# SURVEYING WITH GPS

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## ABSTRACT

GPS is a positioning technology that has revolutionized the surveying industry by providing the surveyor accurate and timely positioning data. For some geomatics practitioners, the advent of a new technology causes wholehearted adoption for all surveying functions. This paper will begin with a reminder that GPS is only one tool within the surveyor's toolbox. A discussion of how to make sure it is being applied correctly to the task at hand will be presented. The paper will cover GPS and other measurement technologies such as robotic total stations and digital levels. Suggestions will be given on how to analyze the surveying project to determine how these combined technologies can be applied most effectively to meet your total surveying requirements

## BIOGRAPHIES

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## INTRODUCTION

The Global Positioning System, (GPS), just as some of the other surveying technologies of the $20^{th}$ century, has caused paradigm shifts in surveying processes. Just as with any new technology, there has been enthusiastic adoption of this new tool on the one hand and a more cautious approach on the other. In the process of developing new tools, GPS and otherwise, the authors have had to think about how the way things are done will change and could be changed. Sometimes the application of the new technology has been observed to be a direct replacement for another. Sometimes it is used as a complement. Sometimes it is used in ways that the older technologies hadn't or couldn't. In this paper the authors present their thoughts and observations on the changes of the surveying scene as technologies are introduced or enhanced.

## SURVEYORS AND ENGINEERS IN THE DEVELOPMENT PROCESS

Geomatics practitioners, engineers, developers, owners and even regulatory authorities use various parts of the surveying process in contributing to the conceptualization, design, actualization and maintenance of engineering and land development projects. With respect to surveying, their requirements in the field and office with respect to the tools they use are for

- Accuracy
- Functionality
- Integration
- Productivity and,
- Ease of use.

These requirements are to ensure that the activities required by surveying processes that contribute to the project are done properly and in a timely manner.

Today, a wide variety of tools are available to the surveyor to accomplish these activities. It is no longer a matter of having a transit, tape and dumpy level on hand. The tools themselves overlap the required functionality in some respects. Determining the optimal tool for the task and time at hand is not done without a lot of thought.

It is incumbent on the surveyor therefore, to do the analysis, synthesis and integration to most effectively use the resources at hand.

# INTEGRATION OF SURVEYING TOOLS

When the surveyor's toolbox is integrated properly, it is possible to optimize the tool to the application easily. The process of selection itself becomes easier. The primary concept in tool integration in the field is to provide the ability to work independently of the *sensor*. By sensor is meant surveying instruments that are used to sense position, whether in one, two or three dimensions. The predominant sensors in use are optical total stations and real time kinematic GPS, but any other possibilities exist.

**Achieving Sensor Independence**

Sensor independence is achieved by have a data processing system that can work equally well, in real time, within the operational parameters of any sensors. Sensor independence is achieved in two principal ways. The first is by using the same data collection system in the field with each sensor. The other is by using some type of digital media to transfer the data between sensors and the office computing system. When thoroughly integrated with the office components of a surveying system, the integrated toolbox enables the reduction, display and analysis of data from different sensors. It also enables the seamless flow of data between these field systems and the office component.

When the integration is complete, the survey concepts key to each technology are handled in a consistent manner so that no corruption of the data occurs. With GPS and optical total stations for example, integration of the data necessarily requires proper conversion of data points on an ellipsoid to a plane or vice versa.

**GPS Technology**

GPS, especially RTK GPS is a widely accepted technology for achieving all aspects of the surveying function. It has been shown to achieve productivity gains over optical total station of 50% to over 1000%. Being able to use it in all kinds of weather and at night helps to increase the progression of the work, especially in projects where work continues into two or three shifts. Its ability to not be limited by line of sight, and to work over a 20 km (10 to 12 mile) range from the reference station increases speed and accuracy. Since data collection is initiated at the antenna pole, which is located at the point of interest, quality of the data collected is greatly improved and the occurrence of blunders is reduced.

Keeping in mind that GPS use will be restricted under some circumstances, the surveyor needs to have an alternative system to reliably make a measurement when GPS cannot.

