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Evaluation of Laser Rangefinders

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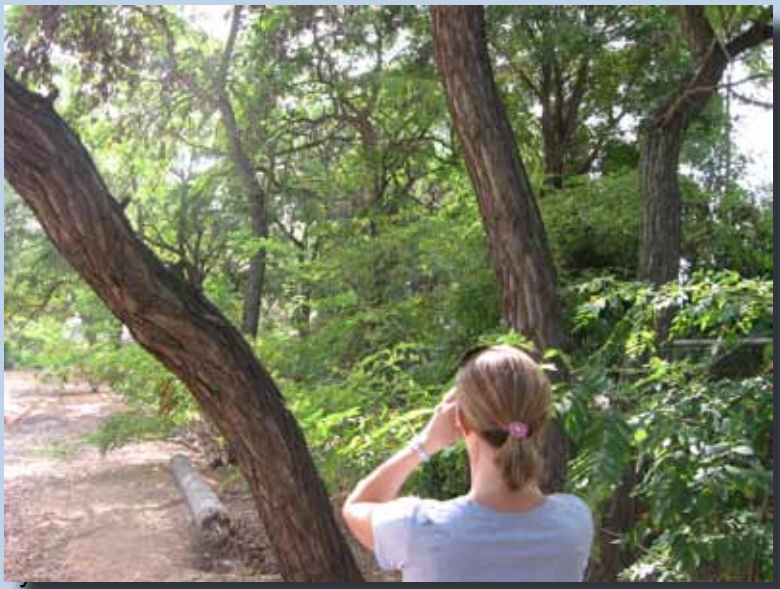

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BACKGROUND

The proposal for an updated rangefinder evaluation was submitted by the Chattahoochee-Oconee National Forest. They requested that the Technology and Development Program update the 1998 rangefinder evaluation (9824 1307—SDTDC). The Inventory and Monitoring Steering Committee directed San Dimas Technology and Development Center (SDTDC) of the Forest Service, U.S. Department of Agriculture, to conduct the new evaluation in fiscal year 2009.

Forest Management
Tech Tips

United States Department of Agriculture
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RANGEFINDER COMPARISON
Lois P. Sicking, Mechanical Engineer

INTRODUCTION
Rangefinders are used to measure distance in a variety of applications for various resource needs in the Forest Service. There are many different types of rangefinders commercially available. In addition, there have been recent advances in rangefinder technology.

The cost of rangefinders varies from $60 to $12,000. Performance varies as much as cost. Significant factors in evaluating performance are range, accuracy, ease of use under field conditions, size and weight.

The required accuracy will vary depending on the application or the task being performed. Typical applications include determining the distance to surrounding trees from a plot center, the distances from one fixed point to another as in traversing, and calculating tree heights. In addition, rangefinders can be used to help determine the volume of a specific tree or stands of timber. The current trend, in the USDA Forest Service and other agencies, is to use more tree measurement sales with lump sum payments. Consequently, it is imperative that the volumes stated in the contracts be very accurate.

Some rangefinders are very accurate, lightweight and compact. Others are quite heavy and cumbersome. The size and weight of equipment carried in the field vest is a consideration for applications which entail walking long distances or on steep terrain.

OBJECTIVE
The objective of this test was to evaluate the performance of various rangefinder devices. The range, accuracy, size and weight of these devices were compared. In addition, test workers were surveyed for their opinion regarding ease of use. Comments were solicited on what effect the weather or other field conditions appeared to have on the readings. Additional performance features were noted. The project goal was to provide information to the field on the performance of various laser, ultrasonic and other current rangefinder devices. There is potential for considerable cost savings for field personnel using this information when selecting the appropriate rangefinder for the application.

RANGEFINDER TECHNOLOGIES

Ultrasonic
Ultrasonic distance measuring devices use a wide band frequency from a transducer, sending out narrow beams of sound waves which "bounce" off an object. The return signal is picked up by a hand held receiver. Accuracy is effected by the position of the receiver, outside sound waves, and noise. Noise generated by wind through the trees or brush, streams, rain, crew talking, road traffic or birds chirping can effect readings. When a horizontal distance measurement is being taken, the inclination or horizontal position of the receiver is critical. An outgoing wide band signal will be scattered, increasing the error, if the transducer is not positioned as close to horizontal as possible.

Optical
Optical distance measuring devices typically use the coincidence method of determining distance. This incorporates the use of a series of lenses and mirrors to produce a double image. The double images on mirrors are brought together by rotating a dial until both images merge into one. The dial has a distance indicator, when the two images merge, the distance to the target is read directly off the dial.

Laser
Pulse lasers determine distance by measuring the amount of time required for a pulse of infrared light to travel to the target and back. The speed of light is constant, so this amount of time is directly proportional to the distance. Many pulses are sent out and returned for each shot, improving the accuracy of the calculated value. Laser instruments are narrow band and require the operator to aim with some

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Figure 1—1998 Rangefinder comparison study (9824 1307—SDTDC).

The Forest Management Steering Committee was also interested in the results of the rangefinder evaluation. They requested that the evaluation make a concerted effort to test a rangefinder's ability to take accurate horizontal distance measurements through dense brush. The steering committee also was interested in having SDTDC evaluate a specific rangefinder, the Opti-Logic. (This rangefinder commonly is used by foresters.)

Rangefinders

A rangefinder measures the distance from the device to a target. Typically, modern rangefinder devices transmit a pulse laser beam that strikes a target, which in turn, is reflected back to the device's receiver lens. (Obviously, the more reflective the target, the more likely the beam reflects properly back to the device.) The device uses time of flight of a beam to reach a target and bounce back to calculate the distance. Other modern devices use the time of flight of ultrasound to calculate distance.

Historically, optical devices (coincidence rangefinders) used a system of lenses, mirrors, and trigonometric relationships to determine distances. Laser and ultrasonic rangefinders have largely replaced that technology.

Both laser and ultrasonic devices must be aimed with some accuracy to strike the intended target properly. This is usually not an issue when the target is a large tree trunk. But obtaining distance to smaller (narrower) targets requires more careful aim, especially when using the narrow laser beam. (Note: the ultrasonic rangefinder tested in this evaluation utilized a transponder (transmitter and responder), which was attached to the target to capture the device's incoming ultrasonic beam and return an ultrasonic response to the device.)

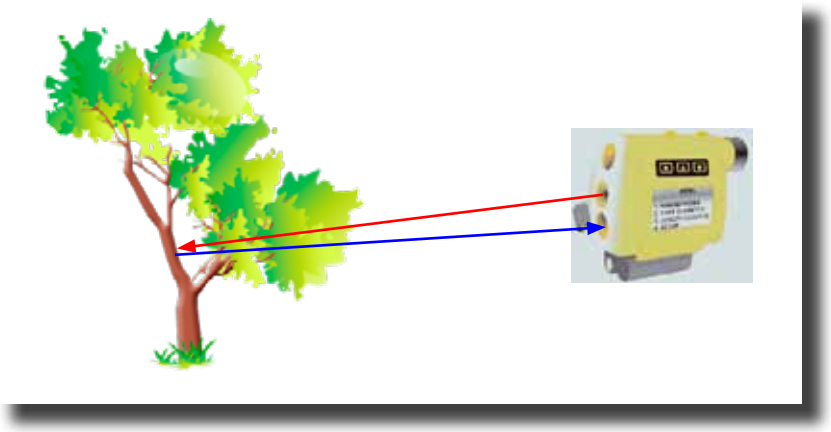

Figure 2— Laser rangefinders transmit pulsed laser beams through the transmitter lens; the target reflects beams back to the receiver lens. The distance between the rangefinder and target is calculated based on the time of flight of beams.

In general, laser rangefinders have an advantage over sound-driven devices because light can travel farther (take longer measurements), and light is essentially unaffected by temperature and not affected by background noise. Both noise and temperature can affect measurements made by ultrasonic devices.

When measuring through dense vegetation, ultrasonic devices benefit from the use of the transponder on the target. Laser rangefinders use reflectors and foliage filters to take accurate measurements in dense vegetation (see Devices Tested for a detailed discussion).

DEVICES TESTED

Several rangefinders were evaluated for their precision and accuracy in taking horizontal distance (HD) measurements—at various distances—to an unobstructed target in a manner similar to the 1998 report. In addition, HD measurements were taken through dense brush to test the rangefinders' ability to take precise and accurate measurements. (Instances where this evaluation deviates from the previous report are identified in this evaluation.)

During the spring of 2009, SDTDC asked several rangefinder manufacturers if they would be interested in loaning the technology and development staff devices to be tested, especially for their precision and accuracy in taking HD measurements[1] .

Since the Forest Management Steering Committee was specifically interested in devices capable of making precise and accurate measurements through dense vegetation, SDTDC tested the devices for this capability. Also, since all devices tested purported to operate as a hypsometer (a device that can measure the height of objects), SDTDC also performed a cursory test of this capability. Table 1 lists the devices SDTDC tested for this evaluation.

[1]SDTDC thanks Russell Bozeman (russell.bozeman@haglofinc.com) of Haglof; Joe Cronn (jcronn@lasertech.com) of Laser Technology, Inc; Michael Hefer (mike@westerndatasystems.com) of MDL/Western Data Systems; and Tim Commons (tim.commons@leicaus.com) of Leica Geosystems, Inc. for the loan of the devices.

Table 1. Devices SDTDC tested for this evaluation.

Device	Manufacturer*	Web site	Approx. cost**
Vertex Laser VL400	Haglof Sweden	haglofsweden.com	$2,500
Vertex IV (ultrasonic)	Haglof Sweden	haglofsweden.com	$1,900
TruPulse (200B and 360B)	Laser Technology, Inc.	lasertech.com	$800 (200B) $1,700 (360B)
LaserAce (2D and 3D)	Measurement Devices Limited (MDL)	laserace.com	$2,200 (2D) $2,800 (3D)
Leica Disto D8	Leica Geosystems, Inc.	leica-geosystems.com	$800
Opti-Logic 1000LH	Opti-Logic Corp.	opti-logic.com	$550

* see footnote 1; **cost as of 2009

The following is a brief description of the devices. The precision and accuracy evaluation of the devices are in the Results section.

Since the 1998 report, rangefinder technology has advanced such that all devices SDTDC staff tested were lightweight and fit easily in the palm of the hand. All came with a convenient protective carrying case that could be clipped on to a belt buckle or carried easily in a field vest or backpack.

The user manuals for all devices were straightforward to follow. When using the devices, navigating to the various features was more or less intuitive. In all cases, however, users should plan on spending some time reviewing the entire manual and practicing navigating through the various features of the devices to get the maximum out of the various features that the devices have to offer.

When a device took a measurement, the user could look into the device's viewfinder for some instruments (to view the information) and/or view the information from a display window on the side of the device.

All devices operated on either regular alkaline batteries or a specialized rechargeable battery pack provided with the device.

Vertex IV and Vertex Laser VL400

(Vertex IV—Weight: 6 ounces; Dimensions: 3.1 inches by 2 inches by 1.1 inches)

(Vertex Laser VL400—Weight: 9 ounces; Dimensions: 3.7 inches by 2.8 inches by 2.3 inches)

Both Vertex devices are products of Haglof Sweden. The USA headquarters is in Madison, MS. The Vertex IV (figure 3) takes measurements by ultrasound only. The Vertex Laser VL400 (figure 4) is a combination laser and ultrasonic rangefinder.

