Introduction to NAVSTAR GPS
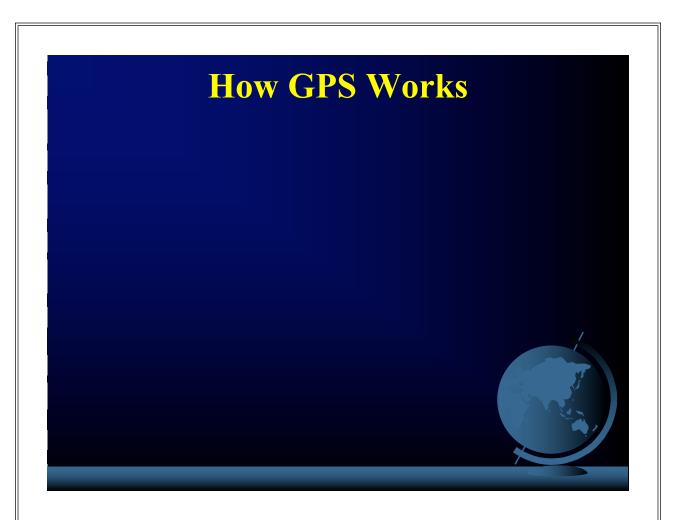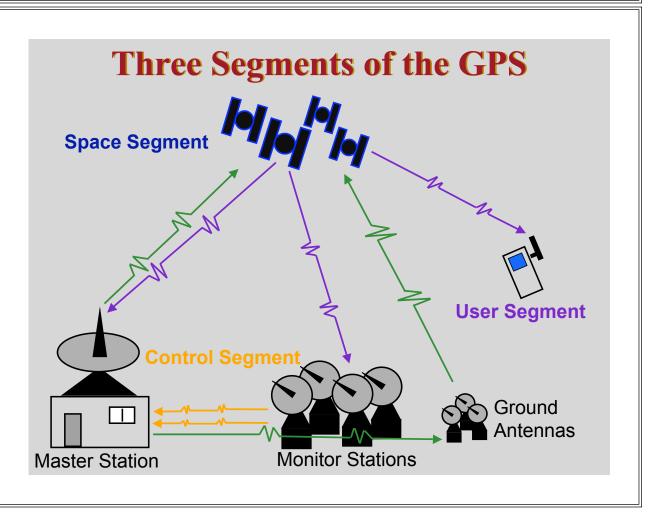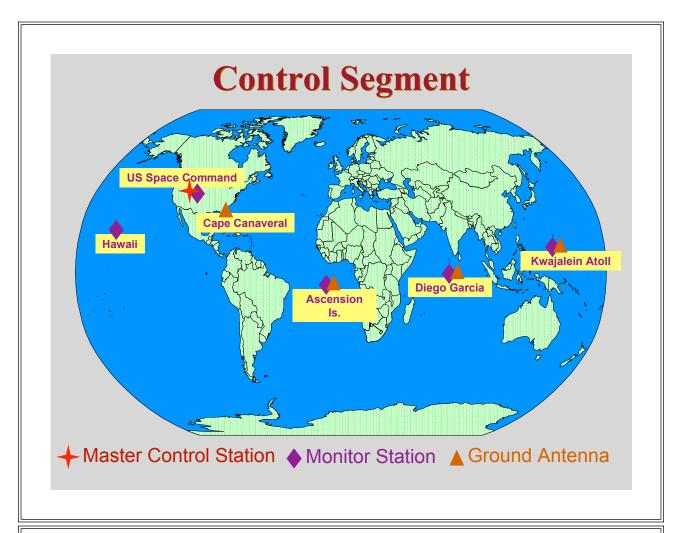
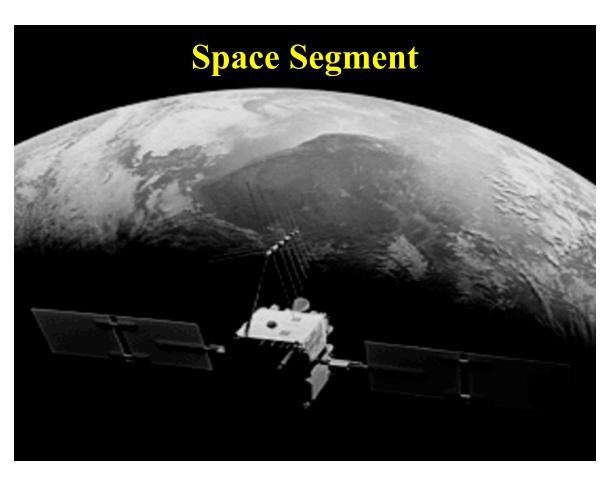Charlie Leonard, 1999
(revised 2001, 2002)

