

Global Positioning Systems

INTRODUCTION

In little more than a decade, the Global Positioning System (GPS) has revolutionized the surveying and mapping sciences. Until the early 1980s, the surveyor's transit had been the primary tool for accurately locating one's position on the earth's surface. This equipment takes months to learn to use properly, and years are required to master the technique sufficiently to become a licensed surveyor. With relatively little training a novice GPS user can now record his or her location to within a few meters.

GPS was developed by the United States Department of Defense (DOD) for military purposes. Although DOD believed that there would be civilian use of the system, it was never anticipated that nonmilitary applications would quickly surpass defense uses in volume and diversity. The system's foundation is a constellation of satellites known as NAVSTAR. These satellites continually send out signals that are picked up by GPS receivers and used to calculate a receiver's location in three-dimensional space. This information is then translated to any of several geographic coordinate systems, such as latitude and longitude or Universal Transverse Mercator (UTM).

There are several types of GPS receivers that are useful for different applications. (See Figure 1.) Military grade receivers, which can decode a special noncivilian signal called precise positioning system (PPS), are very helpful for navigating (within about 10 meters) to known sites. Normal civilian GPS receivers, which use coarse acquisition (CA) signals, are better suited to mapping applications. After data is collected in the field with these receivers, accuracy can be greatly improved (to approximately two to seven meters) through a process called differential correction (discussed later in this section). Some GPS receivers are capable of collecting data in either



Figure 1. Catalog photograph of a GPS rover unit. (Photograph courtesy of Trimble Navigation, Inc., 1995)

PPS or CA mode. There are also receivers specifically designed for extremely high-accuracy surveying. Most of these units can deliver coordinates accurate to within a centimeter. The most precise GPS receivers have even been used to detect motion in the earth's crust to within a millimeter.

APPLYING GPS TO CULTURAL LANDSCAPE MANAGEMENT

In association with a Geographic Information System (GIS), GPS is an expedient and accurate tool for verifying the location of specific landscape characteristics and associated features to

identify UTM coordinates. The coordinates can, in turn, be used to verify georeferenced spatial data in GIS and aerial photographs. A GPS unit with an accuracy to within nine feet horizontally will most often be used to locate cultural landscape characteristics and associated features on a 1 inch = 20 feet base map. A survey grade GPS unit is more likely to be used when locating features on a 1 inch = 20 feet base map.

TECHNICAL CONSIDERATIONS

When a GPS receiver picks up signals from four satellites simultaneously, it can calculate a three-dimensional position for the user. When GPS first came into use, the NAVSTAR satellite system was incomplete. As a result, it was always necessary to plan data collection times to coincide with maximum local satellite visibility to ensure that four satellite signals would be detected by the receiver (often referred to as "mission planning"). Now satellite coverage is available nearly continuously throughout the world, and data collection can be performed almost anywhere at any time. However, there can still be problems receiving a sufficient number of satellite signals in deep canyons or under heavy canopy. Under these conditions, mission planning may still be advisable.

Accounting for Signal Error

Because DOD wants to retain a strategic advantage over other countries' military organizations, it introduces a deliberate random error into the civilian satellite signals called selective availability,

or SA. This error makes it necessary to take extra measures to obtain coordinate locations more accurate than 100 meters.

The most common method of eliminating SA-introduced error is known as post-processed differential correction. This technique requires that a second GPS receiver, known as a base station, be established at a known location, preferably over a survey control monument or other such site. The base station must be collecting data from the same satellites at the same time as the rover unit. As the base station collects data recording its location, the coordinates recorded wander randomly due to the SA error. When field collection is complete, software is used to apply a set of corrections to the base station's data, based on its known, true location. These same corrections are then applied to the corresponding rover data. In this manner, data that was no more accurate than 100 meters can be made as close as two meters or even better. To ensure that the base station and rover unit "see" the same satellites, it is usually recommended that the rover unit be no farther than 500 kilometers from the base station, and that no signals from satellites lower than a certain level above the horizon (usually 15 degrees) be used in calculating rover positions.

Another method of eliminating SA error is real-time differential correction. The process is similar to post-processed differential correction, except that the base station has a radio beacon that transmits its corrections to the rover unit as data is collected. The rover unit is equipped with a radio receiver to pick up the correction signals, and an internal computer to calculate the corrected coordinates.

Military grade receivers that use PPS to record their locations avoid SA altogether. To prevent use by foreign countries, however, PPS is a coded signal that can only be read by a receiver properly configured to decode it. Through an agreement between the departments of Interior and Defense, the NPS has access to purchase and use receivers capable of decoding PPS signals. Most of the receivers of this type procured to date by NPS are Rockwell PLRGs (nicknamed, "pluggers").

Satellite Visibility Constraints

Sometimes, even when more than four satellites are visible, it is not possible for the GPS receiver to get an accurate reading for its location. This is due to other sources of error in the system, such as atmospheric and ionosphere effects on the satellite signals, and errors in the internal timing mechanisms in the receivers. Most of this error can be minimized when the satellites being used to calculate a position are in a desirable geometrical configuration. However, often the angles between the satellites are too shallow or too near 180 degrees to help eliminate enough of these other errors to produce a good positional reading. This problem is known as position dilution of precision (PDOP), and can be quite vexing in less than ideal terrain or canopy situations. Often a GPS user may be having a difficult time just trying to get enough satellites, only to find that when a fourth signal kicks in, it results in a reading with much too high a PDOP to be acceptable for mapping. Sometimes the GPS user can move to a more favorable location and record an "offset" distance to the desired point, but unfortunately there is often nothing that can be done other than



Figure 2. GPS operators and equipment in the field. (Photographs courtesy of Trimble Navigation, Inc., 1995)

to wait for a lower PDOP reading. This is why it is still important to use mission planning software when collecting data under difficult satellite visibility conditions.

Using a Data Dictionary

As data is collected by the user (see Figure 2), the points, lines, and/or polygons being recorded are stored in the receiver's data logger. When collecting data for input into a GIS it is often useful to have a list of the types of features to be collected, and information about

them, stored in the data logger. This list is known as a data dictionary. As an example, if data about a cultural landscape were being collected with a GPS receiver, the data dictionary might contain a field for a unique feature identifier number, and another field containing the type of feature, such as building, fence, or rock wall. The user can select the appropriate codes as each feature is collected, saving time and confusion trying to remember which feature was which after the data has been entered into a GIS. (See *Landscape Lines 10: Geographic Information Systems*.)

WHERE TO GO FOR ASSISTANCE

Within the NPS there are many sources for obtaining technical assistance on GPS. Many parks have staff who are knowledgeable about using GPS and who can respond to inquiries. In addition, many regions and clusters have field technical support centers that provide GPS services. There are regional and cluster GIS coordinators throughout the agency who can provide technical guidance and direct individuals to appropriate resources. The coordinators' names and phone numbers, along with other agency-related GIS information, are available on the NPS GIS world wide web site (www.nps.gov). For general program information, the national GPS coordinator can be reached at 505-988-6710. Finally, the NPS Cultural Resource GIS (CRGIS) Facility of the Heritage Preservation Services Program provides GPS training and data collection service.

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