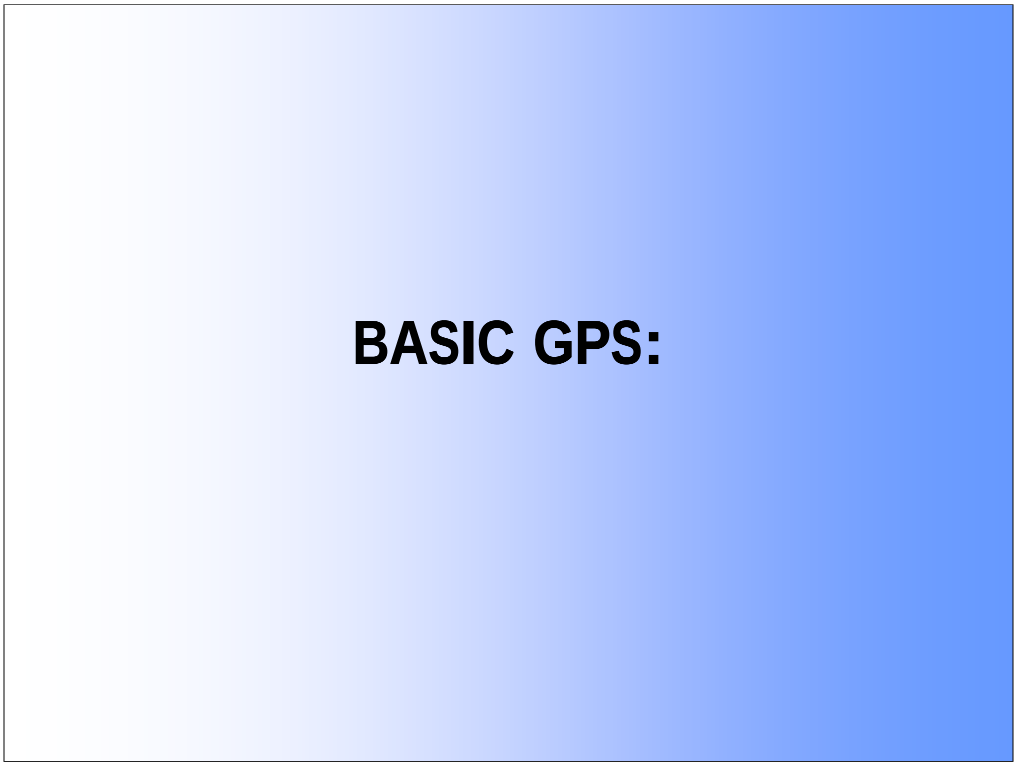
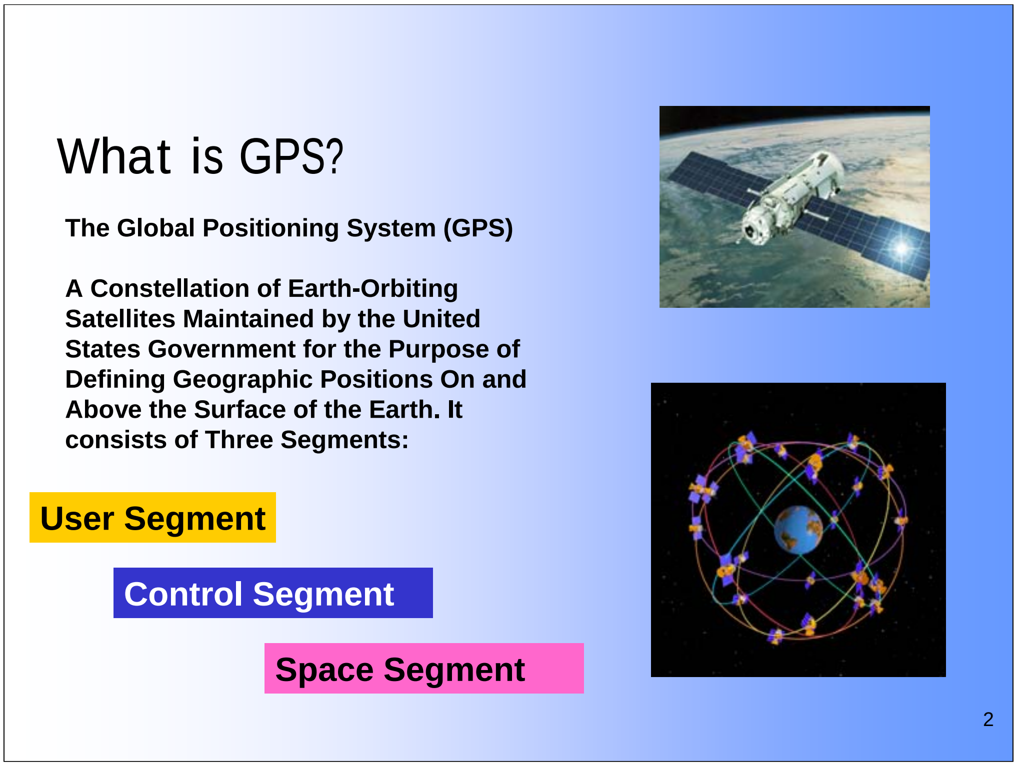


BASIC GPS:

East Fork Fire and Paramedic District
April 2009



What is GPS?

The Global Positioning System (GPS)

A Constellation of Earth-Orbiting Satellites Maintained by the United States Government for the Purpose of Defining Geographic Positions On and Above the Surface of the Earth. It consists of Three Segments:

User Segment

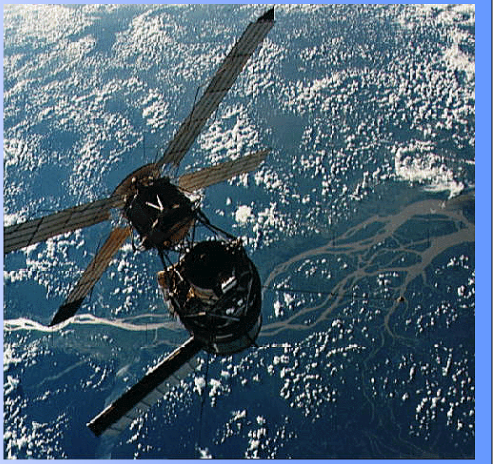
Control Segment

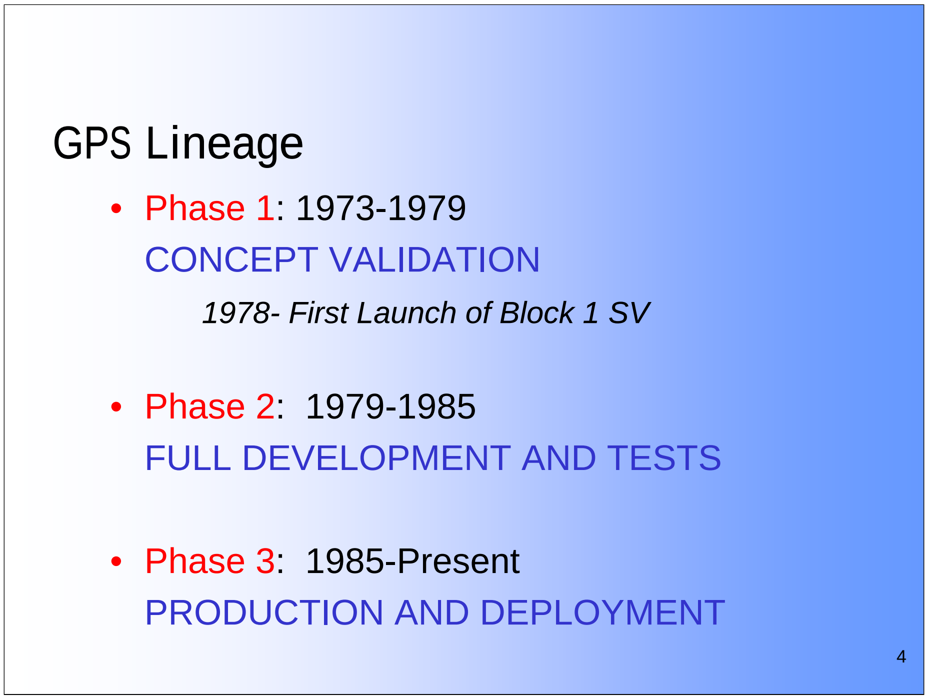
Space Segment

Developed by the US Department of Defense as a worldwide navigation resource for military and civilian use.

