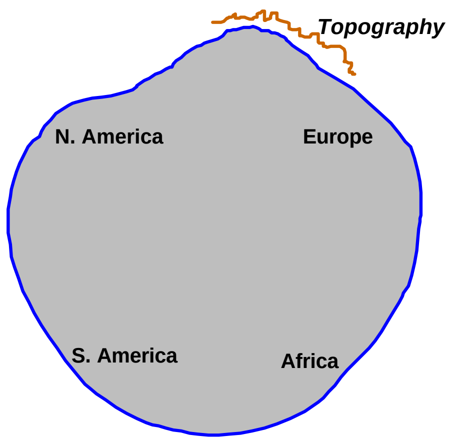
GPS user info

Background Info – Datum's & Ellipsoids

When you turn on a GPS receiver you must select a reference ellipsoid (datum) on which you will base your positions. If YOU don't select one, one will be selected for you (by the previous user). Sort of like magnetic dec. on a compass. If you don't mind that your positions are +/- 100 meters you can ignore this …

The Geoid

- **Equipotential surface that best equates to mean sea level**
- **Physical definition of a complicated surface**
- **Described by an infinite number of parameters**
- **Can be sensed by instruments**

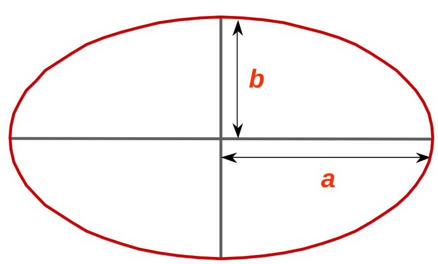


The Ellipsoid

An approximation of the Geoid. Map projections may assume different Ellipsoids. Ellipsoid used as basis for datum's are generated from an ellipse.

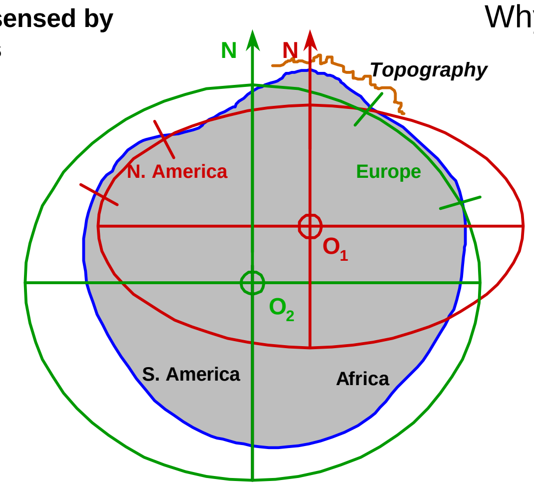
- **An ellipse is a mathematical figure which is defined by**

Semi-Major Axis (a)
and
Semi-Minor Axis (b)
or
Flattening (f) = (a - b)/a



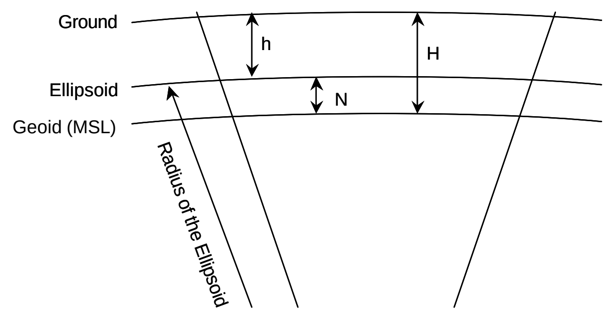
- **It is a simple geometrical surface**
- **Cannot be sensed by instruments**

Why use different Ellipsoids?



