GPS BASICS

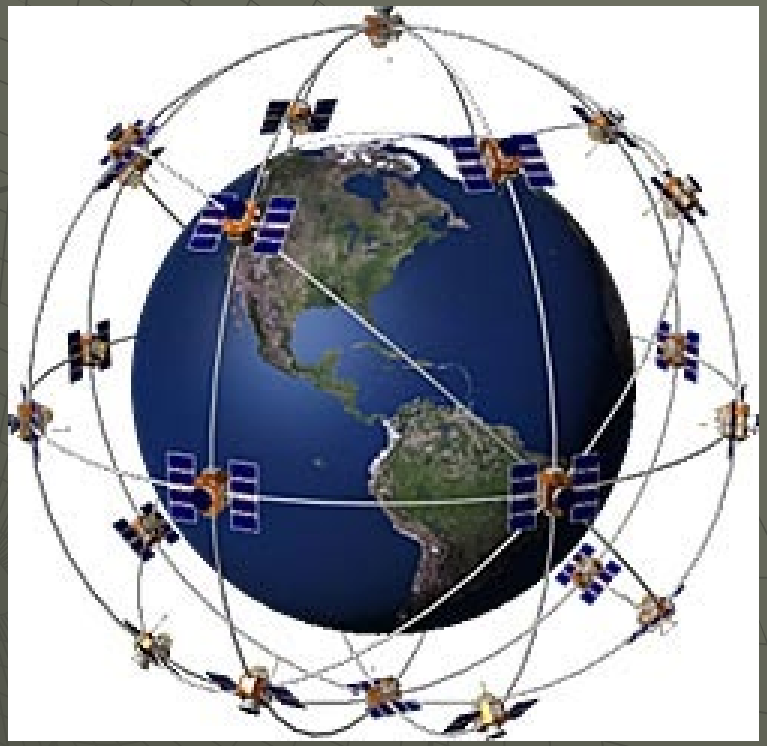
What is GPS?

Developed by Oklahoma 4-H

GPS

- **G**lobal **P**ositioning **S**ystem
- Network of 24 satellites (with spares)
- Developed by Department of Defense
- Operational 24 hours/day
- Available worldwide
- Land, sea and air
- Works in all weather conditions
- It is FREE!!

Satellite Constellation



Navigation Tools of the Past

Sextant

How did we navigate before GPS? Early sailors and travelers used the sun, stars and landmarks to navigate. They used sextants to make precise observation of the sun, stars, and planets to chart their course. In the 18th century clockmaker John Harrison invented the chronometer. It allowed navigators to know what time it was in two places at once, which helped to determine longitude.

Chronometer

Beginnings

- TRANSIT developed by Navy in 1960s
- Used to track nuclear submarines
- Air Force created own system
- Used to locate vehicles on land or in air