GPS Satellites (Satellite Vehicles (SVs))

- First GPS satellite launched in 1978
- Full constellation achieved in 1994
- Satellites built to last about 10 years
- Approximately 2,000 pounds,17 feet across
- Transmitter power is only 50 watts or less



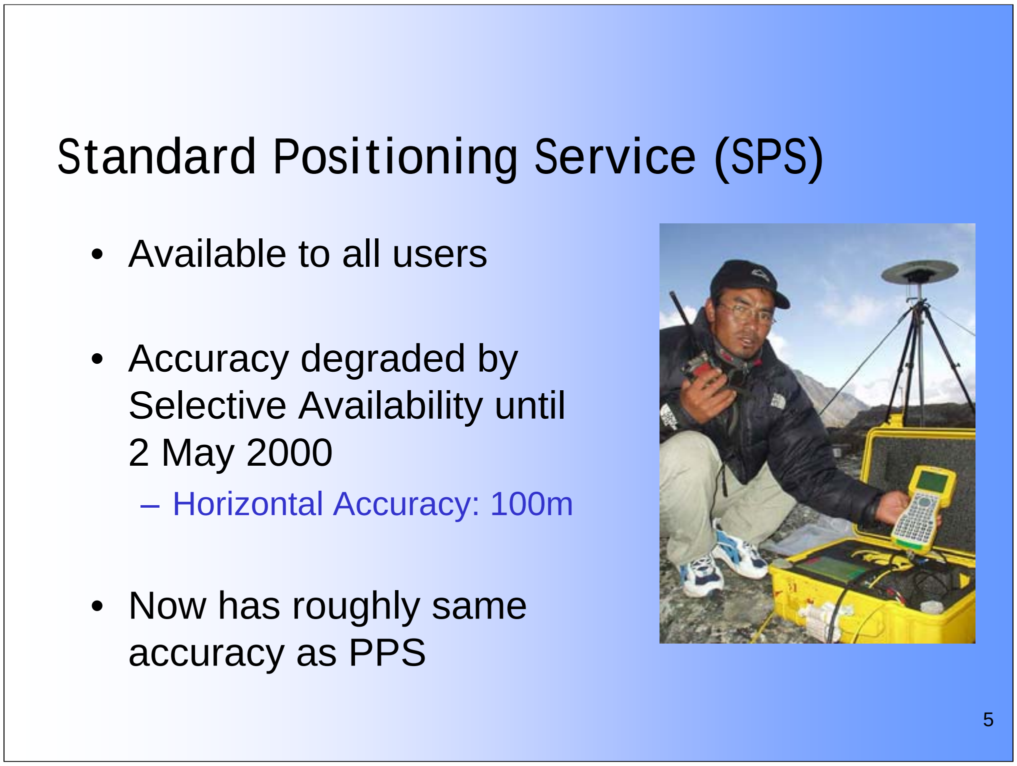


GPS Lineage

- Phase 1: 1973-1979
  CONCEPT VALIDATION
  1978- First Launch of Block 1 SV
- Phase 2: 1979-1985
  FULL DEVELOPMENT AND TESTS
- Phase 3: 1985-Present
  PRODUCTION AND DEPLOYMENT

The important thing to note is that GPS is a type of radio navigation, and that it was specifically designed to eliminate the disadvantages of all the other radio systems we've used for the last 50 years or so.

All of the others have at least one weakness, such as interference in bad weather, limited local coverage, etc. The reason we are so interested in GPS at DMS is that it represents a dramatic change in the way people find their way around the world.

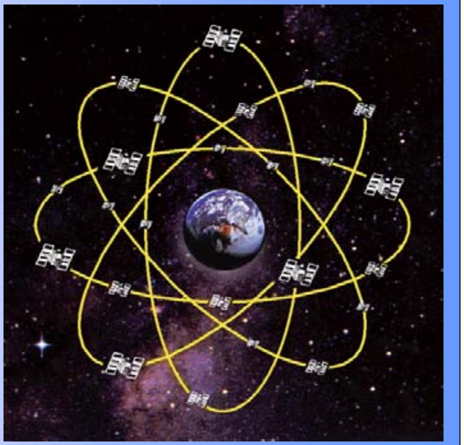


Standard Positioning Service (SPS)

- Available to all users
- Accuracy degraded by Selective Availability until 2 May 2000
  - Horizontal Accuracy: 100m
- Now has roughly same accuracy as PPS

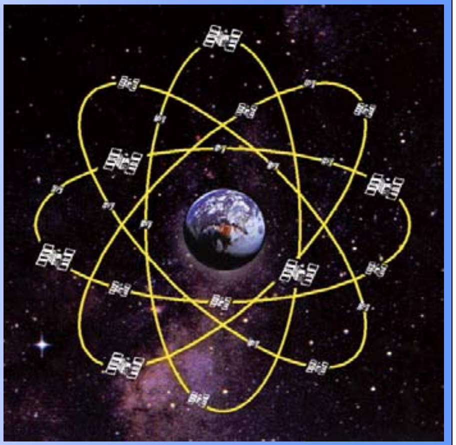
Space Segment

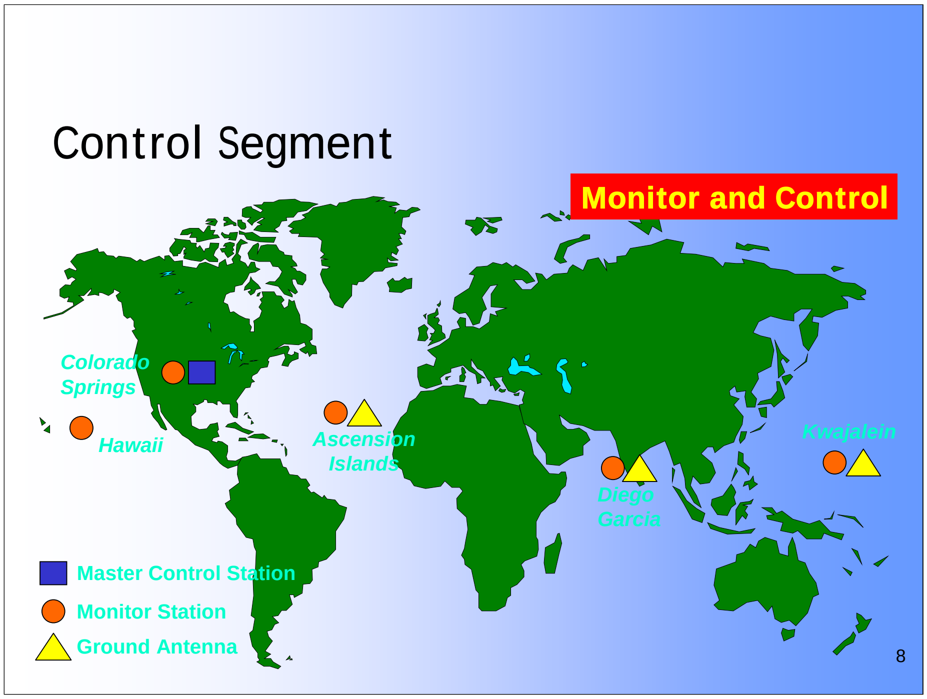
- 24+ satellites
  - 6 planes with 55° inclination
  - Each plane has 4-5 satellites
  - Broadcasting position and time info on 2 frequencies
  - Constellation has spares



