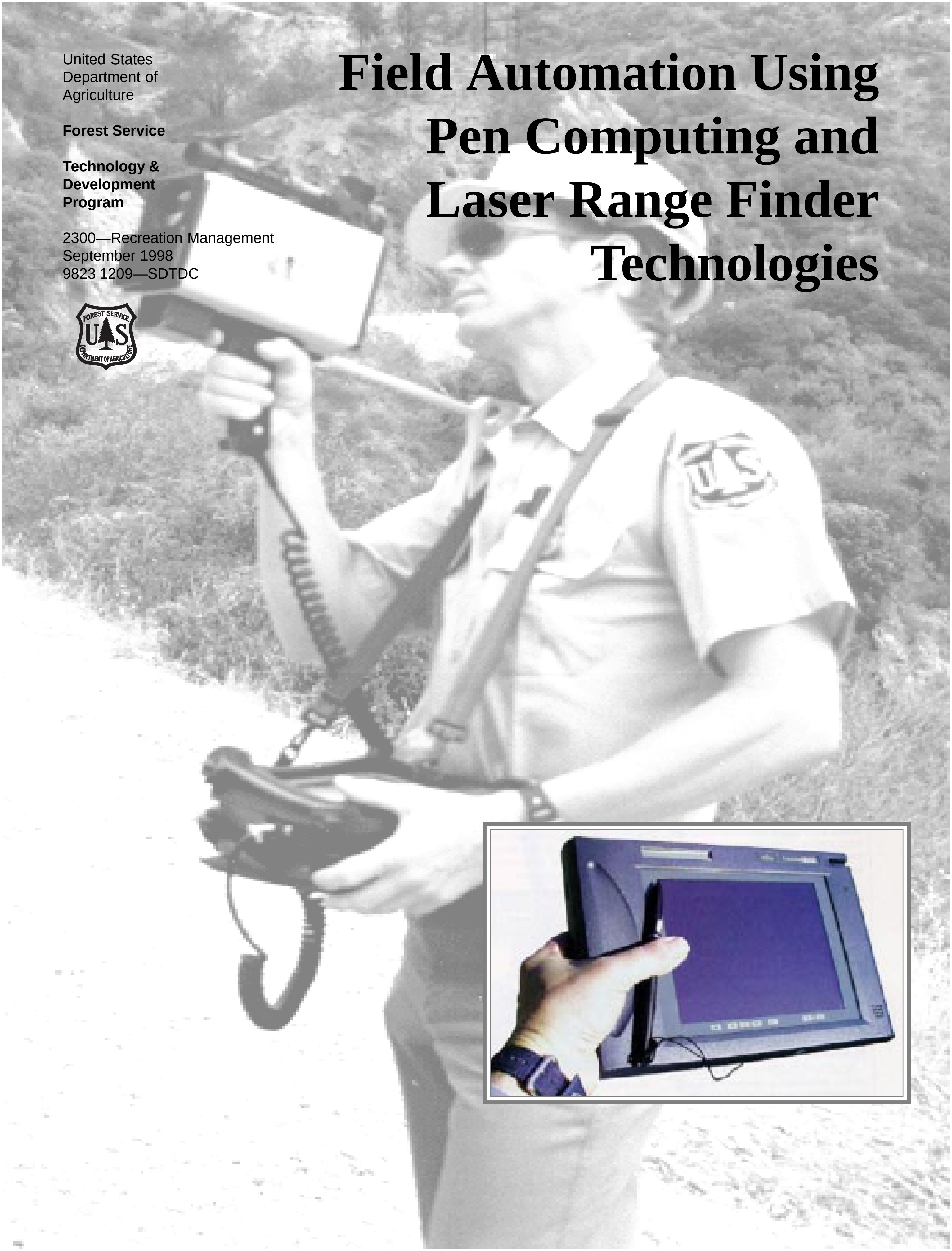


United States
Department of
Agriculture

Forest Service

**Technology &
Development
Program**

2300—Recreation Management
September 1998
9823 1209—SDTDC

Field Automation Using Pen Computing and Laser Range Finder Technologies

Field Automation Using Pen Computing and Laser Range Finder Technologies

Frank Sutton
Civil Engineer

USDA Forest Service
San Dimas Technology and Development Center
San Dimas, California

