RESEARCH PAYS OFF

Improving Productivity in Ground Control Surveys

TEXAS LOOKS TO SPACE

Problem

In the late 1970s, the State Department of Highways and Public Transportation (SDHPT) in Texas faced a large increase in construction projects without a planned increase in the work force. To help resolve the expected labor shortage, the SDHPT decided to investigate and apply automated procedures throughout the highway design and construction process.

One goal was to reduce the manpower and time needed for performing ground control surveys to support the department's production of topographic maps. The maps are developed by observing aerial photographs with stereoscopic photogrammetry techniques. To help interpret the photographs, reference points on the ground are made within the area covered by the aerial photographs. Until recently, the coordinates of these points have been established through ground surveying techniques.

To accommodate mapping needs, the SDHPT anticipated that more than 2250 kilometers per year would have to be surveyed to establish necessary ground control points for aerial photography. The beginning and end of each control survey also had to be tied to the National Geodetic Reference System (NGRS) to obtain the basic coordinate reference information and to control the quality of the survey. Because of the distances involved, 30 to 50 percent of the cost of these surveys can be attributable to this tie to the NGRS, according to one study. What was needed was a new, cost-effective surveying technology capable of replacing the laborious conventional ground surveying methods, especially for large projects such as highway alignments.

Solution

In early 1979, the SDHPT began to investigate the use of earth-orbiting satellites for various applications. These investigations revealed that satellite survey technology had the potential for improving ground surveying operations if sufficient accuracy could be obtained. To support both mapping and other engineering requirements, the SDHPT was looking for satellite technology that would produce accurate measurements to the centimeter level over baselines 1 to 50 kilometers long.

In 1980, the department began studies to test the use of the Global Positioning System (GPS). GPS is a worldwide, 24-hour a day satellite navigation system that is being developed by the U.S. Department of Defense under Air Force management. Existing Defense Department policy authorizes limited use by the civilian community. At present, all of the GPS satellite constellation is not in place and only a 5-hour "window" each day provides access for taking measurements. This window appears 4 minutes earlier each day; therefore, depending on the time of year, the window may not be available during daylight hours. By 1993, however, the full constellation of 21 satellites is expected to be in place and it will be possible to take measurements at any time.

These early studies produced excellent test results: GPS could produce accuracies at the millimeter level over baselines 1 kilometer long and centimeter level accuracies over baselines hundreds of kilometers long. Equally important, where applicable, GPS methods can reduce manpower requirements while attaining these accuracies, which are better than conventional surveying techniques by at least a factor of 4.

Application

On the basis of the results of these studies, the SDHPT purchased three GPS receivers in early 1983 and put them into service supporting field surveys. Using GPS relative positioning techniques (in Figure 1), the department established primary control points along highway project corridors at 2- to 10-kilometer intervals. One receiver was placed on a point of known coordinates (e.g., an NGRS marker) and the two remaining receivers were placed on unknown points. Satellites were tracked for approximately one hour before the two receivers on the unknown points were moved to two additional unknown points and the satellites tracked again, and so on. The number of points that could be obtained in one day was limited by the measurement access window, but 24-hour availability is expected soon. Since 1983, the SDHPT has acquired additional GPS receivers for use by other department field survey parties, who are using them regularly in their engineering survey tasks.

To facilitate the department's expanded use of GPS methods, automated GPS tracking stations have been constructed and installed in the Dallas/Fort Worth, Austin, San Antonio, and Houston areas. Each of these stations acts as the known location for GPS relative positioning within a 200-kilometer radius. A total of nine tracking stations are planned. The stations are connected with data lines to a central location where the data are collected, checked, and filed. A surveyor in the field with one GPS receiver occupies an unknown point for approximately one hour and transmits data over a modem and dial-up telephone line to the central location. The data collected by the surveyor's receiver and the appropriate tracking station are brought together to compute the coordinates of the unknown point. Calculations normally take about 30 minutes to complete.

Other positioning applications being studied by the SDHPT take advantage of GPS "kinematic" relative positioning techniques to locate a moving object. An important development is the use of GPS to locate the camera in an airplane at the instant of photographic exposure. The coordinates of the camera can then be used as the control point to convert photographs to engineering maps. The results of recent tests show that GPS methods can determine the coordinates of an aerial photograph to an accuracy of 5 centimeters (root-mean-square) in all three axes compared with the coordinates derived from standard photogrammetric methods based on ground surveys. With further development and a fully operational satellite system, this GPS procedure will eventually permit the production of photogrammetric maps with little or no ground control, thus creating efficiencies far beyond those now realized.

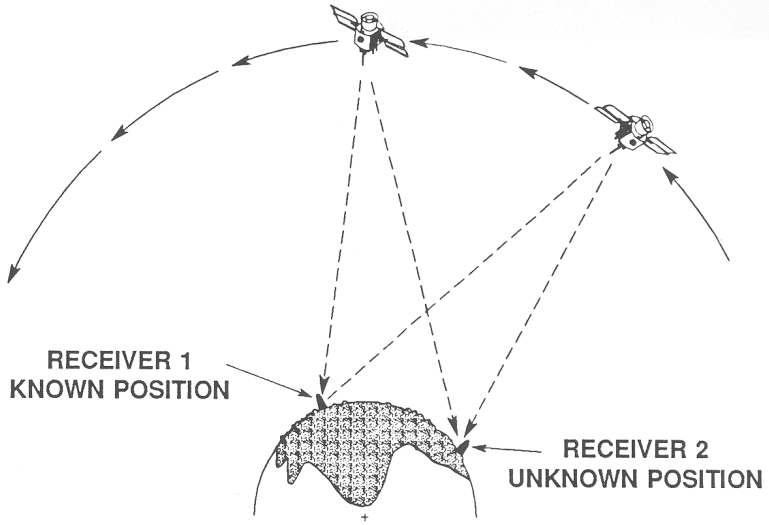

FIGURE 1 Global Positioning System relative positioning techniques.

Benefits

After five years, results show that the use of GPS methods can reduce manpower requirements by at least a factor of 6 in applicable cases, usually large projects with great distances involved. For many applications the factor is much higher, and in some cases GPS techniques have accomplished measurements that were not possible by conventional surveying methods. For this reason, the SDHPT was able to maintain production without using additional employees during a period of increased work.

The initial studies undertaken by the SDHPT to investigate the potential for ground control surveys cost approximately $100,000 and have led to the purchase of new equipment and investigations of additional improvements in surveying and other applications. However, the SDHPT believes that it has already saved $1,000,000 over the use of conventional ground surveying techniques through increased productivity. The total costs in equipment and software are not considered in estimating the savings, but the potential for further improvements in GPS technology and continual applications will provide additional benefits far exceeding any initial investments.

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Suggestions for "Research Pays Off" articles are welcome. Contact Crawford F. Jencks, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418 (telephone 202-334-2379).