**Optical Total Station Technology**

Optical total station technology is a mature technology, which has been in reliable use for over two decades. It required intervisibility between points that are instrument stations and between the instrument stations and the points being surveyed. The range of the EDM on the total station limits range. Usability is usually limited by weather. And low light or night observations, while possible are difficult and slowed down. Finally, because the data collection process occurs at the instrument, the correlation between the surveyed points and the coded data is susceptible to error.

In spite of all this, optical total stations continue to enjoy the lion's share of the burden for carrying out work. They can be "initialized" relatively quickly, and can be used with less fuss, especially when the work involves just a few observations over a limited area. They continue to be the "standard" against which all other types of sensors are compared.

## Servo-driven and Robotic Optical Total Stations

A refinement to an existing technology are the classes of servo-driven and robotic optical total stations. Their importance in the last few years is seen to be steadily increasing. Their added functionality makes them suitable for intense mapping or setting out functions especially. Because of their capacity to improve the surveying operation significantly the authors classify them here as a separate group.

Servo-driven Optical Total Stations: By using motors to aim and position the instrument, servo-driven instruments are particularly appealing where automatic pointing is desired. In the case of setting out, it makes it feasible to set control points for surveying with very little sighting through the telescope. When used with the data collection software, the pre-determined coordinates of the point, once they have been selected after setting up the instrument and making an observation to the backsight point, are used to automatically set the horizontal and vertical angles of the instrument automatically. In the case of traversing or other control survey functions, the servo drives can be used to point the instrument in the direction of the next target of the observing program, requiring only fine-pointing adjustments by hand. When these instruments are used manually, because they are servo-driven, they have friction clutches that afford great speed in pointing as there are no locks to be adjusted. Furthermore fine pointing is aided by having unlimited travel in the tangent screws. Again, because of the servo-driven design, the limit stops of the fine motion screws no longer can exist.

Compared to RTK GPS, the servo-driven instrument still has the disadvantage of data collection and coding occurring at the instrument. It is also mandatory that at least two people be on the crew. Still, tremendous productivity gains have been reported. One user with 71 crews claimed a productivity increase of 62% (*Professional Surveyor*, July 1995).

Auto-tracking Servo-driven Optical Total Station: A further enhancement to the servo-driven instrument is the auto-tracking feature. This enables the servo-driven instrument to lock onto a target and follow it. By having a servo-driven instrument with auto-tracking feature several operational improvements are obtained. Since the target is followed as it moves, the rod person seldom has to wait for the instrument person. Aiming and focussing are eliminated from the manual operations required to take a reading. Errors in observations due to parallax error are eliminated as well.

Phenomenal increases in accuracy have been reported. When active targets are used with the trackers in traversing and other control surveying operations, standard deviations in angle measurement of ±0.2" has been reported. Furthermore, in mapping or setting out operations, multiple rod persons can be used for higher productivity. A review of auto tracking servo-driven instrument use compared to a manually operated total station showed a 107% increase in data collected (*Professional Surveyor*, April 1994).

Robotic Optical Total Stations: When a communications link is added to facilitate the placement of a data collector/total station controller at the rod, so that one-person surveying is possible, we have what is referred to as a robotic optical total station. Robotic instruments have the advantages of being controlled from the rod, thus the coding and quality control is done at the point being measured, which greatly improves the usability of the data. Typically, the auto-tracking feature is used to follow the target. When the operator/rod person is on target, the measurement is initiated with the data collector/controller mounted on the prism pole.

To ensure that quality observations are taken, the operator can remotely initiate checks to the backsight point. Similarly reports on the level vial of the instrument can be transmitted over the communications link to obviate walking back to the instrument periodically. While modern auto-tracking systems are excellent, then can still get confused and lose the target. It is more common for the target to be lost when the prism pole is placed on the ground so that stakes can be driven, to dig for a sub-surface monument, etc. Sometimes the auto-tracker loses the target because it and the rod person get in a vehicle to travel to another part of the site where surveying will continue! In these cases, the robotic instrument of today is set up with sophisticated search algorithms which can be preset by the operator in advance to make the search for the target as efficient as possible. It is possible to preset a search window so that the search operation does not occur over the entire range of 360°.

