



Low-Cost Tools for Skyline Corridor Location And Simple Point-to-Point Navigation

by Ralph Gonzales, Project Leader

BACKGROUND

Timber sale layout personnel currently use a hand-held compass to navigate from point to point. Local areas of magnetic attraction along with the inherent inaccuracies of a hand-held compass can make it difficult to accurately navigate to a known point. A common task which would benefit from the use of an accurate navigation device is locating a tailhold, off-setting, and the ability to run a straight line back to the proposed landing in only one pass.

Determining the exact location of skyline corridors is essential when laying out partial cut units. By knowing where these corridors will be and, therefore, which trees must be removed, tree markers can do a better job of choosing leave and cut trees which will closely follow the intended silvicultural prescription.

The San Dimas Technology and Development Center (SDTDC) was asked to locate and evaluate low-cost tools which could potentially be used to assist with field layout, road location, or point-to-point navigation. Some of the devices evaluated are currently available in trade catalogs; one was a prototype.

LIMITED FIELD TRIAL

A field trial was conducted on the San Bernardino National Forest and attempted to simulate a cable logging layout operation. One 500-foot reference line was surveyed and established using a theodolite. The line ran down rugged terrain with a light to medium covering of trees; the average slope was 50 percent; the forest canopy was dry.

Each device was used to navigate back to the start of the reference line. Flags were used to mark the line position for each device and later used to measure the horizontal variance from the reference line.

TEST UNITS AND RESULTS

Each instrument was evaluated according to objective and subjective criteria. The objective evaluation criteria were: cost, not including assembly; weight of the



test unit; and accuracy—in this case—deviation right or left from a straight line. Subjective evaluation criteria were: training required to learn to operate the device; and the ease of operating and handling while walking in a forest environment.

A discussion of the overall operation, specifications, capability, and accuracy for each device is provided. The results of the limited field trial are also discussed, and summarized in Table 1.

Table 1. Summary of test results.

Test Unit	Cost per Unit	Weight	Average Deviation	Training Required	Ease of Use Rating
Ramsey Direction Finder	\$70 *	1.84 kg	15 m	medium	high
Garmin12XL GPS Receiver	\$250	269 g	20.8 m	medium	low
Wayfinder Outback Electronic Compass	\$99	200 g	12.3m	low	medium
Laser Theodolite Prototype	\$100 *	350 g	1.1 m**	medium	high
LTI Laser Criterion 400	\$10000	2.8 kg	0.6 m	high	medium

* Assembly required

** 2 units were used to achieve this accuracy

RAMSEY DF-1 DIRECTION FINDER

The Ramsey DF-1 (figure 1) is a switched-phase-array direction finder, sold as a kit requiring assembly. It took a skilled person twelve hours to assemble the kit. A separate speaker mount was fabricated because there was not enough room in the case for a small external speaker. PVC pipe was used to hold the antenna array. The DF-1 must also be connected to a radio transceiver. The Forest Service King radio that was used required modification to accept the antenna array connector.

Operation is based on phase difference and can be demodulated on a FM receiver. Two Forest Service King radios with five watts of power on high setting were used in the field test. One radio was used as a transmitter the other as a receiver.

The received radio signal strength determines location relative to the transmitter. The signal received by each antenna element is compared and the direction finder indicates the direction of the transmission by tone, lights, and needle deflection. When the antennas are the same distance away from the transmission source there is no phase difference; the tone disappears; a null is achieved. When the switched array is rotated on either side of the null, the shift in phase is detected and results in the left to right indications. To find the location of the transmitter, the operator follows the null.



Figure 1. Ramsey DF-1.

Using a Forest Service King radio as the transmitter required two people to run the test; one to use the direction finder and one to operate the transmitter because the transmitter had to be constantly depressed to remain in transmit mode. To avoid interfering with other operations in the forest, a clear frequency was used.

The Ramsey DF-1 did not work well; it was difficult to operate; the user had to move the antenna array back and forth to follow the signal, something that may not be possible in a densely wooded area due to the size of the antenna; and the signal frequently indicated the wrong direction. Half-way through the test the signal was lost requiring the operator to travel the same line until the signal was reestablished. The test was terminated when the signal was lost a second time.

