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1991 Engineering Field Notes Article Award Winners

We would like to thank everyone who took the time to fill out and send in a rating sheet. We realize that there was a very short turnaround time offered, so your vote was really appreciated.

We would also like to acknowledge everyone who made the effort to write and submit an article. Your colleagues in the field also appreciate your efforts. According to the comments received, *Engineering Field Notes* articles are saving the Forest Service time and resources. Now it's time to announce the top three *Engineering Field Notes* articles for 1991:

Article	Author
Why Weight, Rate, and Calculate Decisionmaking Is Unsound—A Challenge to the "Rational Method"	Lee Collett Washington Office
Using GPS in Fire Fighting on the Shorts Fire (Okefenokee Swamp Fire)	Douglas Luepke, Region 8 Regional Office
Precautions for the Removal of Vinyl Asbestos Floor Tile	Joe Meadows, Region 8 Daniel Boone National Forest

Congratulations! Due to the number of the excellent articles submitted this year, it was a close race.

In order for *Engineering Field Notes* to continue to be a valuable resource to personnel in the field, it is important that we continue to receive such relevant articles. Can you think of a project on which you worked, a workshop you attended, or other information that may be of value Service-wide? If so, send in an article. Next year you may be selected as the author of one of the top *Engineering Field Notes* articles of the year.

Integration of Remote Sensing into Resource Data Collection: An Overview

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Abstract

Remote sensing is an integral part of Forest Service information management, providing input for forest-wide and other Geographic Information System (GIS) data bases. The Integration of Remote Sensing (IRS) program was established by the Deputy Chief for National Forest System and Deputy Chief for Administration to provide guidance for integrating remote sensing technologies into resource data collection and GIS in the Forest Service. Guidance and partial funding for this program are provided by the Remote Sensing Steering Committee, chaired by Timber Management. Main activities include development and demonstration projects with field units, developing guidelines for users, and awareness and training. Remote sensing is a source of current and repeatable information on the location, quantity, and quality of land cover and other resource variables, with emphasis on vegetation. It allows change detection and monitoring of resource base over time. The primary use of data layers derived from remote sensing is in forest plan development, implementation, and monitoring; ecological mapping; and related activities. Resource managers will have access to the layers derived from remote sensing through GIS technology.

Introduction

The Forest Service has defined a strategy for moving into a new integrated information environment (USDA Forest Service 1992). Project 615, which is part of this strategy, will provide us with GIS hardware and software. GIS—a tool to store, analyze, and present information about land resources—will help us to analyze complex resource issues and with day-to-day management. Data to support these activities are stored in digital data bases. A sizable portion of data comes from a variety of remote sensing technologies. Plans are to place the GIS capability on virtually every national forest ranger district and research laboratory in the near future.

The IRS program was established in 1990 by National Forest System and Administration (USDA Forest Service 1990). It is one of three segments of the Washington Office Engineering—Nationwide Forestry Applications Program (NFAP) located in Salt Lake City, Utah. The 5-year Implementation Plan for Integration of Remote Sensing indicates that the remote sensing and the GIS technologies are complementary and that both will serve land managers in a variety of functions. The main objective of the program is to integrate various remote sensing technologies into resource data collection within the framework of GIS.

Remote Sensing and Geographic Information System

The Forest Service considers remote sensing an integral part of information management, providing input for forest-wide and other data bases. It is an important source for "land cover" information, especially the vegetation layer for GIS. The primary uses of data layers derived from remote sensing are for forest plan development, implementation, and monitoring; ecological mapping; and related activities. We see its use in all phases of resource management, analysis, National Environmental Protection Act (NEPA) documentation, public presentations, and a variety of other areas.

A GIS data base should contain all the basic information layers that are needed to perform these functions. By definition, "basic" refers to those layers that are most common or important to many applications. Basic layers include topography, ownership boundaries, vegetation, transportation, hydrography, and others. Other layers, referred to as "derived," serve more specific functions. These layers may include wildlife habitat units or old growth areas and are usually generated from basic layers or other sources through analysis or modeling.

Remotely sensed data include aerial photographs and imagery/data gathered by various spaceborne and airborne devices, such as multispectral scanners, navigation or positioning systems, and video cameras. The process of using GIS and remote sensing technologies is shown in figure 1. The GIS and image analysis functions are shown as a combined capability. This means that GIS treats remote sensing/image analysis as an important data source and that analysis of remotely sensed imagery requires access to layers stored in the GIS. The new layers, such as vegetation, will in turn be stored in the GIS data base.

