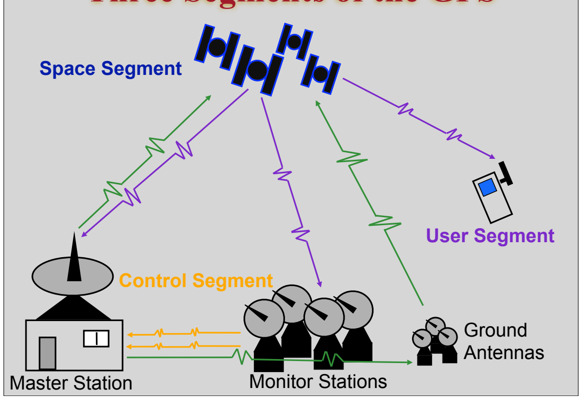
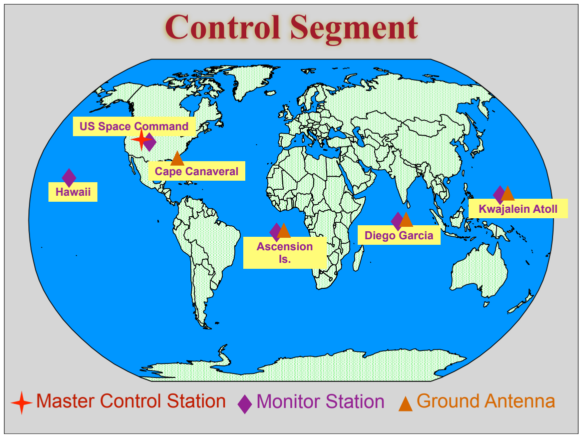
The History of GPS

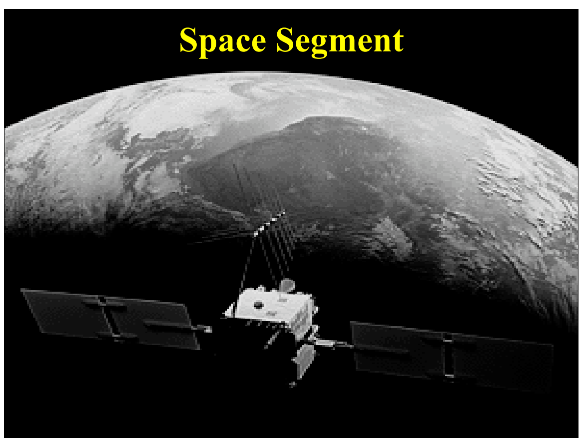
- Feasibility studies begun in 1960’s.
- Pentagon appropriates funding in 1973.
- First satellite launched in 1978.
- System declared fully operational in April, 1995.

How GPS Works

Three Segments of the GPS




Control Segment
US Space Command
Cape Canaveral
Hawaii
Kwajalein Atoll
Diego Garcia
Ascension Is.
Master Control Station
Monitor Station
Ground Antenna