Space Segment

- Very high orbit
  - 20,200 km
  - **1 revolution in approximately 12 hrs**
  - **Travel approx. 7,000mph**
- Considerations
  - Accuracy
  - Survivability
  - Coverage





Control Segment

Monitor and Control

- 🟦 Master Control Station
- ● Monitor Station
- ▲ Ground Antenna

8

The second segment we'll talk about is the Operational Control Segment. This segment consists of 5 Monitor Stations on islands near the equator (Hawaii, Ascension, Diego Garcia, and Kwajelin) and one Master Control Station located at Falcon AFB, CO. All of these stations track the GPS signals, and send them back to the Master Control Station at Falcon. A backup MCS exists at Loral Federal System in Gaithersburg, MD. The four stations track and monitor the where-abouts of each GPS satellite each day. Then land-based and space-based communications are used to connect the monitoring stations with MCS.

User Segment

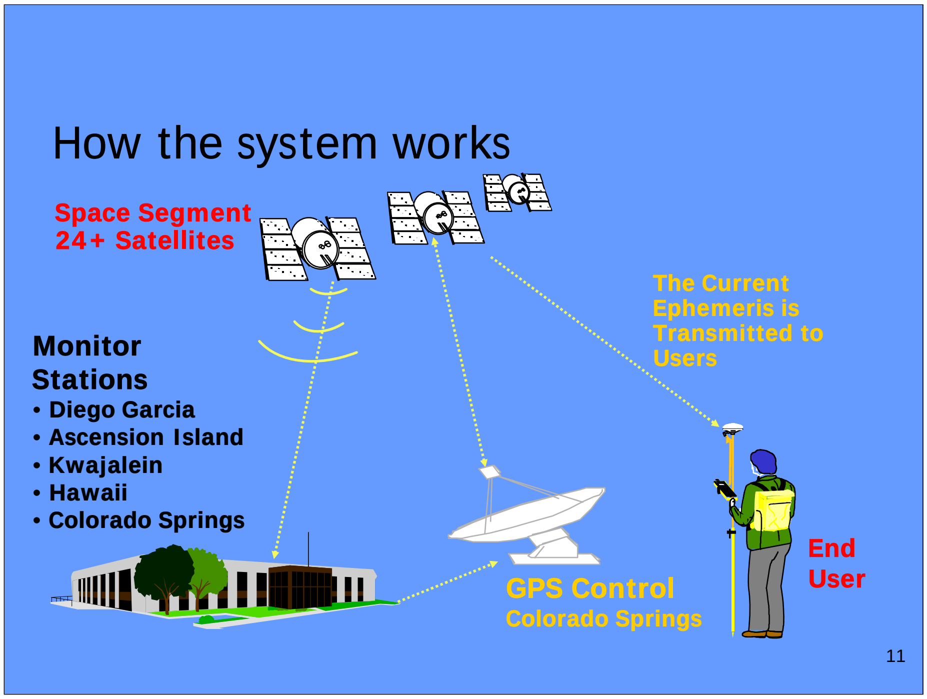
- Over $19 Billion invested by DoD
- Dual Use System Since 1985
  (civil & military)
- Civilian community was quick to take advantage of the system
  - Hundreds of receivers on the market
  - 3 billion in sales, double in 2 years
  - 95% of current users
- DoD/DoT Executive Board sets GPS policy

Common Uses for GPS

- Land, Sea and Air Navigation and Tracking
- Surveying/ Mapping
- Military Applications
- Recreational Uses

Collision avoidance, cargo monitoring, vehicle tracking, search and rescue operations, etc.

Includes geophysical and resource surveys, GIS data capture surveys, etc



How the system works

Space Segment
24+ Satellites

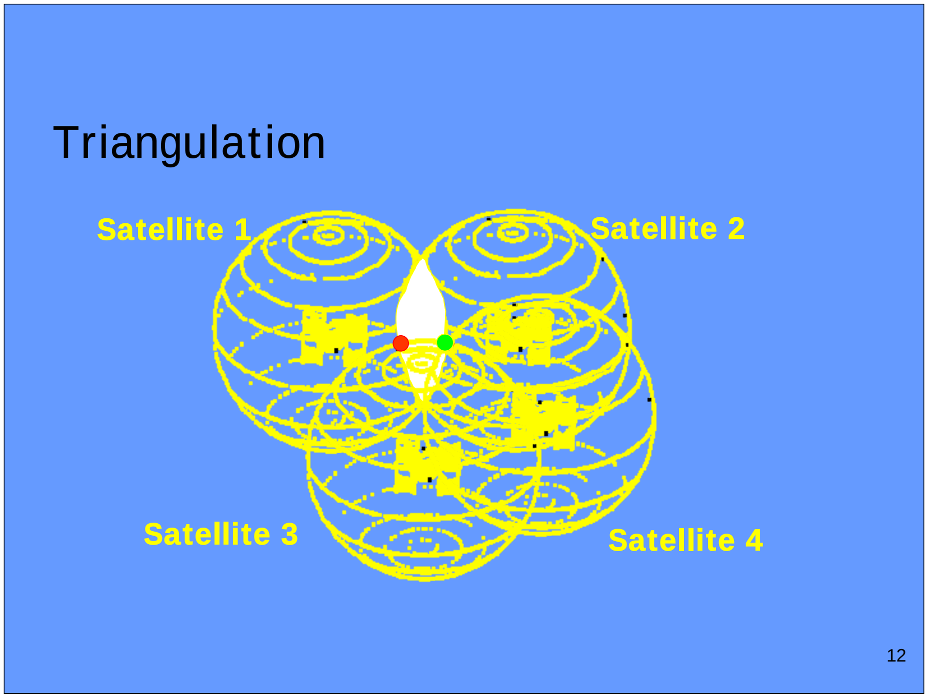
Monitor Stations

- **Diego Garcia**
- **Ascension Island**
- **Kwajalein**
- **Hawaii**
- **Colorado Springs**

The Current Ephemeris is Transmitted to Users

GPS Control
Colorado Springs

End User



Triangulation

For simplicity sake, we calculate our position by understanding where a satellites is in orbit and then further computing how far we are from those satellites.

