Coordinate and Reference Systems

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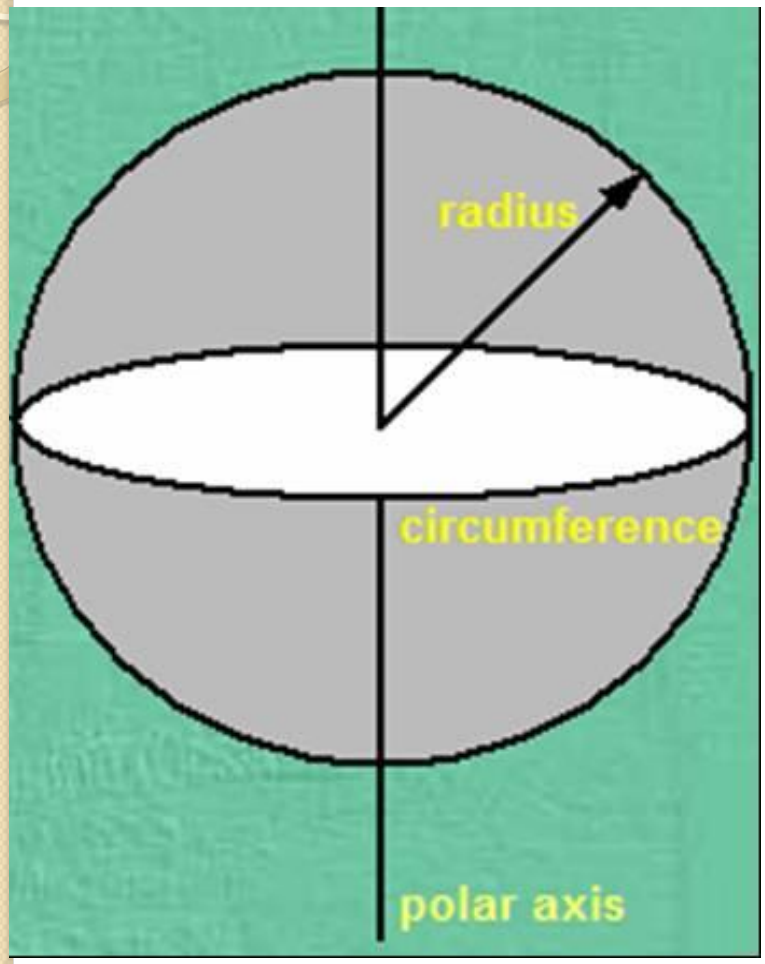
Spatial referencing Systems

- Geodesy
  - Geodesy means dividing the earth.
  - It is the science concerned with the study of the shape and size of the earth in a geometric sense.
  - Through the years 3 shape of the earth have been considered.
    - The Sphere
    - The Ellipsoid
    - The Geoid

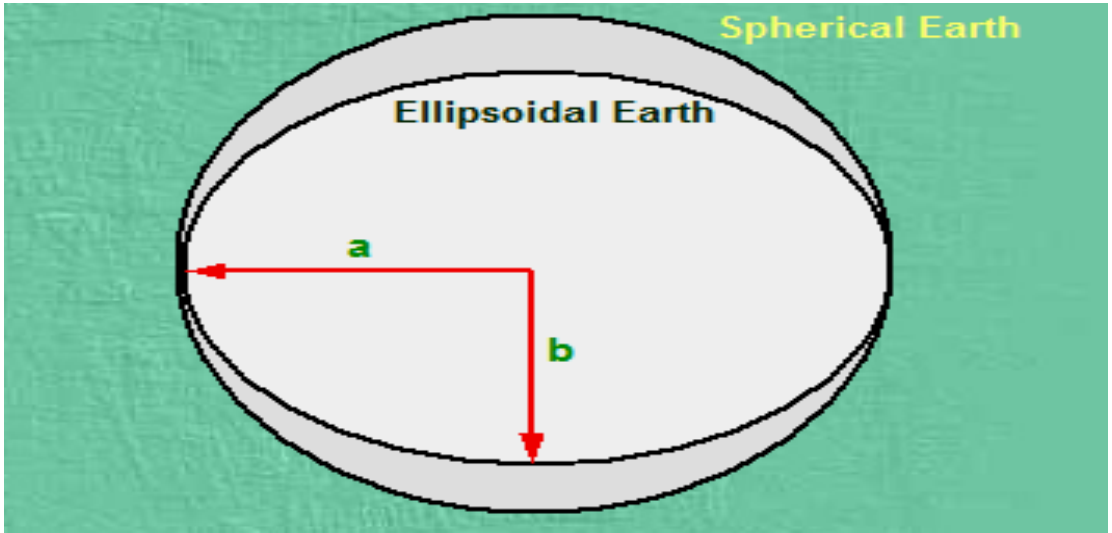
The spherical earth



- More than 2000 yrs ago most educated people knew that if we disregard such features as hills and valleys, the earth is spherical in shape.
- A sphere is based on circle (only one radius).

The Ellipsoid Earth

- The earth is flattened towards the poles.
- Rotating this ellipsoid about the polar axis would outline the 3D figure of the earth called an oblate ellipsoid or oblate spheroid.
- An ellipsoid is based on ellipse (two radius).

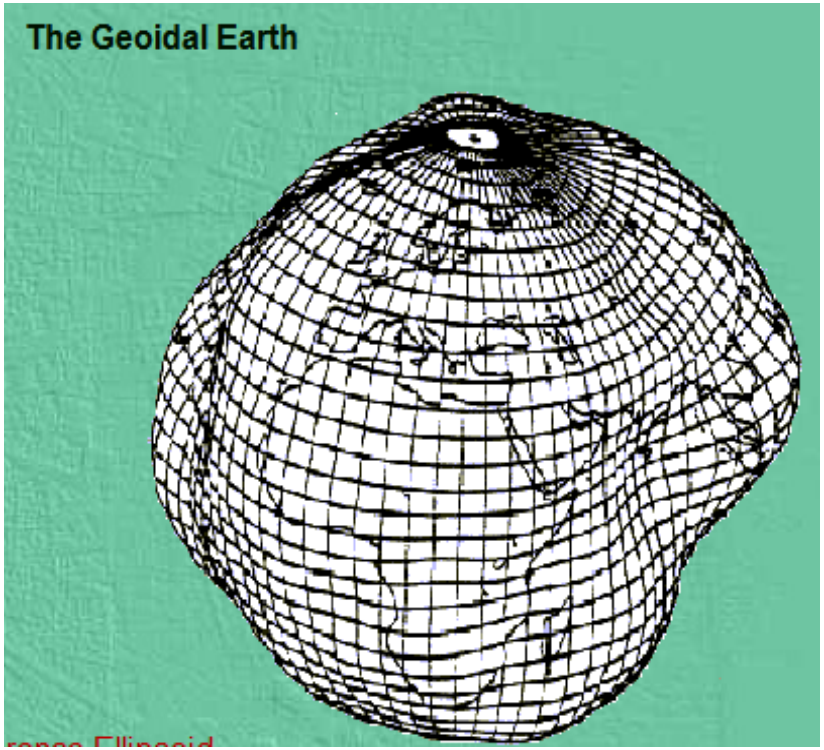


Official Ellipsoids

Name	Date	Equitorial Radius a (meters)	Equitorial Radius b (meters)	Polar Flattening
WGS 84	1984	6,378,137	6,356,752.3	1/298.257
GRS 80*	1980	6,378,137	6,356,752.3	1/298.257
WGS 72	1972	6,378,135	6,356,750.5	1/298.26
Australian	1965	6,378,160	6,356,774.7	1/298.25
Krasovsky	1940	6,378,245	6,356,863.0	1/298.3
International	1924	6,378,388	6,356,911.9	1/297
Clarke	1880	6,378,249.1	6,356,514.9	1/293.46
Clarke	1866	6,378,206.4	6,356,583.8	1/294.98
Bessel	1841	6,378,397.2	6,356,079.0	1/299.15
Airy	1830	6,378,563.4	6,356,256.9	1/299.32
Everest	1830	6,378,276.3	6,356,075.4	1/300.8

*Geodetic Reference System 1980, adopted by the International Association of Geodesy

The Geoidal Earth



- The Geoidal earth is also called Geoid and deviates ever so slightly from ellipsoid in a regular manner.
- The Geoid is the 3D shape that would be approximated by m.s.l. in the oceans.
- It is a m.s.l. surface in which gravity is everywhere equal to its strength at m.s.l.