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

Space Segment

Control Segment

User Segment

Master Station

Monitor Stations

Ground Antennas

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
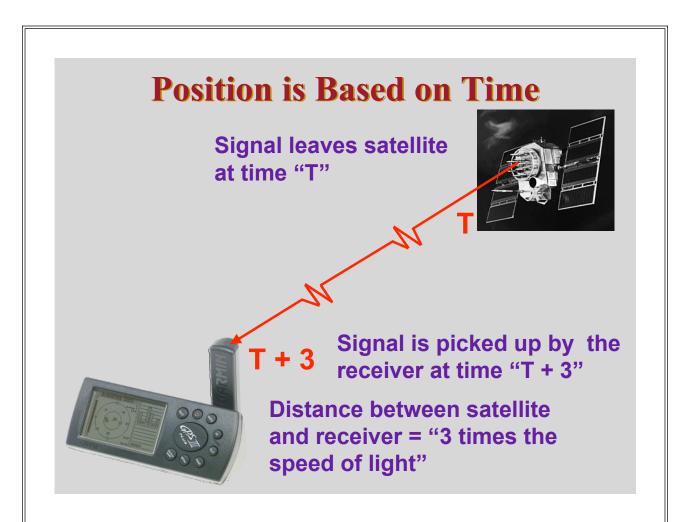
➢ Military.

➢ Search and rescue.

➢ Disaster relief.

➢ Surveying.

➢ Marine, aeronautical and terrestrial navigation.

➢ Remote controlled vehicle and robot guidance.

➢ Satellite positioning and tracking.

➢ Shipping.
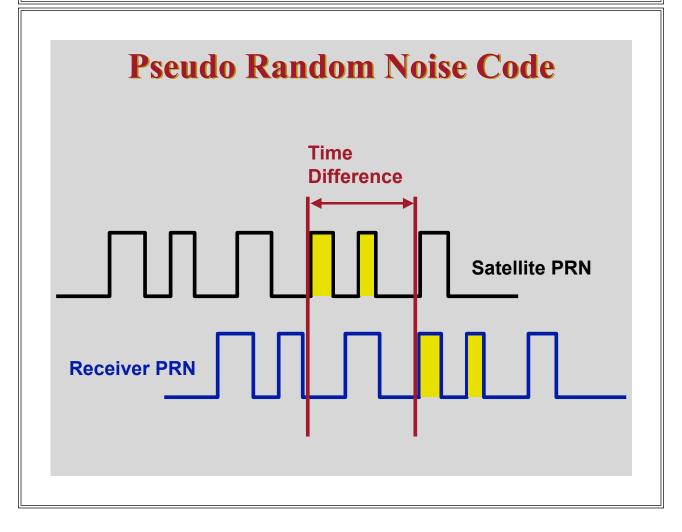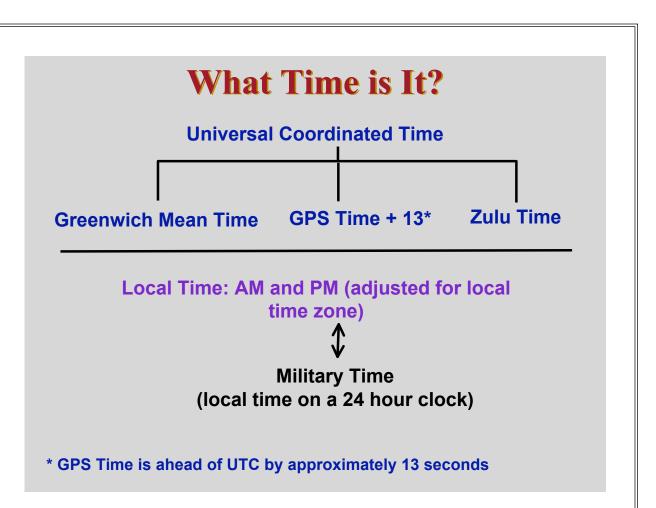
➢ Geographic Information Systems (GIS).
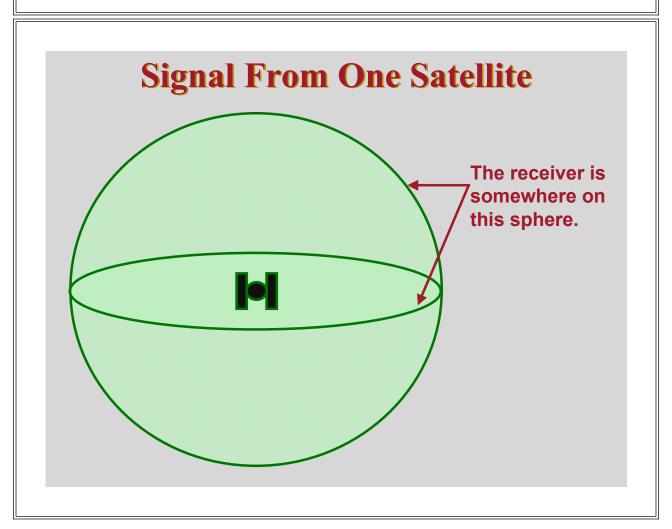
➢ Recreation.