Why is remote sensing an important source of data for GIS? Most data are already in digital format or can be easily digitized. Satellite imagery gives us a view of very large areas and has the locational precision and spatial resolution to satisfy many mapping requirements. In many cases, satellite imagery cannot be used without the closer view that we get from aerial photographs, video cameras, and field surveys. The navigation systems, such as the Global Positioning System (GPS), help us to find out where we are or how to get there. Any of these data sources are valuable on their own; however, proper combination of sources produces best results.

Project 615 will provide us with the GIS technology. The next step is to ensure that we have proper tools and methods to make use of the variety of remote sensing technologies.

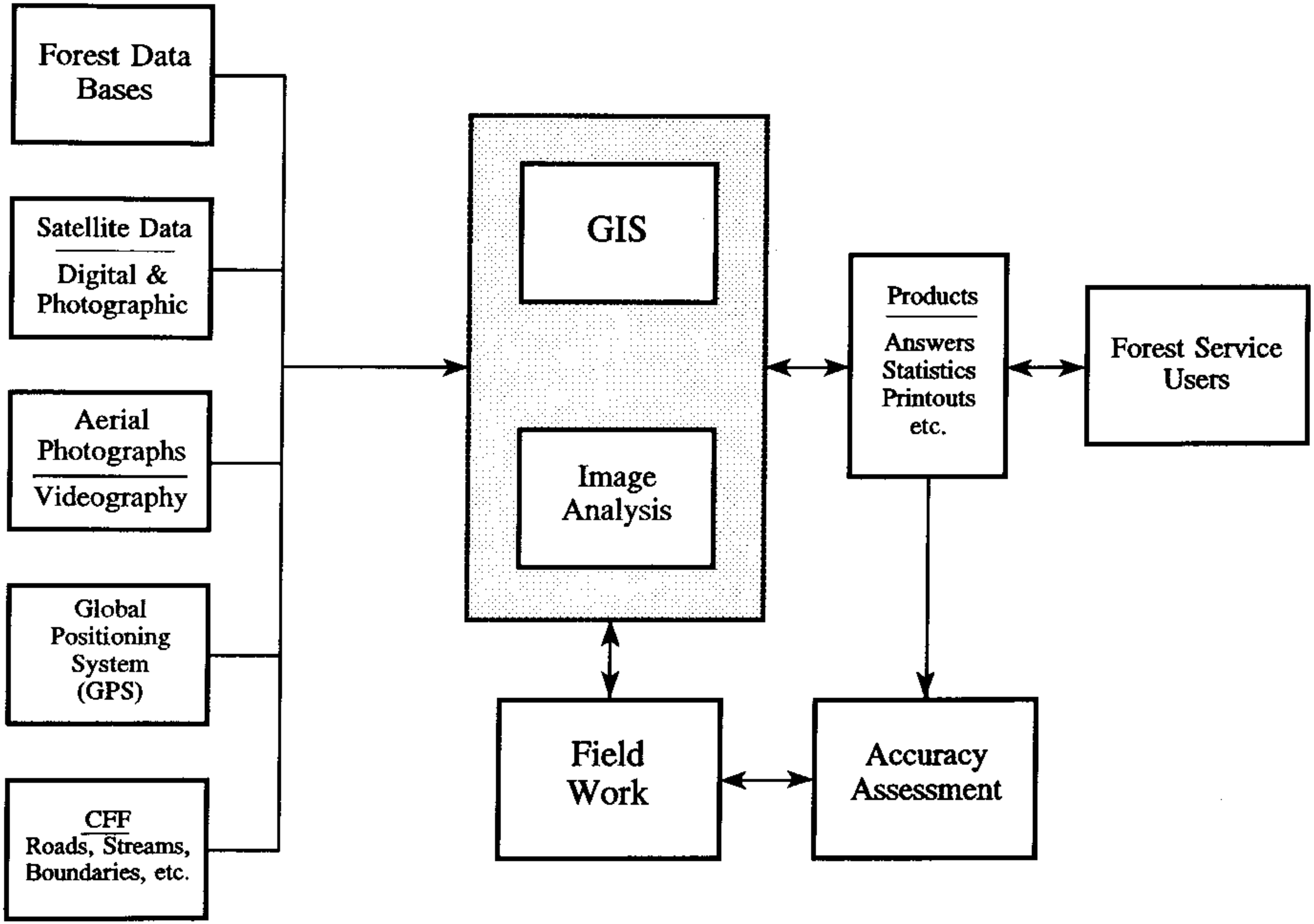

Figure 1.—Analysis of Remotely Sensed Data: "How to get From Pixels to Answers."

