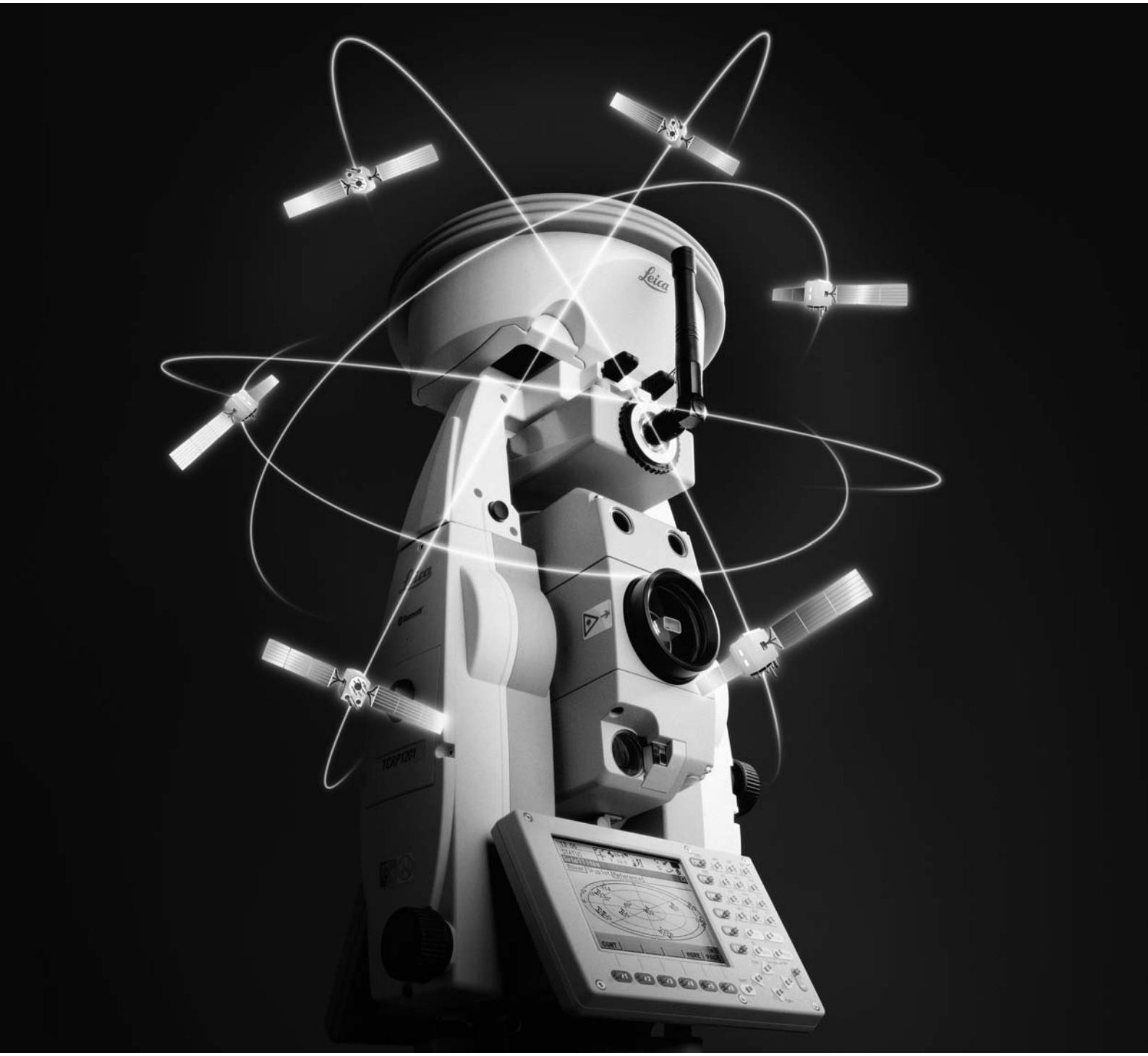
Leica SmartStation

The integration of GPS & total station technologies



- when it has to be **right**

Leica Geosystems

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Abstract

The idea of combining GPS and total stations is not new. Stansell [1983] predicted that by the year 2000 surveyors would combine conventional survey instruments and GPS as an integral part of every survey job. With the release of SmartStation from Leica Geosystems, the world's first integration of GPS and total stations is commercially available. This paper describes SmartStation and shows the productivity improvements that can be achieved by using a survey instrument that integrates GPS and total station technologies. An example survey shows that the survey could be completed in 84 min using SmartStation, whereas using conventional traversing to bring control into the area and complete the survey required 135 min, a saving of 38% using SmartStation.

