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Please direct any comments or recommendations about this publication to the following address:

FOREST SERVICE—USDA
Engineering Staff—Washington Office
Attn: D.J. Carroll, Editor
M.J. Baggett, Editorial Assistant
P.O. Box 2417—Washington, D.C. 20013

Telephone: Area Code 703—235-8198

Close-Range Photogrammetry

Leland D. Whitmill
Geometronics Service Center
Photogrammetry Unit
Salt Lake City, Utah

The Photogrammetry section is making advances in close-range photogrammetry (CRP) using analytical stereoplotter systems. When used effectively, CRP can accurately and cost-effectively meet the measuring and mapping needs of Forest Engineers on projects such as two-dimensional architectural drawings, archaeological sites, bridge site mapping and load testing, detailed historical building mapping and monitoring, trail soil displacement, and slope erosion analysis.

The Geometronics Service Center (GSC), following the lead of Wayne Valentine, Region 1 Geometronics Leader, has completed several engineering application projects that involved both horizontal and vertical close-range measuring and mapping techniques.

We at the GSC also have been working with Rod Dawson of Region 6 Engineering (Geometronics) to answer questions and help in daily operations of the Mapp-Pal-Albany programs, which deal with semi-analytical and fully analytical bundle adjustments.

Some projects recently completed for Regional archaeologists included map documentation of petroglyphs in Region 8 and map documentation of old buildings and other structures on Forest Service property for Regions 1, 4, 5, and 6.

The Region 8 petroglyphs were exposed on a chlorite schist boulder that measured 9 feet by 9 feet by 3 feet. The petroglyphs consisted of several concentric circles and spirals along with a partially finished steatite vessel and several cup holes. The rock was contoured using a vertical interval of 0.1 foot with 0.05-foot supplementals. Digital profiling information was established on a grid increment of 0.075 foot. Approximately 82 scan lines were created to cover the entire rock. The finished contour plot measured 2 feet by 2 feet and had a scale of 1 inch = 0.05 foot. Some 6,570 digital data points were collected during the profiling of the rock.

The techniques, programs, and information used on this and other close-range photogrammetric projects are available at the Geometronics Service Center, Photogrammetry Unit, in Salt Lake City.

A paper on the petroglyphs was presented at the 17th annual joint ACSM-ASPRS-UCLS Conference at Salt Lake City in November 1985. Copies are available from this article's author at the Geometronics Service Center.

A detailed technical paper on these petroglyphs will be presented and published at the ACSM-ASPRS National Spring Convention in Washington, D.C., in March 1986. EFN

Terrain Profiles for Cable Logging in Region 1 With Analytical Photogrammetry

Wayne Valentine
Regional Geometronics Group Leader
Region 1

Collecting profiles of terrain to design cable logging systems is a growing industry in Region 1. As in other Regions, the easy terrain has been logged over, leaving only the more rugged slopes available for harvest. Cable systems have been around for some time, but the technical approach to designing spans and payloads has only comparatively recently appeared. The process of design demands a fairly accurate profile of the terrain under the proposed cable location to determine placement of towers and landings, and compute allowable deflections, spans, loads, and cable systems.

The usual method of obtaining data for a profile is to send a survey party to the field. Surveyors locate and follow the proposed line, measuring slope and distance. This field information is reduced later in the office to a form useful to the logging systems designer.

An alternative method is to scale the profile from a topo map by measuring distances between contours and plotting the distance and elevation. This method varies in reliability because of the nature of mapmaking--cartographers enjoy certain freedoms in interpreting terrain shapes. This "cartographic license" produces aesthetically pleasing maps, but the expression of microrelief often is compromised. High-quality maps of sufficiently large scale and small contour interval are not available in many areas.

A logical notion is to use mapping tools to make direct measurements of the ground for profiles. After all, a photogrammetric stereo plotter is basically a measuring device used to create graphical models of the terrain. Why not use it to make site-specific measurements directly?

Cartographers and photogrammetrists have their "mind-sets" like everyone else. To many of them, a photogrammetric plotter is a machine made to produce maps--nothing else. The idea of using the photogrammetric plotter to make direct measurements of terrain profiles is foreign to them. Besides, older mechanical plotters are not suited for making systematic measurements of randomly placed lines in a stereo model.

The whole system of mapping is not well suited for these types of surveys. For one thing, the computer programs used to determine scale of stereo models are designed for mapping, not for measuring. Older mechanical stereo plotters are just not accurate enough for these surveys. For example, a mapping plotter may need to be only accurate enough to produce a 40-foot contour, not to make point measurements accurate enough for cable profiles.

The turnaround time is also a factor. It often takes years to produce a topo map, and photogrammetrists are comfortable with that. Sales designers, on the other hand, need results in weeks or perhaps months.

Then there is the mysterious matter of control. The photogrammetrist is used to working in absolutes, and he expects control related to an overall absolute scheme. The idea of relative measurements is therefore foreign to the average photogrammetrist.

Finally, there is the problem of reproducing on the ground the line the photogrammetrist measured in his stereo model.

Control, turnaround, ground replication, accuracy, mapping bias, computer systems, plotter limitations--it's no wonder that previous attempts to use photogrammetry for direct measurement of terrain have been only marginally successful. There were just too many factors working against the routine application of this technology.

Fortunately, the analytical plotter has arrived on the scene just in time to finesse these barriers for the Forest Service. The analytical plotter will permit use of crude sources of control to scale stereomodels for accurate relative (not absolute) measurements. It will shorten the turnaround time needed for making direct measurements, allow direct measurements of randomly placed lines in the stereo-model, and permit the direct plotting of the measured line onto a large-scale photo to facilitate placement of the line directly onto the ground.

How is all this possible? The analytical plotter is a computer-controlled measuring machine of high accuracy and utility. Since the computer is tied directly to the plotter, the lag time in computing results of measurements is shortened tremendously. By substituting control from widely spaced points, the analytical plotter will permit relatively accurate scale on a small portion of the model even though absolute position is not known accurately.

When we use the system, we purchase controlled photos or take control from maps or orthophotos by scaling points separated by several miles. We compress the error in scale by measuring only relative positions in a very small portion of the model land expanding this small portion to serve as control for a larger-scale model of the area needing profiles.

We scale the end points of the line to be measured and store them in the plotter's computer. The plotter then "drives" down the line so defined, and the operator makes direct elevation measurements on the line. The computer's file stores these data and later plots them out as a profile in machine-readable format for the logging system designer's applications programs. The data also are converted to photo coordinates and plotted directly onto a large-scale photo of the area. This permits direct layout of the line from the photo.

The turnaround shortens considerably because we need no expensive and error-prone field control and no offsite computing. All plotting and miscellaneous computations are performed onsite.