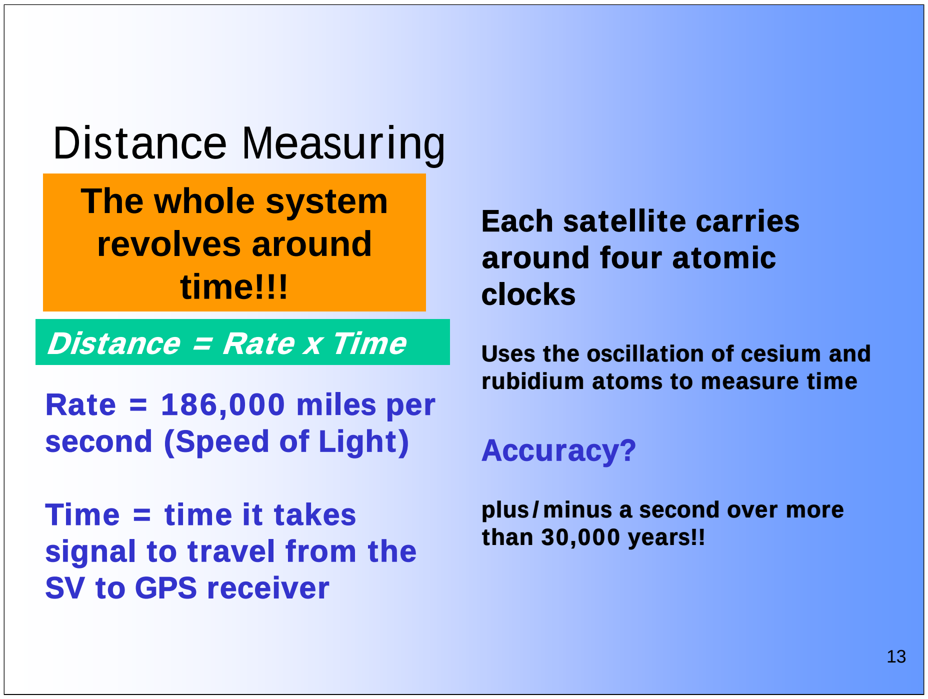
If we know we are a certain distance from satellite A (11,000 miles). This narrows down where we are in the whole universe. This one *range* tells us we are located somewhere on the sphere of the range of this one satellite.

If at the same time we also know that we are 12,000 miles away from a second satellite. This narrows where we are in the universe even more. The only place we can be 11,000 miles from A and 12,000 miles from B is on a circle where those two spheres intersect.

Then if we measure to a third satellite we can pinpoint our location. If we know that we are 13,000 miles from satellite C then there are only two points in the universe that this can be true. One point is where the sphere enters into the circle formed by satellites A and B and the second is where the sphere of satellite C exits the circle formed by satellites A and B.

By ranging from three satellites we can narrow our location down to one of two points. We decide between these two points typically by one of two methods. In some cases the software built into the GPS receivers have various techniques to determine which point is correct and which point is ridiculous.

Technically, trigonometry says we really need four satellites to range to unambiguously locate ourselves. In other words the fourth satellite can be used to determine which of the two points derived from three satellites is the correct choice. The fourth satellite has other functions that relate to time that will be discussed later.



Distance Measuring

The whole system revolves around time!!!

Distance = Rate x Time

Rate = 186,000 miles per second (Speed of Light)

Time = time it takes signal to travel from the SV to GPS receiver

Each satellite carries around four atomic clocks

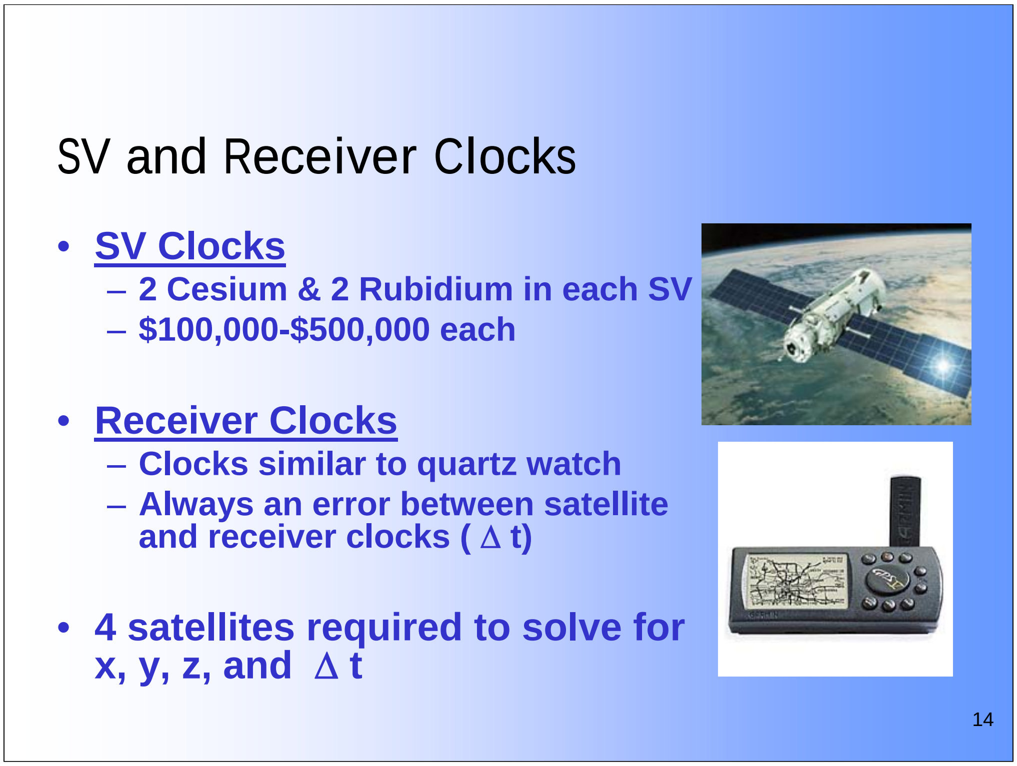
Uses the oscillation of cesium and rubidium atoms to measure time

Accuracy?

plus/minus a second over more than 30,000 years!!

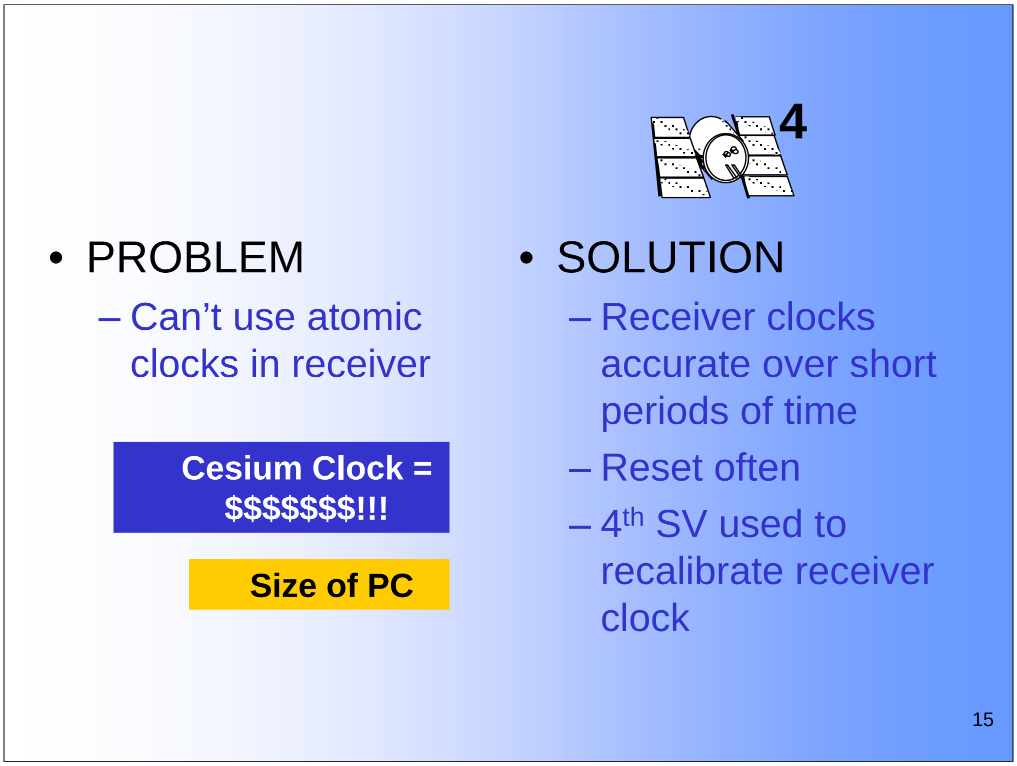
Since GPS is based on knowing your distance to satellites in orbit, a method must be devised to figure out how far we are from the satellites. The GPS system works by timing how long it takes a radio signal to reach us from a satellite and then calculating the distance from that time. We calculate this by measuring distance or the velocity times travel time. Radio waves travel at the speed of light: 186,000 miles per second.