The IRS Program

The Remote Sensing Steering Committee, currently chaired by Doug MacCleery, Assistant Director of Timber Management, provides overall guidance to this program. NFAP provides the technical expertise and facility in conjunction with the Geometronics Service Center.

The IRS program has the following objectives:

- Provide awareness of values of remote sensing to Forest Service resource managers.

- Test and demonstrate techniques and efficiencies of using remote sensing to derive "vegetation" layer and incorporate into GIS data bases.

- Develop guidelines for implementation of remote sensing and disseminate information to Forest Service units.

Development and Demonstration Projects. The most visible activity of the IRS program is a set of development and demonstration projects conducted with national forests and other Forest Service units. These projects address major Forest Service issues as defined by the steering committee. Several projects are summarized in this paper.

Guidelines. Another important activity is the preparation of guidelines for users of remote sensing and others interested in these technologies. The following topics or studies are included:

- Role of remote sensing in GIS structure.

- Checklist for users of remote sensing data.

- Data storage needs for remotely sensed digital data.

- Skill requirements.

Work on some of these topics is done by the Remote Sensing Task Group, which is comprised of volunteer Forest Service resource and technical specialists. Reports are distributed throughout the Forest Service.

Awareness and Training. Finally, the most important part is the people and their skills. The objective is to provide awareness of these technologies and training to Forest Service employees. This is done through a variety of outlets, such as publications, briefings to resource managers, short training sessions, and on-the-job training. Some of these activities are part of development and demonstration projects.

What Remote Sensing Tools Do We Use?

The following is a short description of some of the remote sensing tools being used by the Forest Service. Many of these are finding an ever-widening use. This obviously is not a complete listing of remote sensing technologies.

Aerial Photographs. Aerial photographs have been in use in the Forest Service since the 1930's. They provide an important historical perspective of our forests and are indispensable for a variety of assessments and mapping tasks (Greer 1990). Information from photographs can now be digitized directly into a GIS data base with the use of an analytical stereoplotter (Bobbe 1992).

Airborne Video. Video has existed since the beginning of television. Recent applications from airborne platforms have provided a powerful tool for resource managers. A video camera can be mounted in a small airplane, and imagery can be viewed as soon as the flight is complete. Video imagery linked with GPS can provide locational information for each frame, allowing the user to quickly find specific areas on maps or images (Bobbe 1991).

Satellite Scanners. We currently use data from two satellites: LANDSAT and SPOT (a French satellite). We are also making considerable use of AVHRR for fuel mapping over large areas and for forest mapping across the United States. Data from these satellites, once geocoded and terrain-corrected, can be input into GIS in two forms: first, as an image backdrop for display with other layers (similar to putting a transparent overlay onto an aerial photograph); second (and more widely used) to classify digital data into land cover (vegetation) classes and store the results in raster and/or polygon format. These layers can then be used for a variety of applications, such as modeling. Digital satellite imagery has been used for large area forest assessment, detection of change (Sader 1988), and statewide inventories (Winterberger 1988).

Positioning Systems. The navigation and positioning systems are generally not considered to be remote sensing systems; in our work, however, they are very important tools for data collection. The GPS is a widely used satellite-based system that gives one's location in terms of latitude, longitude, and elevation. The accuracy of GPS ranges from "geodetic quality" (within centimeters of true location) to "resource quality" (within meters), depending on the quality of receivers and collection methods used (Smith 1991). The system can be used to trace features directly on the ground, such as roads, trails, fire damage, and other point, line, or area features. This is done by placing a receiver antenna at an unknown location or walking, driving, or flying along a road, trail, boundary, or other feature. GPS data points can be input directly into a GIS as an additional data layer.

Examples of Integration of Remote Sensing into GIS

The Forest Service has a number of field applications where remote sensing data have been integrated into GIS (Bain 1991). In most of these applications, satellite data serve as a source for "vegetation" layers. This, in addition to other layers, can serve the typical national forest in an endless number of ways.

The following examples of integrating remote sensing into resource data collection and GIS illustrate a cross section of current requirements. Monitoring of forest plans, vegetation mapping and old growth modeling, and vegetation mapping/monitoring on rangelands are a few of the areas where spatial information and analysis have become important.

