Topic Series 12

Global Positioning Systems and Use

I. The GPS System: Satellites and Receivers

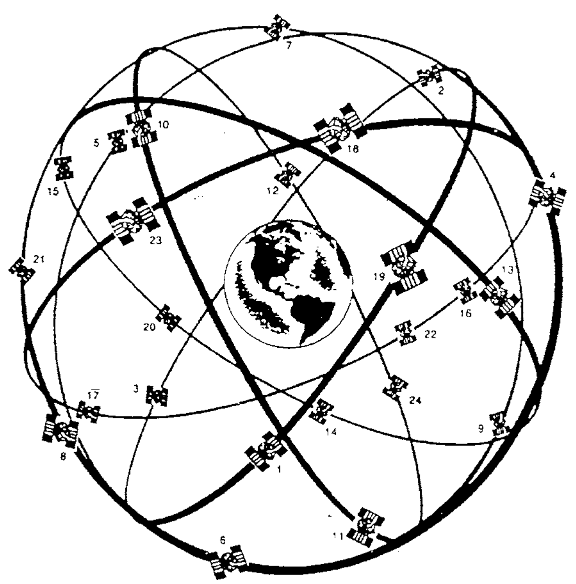
GPS (Global Positioning System) was developed by the Department of Defense (DOD) for military use but is used heavily by civil users worldwide. It is a system of satellites that orbit the earth and transmit information than can be used to determine the receiver's location in x,y,z anywhere on the globe. **What is x, y, z?**

The system can be divided into **three components (segments)**:

1. **Space Segment**
2. **Control Segment**
3. **User Segment**

Space Segment:

Currently there are currently 27 satellites and all are operational. None of the satellites have a fixed altitude, but do have a regular grid pattern.



Satellite altitude is approximately 12,600 miles above the earths surface and each satellite makes approximately 2 orbits per 24 hours. If the earth's circumference is approximately 25,000 miles, what is the approximate speed of a satellite if you disregard the rotation of the earth? Answer: from $C = \pi D$; the earth's diameter is approximately 7,957.7 miles thus the diameter of the orbit is (2 *12,600+7,957.7) or 33,257.7 miles and the equivalent orbital circumference is 104,167.99 miles; which translates to 8,680.7 miles per hour during a 12 hour orbit.

Control Segment:

A system of tracking stations worldwide checks the satellites on regular basis for accuracy.

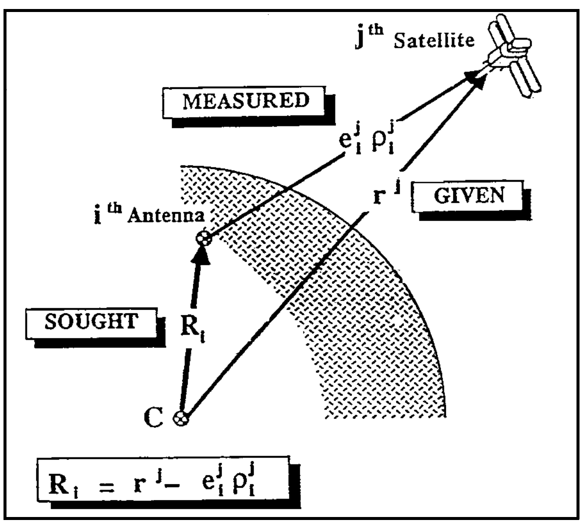
The control segment (1) computes and corrects **orbital ephemeris** (orbit characteristics), (2) computes and updates current (Greenwich Mean/Zulu) clock data for the satellites, and (3) corrects the almanac which defines the orbit of each operational satellite.