Elevations (Different Definitions)

$$EF = \left| \frac{R}{R + N + H} \right|$$



R	**=**	**Radius of Curvature.**
N	**=**	**Geoidal Separation.**
H	**=**	**Mean Height above Geoid.**
h	**=**	**Ellipsoidal Height**

Unless your gps receiver has a local model of the geoid built in (not likely for a handheld unit) your gps heights are heights above ellipsoid (hae) and different (~10 meters in the Fairbanks area for the WGS84 datum). Maps, on the other hand, are referenced to MSL (height above the geoid).

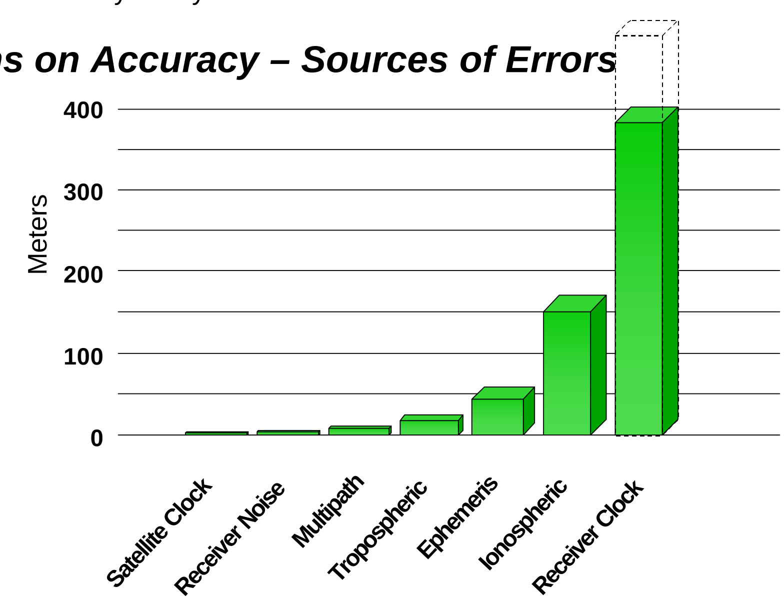
The bad news ➔ position and elevation are more complicated than you thought – a latitude and longitude and elevation do not uniquely specify a location.

The good news ➔ as long as you keep track of what you were measuring and how you measured it, it will be possible to convert between measurements based on different ellipsoids. You need to write down what datum you used in the field.

Background Info – Coordinate Systems

The problems with using geodetic coordinate (Lat/Lon) mapping are: 1)Positions are denoted in angular units and 2)The complexity of calculations. For this reason, most mapping is reported in a planar coordinate system (UTM's or "State Plane"). Once again, you can use either, BUT write down which coordinate system you use.

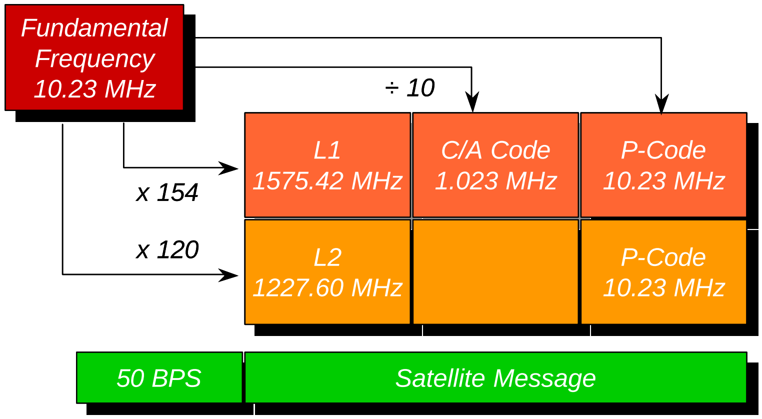
Limitations on Accuracy – Sources of Errors



Most of these errors are the same over a study area (~30km) and can be almost TOTALLY eliminated if one uses two receivers (a base and a rover). If one transmits the corrections over a radio data link from the base to the rover, one can get real time accuracy at the rover on the order of 2 cm.