September 1998

CONTENTS

INTRODUCTION

Recent advances in rugged field computers and powerful pen-based mapping software have prompted a reevaluation of the current methods used by the USDA Forest Service to capture geographic information system (GIS) data. The San Dimas Technology and Development Center (SDTDC) is exploring alternative feature positioning systems such as laser range finders. Combining this technology with a pen-based data management platform and global positioning systems (GPS) will potentially increase field data collection speed, quality, and efficiency. The "real-time" mapping approach provided with current pen-based mapping software will minimize site revisits by providing the surveyor instant error checking while at the site, decreasing the likelihood of missing or incorrect data. Pen-based mapping software will interface with an array of data measurement or input devices, such as total stations, GPS receivers, laser range finders, and digital cameras.

This report will introduce pen-based mapping systems and focus on the laser range finder as a means of rapidly obtaining feature positions for a multitude of USDA Forest Service mapping applications. Penmap, by Condor Earth Technologies, and Archsite, a Penmap application for archeological sites, will be examined in detail.

As a reference, the appendix contains information on hardware and software vendors. Note: This report assumes the reader is familiar with basic survey and computer terminology.

LASER SURVEY SYSTEM PROJECT

Initially, this project was confined to data capture for archeological sites. However, it soon became apparent that the same mapping systems could also be applied to other Forest Service data collection needs, such as roads, trails, recreation sites, facilities, and streams.

In early 1996, a questionnaire was sent out to USDA Forest Service recreation, archeological, and engineering staff to solicit information on survey routines and data usage requirements. The questionnaire results may be viewed from the USDA Forest Service Web site listed below.

EXISTING FIELD SURVEY PROBLEMS

The main cause of errors in the field is the inability to immediately observe end results of data collection. Real-time mapping provides instant feedback so data can be seen as it is collected. Reduction of any raw measurements occurs immediately, and what is displayed on the field computer's screen is the map as it is being built. Traditionally, visualization of data occurs after post-processing the data on the office computer. Up to this point, the surveyor may not be aware of errors or omissions in the data. Errors that may occur with the conventional post-processing approach are:

- Missing features that are not detected while in the field
- Not enough data are gathered; site is only partially surveyed
- Errors caused by an equipment malfunction
- Inconsistency between electronically stored data and any field sketches that are drawn, or misinterpretation of sketches.

Validation of data is an important aspect of any survey. Errors may result from surveyors either partially or completely forgetting to survey certain features. These features are difficult to catch if there is nothing to relate back to. When a check plot is observed in the office, errors are not always apparent. Part of the motivation of a real-time mapping approach is that these errors will become obvious and can be corrected while the surveyor is still in the field.

COMPONENTS OF A REAL-TIME MAPPING SYSTEM

A system containing the following components is suggested. Each of these components will be discussed in detail.

- GPS receivers
- Laser range finders
- Core mapping applications
- Pen-based computers.

GPS Receivers

Inexpensive and compact P(Y) coded GPS receivers are now available for use by the USDA Forest Service. These units will remove the effects of

http://fsweb.sdtdc.wo.fs.fed.us/programs/rec/laser_survey/questionnaire.html

selective availability imposed by the Department of Defense. The latest receivers have been shown to be effective under forest canopy conditions, and now may produce real-time accuracies adequate for the majority of USDA Forest Service resource mapping needs. Publications on these and other receivers are available from the Missoula Technology and Development Center:

Phone: (406) 329-3978;
IBM mail: pubs/wo,mtdc;
FSWeb: http://fsweb.mtdc.wo.fs.fed.us.

Laser Range Finders

Obtaining positional data with a reasonable level of accuracy using GPS devices has traditionally taken too long, or has been hindered by dense canopy or deep canyons that are common in many forest environments. Although there have been dramatic improvements in GPS under these conditions, laser range finders, sometimes called laser instruments or laser guns, offer an alternative by rapidly obtaining measurements of features without physically occupying them.