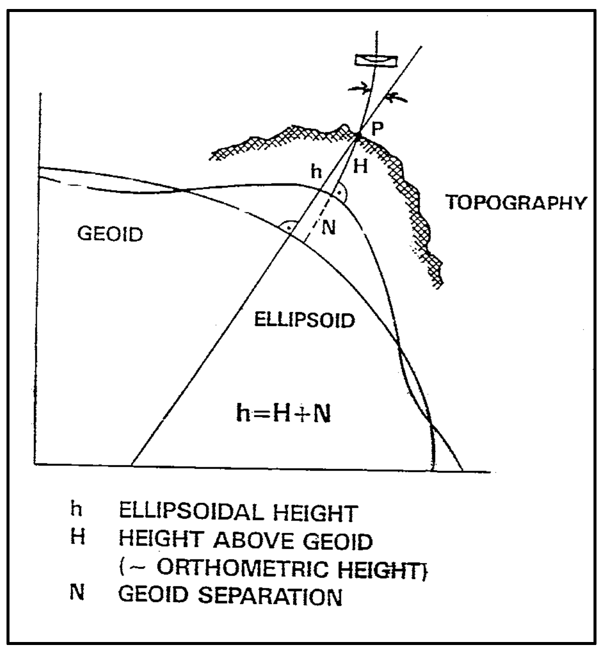
These orbital and time data are updated for each satellite so the satellites are transmitting the correct information to ground receivers.

User Segment:

GPS receivers use data transmitted by the satellites to calculate **position, velocity, and time.** Each satellite signal is transmitted on a fundamental frequency of 10.23 MHz and then received on dual frequencies: L1 @ 1575.42 MHz , C/A code @1.023 MHz, and P-Code @ 10.23 MHz; and L2 @ 1227.60 MHz and P-Code @ 10.23 MHz. The type of GPS receiver determines which frequency is received and the resulting accuracy.

Four satellites are needed for an x,y,z fix; x/y coordinates can be received with 3 satellites, but the 4th satellite is needed for the z (elevation) coordinate.





Receivers come in many forms that can be used in **ships, airplanes, ground vehicles, or hand held.** In airplanes, the GPS signal can be used for navigation from point to point and for obtaining simultaneous elevation (altitude) information. GPS receivers are also an extremely accurate way to obtain precise time for a variety of applications: telecommunications, research.

II. GPS Services and Data Accuracy

The GPS signals are received under two distinct service systems:

<u>Precise Positioning System (PPS)</u>

The PPS is available to the U.S. military and some government agencies with special security clearance.

The PPS services have an accuracy of 17.8 m horizontal, 27.7 m vertical, and 100 ns update time.

<u>Standard Positioning System (SPS)</u>

The SPS is available to civilian users worldwide at no cost.

The accuracy is degraded by the Department of Defense (DOD) with Selective Availability.

Selective Availibility (SA) means the GPS signals are regularly biased/distorted (more or less randomly) so that the lat/long position of the receiver is biased/distorted.

The SPS has an accuracy of +/-100 m horizontal (95% of the time), 156 m vertical, and 167 ns time update time.

III. How GPS Works

<u>Each satellite transmits:</u>

time the signal leaves the satellite (degraded by selective availability),
and **satellite ephemeris** (who I am, where I should be)

A receiver takes the time code and determines where the satellite should be based on the ephemeris data. With **three separate satellites** the receiver can solve its position in **2-D (x,y)**. **Four satellites** will give positions in **3-D (x,y,z)**.

Selective availability is used to degrade the time signal so that a less precise solution is obtained with receivers that do not know how the signal is being biased.

Velocity is calculated by getting the differences between positions over time.

IV. Sources of Errors

The major **sources of error in GPS** are:

Noise
Bias
Blunders

<u>Noise:</u>

Noise has a relatively small effect on transmission error and electronic error in receivers; errors are generally a few meters.

<u>Bias:</u>

Selective Availability bias is different for each satellite so the error is a function of the specific satellites used for the position solution. Generally with SA on, the result is that **95% of the observations** for position are **within 100m** of true position. Height/elevation precision is approximately 1.7 times the horizontal precision.

Other biases occur due to things like small delays due to **atmospheric conditions** and **multi-path** (receiver getting signal reflections from objects rather than straight line signals from satellites).