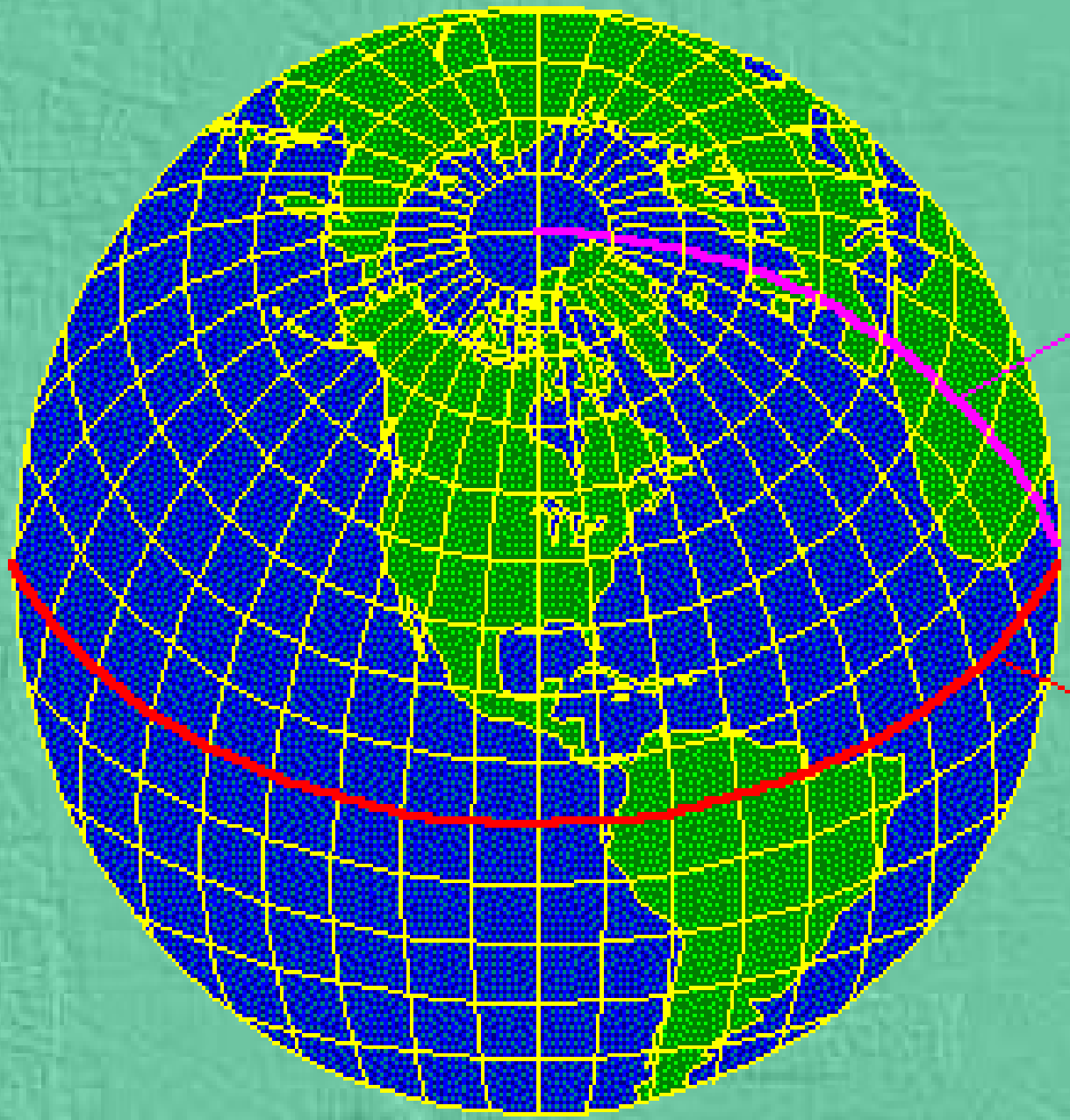
Reference Surface	Map Scale	Use
Sphere	Small Scale (< 1:5.000.000)	Regional maps, World maps
Ellipsoid	Medium and Large-Scale (> 1:5.000.000)	Topographic maps, Cadastral maps, Nautical charts
None (Flat plane)	Large Scale (Areas < 25 km^2)	Town plans, Cadastral maps, Technical maps

World geodetic system

- Geodetic datums can be classified according to the geographic area that they cover into global and local datums
- The world geodetic systems of 1984 (WGS 84) is global geodetic datum that have been developed for georeferencing based on a single point at the center of the Earth
- The Global Positioning system (GPS) is based on the World Geodetic System 1984 (WGS-84).

Geographical coordinate systems

- The geographical coordinates systems is the primary locational reference system for the earth.
- The geographical coordinate system employs latitude and longitude.
- Specifying a location on the earth requires determining latitude the north south angular distances from the equator, and longitude, the east west angular distance from a prime meridian.



Prime Meridian

0 Degrees Longitude

Equator

0 Degrees Latitude

Geographical coordinate systems…cont'

- Prime Meridian and Equator
  - Are the reference planes used to define latitude and longitude
  - The equator is used as a reference plane to measure latitude
  - The prime meridian is used as the origin to measure the longitude
  - The Greenwich Meridian in London is used as the prime meridian, however any meridian can be selected as the prime meridian

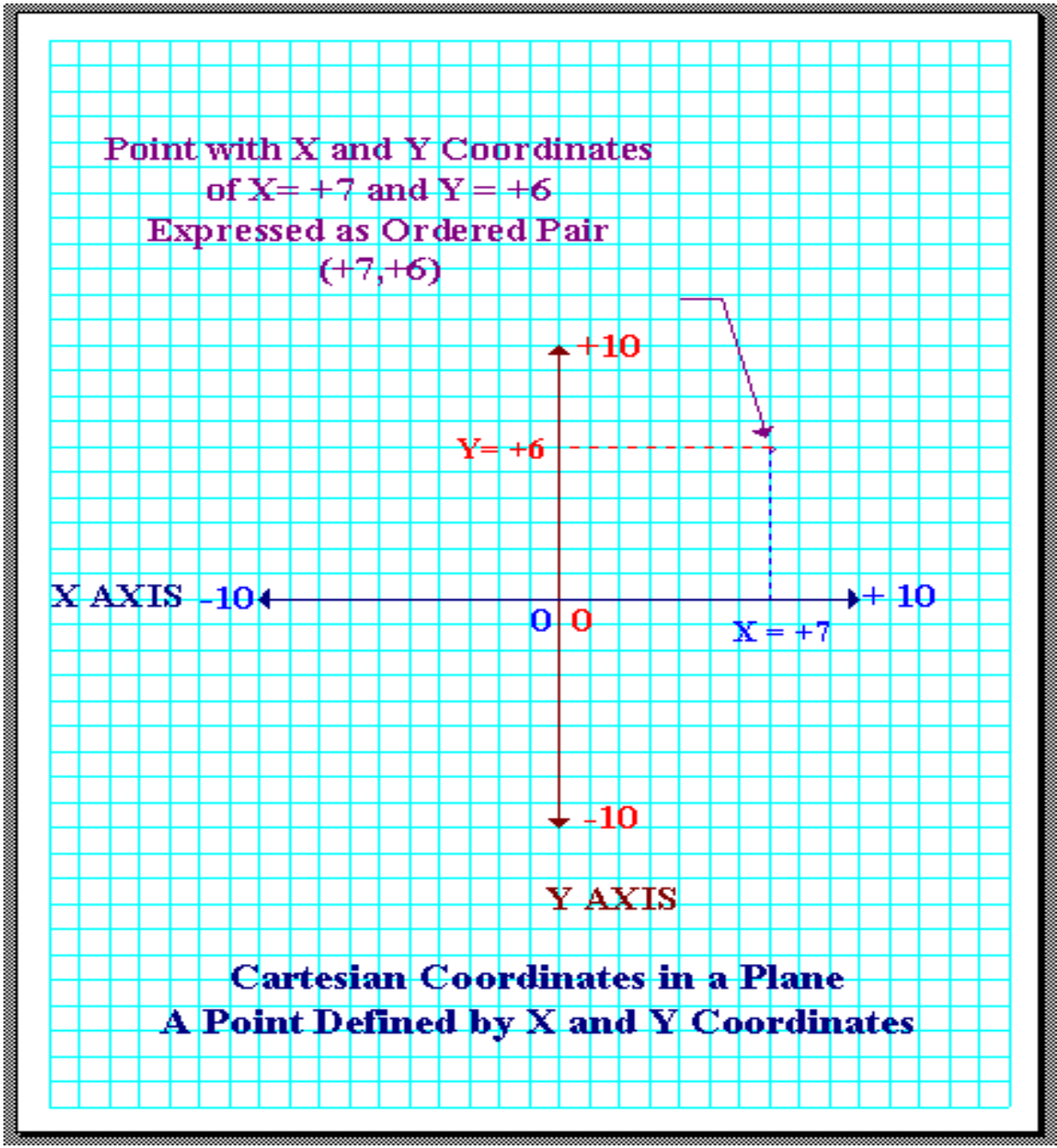
Geographical coordinate systems…cont'