Laser range finders are also useful for mapping signs, utility poles, trees, topography, or other features. Features are mapped in a matter of seconds by simply aiming and triggering the instrument from a known point. Raw measurements from the instrument's sensors (distance, inclination, and azimuth) may be reduced to three-dimensional coordinates by a computer connected to the instrument via an RS-232 interface.

Laser mapping instruments have different features and capabilities, and as such, will influence factors such as accuracy, minimum and maximum range, durability, and utility. They are typically hand-held devices, with an aiming scope, that record distance by measuring the time it takes laser light to travel to a target and reflect to a receiving diode in the instrument. A series of measurements is taken and statistically averaged to obtain the reading. Higher-priced models may include additional sensors that measure tilt (inclination) and an electronic compass for measuring azimuth, the angle referenced from magnetic north. This gives laser instruments qualities similar to total stations, and givesthem the ability to provide the three-dimensional coordinates of a feature based on a known point.

SDTDC acquired a Criterion 400 from Laser Technology, Inc. (LTI), in 1992 for the Low-Volume Roads Survey Laser Project. The Criterion was originally offered by LTI for forestry applications. New range finders manufactured by several different companies have emerged since the debut of the Criterion. Laser Atlanta Optics, Inc., has released a model competitive to the LTI Criterion, but at a much lower cost. An evaluation of the various range-finder instruments has taken place under a project funded by the Forest Management program at SDTDC. For results, see Publication 9824 1307-SDTDC June 1998.

Laser Instrument Limitations

Experience with laser instruments in timber and engineering applications has shown that local attraction adversely affecting the azimuth readings is a common problem under certain conditions. Large metal objects or subterranean ferromagnetic deposits, or anything capable of generating a magnetic field, will pull the azimuth reading well out of an acceptable range of accuracy. It is, however, possible to obtain X and Y coordinates by resectioning, calculating an unknown point by measuring distance to two or more known points (Figures 1 and 2). This is the technique used by GPS receivers for obtaining three-dimensional position information from distances measured from satellites. To derive a two-dimensional location from two known points, an algorithm would need only azimuth to reduce a computation with two solutions to one.

To test the feasibility of resectioning with a laser instrument, a closed-loop test course was placed on the grounds of SDTDC. Using a Criterion 400, a traverse was run using the instrument's compass,

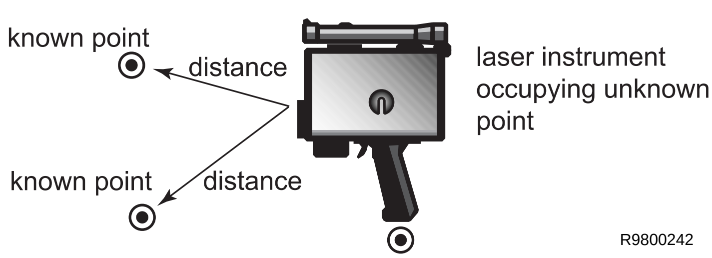


Figure 1—Resectioning with a Laser Range Finder.

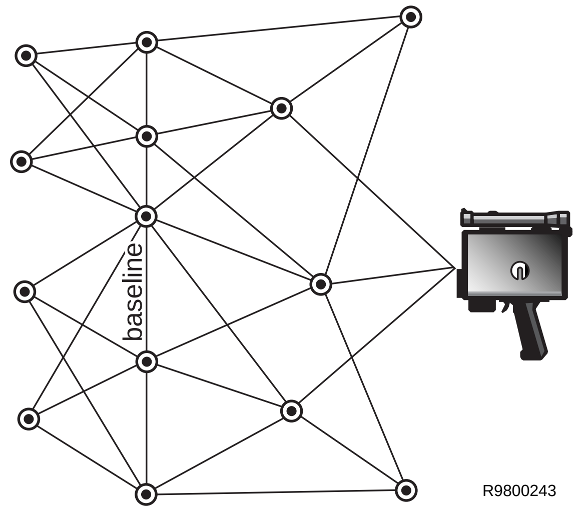


Figure 2—An example of establishing points for a site survey using a three-point resectioning technique that builds a survey from points located along a baseline.

averaging both foresight and backsight measurements of azimuth, vertical inclination, and slope distance. Reflector targets were used, with the foliage filter placed on the instrument. The instrument and the targets were mounted on staffs that were manually plumbed using a bubble level. A precision of 1 in 268 was calculated. Several compass readings were found to be outside the range of accuracy quoted by the manufacturer.