The users (sic) guide is fairly straightforward. With the press of a few buttons, measurements could be taken and viewed through the lens and the display window on the side of the device. The text characters are bold and clear and relatively easy to read, even in bright sunlight. The viewfinder had both 1x and 8x magnification, which provided clear viewing of targets near and far.

Figure 3—Vertex IV Rangefinder (ultrasonic only)

Figure 4—Vertex Laser VL400 (laser and ultrasound).

The main advantage of using ultrasound is being able to take measurements through a dense understory. To take accurate ultrasonic measurements, a transponder must be placed on the target. In this way, the transponder will emit a signal to the rangefinder only if it receives a signal from the rangefinder. This ensures that the signal that returns to the device is from the target (transponder) and not from understory vegetation between the target and device.

Sending and receiving sound is significantly distance limited; accurate measurements are obtained only within 100 or 150 feet from the target.

For more details on devices, see the users guide. Click here for the Vertex IV Users Guide - English. Click here for the Vertex Laser VL400 Users Guide - English.

TruPulse 200B and 360B

(Weight: 8 ounces; Dimensions: 5 inches by 2 inches by 3.5 inches)

The TruPulse laser rangefinder (figure 5) is a product of Laser Technology, Inc., Centennial, CO. The B versions of the devices (200B and 360B) allow for wireless transfer of data to a field data recorder.

Figure 5—TruPulse laser rangefinders.

The device is operated by a few buttons on the side. The user must look through the viewfinder to operate the device. Testers were amazed that the through-the-lens-only viewing was not a disadvantage when compared to devices with a side window display. The clear optics, 7x magnification, and adjustable eyepiece made viewing through the lens simple.

Initially, the block text characters in the viewfinder took some getting used to. But after several minutes of use, the boxy looking text was a nonissue.

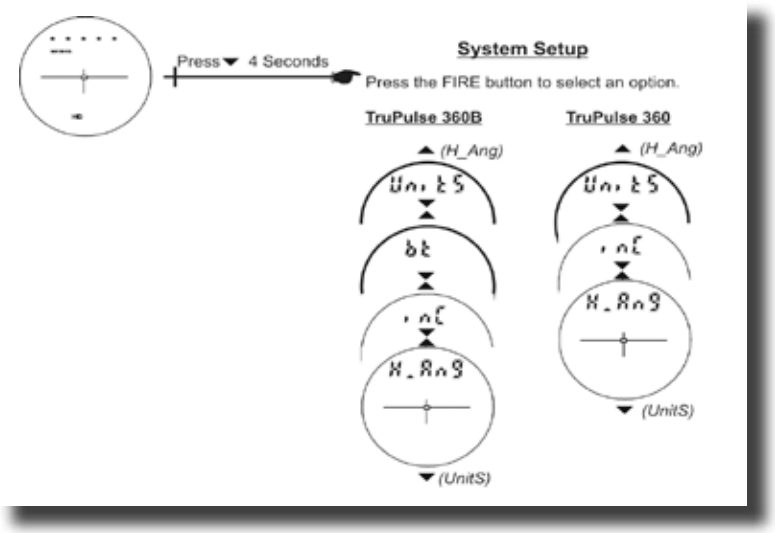

Figure 6—Sample view in TruPulse viewfinder.

The difference between the TruPulse 200 and the TruPulse 360 is the integrated compass of the 360. Once the device is calibrated, it can operate in three dimensions. A user can stand in one spot and not only take an HD measurement to two targets, but also obtain the distance between the two targets by using the device's missing line feature. (Note: the LaserAce 3D uses its missing distance feature to measure distances between two objects.)

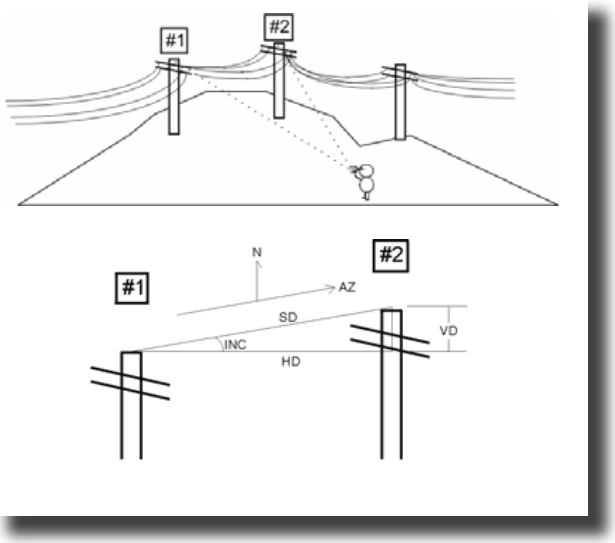

Figure 7—Determining the horizontal distance (HD) between two targets (missing line) using the TruPulse 360 (from the user manual, page 37).

The manufacturer also markets the TruPulse as a device that can take accurate measurements in the field even in areas where there is a dense understory. Even though the laser beam cannot penetrate the understory, if the target is partially visible (capable of being hit by a narrow beam), the device has features that assist in distinguishing the understory from the intended target. To accomplish this, one would use the device in the farthest/closest or filter-target modes.

When the device is in the farthest-target mode, the device will show the readings of the farthest target it acquired (and hide the readings of the closer targets acquired) while laser beams were pulsed. In that way, the user ignores readings that were taken when striking foliage between the observer and the intended target. The reverse is true when the device is used in the closest-target mode.

The most reliable (and accurate) method of obtaining distance measurements through a dense understory is to use a foliage filter and a reflector. This involves placing a reflector on the target and attaching a specialized foliage filter to the rangefinder's receiving lens. The filter reduces the receiving lens' sensitivity to a point where it will only detect pulses returned from a highly reflective target (the reflector). Obviously, when used in this manner, laser beams reflected from the understory vegetation will not be registered and the only reading identified by the device will be from the intended (highly reflective) target.

For more details on the TruPulse laser rangefinder see the Laser Technology, Inc. Web site.

The reader might also be interested in reviewing the evaluation of the TruPulse 360 reported in the March 2009 issue of *The Forestry Source*.

LaserAce 2D and 3D

(Weight: 14 ounces; Dimensions: 4.3 inches by 2.9 inches by 2 inches)

The LaserAce rangefinder is a product of Measurement Devices Ltd. (MDL) of Aberdeen, Scotland. The U.S.A. headquarters (Western Data Systems) is in Houston, TX. The LaserAce 2D and 3D both have Bluetooth capability. The 3D model has an integrated compass, which like the TruPulse 360 allows it to operate in three dimensions.

Figure 8—LaserAce rangefinder with carrying case.

Figure 9—Close up of side display window.

The LaserAce operates with a few buttons on the side of the device, much like the other rangefinders tested. The viewfinder has 5x optics and clear crosshairs that allow targets to be acquired easily. Measurements can be viewed in the viewfinder and on the side window display.

The calibrated 3D device operates much like the TruPulse 360. It allows the user to stand in one spot and take the HD measurements between the two distant objects using its missing-distance feature.

Like the TruPulse, the device is advertised as being able to take accurate measurements through dense brush. The device's last-hit mode operates like TruPulse's farthest-line function. (The first-hit function is its opposite.) The LaserAce also operates in a brush-filter mode much like TruPulse's foliage-filter mode. The difference is that the manufacturer suggests that a 3M reflector foil be used (instead of a prism reflector) on the target and that this mode should not be used at distances less than 100 meters (328 feet).

For more details on the LaserAce laser rangefinder see the MDL Web site.

Leica Disto D8

(Weight: 6.9 ounces; Dimensions: 5.6 inches by 2.2 inches by 1.2 inches)

The Leica Disto D8 is a product of Leica Geosystems, Inc., St. Gallen, Switzerland. The U.S.A. headquarters is in Norcross, GA.

The D8 is marketed primarily for use on construction sites and can operate like an electronic tape measure. The D8 is advertised as being accurate to ±1 millimeter. The D8 has Bluetooth capability.

The D8 was the most unique rangefinder device tested. There is no eyepiece to view the target, rather the target is displayed and acquired by viewing the display window. Alternatively, the user acquires the target by aiming the visible red laser beam dot onto the intended target.

Figure 10—Disto D8 showing display screen in viewfinder mode (left) and normal mode (right).

In an indoor setting at a construction site, acquiring a target is not a problem. Acquiring targets outdoors, however, is a challenge. The device has a digital pointfinder mode that shows the target as crosshairs on the display window and has 3x magnification capability. This greatly improves visibility outdoors. But even with those features, testers found it difficult to acquire targets on our test course that were more than 60 feet away. This was especially true when the observer was in bright sunlight and the target was in dense shade. (See a more detailed discussion of the limitations of the device as a practical field tool for taking HD measurements in the Results section.)

Despite the Disto D8's limitations of taking long HD measurements in a forest setting, the device had many features that might be useful at a construction site that some users (especially engineers) might find valuable.

Figure 11—Measurements that the D8 is capable of taking at construction sites.

For more details on the Leica Disto D8 laser rangefinder, see the Disto D8 Web site or download the brochure or user manual.

Opti-Logic 1000LH

(Weight: 11 ounces; Dimensions: 1.7 inches by 4 inches by 5.1 inches)

The Opti-Logic rangefinder is a product of Opti-Logic Corporation, of Tullahoma, TN. The device was the least expensive of the true field laser rangefinders that we tested. The product comes in a series of models (100LH, 400LH, 600LH, 800LH, and 1000LH), which have varying operational distance ranges. (For example, the 100LH model can take accurate measurements up to 100 yards; the 400LH model operates up to 400 yards, etc.)

As suggested by the price, this device has far fewer features than the other devices tested. The device takes only line-of-sight distances, horizontal distances, height of an object, and the vertical angle to an object measurements. The operating instructions are on only 2 pages.

The target is acquired by sighting through the eyepiece (which has no magnification power) and using the red dot in the viewfinder to aim at the target. The device's only button on the top of the device fires the laser after the button is released.

Figure 12— Opti-Logic laser rangefinder, front view. Insert on top is a rear view that shows the display window (right) and viewfinder (left).

To scroll through the device's features can be cumbersome. To change a setting, you must click through the options (using the only top button) to find the new setting, and then allow the device to turn itself off. When you turn it back on, the new setting is available.

Measurements are read in the display window on a 1.2-inch by 0.5-inch screen next to the eyepiece.

The reader might be interested in reviewing the evaluation of the Opti-Logic in the June 2009 issue of *The Forestry Source*.

For more details on the Opti-Logic laser rangefinder see the company's Web site.

TEST COURSE

HD Measurement on Test Course

SDTDC staff (we) evaluated the six rangefinders on a 220-foot by 330-foot (1.7-acre) woodlot on the SDTDC property. We evaluated five devices during the summer of 2009; we tested the Opti-Logic rangefinder in October 2009.

The SDTDC woodlot is composed of scattered locust trees with occasional evergreens and oaks. Three SDTDC employees took the measurements reported in this evaluation.

Figure 13—View of the SDTDC woodlot from the lower end of the transect, facing northeast.

Figure 14—View of the SDTDC woodlot from the center of the transect, facing northeast.