- MSL-Elevation
  - are usually defined independent of the horizontal position.
  - Elevation is measured in meters above or below mean sea level, i.e. a known vertical coordinate defined by the geodetic survey of the country.
  - Note that for GPS-coordinates, elevation is defined as the distance from reference ellipsoid measured along the normal of the ellipsoid.

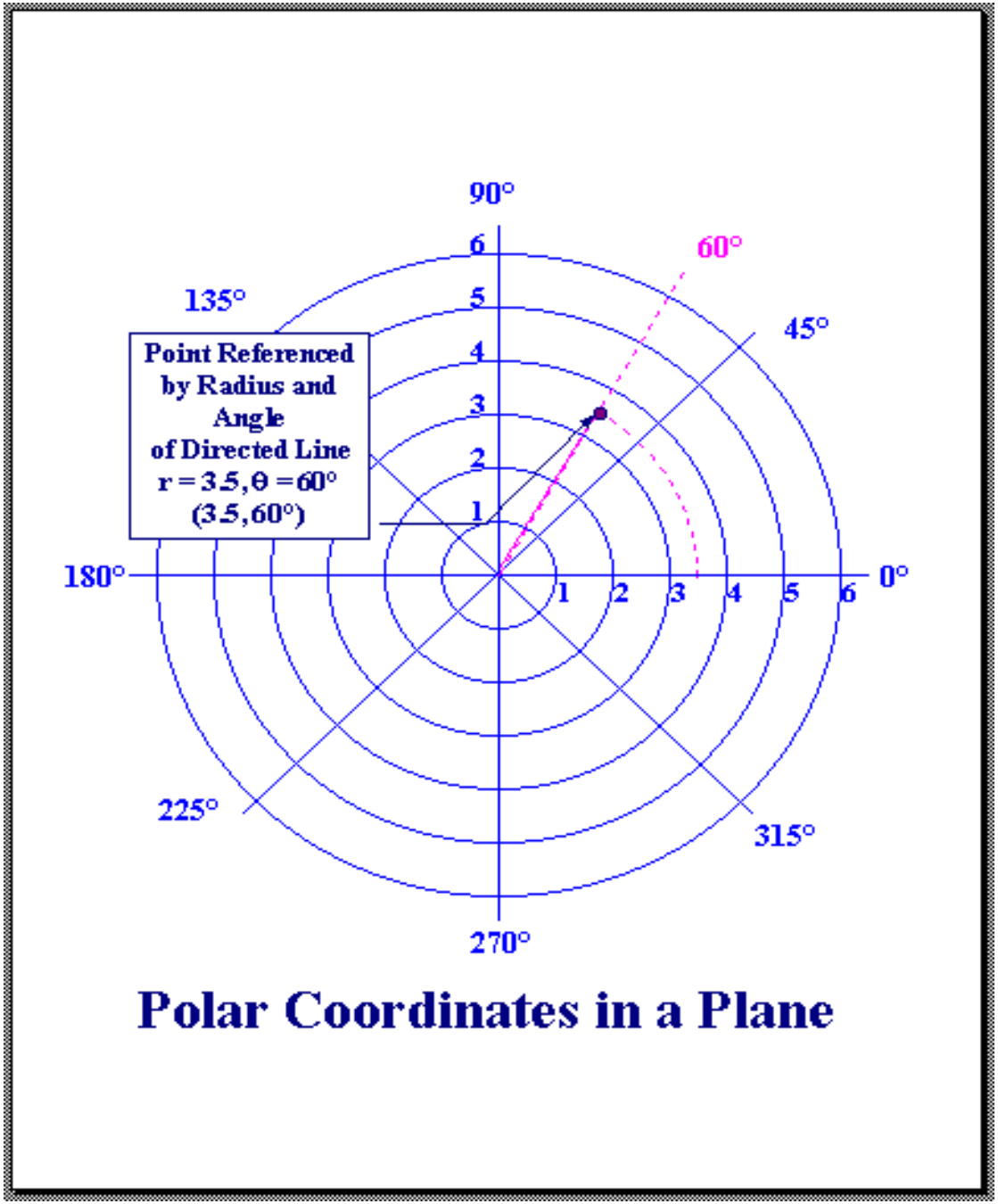
Plane coordinate system

- There are two basic types of coordinate reference systems on a plane (2D space)
  - Plane rectangular (cartesian) rectangular coordinate system
  - Plane polar coordinate system

Plane rectangular coordinate system



Plane polar coordinate system



3D coordinate systems

- Three-dimensional coordinate systems can be defined with respect to two orthogonal planes.
- Fig. shows a point described by 3D Cartesian Coordinates