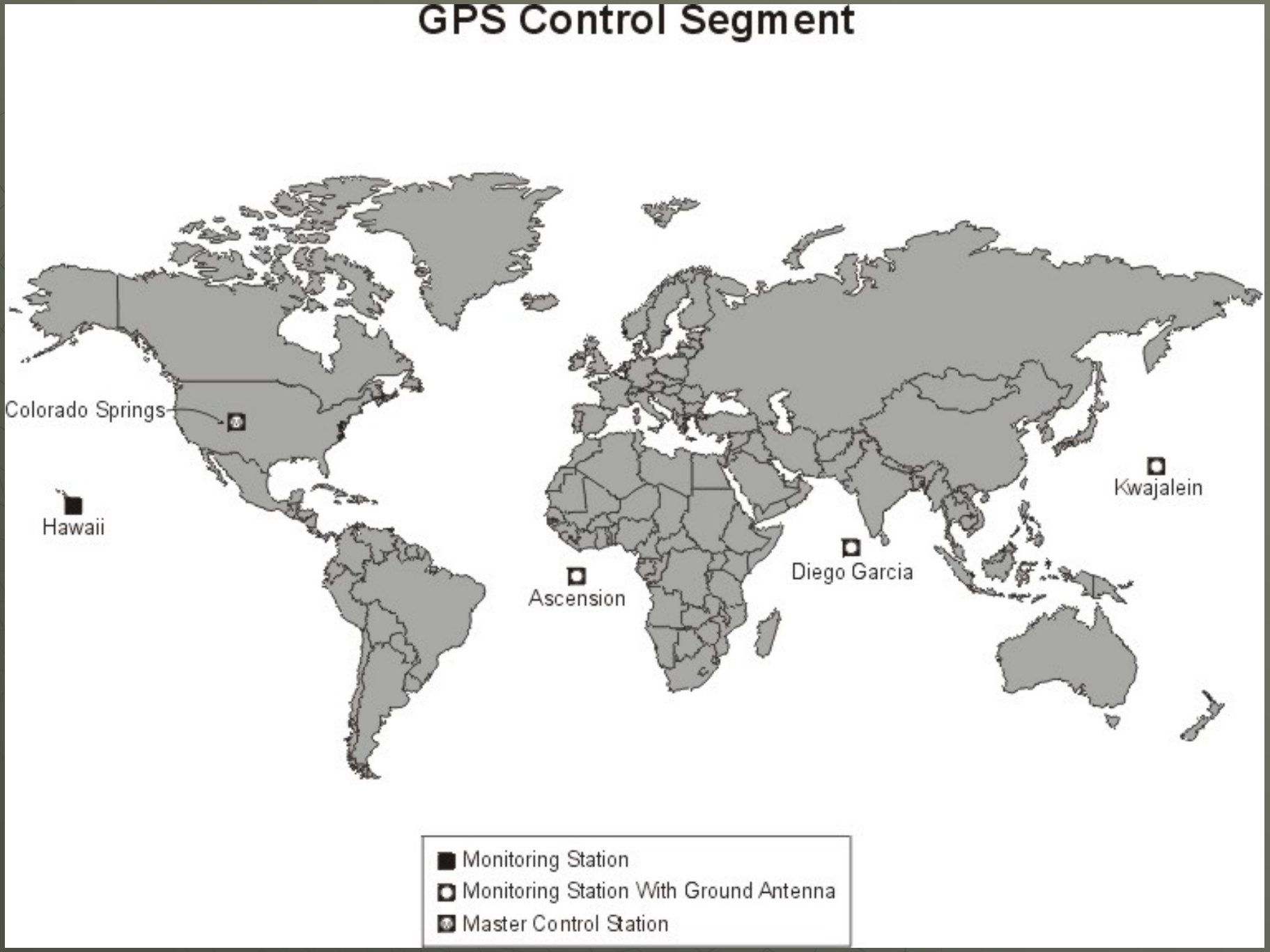
NAVSTAR

- Combined Navy and Air Force systems in 1973
- **NAV**igation **S**atellite **T**iming **A**nd **R**anging (NAVSTAR)
- First used in combat during Operation Desert Storm – 1991
- Full Operational Capability – April 27, 1995

GPS System

- Space Segment – Satellite Constellation
- Control Segment– Monitoring Stations and Ground Antennas
- User Segment – Receivers

GPS Control Segment



GPS Satellite

Satellite Information

- Weighs approximately 2,000 lbs
- Travels 7,000 mph
- 17 feet across with solar panels extended
- Last 10 years
- Orbit 12,500 miles above Earth
- Circle the Earth twice daily

In the next lesson we will learn:

- How GPS works
- Coordinates – Latitude and Longitude
- Creating and Finding Waypoints using a GPS receiver

How Does GPS Work?