Introduction

Traditionally, surveyors used angles measured with theodolites and distance measured with a steel band or Electronic Distance Measurement (EDM) device to propagate coordinates from one point to another using the technique of traversing. The total station simplified the procedure of traversing by integrating the EDM into the theodolite and reading all measurements digitally. The introduction of satellite positioning systems has provided the surveyor with an additional measurement technology to perform survey tasks. GPS, in particular real-time kinematic (RTK) GPS, provides surveyors with an efficient tool to conduct their survey activities. Although RTK GPS is now widely used, there are still many surveyors who do not benefit from GPS technology because of a perception of complexity and expense. SmartStation provides the world's first commercially available survey instrument that integrates GPS and total station technologies that significantly improves the efficiency of surveyors, is easy-to-use and provides a cost effective entry point to RTK GPS technology.

Survey equipment advances

Survey instruments have come a long way since the days of transits and steel chains. Modern total stations now include reflectorless EDM measurements, have a broad range of on-board application programs, automatically conduct fine pointing to prisms, automatically find prisms and allow one-man robotic operation to conduct stakeout and detail surveys in a highly efficient manner.

With regard to GPS, since the first introduction of GPS equipment, there has been a significant reduction in the size of the equipment coupled with significant improvements in the accuracy of the measurements. Today, almost all survey grade receivers have RTK functionality to provide centimeter accuracy in the field. RTK GPS allows surveyors to conduct stakeout and detail surveys in a highly efficient manner. In many regions, the availability of a GPS reference station network means that surveyors can utilize RTK GPS without the need to set-up their own local reference station. They simply enter the field, dial-in to their reference station network and begin RTK GPS surveying.

Reference station networks are increasing in popularity as many government agencies have found it more economically viable to invest in GPS reference station networks rather than maintaining ground control. In addition, many private companies have seen opportunities in setting-up reference station networks and selling the data to an increasing number of users.

Despite many advantages, surveying using only total stations or GPS has disadvantages. Surveying with a total station, unlike GPS surveying, is not disadvantaged by overhead obstructions; however, it is restricted to measurements between inter-visible points. Often control points are located distant to the survey area, and traversing with a total station to propagate the control is a time consuming task. For this reason, GPS is frequently used to bring control to the survey site before continuing the survey with a total station in areas with overhead obstruction that limit the use of GPS. This procedure is a two-sep approach that requires multiple set-ups on points, one with GPS and then again with a total station. SmartStation eliminates lengthy traverses and multiple set-ups by integrating RTK GPS into a total station to provide maximum efficiency for common survey tasks.

SmartStation

A new generation of total station (TPS) and GPS equipment, collectively referred to as System 1200, was introduced in February 2004 [Leica Geosystems, 2004a]. The introduction of System 1200 saw the first step toward a complete integration of GPS and total station instrumentation. The integration, known as X-Function [Leica Geosystems, 2004b], covered all facets of the equipment:

- User interface – identical operation concept and on-board application software;
- Database – seamless data transfer between instruments;
- Batteries & chargers – identical accessories to keep equipment costs down;
- Office software – one office environment to merge all measured data;

TPS1200 provides angular measurement accuracies ranging from 1″ to 5″ of arc and distance measurement to prisms at distances of 7.5km with an accuracy of 2-5mm+2ppm and to other surfaces (reflectorless) at distances of more than 500m with an accuracy of 3-5mm+2ppm. TPS1200 together with the RadioHandle and the remote controller (RX1220) provides efficient one-man operation. GPS1200 includes advanced technologies such as SmartTrack and SmartCheck to provide accurate and reliable GPS positioning. Today TPS1200 and GPS1200 are used in harmony as efficient survey tools to complete challenging tasks.