The test course consisted of a series of stakes that marked the distance from an unobstructed target, which was a locust tree in one corner of the woodlot. The total course length was 300 feet with stakes placed every 10 feet, up to 100 feet, then continuing at 25-foot increments up to 300 feet. (Note: the 1998 report tested rangefinders up to a distance of 500 feet. The longest diagonal length on the woodlot with an unobstructed view to a target was only 300 feet.)

We located stakes by stretching a 300-foot fiberglass tape as taut as possible and using a plumb bob to mark the location. The 1998 report, however, used an electronic distance measuring (EDM) infrared rangefinder to establish the true distance. We decided to use the distance measured by a tape (instead of an EDM rangefinder) as the true measure of distance because we felt that the evaluation was a test of how accurate and precise rangefinders were when compared to the tool normally used for HD measurements, a measurement tape. We felt we established a reasonable true distance from the target, especially when compared to the effort that is likely to be expended by the average field person to determine distance from a target.

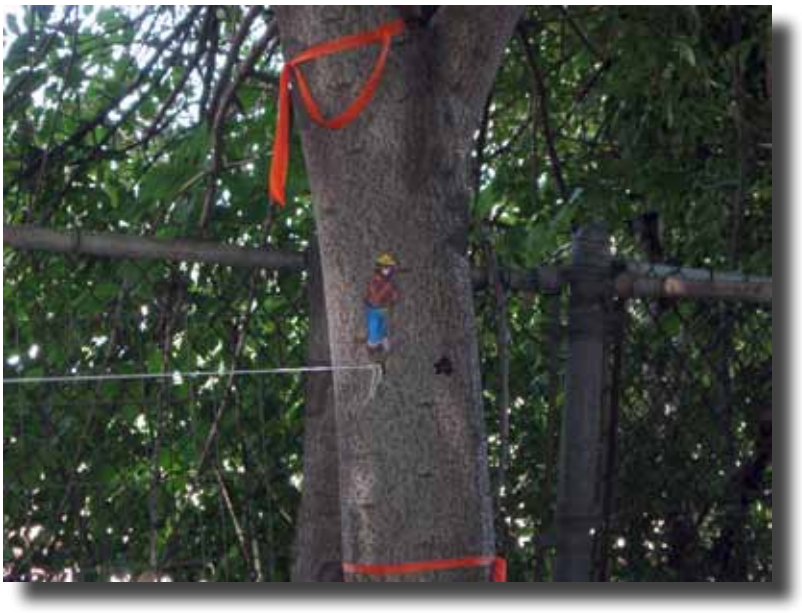

Figure 15—Target tree and target (Smokey Bear bookmark). The target is about 4.5 feet above the ground.

Figure 16— An observer taking a measurement at 70 feet from the target.

One of the observers became an expert on the use of the rangefinders by studying the user manual and practicing with the device before the day of the test. That observer instructed the other two users on the use of the rangefinders. The simple measurement of HD was fairly straightforward for all devices, and within a few minutes each observer could take reliable, repeatable measurements. The more advanced features of the devices took more time and practice. (See the discussion of rangefinders: missing line, farthest/nearest line, tree height, and foliage-filter features.)

Each of the observers took 12 measurements at each distance. Typically, all three observers took measurements on the same day of the test. The usual process involved an observer taking 12 measurements at a given distance and then passing the

device to the next observer who took 12 measurements at that distance. The second observer then passed the device to the third observer. While one observer took measurements, one of the other two observers manually recorded information on a data sheet. Observers took measurements in no particular order.

We tested all rangefinders without a tripod (hand held) and only with fresh batteries (as was done in 1998). None of the three observers wore hardhats or gloves, unlike 1998.

On a rare occasion, an observer was unavailable on a given day or time; in that instance, the single observer took solitary measurements when he/she was available.

HD Measurements Through Brush

Several rangefinders were tested for their ability to take HD measurements 80 feet from a target that was obscured with a dense understory of brush. (We estimated that the target was about 80 percent covered.)

Figure 17— Observer sighting on a target tree 80 feet away with dense brush obstructing view.

Figure 18— Closeup view of the target tree (with reflector).

We tested the TruPulse, LaserAce, and Vertex Laser because their manufacturers' claimed that the devices could be used for taking measurements through dense vegetation. For the TruPulse, we tested the foliage filters and farthest-line/nearest-line features. We used a simple red reflector attached to a target tree for the foliage-filter test of HD.

Since we did not have foliage filters for the Laser Ace, we only tested the last-hit feature, which is similar to TruPulse's farthest-line feature.

In this same dense brush location, we tested the ultrasonic ability of the Vertex Laser to take HD measurements.

Distance Between Two Objects and Height of Object Tests

We tested the LaserAce 3D and the TruPulse 360's ability to take measurements between two objects (trees). We also took simple height measurements of a fence post supporting a chain-link fence with the all-laser devices. Since this was not the primary objective of the evaluation, we only took a few measurements to sense the accuracy and precision of the devices.

Figure 19— Distance measurement between two objects, tree A and B.

RESULTS

Rangefinder Horizontal Distance (HD) Measurements

The test results for the six different rangefinders are shown below. As mentioned previously, 12 readings were taken by 3 different observers. We used the standard deviation of the 12 readings to demonstrate the precision (repeatability) of the device in taking HD measurements. For an accuracy determination, we compared the average of the 12 readings against the true measurement obtained with a fiberglass tape measure.

In general, all devices were relatively easy to operate. As might be expected, the more expensive devices tended to be more accurate and precise. Most devices were more accurate at distances less than 200 feet when compared to their accuracy at 300 feet.

It bears repeating that we took measurements with the devices hand held. All observers felt that using a tripod would produce more accurate and precise HD measurements from any of the devices tested. This was especially true the further the user moved from the target (more than 200 feet). At those distances it is much more difficult to site the target and maintain a steady aim using the devices in hand-held mode. For users that require accurate, long-distance measurements, a tripod is a must for any rangefinder, regardless of the manufacturer.

All devices we tested were reasonably sturdy, lightweight, and came with a canvas field case that would be very easy to pack in a vest or backpack. Each device has slightly different features or means of operating, but overall the testers were impressed.

Vertex Laser VL400 (laser mode)

The results of the HD measurements of each of the three observers can be viewed at the following link—Vertex Laser VL400.

Table 2 combines the readings of the three observers.

The device does not take measurements under 31 feet. At distances less than 150 feet, the measurements are highly precise (repeatable), and were slightly less precise at further distances. In general, the same is true for the accuracy of the device. The data shows that at further distances (more than 200 feet) the device was less accurate.

Table 2—Combined readings (in feet) from the Vertex Laser (VL400) in laser mode

	TOTAL (all observers)		
Station	AVG	DEV	CNG
10	***	***	***
20	***	***	***
30	***	***	***
40	39.4	0.0	-0.6
50	49.3	0.4	-0.7
60	60.1	0.8	0.1
70	70.5	0.0	0.5
80	80.2	0.5	0.2
90	90.2	0.0	0.2
100	100.5	0.8	0.5
125	126.3	0.3	1.3
150	151.0	0.5	1.0
175	175.6	1.2	0.6
200	202.6	1.4	2.6
225	227.2	0.8	2.2
250	252.5	1.7	2.5
275	277.6	0.8	2.6
300	304.1	2.0	4.1

Avg = average; Dev = standard deviation; Cng = average minus station

Vertex Laser VL400 (ultrasound mode)

The results of the HD measurements of each of the three observers can be viewed by following the link—Vertex Laser VL400 (ultrasound), observer #1

The Vertex Laser was unique in that it could take measurements using either a laser or ultrasound. Table 3 combines the ultrasonic readings of all three observers. (The transponder was attached to the target tree to take the ultrasonic HD measurements.)

The manufacturer's specification identified that the device's ultrasonic accuracy is limited to about 100 feet. Our test confirmed that limitation. Beyond 125 feet, we could not get a reading when using the ultrasonic mode. Nevertheless, the results show that this device is highly precise and accurate up to 100 feet.

Using the device (with the transponder) in this mode is very easy and largely foolproof. The user does not need to aim and sight on the target carefully. You simply hold the device sideways (to view the side display window), point the rangefinder at the target (transponder), and press the power button to get highly accurate readings.

Table 3—Combined readings (in feet) from the Vertex Laser VL400 in ultrasound mode

	TOTAL (all observers)		
Station	AVG	DEV	CNG
10	9.9	0.2	-0.1
20	19.9	0.2	-0.1
30	29.9	0.2	-0.1
40	40.0	0.1	0.0
50	50.1	0.1	0.1
60	60.0	0.1	0.0
70	70.0	0.1	0.0
80	79.7	0.2	-0.3
90	89.8	0.2	-0.2
100	99.9	0.3	-0.1
125	125.7	0.1	0.7

Avg = average; Dev = standard deviation; Cng = average minus station

Vertex IV (ultrasound)

The results of the HD measurements of each of the three observers can be viewed by following the link—Vertex IV (ultrasound)

This device only takes ultrasonic measurements. Table 4 combines the ultrasonic readings of all three observers.

As with the Vertex Laser VL400 in ultrasonic mode, the manufacturer's specification identifies that the device's ultrasonic accuracy is limited to about 100 feet. Again, our test confirmed that limitation. Beyond 100 feet, we could not get a reading. We found that the Vertex IV was as precise (gave repeatable measurements) as the Vertex Laser VL400 but were surprised that it was not as accurate. At all distances except 10 feet, the accuracy was outside the manufacturer's predictions (greater than 1 percent). Since the other Haglof product (Vertex Laser VL400) performed so well in the ultrasonic mode, we suspected that the device that we tested might have been defective.

As with the Vertex Laser VL400, the Vertex IV was very easy to use and taking measurements was relatively foolproof.

Table 4—Combined ultrasound readings (in feet) for the Vertex IV

Station	TOTAL (all observers)		
	AVG	DEV	CNG
10	10.1	0.1	0.1
20	20.4	0.1	0.4
30	30.9	0.1	0.9
40	41.0	0.3	1.0
50	51.2	0.3	1.2
60	61.6	0.1	1.6
70	71.9	0.1	1.9
80	82.2	0.2	2.2
90	92.6	0.1	2.6
100	103.3	0.2	3.3
125	***	***	***

Avg = average; Dev = standard deviation; Cng = average minus station

TruPulse 200B (and 360B)

The results of the HD measurements for each of the three observers can be viewed by following the link—TruPulse

Table 5 combines the readings of all three observers using the TruPulse 200B.

At distances less than 250 feet, measurements are very precise (repeatable). Over the entire 300-foot test course, the TruPulse 200B was within the accuracy claimed by the manufacturer of ±3 feet for low-quality (nonreflective) targets. As reported for the other devices, the data shows that at further distances (more than 200 feet) the device is less accurate.

We took several measurements (12 for each observer) at several distances (50, 100, 200, and 300 feet) using the TruPulse 360B and found it to be as accurate and precise as the TruPulse 200B for HD measurements.

Table 5—Combined readings (in feet) for all observers using the TruPulse (200B)

	TOTAL (all observers)		
Station	AVG	DEV	CNG
10	9.6	0.2	-0.4
20	19.7	0.3	-0.3
30	29.8	0.3	-0.2
40	40.0	0.0	0.0
50	49.6	0.2	-0.4
60	59.7	0.3	-0.3
70	69.5	0.1	-0.5
80	79.3	0.2	-0.7
90	89.5	0.5	-0.5
100	99.4	0.3	-0.6
125	124.8	0.4	-0.3
150	149.6	0.2	-0.4
175	174.6	0.5	-0.4
200	200.8	0.6	0.8
225	226.1	0.6	1.1
250	251.4	0.8	1.4
275	277.3	1.3	2.3
300	302.1	1.0	2.1

Avg = average; Dev = standard deviation; Cng = average minus station

LaserAce 2D and 3D

The results of the HD measurements of each of the three observers can be viewed by following the link—LaserAce

Table 6 combines the readings of all three observers for the LaserAce.