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)

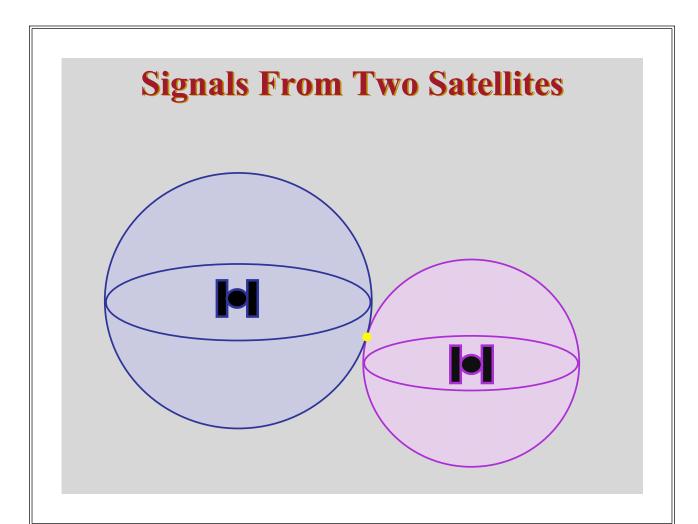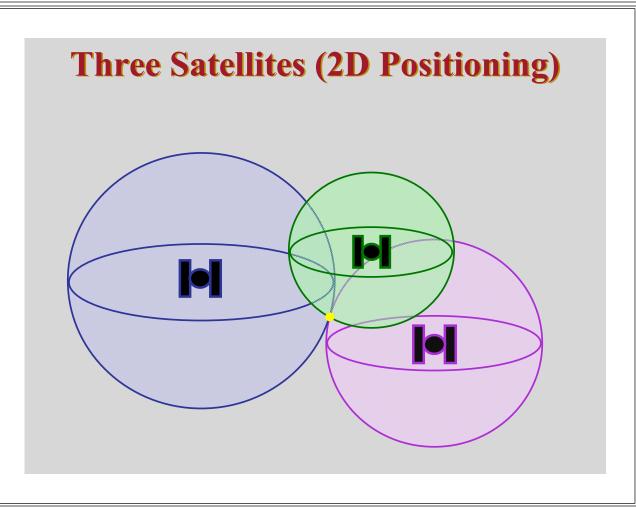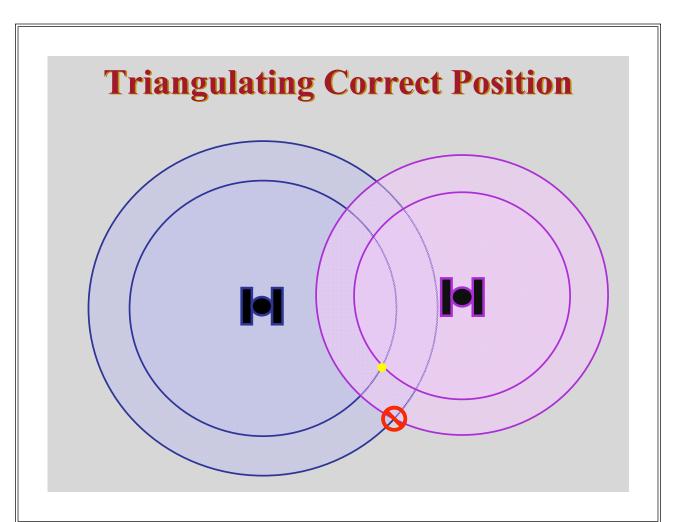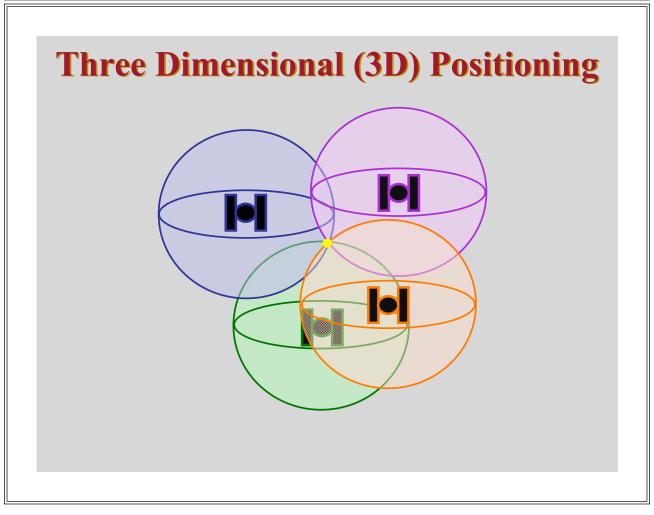# Triangulating Correct Position