How it works

- Satellite circles the Earth and transmits signal
- Signal contains time it was sent and its location
- All satellites send their signal at the same time
- Difference in time to reach receivers is used to determine location

- Formula: Distance = Speed x Time
- Signal travels at the speed of light – 186,282.3976 miles per second
- Speed and Time are known, use to calculate Distance

GPS Pseudorange Navigation Example - Peter H. Dana - 4/24/96

Satellite (SV) coordinates in ECEF XYZ from Ephemeris Parameters and SV Time

$SVx_0 := 15524471.175$ $SVy_0 := -16649826.222$ $SVz_0 := 13512272.387$ SV 15

$SVx_1 := -2304058.534$ $SVy_1 := -23287906.465$ $SVz_1 := 11917038.105$ SV 27

$SVx_2 := 16680243.357$ $SVy_2 := -3069625.561$ $SVz_2 := 20378551.047$ SV 31

$SVx_3 := -14799931.395$ $SVy_3 := -21425358.24$ $SVz_3 := 6069947.224$ SV 7

Satellite Pseudoranges in meters (from C/A code epochs in milliseconds)

$P_0 := 89491.971$ $P_1 := 133930.500$ $P_2 := 283098.754$ $P_3 := 205961.742$ Range + Receiver Clock Bias

Receiver Position Estimate in ECEF XYZ

$Rx := -730000$ $Ry := -5440000$ $Rz := 3230000$

For Each of 4 SVs $i := 0..3$

Ranges from Receiver Position Estimate to SVs (R) and Array of Observed - Predicted Ranges

$$R_i := \sqrt{(SVx_i - Rx)^2 + (SVy_i - Ry)^2 + (SVz_i - Rz)^2} \qquad L_i := \mathrm{mod}\left[\left(R_i\right), 299792.458\right] - P_i$$

Compute Directional Derivatives for XYZ and Time

$$Dx_i := \frac{SVx_i - Rx}{R_i} \qquad Dy_i := \frac{SVy_i - Ry}{R_i} \qquad Dz_i := \frac{SVz_i - Rz}{R_i} \qquad Dt_i := -1$$

Solve for Correction to Receiver Position Estimate

$$A := \begin{bmatrix} Dx_0 & Dy_0 & Dz_0 & Dt_0 \\ Dx_1 & Dy_1 & Dz_1 & Dt_1 \\ Dx_2 & Dy_2 & Dz_2 & Dt_2 \\ Dx_3 & Dy_3 & Dz_3 & Dt_3 \end{bmatrix} \qquad dR := \left(A^T \cdot A\right)^{-1} \cdot A^T \cdot L \qquad dR = \begin{bmatrix} -3186.496 \\ -3791.932 \\ 1193.286 \\ 12345.997 \end{bmatrix}$$