SmartStation introduces the next logical step in the integration of total station and RTK GPS technology. SmartStation consists of a TPS1200 total station together with a SmartAntenna GPS receiver. The SmartAntenna is located collinear with the vertical axis of the TPS1200. Once the SmartAntenna is connected to the TPS1200, all operation is conducted through the keyboard of the total station. Data from the GPS reference station to provide RTK positioning of SmartStation is received through a communication device which is clipped-on to SmartStation (radio modems, GSM, GPRS, TDMA, CDMA) or via a Bluetooth™ wireless connection between the TPS1200 instrument and a mobile phone. GPS RTK positioning is integrated into the normal total station set-up procedure and is simply conducted with as little as one key press to obtain the RTK GPS position. The SmartStation can be located at ranges of up to 50km from a reference station and still provide accurate positioning (horizontal: 10mm+1ppm; vertical: 20mm+1ppm).

SmartStation provides the following set-up possibilities:

- Set-up on an conveniently located unknown point and back-sight to known point(s);
  - determine SmartStation coordinates from RTK GPS and orientation from observation to one (or more) back-sight point(s); if desired the RTK GPS height can be updated from total station observation(s) to point(s) with known height
  - measure all points from current location and then move to another convenient known or unknown location

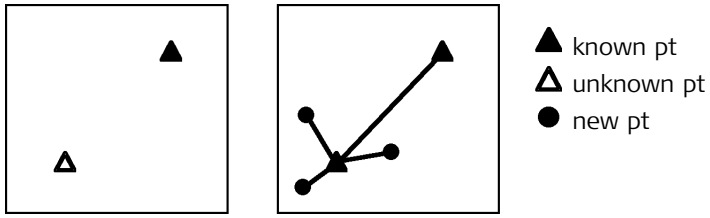


Figure 1 – known back-sight

- Set-up on a conveniently located unknown point and back-sight to another unknown point;
  - determine SmartStation coordinates of the first unknown station from RTK GPS and observe back-sight to another unknown point
  - complete total station measurements from current station
  - move SmartStation to second unknown point and determine RTK GPS positioning
  - back-sight to previously occupied point; orientation is computed and all measurements are updated and coordinates are re-computed!
  - continue with total station measurements from current station