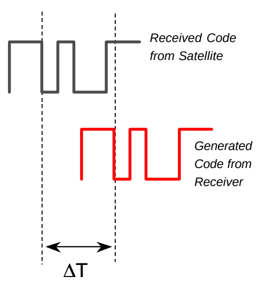
GPS Signal Structure

- Each GPS satellite transmits a number of signals
- The signal comprises of two carrier waves (L1 and L2) and two codes (C/A on L1 and P or Y on both L1 and L2) as well as a satellite orbit message



Pseudorange Signal

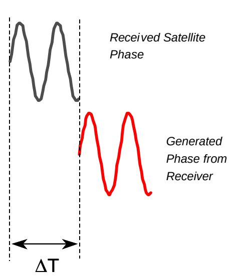
- Pseudoranges (Code)
  - Each satellite sends a unique signal which repeats itself approximately every millisecond
  - Receiver compares self generated signal with received signal
  - From the time difference (dT), a range observation can be determined
  - Receiver clock needs to be synchronized with the satellite clock



$D = V(\Delta T)$

Carrier Signal

- Phase Observations
  - Wavelength of the signal is 19 cm on L1 and 24 cm on L2
  - Receiver compares self-generated phase with received phase
  - Number of wavelengths is not known at the time the receiver is switched on (carrier phase ambiguity)
  - As long as you track the satellite, the change in distance can be observed (the carrier phase ambiguity remains constant)



$D = c\,\Delta T + \lambda N$

Things you can do in the field to determine improve the usefulness of your GPS data:

- Record everything – page through your setup screen, and write down the settings. Check your settings during your field campaign.
- Occupy a benchmark *at least* once before you start taking data and once after you finish taking data.
- Before you leave for the field, locate potential benchmarks in your study area (roads, railroads, airports). A good source for finding benchmarks and benchmark coordinates in N. America is: http://www.ngs.noaa.gov/datasheet.html . If you know the approximate coordinates of your field site, then do a radial search for the nearest benchmarks.
- Load these benchmarks into your GPS receiver before you leave so you can navigate to the benchmarks (or at least get close).
- Compile a typical (or continuous) satellite availability schedule – know what to expect for sat. availability.
- Evaluate and maximize satellite visibility. Avoid blocking the sky (by vegetation, landmass, humans).
- Avoid multipath situations.
- Know what part of the sky the useful satellites will be in.
- Know how your receiver works (and how it can fail).

Exercises ***(don't have to do all, with estimated times):***

1) Occupy Magnetic Observatory benchmark. Record locations in several datum's and coordinate systems with different receivers. (45 minutes).

2) On a topo map locate features, digitize, load as waypoints into handheld and then navigate to points. (30 minutes inside, 30 minutes outside).

3) Determine True North. (20 minutes outside).

4) Demonstrate relative accuracy of static code, differential code, and differential phase positions (15 minutes outside).

5) Make a contour map of the east lawn. (90 minutes outside, 60 minutes inside).

6) Obtain National Coast and Geodetic datasheets for typical sites (15 minutes inside).

Glossary:

Almanac
Library of coarse satellite orbital data used to calculate satellite position, rise time, elevation, and azimuth.

Ambiguity
The unknown integer number of cycles of the reconstructed carrier phase contained in an unbroken set of measurements from a single satellite pass at a single receiver.

Anti-spoofing (A-S)
Encrypting the P-code (to form the Y-code).

Atmospheric propagation delay
Time delay affecting satellite signals due to tropospheric layers of the earth's atmosphere.

Azimuth
A horizontal angle measured clockwise from a direction (such as North).

Bandwidth
A measure of the width of the spectrum of a signal (frequency domain representation of a signal) expressed in Hertz.

Baseline
The length of the three-dimensional vector between a pair of stations for which simultaneous GPS data has been collected and processed with differential techniques.

Bearing
Term used in navigation to describe the angle between a reference direction (e.g., geographic north, magnetic north, grid north) and the trajectory.