Apply Corrections to Receiver XYZ and Compute Receiver Clock Bias Estimate

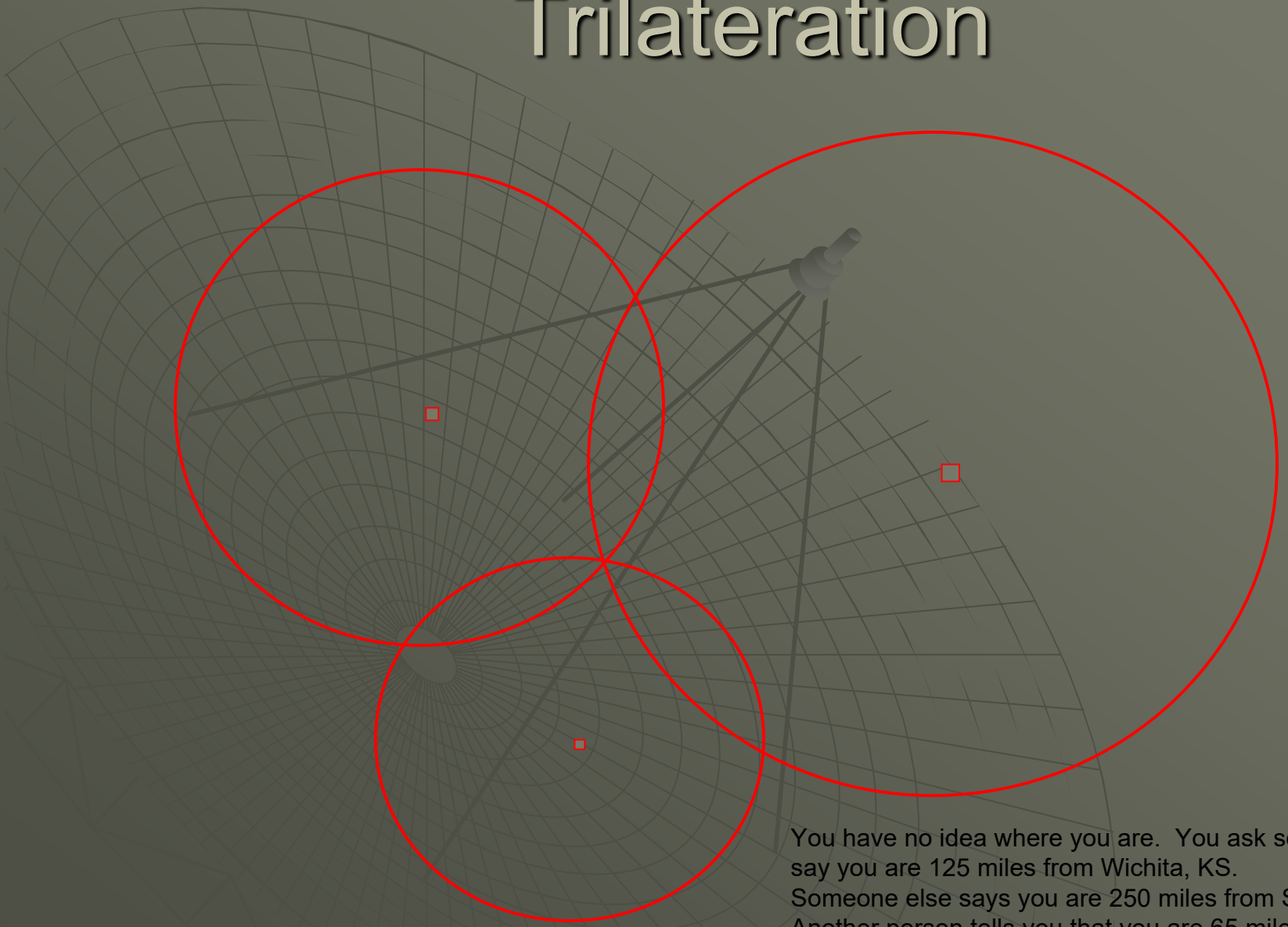
$Rx := Rx + dR_0$ $Ry := Ry + dR_1$ $Rz := Rz + dR_2$ $Time := dR_3$

$Rx = -733186.496$ $Ry = -5443791.932$ $Rz = 3231193.286$ $Time = 12345.997$

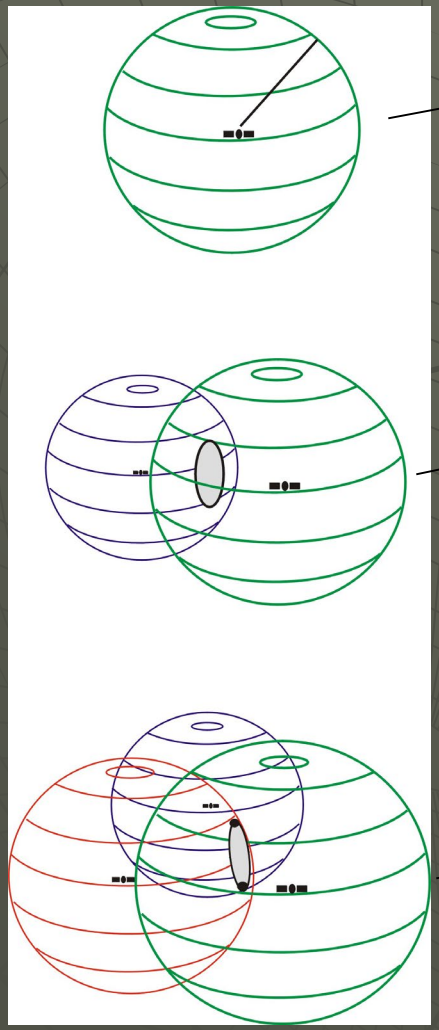
Trilateration

- Process of measuring the distance from at least three satellites
- Three satellites calculate 2D position (Latitude and Longitude)
- Four or more satellites calculate 3D position (Latitude, Longitude, and Altitude)