Additional points were placed both inside and outside the test traverse, so that a series of triangles formed around the traverse. The traverse point coordinates were calculated using the law of cosines, which relies on horizontal distances calculated on all legs of the triangles. Azimuth was dropped and only slope distance and vertical inclination were measured. Only one measurement was taken between all points. Precision with respect to the perimeter of the original traverse was calculated at 1 in 1,204, nearly a 4.5-fold increase.

A disadvantage of using this traversing technique is the increased time required to take additional measurements to known points. Since speed of collection is the main advantage of using a laser instrument, it can be concluded that using one is much less advantageous if unknown features must be occupied. However, in situations where dense forest canopy disallow the use of GPS, the technique may be beneficial.

MAPPING SOFTWARE

Mapping/data-management software is available from several vendors. Some of the features contained in off-the-shelf software packages are outlined below:

1. **Three-dimensional mapping capability.** The application must be able to store all coordinates produced by survey input devices, including elevation.

2. **A graphical user interface (GUI).** Most pen-based applications run under a multi-tasking environment such as the Microsoft Windows operating system (OS), allowing the software to run on both field and office computers. Adding capabilities to the mapping application would be simplified under the Windows OS by its interapplication communications capabilities, allowing other applications and drivers to send data to the core mapping application. A large software base of existing applications exists for Windows, extending the usefulness of the field computer. Examples of such software that can be applied to field computing are handwriting and voice-recognition engines. Another advantage of a GUI is user-friendliness, minimizing the amount of training required for a user to become proficient with the application. Instant on-line help is available, eliminating the need to carry software manuals to the field.

3. **Visual map display.** A display of the map and data being constructed in real time is what sets modern mapping/data collection software apart from the software residing on traditional data recorders. Rapid CAD-like panning and zooming capabilities ease the visualization of the data and speed the collection process. All raw data and measurements are reduced before surveyed features are plotted onto the display, making it unnecessary to post-process any data at the office.

4. **GIS Capabilities.** To provide a useful data-capture system that will interface well with the USDA Forest Service GIS, modern mapping/data-collection software has the ability to record multiple-feature attributes that are tied to the spacial data. The ability to transfer selected ARC/INFO coverages from the USDA Forest Service IBM system to the field computer, useful for field data validation, will be evaluated.

5. **Database form customization.** The ability to design custom database forms that match differing USDA Forest Service data requirements increases the versatility of the data-collection system, making it useful for multiple resource areas. GUI features, such as pull down lists and voice actuated text boxes contained in the database forms, speed attribute collection.

6. **Interfaces to multiple input devices.** With the large array of survey instrumentation such as GPS receivers, laser range finders, total stations, and alternative input devices such as digital cameras and bar-code readers, flexible systems that interface with these devices are available (Figure 3).

Penmap, A Real-Time Mapping Application

As this project was beginning, Region 8 published a report, accompanied by a letter dated August 1, 1995 addressed to Forest Supervisors, on using pen computers for data collection. The letter stated that substantial productivity gains were recognized by using this new technology. Region 8 recommended Penmap as the core application for use with a mapping system. After a SDTDC market search, several other programs were found, but none seemed to offer the advanced survey methods or to incorporate as many input devices as Penmap. As the market continues to change, with more vendors offering improved mapping and data-collection systems, future evaluations will be needed to ensure that USDA Forest Service field units are aware of the most applicable, cost-effective, and time-saving solutions.