Monitoring Forest Plans. Forest land and resource management plans require periodic assessment of current conditions against what was defined in the plans' standards and guidelines (S&G). The Mark Twain National Forest, located in southern Missouri, used two LANDSAT thematic mapper (TM) images (acquired in 1982 and 1989) to detect land cover changes over the 7-year period and to compare them to the plan's S&G. The changes detected with LANDSAT were field verified (about 84 percent accuracy) and stored in a GIS. This, along with management areas and ownership boundaries, allowed monitoring of selected S&G's related to certain vegetation conditions. This process proved to be a very efficient and economical method of forest plan monitoring and acquiring data for GIS (Platt 1992 and Maus 1992).

Vegetation Mapping and Old Growth Modeling. The location and quantity of old growth forests, in conjunction with threatened and endangered species, is a very important management issue. The Southwestern Region used vegetation layers derived from LANDSAT TM and existing ecological data to model old growth on the Santa Fe National Forest (Gonzales 1992). The procedures are similar to those developed in the Pacific Northwest Region (Teply 1990). Three vegetation related layers were derived with the following accuracies: crown closure (four classes), 82 percent accuracy; vegetation cover (nine types), 77 percent accuracy; and tree size (five classes), 76 percent accuracy.

These vegetation layers, along with other GIS data layers, have a multitude of applications for management of natural resources; old growth mapping is just one of them. The derived vegetation information is current, consistently and economically produced, and has a known accuracy.

Range Allotment Mapping/Monitoring. Remote sensing provides range managers a way to extrapolate field sampling over large land areas, and GIS provides for spatial analysis and customized mapping of the stored data. The Southwestern Region utilized airborne video tied to GPS locational information to identify unique vegetation types for mapping with LANDSAT TM (USDA Forest Service 1992). A video camera mounted in an aircraft and linked with GPS provided several hours of "ground" information at various swath widths (zoom factors) ranging from 60 to 1,000 feet. This was patterned after the technology developed by Forest Pest Management (Myhre 1991). The GPS locational information allowed the range conservationists to identify the video images on maps and on georeferenced LANDSAT imagery. A computer-assisted classification of LANDSAT imagery was done for several allotments. This provided range managers with current information in a digital format and focused their more costly field data collection process on specific problem areas.

A combination of remote sensing and GIS provides important tools for range managers. Data derived from various remote sensing sources and stored in a GIS help to determine suitable and unsuitable lands for livestock grazing, derive habitat types, and identify potential range structural improvements and pasture management alternatives.

Conclusions

We have come a long way in the past few years in our use of remote sensing. We now routinely integrate various remotely sensed data into GIS data bases; however, we have just begun exploring all the possible uses of these technologies. The needs of today's resource managers call for more current and consistent information, ranging from small management areas to areas spanning entire national forests and encompassing non-Forest Service lands. The proper combination of technologies should enable us to collect and utilize data for multiresource use in a cost-effective manner.

The most important, and often neglected, part of this new technology equation is the person that makes the whole thing happen. A shortage of people familiar with this technology may hamper wide and quick implementation in the Forest Service. This will require a considerable amount of technology transfer and training throughout the organization.

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Sader, S., *Remote Sensing Investigations of Forest Biomass and Change Detection*, Satellite Imageries for Forest Inventory and Monitoring Proceedings, IUFRO 4.02.05, Hyytiala, Finland, 1988.

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Checklist for Users of Remote Sensing Data

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Introduction

The use of remote sensing for mapping and assessment of land and associated resources has increased dramatically with improvements in sensors, hardware, and software. Digital satellite data have become an important tool for resource managers for creating information layers for geographic information systems (GIS's); however, the effective use of remote sensing requires a very thorough and systematic approach to ensure quality results.

This checklist has been developed as part of the Integration of Remote Sensing (IRS) program, conducted by the National Forestry Applications Program (NFAP), under the direction of the Remote Sensing Steering Committee. The objective is to assist those undertaking remote sensing projects to cover all important items. The checklist is generally in sequential order for activities that occur in a remote sensing project and, as such, provides a roadmap for those activities. Users are encouraged to chart out activities, because many are concurrent, and careful planning is essential for timely completion of projects. Although the checklist is oriented toward digital remote sensing data use, most of the items apply to all forms of remote sensing.

Technical questions concerning remote sensing will be addressed in a revision of Aldrich (1979). This reference and other selected references about remote sensing follow the outline.