<u>Blunders:</u>

Blunders are mistakes carried in control segment data, incorrect geodetic datum, receiver errors/failures.

V. GPS Precision and Differential Correction

<u>Position Dilution of Precision (PDOP):</u>

PDOP is a term used to indicate how good satellite geometry is for position solution; i.e. what is the best position of satellites for solution of the trigonometry.

<u>Differential correction</u>:

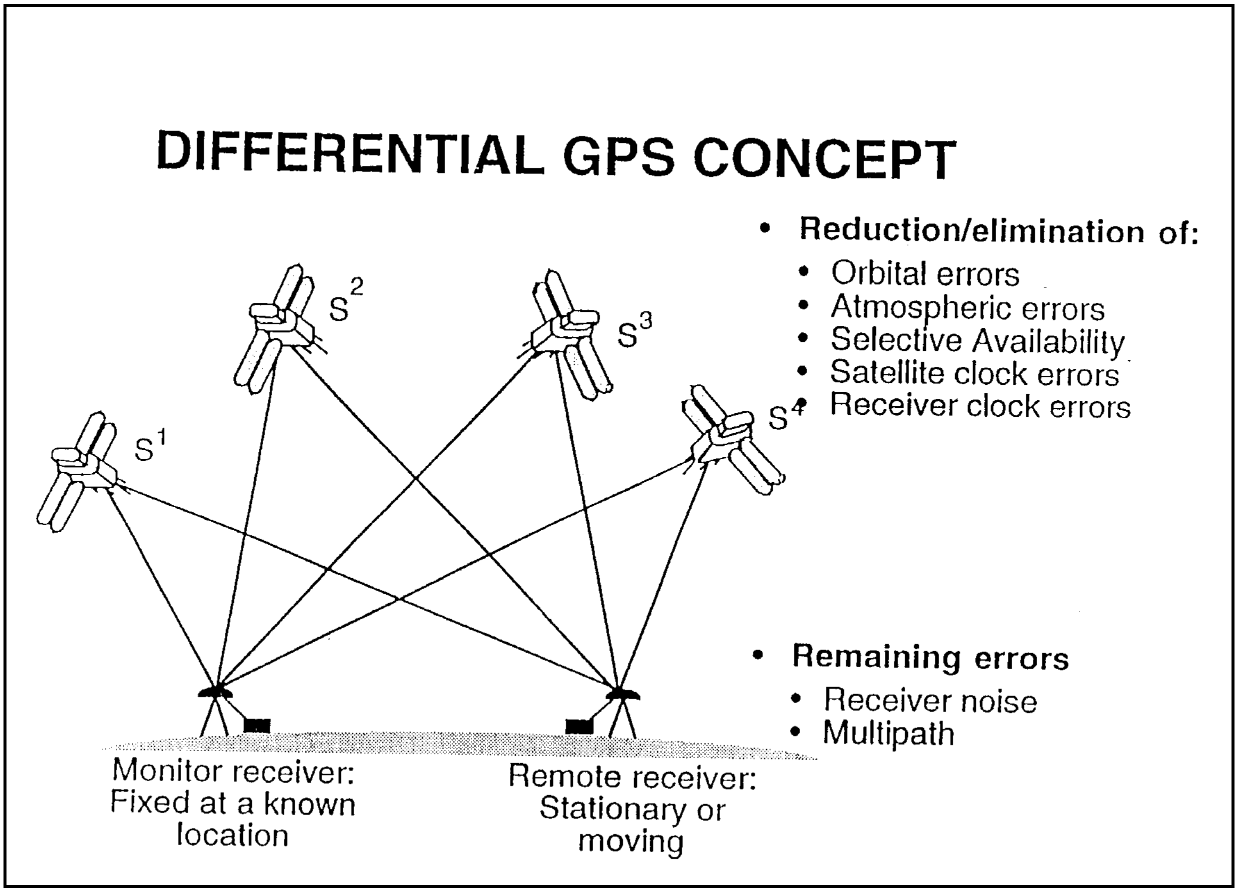
Differential Correction is accomplished by using **two receivers**; one moving and one located on a **known location** in terms of lat/longs/elevation.