The Penmap application is an off-the-shelf product sold by Condor Earth Technologies of Sonora, California. It operates on IBM compatible computers running Microsoft Windows 3.1x or Windows '95. It can be thought of as an electronic plane table, capable of recording survey measurements using a variety of input devices and survey methods. Penmap allows viewing and editing of data in real time, eliminating the need for post-processing. Penmap is most useful running on a powerful pen-based computer with a 486 processor or higher. Some of Penmap's more useful features are outlined below:

1. **Multiple input methods.** The Penmap application collects spacial information from an array of survey instruments (see appendix) or by hand input. Survey methods such as traversing, chain and offset, resectioning, and distance/bearing are

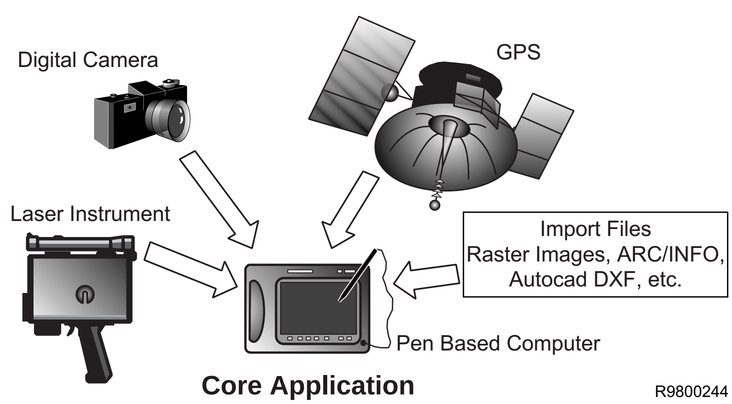


Figure 3—Various input devices of a field data-collection/mapping system.

provided with the software. Adjustment is possible with the traverse method. With the resection method, up to six reference points may be used in calculating the instrument's location. Computation can be determined from angle and distance, angle only, or distance only, the latter being useful for accurate positioning using laser range finders.

2. **Display of collected data over raster or vector maps or images.** Data can be displayed over digital ortho quads or other images using Rasterback, a utility for importing raster images into Penmap as a backdrop to a survey (Figure 4).

3. **User Customization.** A form generator is provided with Penmap to allow custom database forms to be constructed. Forms can be made to match a wide variety of data-collection applications (Figure 5). The database forms record attributes and link them to a feature on the ground. The form can be called and edited anytime during the survey. Database forms also accept input from devices such as digital cameras and bar code readers. Users can also create custom buttons that act as a shortcut to selecting a layer, survey method, graphic, or database form corresponding to the feature being mapped.

4. **On-site dynamic terrain modeling (DTM).** Penmap includes powerful three-dimensional terrain modeling features previously found only on high-end office CAD systems, but with the added advantage of instant data visualization and on-site error checking (Figure 6). The software allows the dynamic generation of contours as three-dimensional points are gathered. Break lines or barrier lines can be either constructed dynamically or by connecting existing points with a line. These DTM features can be useful to engineers or surveyors wishing to accurately construct surface models and compute volumes on site. Up to five surfaces can be generated and their corresponding volumes computed relative to a datum surface. A sectioning feature computes the line resulting from the intersection of a vertical plane with an existing surface. The profile of the line is then displayed.

5. **Multiple file import and export formats.** Arc/Info, Autocad DXF, Genio, and others are supported.

Penmap software with standard instrument interface is available to the USDA Forest Service for $995. Penmap with GPS interface costs $1,895. The license agreement allows one installation of Penmap on a field computer and one installation on an office PC.