Checklist

A. Technology Assessment

(1) Define information needs and time, personnel, and cost constraints.

(2) Decide whether remote sensing is appropriate to meet project requirements. Determine if data is available or whether remote sensing data can be obtained in time to meet need.

(3) Evaluate alternative remote sensing methods, including aerial photography, digital imagery, video, radar, etc.

(4) Consider spatial resolution, spectral resolution, and temporal data availability.

(5) Make literature review; consult knowledgeable sources and other similar activities. Involve the organization remote sensing and GIS coordinators for advice and coordination throughout project. (See remote sensing coordinators list.)

(6) Determine if staffing and skills are available to accomplish work and whether training is available where and when needed. Consider equipment and software availability and needs.

B. Management Approval

(1) Organize information collected and develop outline for the project. Discuss informally with staff to refine ideas.

(2) Prepare briefing for management and staff. Include written proposal for project. Visit project site if appropriate.

(3) Obtain management endorsement, including staffing, funding, and timelines.

(4) Keep management and staff informed throughout project through reports, briefings, and field trips.

C. Project Plan

(1) Clearly define organizational unit purpose and objectives for the project. Involve managers and staff in the planning process.

(2) Define available resources, including personnel, equipment, software, data acquisition, and outside assistance.

(3) Define project objectives and products, including classification schemes, data base outline, data longevity, ultimate product use, hardcopy output needs, and publications.

(4) Define methodology, including hardware and software, in general and in detail. Include responsibilities, steps, Pert chart for operations, and allocation of resources over time frame. Identify potential bottlenecks.

(5) Establish project schedule.

(6) Devise methods for tracking costs for cost/benefit analysis.

(7) Obtain final staff review, followed by management approval of plan.

D. Definitions and Standards

(1) Follow applicable GIS data standards. (See reference list.) Specify relevant remote sensing and other standards and definitions.

(2) Follow resource inventory standards. (See reference list.)

(3) Follow technical standards for resources involved. Consult with appropriate resource specialists. Check information needs assessments.

(4) Use interchangeable data base format.

E. Sampling Design

(1) Select overall sampling design and rules. Specify design for each data set, remote sensing operations, aerial photo operations, and field operations. If data will be used for change detection in future, consider requirements in design.

(2) Identify resource components that need to be sampled. Identify data needed at various levels, subsampling, and mappable and unmappable attributes. Consider information needed versus data that can be obtained using remote sensing technology.

(3) Define allowable error and computational process.

(4) Define ground truth field instructions. Provide for training.

(5) Consider modeling approach for some attributes. Define field data needed to support modeling.

(6) Consolidate field work. For example, collect training site and assessment data during field operations, but do not use the same sites for both purposes.

F. Data Sources

(1) Identify data sources, i.e., LANDSAT, SPOT, AVHRR, NHAP, or NAPP photography or other remote sensing data source. Consider existing data versus purchase. Consider coop data use or funding. Evaluate temporal (season and year) and phenology (growth stage) requirements, etc.

(2) Identify available field data. Assess positional accuracy, reliability, and applicability and definitions used.

(3) Assess supporting map data, such as cartographic feature files (CFF's). Consider scale, reliability, and definitions. Consider importing data from other sources, such as Defense Mapping Agency (DMA) topographic data files or digital elevation models (DEM's). Determine ownership and political and administrative boundaries.

G. Data Assessment

(1) Spatial and spectral resolution: Evaluate in relation to needs. For example, spatial (positional) accuracy is critical for change detection.

(2) Analyze spectral data responses. Use to identify bands, combinations, and transforms appropriate for attributes of interest.

H. Preprocessing

(1) Atmospheric correction: Purchase data corrected or correct in-house. LANDSAT and SPOT data are sold corrected.

(2) Geometric correction: This is essential for most purposes. Purchase data corrected or correct in-house.

(3) Terrain correction: This is desirable in mountainous areas. Purchase data corrected or correct in-house.

(4) Minimize resampling. Resampling degrades image quality. Purchase of data with preprocessing minimizes resampling. Resample to fit other data when necessary. Resampling to smaller unit does not increase resolution.

(5) Data overlays: If two data sets are to be overlaid (compared), purchase data without geometric or terrain correction, so both sets can be processed with the same control data.

I. Alternative Classification Methods

(1) Supervised: Define training sets needed. Establish consistency between satellite data, photo data, and ground measurements.