Costs of this process are amazingly low. The only direct costs are for making the diapositive and the operator's time involved in making the measurements. Typically, one operator can measure between 50 and 80 profiles per day; each profile is several thousand feet long. Costs per profile are less than $7--certainly much cheaper than the $200 by ground methods!

What are the drawbacks? The worst shortcoming of this process involves the old aerial-photo bugaboo. If you can't see the ground, you can't measure it.

So very heavy tree cover that obliterates much of the ground from the observer's eye is a problem. Even in these conditions, however, the logging systems designer can gather enough information to make intelligent decisions about the need for supplemental ground measurements as long as the ground shape is fairly uniform. We label those profiles or portions of profiles where the operator had trouble seeing the ground so the user is aware of this.

What about accuracy? We have checked several profiles in the field. In each case we proved the accuracy of the process. As a rule of thumb, you can expect a vertical accuracy of ±5 feet or better along the profile.

What about timing? We are committed to sending results to the field within 1 month after we receive materials (copies of the photos, etc.) from our sources. This usually takes less than 6 weeks, so the usual total time is less than 2½ months from the time we get the request from the field.

We believe that measuring cable profiles by analytical photogrammetry has tremendous potential to save the Forest Service money and time. As with all systems, it does have drawbacks, but the advantages far outweigh any shortcomings. The Forest Service should aggressively pursue this important new technology for making field measurements.

Region 3 Crew Quarters Standard

Louis Archambault
Engineering Architect
Region 3

During 1985, Region 3 employed its newly developed Crew Quarters Standard at three different project sites. The relatively large number of living units required in the same year, the similarity of the functional programs, and the belief that a repetitive plan would encourage modular contractors to gear-up for our design prompted the standardization. Our preliminary design research included analyzing the plans of 11 recently built and occupied crew quarters from four different Regions and interviewing the operators and crews of six sites in two Regions. Our analysis of these plans revealed a differential in total allotted space per crew member from 140 to 520 square feet, kitchen/-dining spaces designed for as few as two and as many as eight people, toilets for two to six, and bedrooms for two to six. The interviewers discovered that, given a choice, crew members would trade off many features of the facility for a private bedroom space, that kitchens designed for more than four people become inefficient and unsanitary, that space for refrigerated and frozen food is consistently undersized, and that crews with both sexes are increasing and the ratios are highly unpredictable from season to season. The Forests involved developed the following list of design requirements:

(1) Sleeping, toilet, and eating facilities should be under one roof.

(2) Each bedroom should accommodate a maximum of two persons.

(3) The plan should provide for the optional installation of a washer and dryer.

(4) Living spaces may be separated from the sleeping spaces.

(5) Each living/dining/kitchen unit should accommodate a maximum of four people.

(6) There should be a toilet for every two people.

(7) Kitchens should have space for a microwave oven as well as a conventional oven.

(8) The plan should include a covered porch.

(9) Heating with wood should be an option.

(10) Modules should be easily relocatable.

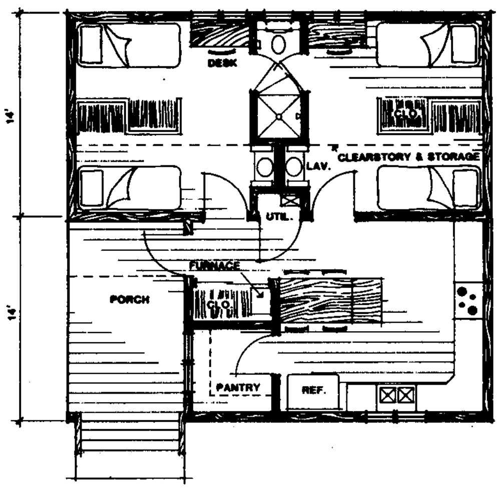
(11) The plan should allow for a crew of both sexes, in the smallest feasible increment.

(12) The plan should be easily converted from housing regular crews to preferred singles or childless couples.

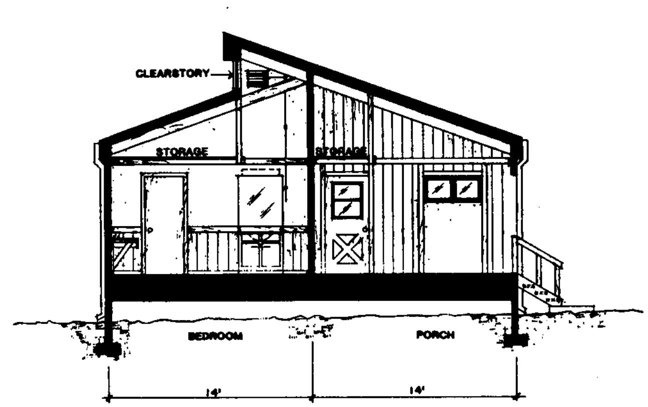
When the design was 75-percent completed, a value analysis was performed and an estimated cost savings of 7 percent was realized. One of the changes was a $600 pantry in place of $3,400 of kitchen cabinetry for each four-person living unit. The value analysis process probably could provide even greater savings during the schematic design stage. We recommend a value analysis group of nonfacility personnel, because they can see alternatives more easily.

The Region 3 Standard as issued (see Plan No. 2 in figure 1) implemented a consolidated living room/-recreation hall. For project sites with fewer than 10 people, the separate commons building cannot be justified and, instead, the enclosed porches of two adjacent units can form an enclosed living room. The four-bed, two-bedroom unit can easily convert to a two-bed, two-bedroom unit that will accommodate two "preferred" crew members. It also can convert to a one-bed, one-bedroom plus living room for a childless couple.

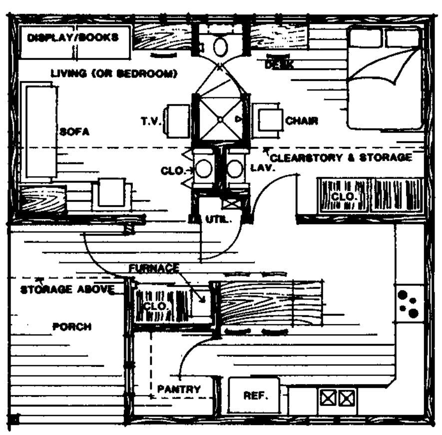
We are pleased with the bids received on our 1985 projects. Although each is a remote site, the average cost per square foot is $48. Also, each of the three low bidders chose an alternate method of construction: stick-built, USDA truss frame, and factory-prebuilt. (The Forest Service contracted and supplied the truss frames to the site for the



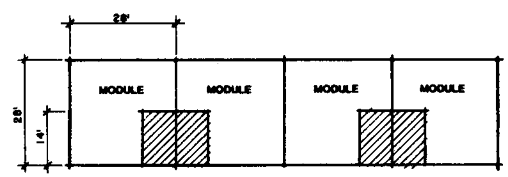
PLAN MODULE-4 PERSONS



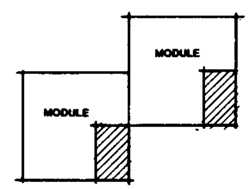
CROSS-SECTION



PLAN MODULE-FAMILY (2 PERSONS)



TYPICAL LAYOUTS



R3
CREW QUARTER
STANDARD

PLAN
NO. 2

Figure 1.--Plan No. 2.

general contractor.) As more of these units are built, we will approach a more error-free set of contract documents and more predictable costs.