At distances of less than 150 feet, measurements are very precise (repeatable). Over the entire 300-foot test course, the LaserAce was the most accurate field device tested. On 10 of the 18 measurements taken on the test course, the device was within the ±0.2 foot (2.4 inches) accuracy claimed by the manufacturer. The device maintained high accuracy at all distances. (The LaserAce was the most expensive device tested.)

We took several measurements (12 for each observer) at several distances (50, 100, 200, and 300 feet) using the LaserAce 2D and found it to be as accurate and precise as the LaserAce 3D for HD measurements.

Table 6—Combined readings (in feet) for all observers for LaserAce (3D)

	TOTAL (all observers)		
Station	AVG	DEV	CNG
10	9.7	0.2	-0.3
20	19.8	0.2	-0.2
30	29.9	0.3	-0.1
40	39.8	0.2	-0.2
50	50.0	0.3	0.0
60	60.1	0.2	0.1
70	69.8	0.2	-0.2
80	79.8	0.2	-0.2
90	89.7	0.3	-0.3
100	99.7	0.5	-0.3
125	125.1	0.3	0.1
150	150.3	1.4	0.3
175	175.3	1.3	0.3
200	201.7	3.9	1.7
225	225.9	5.1	0.9
250	250.2	1.7	0.2
275	275.0	0.7	0.0
300	300.5	0.5	0.5

Avg = average; Dev = standard deviation; Cng = average minus station

Leica Disto D8

The results of the HD measurements of each of the three observers can be viewed by following the link—Lecia Disto D8

Table 7 combines the readings of all three observers using the Leica Disto D8.

As stated previously (in the Devices Tested section), the D8 has no eyepiece to view the target, rather the target is displayed and acquired by viewing the display window. Viewing targets outdoors, especially in bright sunlight, is very difficult at distances greater than 60 feet. The device's digital pointfinder helped somewhat, but if the target is in dense shade and the viewer in bright sunlight detecting the target is still very difficult. Even though the manufacturer claims that the device takes accurate measurements as far as 328 feet (100 meters), after 100 feet it became very time consuming and difficult to acquire the target, and the test was terminated.

Despite this limitation, our data shows that the D8 is extremely accurate (although not as accurate [±1 millimeter] as the manufacturer claims). We found that even hand held, the device never differed from the true (tape measured) distance by more than a few inches.

Table 7—Combined readings (in feet) of all three observers for the Disto D8

	TOTAL (all observers)		
Station	AVG	DEV	CNG
10	9.9	0.2	-0.1
20	20.0	0.4	0.0
30	30.3	0.1	0.3
40	40.2	0.3	0.2
50	50.0	0.2	0.0
60	60.1	0.3	0.1
70	70.1	0.3	0.1
80	80.1	0.3	0.1
90	89.8	0.3	-0.2
100	99.6	0.7	-0.4

Avg = average; Dev = standard deviation; Cng = average minus station

The device is not marketed for field forestry use but may be of value at construction sites.

Opti-Logic 1000LH

The results of the HD measurements for each of the three observers can be viewed by following the link—Opti-Logic 1000LH

Table 8 combines the readings of all three observers for the Opti-Logic LH1000.

The Opti-Logic was the least expensive of the field rangefinders tested. It also was the least precise and accurate. Nevertheless, the device met the manufacturer's claim of measurement accuracy to dark targets (±6 feet). This device offers a no-frills alternative for a laser rangefinder, especially for users that do not require high-accuracy measurements.

Table 8—Combined readings (in feet) of the three observers for the Opti-Logic LH1000

	TOTAL (all observers)		
Station	AVG	DEV	CNG
10			
20	21.1	0.6	1.1
30	30.9	0.5	0.9
40	40.9	0.5	0.9
50	51.7	0.5	1.7
60	62.1	0.6	2.1
70	71.8	0.6	1.8
80	82.0	0.0	2.0
90	91.3	0.6	1.3
100	101.8	0.7	1.8
125	127.3	0.6	2.3
150	152.9	1.0	2.9
175	176.8	1.1	1.8
200	203.7	2.1	3.7
225	227.9	1.0	2.9
250	253.8	1.6	3.8
275	279.2	1.4	4.2
300	303.9	2.1	3.9

Avg = average; Dev = standard deviation; Cng = average minus station

Tables 9 through 29 show the measurements taken by each of the three observers for the seven devices.

Table 9—Vertex Laser VL400, observer #1

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	too close												***	***	***
20	too close												***	***	***
30	too close												***	***	***
40	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	0.0	-0.6
50	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	0.0	-0.8
60	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	0.0	0.7
70	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	0.0	0.5
80	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	0.0	0.4
90	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	0.0	0.2
100	101.7	100.1	101.7	100.1	101.7	101.7	100.1	101.7	100.1	101.7	100.1	101.7	101.0	0.8	1.0
125	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	0.0	1.3
150	150.9	150.9	150.9	150.3	150.3	150.3	150.3	150.9	150.9	150.9	150.9	150.9	150.7	0.3	0.7
175	175.5	175.5	175.5	175.5	175.5	175.5	175.5	175.5	175.5	175.5	175.5	175.5	175.5	0.0	0.5
200	201.8	201.8	201.8	201.8	201.8	201.8	201.8	208.3	203.4	201.8	201.8	201.8	202.5	1.9	2.5
225	226.4	226.4	226.4	226.4	228	226.4	228	226.4	226.4	226.4	226.4	226.4	226.7	0.6	1.7
250	252.6	250.9	252.6	252.6	252.6	252.6	252.6	252.6	252.6	252.6	259.2	252.6	253.0	2.0	3.0
275	278.9	277.2	277.2	277.1	277.2	277.2	277.2	278.9	278.8	277.2	277.2	277.2	277.6	0.8	2.6
300	303.4	303.4	306.8	301.9	303.5	301.8	303.4	303.4	303.4	301.9	306.8	303.4	303.6	1.6	3.6

[1] *Station distance measured with a 300-foot fiberglass tape.*
[2] *Range of meter's ability to take accurate measurements (per manufacturer) = 31.5 feet to 1,311 feet.*
[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 1.2 feet for distances less than 300 feet and ± 3 feet for distances greater than 300 feet.*

Table 10—Vertex Laser VL400, observer #2

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	too close												***	***	***
20	too close												***	***	***
30	too close												***	***	***
40	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.1	39.4	39.4	39.4	39.4	39.4	0.1	-0.6
50	49.2	49.2	49.2	49.2	50.9	49.2	50.9	49.2	49.2	49.2	49.2	49.2	49.5	0.7	-0.5
60	60.7	60.7	60.7	59.1	60.7	60.7	60.7	59.1	60.7	59.1	59.1	59.1	60.0	0.8	0.0
70	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	0.0	0.5
80	80.4	80.4	78.7	80.4	78.7	80.4	80.4	78.7	80.4	80.4	80.4	80.4	80.0	0.8	0.0
90	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	0.0	0.2
100	100.1	100.1	100.1	100.1	100.1	100.1	98.4	100.1	100.1	100.1	100.1	100.1	100.0	0.5	0.0
125	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	0.0	1.3
150	152.6	150.9	150.9	150.9	150.9	152.6	150.9	150.9	150.9	150.9	150.9	150.9	151.2	0.7	1.2
175	175.5	175.5	175.5	177.2	175.5	177.2	175.5	175.5	175.5	175.5	175.5	177.2	175.9	0.8	0.9
200	203.4	203.4	205.1	203.4	201.8	201.8	201.8	201.8	201.8	201.8	201.8	203.4	202.6	1.1	2.6
225	228	226.4	228	228	226.4	228	226.4	228	226.4	226.4	226.4	226.4	227.1	0.8	2.1
250	251	251	251	252.6	254.3	252.6	251	252.6	251	251	257.6	251	252.2	2.0	2.2
275	277.2	277.2	277.2	277.2	278.9	277.2	278.9	277.2	277.2	277.2	278.9	277.2	277.6	0.8	2.6
300	301.9	301.9	301.9	303.5	306.8	301.9	303.5	303.5	301.9	301.9	303.5	303.5	303.0	1.4	3.0

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 31.5 feet to 1,311 feet.

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 1.2 feet for distances less than 300 feet and ± 3 feet for distances greater than 300 feet.

Table 11—Vertex Laser VL400, observer #3

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	too close												***	***	***
20	too close												***	***	***
30	too close												***	***	***
40	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	0.0	-0.6
50	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	0.0	-0.8
60	59.1	59.1	59.1	59.1	59.1	60.7	59.1	59.1	60.7	60.7	60.7	59.1	59.6	0.8	-0.4
70	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	0.0	0.5
80	80.4	80.4	78.7	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.3	0.5	0.3
90	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	90.2	0.0	0.2
100	100.1	100.1	101.7	100.1	101.7	100.1	100.1	100.1	100.1	100.1	101.7	101.7	100.6	0.8	0.6
125	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	128	126.3	126.4	0.5	1.4
150	150.9	150.9	150.9	150.9	150.9	152.6	150.9	150.9	150.9	150.9	150.9	150.9	151.0	0.5	1.0
175	177.2	175.5	175.5	177.2	175.5	178.8	175.5	172.2	175.5	175.5	172.2	175.5	175.5	1.9	0.5
200	203.4	203.4	203.4	201.8	201.8	201.8	201.8	201.8	203.4	201.8	205.1	201.8	202.6	1.1	2.6
225	228	228	228	226.4	228	228	228	228	228	228	227.9	228	227.9	0.5	2.9
250	251	252.6	252.5	252.6	252.6	252.6	250.9	252.5	252.6	252.6	252.5	252.5	252.3	0.6	2.3
275	277.1	277.1	277.1	277.1	278.8	277.2	278.9	278.8	277.1	277.1	277.1	278.8	277.7	0.8	2.7
300	306.7	308.3	306.7	303.5	306.1	306.8	303.4	308.3	306.7	303.4	306.7	303.4	305.8	1.9	5.8

[1] *Station distance measured with a 300-foot fiberglass tape.*
[2] *Range of meter's ability to take accurate measurements (per manufacturer) = 31.5 feet to 1,311 feet.*
[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 1.2 feet for distances less than 300 feet and ± 3 feet for distances greater than 300 feet.*

Table 12—Vertex Laser VL400 (ultrasound), observer #1

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.5	9.7	9.8	9.8	9.8	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.8	0.1	-0.2
20	19.4	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	0.1	-0.1
30	29.7	29.8	29.9	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.0	0.1	0.0
40	39.7	39.8	40	40	40	40	40	40.1	40.1	40.1	40.1	40.1	40.0	0.1	0.0
50	50.2	50.2	50.3	50.2	50.2	50.2	50.2	50.2	50.2	50.2	50.2	50.2	50.2	0.0	0.2
60	60	60	60.1	60.1	60	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	0.0	0.1
70	69.9	69.9	69.9	69.9	69.9	69.9	69.9	69.8	69.9	69.9	69.9	69.9	69.9	0.0	-0.1
80	79.9	79.9	80	79.9	79.9	79.9	79.9	79.9	79.9	79.9	80	79.9	79.9	0.0	-0.1
90	89.9	89.9	90	90	90	89.9	89.9	89.9	90	90	90	90	90.0	0.1	0.0
100	100.2	100.1	100.1	100.1	100.1	100.2	100.2	100.1	100.1	100.2	100.2	100.1	100.1	0.1	0.1
125	125.7	125.7	125.8	125.7	125.8	125.8	126	125.9	126	125.8	125.9	125.8	125.8	0.1	0.8
150	Beyond Range of Device														
175															
200															

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = up to 100 feet.