(2) Unsupervised: Define parameters for classes and number of classes. Establish method for labeling.

(3) Guided clustering: This is a combination of supervised and unsupervised classification, using information from data histograms. Supervised and unsupervised classification may be mixed, depending upon the attribute of interest; guided clustering may be the best alternative, but requires more time and effort.

J. Classification Processes

(1) Use ancillary data. Supplemental information aids classifications. Consider elevation, slope, aspect, vegetation range maps, and available data.

(2) Iterative classification: Schedule as a required process. Use to incorporate field data for verification and mask out cumulative acceptable classes. Use to reclassify if necessary.

(3) Postprocessing, aggregation: Consider polygon size, minimum area definitions, and final data format needed. Define technique for polygon creation after all classification steps are completed.

K. Product Assessment

(1) Field data collection: Establish methods for both field training sites and accuracy assessment sites.

(2) Accuracy assessment: Specify standards, process, and sampling procedure for error matrix. Assessment may be by polygon or pixel (point).

(3) Sampling errors: Must be able to compute sampling errors and confidence levels. Requires followthrough of original design.

(4) Confidence level: Ensure that methods are statistically sound. Use a statistical data base for analysis if available.

L. Data Compilation

(1) Products and formats: Format remote sensing outputs as inputs into statistical design data analysis. Format data for retrieval and transferability.

(2) Procedures and software: Define processes and software to adequately compile data, using the appropriate design.

(3) Hardware: Must handle storage and computational requirements. Hardware should link all software to facilitate file transfer.

M. GIS Integration

(1) Topology (spatial relationship between polygons by lookup table): Ensure software capability to transfer data into GIS format. Include georeferencing, full topology, and attribute data.

(2) Raster/Vector: Identify where raster to vector transfer is needed, preserve full georeferencing and full topology, and provide for all attribute data.

(3) Attribute transfer: Identify attributes to be transferred.

N. Project Documentation

(1) Map and image products: Define early in project because of cost and preparation time. Design scale and format.

(2) Final report: Summarize project and describe results. Include positive and negative results. Include reference to documentation and recommendations for future work.

(3) Publications: Define audience and publication outlet. Make outline, and then fill in details. Include references. Get internal and external review.

(4) Product documentation: Carefully label all materials. Describe all data formats by variable. Obtain secure storage. Provide for reuse if appropriate.

(5) Archive data: Deposit with documentation if appropriate.

O. Technology Transfer

(1) Provide for technology transfer and training needed to transfer results and continue work if necessary. Consider papers or posters as well as formal publications. Slide shows and videos work well for presentations and training.

(2) Distribute publications or other products as appropriate.

Selected References

Accessing the World Proceedings, Vols. I and II, GIS/LIS '88, American Society for Photogrammetry and Remote Sensing, 1988.

Selected topics: Data base design and development, cartography, image integration, emerging technologies, project management, and software/hardware.

Aldrich, R.C., *Remote Sensing of Wildland Resources: A State-of-the-Art Review*, USDA Forest Service General Technical Report RM-71, 1979.

Selected topics: Terminology review, scale considerations, systems, interpretation and mapping, resource measurement, cost considerations, and future systems.

Colwell, R.N., Ed.-in-Chief, *Manual of Remote Sensing*, Second Ed., Vols. I and II, American Society for Photogrammetry and Remote Sensing, 1983.

Selected topics: Principles of remote sensing, electromagnetic spectrum, photographic and non-photographic systems, GIS, image processing techniques, applications, forestry, wildlife, and rangeland assessments.

Draft Service-wide Standard Terms and Definitions for Resource Data, USDA Forest Service, 1990.

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Selected topics: Type mapping, surveillance, damage assessment, and multispectral video.

Greer, J.D., Ed., *Remote Sensing for Resource Inventory, Planning and Monitoring*, American Society for Photogrammetry and Remote Sensing, 1988.

Selected topics: Remote sensing in the Forest Service; SPOT, TM, and other sensors; GIS; and applications.

Interim Resource Inventory Glossary, USDA Forest Service, 1989.

Johannsen, C. J., and J. L. Sanders, Eds., *Remote Sensing for Resource Management*, Soil Conservation Society of America, 1982.

Selected topics: Information organization, GIS data quality, multiresource inventories, mapping, verification, forest, soils, watershed analysis, industry applications, national inventories.

Paine, D. P., *Aerial Photography and Image Interpretation for Resource Management*, John Wiley and Sons, 1981.