Perhaps the signal problems encountered during this test could be overcome by using a higher powered transmitter. Also a transmitter which would remain in transmit mode would allow one-person operation.

Garmin 12XL Global Positioning System

High quality Global Positioning System (GPS) equipment is available on many Forest Service field units. However, the objective of this test was to look at available low cost alternatives. One such alternative is the Garmin 12XL (figure 2). It is a 12-channel GPS receiver that calculates its position by tracking signals sent by 24 satellites. These satellites circle the earth twice each day in a very precise orbit and transmit information back to earth. The Garmin receiver is able

to save specific locations or waypoints allowing the user to navigate back to a stored point.

Four satellites are required to provide a 3-dimensional fix (longitude, latitude, and altitude); three satellites are required for a 2-dimensional fix; and all satellites must be above the horizon. An almanac containing information on satellite numbers and orbits is necessary to determine the distance and position of any GPS satellite. Fifteen to 45 seconds are required, depending on the receiver's view of the sky, to acquire a 2-D fix on 3 satellites once the data is input into the receiver. Once the Garmin 12XL calculates a position fix, the receiver continuously selects the best satellite in view to update position. The signals are relatively weak, do not travel through rocks or trees, and any significant obstruction degrades receiver performance. A dense and wet forest canopy attenuates the signal making it difficult to obtain a fix.

According to the manufacturer, the accuracy of the position provided by the GPS receiver is 15 meters when the receiver has acquired a 3-D fix with good signal strength. However, this is subject to accuracy degradation to 100 m radius under the United States Department of Defense (DoD) imposed selective availability. The test unit was not equipped with differential correction (the ability to correct errors in location).

The SDTDC trial required the operator to establish a waypoint at a designated yarder location and walk to a designated tailhold location. The operator acquires another position fix at the tailhold and uses the GPS receiver to navigate back to the start. The "GOTO" function gives the operator a bearing to follow back to a stored waypoint, in this case the yarder.

A clearing at the end of the reference line was required for the operator to obtain a position fix. The offset was measured and accounted for when navigating back. The average deviation of the GPS unit was 20.8 meters. At times, the GPS receiver gave false bearings and poor satellite coverage was experienced but the signal was never lost. A bar graph display on the unit indicates satellite signal reception and an audible tone warns the user when the signal is poor.

Wayfinder Outback Electronic Compass

The Wayfinder Outback Electronic Compass is a tilt compensated compass that, according to manufacturers specifications, is accurate to within two degrees even when tilted up to plus or minus fifteen degrees (figure 3). The compass can be calibrated to account for local magnetic



*Figure 2.
Garmin 12XL global
positioning system.*

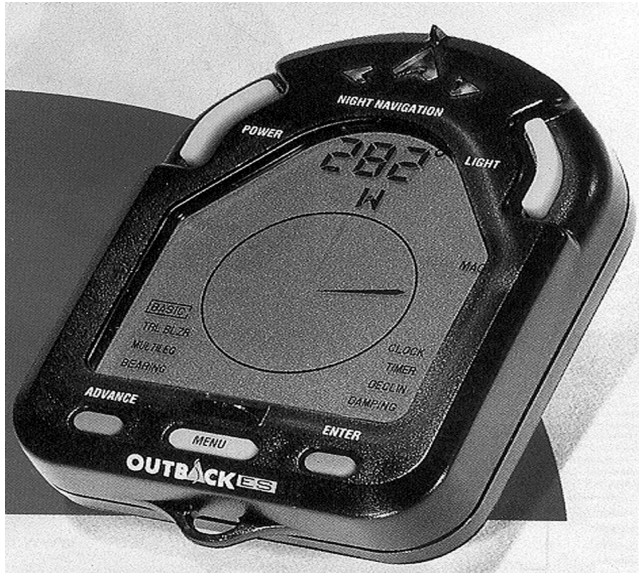


Figure 3.
Wayfinder Outback Electronic Compass.

interference. A warning is displayed when magnetic influences exceed a predetermined level and an alarm warns the operator when outside magnetic influence is causing errors in the compass heading. The device must be recalibrated when outside magnetic influence is encountered. The compass also has an “Off Track” function which alerts the operator when a deviation occurs from a preselected bearing.