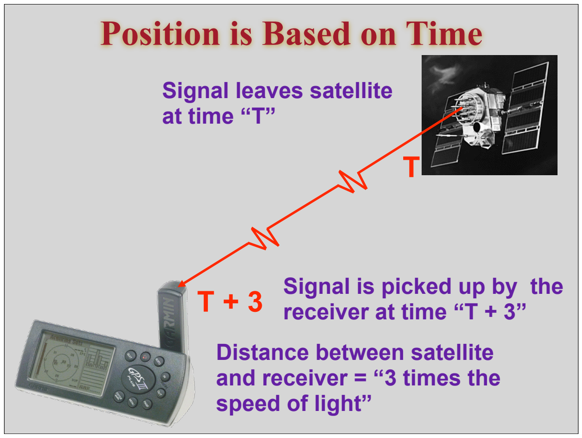

Space Segment

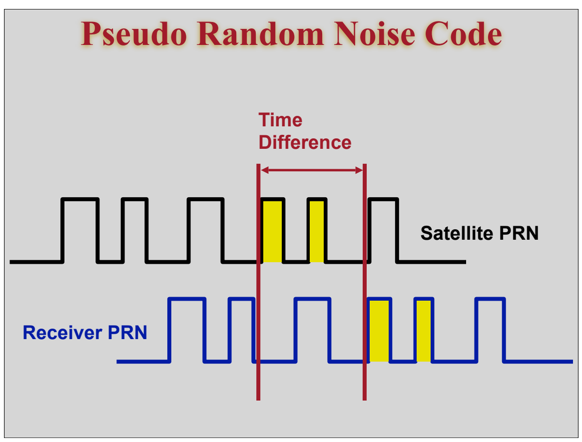
User Segment

- Military.
- Search and rescue.
- Disaster relief.
- Surveying.
- Marine, aeronautical and terrestrial navigation.
- Remote controlled vehicle and robot guidance.
- Satellite positioning and tracking.
- Shipping.
- Geographic Information Systems (GIS).
- Recreation.

Four Basic Functions of GPS

- Position and coordinates.
- The distance and direction between any two waypoints, or a position and a waypoint.
- Travel progress reports.
- Accurate time measurement.


Position is Based on Time
Signal leaves satellite at time "T"
T
T + 3
Signal is picked up by the receiver at time "T + 3"
Distance between satellite and receiver = "3 times the speed of light"


Pseudo Random Noise Code
Time Difference
Satellite PRN
Receiver PRN

What Time is It?

Universal Coordinated Time

Greenwich Mean Time | GPS Time + 13* | Zulu Time

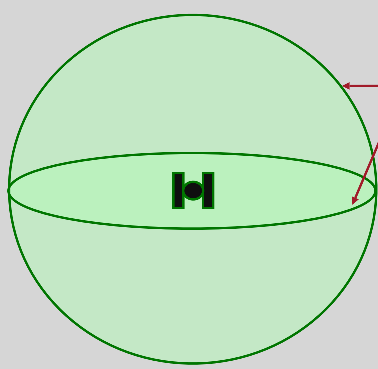
Local Time: AM and PM (adjusted for local time zone)

↕

Military Time
(local time on a 24 hour clock)

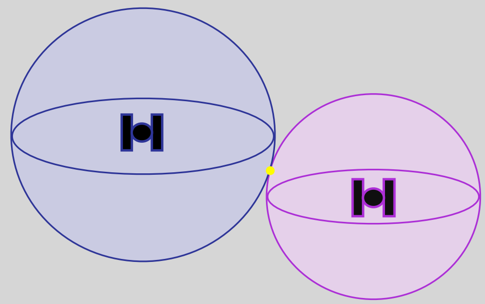
* GPS Time is ahead of UTC by approximately 13 seconds

Signal From One Satellite

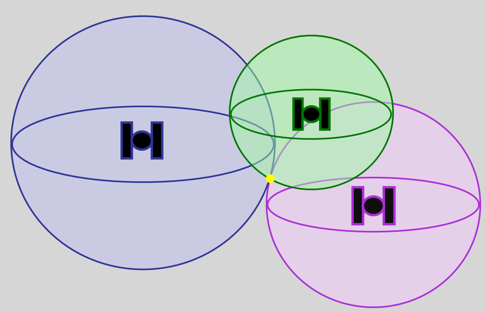


The receiver is somewhere on this sphere.

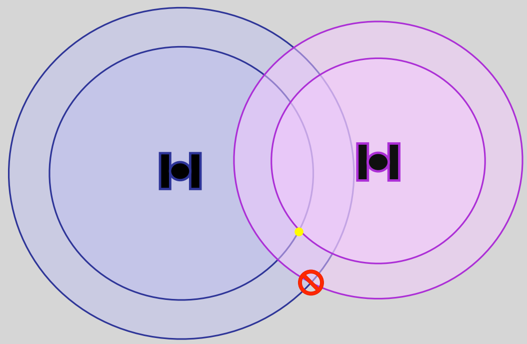
Signals From Two Satellites



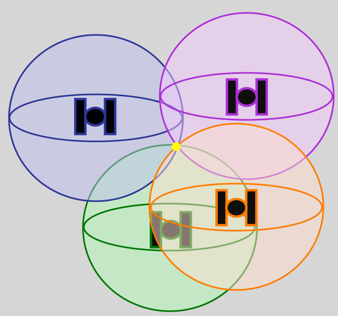
Three Satellites (2D Positioning)