The **rover** receiver collects position data at unknown locations. The data from the roving receiver may have several sources of error. If both receivers collect data from the same set of satellites, then the data from the known position can be used to determine the magnitude of errors to correct the data from the receiver used on the unknown locations.
Differential Correction can be done:

a. with **post processing** on a computer to meter/centimeter accuracy, or

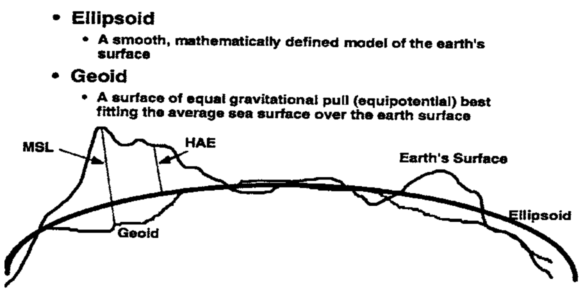
b. in **real time** by using a computer and an **FM radio** or a **Geostationary Satellite link** to get the known position data with the rover data and collect on the fly; accuracy is less than 1 meter.

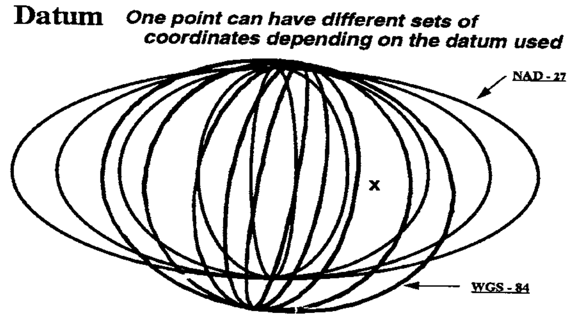
VI. Datums and Altitude References



Datums and coordinate systems are fundamental to GPS. In order to use GPS data with existing map data, both must be referenced to the same datum and coordinate system.

The 3D coordinate system used for satellite positioning is called the earth-centered **Cartesian coordinate system**. The origin is the center of the earth's mass. The X-direction is the Greenwich meridian (0 degree Longitude), the Y-direction is the 90 degree east longitude, and the Z direction is the northerly rotational axis of the earth. Geographic coordinates (latitude, longitude, and height) are given for a given reference ellipsoid. An **ellipsoid** is a 3D mathematical figure/surface formed by rotating an ellipse around its minor axis (earth's polar axis). A **geoid** is a surface that undulates and is sensitive to gravity forces such as Mean Sea Level (MSL).





GPS **altitude** is the vertical distance above the ellipsoid or geoid. Altitude is generally stored in a GPS receiver as height above an ellipsoid but it can be displayed as height above MSL.

Geodetic datum is a mathematical model designed to fit a geod, defined as the relationship between an ellipsoid and a point on the topographic surface established as the origin of the datum. World geodetic datums are defined by the size and shape of an ellipsoid and the location of the center of the ellipsoid with respect to the center of the earth. Maps in the U.S. are based on the North American Datum of 1927 (i.e. NAD 27) or 1983 (NAD 83). All GPS coordinates are based on the World Geodetic System (WGS 84). There is very little difference betwen NAD 83 and WGS 84.

VII. Choosing the GPS Receiver/System You Need

* Accuracy needed
* Realtime vs. post-processing data access
* Fixed station vs. moving platform applications
* Level of reliability required

VIII GPS Applications in Forestry

Mapping:
New and existing roads, streams, stand boundaries, clearcuts, regeneration areas, fires

Area/Acreage Determination:
Stands, regeneration areas, aerial spray areas, fires

Point Location:
CFI inventory plot centers, SPBB spots, RCW colonies, control points for mapping

Acquisition of Aerial Imagery:
Aerial photography missions (flight lines, property boundaries), digital imagery