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

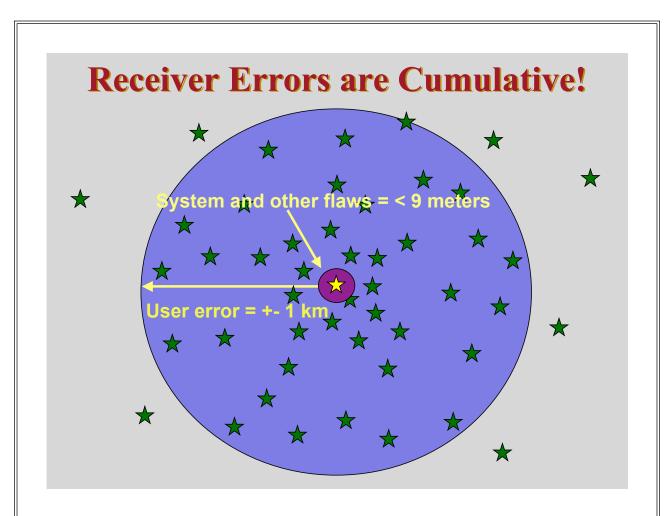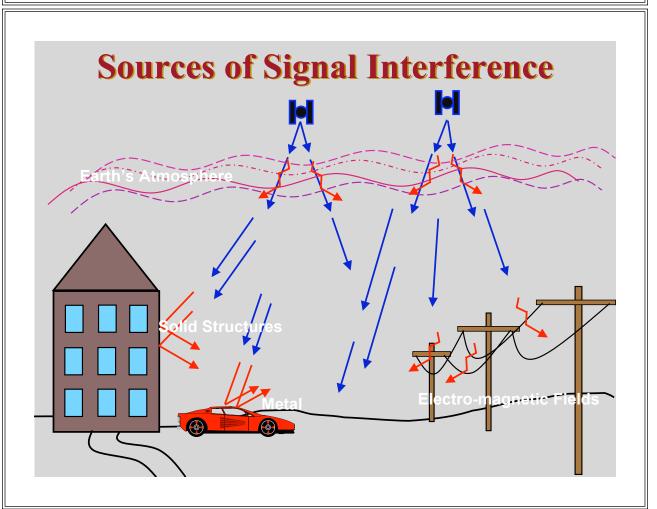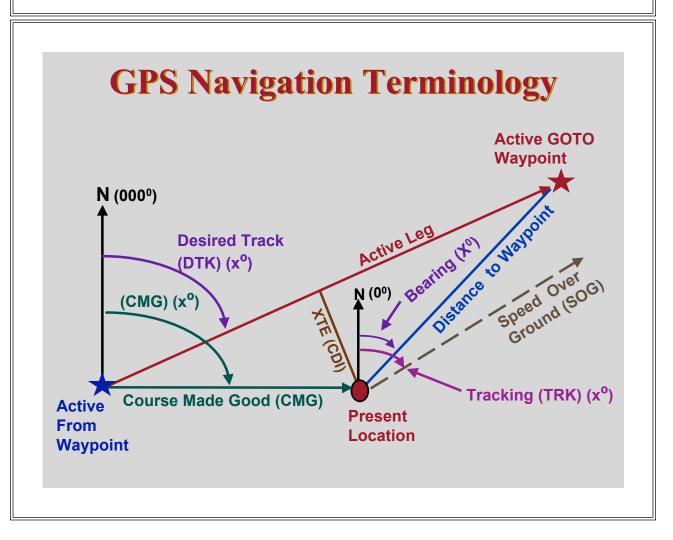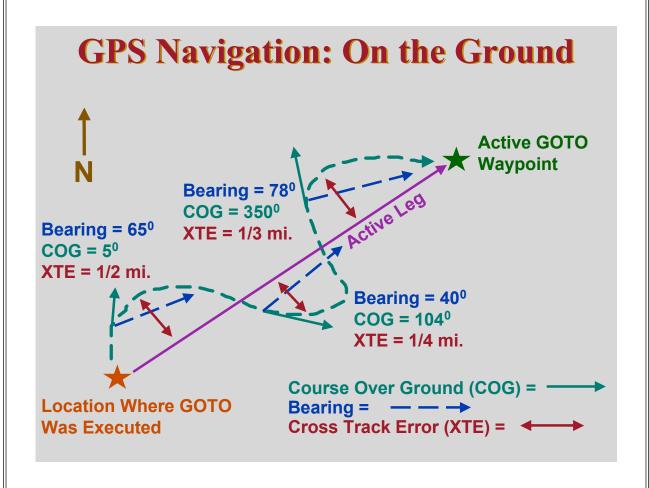| Source	Amount of Error
Satellite clocks:	1.5 to 3.6 meters
Orbital errors:	< 1 meter
Ionosphere:	5.0 to 7.0 meters
Troposphere:	0.5 to 0.7 meters
Receiver noise:	0.3 to 1.5 meters
Multipath:	0.6 to 1.2 meters
Selective Availability	(see notes)
User error:	Up to a kilometer or more