Triangulating Correct Position



Three Dimensional (3D) Positioning



Selective Availability (S/A)

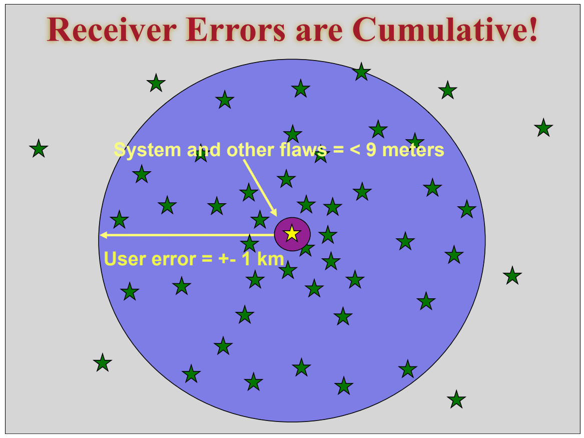
- The Defense Department dithered the satellite time message, reducing position accuracy to some GPS users.
- S/A was designed to prevent America's enemies from using GPS against us and our allies.
- In May 2000 the Pentagon reduced S/A to zero meters error.
- S/A could be reactivated at any time by the Pentagon.

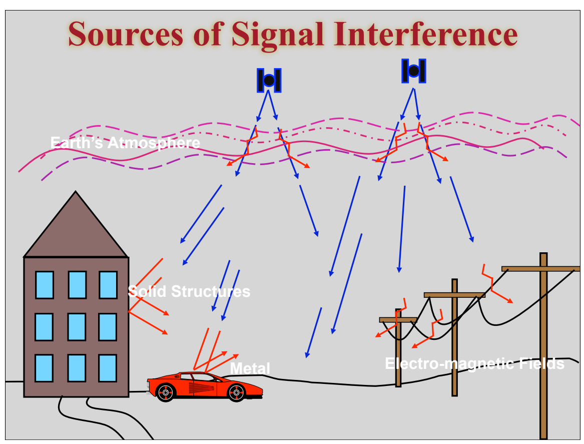
Sources of GPS Error

Standard Positioning Service (SPS): Civilian Users

Source	Amount of Error
Satellite clocks:	1.5 to 3.6 meters
Orbital errors:	< 1 meter
Ionosphere:	5.0 to 7.0 meters
Troposphere:	0.5 to 0.7 meters
Receiver noise:	0.3 to 1.5 meters
Multipath:	0.6 to 1.2 meters
Selective Availability	(see notes)
User error:	Up to a kilometer or more

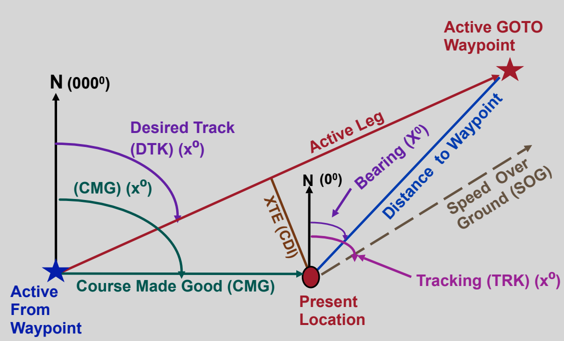
Errors are cumulative and increased by PDOP.