Selected topics: Characteristics of aerial photos, stereo interpretation, mission planning, measurements, mapping, landform analysis, forestry applications, recreation, sampling techniques, photo-mensuration and timber cruising, and non-photographic systems.

Renewable Resources Management: Applications of Remote Sensing, American Society for Photogrammetry and Remote Sensing, 1983.

Selected topics: Approaches to remote sensing of resources, LANDSAT uses, environmental monitoring, damage assessments, legal considerations, and water resources.

Second Annual International Conference, Exhibits, and Workshops on Geographic Information Systems, Vols. I and II, GIS '87, American Society for Photogrammetry and Remote Sensing, 1987.

Selected topics: Value of GIS, funding systems, GIS selection, data integration, and GIS for resource management/ planning.

Journals

Cartography and Geographic Information Systems, American Congress on Surveying and Mapping.

GIS World, GIS World, Inc.

Photogrammetric Engineering and Remote Sensing, American Society for Photogrammetry and Remote Sensing.

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Data Storage Needs for Remotely Sensed Digital Data

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Background

Remotely sensed data in digital format are being used increasingly throughout the Forest Service to create, expand, and update spatial data bases, most commonly within the framework of geographic information systems (GIS's). Current examples include using LANDSAT and SPOT satellite data to map forest vegetation in the Pacific Northwest, mapping pest outbreaks in the Intermountain Region from airborne video data, and using AVHRR data to conduct FIA studies in the Southern Region. As the use of digital data expands, there will be a corresponding need for adequate data storage and manipulation capacities.

This paper is intended to provide the reader with very basic information concerning the amount of on-line and off-line data storage that will be needed as the Forest Service moves toward the use of remotely sensed digital data. The storage needs apply to remote sensing and to ancillary data needed in the analysis process. The study was part of the Integration of Remote Sensing (IRS) Program with participation of members of the Remote Sensing Task Group.

Storage Needs

Data Files

Table 1 lists file sizes for the digital data most commonly available within the Forest Service for an average 7.5-foot quad. As the numbers in the table demonstrate, data resolution directly determines file size for a given area of coverage. As spatial resolution (pixel size) and spectral resolution (number of bands, bits per pixel) increase, file size increases dramatically. This information was derived from projects conducted by the Forest Service and others dealing with management of natural resources.

Table 1.—File Sizes of Various Digital Data for a Typical USFS/USGS 7.5-Foot Quad

Data Source	Data Type	Pixel Size	File Size (Mb)
FS CFF Primary Base Layers	GSC vector format	N/A	0.8-1.20
FS/GS Digital	16-bit raster	30 m	0.40
Elevation Model (DEM)	16-bit raster	25 m	0.50
LANDSAT Multi-Spectral Scanner (MSS), 4 bands	8-bit raster	80 m	0.10
LANDSAT Thematic Mapper	8-bit raster	30 m	1.25
(TM), 7 bands	8-bit raster	25 m	1.75
SPOT Panchromatic, 1 band	8-bit raster	10 m	1.60
Generic Resource Layer	4-bit raster	10 m	0.80
(Derived from Any Above)	4-bit raster	25 m	0.12
	8-bit raster	10 m	1.60
	8-bit raster	25 m	0.25
	16-bit raster	10 m	3.20
	16-bit raster	25 m	0.50
Scanned Aerial Photographs			
Black and White, 1 band	8-bit raster	5 m	6.40
Color/CIR, 3 bands	8-bit raster	5 m	19.20
Black and White, 1 band	8-bit raster	2 m	40.00
Color/CIR, 3 bands	8-bit raster	2 m	120.00

Using the above general file sizes, we can estimate the size of a purely hypothetical set of data for a 7.5-foot quad at "Medium" and "Higher" resolution to be:

Medium Resolution Dataset (25 m pixels):

Primary Layers from CFF	1.00
DEM model @ 25 m, 16-bit	0.50
LANDSAT TM data @ 25 m, 8-bit	1.75
10 Resource Layers @ 25 m, 8-bit	2.50
10 Resource Layers @ 25 m, 4-bit	1.25
Storage Total	7.00 Mb/quad

Higher Resolution Dataset (10 m pixels):

Primary Layers from CFF	1.00
DEM model @ 10 m, 16-bit	3.20
SPOT Pan. data @ 10 m, 8-bit	1.60
10 Resource Layers @ 10 m, 8-bit	16.00
10 Resource Layers @ 10 m, 4-bit	8.00
Storage Total	29.80 Mb/quad

Data storage requirements for a hypothetical 30-quad study area containing the data layers would thus be in the range of 210 to 900 megabytes depending on the data resolution desired. From our experience we know that users produce a variety of intermediate and final resource layers, partly based on remote sensing data, during the course of a typical project.