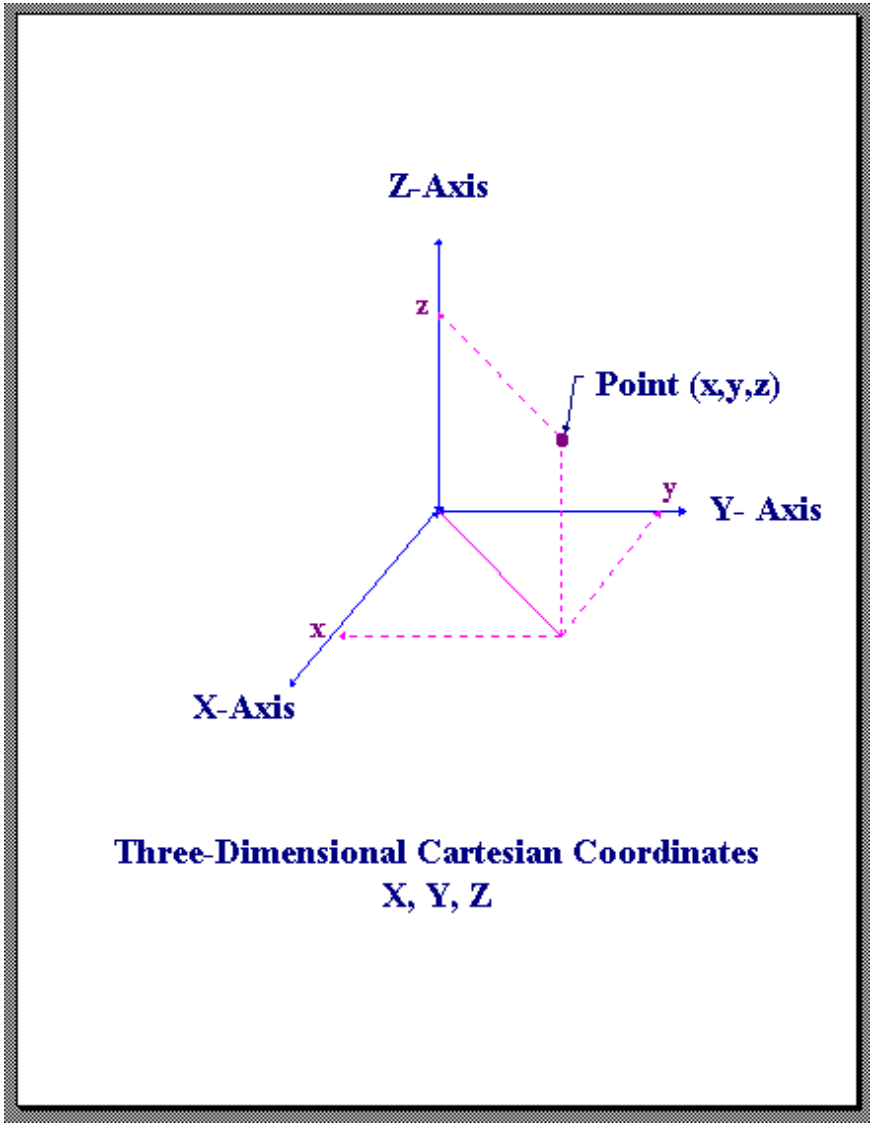
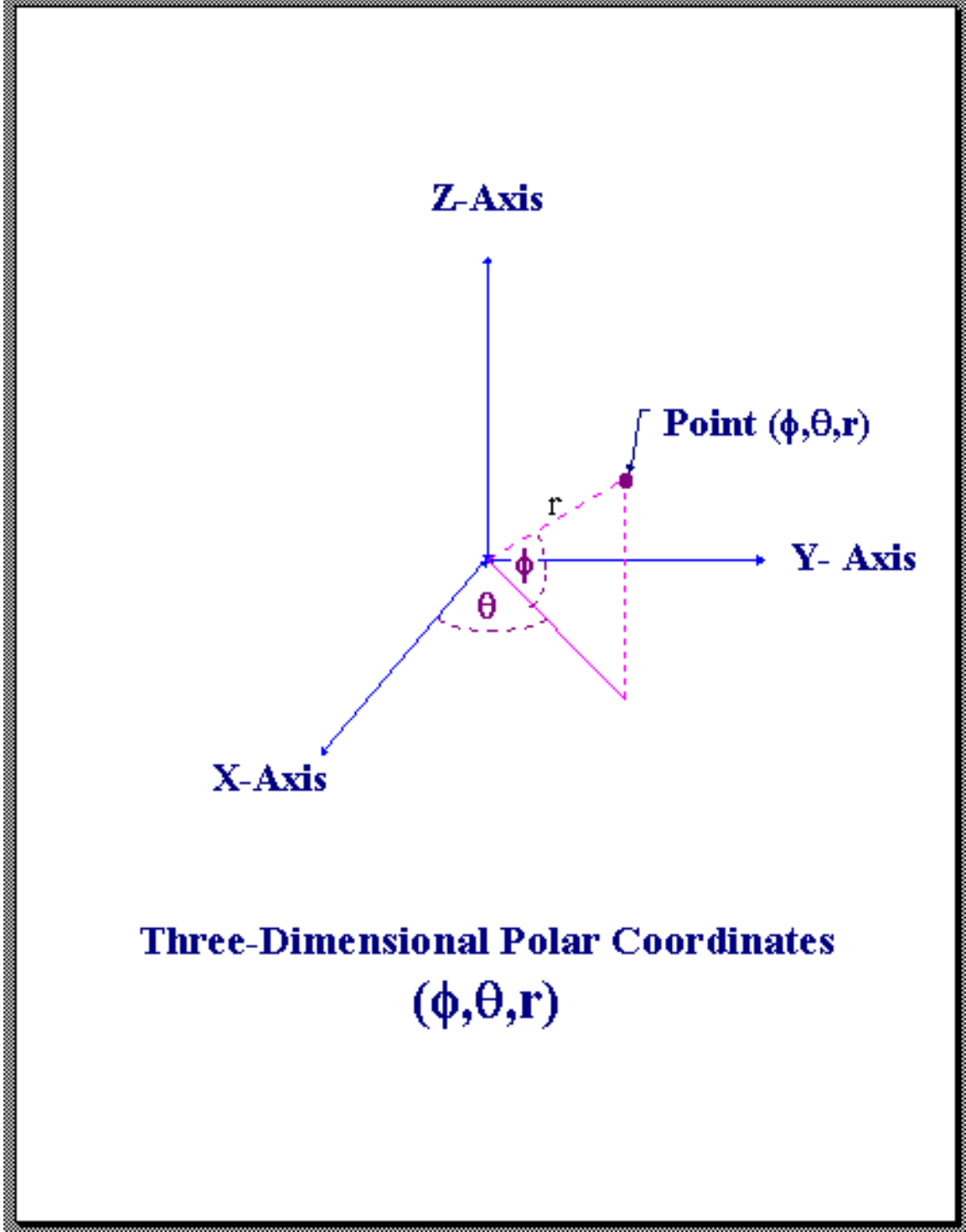
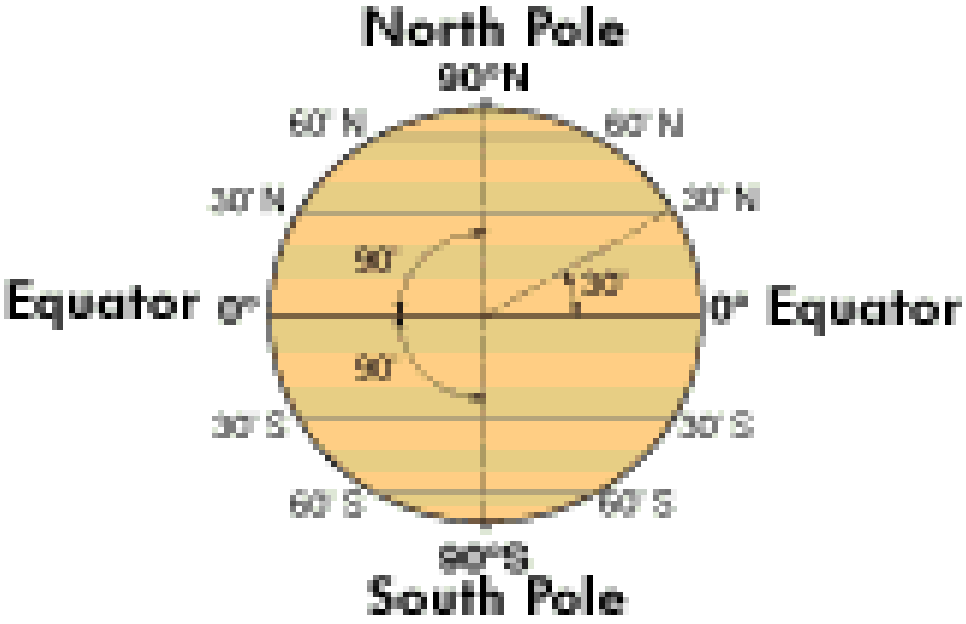