If we can then compute exactly when the signal started at the satellite and ended at the receiver then we have our required distance. We then multiply the time by the velocity to derive the distance.



SV and Receiver Clocks

- **SV Clocks**
  - **2 Cesium & 2 Rubidium in each SV**
  - **$100,000-$500,000 each**
- **Receiver Clocks**
  - **Clocks similar to quartz watch**
  - **Always an error between satellite and receiver clocks (Δ t)**
- **4 satellites required to solve for x, y, z, and Δ t**



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- PROBLEM
  - Can’t use atomic clocks in receiver

Cesium Clock = $$$$$$$!!!

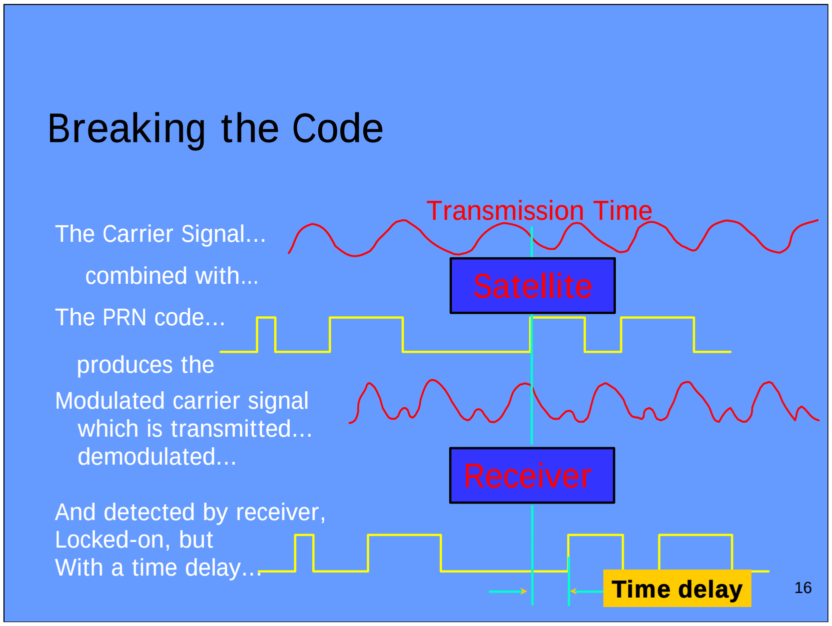
Size of PC

- SOLUTION
  - Receiver clocks accurate over short periods of time
  - Reset often
  - 4th SV used to recalibrate receiver clock

Okay, we have accurate clocks in the satellites. Now all we need are accurate clocks in the receivers, sync 'em up and we're in business. Of course, if your discount GPS receiver had to have a cesium clock, it'd cost about $200,000 and be about the size of a desktop computer. The way around that was to develop internal receiver clocks that are consistently accurate over relatively short periods of time, as long as they're reset often.

So, just to be sure, the receiver listens for a fourth satellite. If the fourth line of position doesn't pass through the other three, the receiver knows something is wrong; it's geometrically impossible for four mutually intersecting spheres to merge at the same point unless the clock is spot on. The receiver assumes, then, that because the fourth line doesn't jive with the others, the receiver's internal clock must be out of sync.

The receiver then runs a simple little routine to adjust the clock until all four lines of position intersect the same point. This is known as correcting clock bias and it's how the receiver resets its clock. That's one of the things that's going on when your receiver has just been turned on and you're waiting for it to initialize.



Breaking the Code

The Carrier Signal…

combined with…

The PRN code…

produces the

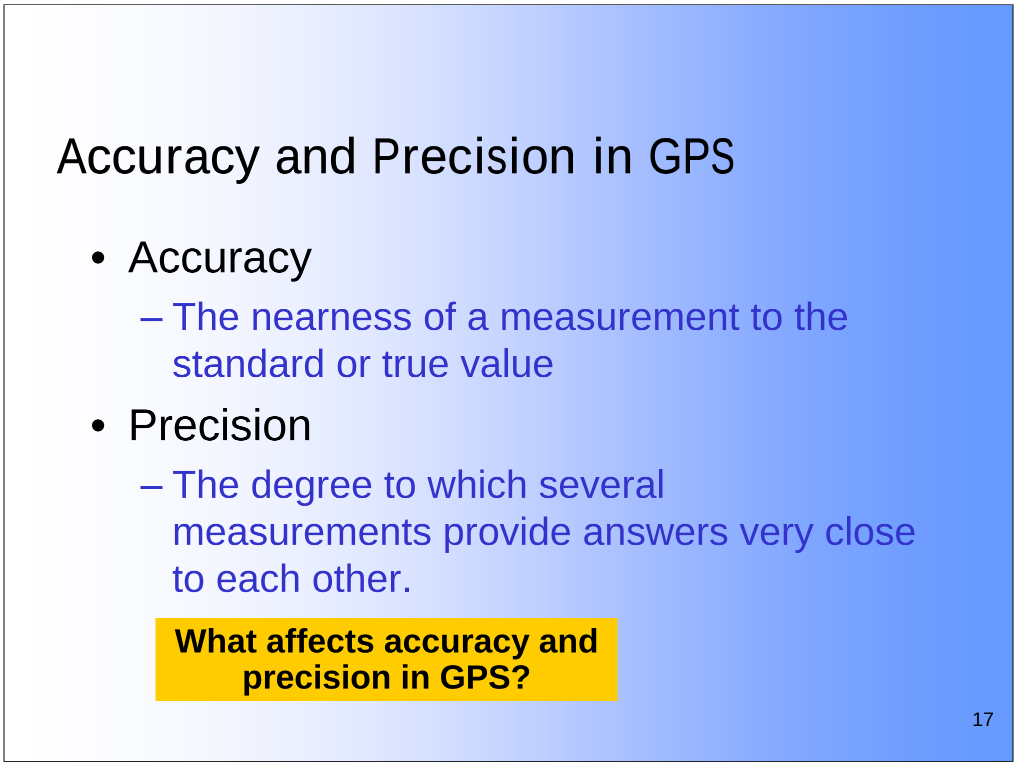
Modulated carrier signal
which is transmitted…
demodulated…

And detected by receiver,
Locked-on, but
With a time delay…

This is a diagram that shows how radio signals work in general. Each SV generates a plain sine wave called the Carrier 1575.42Mhz and 1227.6Mhz. This carrier is Modulated (altered) by adding **three** signals to it. (The C/A code, P-Code and the Navigation message). In this case, it is that particular SV's Pseudo-Random Noise (PRN) Code this is essentially the P-Code and the C/A code for each SV. The PRN code looks like a square wave because it's just 1's and 0's; digital information that is Phase Modulated (PM).

Then what the SV actually broadcasts is that modulated signal. Your receiver picks this up, subtracts the carrier (it can generate a copy of the carrier on its own), and is left with a copy of the original signal. The significance for GPS is that the signal that is produced in the receiver is delayed by a small amount of time. For GPS, the information in the signal is not the only important part - as we've seen, it's the time delay that we really care about. Remember, all the SVs are talking on the same frequency, so we can't pick them out of the chatter without knowing what to expect ahead of time.