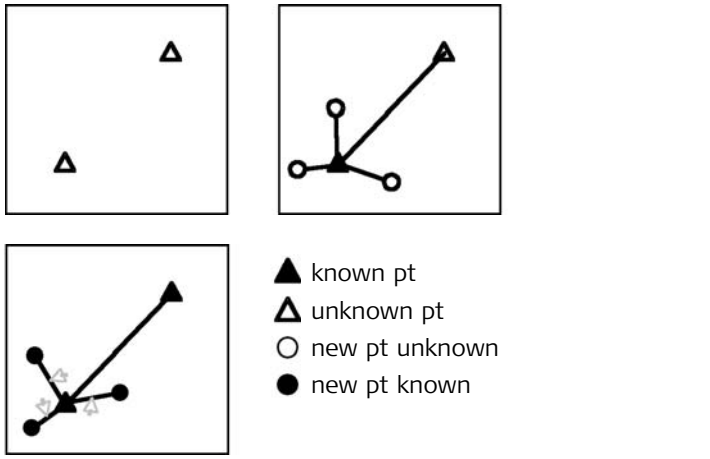


Figure 2 – unknown back-sight

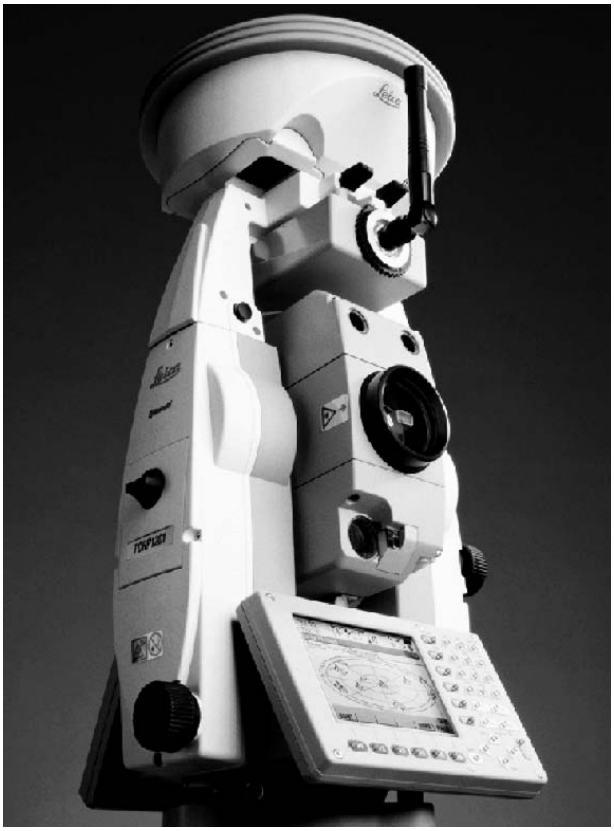


Figure 3 – SmartStation

Once positioning of the total station is complete, if desired the SmartAntenna can be removed from the SmartStation and used as an RTK GPS rover.

Survey scenarios

To describe the benefits of SmartStation, four typical survey scenarios are illustrated, namely:

- Remote Area – Topographic Survey;
- Rural Area – Boundary Survey;
- Construction site – Stakeout;
- Urban Area – Utilities Survey;

Remote Area – Topographic Survey

Topographic surveys in remote areas often have vegetation that limits the exclusive use of GPS to complete the survey. In many cases, GPS is used to establish control before the survey is continued using total stations. Given that a GPS reference station is operating in the vicinity (up to 50km) and transmitting RTK corrections, RTK GPS can be used to establish control points.

To complete such a survey using conventional techniques RTK GPS would be used to measure a series of control points. These coordinates would then be transferred to the total station and one of the newly established control points would be used as the total station set-up location and a back-sight would be observed to another newly established control point. All necessary detail points would be observed from the first station before moving to subsequent points to complete the survey. If the total station survey was conducted before the GPS control was established, an additional step would be required. The total station observations would need to be transformed in the office to be compatible with the GPS control points.

With SmartStation, this survey would be conducted by setting-up SmartStation in a convenient location and determining the coordinates with RTK GPS. A back-sight would then be observed to a second unknown point that will be used, but is not yet coordinated. All necessary detail would be observed from the current location before re-locating to the second point. When set-up at the second point the coordinates are determined with SmartStation RTK GPS. The availability of this second coordinate then allows the system to automatically update all observations made from the first set-up. After back-sighting to the first set-up point all detail can be observed from the second point in the required coordinate system.

Benefits of SmartStation:

- Points are only occupied once;
- Only SmartStation is needed, not two independent sets of equipment;
- Survey is completed in less time;

Rural Area – Boundary Survey

In rural areas, it is not uncommon that control points are located up to 5km away. With a conventional total station this demands a time consuming traverse. An open traverse is liable to error, and a closed traverse back to the same point can take twice as long. Traversing is complicated and time consuming, especially in difficult terrain. Once control has been introduced to the area, the boundary survey can continue by traversing around the boundary of the parcel and taking observations to boundary markers.

With GPS reference station data available, SmartStation can be set-up at any convenient location close to a boundary marker. After determining an RTK GPS position with SmartStation, and observing a back-sight to another suitably located point (known or unknown), observations to the boundary marker can be taken. SmartStation can then be taken to the next convenient location to continue the boundary survey.

Benefits of SmartStation:

- No long traversing required;
- Fewer instrument set-ups required;
- Survey is completed in less time;
- Uniform, higher accuracy obtained;

Construction site – Stakeout

Construction sites normally include a large number of control points, however, these points are often obstructed by machinery and material. In addition, frequently control points are damaged during construction activities, further hindering survey activities. Construction sites demand a high level of efficiency of survey tasks as designs are continually changing and many points need to be staked-out in a short period of time. GPS is increasingly being used for construction site survey activities and a GPS reference station is often set-up at the site office to provide RTK corrections for the site.