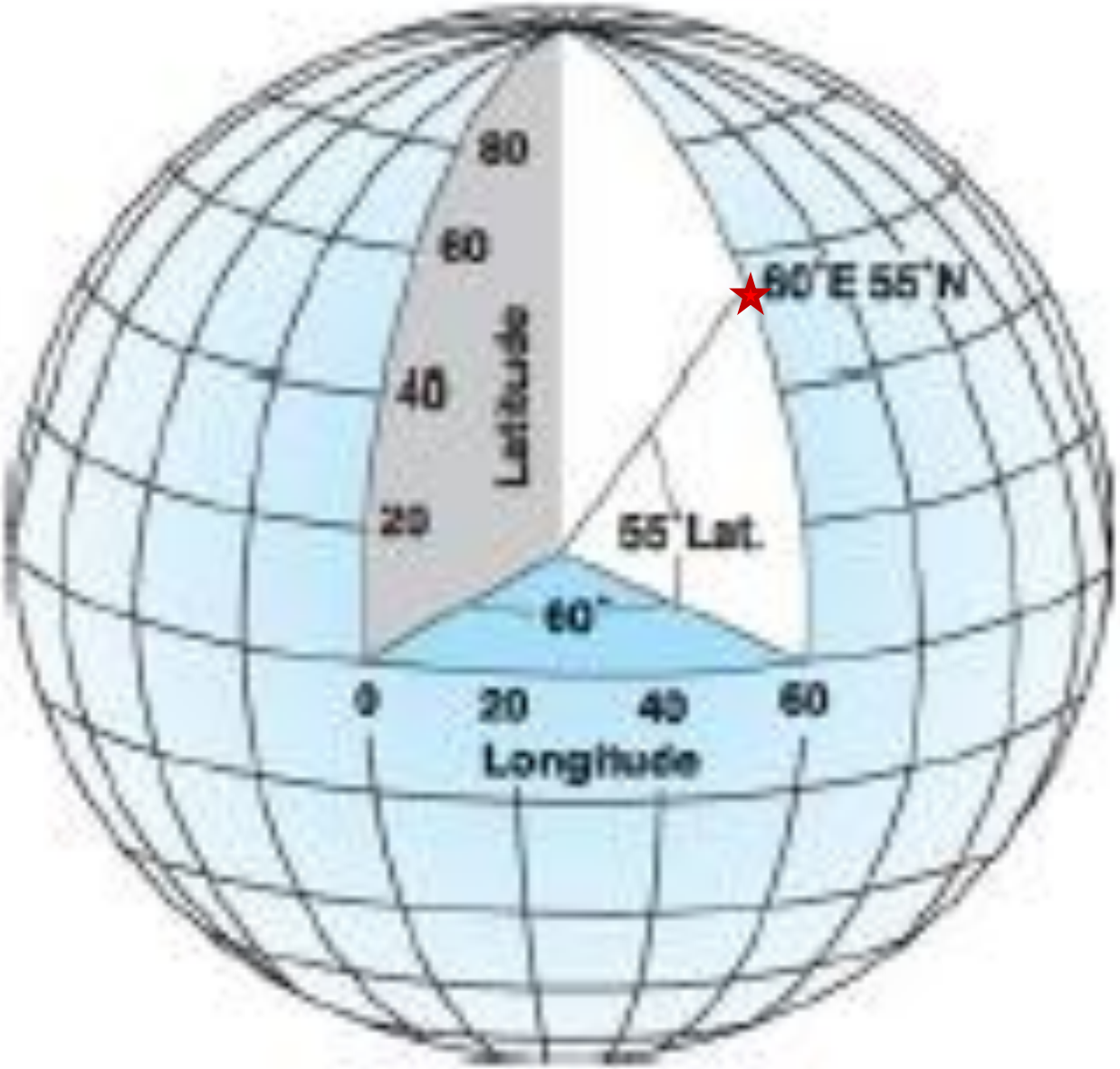
Fig. shows a point described by 3D polar coordinates



Geographic coordinate systems

- Latitude and longitude are angles measured from earth's center to a point on the earth's surface.
- The angles are measured in degrees.




80
60
40
20
Latitude
90°E 55°N
55° Lat.
60°
0
20
40
60
Longitude

Geographic coordinate systems…cont'

- Latitude/Longitude systems
  - Lines of longitude are drawn from N pole to S pole.
  - The line of longitude passing through the Greenwich Observatory in England has the value of 0°.
  - Moving west, the value of any line of longitude is the horizontal angle formed b/n the line drawn from that point to the center of the earth and a line drawn from the center of the earth to a point along the 0° line of longitude.

Geographic coordinate systems…cont'

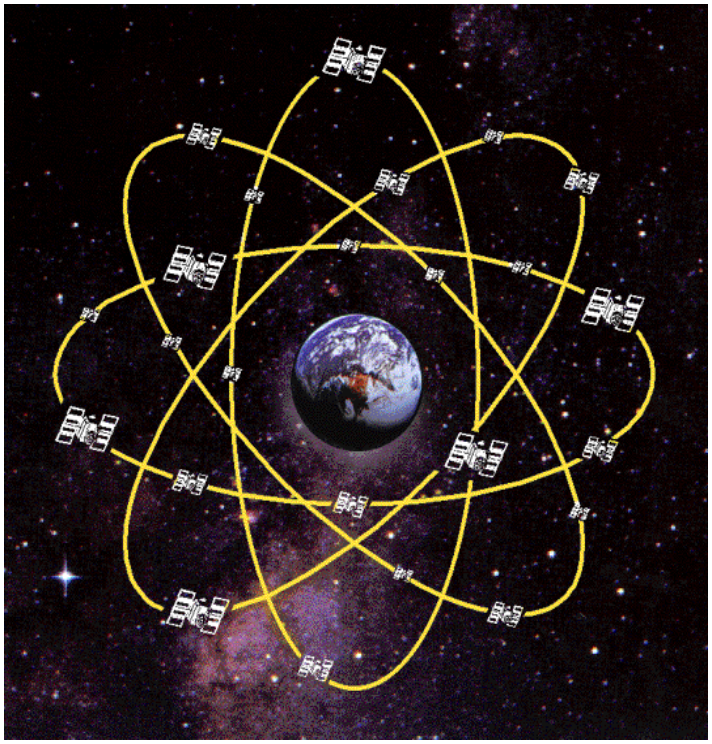
- Lines of longitude E of 0° longitude are termed East longitude values and those of W are called west longitude.
- The two sets of longitude values meet at 180° longitude on the opposite side of the earth from 0°.

Global Positioning System (GPS)

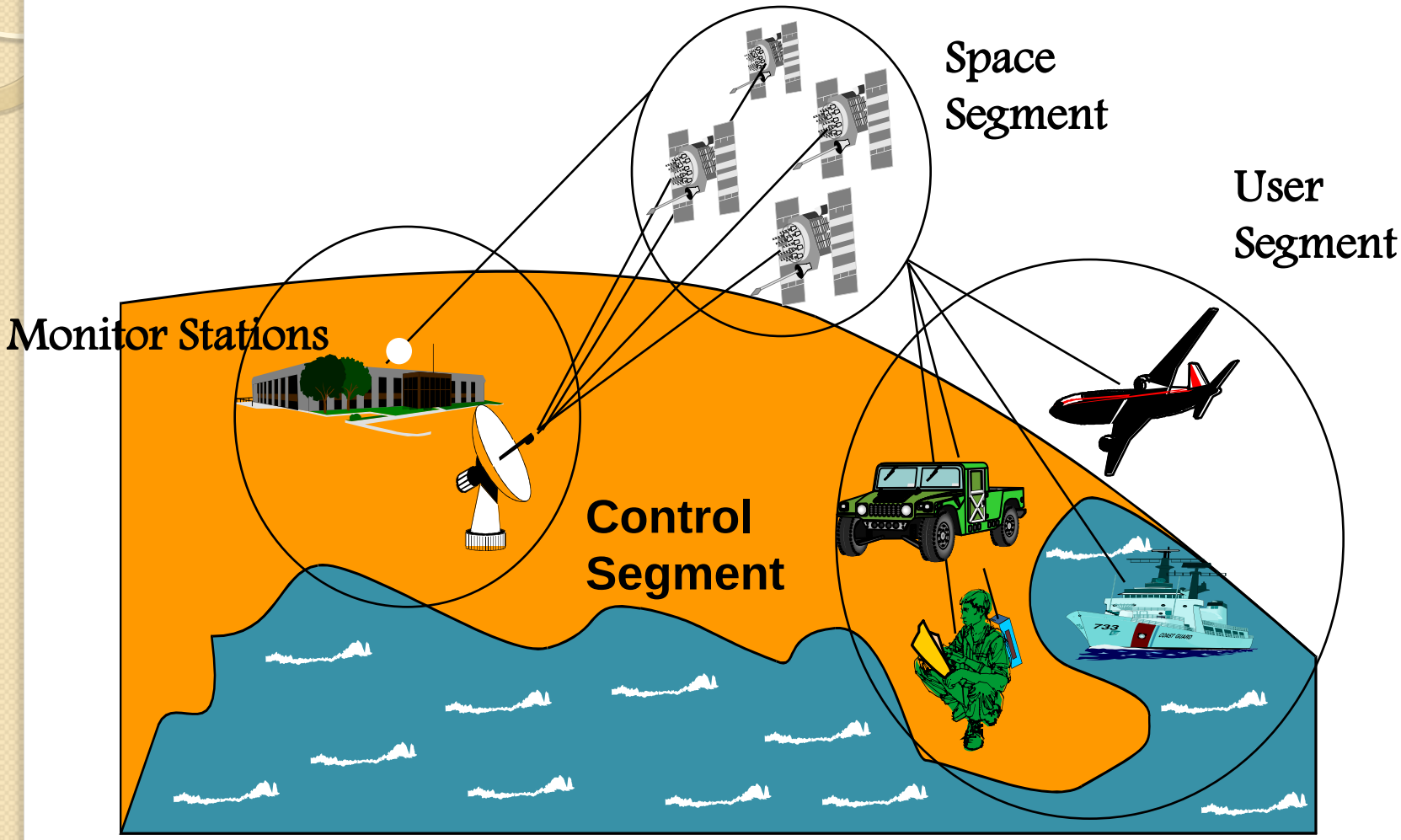
- First GPS satellite launched in 1978
- Full constellation achieved in 1994
- Approximately 2,000 pounds,17 feet across
- Satellites are identified by space vehicle (SV) number or pseudo-random noise (PRN) number

GPS…cont’

- Very high orbit
  - 1 revolution in approximately 12 hrs
  - Travel approx. 7,000mph
  - The total GPS configuration is comprised of 3 distinct segments.
    - Space segment,
    - Control segment,
    - User segment.