Beat frequency
Either of the two additional frequencies obtained when signals of two frequencies are mixed. The beat frequencies are equal to the sum or difference of the original frequencies, respectively.

Binary biphase modulation
Phase changes of either 0° or 180° (to represent binary 0 or 1, respectively) on a constant frequency carrier. These can be modeled by $y = A \cos (wt + p)$, where the amplitude function A is a sequence of +1 and -1 values (to represent 0° and 180° phase changes respectively). GPS signals are biphase modulated

C/A code
The Coarse/Acquisition GPS code modulated on the GPS L1 signal. This code is a sequence of 1023 pseudorandom binary biphase modulations on the GPS carrier at a chipping rate of 1.023 MHz, thus having a code repetition period of one millisecond.

Cartesian Coordinates
The coordinates of a point in space given in three mutually perpendicular dimensions (x, y, z) from the origin.

Carrier
A radio wave having at least one characteristic (e.g., frequency, amplitude, phase) which may be varied from a known reference value by modulation.

Carrier beat phase
The phase of the signal which remains when the incoming Doppler-shifted satellite carrier signal is beat (the difference frequency signal is generated) with the nominally constant reference frequency generated in the receiver.

Carrier frequency
The frequency of the unmodulated fundamental output of a radio transmitter. The GPS L1 carrier frequency is 1575.42 MHz, the GPS L2 carrier frequency is 1227.60 MHz.

Chip
The time interval of either a zero or a one in a binary pulse code

Chip rate
Number of chips per second (e.g., C/A code : 1.023*10^6cps)

Clock offset
Constant difference in the time reading of two clocks.

Code
A system used for communication in which arbitrarily chosen strings of zeros and ones are assigned definite meanings.

Compacted data
Raw data compacted over a specified time interval (compaction time) into one single observable (measurement) for recording.

Conformal Projection
A map projection that preserves angles on the ellipsoid after they have been mapped onto the plane.

Control segment
Ground-based GPS System equipment operated by the U.S. Government that tracks the satellite signals, determines the orbits of the satellites, and transmits orbit definitions to the memories of the satellites

Cutoff angle
The minimum elevation angle below which no more GPS satellites are tracked by the sensor.

Cycle slip
A discontinuity of an integer number of cycles in the measured carrier beat phase resulting from a temporary loss of lock of a GPS satellite signal.

Data message
A message included in the GPS signal

that reports the satellite's location, clock corrections, and health. Included is rough information on the status of other satellites in the constellation.

DGPS

Differential GPS. The term commonly used for a GPS system that utilizes differential code corrections to achieve an enhanced positioning accuracy of around 0.5 - 5m.

Deflection of the vertical

The angle between the normal to the ellipsoid and the vertical (true plumb line). It is usually resolved into a component in the meridian and a component perpendicular to the meridian.

Delay lock

The technique whereby the received code (generated by the satellite clock) is compared with the internal code (generated by the receiver clock) and the latter shifted in time until the two codes match.

Differenced measurements

GPS measurements can be differenced across receivers, across satellites and across time. Although many combinations are possible, the present convention for GPS phase measurement differencing is to perform the differences in the above order: first across receivers, second across satellites and third across time.

A single difference measurement (across receivers) is the instantaneous difference in phase of a received signal, measured by two receivers simultaneously observing one satellite.

A double difference measurement (across receivers and satellites) is obtained by differencing the single difference for one satellite with respect to the corresponding single difference for a chosen reference satellite.

A triple difference measurement (across receivers, satellites and time) is the difference between a double difference at one epoch of time and the same double difference at another epoch of time.