Stakeout activities using a total station on a construction site are often difficult and time consuming. Normally, the total station is set-up in a convenient location and a resection is conducted to determine station coordinates and orientation. Finding a suitable location is often not trivial; control points are frequently damaged or obstructed and the geometry of the resection also needs to be considered. All of these constraints regularly lead to a lengthy process in establish station coordinates and orientation. Under time pressure, the extra time required to find a suitable location is undesirable.

Using SmartStation, a location can be chosen that best suits the stakeout task at hand. Set-up SmartStation and determine the station coordinates using RTK GPS, then simply back-sight to any control point to determine orientation. Stakeout activities can then begin immediately.

Benefits of SmartStation:

- Set-up where convenient;
- No traversing or resection required;
- Obstructions on site are no longer a hindrance;
- Stakeout can begin rapidly;
- Construction work can be completed sooner;

Urban Area – Utilities Survey

Increasingly, the positions of utilities are being coordinated with high accuracy to update spatial databases. The features that are surveyed include manholes, covers, hydrants, distribution boxes for water, gas and electricity. The features are often in locations where buildings and tree cover prohibits the exclusive use of GPS to coordinate such features.

A total station provides an excellent tool to capture utilities, however, often control points are obstructed by traffic, parked vehicles and a like, hence rendering traversing essential. Whenever traversing is required, careful reconnaissance needs to be conducted which is time consuming. Once traversing to the station location is complete, the total station is used to coordinate the utility features.

With SmartStation, no reconnaissance is required. Set-up at any convenient location, determine station coordinates using RTK GPS, and measure all features in the vicinity. If no control point was visible from the current location, the point used for a back-sight is occupied with SmartStation and coordinated with RTK GPS. All measurements are automatically updated.

Benefits of SmartStation:

- Control points are not needed;
- No awkward traversing required;
- Consistent high accuracy;
- Complete survey quicker;
- Traversing skills not required;