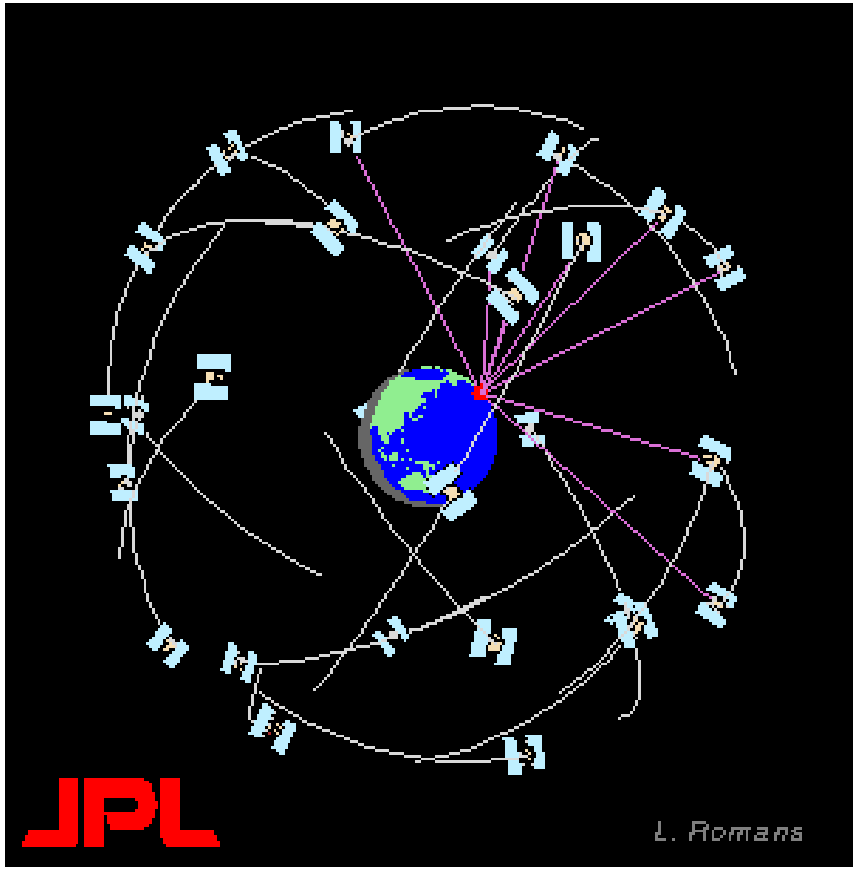


GPS System


Space
Segment
User
Segment
Monitor Stations
Control
Segment

Space segment

- 24 Satellite orbiting the earth in 6 orbital plane.
- Military originally, but after 1980 for Civil use.
- The satellites are orbiting about 20200km from earth's surface.
- The space segment is so designed that there will be minimum of 4 satellites.



Space segment

- Each GPS satellite has several very accurate atomic clock.
- The clock operate at a fundamental frequency of 10.23MHz.
- This is used to generate the signals that are broadcast from the satellite.

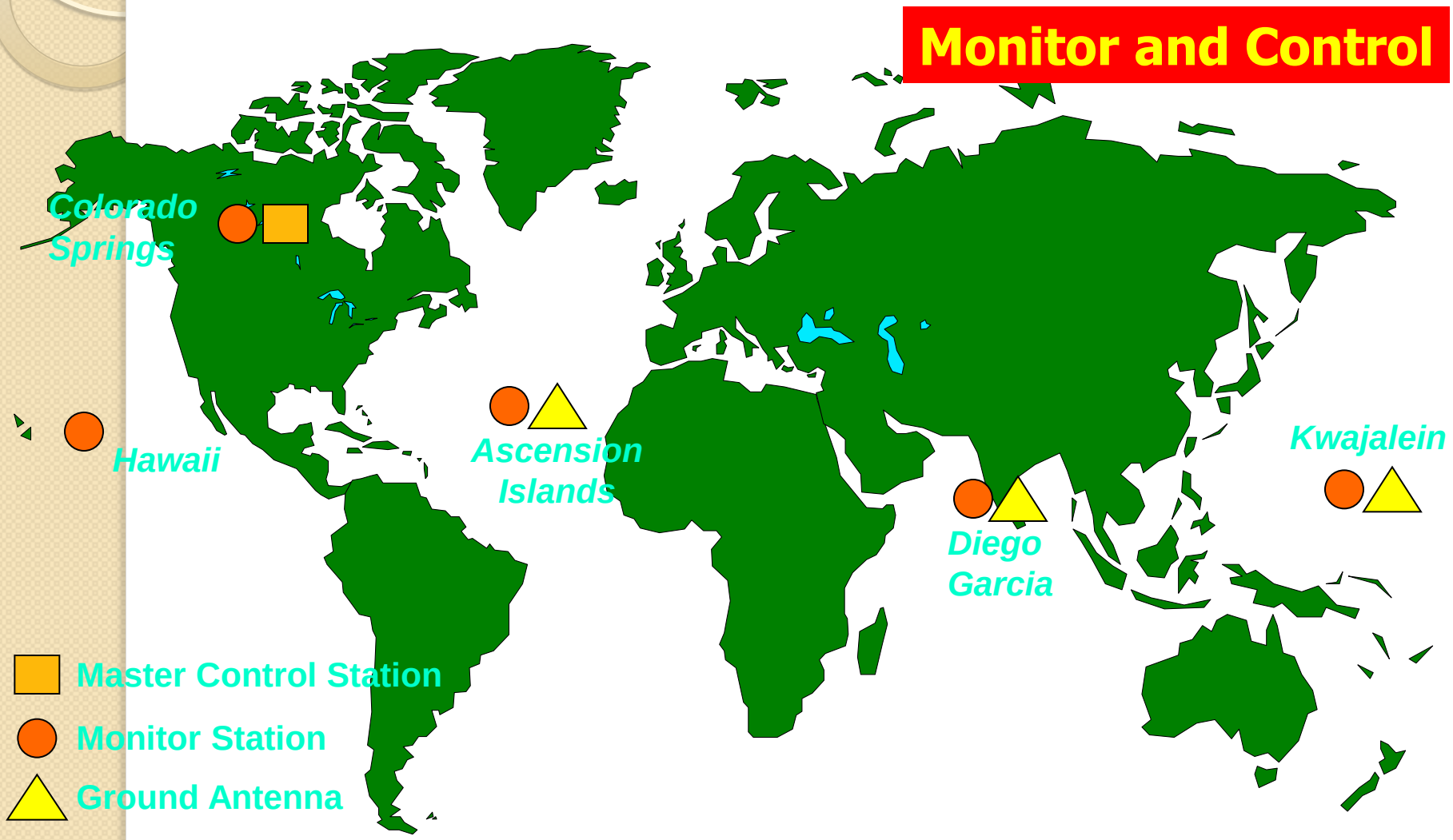
The control segment

- Control stations enable information on Earth to be transmitted to the satellites
- Control stations continuously track satellites, and update the positions of each satellite.
- Without control stations, the accuracy of the system would degrade in a matter of days.

