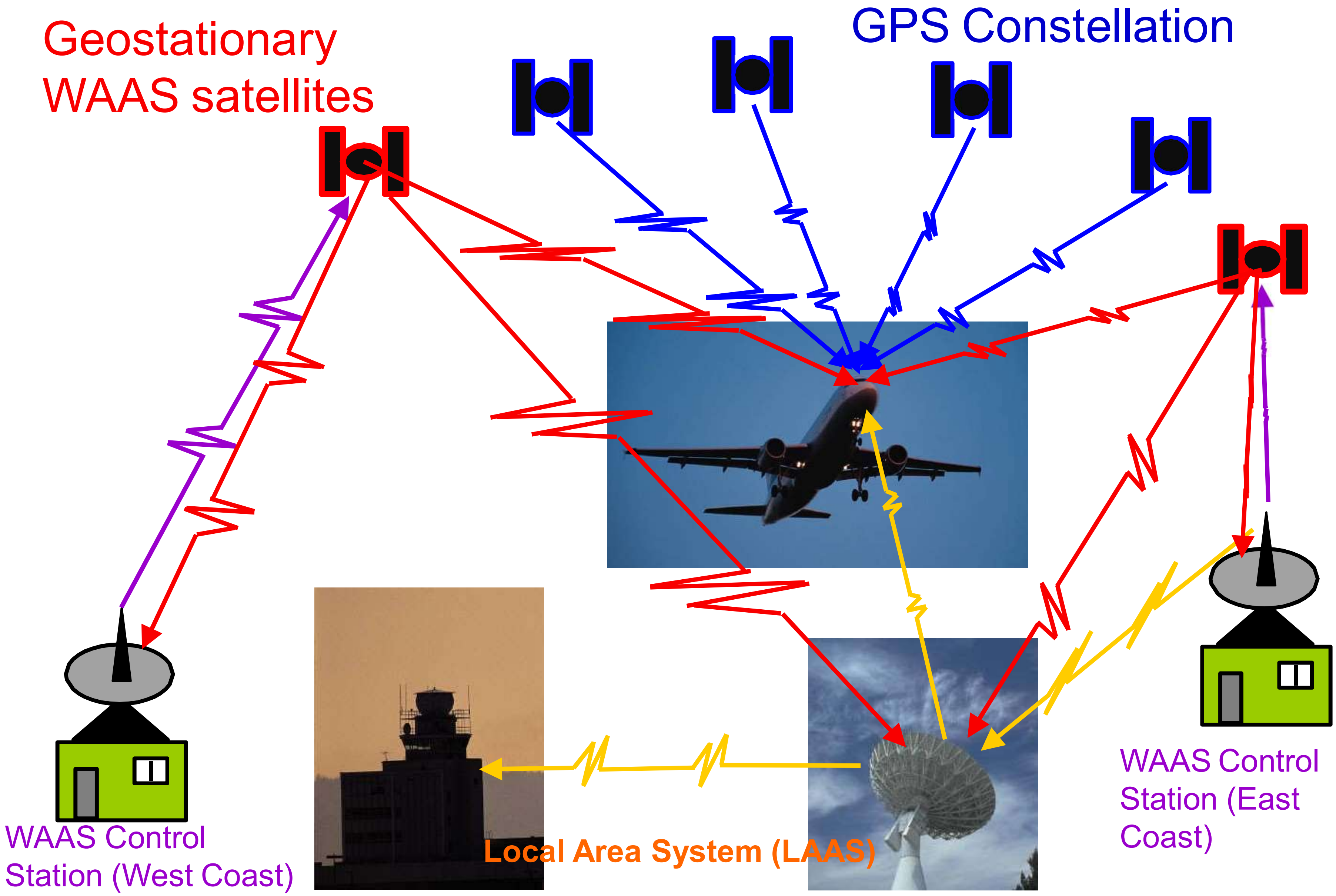
- Blunders can result in errors of hundred of kilometers.
  - Control segment mistakes due to computer or human error can cause errors from one meter to hundreds of kilometers.
- User mistakes, including incorrect geodetic datum selection, can cause errors from 1 to hundreds of meters.
- Receiver errors from software or hardware failures can cause blunder errors of any size.

Wide Area Augmentation System (WAAS)



- Wide Area Augmentation System – Augmentation to GPS that provides the ability to conduct precision approaches using GPS

Wide Area Augmentation System



Calculating a Position

- Measure distance to satellites.
- Obtain satellite positions.
- Perform triangulation calculations. (Trilateration)
- Adjust local clock bias.

Measuring Distance

Distance

- Distance = Velocity * Time
- Velocity is that of a radio wave.
- Time is the travel time of the signal.
- Measure the travel time.
- Receiver generates the same codes as the satellite (PRN codes).
- Measure delay between incoming codes and self generated codes.
- D = Speed of light * measured delay.

Obtain Satellite positions.