Data Collection Concepts

- **Feature: An object that can be described as a point, line, or polygon**
- **Attribute: Information about the object**
  - **Species, DBH, Age, Height, number**

  Value: The attribute results
  - **Loblolly Pine, 17.5 inches, 45 years, 87 ft, 4**

Feature

An Object that can be described as a:

» **Point** = **Tree, Lightpole, specific location**

» **Line** = **Stream/road centerline, boundary line**

» **Area/Polygon** = **Timber stand, field**

Attribute

Information about the object

» **Species, DBH, Age Height, number**

Attribute Values

The answers to the attribute questions

» **Loblolly Pine, 17.5 inches, 45 years, 87 ft**

GPS Collection of a Point

1. **Standard Point**
   GPS receiver is placed at exact point location

2. **Offset Point**
   Location of the point is calculated from a user-
   » described distance,
   » azimuth, and
   » slope from the GPS receiver.

3. **Nested Point**
   Location is the average of multiple points

GPS Collection of a Line or Area

1. **A number of GPS position fixes (X, Y, Z) are connected to follow the course of a line or the boundary of an area/polygon**

2. **Modes** = static or dynamic
   » Static = assumes GPS receiver is in motion
   » Dynamic= assumes GPS receiver is stationery

3. **Interval** = how often a GPS fix is recorded
   » Seconds or Distance

4. **Offset** = distance and direction of actual point/line from GPS unit
   » feet and/or azimuth of point/line from unit

Data Dictionary or Feature List

Name	Type	Mode	Interval	Attribute
Exercise Area	Area	Dynamic	1 second	Area #
Side Walk	Line Offset	Dynamic w/	1 second	none
Light Pole	Point	Static	5 readings	Pole #
Storm Drain	Point	Static	5 readings	Drain #
Tree	Point	Static	5 readings	Species DBH

Differential Correction with CMTs

A. Manual Correction

Obtain bench mark data from the: Ms Dept of Environmental Quality web site for Central or Northern region (i.e. Jackson, MS) at:

http://geology.deq.state.ms.us/gps/default.asp

a. Download and save into a zip file the files CR for Central Rinex type or NR for Northern Rinex for the date and hour desired into the **d:\gps directory:**

Example : CR101814.zip Central Rinex
10 18 for Month, day
14 for 14 hours Zulu (GMT) or 9:00 a.m. CDT

b. Unzip the three files: *.nav
*.obs
*.hdr

c. For CMT manual use, rename the .nav and .obs files (in DOS or windows mode) to .YYn and .YYo; where YY is the last 2 digits of the year, i.e. 02 for 2002, etc.

In dos mode, change to the directory and enter the command

```
ren *.nav *.02n
ren *.obs *.02o
```

In windows mode, rename the file extensions only to .02n and .02o

d. Enter the location and elevation of the desired bench mark station:

Central: Jackson, MS	32^0 20' 20.29064" North
	90^0 08' 42,44938" West
	120.365 meters
North: Oxford, MS	34^0 21' 52.71587" North
	89^0 32' 09.49526" West
	145.012 meters

2. Differentially correct the raw GPS data.

3. Display the corrected data on the screen.

4. Export the data as shape files for use in ARC/View.

Differential Correction with CMTs

B. Automatic Correction with Corps of Engineers data:

The national directory is: http://www.ngs.noaa.gov/CORS/cors-data.html

a. Under GPS tab, select Differential.... CA Code

b. Set directories for rover and base station files (i.e. browse and select)

c. Choose rover file to correct

d. Click on the Differential Tab (lower right)

e. Either choose to automatically locate, download and correct, or

to manually download from Millers Ferry, AL or Okalona, MS

Millers Ferry, AL	32^0 05' 24.9169" North 87^0 23' 30.5051" West 10.45 meters
Okalona, MS	34^0 05' 24.92622" North 88^0 51' 44.90106" West 107.126 meters

2. Differentially correct the raw GPS data.

3. Display the corrected data on the screen.

4. Export the data as shape files for use in ARC/View.