Differential positioning

Determination of relative coordinates between two or more receivers which are simultaneously tracking the same GPS signals

Dilution of precision (DOP)

A description of the purely geometrical contribution to the uncertainty in a position fix. The DOP factor indicates the geometrical strength of the satellite constellation at the time of measurement. Standard terms in the case of GPS are

GDOP three position coordinates plus clock offset

PDOP three coordinates

HDOP two horizontal coordinates

VDOP height only

TDOP clock offset only

HTDOP horizontal position and time

Doppler shift

The apparent change in frequency of a received signal due to the rate of change of the range between the transmitter and receiver.

Eccentricity

The ratio of the distance from the center of an ellipse to its focus to the semimajor axis.

$e = (1 – b^2/a^2)^{1/2}$

where a and b are the semimajor and semiminor axis of the ellipse, respectively.

Elevation

Height above the Geoid. See Orthometric height.

Ellipsoid

In geodesy, unless otherwise specified, a mathematical figure formed by revolving an ellipse about its minor axis (sometimes also referred to as spheroid). Two quantities define an ellipsoid; these are usually given as the length of the semimajor axis a and the flattening f.

Ellipsoid height

The vertical distance of a point above the ellipsoid.

Ephemeris

A list of positions or locations of a celestial object as a function of time.

Ephemeris error

Difference between the actual satellite location and the location predicted by the satellite orbital data (ephemerides).

Epoch

A particular fixed instant of time used as a reference point on a time scale.

Equipotential Surface

A mathematically defined surface where the gravitational potential is the same at any point on that surface. An example of such a surface is the geoid

Flattening

Relating to Ellipsoids.

$f = (a-b)/a = 1-(1-e^2)^{1/2}$

where a ... semimajor axis
b ... semiminor axis
e ... eccentricity

Fundamental frequency

The fundamental frequency used in GPS is 10.23 MHz. The carrier frequencies L1 and L2 are integer multiples of the fundamental frequency.

L1 = 154F = 1575.42 MHz

L2 = 120F = 1227.60 MHz

GDOP

Geometric dilution of precision

See *Dilution of precision*

Geocentric

Relating to the centre of the earth.

Geodesy

The study of the earth's size and shape

Geodetic Coordinates

Coordinates defining a point with reference to an ellipsoid. Geodetic Coordinates are either defined using latitude, longitude and ellipsoidal height or using Cartesian coordinates.

Geodetic Datum

A mathematical model designed to best fit part or all of the geoid. It is defined by an ellipsoid and the relationship between the ellipsoid and a point on the topographic surface established as the origin of datum. This relationship can be defined by six quantities, generally (but not necessarily) the geodetic latitude, longitude, and the height of the origin, the two components of the deflection of the vertical at the origin, and the geodetic azimuth of a line from the origin to some other point.

Geoid

The particular equipotential surface which coincides with mean sea level, and which may be imagined to extend through the continents. This surface is everywhere perpendicular to the direction of the force of gravity.

Geoidal Height

See Geoid separation

Geoid separation

The distance from the surface of the reference ellipsoid to the geoid measured outward along the normal to the ellipsoid.

GPS

Global Positioning System

GPS time

A continuous time system based on the Coordinated Universal Time (UTC) from 6th January 1980.

Greenwich mean time (GMT)

The mean solar time of the meridian of Greenwich. Used as the prime basis of standard time throughout the world.

Great circle course

Term used in navigation. Shortest connection between two points.

Graticule

A plane grid representing the lines of Latitude and Longitude of an ellipsoid.

Gravitational constant

The proportionality constant in Newton's Law of gravitation.

G = 6.672 * 10^ -11 $m^3 s^{-2} kg^{-1}$

Inclination

The angle between the orbital plane of an object and some reference plane (e.g., equatorial plane).

Integer bias term

See Ambiguity

Ionospheric Delay

A wave propagating through the ionosphere (which is a non-homogeneous and dispersive medium) experiences delay. Phase delay depends on electron content and affects carrier signals. Group delay depends on dispersion in the ionosphere as well, and affects signal modulation (codes). The phase and group delay are of the same magnitude but opposite sign.