Trilateration



You have no idea where you are. You ask someone and they say you are 125 miles from Wichita, KS.
Someone else says you are 250 miles from Springfield, MO.
Another person tells you that you are 65 miles from Oklahoma City, OK.
Where are you? Stillwater, OK



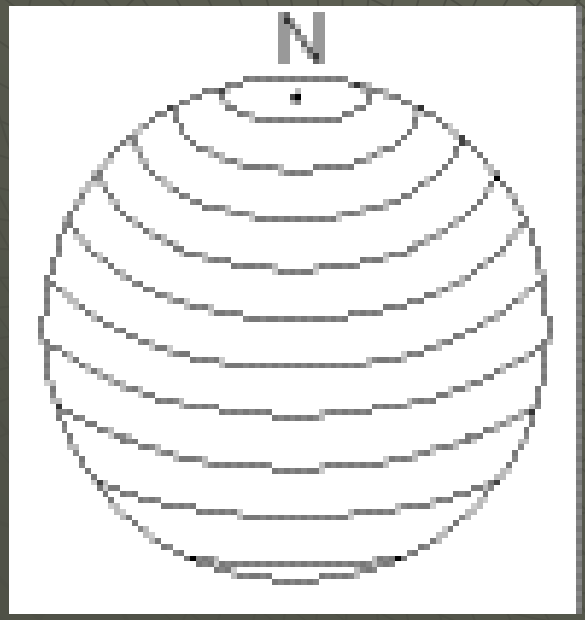
One satellite can locate a receiver's position somewhere on a sphere

Two satellites can locate a receiver's position to a circle representing the intersection of two spheres

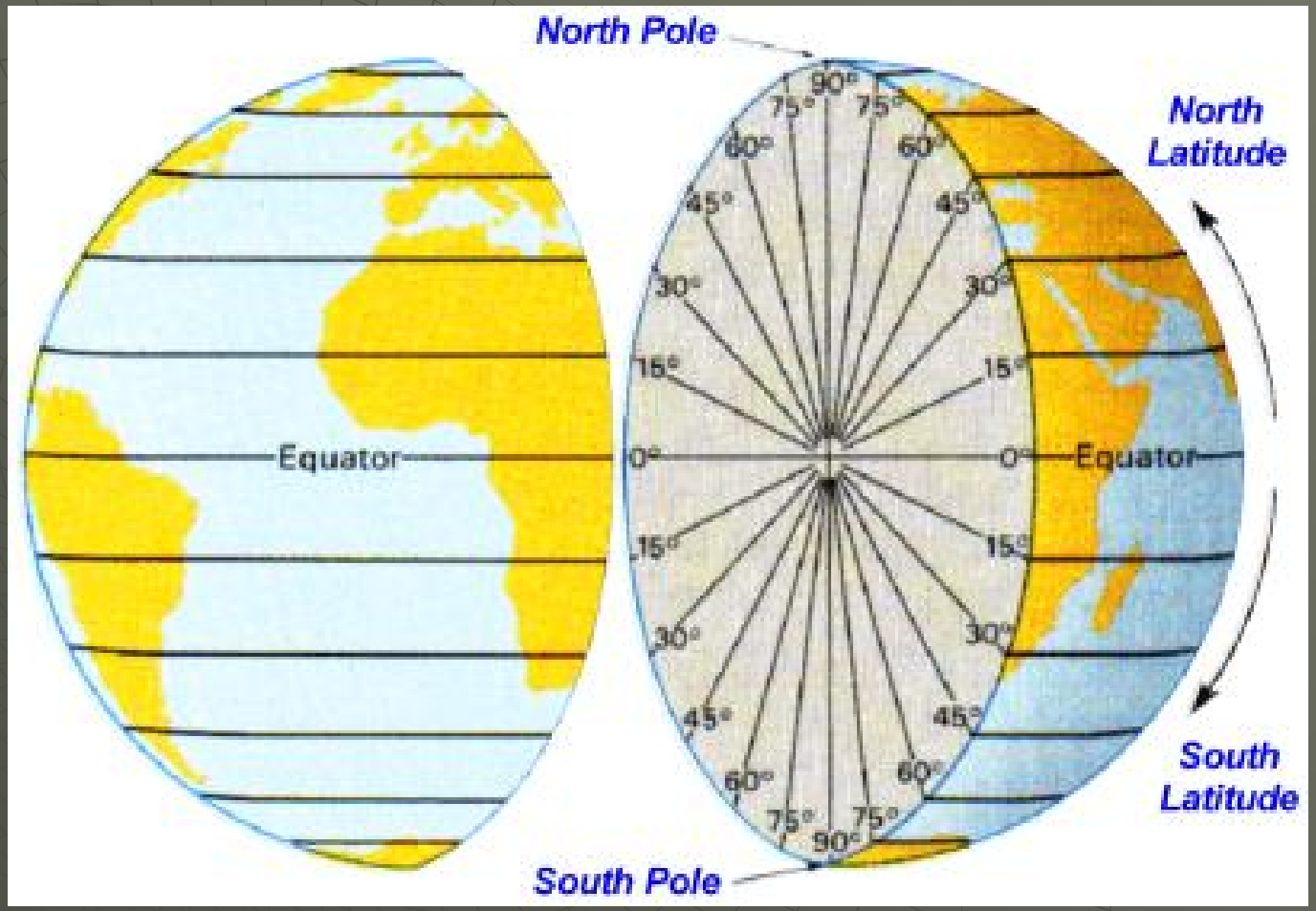
Three satellites can locate a receiver's position to one of two points represented by the intersection of three spheres.