The Wayfinder operates in four modes: Basic, Trail Blazing, Multi-Leg, and Bearing. In Basic Mode, it functions similar to a traditional compass—heading is shown on the numeric display and the compass rose points to North. Trail Blazing mode tracks the course of travel; and Multi-Leg allows following a previously planned course. The only difference between Multi-Leg and Trail Blazing is how and when legs are stored. The Wayfinder stores Multi-Leg headings two ways: manually if the heading is already known in degrees, and automatically if both a map and the device will be used to determine the headings. In both modes, it gives an audible warning when the actual heading deviates from the desired heading by an amount greater than the “Off Track” angle. When operating in either the Multi-Leg or Trail Blazing mode, the device has an automatic return. The Wayfinder automatically calculates a return course to the starting point. In Bearing mode, it can be either used as described above or to store bearings. The numeric display shows the current heading, a solid

arrow on the compass rose points to North, a flashing arrow on the compass rose points in the stored bearing direction, and the display shows the stored bearing.

Due to the steep terrain, and the use of a 25-foot tape to measure horizontal distance, twenty-four azimuth and distance measurements were taken as the operator headed downhill to the reference end point (tailhold). A conscious effort was made not to follow the reference line. The return bearing was calculated from the azimuth and distance measurements taken coming downhill, and was used to navigate back to the yarder location. A one degree “Off Track” was set initially. At this setting, the compass pointer fluctuated too much and was difficult to follow; the setting was increased to five degrees (twenty degrees is maximum). During the test the compass had to be recalibrated several times due to magnetic interference and once due to an erroneous reading.

The Wayfinder Outback Electronic Compass worked well. However, the method used in the field test was time consuming. The compass did not have a mirror which made it difficult to sight on an object for a reading. A 12-meter average deviation from the reference line was measured for this device.

Laser Theodolite Prototype

The laser theodolite (figure 4) is a prototype device developed by SDTDC as an aid for walking a straight line through the woods rather than as a navigation device. The laser theodolite works on two principles. First, the operator could follow a laser beam through the woods until the beam encounters an obstruction. Second, the geometry in overcoming an obstruction is based on an equilateral triangle. By using 60 degree angles and equal horizontal distance measurements, the operator could offset around an object and still maintain a straight line.



Figure 4.
Laser theodolite prototype.

The prototype is a Class IIIa laser diode inserted

perpendicularly through a one-inch Teflon pipe, held by a cradle constructed from 4.5-inch PVC pipe, and mounted on a tripod. The cradle is in-dexed in degrees to facilitate locating the proper angle. The laser has a maximum output of 5mV and can be operated up to three hours with two SR44 silver oxide batteries. Beginning at the designated tailhold location, the operator activates the laser and follows the beam. A small laser “dot” is visible when the laser beam en-counters an object. The operator must navigate around the object by offsetting. Figure 5 is a diagram of offsetting around an object.