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances is 1 percent or better.

Table 13—Vertex Laser VL400 (ultrasound), observer #2

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.7	9.8	9.8	9.9	9.9	9.8	10	9.8	9.9	9.8	9.8	9.8	9.8	0.1	-0.2
20	19.8	20.5	19.8	19.8	19.7	19.7	19.8	19.8	19.8	19.7	19.7	19.7	19.8	0.2	-0.2
30	30.1	30.1	30.1	29.5	30.2	30.1	30.1	30.1	30.1	30	30	30.1	30.0	0.2	0.0
40	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	0.0	-0.1
50	50.1	50.1	50.1	50.1	50	50	50	50	50	50	50	50	50.0	0.0	0.0
60	59.9	59.9	59.9	59.9	59.9	59.9	59.9	59.9	59.9	59.9	59.9	59.9	59.9	0.0	-0.1
70	69.9	69.9	69.9	70	69.9	69.9	69.9	69.8	69.8	69.8	69.8	69.9	69.9	0.1	-0.1
80	79.9	79.8	79.9	79.8	79.9	79.8	79.9	79.8	79.7	79.7	79.8	79.5	79.8	0.1	-0.2
90	89.9	89.8	89.9	89.8	89.8	89.8	89.9	89.9	89.9	89.8	89.9	89.9	89.9	0.1	-0.1
100	100.2	99.8	99.8	100	100	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.0	0.1	0.0
125	125.5	125.6	125.5	125.7	125.7	125.6	125.6	125.6	125.6	125.8	125.7	125.6	125.6	0.1	0.6
150	Beyond Range of Device														
175															
200															

[1] *Station distance measured with a 300-foot fiberglass tape.*

[2] *Range of meter's ability to take accurate measurements (per manufacturer) = up to 100 feet.*

[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances is 1 percent or better.*

Table 14—Vertex Laser VL400 (ultrasound), observer #3

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	10.2	10.2	10.2	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	0.0	0.1
20	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	0.0	-0.1
30	29.6	29.7	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	0.0	-0.4
40	40	40	40	40	40	40.1	40.1	40.1	40	40	40	40	40.0	0.0	0.0
50	49.9	50	50	50	50	50	50	50	50	50	50	50	50.0	0.0	0.0
60	60	60.1	60.1	60.1	60.1	60.1	60.1	60	60	60	60.1	59.9	60.1	0.1	0.1
70	70.1	70.2	70.2	70.2	70.2	70.1	70.1	70.2	70.2	70.2	70.2	70.2	70.2	0.0	0.2
80	79.4	79.4	79.4	79.4	79.4	79.4	79.5	79.5	79.4	79.6	79.5	79.6	79.5	0.1	-0.5
90	89.6	89.5	89.5	89.5	89.6	89.7	89.6	89.7	89.6	89.6	89.6	89.5	89.6	0.1	-0.4
100	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.7	99.4	99.4	99.4	99.4	99.4	0.1	-0.6
125	125.7	125.6	125.8	125.6	125.7	125.7	125.6	125.7	125.6	125.6	125.6	125.5	125.6	0.1	0.6
150	Beyond Range of Device														
175															
200															

[1] *Station distance measured with a 300-foot fiberglass tape.*

[2] *Range of meter's ability to take accurate measurements (per manufacturer) = up to 100 feet.*

[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances is 1 percent or better.*

Table 15—Vertex IV (ultrasound), observer #1

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	10	10	10	10.1	10.1	10.1	10.1	10.1	10.2	10.1	10.1	10.1	10.1	0.1	0.1
20	20.4	20.7	20.5	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.7	20.7	20.6	0.1	0.6
30	30.7	30.8	30.8	30.8	30.8	30.8	30.9	30.9	30.9	30.9	30.9	30.9	30.8	0.1	0.8
40	41.1	41.3	41.3	41.3	41.2	41.2	41.2	41.3	41.3	41.3	41.3	41.3	41.3	0.1	1.3
50	51.3	51.3	51.3	51.4	51.4	51.4	51.4	51.4	51.5	51.5	51.5	51.4	51.4	0.1	1.4
60	61.7	61.7	61.7	61.7	61.7	61.6	61.6	61.6	61.6	61.7	61.8	61.8	61.7	0.1	1.7
70	72.1	72	72	72	71.9	72	71.9	72	72	72	72	72	72.0	0.1	2.0
80	81.8	81.9	81.9	82	82	82	82	82	82	81.9	81.9	82	82.0	0.1	2.0
90	92.4	92.6	92.6	92.6	92.5	92.7	92.6	92.6	92.6	92.7	92.7	92.6	92.6	0.1	2.6
100	103.4	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	0.0	3.5
125	Beyond Range of Device														
150															

[1] *Station distance measured with a 300-foot fiberglass tape.*

[2] *Range of meter's ability to take accurate measurements (per manufacturer) = up to 100 feet.*

[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances is 1 percent or better.*

Table 16—Vertex IV (ultrasound), observer #2

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	10	10.1	10.1	10.1	10.2	10.2	10.3	10.1	10.1	9.9	10	10	10.1	0.1	0.1
20	20.3	20.4	20.4	20.4	20.3	20.3	20.3	20.4	20.3	20.3	20.3	20.3	20.3	0.0	0.3
30	30.8	30.8	30.8	30.8	30.8	30.7	30.7	30.7	30.8	30.7	30.7	30.7	30.8	0.1	0.7
40	41	41.1	41	41	41	41	41	41.1	41.1	41.1	41.1	41.1	41.1	0.1	1.1
50	51.3	51.4	51.4	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	0.0	1.3
60	61.7	61.8	61.8	61.8	61.7	61.8	61.7	61.8	61.7	61.6	61.7	61.7	61.7	0.1	1.7
70	71.9	71.9	71.9	72	72	72	72	72	72	72	72	72	72.0	0.0	2.0
80	82	82.1	82	82.1	82	82	82	82.1	82.1	82.1	82	82	82.0	0.1	2.0
90	92.6	92.7	92.8	92.8	92.8	92.8	92.7	92.6	92.6	92.6	92.6	92.6	92.7	0.1	2.7
100	103.4	103.4	103.4	103.4	103.4	103.4	103.4	103.4	103.4	103.3	103.4	103.4	103.4	0.0	3.4
125	Beyond Range of Device														
150															

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = up to 100 feet.

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances is 1 percent or better.

Table 17—Vertex IV (ultrasound), observer #3

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	10	10.1	10	9.9	9.9	10.1	10	10.1	10	10.1	10.1	10	10.0	0.1	0.0
20	20.5	20.5	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	0.1	0.3
30	31	30.9	30.9	31	31	31	31	31	31	31	31	31	31.0	0.0	1.0
40	40.6	40.6	40.5	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	0.0	0.6
50	51.5	51	50.9	50.6	50.6	50.7	50.7	50.7	50.7	50.6	50.6	50.7	50.8	0.3	0.8
60	61.6	61.6	61.5	61.5	61.5	61.5	61.6	61.5	61.5	61.5	61.5	61.5	61.5	0.0	1.5
70	71.8	71.8	71.8	71.8	71.8	71.9	71.8	71.9	71.9	71.9	71.9	71.9	71.9	0.1	1.8
80	82.6	82.5	82.5	82.5	82.5	82.5	82.5	82.4	82.4	82.4	82.4	82.4	82.5	0.1	2.5
90	92.5	92.6	92.6	92.7	92.7	92.7	92.7	92.7	92.7	92.6	92.7	92.6	92.7	0.1	2.7
100	103	103	103.1	103.1	103.1	103	103	103	103	102.9	102.9	102.9	103.0	0.1	3.0
125	Beyond Range of Device														
150															

[1] *Station distance measured with a 300-foot fiberglass tape.*

[2] *Range of meter's ability to take accurate measurements (per manufacturer) = up to 100 feet.*

[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances is 1 percent or better.*

Table 18—TruPulse 200B, observer #1

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	0.0	-0.5
20	20	20	19.5	19.5	19.5	20.5	20	19.5	19.5	20	19.5	20	19.8	0.3	-0.2
30	30	30	30	30	29.5	30	30	30	30	29.5	29.5	29.5	29.8	0.2	-0.2
40	40	40	40	40	40	40	40	40	40	40	40	40	40.0	0.0	0.0
50	49.5	49.5	49.5	50	49.5	49.5	50	50	49.5	50	49.5	50	49.7	0.3	-0.3
60	60	60	60	60	60	60	60	60	59.5	60	60	59.5	59.9	0.2	-0.1
70	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69	69.5	69.5	69.5	69.5	0.1	-0.5
80	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	0.0	-0.5
90	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	90	89.5	0.1	-0.5
100	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	0.0	-0.5
125	124.5	126	125	124.5	124.5	124.5	124.5	125.5	124.5	124.5	124.5	124.5	124.7	0.4	-0.3
150	150	150	149.5	150	149.5	149.5	150	150	149.5	150	149.5	149.5	149.7	0.3	-0.3
175	175	175	174.5	175	175	174.5	174.5	175	174.5	174	175	174.5	174.7	0.3	-0.3
200	201	201	201.5	201	201	200.5	201	200.5	200.5	200.5	200.5	201	200.8	0.3	0.8
225	226	226	226	225.5	226	226	226.5	226.5	226.5	225.5	226	225.5	226.0	0.4	1.0
250	251	252	251	251.5	251	251	251.5	253	251	251	251	254	251.5	1.0	1.5
275	279.5	280	278	277	276.5	279	276.5	278.5	276.5	276.5	276.5	277	277.6	1.3	2.6
300	303.5	302	303	301	302	301	301	303.5	303.5	302.5	301.5	301.5	302.2	1.0	2.2

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 3,280 feet (1 kilometer).

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 3 foot (1 meter) to low quality targets.