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

GPS Navigation: On the Ground

N

Active GOTO
Waypoint

Bearing = 78^0
COG = 350^0
XTE = 1/3 mi.

Active Leg

Bearing = 65^0
COG = 5^0
XTE = 1/2 mi.

Bearing = 40^0
COG = 104^0
XTE = 1/4 mi.

Location Where GOTO
Was Executed

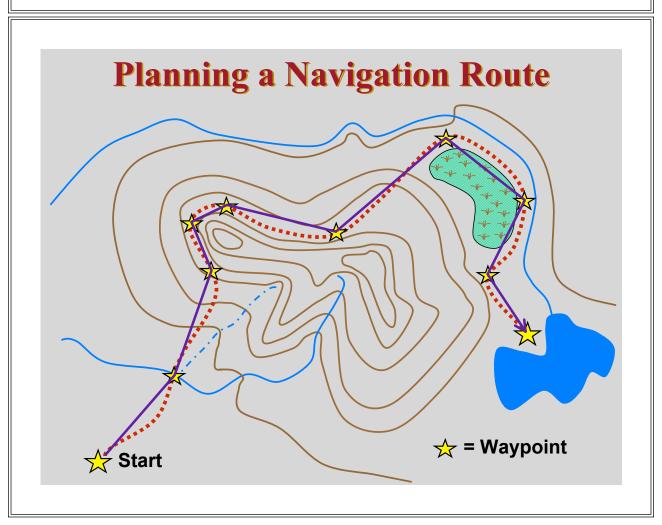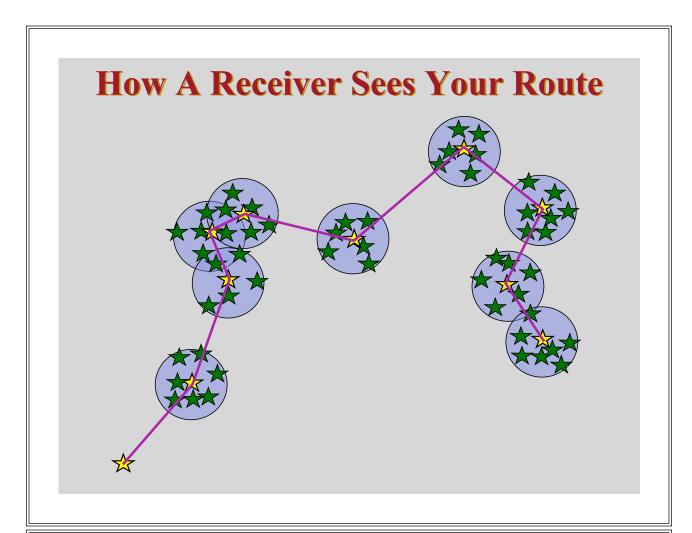Course Over Ground (COG) =
Bearing =
Cross Track Error (XTE) =

Position Fix
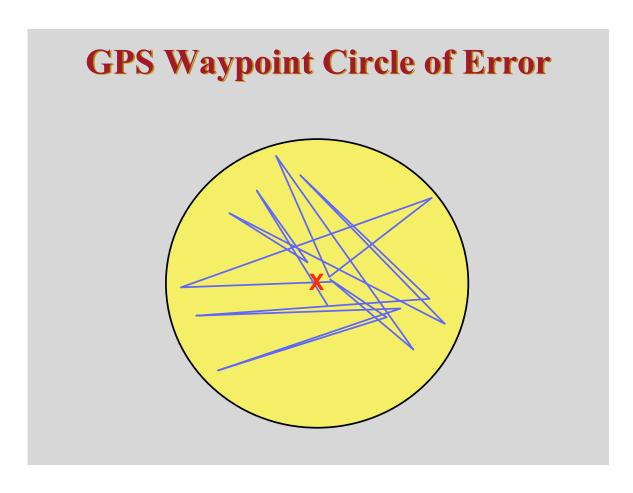
➤ A position is based on real-time satellite tracking.

➤ 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.
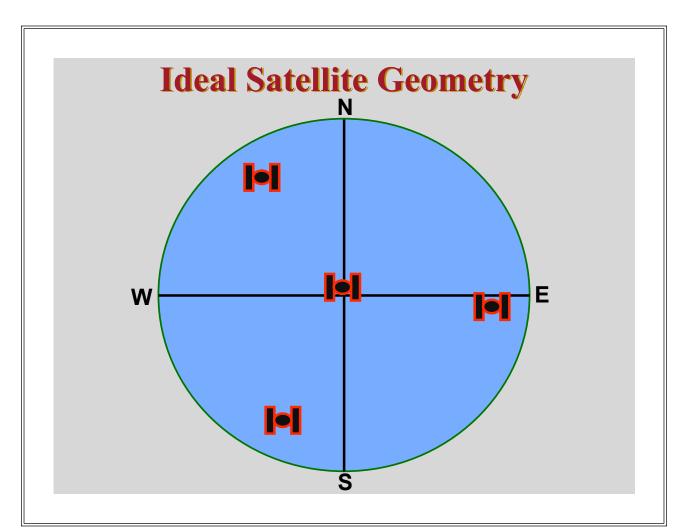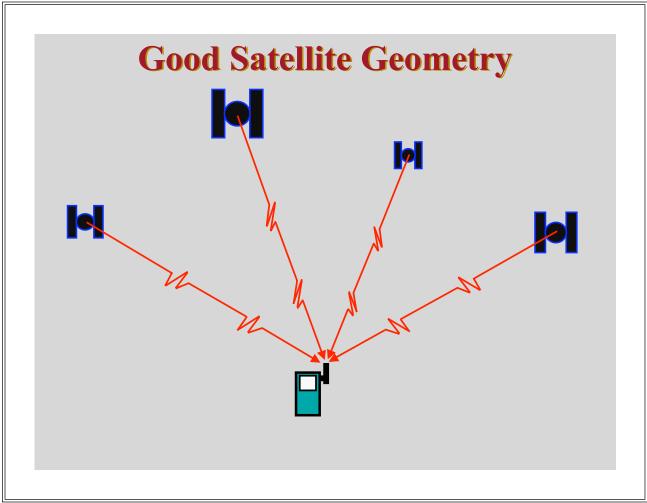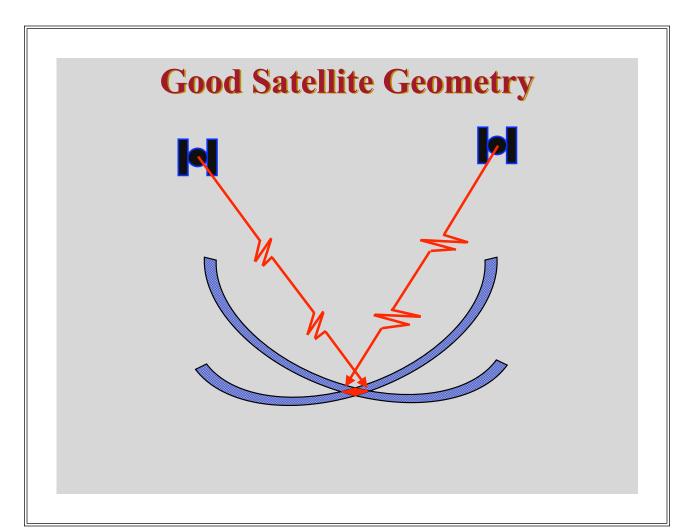- Once entered and saved, a waypoint remains unchanged in the receiver's memory until edited or deleted.