Comparison – SmartStation vs. conventional traversing

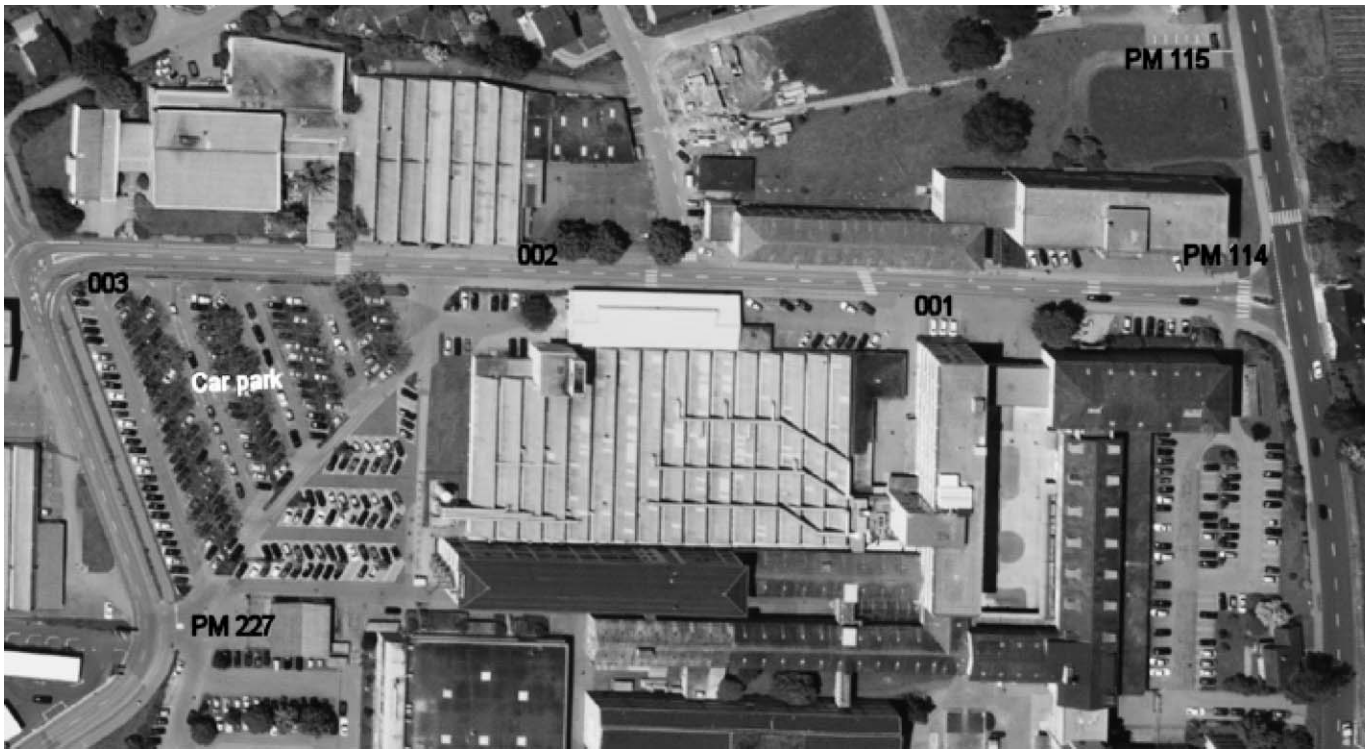
A survey was conducted to compare the efficiency of conventional traversing and SmartStation. The topographic survey of a car park (5700m²) was conducted twice, once using a conventional total station and a second time using SmartStation. Three control points (PM 115, PM 114, PM 227) existed in the vicinity of the area to be surveyed, one adjacent to the car park and another two on the main road, 200m away from the car park and not visible from the survey area.

The conventional total station traverse involved four instrument set-ups (PM 114, 001, 002 & 003). The points 001, 002 & 003 were established during the reconnaissance period of 20 minutes. At each set-up, one round of Face left and Face right observations were observed to each back-sight and fore-sight point. The control portion of the survey took 55 minutes and the detail survey took an additional 60 minutes.

Activity	Time taken
Reconnaissance	20 min
Control traverse	55 min
Detail survey	60 min
Total	135 min

Table 1 – Time taken to complete the topographic survey using conventional traversing

Figure 4 – Survey Area



Closing the traverse from set-up 003 to point PM227 generated a misclosure of 12mm horizontal and 10mm vertical. A portion of the detail measured can be seen in Figure 5.

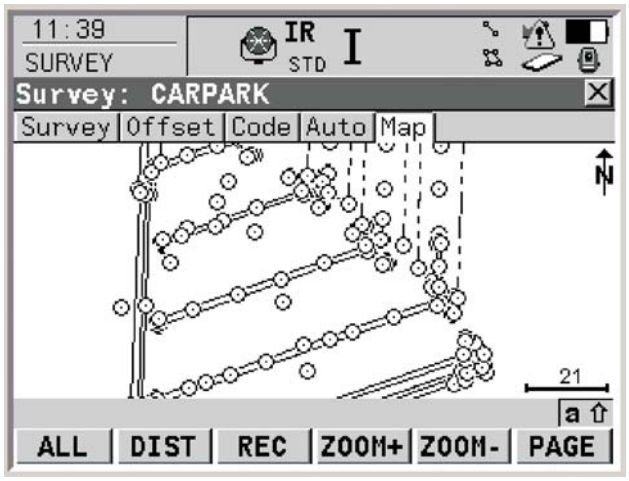


Figure 5 – Car park – topographic survey

To complete the survey using SmartStation, two instrument set-ups were used. At each set-up RTK GPS positioning was conducted, and one set of Face left and Face right observations were observed to a back-sight. At station 003, PM 227 was used as the back-sight and at station 002, point 003 was used as the back-sight. PM 227 was not visible from point 002 due to obstructions.