Latitude

- Latitude lines run horizontal
- Equator is 0°
- North and South Poles are 90°

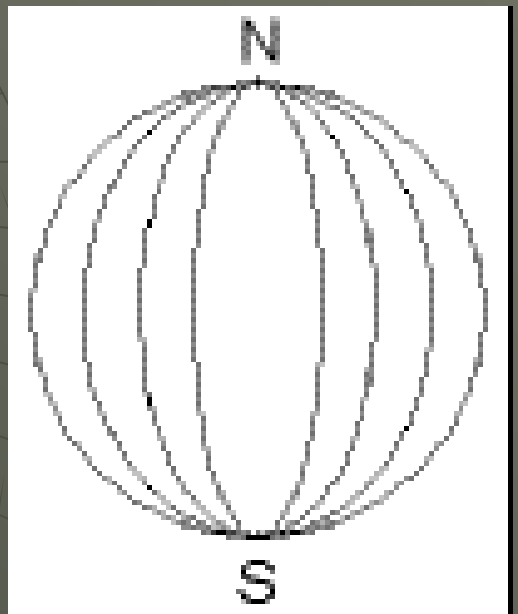


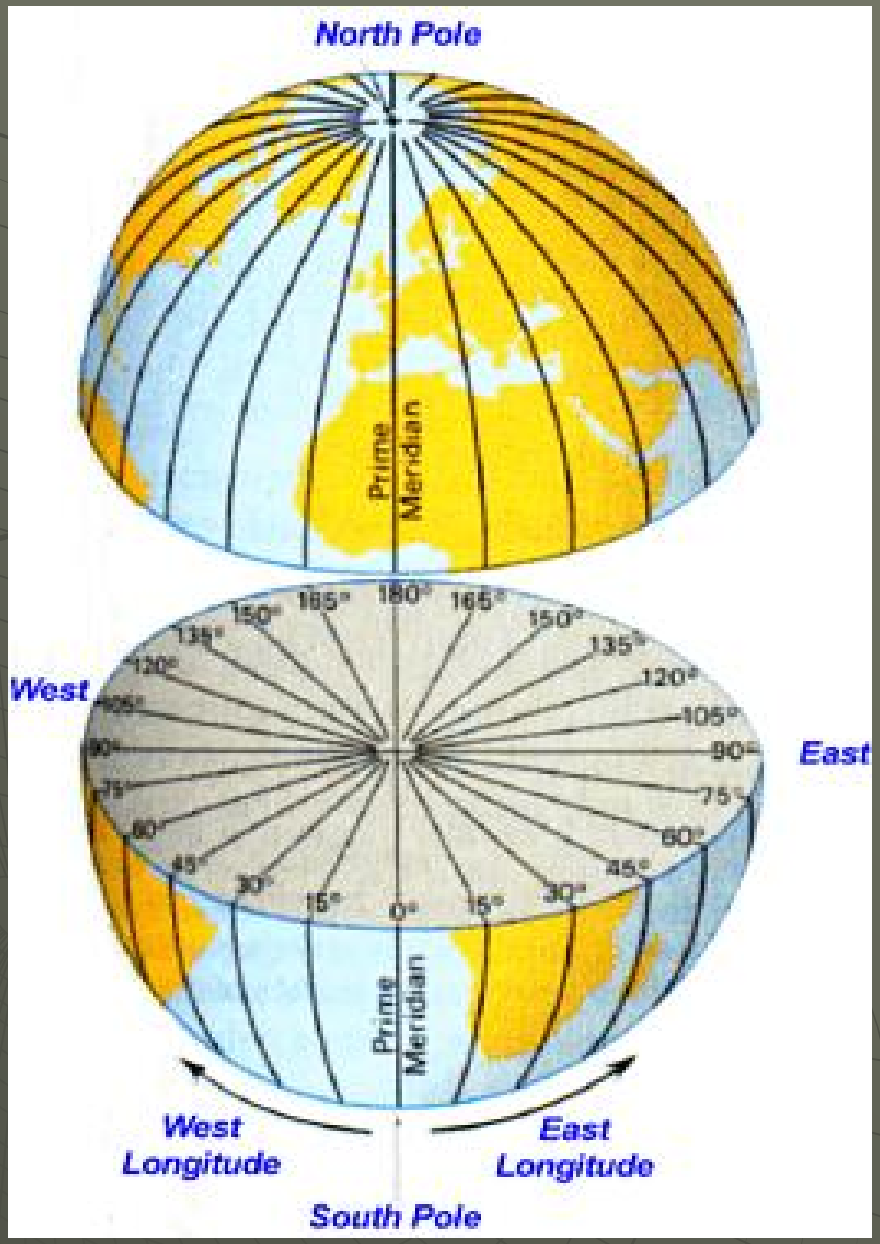
Lines of Latitude



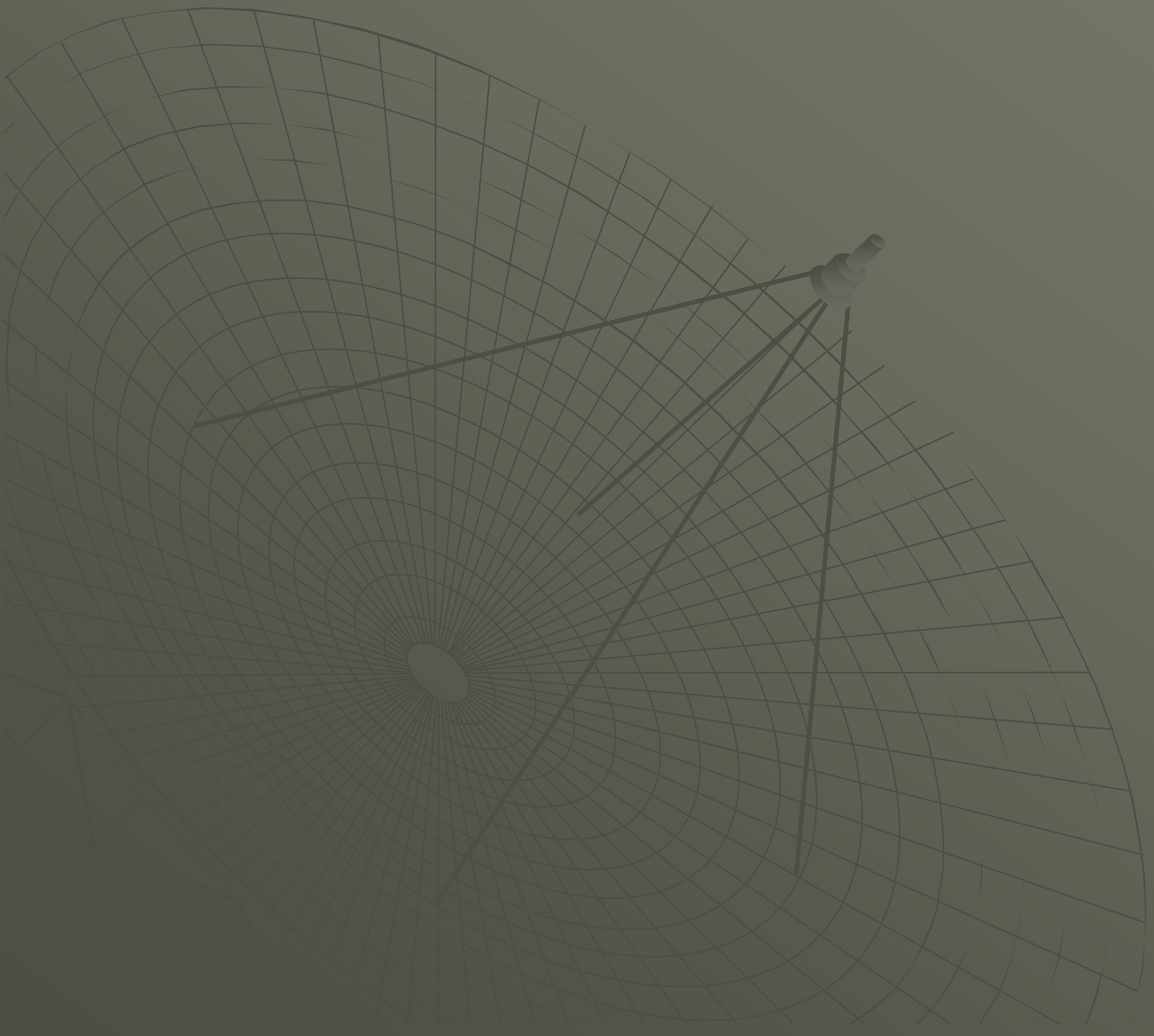
Longitude

- Also known as meridians, run vertical
- The Prime Meridian in Greenwich, England is 0°
- Lines range from 0° to 180°
- International Date Line is 180°




North Pole
Prime Meridian
West
East
180°
165°
150°
135°
120°
105°
90°
75°
60°
45°
30°
15°
0°
Prime Meridian
West Longitude
East Longitude
South Pole

What can you do with GPS?



GPS/GIS and 4-H

- Potential Projects
  - Youth Favorite Places
    - www.youthfavoriteplaces.org
  - Geocaching
    - www.geocaching.com
  - National GPS / GIS Integration Team
    - http://www.4-h.org/
  - The National Map Corps
    - http://nationalmap.gov/TheNationalMapCorps/

GPS/GIS and 4-H

- Community Atlas
  - ESRI Grants
  - http://www.esri.com/industries/k-12/atlas/index.html
  - http://gis.esri.com/industries/k-12/commatlas/browse.cfm
- Environmental Impact Team
  - Waterwell Mapping
- The Globe Project
  - www.globe.gov

GPS/GIS and 4-H

- Oklahoma Project Ideas
  - Danger Signs
  - Historic Downtown Areas
  - Illegal Dump locations
  - Health and Wellness benefits
  - Storm Shelters
  - Nature Trails and/or Vegetation