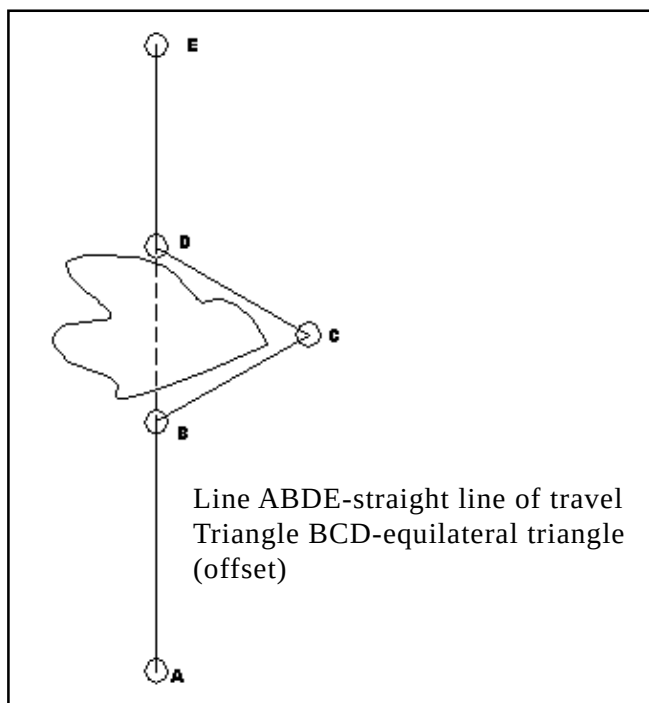


Figure 5. Offsetting around an object.

Point A on the diagram is the designated tailhold location. The laser beam is broken by an obstacle near B. Point B must be far enough away from the object not to interfere with the beam when the laser is rotated 60 degrees for the first offset. The operator then moves a second theodolite to B and aims the laser in the direction of A to verify that B is on the same line. Point B is now established.

The cradle is rotated 60 degrees from B to begin the offset process. Following the diagram above, the laser beam is now pointing along line BC. The horizontal distance along this line is measured; the distance will vary depending on the size of the object

requiring the offset. Point C is marked and the other theodolite is moved to C. At point C the cradle is rotated 120 degrees in the opposite direction (in this example the rotation is counter-clockwise). The same horizontal distance that was measured along line BC is used for the new line CD and to establish point D. One final 60 degree (clockwise) rotation of the cradle will bring the laser to a point along the original straight line of travel.

The same offset process is repeated when the next obstacle is encountered. To minimize the number of offsets the tripod could be raised to go over low brush.

An average deviation of 1.1 meters was measured. This device is a prototype and improvements are necessary to improve accuracy and efficiency. The initial test results indicate that the device also has potential as a navigational aid. Improvements to the tripod such a bubble level or plumb bob are needed and the accuracy of the theodolite can be improved by using a better laser. The body of the laser used in the test was not parallel to the beam it projected which contributed to its overall inaccuracy.

The LTI Criterion 400 Survey Laser Instrument

The objective was to test low cost devices. The LTI Criterion 400 Survey Laser Instrument, which costs \$10,000, was included to provide a reference to field users familiar with this device. The LTI Criterion 400 (figure 6) uses an infrared semi-conductor laser diode for slope distance measurement. A vertical tilt-sensing encoder provides vertical inclination, while a fluxgate electronic compass measures magnetic azimuth, completing the data required to establish a point's three-dimensional location in space.

According to manufacturers specifications the LTI Criterion 400 has a slope distance measurement range of 1.5 to 9150 meters when sighted on a retrodirective prism, and from 1.5 to 450 meters when sighted on a “non-cooperative” target, such as a tree or the ground. Accuracy specified by LTI for slope distance measurements is plus-or-minus 0.1 meter for vertical inclination, plus-or-minus 0.2 degree; and for azimuth, plus-or-minus 0.5 degree. Results of controlled tests performed by SDTDC show average error to be within these values.

The LTI laser meets FDA Class 1 (CFR 21) requirements: No measurable eye damage results after three hours of constant exposure to the laser beam.

The laser beam contains only five percent of the energy of the average TV remote control.

For ease of operation within the test site, the LTI laser was used without a tripod. The operator held the laser device like a rifle when sighting at a target. The operator walked downhill taking four sets of azimuth and distance measurements until the designated tailhold location was reached. A bearing to the start point was calculated. The operator then navigated back using the built-in compass.

The LTI laser was the most accurate instrument tested, having an average deviation of 0.6 meters. Using the LTI laser with a tripod and surveying rods would increase the accuracy. Only one person was used in the test. Approximately 300 LTI laser instruments are currently in use throughout the National Forest system. For a specific project these instruments have occasionally been shared between forests.

For more information on the LTI laser and surveying application see *Lasersoft Revolution* by Jeffrey E. Moll. This publication is available through SDTDC.