A distinct advantage of SmartStation is the reduced time needed for reconnaissance. To facilitate comparison calculations, the same stations were used as for traversing and SmartStation set-ups (i.e. 002 & 003). The reconnaissance time needed for the SmartStation survey was half that of the traverse survey as fewer set-up and back-sights were required. If one point could have been found that enabled the topographic survey to be completed whilst maintaining visibility to the control point PM 227, additional time savings could have been realized.

SmartStation automatically begins acquiring satellites and computing precise positions once turned on. By the time the instrument is leveled and positioned over the point, SmartStation can immediately deliver precise RTK positions. The time taken for each SmartStation set-up was the time required to set-up over the point and observe the back-sight (Face left & right). In normal SmartStation applications, the instrument set-up can be greatly expedited (especially for inexperienced total station users) by not requiring a set-up over a particular point. All that needs to be done to set-up SmartStation is to level the instrument using the foot-screws at any location that is conveniently located in the survey area and has visibility to a known point, press a single button to get the RTK GPS position and sight to the back-sight.

Activity	**Time taken**
Reconnaissance	10 min
2 x SmartStation set-ups	14 min
Detail survey	60 min
Total	84 min

Table 2 – Time taken to complete the topographic survey using SmartStation

The differences between the coordinates derived from SmartStation and from conventional traversing for points 002 and 003 are shown in the following table:

Point	△Horiz	△Vert
002	11mm	13mm
003	9mm	12mm

Table 3 – Coordinate differences between traversing and SmartStation RTK GPS

Additional points were observed twice during the topographic surveys, once during the survey from the conventional traverse and once again from the SmartStation set-up's. Each of the points delivered coordinate differences of less than 15mm in both the horizontal and vertical components. This additional check confirms correct determination of orientation using the SmartStation instrumentation.

In this survey, the time saving (41 min or 38% of the total time) was obtained by eliminating the need to traverse from points PM 114 & PM 115 and reducing the time required for reconnaissance. In cases where control is located further away from the survey area far greater time savings can be expected when comparing conventional traversing and SmartStation RTK GPS positioning.

Summary

SmartStation is the world's first commercially available true integration of GPS and total station technology. SmartStation removes the need for traversing to propagate coordinates from distant control points by providing RTK GPS positioning of the total station. To use SmartStation, the surveyor does not need any specialist GPS know-how, RTK GPS positioning of the total station is achieved simply by the push of one button in the standard total station set-up application. The proliferation of GPS reference station networks means that in many cases a surveyor is within 50km of a reference station and can hence dial-up and use SmartStation to determine accurate RTK GPS positioning of the instrument.

With SmartStation, it is no longer necessary for surveyors to conduct extensive traversing, the equipment can be set-up at a convenient location and the survey can begin immediately. If at least one point with known coordinates exists in the survey area then as little as one SmartStation set-up is needed that has inter-visibility to the known point to complete the survey. If no known coordinates exist in the survey area, a minimum of two inter-visible SmartStation set-ups would be required to complete the survey.

When compared to existing, commonly used, methods of traversing or separately establishing GPS control before the survey is continued with a total station, SmartStation delivers substantial efficiency improvements.

Conclusion

SmartStation is a significant advance in surveying instrumentation. Being the world's first integration of total station and GPS technologies, SmartStation offers new opportunities to the surveying community. No longer is it necessary for surveyors to undertake time consuming traversing to propagate control into the survey area. With the press of a single button, the total station location is determined using RTK GPS. No specific GPS knowledge is required; SmartStation is easy-to-use.

A comparison between conventional traversing and SmartStation on a topographic survey showed that the survey was completed 38% faster using SmartStation whilst maintaining an accuracy of better than 15mm in both horizontal and vertical components. The time savings were achieved through reduced reconnaissance and eliminating a control traverse to propagate control to the survey area.

References

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Leica System 1200 – working together

TPS, GPS and SmartStation.
Use TPS and GPS together or separately according to the work you do.
Use whichever is the most suitable for the job in hand.
Change easily from one to the other and use them in the same way.
Enjoy all the freedom, flexibility and power of System 1200.

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