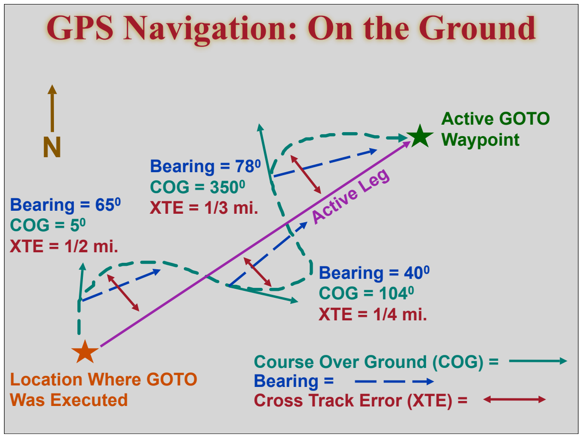

Receiver Errors are Cumulative!
System and other flaws = < 9 meters
User error = +- 1 km


Sources of Signal Interference
Earth's Atmosphere
Solid Structures
Metal
Electro-magnetic Fields

Using GPS Receivers for Positioning and Navigation

GPS Navigation Terminology





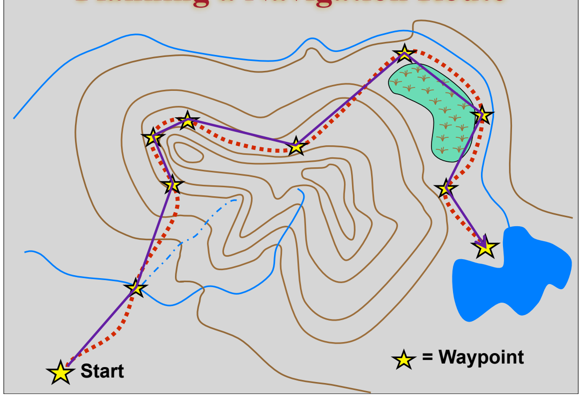
Position Fix

- A position is based on real-time satellite tracking.
- It's defined by a set of coordinates.
- It has no name.
- A position represents only an *approximation* of the receiver's true location.
- A position is not static. It changes constantly as the GPS receiver moves (or wanders due to random errors).
- A receiver must be in 2D or 3D mode (at least 3 or 4 satellites acquired) in order to provide a position fix.
- 3D mode dramatically improves position accuracy.

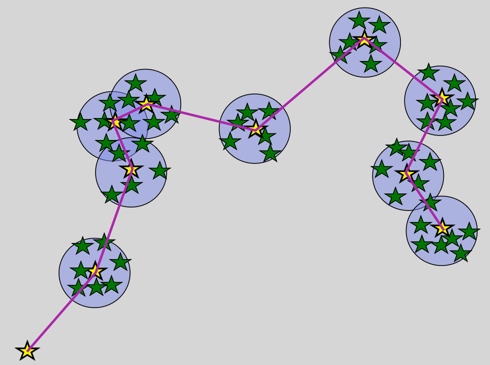
Waypoint

- A waypoint is based on coordinates entered into a GPS receiver's memory.
- It can be either a saved position fix, or user entered coordinates.
- It can be created for any remote point on earth.
- It must have a receiver designated code or number, or a user supplied name.
- Once entered and saved, a waypoint remains unchanged in the receiver's memory until edited or deleted.