During the design phase, we tried to accommodate the crew's desire for private bedrooms. To make the cost of such an amenity competitive with the standard approach, we proposed trading the individual kitchen/dining space and the living room for centralized facilities (see Plan No. 1 in figure 2). The plan created sleeping modules or pods small enough for easy relocation as the work loads moved from one area to another. Setting the pods on a fixed platform or raised deck minimized the environmental impact, and the one-person bedrooms provided the ultimate flexibility for mixed-sex crews. The centralized "kitchen" contained minikitchens for groups of four to six people, and the dining room and living space/recreation room were common to all. This plan was rejected because of the separate kitchen/dining facility, but I am intrigued with this concept and hope to see it adapted in the future.

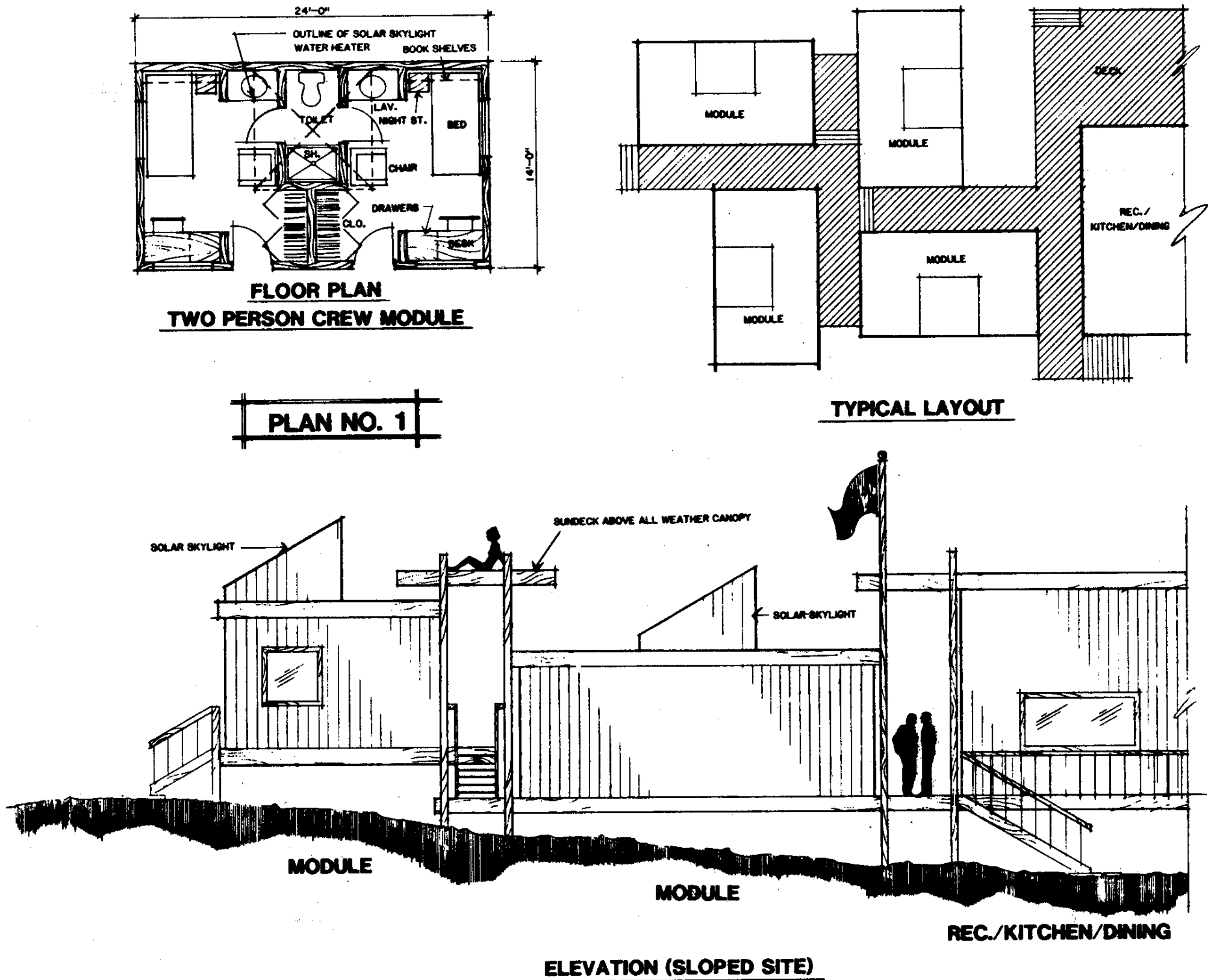


Figure 2.--Plan No. 1.

Report on the Photogrammetric Survey on the Kaibab National Forest Hearst Mountain Project in Fiscal Years 1983 & 1984

Dennis J. Mouland
Professional Land Surveyor
Region 3

William E. Stephens
Professional Land Surveyor
Region 3

INTRODUCTION

During fiscal year 1983, the Forest Service created a Productivity Improvement Team (PIT) to examine the Cadastral Survey Program throughout the Forest Service. The team made several recommendations to increase use of new and existing technology to increase productivity. In the PIT report "Landlines--A Productivity Analysis," Issue 3 mentioned the increased use and application of photogrammetry for cadastral work. In July 1983, Region 3 began planning a demonstration of photogrammetric technology applied to a cadastral surveying project on the Kaibab National Forest in Arizona. Two sections were to be field controlled and subdivided (to 1/256 corners) using currently existing photogrammetric technology.

The principal people involved in the project were Dennis Mouland, Professional Land Surveyor (then the Supervisory Land Surveyor for the Kaibab National Forest) and Bill Stephens, Professional Land Surveyor and Region 3 Geometronics Group Leader.

The project site is located about 10 miles northwest of Williams in Township 22 North, Range 1 East, sections 8 and 9, Gila and Salt River Meridian, Coconino County, Arizona. The project has an average elevation of 6,500 feet above mean sea level and is covered with pinon and juniper, with scattered large meadows.