Table 19—TruPulse 200B, observer #2

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.5	10	10	10	9.5	10	10	10	9.5	10	10	10	9.9	0.2	-0.1
20	19.5	19.5	20	20	19.5	19.5	19.5	19.5	19.5	19.5	20.5	20	19.7	0.3	-0.3
30	29.5	29.5	29.5	30	29.5	30	29.5	29.5	29.5	29.5	29.5	29.5	29.6	0.2	-0.4
40	40	40	40	40	40	40	40	40	40	40	40	40	40.0	0.0	0.0
50	49.5	50	49.5	49.5	49.5	49.5	49.5	50	49.5	49.5	49.5	49.5	49.6	0.2	-0.4
60	59.5	59.5	60	59.5	59.5	59.5	60	59.5	60	59.5	59.5	60	59.7	0.2	-0.3
70	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	0.0	-0.5
80	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	79.5	0.0	-0.5
90	89	89.5	89.5	89.5	89.5	89.5	89	92	89.5	89.5	89	89.5	89.6	0.8	-0.4
100	99.5	100	99.5	99.5	99.5	99.5	99.5	99	99	100	99.5	99.5	99.5	0.3	-0.5
125	126	125	124.5	125	124.5	125.5	125	124.5	124.5	125	124.5	125	124.9	0.5	-0.1
150	149.5	150	149.5	149.5	149.5	149.5	149.5	149.5	150	150	149.5	149.5	149.6	0.2	-0.4
175	174.5	174	174	174.5	174.5	174	174	173	174	174	175.5	174	174.2	0.6	-0.8
200	201.5	201	200	200	200.5	200.5	201	201.5	200	200	200	200.5	200.5	0.6	0.5
225	226.5	226	225.5	225.5	225.5	225.5	227	226	225.5	227	227	225.5	226.0	0.7	1.0
250	251	251	251	251.5	251.5	251.5	253.5	251.5	252	252	251.5	252.5	251.7	0.7	1.7
275	280.5	277	276.5	276.5	279.5	277.5	276.5	276	278.5	277.5	277	279	277.6	1.4	2.6
300	302.5	303	302.5	303.5	303	301.5	301	302.5	301	302.5	302	304	302.4	0.9	2.4

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 3,280 feet (1 kilometer).

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 3 foot (1 meter) to low quality targets.

Table 20—TruPulse 200B, observer #3

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	0.0	-0.5
20	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	0.0	-0.5
30	30	30	30	29.5	30	30	30	30	30	30	30	30	30.0	0.1	0.0
40	40	40	40	40	40	40	40	40	40	40	40	40	40.0	0.0	0.0
50	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	0.0	-0.5
60	59.5	59.5	59.5	59.5	59.5	59.5	59.5	59.5	59.5	60	59.5	59.5	59.5	0.1	-0.5
70	69.5	69.5	69	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	69.5	0.1	-0.5
80	79	79	79	79	79	79	79	79	79.5	79	79	79	79.0	0.1	-1.0
90	89.5	89.5	89.5	89.5	89.5	89.5	89	89.5	89.5	89.5	89.5	89.5	89.5	0.1	-0.5
100	100	99.5	99.5	99	99	99	99.5	99	99	99	99	99	99.2	0.3	-0.8
125	124.5	125	124.5	124.5	124.5	124.5	124.5	124.5	125.5	125	124.5	124.5	124.6	0.3	-0.4
150	149.5	150	149.5	149.5	149.5	149.5	149.5	149.5	149.5	149.5	149	149.5	149.5	0.1	-0.5
175	174.5	175	175	175	175	174.5	174.5	175	175.5	175	175	174.5	174.8	0.3	-0.2
200	201	201	201	202	201	201.5	200.5	201	200.5	202	202	201	201.2	0.5	1.2
225	225.5	226	226.5	225	226.5	226	226.5	226	227	225.5	227.5	227	226.2	0.8	1.2
250	251	251	250.5	250.5	250.5	252.5	251	250.5	251	250.5	251	251.5	251.0	0.6	1.0
275	277	278	276	276	276.5	276.5	276	276.5	276	277	277	276	276.5	0.6	1.5
300	301	303	302.5	303	303.5	301	301.5	301.5	300.5	301.5	301	301	301.8	1.0	1.8

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 3,280 feet (1 kilometer).

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 3 foot (1 meter) to low quality targets.

Table 21—LaserAce 2D and 3D, observer #1

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.5	9.2	9.7	9.6	9.7	9.7	9.6	9.6	9.7	9.6	9.7	9.7	9.6	0.1	-0.4
20	19.5	19.9	19.9	19.9	19.9	20.1	20.1	20.1	20.1	20	20	20	20.0	0.2	0.0
30	30.8	30.1	29.8	29.7	29.7	29.6	29.7	29.6	29.6	29.6	29.6	29.6	29.8	0.4	-0.2
40	39.6	39.6	39.7	39.6	39.7	39.6	39.6	39.6	39.5	39.6	39.7	39.7	39.6	0.1	-0.4
50	49.6	49.6	49.7	49.6	49.7	49.5	49.8	49.7	49.8	49.6	50.1	49.8	49.7	0.2	-0.3
60	59.9	59.8	59.8	59.8	59.9	59.9	59.8	60	60	59.7	60	60.1	59.9	0.1	-0.1
70	69.5	69.6	69.6	69.5	69.6	69.6	69.6	69.6	69.6	69.6	69.6	69.5	69.6	0.0	-0.4
80	80	79.9	80	79.9	80	80	79.9	79.9	80	80	80.1	80.1	80.0	0.1	0.0
90	89.5	89.5	89.5	89.5	89.4	89.4	89.6	89.4	89.5	89.7	89.4	89.4	89.5	0.1	-0.5
100	99.5	99.7	99.7	99.8	99.7	99.6	99.8	99.6	99.6	100.1	100.2	100.1	99.8	0.2	-0.2
125	124.9	124.7	124.7	124.9	124.7	124.9	124.7	124.9	124.7	124.6	124.7	124.9	124.8	0.1	-0.2
150	150	150.4	150	150.2	150	150.1	154.9	150.1	149.9	150	149.9	150	150.5	1.4	0.5
175	175	175.2	175.1	175	175.4	175	175.1	175.3	175.1	180.2	175.4	175.1	175.6	1.5	0.6
200	201.1	204.7	200.6	210.8	201.4	200.4	200.7	206.5	200.8	208.5	200.8	200.5	203.1	3.6	3.1
225	224.8	225.2	225	226.2	225.2	225	224.7	224.7	225	225.1	225	225.4	225.1	0.4	0.1
250	250	250	250.1	250	250.1	250.1	256.4	250.2	250.1	257.6	250.1	250.3	251.3	2.7	1.3
275	274.6	275.2	275.2	275.4	275.2	275.6	275.8	275.6	275.7	276.2	275.5	275.4	275.5	0.4	0.4
300	301	301	301	301.5	301	301.4	301	301.2	301	301.2	301.3	301	301.1	0.2	1.1

[1] *Station distance measured with a 300-foot fiberglass tape.*

[2] *Range of meter's ability to take accurate measurements (per manufacturer) = 500 feet (150 meters)*

[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 0.2 foot (5 centimeters).*

Table 22—LaserAce 2D and 3D, observer #2

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.9	9.5	9.5	9.5	9.7	9.7	9.6	9.5	9.6	9.7	9.6	9.6	9.6	0.1	-0.4
20	19.4	19.5	19.6	19.5	19.5	19.5	19.5	19.6	19.5	19.6	19.6	19.5	19.5	0.1	-0.5
30	30.2	30.1	30.2	30.3	30.2	30.1	30.2	30.1	30.1	30.2	30.1	30	30.2	0.1	0.2
40	39.9	39.9	40	40	40	39.9	39.9	40	40	40	39.9	40	40.0	0.1	0.0
50	50.3	50.3	50.2	50.3	50.3	50.2	50.3	50.2	50.2	50.4	50.4	50.3	50.3	0.1	0.3
60	60.3	60.2	60.2	60.2	60.2	60.2	60.3	60.2	60.2	60.2	60.1	60.1	60.2	0.1	0.2
70	70	70.1	70	70	70	70	70.1	70	70	70	70.1	70	70.0	0.0	0.0
80	79.9	80.1	80	79.8	80	79.9	80	79.8	79.7	79.6	79.8	79.7	79.9	0.2	-0.1
90	90.4	90.2	90.3	90.2	90.1	89.9	90	90	90.1	90	90.1	90	90.1	0.1	0.1
100	100.1	100.1	100.2	100.6	100.1	100.2	100.3	100.2	100.1	100.2	100.4	100.3	100.2	0.1	0.2
125	125.4	125.5	125.3	125.4	125.5	126.3	125.3	125.2	125.3	125.2	125.3	125.3	125.4	0.3	0.4
150	149.9	150.1	156.6	150	149.9	150	149.9	150	150.3	150	149.9	150.1	150.6	1.9	0.6
175	175.5	175.3	177.5	175.5	175.1	175.1	177.4	176.3	175.1	175.1	175.2	175.1	175.7	0.9	0.7
200	213.7	199.8	200.3	213.6	199.5	200.1	203.8	199.8	199.7	199.8	199.7	200.3	202.5	5.3	2.5
225	225.5	225.9	225.3	225.4	255.5	225.4	225.6	225.5	225.6	225.6	225.8	225.7	228.1	8.6	3.1
250	250.2	249.8	249.9	249.8	249.9	250.2	250.1	250	250.1	250.3	250.1	250.5	250.1	0.2	0.1
275	275	275.3	275.3	276.6	275	275.2	275.6	276.1	275.3	275.3	275.5	275.3	275.5	0.5	0.5
300	300.3	300.2	300.1	300.3	300.3	300.3	300.2	300.2	300.1	300.1	300.3	300.1	300.2	0.1	0.2

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 500 feet (150 meters)

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 0.2 foot (5 centimeters).

Table 23—LaserAce 2D and 3D, observer #3

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.9	9.8	9.8	9.9	9.9	9.8	9.8	9.8	9.9	9.9	9.9	9.8	9.9	0.1	-0.1
20	19.8	19.9	19.8	19.9	19.8	19.9	19.8	19.8	19.8	19.8	19.7	19.8	19.8	0.1	-0.2
30	29.9	29.9	29.8	29.7	29.8	29.8	29.8	29.8	29.8	29.9	29.9	29.9	29.8	0.1	-0.2
40	40.2	39.9	39.9	39.9	39.9	39.9	39.9	40	39.8	39.9	39.9	39.9	39.9	0.1	-0.1
50	50.2	50.2	50.1	50.2	50	50.1	50	50.1	50.1	50.1	50.1	50.1	50.1	0.1	0.1
60	60.2	60.1	60.1	60.2	60.2	60.1	60.1	60.1	60.2	60.2	60.2	60.2	60.2	0.1	0.2
70	69.8	69.7	69.8	69.8	69.9	69.8	69.9	69.7	69.7	69.7	69.7	69.8	69.8	0.1	-0.2
80	79.6	79.7	79.8	79.7	79.7	79.6	79.7	79.6	79.8	79.7	79.7	79.7	79.7	0.1	-0.3
90	89.5	89.4	89.3	89.3	89.6	89.6	89.8	89.7	89.7	89.7	89.8	89.8	89.6	0.2	-0.4
100	99.2	99.2	99.1	99.2	99.3	99.2	99.2	99.3	99.1	99.3	99.2	99.2	99.2	0.1	-0.8
125	125.1	125.2	125.1	125.1	125.1	125.1	125.1	125	125.1	125.1	125.2	125.1	125.1	0.1	0.1
150	150.1	149.9	149.7	149.8	149.8	149.8	150.8	150	151	149.1	150	149.8	150.0	0.5	0.0
175	174.3	174.4	174.3	174.4	174.4	174.5	174.3	174.3	174.4	174.3	174.4	178.8	174.7	1.3	-0.3
200	199.5	199.7	199.7	199.7	199.7	200.1	199.7	199.5	199.6	199.6	199.6	199.5	199.7	0.2	-0.3
225	225.2	224.6	224.6	224.5	224.8	224.6	224.5	224.5	224.5	224.5	224.4	224.5	224.6	0.2	-0.4
250	249.8	249.4	249.2	249.2	249.2	249	249.2	249.2	249.3	249.2	249.3	249.1	249.3	0.2	-0.7
275	274.9	273.9	274	274	274.3	274.1	274.3	274.2	274.2	274.2	274.2	274.3	274.2	0.3	-0.8
300	300	300.1	300.1	299.9	300	299.8	300	300	300.2	300	300.2	300.4	300.1	0.2	0.1