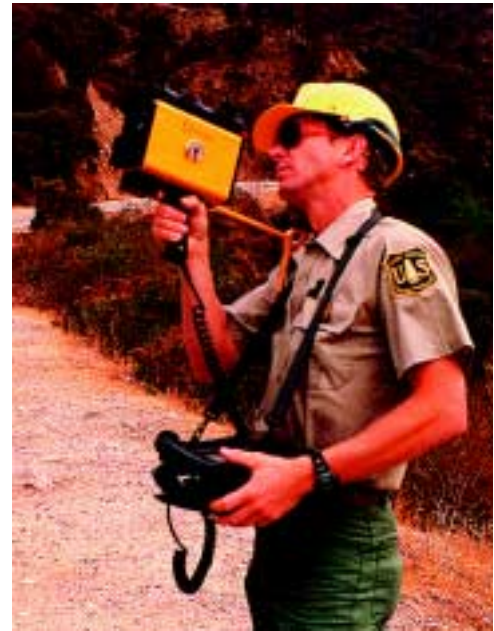


Figure 6.
LTI Criterion
400 survey laser instrument.

CONCLUSION

Each instrument tested has benefits. The Wayfinder Outback compass is inexpensive, lightweight, handles reasonably well, requires little training and had an average deviation of 12.3 meters. The Laser Theodolite is inexpensive to purchase but assembly is required, relatively lightweight, the most difficult to handle, requires more training than the Wayfinder, and had an average deviation of 1.1 meters using two theodolites. The Garmin 12XL GPS Receiver is more expensive than either the compass or the theodolite, weighs less than the theodolite, requires the same training as the theodolite, is very easy to handle, and had an average deviation of almost 21 meters. The LTI Laser is very expensive when compared with the test units, significantly heavier, requires specialized training, handles reasonably well, and is extremely accurate with an average deviation of 0.6 meters. The Ramsey DF-1 did not perform well enough to rate.

MANUFACTURERS

Further information on the devices discussed in this *Tech Tip* can be obtained through the manufacturers listed below.

Garmin GPS 12XL
Garmin Corporation
1200 East 151st
Olathe, KS 66062
Phone (913) 397-8200
www.garmin.com

Laser Pointer (used for prototype)
Edmund Scientific Company
101 East Gloucester Pike
Barrington, NJ 08007-9889
(800) 728-6999

Laser Criterion 400
Laser Technology Inc.
7070 South Tucson Way
Englewood, CO 80112
(303) 649-1000

Ramsey DF-1 Direction Finder
Ramsey Electronics, Inc.
793 Canning Parkway
Victor, New York 14564
Phone (716) 924-4560
Fax (716) 924-4555

Wayfinder Outback
Precision Navigation, Inc.
1235 Pear Avenue, Suite 111
Mountain View, CA 94043
Phone (415) 962-8777
Fax (415) 962-8776
www.PrecisionNav.com/pmi



PROJECT PROPOSAL
USDA Forest Service
Technology and Development Program

SDTDC solicits input from the field for suggestions for future projects. Your suggestions are important to us, so please take a few moments to complete this form and return to the address provided.

Project Originator: _____ Name _____ Date _____

Title _____

Unit _____

Mailing address _____

DG address _____ Telephone _____

Project Title: _____

Current Problem/Need

Describe how work is currently being done; current problem/need, location; why improvement is needed.

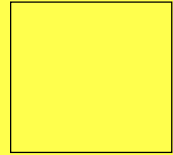
Proposed Solution

Describe your concept of the end product, i.e., new equipment design, video production, handbook, etc.

Potential Benefits

Describe how this product will improve safety, resource management; increase efficiency, customer satisfaction, productivity; reduce cost, time.

- affix here -



USDA, Forest Service
SDTDC
Attn: Forest Mgmt Program Leader
444 E. Bonita Avenue
San Dimas, CA 91773-3198

User Feedback Survey

User Name (optional) _____
_____ Title
_____ Unit

Low-Cost Tools for Skyline Corridor Location and Simple Point-to Point Navigation 9824 1306

Benefits	Yes	No	Amount
Saves money	_____	_____	_____
Saves time	_____	_____	_____
Increases efficiency	_____	_____	_____
Other	_____	_____	_____

How effective or relevant is this information?

What would you change?

General comments: