



Developing a Laser Surveying Station for Archeological and Paleontological Sites

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Several years ago, the Missoula Technology and Development Center (MTDC) was asked by a paleontologist in the U.S. Department of the Interior Bureau of Land Management (BLM) to investigate and, if necessary, construct a surveying tool that would require very little training for novice users. Frequently, surveying tasks are performed by seasonal or temporary workers, so project managers are interested in getting reliable measurements with minimal training for new personnel.

The original concept was to develop an ultrasonic range-finding network that would measure the distance between the survey target and several reference points. If the reference point locations were accurately measured, the position of the target could be calculated. The position measurement accuracy of the ultrasonic transponders tested was on the order of ± 5 centimeters, less accurate than the subcentimeter accuracy the BLM had requested. The only viable option appeared to be a laser rangefinder.

After investigating the availability of suitable components, the project team at MTDC determined that something resembling a total surveying station could be assembled from materials costing less than \$4,000, not including the cost of a laptop computer that would convert positions in polar coordinates to rectangular coordinates and store those points in a database. The laser rangefinder selected had an accuracy of 1 millimeter. The angle encoders that detected the laser's aiming point could resolve angles with an accuracy of $\frac{1}{20}$ of a degree or less. The resulting accuracy for a point 5 meters from the laser would be better than ± 6 millimeters, adequate for this application.

A critical component that allowed the MTDC laser surveying station (figure 1) to be constructed relatively inexpensively was a mounting gimbal for the laser. The

project's mechanical engineer found a surplus unit with vernier adjustments that could be used when aiming the laser. Although the project team discussed building a second laser surveying tool, the team had the last surplus gimbal. Purchasing or manufacturing a commercial gimbal of the same quality would increase the cost of a station by several thousand dollars, meaning that the MTDC laser surveying station would cost as much as a commercial total station.



Figure 1—The prototype MTDC laser surveying station (the laptop computer and the box with the electronic interface to the laptop are not shown).



The MTDC laser surveying station measured locations in a polar coordinate system based on:

- Distance from the laser (or radius)
- Elevation angle
- Compass angle (or azimuth)

Total stations also use a polar coordinate system.

Typically, users are interested in rectangular, or NEZ (north, east, and elevation) coordinates. Calculations must be performed to convert a location in polar coordinates into one with rectangular coordinates. For the MTDC device, the calculation was performed by software in a laptop computer. In total stations, the calculation is done internally. MTDC's customer already had a laptop computer for cataloging the surveyed points and keeping records of the excavation sites, so the laptop provided "free" computing.

It is desirable to measure locations of points or artifacts by specifying those locations in reference to a local coordinate system, such as the floor of a rectangular building. Frequently, it is impractical to set up the surveying tool on the exact origin of a coordinate system, so some method is needed to translate the points measured relative to the surveying tool to coordinates based on the local environment. For the MTDC station, the team performed this translation with software in the laptop computer. Most new total stations also perform this task.

The MTDC laser surveying station used a laser range finder that produced a visible red spot on the target. The most expensive total stations (figure 2) the project team surveyed are available with a red dot for aiming. All total stations included a telescope with crosshairs that provides a magnified view of the target. Although the red dot provides some assurance that the correct point is being measured, the red dot is not required with the total stations. In direct sunlight, the red laser dot can be difficult to see from a distance. In such situations, the telescope with its integral crosshairs is a better alternative.

Regardless of how the surveying measurements are obtained, the data typically need to be stored in a computer database when documenting the site. For the MTDC laser surveying station, the database was in the laptop that translated the coordinates. The interface software for the electronic components was written in Microsoft Visual Basic by MTDC, and the data were stored in a Microsoft Access database.



Figure 2— A commercial total station used for surveying (instrument provided for this study by Selby's Engineers Service and Supply Co., Missoula, MT).

The total stations surveyed have serial data interfaces that allow the measured coordinates to be transferred to a computer for storage and association with other files. Several programs, such as Terramodel from Trimble, Land Desktop from Autodesk, and Eagle Point from Eagle Point Software Corp., allow the measured coordinates to be used to model surfaces and prepare maps. All three of these programs are being used by archeologists, hydrologists, surveyors, and engineers in the USDA Forest Service.

Pros and Cons of the MTDC Prototype and Commercial Total Stations

The MTDC laser surveying station solved some problems while creating others. In its favor, the surveying station stored the point coordinates directly in the computer's database. The database allowed the user to document site features and associate a digital photograph with a particular location. Total stations can be set up to transfer data to a hand-held data collector.

A less desirable feature of the surveying station was the electronic box with interface circuitry that linked the laptop computer to the laser and angle encoders. It was cumbersome—but necessary—for the prototype. In addition, the station only operated as long as the battery in the laptop. Both the laptop and the interface box could be damaged by dust or rain. At this time, the MTDC surveying station is a one-of-a-kind prototype. Maintenance or upgrades would have to be negotiated with MTDC.

Commercial total stations offer a number of features that facilitate a site survey. They also provide better accuracy than the MTDC laser surveying station, a major issue for sites spanning large areas. The procedures for calibrating and maintaining the commercial instruments also are well established. Commercial stations are routinely upgraded so they can remain compatible with current technology. In addition, support contracts for commercial total stations assure that they can be maintained and calibrated.

The major drawbacks to the total stations are:

- Site coordinates must be downloaded to a PC for postprocessing.
- Users might need to know more about the operation of a total station than they would need to know to operate the MTDC laser surveying station.

Although no one could learn all the functions of a total station in a few hours, some 4-hour courses have given archeology students sufficient skills to perform elementary surveys with a total station.

Features of Commercial Total Stations

The following list shows the features of total stations priced under \$10,000 (table 1). The list was compiled from responses received from vendors and manufacturers contacted by MTDC. Any omission of comparable units is unintentional.

Manufacturer's Web Sites

Topcon

<http://www.topconsurvey.com/hardware/gpt2000.html>

Nikon

<http://www.ave.nikon.co.jp/survey-e/npl-352/index.htm>

Leica

<http://www.leica-geosystems.com/surveying/product/totalstations/tc400.htm>

Pentax

<http://www.pentaxsurvey.com/>

Table 1—Comparison of nine commercial total surveying stations costing less than \$10,000. All stations are reflectorless models that transform coordinates for the polar coordinate system to the NEZ (north, east, and elevation) rectangular coordinate system. All stations can be configured with a prism to increase accuracy, particularly when surveying over distances longer than 80 meters. All have internal memory for data collection and include an RS-232 serial port for downloading data to a computer.

Model	Accuracy (seconds)	Optical power (x)	Laser plummet (serves as a plumb bob)	Red dot laser sighting	Technology type	Approximate cost (dollars)	GSA contract	Operating time (hours)	Charging options
Topcon GPT 2003	3	30	Yes	No	Pulse	6,600	Yes	8	12-volt car cigarette lighter
Nikon NPL-332	5	26	No	No	Pulse	7,195	No	6.5	12-volt car cigarette lighter
NPL-352	5	26	No	No	Pulse	8,295	No	6.5	12-volt car cigarette lighter
Leica TCR 403	3	30	Yes	Yes	Phase shift	9,995	Yes	6	12-volt car cigarette lighter
TCR 405	5	30	Yes	Yes	Phase shift	8,795	Yes	6	12-volt car cigarette lighter
TCR 407	7	30	Yes	Yes	Phase shift	7,495	Yes	6	12-volt car cigarette lighter
Pentax R-323N	3	30	Yes	Yes	Phase shift	9,450	No	5	Camcorder battery
R-325N	5	30	Yes	Yes	Phase shift	8,650	No	5	Camcorder battery
R-315N	5	30	Yes	Yes	Phase shift	7,750	No	5	Camcorder battery

About the Authors

Ted Etter joined MTDC in 2002 to work on electronics projects. He has spent more than 25 years working in the areas of electronic instrumentation and display technology. He received a bachelor's degree in mathematics from the University of Oregon in 1992 and a master's degree in teacher's education from Eastern Oregon State University in 1993. Before coming to MTDC, he taught courses in programming, digital circuits, data communications, radio frequency communications, robotics, microprocessors, and operating systems at the University of Montana College of Technology.

James "Scott" Groenier, Professional Engineer, began working for MTDC as a project leader in 2003. Scott earned a bachelor's degree in civil and environmental engineering from the University of Wisconsin at Madison and a master's degree in civil engineering from Montana State University. He worked for the Wisconsin and Illinois State Departments of Transportation before joining the USDA Forest Service in 1992. He worked as the east zone structural engineer for the Eastern Region and as a civil engineer for the Ashley and Tongass National Forests before coming to MTDC.

Library Card

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Discusses a prototype laser surveying station developed by the Missoula Technology and Development Center to make it easier for employees with little training to survey archeological and paleontological sites. Commercially available surveying products known as total stations can serve the same purpose and are more accurate, so development of the prototype was discontinued. A table compares nine commercially available total stations costing less than \$10,000.

Keywords: archaeology, archeology, distance, measurement, paleontology, surveying, surveying instruments, surveys, total stations

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