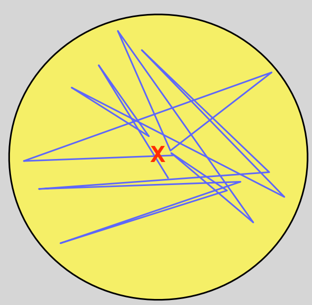
Planning a Navigation Route



How A Receiver Sees Your Route



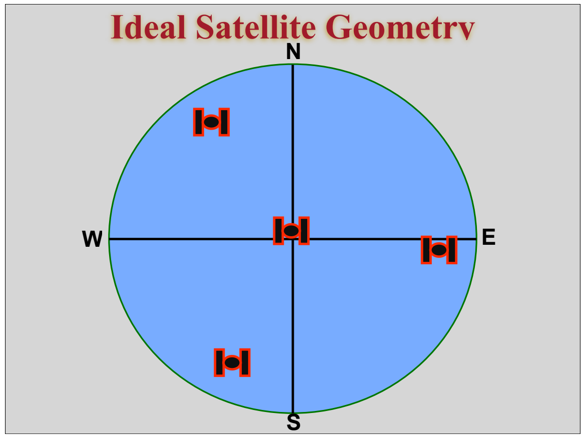
GPS Waypoint Circle of Error

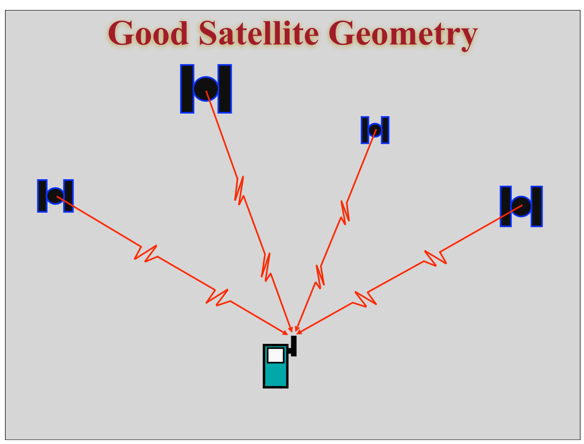


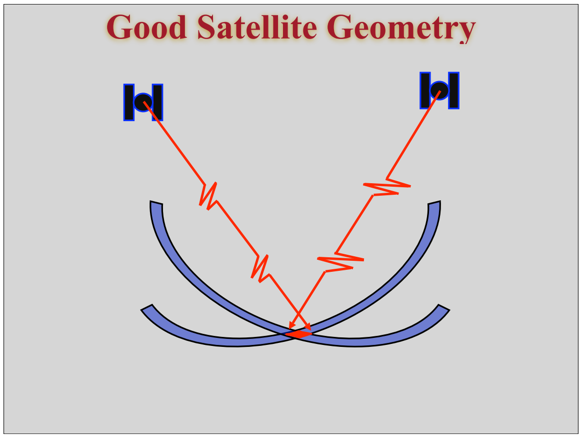
GPS Dilution of Precision and Its Affects On GPS Accuracy

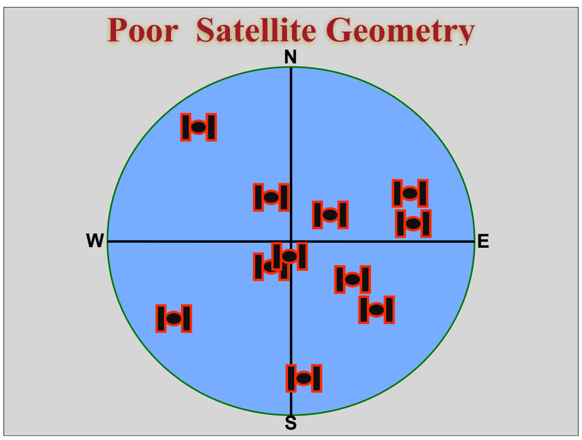
GPS Satellite Geometry

- Satellite geometry can affect the quality of GPS signals and accuracy of receiver trilateration.
- Dilution of Precision (DOP) reflects each satellite's position relative to the other satellites being accessed by a receiver.
- There are five distinct kinds of DOP.
- Position Dilution of Precision (PDOP) is the DOP value used most commonly in GPS to determine the quality of a receiver's position.
- It's usually up to the GPS receiver to pick satellites which provide the best position triangulation.
- Some GPS receivers allow DOP to be manipulated by the user.

