GPS: The New Observatory

by David Paul Johnson, PLS

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Yesterday's astronomers, Kepler, Copernicus and Galileo, recorded the motion of the stars and planets in what turned out to be very consistent and predictable paths. These planetary motions were observed with relatively crude instruments, and noted in a book of tables similar to a bus schedule or almanac.

Today's astronomers can still use this solar almanac, called a Solar Ephemeris, to locate any known star. Given a specific point of observation (position) and accurate time, an astronomer can use a Solar Ephemeris to calculate where in the sky the star is on any day, at any time. An astronomer can also, therefore, calculate a position anywhere on the surface of the earth by making a solar observation and noting accurate time.

Using the Global Positioning System (GPS), today's astronomers have access to this same kind of position-fix information almost instantaneously. In effect, the GPS is a kind of miniature solar system. As of January 1993, the GPS satellite network is a constellation of 21 man-made "stars" (totalling 24 upon completion). These satellites are positioned in closely monitored orbits approximately 20,000 kilometers above the earth.

Each GPS satellite is equipped with a radio receiver/transmitter that allows updated satellite position information to be transmitted to the individual satellites (uploaded) from earth-based tracking stations around the world. This satellite position information can be transmitted to GPS receivers (downloaded) to be used for general navigation purposes, and for precise, long-distance geodetic measurement.

A simplified view of this system may be drawn from the child's game blindman's bluff, where a GPS receiver is chosen as "it," and left "blindfolded," unaware of its position in relation to the constellation of GPS satellites. From this unknown position, a GPS receiver continues to collect satellite position-fix data transmitted from the monitored satellites occupying precisely known positions. This process, called realtime (instantaneous) positioning, must continue until the GPS receiver is able to collect enough satellite signal data to determine a realtime navigational position fix in relation to the orbiting GPS satellites.

Realtime positioning defines the position fix of a GPS receiver somewhere within an imaginary circle having a radius of ±100 meters. This means the instantaneous position displayed by a GPS receiver can differ from the true position by as much as 100 meters in any direction. Although it may appear that this positional error is a significant shortcoming of the GPS, it is actually an intentional degradation of the realtime position fix known as "selective availability."

Military GPS receivers are "selectively available" to collect and process a second, scrambled frequency Precise Code (P-Code) that is able to render realtime position fixes within a range of ±10 meters. Single-frequency civilian GPS receivers only have access to a less-precise radio frequency code, known as Course Acquisition Code (CA-Code). Selective availability was devised by the Defense Department to intentionally downgrade the CA-Code in order to keep unauthorized users (bad guys) from obtaining precise, instantaneous position fixes, and launching mobile nuclear warheads against authorized users (good guys).

A realtime position fix of ±100 meters is sufficient to navigate a cruise ship from San Francisco to Singapore, but not accurate enough for land surveying measurement. A computer procedure know as "post processing" is used to change the navigational realtime positioning data into precise geodetic relative positioning data.

Since the magnitude and direction of the positional error is relatively the same for all GPS receivers simultaneously collecting satellite signal data during any given session, this realtime positional error can be isolated as a constant, and its effects eliminated during post processing. Commonly referred to as "systematic errors," once identified, these errors can be removed from an entire system of calculations.

Although the realtime position fix for all GPS receivers in an observation session can be in error up to 100 meters in any direction, the vector measurements between observation points will remain very precise for vector distances up to 15 kilometers, with consistent results in the range of ±1 centimeter. If a GPS control survey can be anchored on a control point with a precise geodetic latitude and longitude, a computer can be used to

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translate the realtime navigational position-fix values into the precise record latitude and longitude values. Using a method known as "differential positioning," vector measurements between GPS observation points are applied to an anchored "point of beginning," rendering precise position fixes for all observation points of a GPS survey.

A land surveyor can transform three-dimensional vector measurements into two-dimensional distance measurements based on a common statewide reference system, known as a state plane coordinate system. By definition, this "plane" is a perfectly flat, horizontal surface that does not take into account the curvature of the earth. A state plane coordinate system may be thought of as a large sheet of graph paper superimposed over a state at some constant elevation. This standardized reference system allows land surveyors to share mapping information.

Land surveyors are able to apply specific multipliers for project latitude (scale factor) and elevation (elevation factor) in order to adjust any state plane coordinate map to fit specific local conditions. On a map or report, these two factors are often shown together as a local project combination factor. Land surveyors can use this combination factor to transform state plane grid coordinates into local ground coordinates, and vice-versa, in order to integrate smaller plane surveying projects with larger geodetic surveying projects involving measurement techniques such as GPS. (IRWA)

One utility is studying the growth of electrical demand as electric vehicles become available. This GIS combines imagery with demographics and will predict which areas will use electric cars first.

The program looks at the income of the residents and driving habits. Since electric vehicles will be major electricity users, the utilities must develop plans to provide the additional power when electric cars become available to the public.

Although satellite imagery has been used by utilities for 15 years, most companies aren't aware of the high-resolution imagery available and still don't appreciate all of its applications. According to Willis, developing a GIS based on satellite imagery only costs about $250,000, which is paid back in about a year. Not only does it allow utility executives to develop plans quicker and for a tenth of the cost of traditional methods, the visual information convinces critics and commissions. As the industry moves into an era of increased regulation and oversight, persuasive tools will become more valuable. In this case, an image will be worth a thousand arguments. (IRWA)

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