Kinematic positioning

Determination of a time series of sets of coordinates for a moving receiver, each set of coordinates being determined from a single data sample, and usually computed in real time.

Keplerian orbital elements

Allow description of any astronomical orbit:

a: semimajor axis
e: eccentricity
w: argument of perigee
W: right ascension of ascend
ing node
i: inclination
n: true anomaly

Lambert Projection

A conformal conic map projection that projects an ellipsoid onto a plane surface by placing a cone over the sphere.

Latitude

The angle between the ellipsoidal normal and the equatorial plane. Latitude is zero on the equator and 90° at the poles

L-band

The radio frequency band extending from 390 MHz to 1550 MHz. The frequencies of the L1 and L2 carriers transmitted by GPS satellites lie within this L-band.

Least squares estimation

The process of estimating unknown parameters by minimizing the sum of the squares of measurement residuals.

Local Ellipsoid

An Ellipsoid that has been defined for and fits a specific portion of the earth. Local ellipsoids usually fit single or groups of countries.

Local Time

Local time equals to GMT time + time zone.

Longitude

Longitude is the angle between the meridian ellipse which passes through Greenwich and the meridian ellipse containing the point in question. Thus, Latitude is 0° at Greenwich and then measured either eastward through 360° or eastward 180° and westward 180°.

Meridian

An imaginary line joining north to south pole and passing through the equator at 90°.

Multipath error

A positioning error resulting from interference between radio waves which have travelled between the transmitter and the receiver by two paths of different electrical lengths.

NAVSTAR

Acronym for Navigation System with Time and Ranging, the original name for GPS.

NMEA

National Marine Electronics Association. Defined a standard (NMEA 0183) to enable marine electronics instruments, communication and navigation equipment to communicate. This standard is used to get time and position data out of GPS instruments in many applications.

Observing Session

A period of time over which GPS data is collected simultaneously by two or more receivers.

Orthometric height

The distance of a point above the geoid measured along the plumb line through the point (height above mean sea level). See also Elevation

P-code

The Precise GPS code - a very long (about 10^{14}bit) sequence of pseudorandom binary biphase modulations on the GPS carrier at a chipping rate of 10.23 MHz which does not repeat itself for about 267 days. Each one-week segment of the P-code is unique to one GPS satellite, and is reset each week. Access to the P-code will be restricted by the U.S. Government to authorized users only.

PDOP

Position dilution of precision.
see Dilution of Precision

Phase observable

See Reconstructed Carrier Phase

Point Positioning

The independent reduction of observations made by a particular receiver using the pseudorange information broadcast from the satellites.

Post processing

The process of computing positions in non-real-time, using data previously collected by GPS receivers.

Precise positioning service (PPS)

The highest level of point positioning accuracy provided by GPS. It is based on the dual-frequency P - code.

Propagation delay

See Atmospheric propagation delay, and Ionospheric delay

Pseudolite

The ground-based differential GPS station which transmits a signal with a structure similar to that of an actual GPS satellite.

Pseudorandom noise (PRN) code

Any group of binary sequences that appear to be randomly distributed like noise, but which can be exactly distributed. The most important property of PRN codes is that the sequence has a minimum autocorrelation value, except at zero lag.

Pseudorange

A measure of the apparent signal propagation time from the satellite to the receiver antenna, scaled into distance by the speed of light. The apparent propagation time is the difference between the time of signal reception (measured in the receiver time frame) and the time of emission (measured in the satellite time frame). Pseudorange differs from the actual range by the influence of satellite and user clock.

Range

Term used in Navigation for the length of the trajectory between two points. The trajectory is normally the great circle or the rhumb line.

Rapid static survey

Term used in connection with the GPS System for static survey with short observation times. This type of survey is made possible by the fast ambiguity approach that is resident in the SKI software.

Raw data

Original GPS data taken and recorded by a receiver.