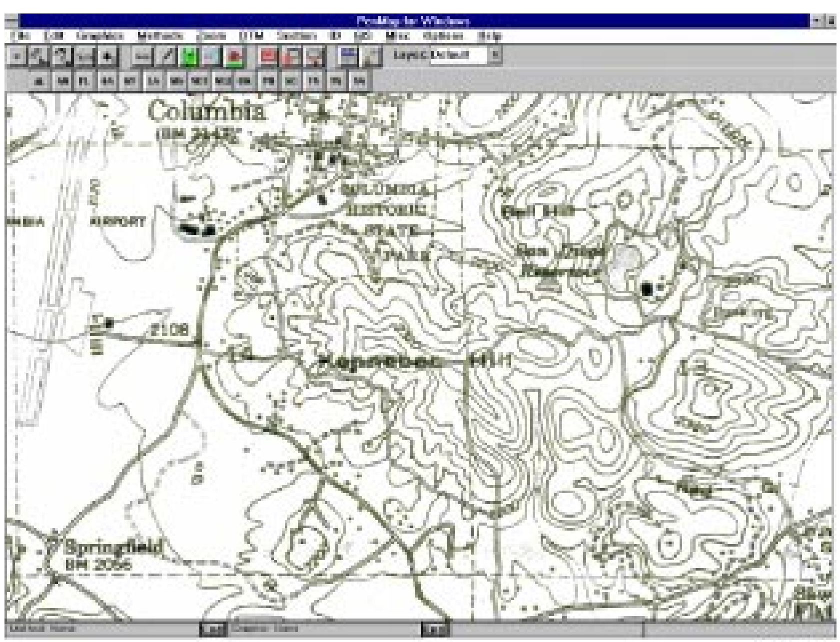
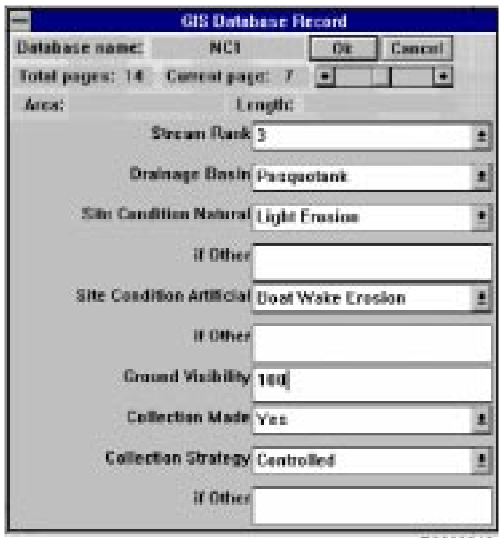


Figure 4—A raster image derived from a USGS 7.5' quadrangle is displayed in the Archsite application using Rasterback, a feature of Penmap for Windows (courtesy of Condor Earth Technologies).

Archsite

Archsite, a partnership between Condor Earth Technologies and the USDA Forest Service Southern Region, is a customization of Penmap to capture archeological data and export it to the appropriate State Historical Preservation Office form. A report on Archsite and its configuration files is available, and further information can be obtained from Kent Schneider, Heritage Program Manager, Southern Region.

Archsite configuration files for Penmap are public domain and can be obtained from the USDA National Forest Region 8 office or Condor Earth Technologies, Inc. More information can be obtained from Condor Earth Technologies, Inc., 21663 Brian Lane, Sonora, CA 95370. Phone: (209) 532-0361. Internet: http://www.condorearth.com.



R9800246

Figure 5—A database form in Penmap constructed for stream inventories (courtesy of Condor Earth Technologies).

R9800247

Figure 6—Fujitsu Stylistic 1200 Pen Computer (Courtesy of Pen Computing Magazine).

PEN-BASED COMPUTERS

Computer hardware has gone through remarkable changes in recent years. Smaller size, increased processor power, increased storage capacity and decreased cost have been some of the technological changes that have taken place. Computer history tells us that the trends will continue, with more manufacturers producing low cost, ruggedized computers capable of meeting the demands of USDA Forest Service field personnel. Recently, new models of pen-based computers are appearing that offer features that make mobile computing in harsh field conditions possible, while maintaining the functionality of desktop computers. Field ruggedness, compactness, low power consumption and user-friendliness have become the focus of many of the manufacturers.

A pen computer (or pen-based computer) consists of a flat display with an incorporated digitizer that records the traces of a pen (stylus) in contact with the display surface. The pen is the input device that replaces the traditional mouse and keyboard found on desktop computer systems (Figure 7).

The majority of the pen computers on the market use a monochrome liquid crystal display (LCD) and an Intel 80486DX compatible processor. Processors manufactured by Advanced Micro Devices have become a popular choice by makers of pen computers because of low heat output and decreased power requirements, but these processors do not offer near the CPU speed as newer desktops computers. Several of the latest models of pen computers offer Intel Pentium CPUs. Batteries are generally nickel metal hydride or lithium ion, and typically last a maximum of four hours, so it is essential that a sufficient number of batteries be taken along for field work.

Sufficient computing power is essential when selecting a pen computer. Tasks such as handwriting recognition are CPU intensive and require immediate feedback to the user. Having adequate random access memory will speed graphical oriented applications.