There's another important reason for random code; it relates to some basic GPS design limitations. In order to be affordable, GPS satellites had to be relatively small and light—the Block II production SVs weigh just less than 2,000 pounds. That means that power requirements are limited and the radiated signal power is also quite low, on the order of 40 watts. Think about that. There's a 40-watt transmitter floating out there almost 11,000 miles away and it has to blanket a very large portion of the earth's surface with a receivable signal. Big problem. Rather than directing a high power signal, then, a GPS satellite spreads a very low power signal over a large area. It's so low-powered that it's completely hidden in the background hash of cosmic rays, car ignitions, neon lighting, computer drive fuzz and so forth. That's where random code comes in. The receiver starts generating its own code and listening for matches in the background noise. Once it has enough matches to recognize the SV's transmission, it drags the signal out of background muck and "locks on." When three SVs are locked up, navigation can begin. This is why a receiver can get by with a very small, relatively nondirectional antenna. Handheld GPS units have antennas that are only a couple of inches square or perhaps about the size of a cigar. One other thing: using pseudo-random code and low, low power makes it very hard to jam a GPS signal. For military purposes, this is obviously very desirable.



Accuracy and Precision in GPS

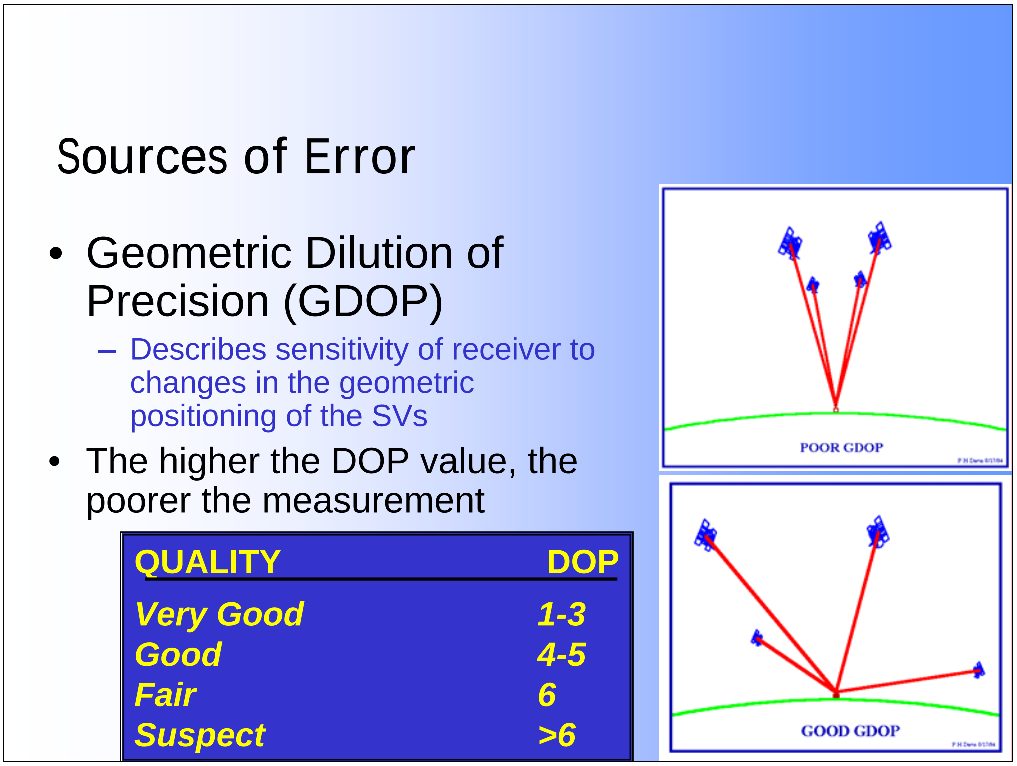
- Accuracy
  - The nearness of a measurement to the standard or true value
- Precision
  - The degree to which several measurements provide answers very close to each other.

What affects accuracy and precision in GPS?

It is an indicator of the scatter in the data. The lesser the scatter, higher the precision.

Precision is not the same as accuracy. Accuracy is a measure of departure from the true value of a quantity. Precision, on the other hand, is a measure of the "repeatability" of the data. The difference between accuracy and precision is known as "bias" or "systematic error". Taking large amounts of data will improve the precision of a sample mean, but will not remove systematic error.

Accuracy is a very desirable measure. However, it is generally quite difficult to obtain. It requires strict control over sources of systematic error



Sources of Error

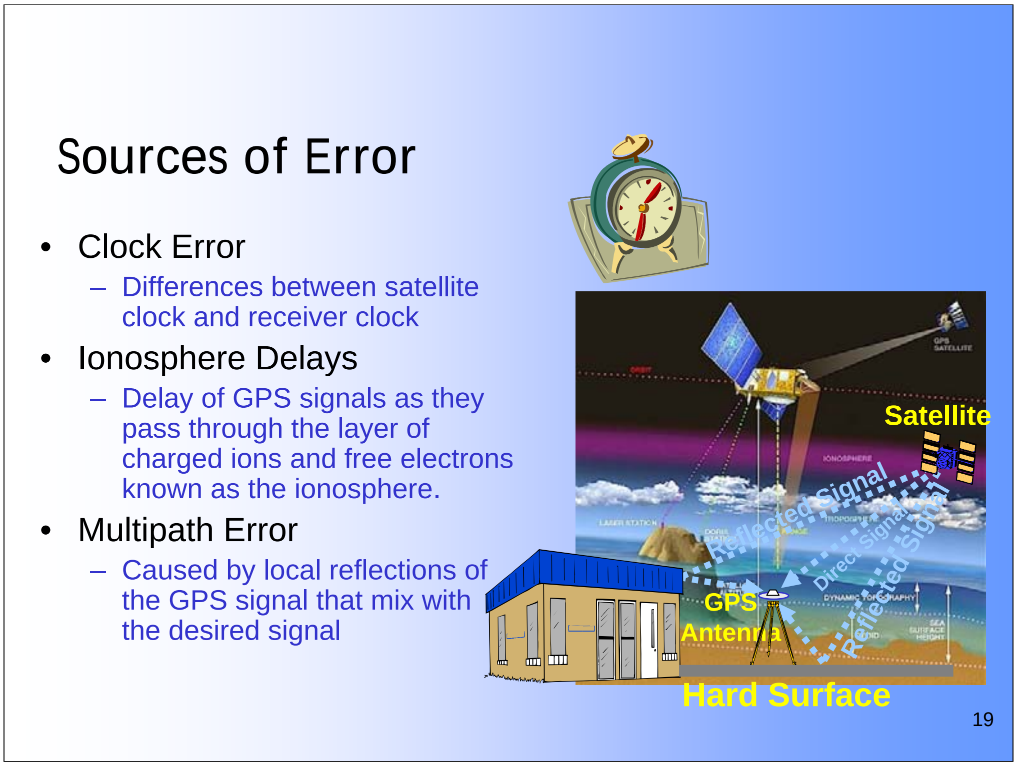
- Geometric Dilution of Precision (GDOP)
  - Describes sensitivity of receiver to changes in the geometric positioning of the SVs
- The higher the DOP value, the poorer the measurement

QUALITY	DOP
Very Good	*1-3*
Good	*4-5*
Fair	*6*
Suspect	*>6*

Although at certain times of the day there may be up to12 satellites visible simultaneously, there are nevertheless occasional periods of degraded satellite coverage (though naturally their frequency and duration will increase if satellites fail). "Degraded satellite coverage" is generally defined in terms of the magnitude of the Dilution of Precision (DOP) factor, a measure of the quality of satellite geometry. The highest the DOP value, the poorer the satellite geometry.