- Orbital data (Ephemeris) is embedded in the satellite data message.
- Ephemeris data contains parameters that describe the elliptical path of the satellite.
- Receiver uses this data to calculate the position of the satellite. (X,Y,Z)

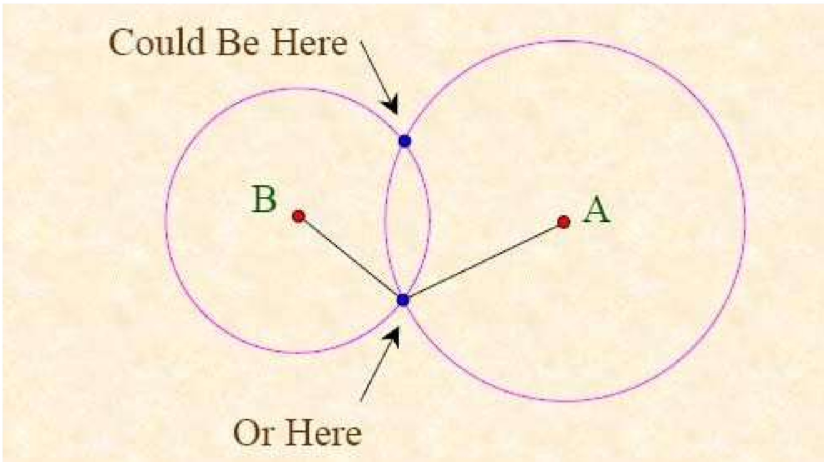
Perform triangulation calculations.

Triangulation in 2D

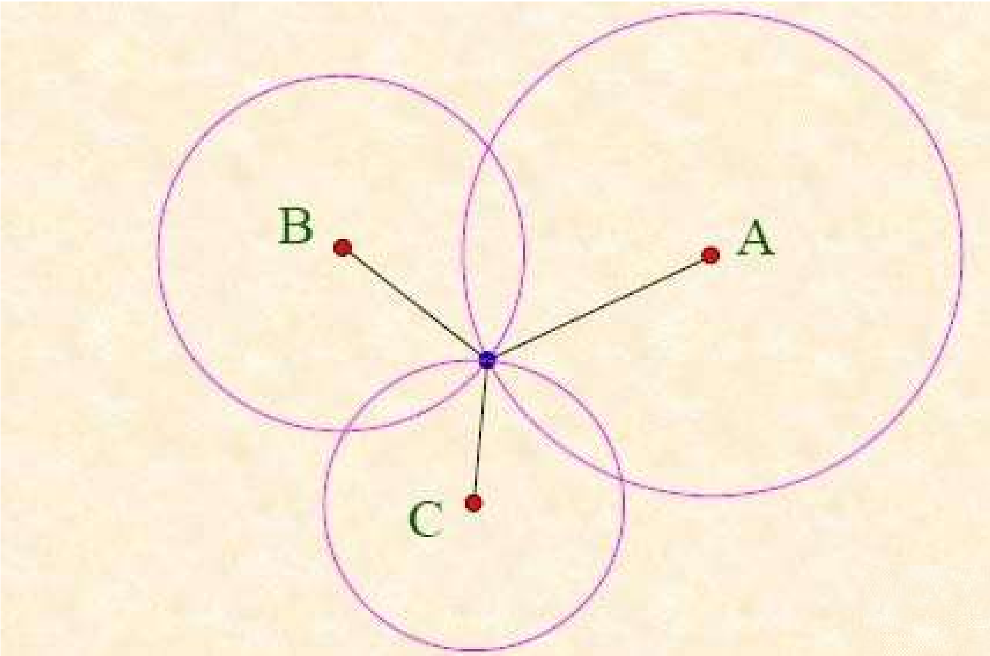
- If location of point A is known, and the distance to point A is known, desired position lies somewhere on a circle.
- Could be anywhere along circle A

Triangulation in 2D

- Distance to two points are known.
- Desired position is in one of two locations.



- Distance to three points are known.
- Position is known!



• Calculating a Position Review

- Measure distance to satellites.
    - Use pseudo ranges
    - Obtain satellite positions.
    - Decoded ephemeris from satellite message.
- Perform triangulation calculations.
    - Need at least 3 satellites for triangulation.
    - Adjust local clock bias to find position.
    - Need 4th satellite to adjust bias.

DATA DISPLAY IN GPS

Once the GPS receiver has located its position it is usually displayed in one of two common formats:

- Latitude and longitude
- Universal transverse mercator (UTM).

The main components of GPS receivers are:

- Antenna with pre-amplifier
- Sensor to sense the data
- Memory and display panel
- Keyboard
- Precision oscillator (clock)-quartz
- Power supply – Ni-Cd - 12v battery
- Computer with supporting software for data download and processing.

Antenna detects the electromagnetic waves arriving form satellite, converts the wave energy into electric current, amplify the signal strength and hands the signal over to receive electronics.

Several antennas are available

- ❑ **Monopole or dipole**
- ❑**Helix**
- ❑**Spiral helix**
- ❑**Microstrip**
- ❑**Choke ring**

GPS

Different Hardware available

- Trimble dual frequency 5000 series
- Ashtech single frequency
- Leica (Garmin)
- Links point

GPS

Software available for downloading and processing the data

- ESRI Arc Pad
- Links Point
- GPS Pathfinder
- Thales Navigation
- Trimble Data Transfer
- Trimble Geomatics Office

Various sizes

- Delivers position for a moving receiver:
  Latitude, Longitude, Altitude
- Speed and direction of movement can be estimated

Garmin eTrex

- Vista
- Legend
- Venture

- 5^{th} generation
- WAAS capable

Getting to Know Your Unit

Tasks for the Field Exercise

- Determine position
- Convert the position between UTM, dd.dddd° and dd° mm′ ss″
- Create Waypoints
- Enable Tracking
- Find established waypoints (scavenger hunt)

THANK YOU