The instrument can be directed to point to a certain direction on command from the instrument controller when all other automatic search methods don't work or consume too much time. When setting out, the opposite problem of aligning the rod-person with the pre-determined aim of the instrument is required. A feature called a tracklight that emits twin beams of light along the line of sight generally facilitates this. When to one side or another the color visible in the beam indicates to the rod person in which direction it is required to move to be aligned with the cross hairs of the instrument. When the rod person is on light both colors are simultaneously visible. In some configurations, a third color is visible. When a trial measurement is made one embodiment flashes the light at different speeds to indicate to the rod person whether the next trial measurement should be taken closer or further away from the instrument.

By moving the person with responsibility for the survey to the point being measured, robotic instruments enable more freedom for the surveyor from mistakes that may sully his or her reputation. By performing the data collection and coding functions at the rod, walkie-talkies are eliminated both from an equipment and operational point of view. It also then eliminates communication errors. During setting out, the stake out results can be seen and evaluated immediately and compared directly to the point instead of having to rely on a rod person to do this. Work thus progresses more swiftly, more correctly and more effectively.

Finally, with robotic instruments it is possible to claim one-person operation, especially when mapping. When setting out, unless the volume of points to be set out is low, or they are widely spaced, surveyors have found that having a two-person crew, with both at the rod, greatly increases the speed. In many cases the surveyors who opt to use two-person crews with robotic instruments have used three person crews for setting out with manual total stations.

Studies showing speed and productivity increases in excess of 100% using robotic instruments over manual instruments have been reported.

## IMPACT ON SURVEYING OPERATIONS

Surveying operations thus have at a minimum a choice of three different kinds of technologies to use as sensors: RTK GPS; robotic and servo-driven total stations; manual total stations. But these technologies don't offer a panacea for the surveyor. Reliance on tried and true principles of surveying are still required. In fact because different basic principles underlie GPS as compared with total stations, *more* understanding of the differences is required to properly assimilate and integrate the methodologies.

In the case of GPS it must be remembered that vectors are still being measured, similar to those measured with total stations. Because a line of sight is not required, it is often easy to become careless and forget this fact. Just as with optical total stations, how a traverse is done, or a control survey is observed will determine if the survey will stand up or fall down. The concepts of traversing, strength of figure and designed redundancies are still important with GPS, and in many ways, because the distances involved are typically larger than with total stations, more so.

It is true that these new technologies have the great asset of introducing a much lower learning curve to be *apparently* productive. It is the geomatics professional's job to ensure that the proper experience and judgment are still being applied together with the basic surveying principles to assure that the integration of all these technologies is producing a result which the surveyor and the client want.

### Opportunities for More Effective Surveying

By combining these options into an integrated system and selecting from them, the surveyor is able to be more effective. Selection of the appropriate sensor enables most tasks to be done with more efficiency. Often this improvement also involves using one less person. One of the great challenges for managers of surveying operations is to obtain qualified, experienced personnel. The manpower improvement makes the pressure in this area a little less.

By moving the judgment and experience to the rod, we finally find that surveying is being practiced the way it should be and if you go far back enough, the way it used to be! This improves the ability to perform various quality control aspects where it was practically impossible before. In addition, the opportunities for reducing exposure to liability for incorrect are at hand.

The new technologies improve effectiveness in surveying never before appreciated. Some of these ways include increased safety, improved ergonomics (to improve efficiency as well as health), and reduced fatigue (in addition to affecting safety, also affects accuracy, particularly with respect to blunders). Combined with the advantages provided to managers, the new technologies improve the flexibility of the business to respond to needs by being able to manage productivity, accuracy and quality control.

Finally, the increased flexibility can even add choices as to when to survey. All the sensors provide methods to do topographic surveys, short range hydrographic surveys, as-built surveys, construction layout, roadways and airports and mining surveys. Depending on personnel, their training, the nature of the site and the surrounding, the density of points to be surveyed, the difficulty of access to the points, a variety of the technologies will have to be selected.

Summarizing, the criteria for judging sensor to be used are:

- Project size
- Accuracy requirements
- Geography
- Proximity of known control
- Safety issues
- Manpower available
- Distance from home base