SCOPE of WORK

Sections 8 and 9 each contained Forest Homestead Patents in need of surveying, monumentation, and posting. The project was conducted in the following sequence:

(1) Locate all the controlling section and quarter corners originally established by the General Land Office in 1883.

(2) Determine the approximate locations of all section subdivisional corners.

(3) Place ground targets on all points in items 1 and 2 above.

(4) Establish a network of field control and ties to all ground targets placed at the controlling corners in item 1.

(5) Acquire special aerial photography.

(6) Using analytical aerotriangulation procedures, determine the coordinate positions of the uncontrolled ground targets set in item 2.

(7) Perform section subdivision computations in accordance with Bureau of Land Management manual procedures.

(8) Make all corner moves from the ground targets to the computed subdivisional corner positions.

(9) Field measure all distances and angles between the newly established subdivisional corners for comparison with the analytically derived positions.

(10) Post and monument all private lands after making any adjustments.

(11) Prepare and file plats of the survey in accordance with Arizona law.

AERIAL PHOTOGRAPHY & PHOTOGRAMMETRIC CONTROL REQUIREMENTS

Because of the requirements of the survey and the apprehension of the field surveyor, the demonstration followed traditional methods as closely as possible. Thus all the procedures conceptually would closely parallel those typically used in the field.

The required photogrammetric field control and flight lines were planned in the Regional Office. Since the project area was two rectangular sections that were longer from east to west, the flight was oriented in the same direction, with four flight lines at a scale of 1:3,000 and with 60 percent forward overlap. This produced 56 exposures. The black-and-white photography, which was acquired by contract, was shot with a 6-inch focal length metric aerial camera.

The team suggested that Forest personnel responsible for providing the field control use electronic traverse procedures. Since the primary concern from the photogrammetric point of view was the accuracy of horizontal measurements, all vertical control was accomplished with a reciprocal vertical angle traverse and the resulting closures were well within the required limits.

Following the receipt of the field control, the project was submitted for analytical aerotriangulation. The results were very good. Of the 15 control points used, only one had a questionable value. As it turned out later, that ground target had been disturbed and was not in the correct position.

FIELD WORK

Items 1 through 4, 7, and 11 described under "Scope of Work" were performed by Land Line Location personnel from the Kaibab National Forest. The Regional Office Geometronics Group accomplished items 5 and 6 by contract and the Kaibab National Forest handled items 8, 9, and 10 under a contract with a Registered Land Surveyor.

The project proceeded well with few problems and only minor damage to some ground targets before flight time. All corners controlling the section subdivision were found, with the exception of the north 1/4 corner of section 8. This corner was reset by single proportionate measurement using the same photogrammetric methods described earlier for setting subdivisional corners from ground target coordinate points. The surveying contractor performed the corner moves as computed by the Forest Service and then checked all angles and distances between the newly established subdivisional corners. The results of these field checks were extraordinarily good. (These comparisons are discussed later.)

After the placement of all the corners defining private lands, the land surveying contractor posted the boundary in accordance with Forest Service standards.

COMPARISON of RESULTS—FIELD VERSUS ANALYTICAL

Two field methods were used to determine comparisons with the analytically derived coordinate positions:

(1) Coordinate positions were physically established on four of the ground targets but were not provided for the analytical computations.

The analytically derived coordinate values of these targets were then compared to the results from traditional field procedures. The maximum positional difference was 0.31 foot. This comparison was well within the acceptable and predicted limits.

(2) The primary method of evaluating the analytically derived coordinates was by performing a precise electronic traverse through all of the subdivisional corners established by corner moves from the ground targets set at the approximate location of the subdivisional corners. Closed traverses were run and accepted only if the closure was 1 part in 10,000 or better. All angles were balanced prior to the closure computations. The results were excellent. No traverse adjustments were made afterward.

Table 1 compares computed distances and field-measured distances and gives the resultant error ratio for each particular line. These results are a representative sample of the project.

Table 1.--Comparison of computed distances and field-measured distances (in feet).

Computed Distance	Field Measurement	Difference	Error Ratio(1/X)
1,959.39	1,959.83	0.44	4,454
640.93	640.97	0.04	16,024
648.34	648.34	0.00	--
2,608.85	2,609.36	0.51	5,116
659.30	659.09	0.21	3,138
1,270.56	1,270.64	0.08	15,881
1,331.70	1,332.04	0.34	3,918
654.70	654.79	0.09	7,275
675.64	675.46	0.18	3,750
670.62	670.57	0.05	13,412

We should note here that the first, fifth, seventh, and ninth lines probably were affected by a disturbance of the temporary monuments at the ground target positions. Cattle were present in the area and the ½-inch diameter rebar used to mark the center of the targets was bent over. In another situation, not shown in the table, the rebar was completely removed, requiring some secondary methods to set the final corners.

All in all, the results were very satisfying. Some minor adjustments were made to ensure that all lines would fall within 1 part in 5,000 of the computed distance. The plats have been prepared and filed in accordance with Arizona State law.

COST ANALYSIS

The team maintained a record for all costs associated with the project. Scope of work item 9 is not included in this cost analysis as it was a checking system for this project and would not be included in similar future projects. Items 1, 7, 10, and 11 would cost the same regardless of the method used to perform the survey.

Table 2 compares the costs of the traditional survey method (closed traverse) and the analytical photogrammetric method.

One of the reasons the project area was selected was that much of it was free from dense trees and brush. This allowed easy access and good visibility for the intended demonstration. It also minimized the number of system variables in our assessment of the results. Items 4 and 8 could increase significantly with the traditional method in dense vegetative cover. Assuming that a project was in moderately dense Ponderosa pine, the total cost of the traditional method would increase by approximately $1,800 to a total of $11,861.

Among the things we learned in this project was that smaller scale photographs could have yielded fewer exposures while maintaining the same desired results. Also, not all of the uncontrolled points required a ground target. That is, where adjacent 1/256 corners were to be established, some approximate positions could have been left untargeted and set by using the nearby analytically derived corner coordinates. This would reduce some of the photography and analytical aerotriangulation costs of the photogrammetric process and cause no significant increase in field costs.

Table 2.--Comparison of traditional survey method and analytical photogrammetric method costs for scope of work items (in dollars).

Item	Traditional Method	Photogrammetric Method
1	908	908
2	0	325
3	0	361
4	1,835*	471
5	0	1,200
6	0	3,300
7	104*	104
8	4,200*	1,220
9	2,024	2,024
10	990	990
Total	10,061	10,903

*Estimated cost.