Receiver channel

The radio frequency and digital hardware and the software in a GPS receiver, required to track the signal from one GPS satellite at one of the two GPS carrier frequencies.

Reconstructed carrier phase

The difference between the phase of the incoming Doppler-shifted GPS carrier and the phase of a nominally-constant reference frequency generated in the receiver.

Relative positioning

See Differential positioning

Rhumb line

Term used in navigation. Trajectory between two points with constant bearing.

RINEX

Receiver INdependent EXchange format. A set of standard definitions and formats to promote the free exchange of GPS data

RTCM

Radio Technical Commission for Maritime services. Commission set up to define a differential data link to relay GPS messages from a monitor station to a field user.

RTK

Real Time Kinematic. A term used to describe the procedure of resolving the phase ambiguity at the GPS receiver so that the need for post-processing is removed.

Satellite Constellation
The arrangement in space of the complete set of satellites of a system like GPS.

Satellite Configuration
The state of the satellite constellation at a specific time, relative to a specific user or set of users.

Selective availability (SA)
Degradation of point positioning accuracy for civil users by the U.S. Department of Defense. SA is produced by either clock dithering or orbit degradation.

Sidereal day
Time interval between two successive upper transits of the vernal equinox.

Site
A location where a receiver has been setup to determine coordinates.

Space segment
The part of the whole GPS system that is in space, i.e. the satellites.

Solar day
Time interval between two successive upper transits of the Sun.

Squared reception mode
A method used for tracking GPS L2 signals which doubles the carrier frequency and does not use the P-code.

Squaring-type channel
A GPS receiver channel which multiplies the received signal by itself to obtain a second harmonic of the carrier which does not contain the code modulation.

Standard positioning service (SPS)
Level of point positioning accuracy provided by GPS based on the single-frequency C/A - code.

Static Survey
The expression static survey is used in connection with GPS for all non-kinematic survey applications. This includes the following operation modes:

- Static survey
- Rapid static survey

Stop & Go Survey
The term Stop & Go survey is used in connection with GPS for a special kind of kinematic survey. After initialization (determination of ambiguities) on the first site, the roving receiver has to be moved between the other sites without loosing lock to the satellite signal. Only a few epochs are then necessary on these sites to get a solution with survey accuracy. Once loss of lock occurred, a new initialization has to be done.

Time Zone
Time zone = Local Time - Greenwich Mean Time (GMT). Note that Greenwich Mean Time is approximately equal to GPS time.

Topography
The form of the land of a particular Region

Transformation
The process of transforming coordinates from one system to another.

Transit
The predecessor to GPS. A satellite navigation system that was in service from 1967 to 1996.

Transverse Mercator Projection
A conformal cylindrical map projection which may be visualized as a cylinder wrapped around the earth.

Translocation
The method of using simultaneous data from separate stations to determine the relative position of one station with respect to another station. See differential positioning.

Universal time
Local solar mean time at Greenwich Meridian
UT- Abbreviation for universal time
UT0- UT as deduced directly from observation of stars
UT1- UT0 corrected for polar motion
UT2- UT1 corrected for seasonal variations in the Earth's rotation rate
UTC Universal Time Coordinated; uniform atomic time system kept very close to UT2 by offsets.

User equivalent range error (UERE)
The contribution to the range measurement error from an individual error source, converted into range units, assuming that error source is uncorrelated with all other error sources.

User segment
The part of the GPS system that includes the receivers of GPS signals.

UTM
Universal Transverse Mercator Projection. A form of Transverse Mercator projection. The projection has different zones, each 6° wide with a central scale factor of 0.996. Which zone is used depends upon your location on the earth.

Y-code
An encrypted version of the P-code that is transmitted by a GPS satellite when in the anti-spoofing mode.

WGS 84
World Geodetic System 1984. The system on which all GPS measurements and results are based.

Zenith angle
Vertical angle with 0° on the horizon and 90° directly overhead.