[1] *Station distance measured with a 300-foot fiberglass tape.*

[2] *Range of meter's ability to take accurate measurements (per manufacturer) = 500 feet (150 meters)*

[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 0.2 foot (5 centimeters).*

Table 24—Leica Disto D8, observer #1

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	10.0	10.0	10.0	10.0	10.0	10.0	9.9	10.1	10.0	10.0	10.0	10.0	10.0	0.0	0.0
20	20.3	20.3	20.3	20.4	20.3	20.3	20.4	20.3	20.3	20.3	20.3	20.4	20.3	0.1	0.3
30	30.1	30.2	30.2	30.2	30.1	30.2	30.2	30.3	30.2	30.2	30.1	30.2	30.2	0.1	0.2
40	39.8	39.9	39.9	39.9	39.9	40.0	40.0	39.9	39.9	40.0	40.0	40.0	39.9	0.1	-0.1
50	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	0.0	-0.2
60	59.8	60.0	61.5	60.0	60.0	59.9	59.9	60.0	59.9	59.9	60.0	60.0	60.1	0.5	0.1
70	69.8	69.9	69.8	71.3	70.0	69.9	69.9	70.0	69.9	69.9	70.0	70.0	70.0	0.4	0.0
80	79.9	79.5	79.8	80.0	81.6	80.0	79.9	79.9	79.9	79.9	79.9	79.9	80.0	0.5	0.0
90	90.0	89.6	89.7	89.8	89.8	89.7	89.7	89.6	89.8	89.7	89.7	89.8	89.7	0.1	-0.3
100	99.6	99.4	102.8	99.9	99.4	99.4	99.7	99.6	99.5	99.5	---	---	99.9	1.0	-0.1
125	Did not try														

[1] *Station distance measured with a 300-foot fiberglass tape.*

[2] *Range of meter's ability to take accurate measurements (per manufacturer) = 328 feet (100 meters)*

[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 0.04 inch (1 millimeter) up to 33 feet (10 meters).*

Table 25—Leica Disto D8, observer #2

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.9	10.0	9.9	10.0	10.0	9.9	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0
20	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	0.0	0.3
30	30.3	30.3	30.4	30.4	30.4	30.4	30.5	30.5	30.4	30.5	30.5	30.5	30.4	0.1	0.4
40	40.3	40.3	40.4	40.4	40.4	40.4	40.3	40.3	40.4	40.3	40.3	40.4	40.4	0.1	0.4
50	50.2	50.2	50.3	50.3	50.3	50.3	50.3	50.3	50.3	50.3	50.3	50.3	50.3	0.0	0.3
60	60.3	60.3	60.3	60.4	60.3	60.4	60.5	60.3	60.3	60.3	60.3	60.3	60.3	0.1	0.3
70	70.2	70.3	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.1	70.1	70.2	0.0	0.2
80	80.1	80.0	80.1	80.1	80.1	80.2	80.2	80.1	80.2	80.2	80.1	80.1	80.1	0.1	0.1
90	90.0	90.0	89.9	89.8	90.0	89.9	89.9	91.5	89.9	89.9	89.9	89.9	90.1	0.5	0.1
100	99.8	99.7	99.8	---	---	---	---	---	---	---	---	---	99.8	0.1	-0.2

[1] *Station distance measured with a 300-foot fiberglass tape.*

[2] *Range of meter's ability to take accurate measurements (per manufacturer) = 328 feet (100 meters)*

[3] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 0.04 inch (1 millimeter) up to 33 feet (10 meters).*

Table 26—Leica Disto D8, observer #3

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	9.6	9.5	9.6	9.6	9.6	9.6	9.6	9.7	9.7	9.7	9.7	9.7	9.6	0.1	-0.4
20	19.4	19.4	19.4	19.4	19.4	19.3	19.4	19.4	19.4	19.4	19.4	19.4	19.4	0.0	-0.6
30	30.3	30.3	30.3	30.4	30.4	30.4	30.3	30.3	30.3	30.3	30.3	30.4	30.3	0.1	0.3
40	39.9	39.9	40.9	40.9	40.9	39.8	40.0	40.0	40.0	40.1	40.0	39.9	40.2	0.4	0.2
50	49.8	49.8	49.8	49.8	49.8	49.8	49.9	49.8	49.8	49.8	49.8	49.8	49.8	0.0	-0.2
60	59.9	59.8	59.8	59.9	59.9	59.9	59.8	59.8	59.8	59.9	59.8	59.8	59.8	0.1	-0.2
70	70.0	70.0	70.0	70.0	69.9	69.9	70.0	69.9	70.0	70.0	69.9	69.9	70.0	0.0	0.0
80	80.1	80.2	80.2	80.2	80.1	80.2	80.2	80.2	80.2	80.3	80.3	80.2	80.2	0.1	0.2
90	89.6	89.7	89.7	89.7	89.6	89.6	89.6	89.6	89.6	89.6	89.6	89.7	89.6	0.0	-0.4
100	99.4	99.4	99.4	99.4	99.5	99.4	99.4	99.4	99.4	99.3	99.4	99.5	99.4	0.0	-0.6
125	125.3	125.3	125.3	125.3	125.2	125.3	---	---	---	---	---	---	125.3	0.1	0.3

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 328 feet (100 meters)

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 0.04 inch (1 millimeter) up to 33 feet (10 meters).

Table 27—Opti-Logic 1000LH, observer #1

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	too close														
20	21	21	21	22	22	22	22	21	22	22	22	22	21.7	0.5	1.7
30	32	30	31	31	30	30	31	31	31	31	30	30	30.7	0.7	0.7
40	42	42	41	41	41	41	41	41	41	41	41	41	41.2	0.4	1.2
50	52	52	52	52	52	52	52	52	52	52	51	52	51.9	0.3	1.9
60	62	62	62	62	62	62	62	62	61	62	62	62	61.9	0.3	1.9
70	72	72	72	71	71	72	72	71	73	71	71	71	71.6	0.7	1.6
80	82	82	82	82	82	82	82	82	82	82	82	82	82.0	0.0	2.0
90	91	91	92	91	91	92	91	91	91	91	91	91	91.2	0.4	1.2
100	102	102	102	101	101	101	101	101	101	102	101	102	101.4	0.5	1.4
125	127	129	127	127	127	127	127	127	127	127	129	128	127.4	0.8	2.4
150	154	151	151	152	152	152	153	152	153	153	152	153	152.3	0.9	2.3
175	178	177	176	178	177	176	177	177	177	177	177	177	177.0	0.6	2.0
200	203	202	202	203	202	203	202	202	203	202	203	202	202.4	0.5	2.4
225	227	227	227	227	227	229	227	227	227	228	232	229	227.8	1.5	2.8
250	254	256	252	253	252	253	253	253	254	256	253	257	253.8	1.6	3.8
275	278	278	278	280	278	279	280	279	281	280	279	278	279.0	1.0	4.0
300	304	304	301	303	303	303	303	303	303	303	303	303	303.0	0.7	3.0

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 4 to 1,000 yards.

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 3 foot (± 6 foot for very bright or dark targets).

Table 28—Opti-Logic 1000LH, observer #2

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	too close														
20	20	21	20	21	20	21	21	20	20	21	21	21	20.6	0.5	0.6
30	30	31	30	31	31	30	31	31	31	31	31	31	30.8	0.5	0.8
40	40	41	41	40	40	41	41	40	40	40	41	41	40.5	0.5	0.5
50	51	51	51	52	51	51	51	51	51	51	51	51	51.1	0.3	1.1
60	62	62	62	62	62	61	62	61	62	62	62	61	61.8	0.5	1.8
70	72	72	72	71	71	71	73	71	72	72	71	71	71.6	0.7	1.6
80	82	82	82	82	82	82	82	82	82	82	82	82	82.0	0.0	2.0
90	91	92	91	91	94	91	91	91	91	91	92	91	91.4	0.9	1.4
100	102	104	102	101	101	102	102	101	101	102	101	101	101.7	0.9	1.7
125	127	127	127	127	127	127	127	127	128	127	127	127	127.1	0.3	2.1
150	153	154	152	152	155	154	154	153	153	156	154	152	153.5	1.2	3.5
175	177	178	177	177	177	177	177	177	177	179	180	179	177.7	1.1	2.7
200	204	205	207	208	202	202	202	201	202	202	203	210	204.0	2.9	4.0
225	228	228	228	227	229	229	228	228	228	228	228	228	228.1	0.5	3.1
250	252	253	252	252	256	254	252	252	252	252	254	255	253.0	1.4	3.0
275	279	279	278	281	280	279	284	279	279	279	278	279	279.5	1.6	4.5
300	302	304	307	306	300	302	302	302	305	302	306	303	303.4	2.2	3.4

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 4 to 1,000 yards.

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 3 foot (± 6 foot for very bright or dark targets).

Table 29—Opti-Logic 1000LH, observer #3

READINGS[2] (all measurements are in feet)															
STAT[1]	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[3]
10	too close														
20	21	21	21	21	21	21	21	21	21	21	21	21	21.0	0.0	1.0
30	31	32	31	31	31	31	31	31	31	32	31	31	31.2	0.4	1.2
40	41	41	41	41	41	41	41	41	41	41	41	41	41.0	0.0	1.0
50	52	52	52	52	52	52	52	52	52	52	52	52	52.0	0.0	2.0
60	63	62	63	63	63	63	62	62	63	63	63	62	62.7	0.5	2.7
70	73	72	72	72	73	72	72	72	72	72	72	72	72.2	0.4	2.2
80	82	82	82	82	82	82	82	82	82	82	82	82	82.0	0.0	2.0
90	92	91	91	91	92	91	91	91	91	91	91	91	91.2	0.4	1.2
100	103	103	102	102	102	102	102	102	102	102	103	102	102.3	0.5	2.3
125	127	127	127	127	128	128	127	127	127	128	129	127	127.4	0.7	2.4
150	153	153	153	153	153	153	153	153	153	153	153	153	153.0	0.0	3.0
175	176	175	175	175	176	176	176	176	175	176	176	176	175.7	0.5	0.7
200	205	204	208	204	203	203	207	205	203	207	204	204	204.8	1.7	4.8
225	228	227	228	228	228	228	228	227	228	228	228	229	227.9	0.5	2.9
250	257	257	255	253	253	253	253	254	255	255	255	253	254.4	1.5	4.4
275	278	279	281	281	279	278	281	282	277	278	278	278	279.2	1.6	4.2
300	305	303	303	309	308	308	303	303	307	303	308	303	305.3	2.5	5.3

[1] Station distance measured with a 300-foot fiberglass tape.

[2] Range of meter's ability to take accurate measurements (per manufacturer) = 4 to 1,000 yards.

[3] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 3 foot (± 6 foot for very bright or dark targets).