Planning a Navigation Route

☆ Start

☆ = Waypoint

How A Receiver Sees Your Route

GPS Waypoint Circle of Error

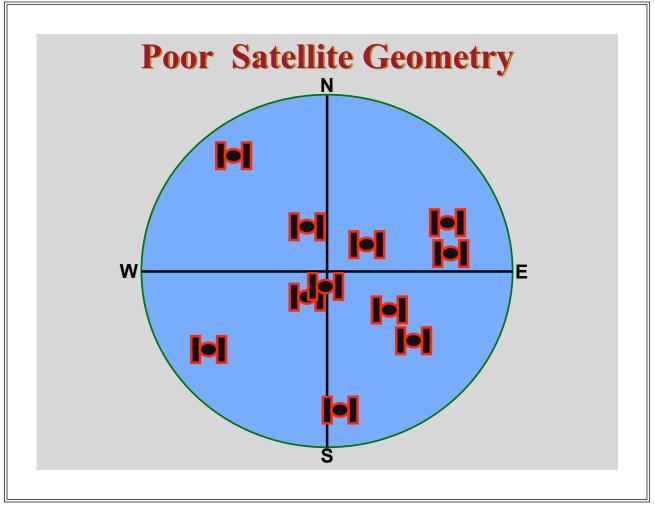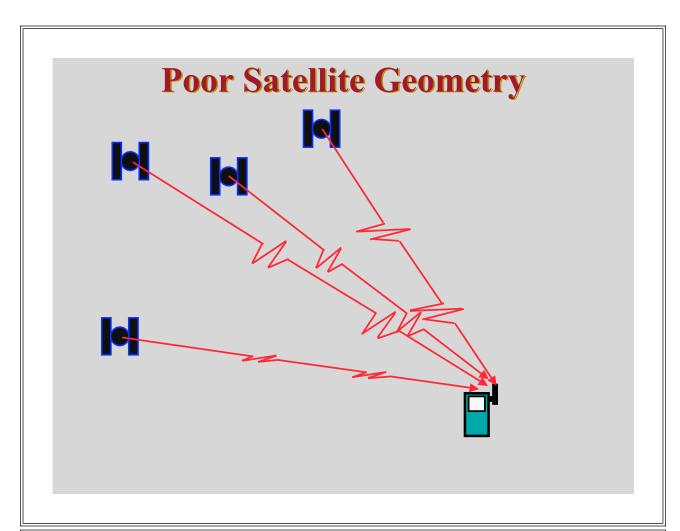# GPS Dilution of Precision and Its Affects On GPS Accuracy