CONCLUSION of the FIELD SURVEYOR

Although the field surveyor (Mouland) was somewhat skeptical of the photogrammetric approach to this project at first, he is now quite enthusiastic about it. The relatively minor problems mentioned in the section of this article comparing the field and analytical results could have been avoided if the period between originally setting the ground targets and finalizing the field work was minimized. In the case of this project, that time interval approached 6 months. No other significant problems were encountered during the course of the work and Mouland welcomed the opportunity to sign and file the completed plats.

The savings resulting from the use of photogrammetry were not as great as hoped. However, this demonstration project was executed with undue care to ensure no blunders. Two additional factors could affect potential savings. First, there is some merit to the idea of "economy of scale." Savings could be increased proportionally with a larger size project. Second, the less accessible the terrain, the greater the potential benefit from the photogrammetric approach.

This project was very interesting and enlightening to the field surveyor; the opportunity to observe the two methods side by side in a real situation was rewarding. The projected savings from using photogrammetry are 35 percent of the cost for the traditional approach.

CONCLUSION of the PHOTOGRAMMETRIST

Recalling that the primary objective of this project was to demonstrate the use and value of photogrammetric technology on a Land Line Location property boundary, as suggested in the 1983 PIT report, the photogrammetrist feels that the result is very positive and that the objective was met in several ways:

(1) Although similar previous projects showed no substantial savings, this project clearly demonstrated that a considerable amount of personnel time could be saved and the Forest's human resources redirected into other projects.

(2) The result of this project will serve as a positive testimonial to encourage potential users, who may not have a clear understanding of the value, benefits, and applications of photogrammetry, to be less apprehensive in its use.

(3) The photogrammetric approach used in this project was "overkill," but it was done intentionally so that the results would indeed be positive. This project shows that the same results can be achieved with a more conservative approach.

Electronic Navigation Systems May Offer Accurate Field Coordinate Location for Resource Management Activities

David S. Gasvoda
Project Manager
Missoula Equipment Development Center

Electronic navigation equipment is improving all the time and so are the chances of getting some kind of electronic position-fixing system that operates with accuracy in the Forest environment. Products are evolving into smaller, better, and cheaper packages. Loran C and satellite navigation receivers are becoming more accurate and more reliable and their price and size are declining as well.

Such developments are important to the Forest Service because so many activities depend on knowing one's exact location in the field. One example of the potential for revolutionizing the way we do business is computer-based vehicle monitoring. A system developed by a Massachusetts firm uses Loran C together with radio transmitters to monitor continuously the positions of up to 1,000 vehicles on a large computer-generated map display. Imagine such a system at work on your Forest.

No doubt that kind of system is a long way off for us, but accurate electronic position fixing for timber cruisers, road surveyors, and others who work in the Forests could be a reality soon.

The challenge for the Forest Service is to keep up with what's happening in the industry so we can begin to link equipment with the needs of our people for a better position location system.

Field people recognize that better position-fixing equipment would help them do their jobs more efficiently. In a 1984 survey, timber sales people told us their number one problem was the need for a better method of locating positions in the field.

To begin addressing this field need, the Engineering and Timber Management staffs in the Washington Office asked the Missoula Equipment Development

Center to determine the Forest Service requirements for a field locating system and to learn what equipment is available to meet these needs.

We began with a market and literature search to learn what equipment might help accomplish Forest Service tasks. We also initiated a survey of timber and engineering personnel in the different Regions to help us determine what Forest Service people wanted in a field location system. Our survey revealed that personnel in the field have many specific uses for a system to fix positions accurately.

Through our market and literature search we found that both public and private organizations are expanding existing systems and developing new ones. Some of these systems have been around for years and are merely being expanded or refined. Others are totally new and operate with orbiting satellites. They all offer the potential for accurate position fixing in the field.

Just how well some of these systems might work in the varied terrain and vegetation typical of National Forest land is not clear, and separating claims for the new systems from performance is not possible until they become operational. With this in mind, let's review the systems. Then we'll look at some of the specific needs for a Forest Service system as revealed in responses to our survey.

RADIO DIRECTION FINDING

Radio direction finding is one of the oldest methods for fixing a position. It is commonly used by wildlife managers to track game animals. The direction finder provides a relative direction to a transmitter. A transmitter can be pinpointed by two direction headings from known locations. Or, if the locations of two transmitters are known, the location of the direction finder can be calculated.

The accuracy of direction finders ranges from 1 to 5 degrees, depending on method, equipment, and operator skill. The absolute accuracy of a location depends on the accuracy of the reference points, angle measurement accuracy, geometry of the points, and the distance between points.

The area of coverage depends on radio frequency used, terrain, and equipment. Typical range is from 1 mile to hundreds of miles under ideal conditions.

Receivers range in price from $400 for manual direction finders to $10,000 for sophisticated automatic equipment. A low-power portable transmitter costs only a few hundred dollars. But installation and maintenance can increase operating costs.

Automatic direction finders establish the heading to a transmitter nearly instantaneously and require less training to use than manual systems. On the other hand, manual range finders are more accurate when used by skilled operators under multiple-path signal conditions. Manual direction finding is nearly impossible to use in brushy areas.

LORAN C

Loran C is a navigation system that provides position fixes based on the arrival time of radio signals from a network of land-based transmitting stations. Loran receivers analyze and process these signals to provide position information in longitude and latitude. Costs for portable receivers range from $2,000 to $4,000. These receivers provide continuous, nearly instantaneous position display of latitude and longitude and can be operated by moderately skilled personnel.

Over the years, Loran has been expanded from a navigation system solely for coastal zones and open waters. Today, Loran stations cover all but a portion of the central United States. Accuracies of 400 to 1,500 feet are typical. Loran gives the person in the field the ability to return to within 60 to 300 feet of an established point. Differential relative position operation can enhance accuracy by using a reference station to broadcast error corrections to nearby users. Differential mode accuracy is 26 to 66 feet. While land coverage with this system is now extensive--including mountainous areas--soil conductivity and terrain can combine to reduce its accuracy to no better than 2 miles. For this reason, accuracy and good signal coverage is not available for many inland National Forests.

OMEGA

Omega is a very-low-frequency, very-long-distance navigation system. Position is determined by phase comparison of continuous wave signals from two transmitters separated by 5,000 to 6,000 nautical miles; a nautical mile is 6,076 feet. Omega's accuracy is 2 to 4 nautical miles, with a repeatability of 1 to 2 nautical miles, and differential relative position accuracies are 1,000 to 2,000 feet, so it would have little Forest Service application.

NAVY NAVIGATION SATELLITE SYSTEM (TRANSIT)

TRANSIT is a space-based radio positioning and navigation system consisting of four or more satellites in polar orbit and four ground monitors. It began operating in October 1968. TRANSIT provides worldwide coverage, and it is possible to gain a position fix anywhere in the world. Fix rate varies with latitude, theoretically from an average of 110 minutes at the equator to an average of 30 minutes at 80 degrees latitude.