Pen computers range in price from $2,000 to $7,000, depending on configuration and performance. See the appendix for pen computer vendor contact information.

Figure 7—Operator with pen-based computer receiving input from a Laser Technology, Inc., Criterion 400 laser survey instrument. Computer is a ALPS, Inc. Kalidor 2500 pen-based computer (no longer manufactured).

RECOMMENDATIONS

Because the market for field data-collection-system components is changing very rapidly, and further investigation and evaluation are required, the project will continue. Further work in customizing a field data-collection system to meet differing resource needs will be developed. Additional information regarding this project may be found at the website listed below.

http://fsweb.sdtdc.wo.fs.fed.us/programs/eng/gis/gis.html

LITERATURE CITED

Bernard, J., "Attribute Collection and GPS." *Proceedings from 1994 AM/FM International Conference.*

Bradshaw, M. and B. Zykan. "Increasing Productivity using Laser Mapping Systems." *Proceedings from 1994 AM/FM International Conference.*

Elliott, B. "Moving AM/FM to the Field: Technology, Trends and Success Stories." *Proceedings from 1994 AM/FM International Conference.*

Griswold, G. "Field Application and Review of Hand-Held Laser Instrument Grand Mesa, Uncompahgre, and Gunnison National Forests, Gunnison Engineering Zone." USDA Forest Service Engineering Field Notes, May-August 1994.

Kent W. K. Lam, and Albert W. K. Chow. "A Topologically Integrated Field Data Capture System." *Proceedings from 1994 Urban and Regional Information Association.*

Lee A. Graham. "Land, Sea, Air GPS/GIS Field Mapping Solutions for Terrestrial, Aquatic and Aerial Settings." GIS World, January 1997.

Moll, J. "Low-Volume Roads Survey Laser." Project Report, San Dimas Technology and Development Center, June 1993.

Moll, J., M. Harrison, R. Turner, and W.F. Sutton. "The Spelunker's Delight: Cave Surveying Made Easy." Project Report, San Dimas Technology and Development Center, February 1995.

Nunnelley, G., G. Wood, and K. Schneider. "Archsite: Innovative Software for Heritage Field Data Collection and More." *Proceedings from 1997 ACSM/ASPRS Convention and Exposition.*

APPENDIX

APPENDIX

REAL-TIME MAPPING AND DATA COLLECTION SOFTWARE

Penmap
Condor Earth Technologies
(209)-532-0361
http://www.condorearth.com

GeoLink
GeoResearch, Inc.
(800)-436-5465
http://www.georesearch.com

VoCarta
Datria Systems Inc.
(800)-583-9509
http://www.datria.com

Field Notes
Penmetrics Inc.
(541)-752-9000
http://www.penmetrics.com

Aspen
Trimble Navigation Ltd.
http://www.trimble.com

Conic GIS
Conic Systems, Inc.
(210)-832-0100
http://www.conic.com

FieldSmart
MapFrame Corporation
(214)-741-2264
http://www.mapframe.com

PEN-BASED AND OTHER RUGEDIZED COMPUTER MANUFACTURERS

Walkabout Computers
(561)-881-9050
http://www.walkaboutcomp.com

Fujitsu
(800)-831-3183
http://www.fpsi.fujitsu.com

Telepad
(703)-834-9000
http://www.telepad.com

Texas Micro
(800)-627-8700
http://www.texmicro.com

Itronix
(800)-441-1309
http://www.itronix.com

Teklogix
(800)-633-3040
http://www.teklogix.com

Norand Corp.
(800)-553-5971
http://www.norand.com/terminals.html

Husky Computers
(813)-530-4141
http://www.wpihusky.com

Microslate
(514)-444-3680
http://www.microslate.com

LASER RANGE FINDER MANUFACTURERS

Criterion, Impulse
Laser Technology Inc.
(303)-649-1000
http://www.lasertech.com

Advantage
Laser Atlanta, Inc.
(770) 446-3866
http://www.laseratlanta.com

For up-to-date information listed in this appendix, visit the SDTDC FSWeb site at:

http://fsweb.sdtdc.wo.fs.fed.us/programs/eng/gis.html