The control segment…cont

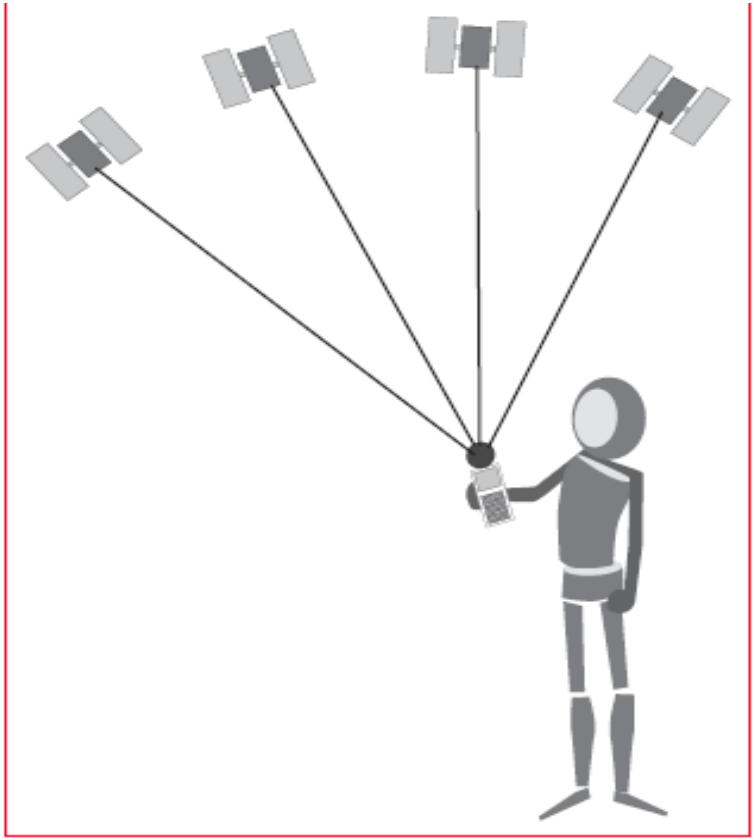
- The control segments are distributed in five location around equator.
- The control segments:
  - Tracks the GPS satellites,
  - Updates their orbiting position,
  - Calibrate their clocks.

Control Segment



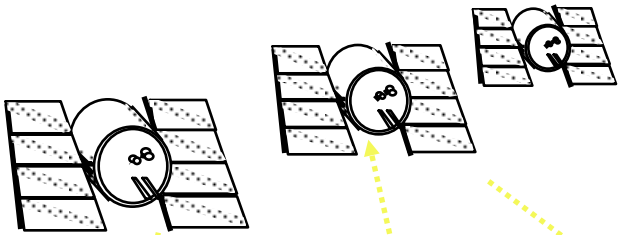
The user segment

- The user segment comprises of any one using a GPS receiver to receive a GPS signal.
  - Land navigation,
  - Marine navigation,
  - Aerial navigation,
  - Surveying, etc…
- Dual Use System Since 1985 (civil & military)



How the system works

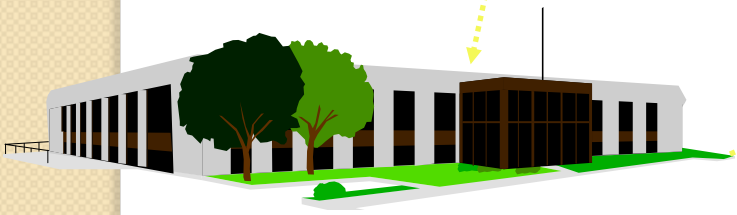
Space Segment
24+ Satellites

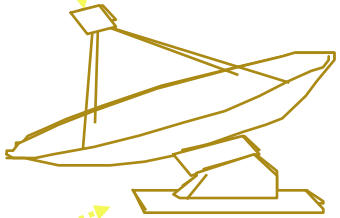


The Current Ephemeris is Transmitted to Users

Monitor Stations

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





GPS Control
Colorado Springs

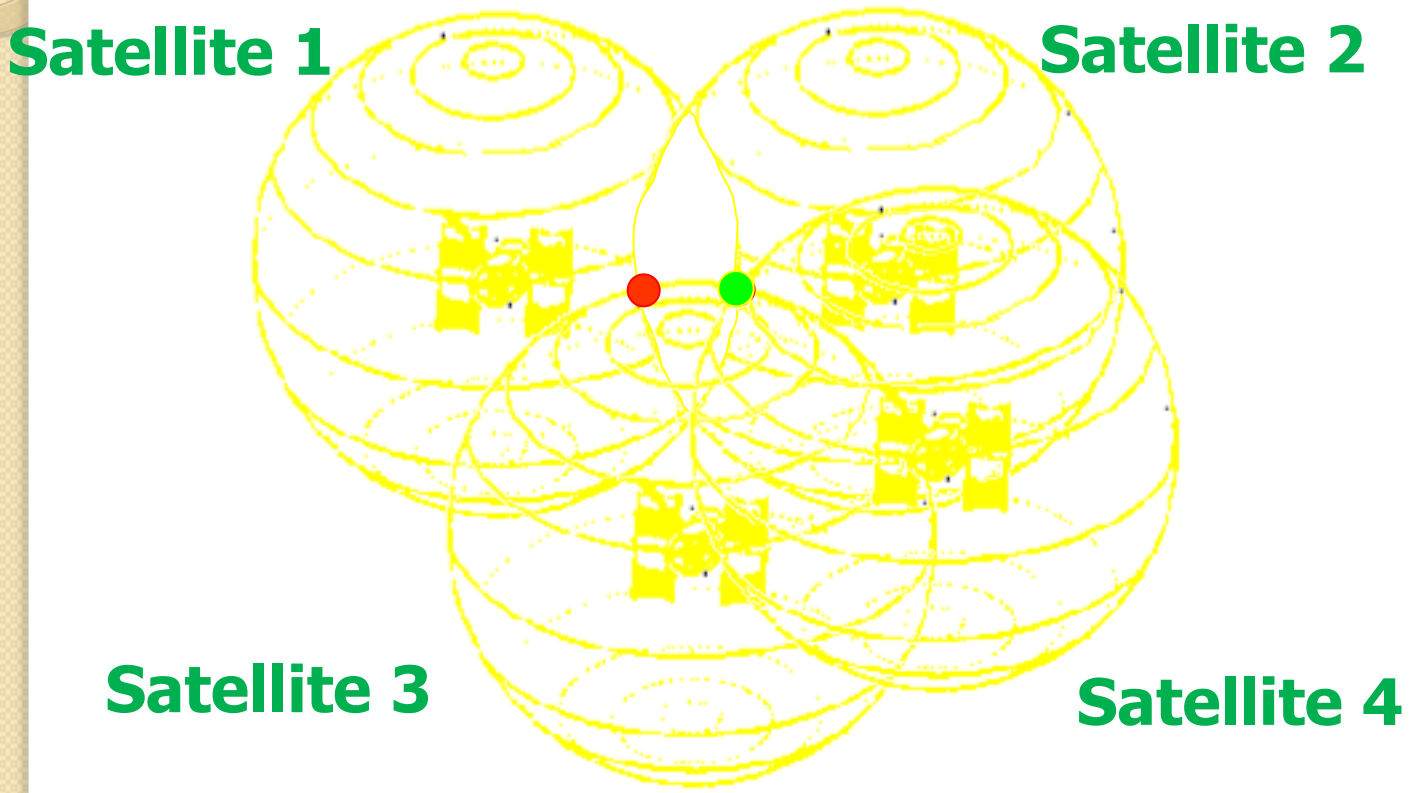
End User

Basic Positioning Concept

- If a satellite's location is known, and a receiver can determine how far away it is, the receiver must be somewhere on a sphere.
- If a second satellite is used simultaneously, the receiver must be somewhere where the two spheres intersect (on a circle).
- If a third satellite is added, the receiver must be located at one of two points.

- **Triangulation**

You can find any point if given distances from 3 other points



How GPS works

- **Principles of satellite based positioning:**

1. The satellite equipped with clock & sends a radio message.
   a) Satellite identifier,
   b) Satellite position in orbit,
   c) Satellite clock reading.

How GPS works

2. A receiver equipped with clock receive the message slightly latter & reads its own clock.
3. From the time delay observed the receiver compute the distance to the sender (pseudorange).