The satellites broadcast continuously on 150 and 400 MHz. A position can be determined with one frequency but more accuracy is obtained using two. A receiver measures successive Doppler, or apparent frequency shifts of the signal, as the satellite approaches or passes the user. The receiver calculates the user's position based on knowledge of the satellite position that is transmitted from the satellite every 2 minutes and a knowledge of the Doppler shift of the satellite signal.

Predictable position accuracies for a single frequency receiver is about 12,000 feet, for a dual frequency receiver, 75 feet. Repeatable positioning accuracy is 150 feet for a single frequency receiver and 45 feet for a dual frequency receiver. Relative positioning accuracy of less than 30 feet has been measured through translocation techniques.

A typical receiver costs about $3,000 and requires 15 minutes or more to obtain a position fix.

The plan is to begin phasing out TRANSIT in 1988. TRANSIT will be completely phased out by 1994, replaced by the Department of Defense Global Positioning System.

GLOBAL POSITIONING SYSTEM

The Global Positioning System (GPS)--sometimes called NAVSTAR--is the Defense Department's anywhere, anytime, any weather navigation and position-fixing system. It is a satellite-based, radio-navigation system that provides accurate three-dimensional position and speed. When fully operational in late 1988, 18 satellites and 3 active spares will circle the Earth in six orbital planes inclined at 55 degrees. Each plane will contain three satellites spaced 120 degrees apart in 12-hour orbits. Currently, six satellites provide up to about 4 hours of coverage per day to most of the continental United States.

Position fixes are based on the transit time of radio frequencies from four satellites within the constellation. Ranges to the satellites are determined by scaling the transit time by the speed of light. The transmitted messages contain ephemeris (computed positions of satellites) parameters that enable the user's receiver to calculate the position of each satellite at the time it transmits a signal. The user's position is calculated from the range intersection of spheres centered on the satellites.

GPS will provide two basic accuracies, one for DOD-approved users and the other for the general public. The Precise Positioning Service (PPS) will be restricted primarily to the military for national security considerations. It will provide 40-foot accuracy to stationary users. The Standard Positioning Service (SPS) will be continuously available to all users and will provide 325-foot accuracy.

GPS accuracy can be enhanced by using what is called relative positioning. By placing a reference receiver at a known accurate position, measurement corrections can be determined. According to DOD, 93-foot accuracy is possible for real-time relative positioning. However, some equipment manufacturers anticipate 5-foot accuracy over a 200-mile range. Also, accuracy of a few inches can be obtained by recording GPS data at a fixed position for later comparison with similar data obtained at a known receiver location.

Forestry applications under a dense tree canopy or in steep mountainous country will adversely affect access to the satellite signals. Just how much this will complicate operations may not be fully known until the system is operational.

Civilian GPS receivers are available today for $24,500 to $150,000, but they are not easily portable because most weigh more than 50 pounds. Lightweight receivers, suitable for resource management activities, will cost about $10,000 when GPS becomes fully operational in 1988. The price should come down to about $1,000 by the year 2000.

GEOSTAR SATELLITE SYSTEM

Unlike GPS, Geostar is a privately financed venture. It is expected to be operational sometime in late 1987.

Geostar consists of three elements: a trio of communication satellites covering the continental United States; a ground station and computer center; and portable transceivers for getting position information and for sending messages to others. The satellites are simply relay stations that exchange data with the transceivers and retransmit this information to the central computer.

According to Geostar founder Dr. Gerard K. O'Neill, a Princeton University physicist, the system will be able to provide three-dimensional positioning with accuracies of 3 to 23 feet. Like GPS, this system's availability depends on an unobstructed line of sight to the orbiting satellites, and interference from terrain and foliage can limit areas of use.

Geostar is designed so that all the sophisticated instrumentation is at a central computer facility. This means user equipment--mobile transceivers--can be kept simple, easy to use, and relatively cheap. O'Neill estimates these units will cost about $450, with a monthly service charge ranging from $30 to $40, depending on the number of messages sent.

FIELD SURVEY

In an attempt to find out what Forest Service people want in a position-fixing system, we surveyed engineering and timber personnel Service-wide. We sent questionnaires to each Regional Office. In some cases, the Timber or Engineering Staff duplicated the questionnaire and sent it on to their Forests or other units for comments. We received 22 responses.

The questionnaire asked respondents about the kinds of tasks a position locator system would help them accomplish. We asked their opinions about real-time response, equipment portability, accuracy, price, complexity, and type of readout, and we solicited any general comments they might have.

The question on tasks produced a multitude of answers. Our respondents identified 46 separate uses for such a system. These included timber plot boundary locations, boundaries between leasable and nonleasable land, road/trail/ski locations, sale areas, oil/gas wellhead locations, cabins, geotechnical mapping, mine entrances, helispots, aircraft guidance, topographic mapping, and location of crews in emergencies.

In answer to our questions on real-time response, field people strongly indicated that the shorter the real-time response the better. Forty-two percent of all respondents indicated a need for a response of less than 1 minute. However, the job to be done and the accuracy required influenced opinions on response time. For example, engineering people felt that longer response time was acceptable if it meant more accuracy. Timber management people, whose tasks require less stringent accuracy, favored faster response time.

Responses about portability ranged from a desire for hand-held units weighing only a few pounds to a backpack model of 60 pounds. Most people felt a unit weighing less than 30 pounds would be best. About 70 percent of the timber management respondents indicated they wanted hand-held units, while a majority of engineering personnel felt a backpack unit weighing as much as 30 pounds would be acceptable. No doubt the engineering responses were probably influenced by current electronic surveying equipment, which is fairly heavy and bulky.

Roughly one-third of our respondents felt they needed accuracies of 2 to 10 feet, but 23 percent of all those responding felt they needed 1 foot or less and another 23 percent felt accuracies of 26 to 50 feet would be adequate.

Acceptable prices for a position-locating device ranged from $200 to $100,000 for a very accurate unit, obviously a surveying-grade instrument. Many respondents indicated price would depend on the unit's accuracy and response time. Fully half felt the unit should be less than $5,000. Most timber management responses indicated an acceptable price would be under $3,000. Engineering responses showed a willingness to pay up to $100,000. Again, this probably reflects the need for an accurate surveying instrument to replace time-consuming methods and increase productivity.

The responses we received concerning complexity can be summed up in one statement: keep it as simple as possible. This sentiment applied both to training and to actual field operation.

There was a general consensus on the type of location readout. Most respondents favored coordinates in latitude/longitude. While these do not appear on Forest Service maps, computer programs are available to convert them.

