Introduction to NAVSTAR GPS


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

The History of GPS
How GPS Works

Three Segments of the GPS

- Space Segment
- Control Segment
- User Segment

Master Station, Monitor Stations, Ground Antennas
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”

Distance between satellite and receiver = “3 times the speed of light”

Signal is picked up by the receiver at time “T + 3”

Pseudo Random Noise Code

Receiver PRN
Satellite PRN

Time Difference
**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

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount of Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite clocks:</td>
<td>1.5 to 3.6 meters</td>
</tr>
<tr>
<td>Orbital errors:</td>
<td>&lt; 1 meter</td>
</tr>
<tr>
<td>Ionosphere:</td>
<td>5.0 to 7.0 meters</td>
</tr>
<tr>
<td>Troposphere:</td>
<td>0.5 to 0.7 meters</td>
</tr>
<tr>
<td>Receiver noise:</td>
<td>0.3 to 1.5 meters</td>
</tr>
<tr>
<td>Multipath:</td>
<td>0.6 to 1.2 meters</td>
</tr>
<tr>
<td>Selective Availability</td>
<td>(see notes)</td>
</tr>
<tr>
<td>User error:</td>
<td>Up to a kilometer or more</td>
</tr>
</tbody>
</table>

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

- **Tracking (TRK)**: The direction of travel relative to the present location.
- **Distance to Waypoint**: The distance between the present location and the active GOTO Waypoint.
- **Course Made Good (CMG)**: The direction the vessel is actually making progress.
- **Active GOTO Waypoint**: The waypoint being navigated to.
- **Active Leg**: The leg from the present location to the active GOTO Waypoint.
- **Desired Track (DTK)**: The intended track to the active GOTO Waypoint.
- **Present Location**: The current position of the vessel.
- **Speed Over Ground (SOG)**: The speed of the vessel over the ground.
- **Active From Waypoint**: The active waypoint from which the navigation is being performed.
- **XTE (CDI)**: Cross Track Error (Course Deviation Indicator).
GPS Navigation: On the Ground

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.
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.
How A Receiver Sees Your Route

GPS Waypoint Circle of Error
GPS Dilution of Precision and Its Affects On GPS Accuracy

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

DGPS Site

x + 30, y + 60

x + 5, y - 3

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

Real Time Differential GPS

DGPS Receiver

Receiver

x + 30, y + 60

x - 5, y + 3

DGPS Site

True coordinates = x + 0, y + 0

Correction = x - 5, y + 3
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?

+ -3 meters
+-15 meters

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.