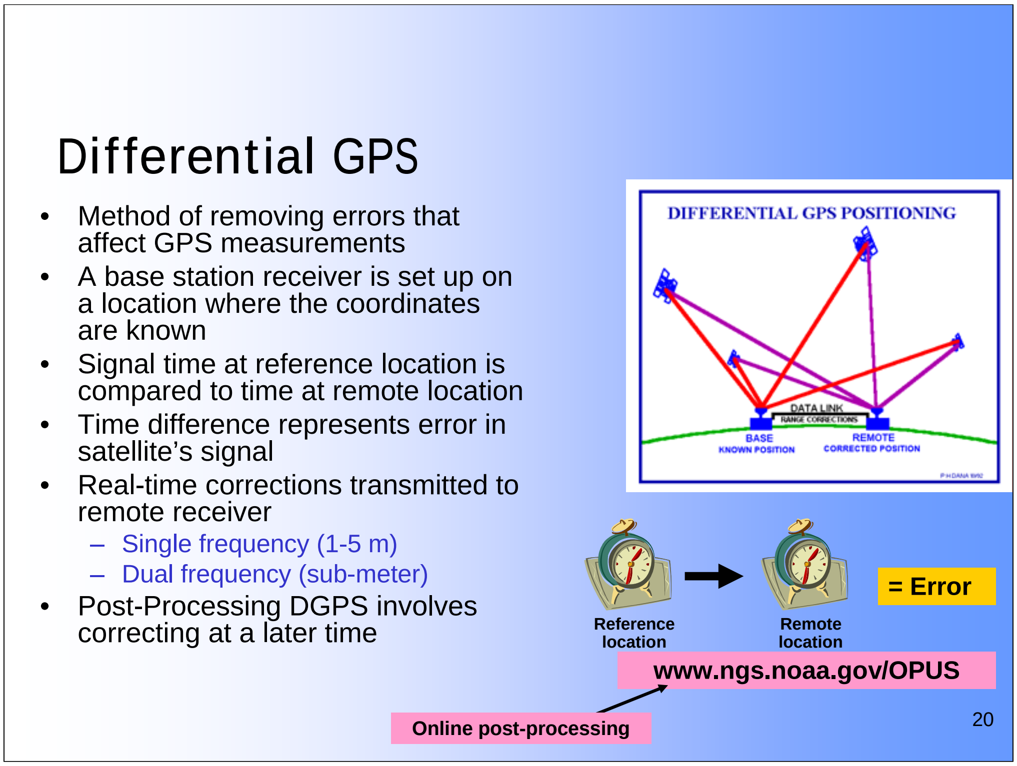
There are a variety of DOP indicators, such as GDOP (Geometric DOP), PDOP (Position DOP), HDOP (Horizontal DOP), VDOP (Vertical DOP), etc.

PDOP, or Precision Dilution of precision, probably the most commonly used, which is the dilution of precision in three dimensions. Some- times called the Spherical DOP.



Sources of Error

- Clock Error
  - Differences between satellite clock and receiver clock
- Ionosphere Delays
  - Delay of GPS signals as they pass through the layer of charged ions and free electrons known as the ionosphere.
- Multipath Error
  - Caused by local reflections of the GPS signal that mix with the desired signal



Differential GPS

- Method of removing errors that affect GPS measurements
- A base station receiver is set up on a location where the coordinates are known
- Signal time at reference location is compared to time at remote location
- Time difference represents error in satellite's signal
- Real-time corrections transmitted to remote receiver
  - Single frequency (1-5 m)
  - Dual frequency (sub-meter)
- Post-Processing DGPS involves correcting at a later time

= Error

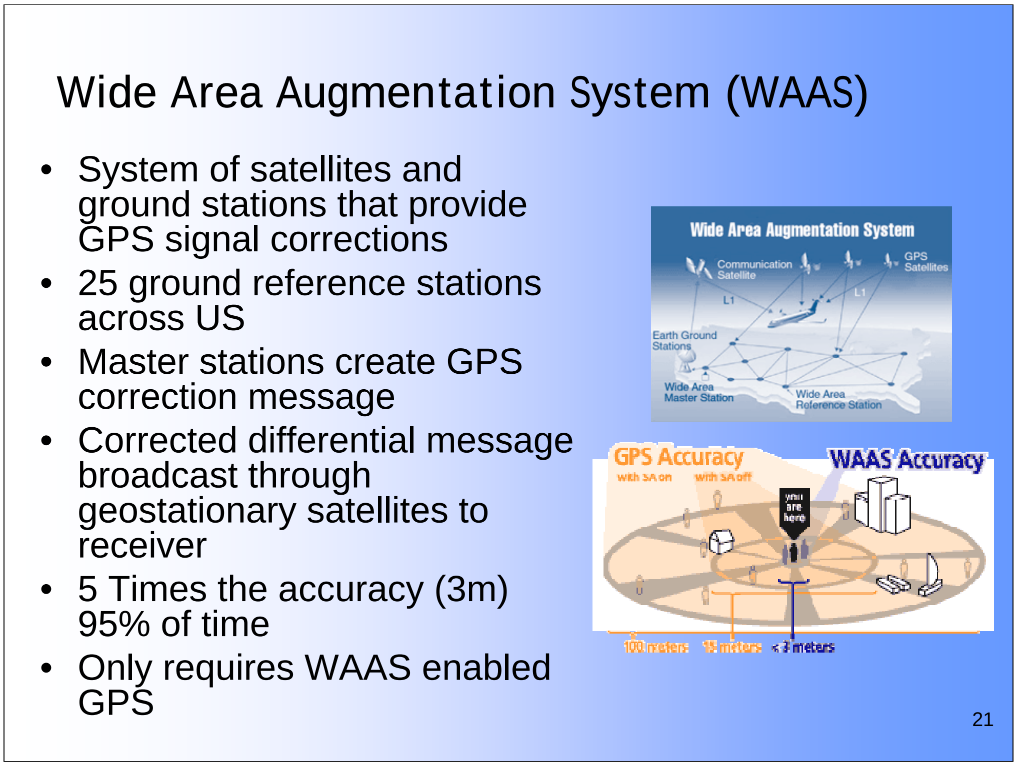
www.ngs.noaa.gov/OPUS

Online post-processing

To detect systematic error, one needs reference coordinates; preferably, as error free as possible. A typical source of such control is a monumented point surveyed by a geodetic agency or a state highway department.