We encouraged those filling out the questionnaire to include any general comments they had. The vast majority of them were concerned that the unit must be weatherproof and rugged enough to withstand hard field use.

The FUTURE

We are continuing to monitor new developments in position-fixing equipment, as well as encouraging and assisting manufacturers to produce equipment that will meet the needs of field people that were identified in our survey. We hope to initiate an evaluation program for commercially available equipment we identify as being most likely to meet resource management needs. Beyond that, we will be working to implement position-fixing equipment in the Forest Service so that there is orderly acceptance and use throughout all Regions.

We feel that operational tests are the best way to answer the many questions about just how well systems such as GPS and Geostar will work in a Forest. As these systems become fully operational in the next few years and as increasingly sophisticated mobile receivers come on the market, the future looks promising for position-fixing techniques that will fulfill many of the expectations Forest Service people have about a locator system.

Microcomputer Programs Available on the RTIP Bulletin Board

Chris Schwarzhoff
Civil Engineer
Washington Office Engineering

The publication Road TIPS (EM-7100-5, October 1985) described the RTIP Bulletin Board in general terms and provided an abbreviated users guide. As described, the RTIP Bulletin Board provides the following functions:

(1) Bulletin posting.

(2) Road engineering topic conferencing.

(3) User-to-user contact list.

(4) File upload and download.

Any telecommunications device (including many Data General terminals) can access the bulletin board by calling FTS 235-3573 or commercial (703) 235-3573.

The file upload and download capabilities of the bulletin board should interest engineering personnel with access to microcomputers--particularly those using either MS-DOS or PC-DOS operating systems.

There are about 200 public domain program files available for downloading (transferring to your system). You will need a telecommunication device capable of XMODEM file transfer. If you do not have a program with XMODEM capabilities, you still can call the bulletin board and look over the selections. Then, if you find something you like, leave a message and a diskette with the program will be sent to you. There are several excellent public domain telecommunications programs with XMODEM capabilities on the bulletin board. Other programs range from simple DOS enhancements to sophisticated engineering applications such as road design. The files are grouped by subject matter into 11 directories on the bulletin board. The rest of this article briefly describes what is available, organized by directory.

DIRECTORY 1—PROGRAMMING AIDS

Help for BASICA Programmers

ADVBAS. This is an OBJ file that provides many routines that are not available from BASIC programs that are compiled with either the MICROSOFT or IBM compilers. If you are still using the version 1.0 compiler, this utility is a must and should still be very valuable with the new compiler (version 2).

BASICAID. General programming aid to expand and compress program listing. Will generate a cross-reference list of reserved words, program variables, and line numbers called by branching calls.

EXEC. Utility that allows direct use of DOS commands in a BASIC program.

LISTER. Utility program to format BASIC programs so they are much easier to read and understand. Easy to use.

SQUISH. Useful utility for large BASIC programs to reduce size when program is compiled. Several nifty options and easy to use.

Help for PASCAL Programmers

PIBMENU. Subroutines for implementing menu windows in TURBO PASCAL program.

VISIBLE-PASCAL. Special version of PASCAL to provide beginning programmers an easy way of developing initial skills in writing PASCAL programs.

TURBO-LESSONS. A series of tutorials to help beginners get started using TURBO PASCAL. All work is done online and is easy to follow.

General Programming Aids

PROGRAMMERS CALCULATOR. Converts HEX to Decimal to Octal. Helps keep track of stack commands and should be useful for Data General programs that require converting HEX to Octal.

DIRECTORY 2—DATA BASE MANAGEMENT

pBASE. This is a data base management system--a programmable relational data base program that provides facilities for querying and manipulating data as well as report writing. This is a powerful system, but not particularly user friendly.

PC-DBMC. This is a data base management system. It is an excellent all-purpose data base management with help screens and tutorial.

FILE EXPRESS. An information management system. It has an easy-to-use data base management system that includes report writer, global search, merge data bases, and mailmerge files.

DBMEMOPO. A utility program for use with dBASE3. It makes it easy to add data to memo fields in dBASE3.

dGENERATE. A utility program for use with dBASE3. It has a screen generator for dBASE3 and it executes command files.

DIRECTORY 3—DESK HELPERS

PC-DESK. General desk manager: calculator, miniword processor, calendar, clock, automatic phone dialer, and memory partitioning (cannot use memory partitioner with some other memory resident programs).

PC-DESK MATES. General desk manager: notepad, printer control, phone dialer, and typewriter emulation (good for filling out forms).

MANAGER'S PLANNER. Super calendar to plan time effectively, with Wordstar-type word processor.

DIRECTORY 4—DISK MANAGEMENT

CD. An easy-to-use file selection program.

DOSamatic. File selection and simplified DOS.

DIRENAME. Rename a directory without deleting files.

DIR-X. Another easy to use file selection program.

FINDUP21. Nice little program to find files on HD.

LF. A powerful substitute for DOS DIR.

ND. Another substitute for DOS DIR.

PC-SWEEP. Easy to use disk maintenance utility.

SDIR. Directory utility and command shell that will run BASICA programs directly.

SDIR26. Only file lister with up to 6 columns.

SEARCH. Great program that extends PATH to files called by programs.

ZIP. Super file management utility and command shell.

Disk Catalog Programs

DISKCAT. Most powerful and flexible stand alone disk catalog program; does take a little study to use.

CATUTILITY. Easy to use catalog utility.

DSI dCAT. If you are a dBASE3 user, then this is the one for you. (Requires use of dBASE3.)

FANSI-Console

Very powerful DOS console driver and BIOS driver, speeds up nearly all screen operations, takes snow out of IBM color displays, screen saver, and lots more.

DIRECTORY 5— FINANCIAL, ECONOMIC, & STATISTICAL

ALOAN. Very easy to use loan amortization program.

AMORTIZE. Multipart loan amortization program.

EPISTAT. Collection of all common statistical analysis procedures in BASICA (not compiled). Has abbreviated manual.

HOME FINANCIAL ANALYST. Anyone considering a job transfer or change in home ownership should try this program.

MULTREG. Powerful stepwise linear regression with data weighing, confidence limits, forecasting, and transformations.

SOLVER. Easy to use formula solver--can input almost any combination of commands.

SPPC. Statistical Programs for Personal Computer. Menu driven, help screens, and easy to use interactive statistical program. No manual, but help screens are reproduced here.

TIME AND MONEY. Basically a home financial program. For those who still keep cuff records or want to track costs on a special project, this should be a help.

FINANCE. General economic analysis plus calculates internal rate of return. Menu-driven BASICA program--no manual or doc.

