The Global Positioning System
A Quick Overview
Curt Crow, NGS, NOAA
Why is GPS such a big deal?

Sometimes it’s good to know where you are!!

Anyone who needs to keep track of their location, to find their way to a certain place, or know what direction and how fast they are going can utilize GPS.

GPS is great for:
- Navigation
- Recreation
- Tracking
- Surveying
- Mapping
Countless uses of GPS: map, track, find, time

GPS is usable everywhere where it's possible to receive the signal

At Sea: used for navigation by boaters, commercial fishermen, and maritime shipping.

In the Air: used for navigation by general aviation and commercial aircraft.

On Land:
  - Recreational uses are as varied as the number of recreational sports: hikers, hunters, snowmobilers, mountain bikers, cross-country skiers,
  - The scientific community uses GPS for precision timing capability and position information.
  - Surveyors use GPS for its reduced survey time and incredible accuracy.
    - Mapping units cost a few thousand dollars with accuracies down to one meter.
    - Geodetic systems cost a little more but provide accuracies to within a centimeter.

GPS in vehicles:
  - Systems provide emergency roadside assistance by transmitting your current position to a dispatch center.
  - Navigation systems show your position on a street map and suggest the best route to a designated location.
GPS Facts

Satellite Constellation

- 28 Satellites
- 6 Planes,
- 55° Rotation
- 4/5 Satellites /Plane
- 12,536 mi Orbit
- 1 Revolution /12 Hrs
## GPS Signal Structure

<table>
<thead>
<tr>
<th>Carrier</th>
<th>L1</th>
<th>L2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1575.42 MHz</td>
<td>1227.60 MHz</td>
</tr>
<tr>
<td>Wavelength</td>
<td>19cm</td>
<td>24cm</td>
</tr>
<tr>
<td>Code Modulation</td>
<td>C/A-code</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>P or Y code</td>
<td>P or Y code</td>
</tr>
<tr>
<td></td>
<td>Navigation Data</td>
<td>Navigation Data</td>
</tr>
</tbody>
</table>

- **C/A** - Coarse Acquisition Code (available for civilians)
- **P or Y** - Precise Code (military only)
- **Navigation Data** - ephemeris parameters (satellite orbits), satellite clock corrections and satellite health
Low and High Precision GPS

GPS Observables

Recreational GPS
- Code Ranges
- Lower Accuracy
- Autonomous Positioning

Geodetic GPS
- Carrier Phases
- Higher Accuracy
- Relative Positioning
Control Points in the Sky

Distance = Speed of Light \times \text{Time}
The GPS Signal

Based on the phase of the electromagnetic signal carrying the timing codes and NAVDATA

<table>
<thead>
<tr>
<th>Carrier</th>
<th>![Carrier Waveform]</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/A-code</td>
<td>![C/A-code Waveform]</td>
</tr>
<tr>
<td>P-code</td>
<td>![P-code Waveform]</td>
</tr>
<tr>
<td>NAVDATA</td>
<td>![NAVDATA Waveform]</td>
</tr>
<tr>
<td>Received Signal</td>
<td>![Received Signal Waveform]</td>
</tr>
</tbody>
</table>
Counting Wavelengths
(aka - Integer Ambiguity)

Resolving the integer ambiguity allows phase measurements to be related to distances

\[ \Delta \lambda = \text{First Partial Wavelength} \]

\[ N = \text{Integer Ambiguity} \]

\[ \text{Distance} = N + \Delta \lambda \]
Carrier Phase Differencing

\[
\text{Distance} = \frac{\text{Phase Difference}}{2\pi} \\
\lambda = (\Delta \lambda_1 - \Delta \lambda_2) + \lambda_1 (N_1 - N_2)
\]
Both receivers are held immobile on points until there is sufficient data to determine coordinates.
Real Time Kinematic (RTK) Surveying

One receiver is on a known location while measurements are made.

One receiver is in motion while measurements are made.
GPS Error Sources

Atmospheric Conditions
The ionosphere and troposphere both refract the GPS signal. This causes the speed of the GPS signal in the ionosphere and troposphere to be different from the speed of the GPS signal in space.