With "traditional" DGPS, a base station receiver is set up on a location where the coordinates are known. The difference between the known location and the calculated location based on satellite signals is used to determine individual corrections

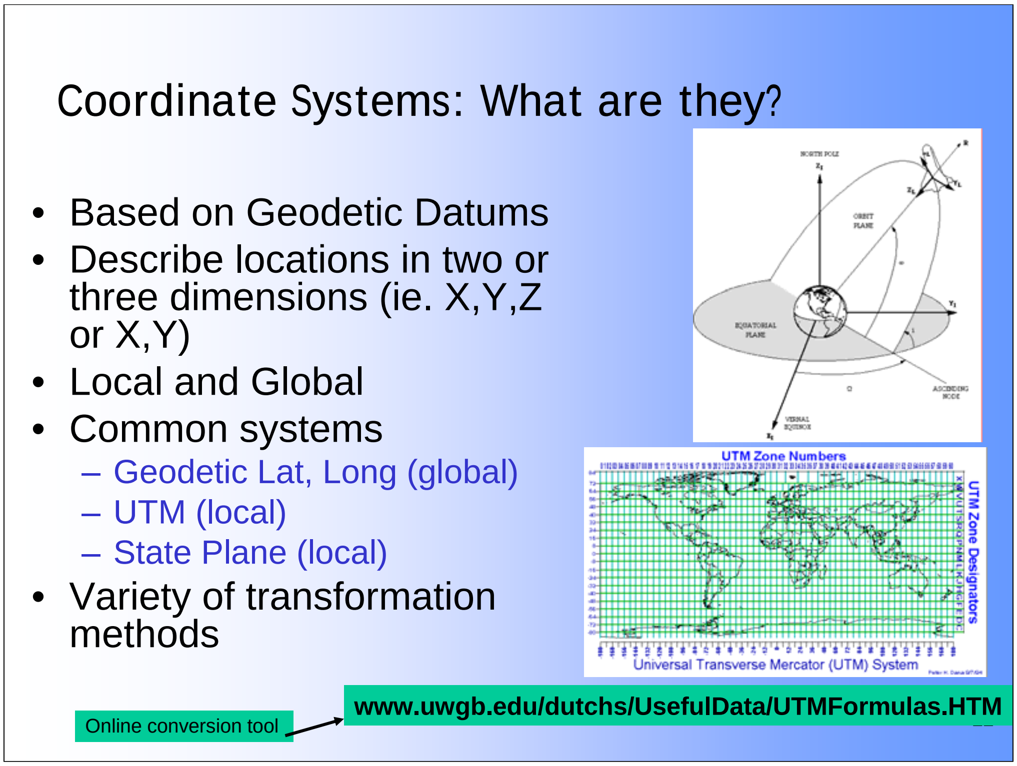
Provided that the exact location of a reference receiver (on a point that has been very accurately surveyed), and the location of satellites in space are known, it is possible to compute a distance between the receiver and each satellite. The reference receiver then divides that distance by the speed of light and gets a time for how long the signals should have taken to reach it. This theoretical time is compared with the time the signals actually took to reach it, and the difference is the error in the satellite's signal.



Wide Area Augmentation System (WAAS)

- System of satellites and ground stations that provide GPS signal corrections
- 25 ground reference stations across US
- Master stations create GPS correction message
- Corrected differential message broadcast through geostationary satellites to receiver
- 5 Times the accuracy (3m) 95% of time
- Only requires WAAS enabled GPS

System of satellites and ground stations that provide GPS signal corrections, giving you even better position accuracy. How much better? Try an average of up to five times better. A WAAS-capable receiver can give you a position accuracy of better than three meters, 95 percent of the time. And you don't have to purchase additional receiving equipment or pay service fees to utilize WAAS.



Coordinate Systems: What are they?

- Based on Geodetic Datums
- Describe locations in two or three dimensions (ie. X,Y,Z or X,Y)
- Local and Global
- Common systems
  - – Geodetic Lat, Long (global)
  - – UTM (local)
  - – State Plane (local)
- Variety of transformation methods

Online conversion tool

www.uwgb.edu/dutchs/UsefulData/UTMFormulas.HTM

UTM Coordinate System UTM=Universal Transverse Mercator, a worldwide system for exact determination of location.

Squares are 1 km (1000 meters) per side.. Easting numbers increase as you move East. Northing numbers increase as you go North. The last 3 digits, not given on the map, are 000. These last three digits can be

used to estimate location between the lines. For example, halfway from one Northing line

to the next is 500. There are simple plastic overlay devices to give even more accurate numbers.

UTM can be used to identify a location for Search and Rescue. To identify your location, give information in the following order

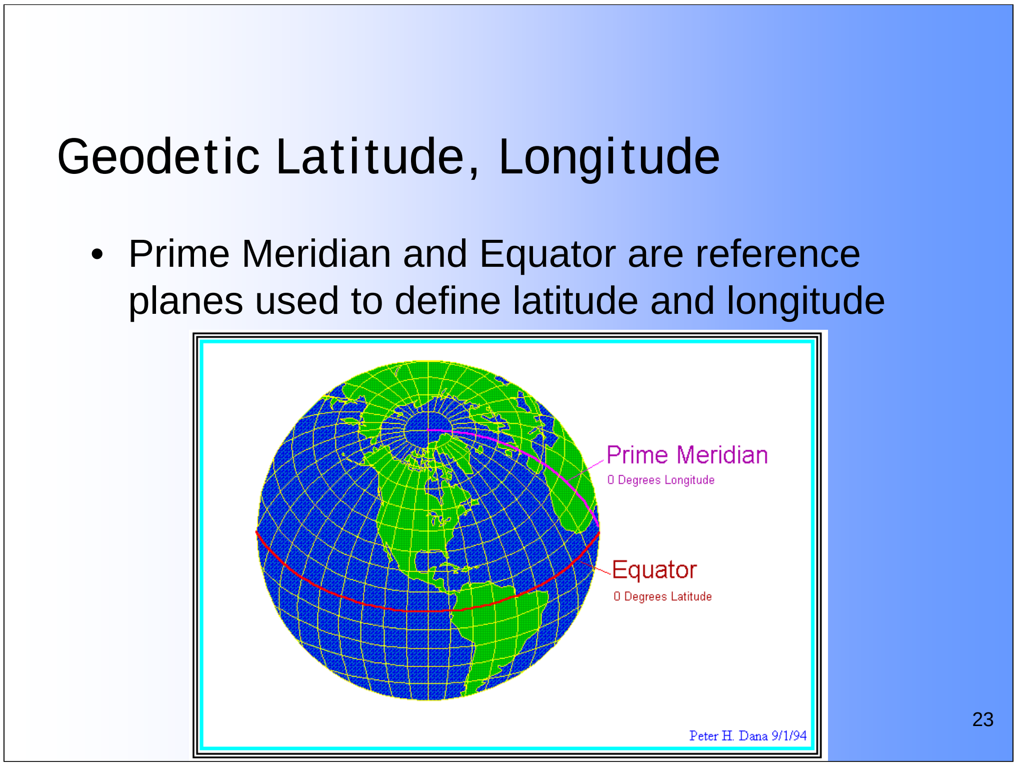
1) Datum (usually NAD27 in USA)

2) Zone (10)

3) Easting

4) Northing

UTM is used increasingly in guidebooks for hiking and climbing to describe waypoints on routes and exact locations of landmarks. UTM coordinates can be used to navigate with a GPS.



Geodetic Latitude, Longitude

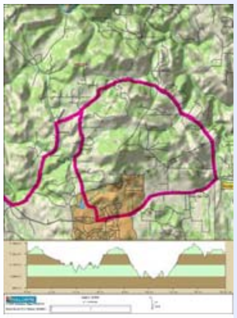
- Prime Meridian and Equator are reference planes used to define latitude and longitude

Peter H. Dana 9/1/94

Any location on Earth is described by two numbers--its **latitude** and its **longitude**. Actually, these are two **angles**, measured in degrees, "minutes of arc" and "seconds of arc." These are denoted by the symbols (°, ', ") e.g. 35° 43' 9" means an angle of 35 degrees, 43 minutes and 9 seconds (do not confuse this with the notation (', ") for feet and inches!). A degree contains 60 minutes of arc and a minute contains 60 seconds of arc--and you may omit the words "of arc" where the context makes it absolutely clear that these are **not** units of time.

Hands on with GPS

- Review the user manual for your specific GPS unit
  - If you can not find the manual, check the manufacture website and download the manual
- Go out and use your GPS unit learn its functions and limitations



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