DIRECTORY 6— HIGHWAY ENGINEERING APPLICATIONS

NETWORK ANALYSIS FOR LOGGING PLANNING USING MICRO COMPUTERS. Demo (but operational) MS-DOS version of NETWORK ANALYSIS. Program allows for multiple logging systems, destinations, products, road locations, road standards, and different time periods.

Works well but next version will be much faster with many more links. Fairly easy to run as it is menu driven; however, you really need the documentation to get the program working quickly.

MINNESOTA DOT HYDRAULIC SYSTEM. Set of hydraulic analysis programs for a variety of drainage situations including: culvert analysis, flood routing, gutter design, archpipe analysis, and open channel flow. Be sure to review instructions before running the programs.

TENNESSEE COORDINATE GEOMETRY PROGRAM. Powerful program but not very user friendly. This program will require a detailed review of input instructions before it can be used.

IVY LEAGUE PROJECT MANAGEMENT. This Critical Path Project Manager is easy to use and does a good job of basic CPM. Shortcomings are lack of calendar function and project tracking.

DIRECTORY 7—SPREADSHEET APPLICATIONS

LOTUS123 Utilities & Worksheets

123PREP. Allows you to vertically divide ASCII files into fields and quickly create a properly formatted input file for 123's IMPORT feature, with numeric values preserved and fields correctly split into separate columns.

AUTO123.WKS. A main menu for 123 (use with LOTUS.ARC).

123SHELL (LOTUS.ARC). Easy to use main menu and supporting files that include predefined Macros, ASCII character set, help menu, graphics, and colorful terminal driver.

BREAKEUN. Fairly straightforward break-even analysis (no doc).

LOTUSP. New LOTUS printer driver--many more printers better handled.

PC-CALC

This is a very nice spreadsheet, and it will handle 90 percent of all the applications I have seen used in the Forest Service.

DIRECTORY 8—TELE-COMMUNICATIONS

QMODEM. Versatile Telecommunications program, many features and good support programs (does not support odd parity). This is the one I use most.

PCTQMD. Convert PC-Talk phone director to QMODEM.

QDIRUTIL. Sort QMODEM phone director many ways.

PC-TALK. This is the all time best seller--only supports XMODEM, but does handle odd parity, and DTR is optional.

PC-VT. Emulates DEC VT102 or VT100 Terminal, accesses DEC and UNIVAC with KERMIT. Excellent manual.

PIBTERM. Versatile Telecommunications program, many file transfer protocols, good manual, and mini bulletin board will automatically convert QMODEM phone directory to PIBTERM.

DIRECTORY 9—UTILITY PROGRAMS

Miscellaneous Utilities

More than 30 small programs to do many of the chores that PC-DOS left out, that is, backscrolling, file fixers, ram disks, help menus, file listers, speaker control, and improved DOS editing.

Library & Squeeze Programs

ARC. This library program automatically squeezes and unsqueezes files as they are added to the library. It also allows you to run (execute) any COM, EXE, or BAT file from within the library. Nearly all files in these volumes have been "libraried" with this program. Library files generated by ARC normally have a file name with the extension ARC.

VBUERG.ARC. This file contains three of the early versions of the "LU" series of programs.

(1) LUE. Removes files from library file with the LBR extension.

(2) LUT18. Lists files from library file with LBR extension.

(3) LUU. Adds or replaces individual files in a library file with LBR extension.

(4) LU87. This is a single program that lists, adds, and extracts files from a library file with the LBR extension. It does not squeeze.

(5) UNLBR. If none of the above work to extract a file from a library (LBR) file, try this one--it is a bit slow but thorough.

(6) SQ-UNSQ.

(a) SQPC. This program squeezes any file.

(b) NUSQ. This program unsqueezes files that have been squeezed by SQPC.

DIRECTORY 10—WORD PROCESSING

PC WRITE

This is the premier user-supported word processing program. It is often used as a vital part of public domain software, such as the structural design and analysis, and construction engineering programs from the Tennessee DOT. The program has nearly all the features of most commercial word processors. The user interface is not quite as smooth as most commercial software, although most people find it only takes an hour or so to be "cooking" with PC-WRITE.

Wordstar Utilities

A major challenge with Wordstar files is using them in other applications or telecommunicating them to someone who does not have Wordstar. The following programs convert Wordstar files to ASCII and ASCII to Wordstar: CONVERT; WSTODOS; WSDOS (no doc); XWORD; and WSCNVN11. Each program is a little different so you may want to try each for your circumstances (I normally use WSDOS).

Also included is an informational text file, WS33LPT.ARC on nondocumented patches for WS to run it off the hard disk, along with several other informational items.

Printer Control Utilities

These files offer a wide variety of options for printing text and graphics characters, including one program that turns the IBM-PC into a $300 typewriter (ever tried filling out a form with a word processor?).

Text File Filters

These programs are used to filter out or add special control codes to a text file. If you have ever converted a Data General CEO file to the IBM-PC you will understand the need for these programs.

Text Editors

Because the only editor supplied with PC-DOS is the very crude EDLIN, several public domain program text editors have been developed.

OmniEdit. Full screen editor that includes built-in calculator and telecommunications with XMODEM.

EZ-FORM. This is a unique text editor that is great for making and filling out forms.

FRED. If you are just looking for a replacement for EDLIN then this is what you want. (It is a full screen editor.)

CED. If you are "hooked" on line editors, then throw away EDLIN and use this one. It has great keyboard redefinition. Good for programmers because it is compatible with DEBUG.

DIRECTORY 11—GRAPHICS PROGRAMS

dbGRAF. BASICA type graphics editor: slow but fairly easy to use, uses standard screen dump to printer.

DRAWMAN (Draftsman). Excellent Business Graphics: bar charts, pie charts, line diagram, good dumps to printer, plotters, and Polaroid Palette.

ESCREENS. Another screen generator for BASICA and FORTRAN programs.

I6CGRAFS. 16-color graphics in BASICA and FORTRAN programs.

MACH II. Similar to BASICA graphics: allows 5 text fonts, good editing capabilities, good for making text slides.

PC PICTURE GRAPHICS (PCGRAFIX). Public domain version of IBM graphics program.

PRESENT. Versatile graphics program: good for making computer slide shows for training sessions. Slide shows will run on timer.

SUPER GRAPHICS 3. Graphics word processor to enter the 256 ASCII characters into text files.

VINCENT. Screen painter for ANSI screens: call function from BASICA, video ram files, use in BAT programs.

USEANS1.TXT. An excellent description of how to get the most out of DOS ANSI.SYS including keyboard redefinition.

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Engineering Staff—Washington Office
Attn: D.J. Carroll, Editor
M.J. Baggett, Editorial Assistant
P.O. Box 2417—Washington, D.C. 20013

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