Rangefinder Horizontal Distance (HD) measurements through dense brush

As previously mentioned (see Test Course section), we examined the ability of the Vertex Laser VL400 (ultrasound mode), TruPulse 360, and LaserAce to take accurate HD measurements to a target that was partially (about 80 percent) obscured by understory vegetation. Three observers took 12 measurements 80 feet from the target, except for the tests using the farthest-line feature of the TruPulse. (The TruPulse was the first device tested in dense brush. We used 2 observers taking 12 measurements at 60 feet from the target. We subsequently changed the evaluation to involve 3 observers who took 12 measurements 80 feet from the target.)

Vertex Laser (ultrasound)

See table 30 for the results of HD measurements using the Vertex Laser VL400 (ultrasound).

The results are very precise and within the manufacturer's claims of accuracy. It bears repeating, however, that ultrasound measurements are limited to within 100 feet of the target.

TruPulse 360 (w/reflector)

See table 31 for the results of HD measurements using the TruPulse 360 with a reflector.

We report reasonably accurate and precise results.

Table 30—Results of HD measurements using the Vertex Laser VL400 (ultrasound)

READINGS[1] (taken 80 feet from target)															
Observ	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[2]
#1	80.4	80.6	80.5	80.4	80.5	80.7	80.5	80.5	80.6	80.5	80.6	80.5	80.5	0.1	0.5
#2	80.8	80.8	80.5	80.7	80.6	80.5	80.6	80.6	80.8	81.1	80.6	80.6	80.7	0.2	0.7
#3	81.2	81.1	80.9	80.9	81.1	80.5	80.5	80.8	80.7	80.7	80.7	80.9	80.8	0.2	0.8
ALL	ALL 3 OBSERVERS COMBINED												80.7	0.2	0.7

[1] *Distance measured with a fiberglass tape. (All readings are in feet.)*

[2] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances is 1 percent or better.*

Table 31—Results of HD measurements using the TruPulse 360 with reflector

READINGS[1] (taken 80 feet from target)															
Observ	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[2]
#1	79	79	79	79	79	79	79	79	79	79	79	79.5	79.0	0.1	-1.0
#2	80	80	79	79.5	80	79	79.5	80.5	78	80	80	80	79.6	0.7	-0.4
#3	77	79	80	79	80	78	79	78	79	79	79	80	78.9	0.9	-1.1
ALL	ALL 3 OBSERVERS COMBINED												79.2	0.7	-0.8

[1] *Distance measured with a fiberglass tape. (All readings are in feet.)*

[2] *Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 1 foot to high-quality targets.*

TruPulse 360 (farthest-line mode)

See table 32 for the results of HD measurements using the TruPulse 360's farthest-line feature.

As might be expected, we report less precise results as some HD reading might have been of the farthest understory shrub and not the intended target. Nevertheless, reasonable accuracy is possible in this measurement mode.

LaserAce (using last-hit feature)

See table 33 for the results of HD measurements using the LaserAce last-hit feature.

As shown in tables 21 through 23, the LaserAce was very accurate taking HD measurements to an unobstructed target, even when taking measurements in the last-hit mode.

CONCLUSION

The results demonstrate that precise and accurate HD measurements through a dense understory are possible, if it is practical for the user to attach a transponder or reflector to the intended target site. If occupying the target site is not desirable (or practical), the LaserAce and TruPulse both have features (last hit/farthest line) that allow the user to disregard HD measurement readings to closer foliage and possibly capture the HD to the intended target in the background. This method produces less precise (or accurate) results relative to using a reflector or transponder, but it may meet the needs of many users. (Note that the LaserAce was surprisingly accurate (if not precise) even when taking last-hit measurements.)

Rangefinder distance measurements between two objects and measurement of height of objects

Since the primary objective of the evaluation was to test a rangefinders' ability to take HD measurements, investigating the ability of devices to measure between two objects and take height measurements was cursory.

Table 32—Results of HD measurements using the TruPulse 360 farthest-line feature

READINGS[1] (taken 60 feet from target)															
Observ	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[2]
#1	57.5	58	57.5	58	56	58	56	58	57.5	58.5	58	58	57.6	0.8	-2.4
#2	58	56	58	54	52	58	58	58	58	57	58	58	56.9	2.0	-3.1
ALL	BOTH OBSERVERS COMBINED												57.3	1.5	-2.8

[1] Distance measured with a fiberglass tape. (All readings are in feet.)

[2] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 3 feet (1 meter) to low-quality targets.

Table 33—Results of HD measurements using the LaserAce last-hit feature

READINGS[1] (taken 60 feet from target)															
Observ	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[2]
#1	80	80	81.2	81.4	81.3	81.2	81.2	79.4	81.4	78	80.6	81.6	80.6	1.1	0.6
#2	80.7	81.1	79.4	78.6	81.3	81.3	78.1	81	80.4	81.1	81	79.7	80.3	1.1	0.3
#3	80.9	80.8	80.9	81	80.9	81	80	80.8	81	79.5	80.3	81	80.7	0.5	0.7
ALL	ALL 3 OBSERVERS COMBINED												80.5	0.9	0.5

[1] Distance measured with a fiberglass tape. (All readings are in feet.)

[2] Change = Average distance recorded with rangefinder minus measured distance. Manufacturer's claim of meter accuracy at distances = ± 0.2 feet. (5 centimeters).

Distance between two objects

Both the LaserAce 3D and the TruPulse 360 have an intergraded compass that enables the user to take measurements between two stationary objects. We took several measurements with these rangefinders (at about 80 feet from the two objects) using this feature, and the results are shown in tables 34 and 35.

We were surprised that the LaserAce was almost +2 feet off the true (measured) distance, given how accurate it performed in HD measurements. Perhaps we may not have calibrated the device properly, even though we followed the directions from the user manual.

The TruPulse gave readings that were reasonably precise (repeatable) and accurate.

Height of object measurements

All rangefinders tested claimed to operate as a hypsometer (a device that can measure the height of objects). Table 36 provides the results of our cursory test on the accuracy and precision of this ability.

All devices provided reasonably accurate height measurements.

Table 34—LaserAce – using missing distance

	READINGS[1] (ft)									
Observ	1	2	3	4	5	6	7	AVG	STAND DEV	CNG[2]
#1	18.6	18.2	19.5	18.9	18.4	18.5	17.9	18.6	0.5	1.8
#2	18.2	18.8	17.8	18.6	18.5	18.6	18.7	18.5	0.3	1.7
#3	18.4	18.8	17.8	18.6	18.5	18.6	18.7	18.5	0.3	1.7
ALL	ALL OBSERVERS COMBINED							18.5	0.4	1.7

[1] *Actual distance between the two objects (trees) was 16.8 feet as measured with a fiberglass tape. Rangefinder readings were taken at a point about 80 feet from targets.*

[2] *Change = Average distance recorded with rangefinder minus measured distance.*

Table 35—TruPulse 360 - using missing line

READINGS[1] ft)															
Observ	1	2	3	4	5	6	7	8	9	10	11	12	AVG	STAND DEV	CNG[2]
#1	16.1	15.9	16.2	16.2	16.3	16	17.8	16.2	16.2	16.5	16.1	16.1	16.3	0.5	-0.5
#2	16.1	16.3	16.3	16.6	16.9	16.3	16.1	16	15.7	16.2	15.8	16	16.2	0.3	-0.6
ALL	BOTH OBSERVERS COMBINED												16.2	0.4	-0.6

[1] *Actual distance between the two objects (trees) was 16.8 feet as measured with a fiberglass tape. Rangefinder readings were taken at a point about 80 feet from targets.*

[2] *Change = Average distance recorded with rangefinder minus measured distance.*

Table 36—Results of cursory test on accuracy and precision of using rangefinder as hypsometer

Readings[1] (ft)											
Device	1	2	3	4	5	6	7	Avg	Stand Dev	True Height	CNG[2]
Vertex Laser	4.4	4.6	4.5	4.4	4.4	4.6	4.4	4.5	0.1	4.5	0.0
TruPulse	5.2	5.4	5.4	5.3	5.4	5.4	5.4	5.4	0.1	5.7	-0.3
LaserAce	5.5	5.4	5.4	5.5	5.6	5.7	5.4	5.5	0.1	5.7	-0.2
Disto D8	5.5	5.5	5.1	5.3	5.5	5.6	5.5	5.4	0.2	5.7	-0.3
Opti-Logic	5	5	5	5	5	5	5	5.0	0.0	5.7	-0.7

[1] *Rangefinder readings were taken at a point about 20 feet from targets.*

[2] *Change = Average distance recorded with rangefinder minus measured (true) height.*

SUMMARY

The primary objective of this evaluation was to compare and evaluate laser rangefinders' accuracy and precision in taking horizontal distance (HD) measurements similar to an evaluation performed by SDTDC in 1998. A secondary objective was to test a device's ability to take HD measurements to a target that was obscured partially by understory vegetation.

We tested the following field rangefinders, listed from most to least expensive: LaserAce 3D, Vertex Laser VL400 (laser and ultrasound), LaserAce 2D, TruPulse 360, Vertex IV (ultrasound only), TruPulse 200B, and the Opti-Logic. We tested the Lecia Disto D8, but considered it more of a tool for a construction-site setting (as opposed to a field forestry tool). All devices operated by using a laser beam, except the Vertex IV, which operated by ultrasound only. The Vertex Laser VL400 was a combination laser and ultrasonic device.

We found that rangefinder technology had improved significantly since the 1998 report. Commercial rangefinders are now all lightweight, sturdy, and portable. Two new features that are now available are rangefinders with an integrated compass and a device that can operate by either laser or ultrasound.

All devices tended to operate within the accuracy claims of the manufacturers. In general, the more accurate and precise devices were the more expensive. Also, the more features a device has, such as an integrated compass or Bluetooth capability, the more expensive they are. If a user is interested in very high accuracy, the LaserAce (the most expensive device tested) was accurate to within a few inches of what could be achieved from using a tape measure. If the user's demand for accuracy is significantly less (say ±several feet), a relatively inexpensive option exists in the Opti-Logic. Intermediate accuracy (and expense) can be had with the TruPulse and Vertex Laser VL400.

Any user seriously interested in taking accurate and precise measurements should invest in a tripod.

We found that ultrasound can be used to achieve very accurate HD measurements through a dense understory; an ultrasonic device has a range of only 100 feet.

Laser rangefinders (high-end devices) have features that assist the user to obtain reasonably accurate field measurements even if there is a dense understory. These devices have features that help distinguish the understory from the intended target. The device can be operated to show the readings of the farthest target it acquired (and hide the readings of the closer targets acquired) while laser beams were pulsed. In that way, the user ignores readings that were taken when striking foliage in between the observer and the intended target. High-end devices can also operate with a foliage filter and reflector to obtain accurate HD measurements through a dense understory. In this mode, the device only registers beams that are returned from a reflector attached to the target tree.

A rangefinder with an integrated compass expands the measuring capacity into three dimensions. With a compass rangefinder, from one point the user can measure the distance between any two visible objects (two trees or edges of a streambank to determine stream width).

Depending on the user's needs and the features desired, a reasonably priced and reasonably accurate device should be available commercially.

The National Technology and Development Center's national publications are available on the Internet at: http://www.fs.fed.us/eng/pubs/

USDA Forest Service and U.S. Department of the Interior, Bureau of Land Management employees also can view videos, CDs, and National Technology and Development Center's individual project pages on their internal computer network at: http://fsweb.sdtdc.wo.fs.fed.us/

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