Ephemeris Errors/Clock Drift/Measurement Noise
GPS signals contain information about satellite orbital positions and the rate of clock drift for the broadcasting satellite. The broadcast data may not exactly model the true satellite motion or the exact rate of clock drift. Distortion of the signal by measurement noise can further increase positional error.

Selective Availability
Selective Availability (SA) is the intentional alteration of the time and ephemeris signal by the Department of Defense. Fortunately, positional errors caused by SA can be removed by differential correction and SA has been turned off since May 1, 2000.

Multipath
Multipath is caused by the GPS signal bouncing off a reflective surface before it reaches the GPS antenna. Multipath is difficult to correct even in high precision GPS units and is a serious concern to the GPS user.
## GPS Error Budget

<table>
<thead>
<tr>
<th>Source</th>
<th>Uncorrected Error Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionosphere</td>
<td>0-30 meters</td>
</tr>
<tr>
<td>Troposphere</td>
<td>0-30 meters</td>
</tr>
<tr>
<td>Measurement Noise</td>
<td>0-10 meters</td>
</tr>
<tr>
<td>Ephemeris Data</td>
<td>1-5 meters</td>
</tr>
<tr>
<td>Clock Drift</td>
<td>0-1.5 meters</td>
</tr>
<tr>
<td>Multipath</td>
<td>0-1 meter</td>
</tr>
<tr>
<td>Selective Availability</td>
<td>0-70 meters</td>
</tr>
</tbody>
</table>

Tree Canopy – The New Hampshire Wild Card
## Expected Accuracies

<table>
<thead>
<tr>
<th>Source</th>
<th>Accuracy Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous Positioning</td>
<td>5-10 meters</td>
</tr>
<tr>
<td>WAAS Corrected</td>
<td>2-5 meters</td>
</tr>
<tr>
<td>Beacon Diff. Corr.</td>
<td>1-3 meters</td>
</tr>
<tr>
<td>Local Diff. Correction</td>
<td>0.5-1.5 meters</td>
</tr>
<tr>
<td>Geodetic</td>
<td></td>
</tr>
<tr>
<td>Static or Kinematic</td>
<td>1-5 centimeters</td>
</tr>
</tbody>
</table>

& we still have those trees
SV locations
Noon to 1 pm
August 11, 2007

SV path is along arc toward SV #

8 SVs generally available at this time

If we have a clear view of the sky

SVs 1, 6, 7, 14, 16, 20, 30, 31
Be aware of obstructions when planning a project and collecting GPS data.
Number of available SVs

Common sense would indicate that GPS data collection would be optimum when the most satellites are available. Sometimes
Settings to Check on YOUR GPS

**Read the Manual!!!**

We don’t give any extra points for being too cool to *Read the Manual*.

**Position Format:**

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hddd.dddddº</td>
<td>latitude / longitude in decimal degrees</td>
</tr>
<tr>
<td>Hdddºmm.mmm’</td>
<td>latitude / longitude in degrees, decimal minutes</td>
</tr>
<tr>
<td>Hdddºmm’ss.s”</td>
<td>latitude / longitude in degrees, minutes, decimal seconds</td>
</tr>
<tr>
<td>US National Grid</td>
<td></td>
</tr>
<tr>
<td>UTM – Universal Transverse Mercator – West of longitude 72° in Zone 18, East of longitude 72° in Zone 19</td>
<td></td>
</tr>
<tr>
<td>State Plane Coordinates – New Hampshire, Transverse Mercator, Zone 2800</td>
<td></td>
</tr>
</tbody>
</table>
## Settings to Check on YOUR GPS

### Map Datum
- NAD 83 – preferred
- WGS84 – very close to NAD83 but not exactly the same +/- 1 meter

### Coordinate Units
- US Survey Feet (by statute, NOT the International Foot)

### Distance/Speed
- Your choice, I use US Feet when walking, Miles when driving

### Elevation
- Same as Coordinate Units

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Read the Manual!!! We still don’t give any extra points for NOT reading the Manual.