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

Good Satellite Geometry

Good Satellite Geometry

Poor Satellite Geometry

Poor Satellite Geometry

Poor Satellite Geometry

Differential GPS

Real Time Differential GPS

x+5, y-3

x+30, y+60

x-5, y+3

Receiver   **DGPS Receiver**

DGPS Site
True coordinates = x+0, y+0

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

True coordinates = x+25, y+63
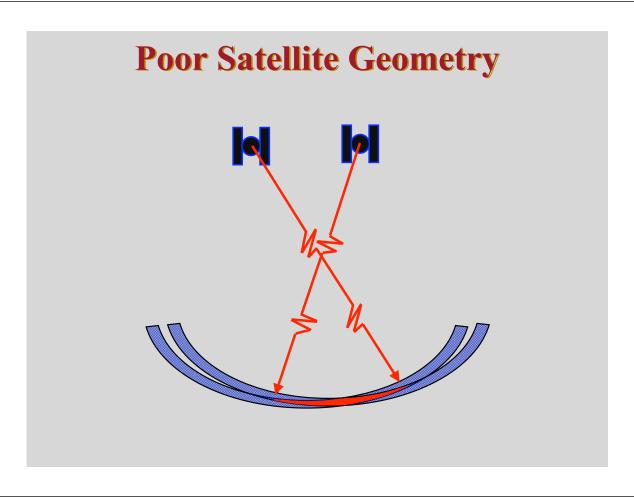
Correction = x-5, y+3

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.
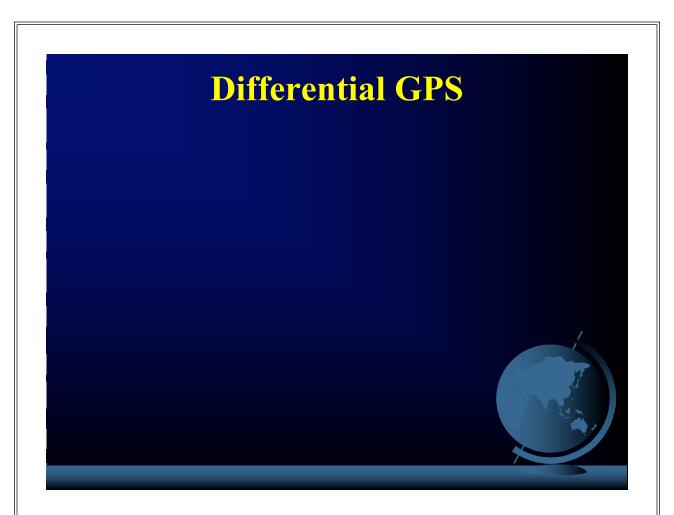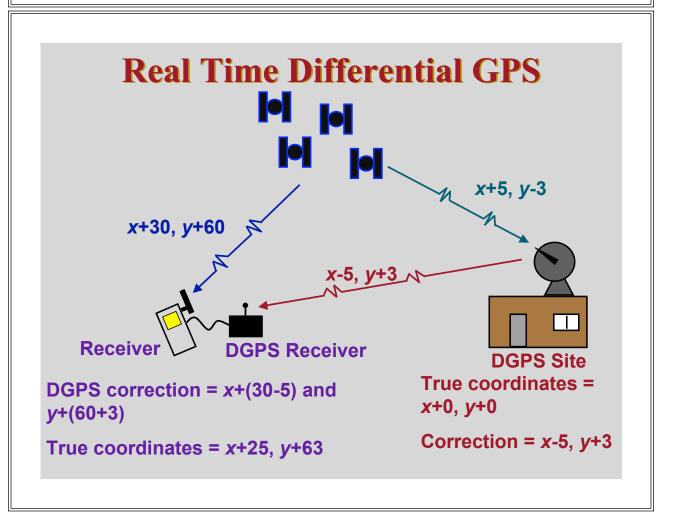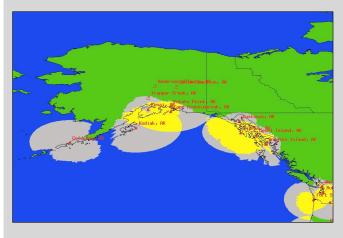
NDGPS Ground Stations
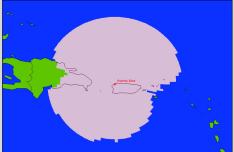## National Differential Global Positioning System

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

Geostationary
WAAS satellites

GPS Constellation

WAAS Control
Station (West Coast)

Local Area System (LAAS)

WAAS Control
Station (East
Coast)

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.*

+-15 meters

+ -
3 meters

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.