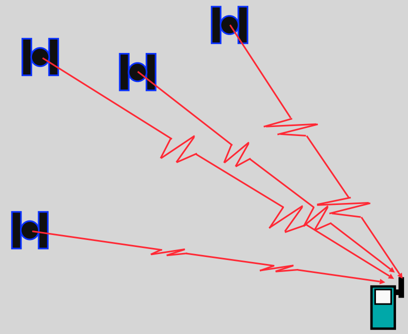

Ideal Satellite Geometry
N
W
E
S


Good Satellite Geometry

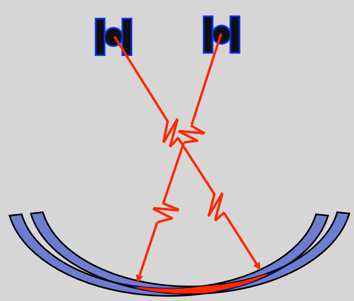

Good Satellite Geometry


Poor Satellite Geometry
N
W
E
S

Poor Satellite Geometry

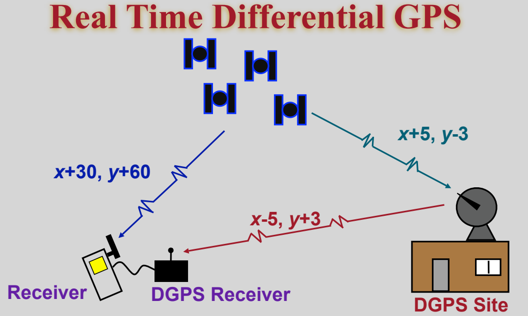


Poor Satellite Geometry



Differential GPS

Real Time Differential GPS



True coordinates = $x+0$, $y+0$

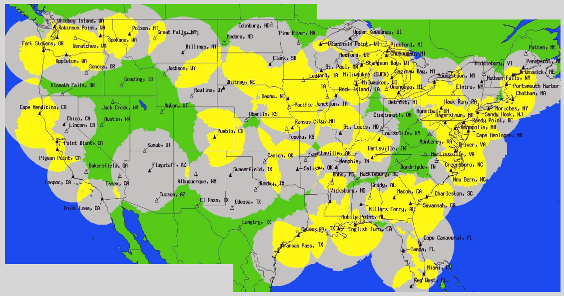
Correction = $x-5$, $y+3$

DGPS correction = $x+(30-5)$ and $y+(60+3)$

True coordinates = $x+25$, $y+63$

NDGPS Ground Stations

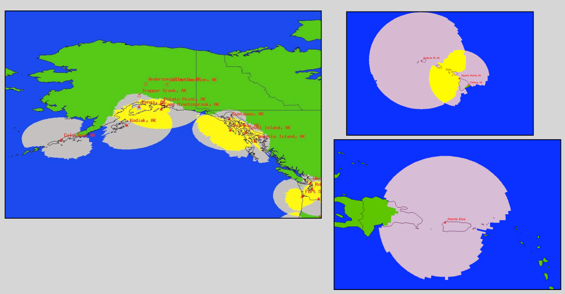
National Differential Global Positioning System



Yellow areas show overlap between NDGPS stations. Green areas are little to no coverage. Topography may also limit some areas of coverage depicted here.

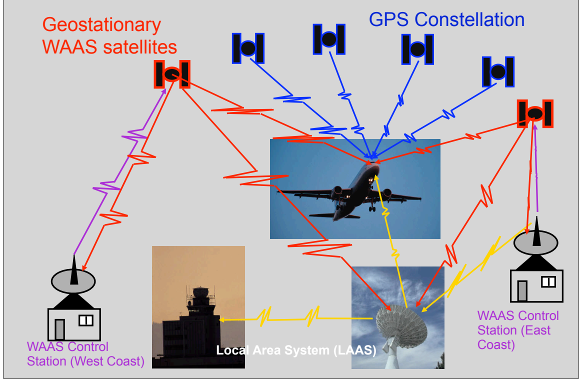
NDGPS Ground Stations

National Differential Global Positioning System



Yellow areas show overlap between NDGPS stations. Green areas are little to no coverage. Topography may also limit some areas of coverage depicted here.

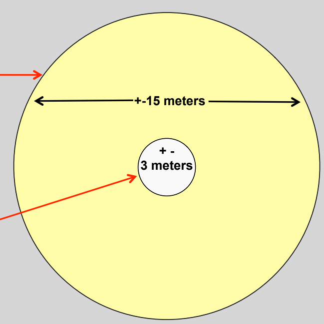
Wide Area Augmentation System



How good is WAAS?

With Selective Availability set to zero, and under ideal conditions, a GPS receiver without WAAS can achieve fifteen meter accuracy most of the time.*

Under ideal conditions a WAAS equipped GPS receiver can achieve three meter accuracy 95% of the time.*



* Precision depends on good satellite geometry, open sky view, and no user induced errors.