- **Def.**
  - Pseudo range of a satellite with respect to a receiver is its apparent distance to the receiver, computed from the time delay with which its radio signal is received.
  - Distance=Velocity x Time.

Types of GPS services

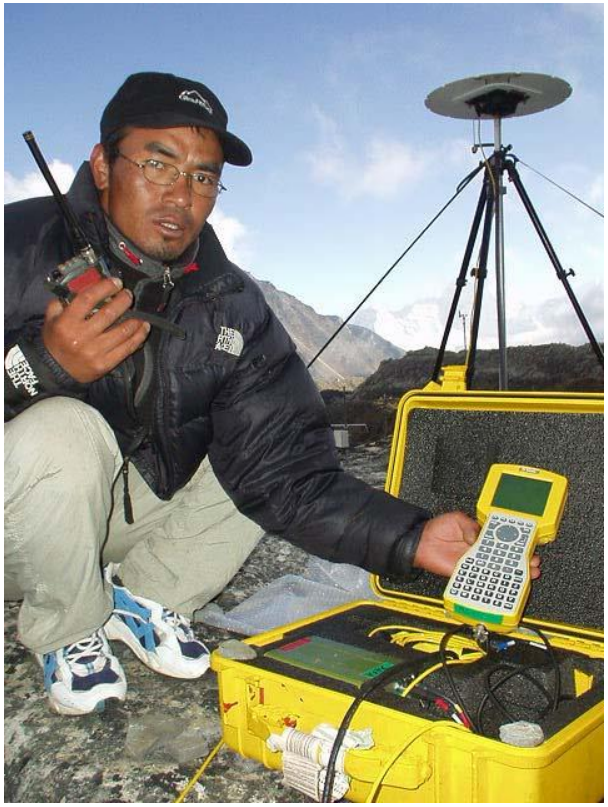
- GPS service divided into 2 classes.
  - Precise Positioning Service (PPS) - military and authorized service.
  - Standard Positioning Service (SPS) - civilian, non-military service.

Precise Positioning System (PPS): (P-code)

- Authorized users ONLY
- U. S. and Allied military
- Requires cryptographic equipment, specially equipped receivers
- Accurate to 21 meters 95% of time
- Very precise, not degraded.

Standard Positioning Service (SPS)

- Less precise
- Available to all users
- Accuracy degraded by Selective Availability until 2 May 2000
  - Horizontal Accuracy: 100m
  - SA was intentionally degraded the SPS service to limit the accuracy for non-military users.



Major Application

- Environmental resource management
- Aviation
- Military
- Local planning
- Surveying
- Recreation
- Business

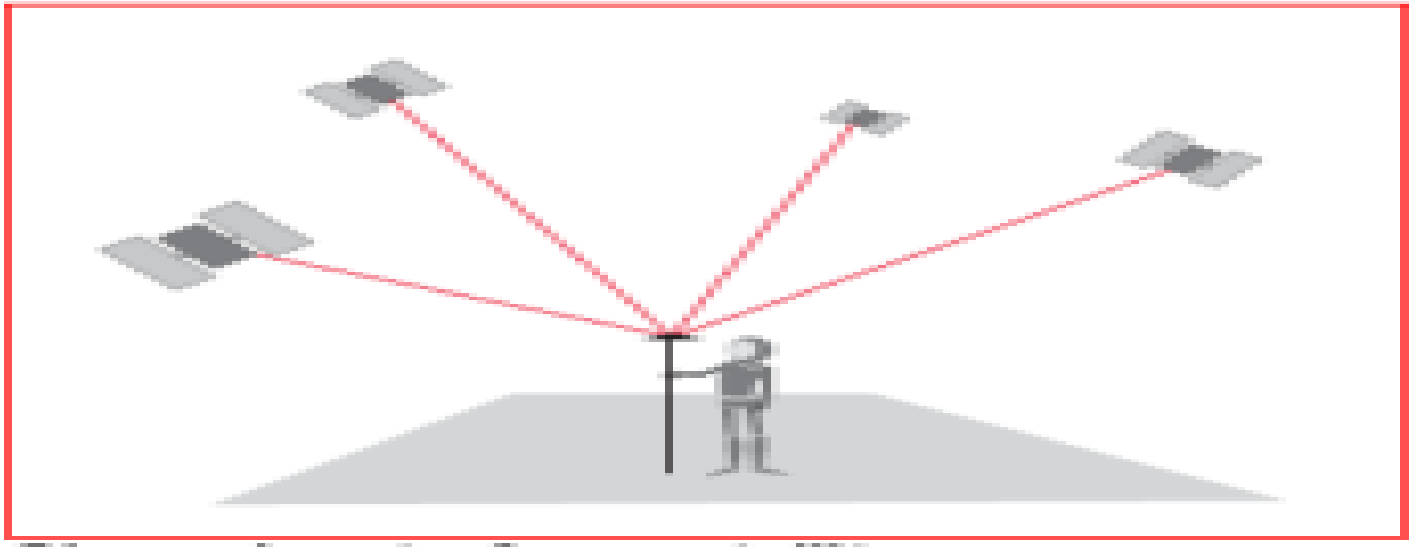
Advantages and limitations of GPS

- GPS has numerous advantages over traditional surveying methods:
  - Inter visibility between points is not required.
  - Can be used at any time of the day or night and in any weather.
  - Produces results with very high geodetic accuracy.
  - More work can be accomplished in less time with fewer people.

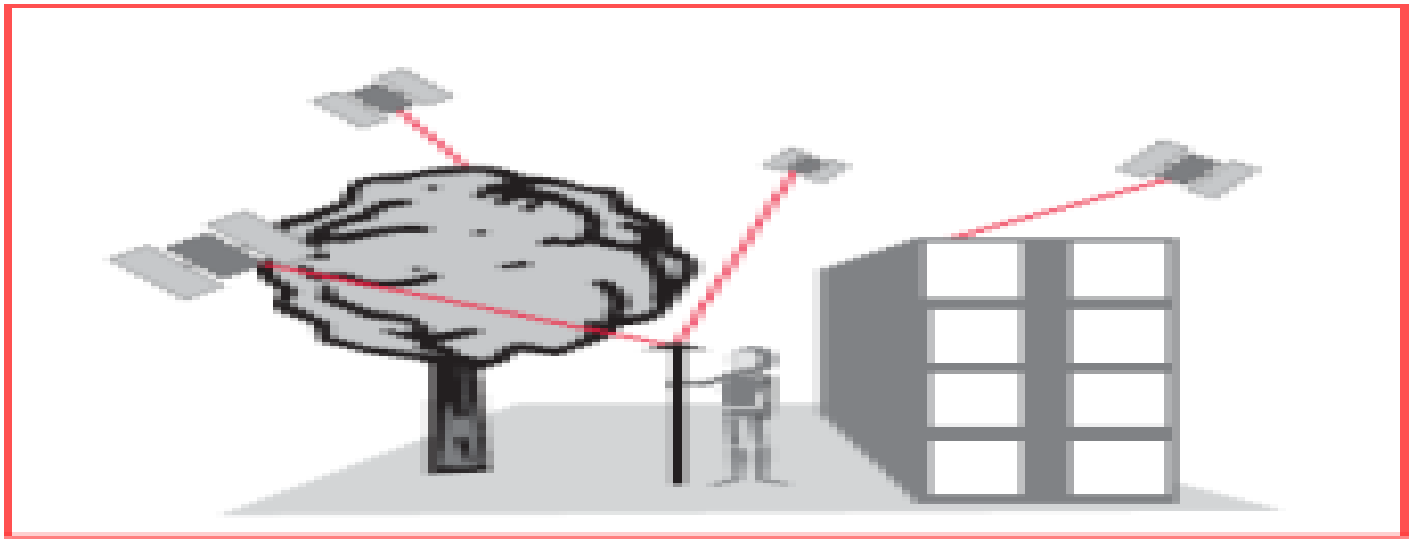
Limitations of GPS

- In order to operate with GPS it is important that the GPS Antenna has a clear view to at least 4 satellites.
- Sometimes, the satellite signals can be blocked by tall buildings, trees etc.
- Hence, GPS cannot be used indoors.
- It is also difficult to use GPS in town centers or woodland.

Limitations of GPS



Clear view to four satellites

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