Data Analysis

In order to efficiently analyze and manipulate this data, a system will need large amounts of space for intermediate files, temporary files, plot files, etc. Depending on the software system being used, the amount of temporary storage space needed for analysis may be 5 to 15 times the size of the data to be analyzed.

At this point, it is appropriate to discuss on-line and off-line data storage. On-line storage is directly accessible by the computer and is typically read/write capable. Hard drives and some optical disk drives are examples. Off-line storage is not directly accessible by the computer and must be transferred to an on-line device for further processing. Floppies, reel tapes, and cartridge tapes are typical off-line storage mediums.

Traditionally, off-line devices are used for data archiving and transfer of data from one system to another, while only the data to be analyzed, along with space for the analysis, resides on the on-line storage devices. Fortunately, new technologies, specifically erasable optical drives, are blurring the distinction between on-line and off-line devices.

Recommendations

Having generally discussed data size, data analysis needs, and on-line and off-line devices, we can now offer the following guidelines for the reader's use when considering data storage needs for projects involving digital remotely sensed data:

- Provide adequate on-line storage for the completion of the largest feasible project that is envisioned. For example, if project data will take up 300 megabytes, and processing will consume five times that much space at certain steps in the analysis, then 1.8 to 2 gigabytes (@1024 megabytes per gigabyte) of available on-line storage space will be required.

- Keeping the above guideline in mind, be conservative when estimating needed on-line storage space. Include provisions for multiple copies of important files, system overhead, software, and uncertainty about a particular software package's storage methods, as well as space for the project data and its analysis.

- Provide for an efficient off-line storage system that allows data sets to be archived, reloaded, analyzed, and rearchived with a minimum of trouble. Optical drives and tape cartridges are well suited to this task.

- Recognize that on-line storage is a very versatile and valuable resource and will be used if available. While there is always a use for "excess" disk space, lack of adequate on-line storage can severely limit the timely completion of a project by complicating processing steps, by requiring constant attention to transfers to and from off-line data storage devices, and even by discouraging personnel from utilizing higher resolution data at the expense of precious disk space.

Networking Geometronics Style

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Computer Systems, GSC

The Geometronics Service Center (GSC) in Salt Lake City has successfully implemented a Local Area Network (LAN) to support its various missions, as well as the National Forestry Applications Program (NFAP) activities. During the design and implementation of the LAN, Computer Systems staff members were faced with many technical challenges and discovered that the development of an efficient network strategy is a complex process involving much more than basic connectivity issues. A proper design must include work process flow and data interaction requirements. Of paramount importance is the early and constant involvement of users from all levels within the organization: A network strategy developed in isolation from its potential users is doomed. This paper describes the design and implementation of a LAN at GSC; its primary purpose is to provide a historical perspective, or hindsight, for units preparing to enter the world of networking.

At GSC, each working unit was an island unto itself. The transfer of information, when it did occur, was essentially a hand-to-hand hard copy. Reiteration of data was the only way to use the information generated by another unit. This resulted in the development of redundant data bases generated by duplicated data collection efforts. This situation was not cost effective, and it failed to promote teamwork or user interest in overall processes. The emergence of the Automated Cartography (AC) unit introduced graphics workstations capable of creating mega files. The information created by access to workstation capabilities caused a clamor to share the digital mapping area's resources more efficiently.

Electronic file transfer between disparate units was by the ever popular "sneaker net," the creation of a file on one system which is downloaded to a nine-track tape and reloaded onto another system for the next value-added process. It was a frustrating chore that required too much time and excessive storage space to create, move, and regenerate data.

In addition, our Data General (DG) and DEC VAX Minicomputer terminals and printers were directly wired into the computers. There was no sharing of resources, and redundant hardware appeared and then multiplied. It was definitely a spaghetti nightmare—cabling snaked under floors, tossed through ceilings, and dragged across work areas. Here again, the computer systems were as distinct and separate as the work areas they supported.

During a preliminary inventory of network hardware, software, and operating systems, we developed a users' "wish list" which included all of the known user needs and desires. This summary included descriptive statements like, "I would like to be able to move files from the Stereo Plotter personal computers (PC's) without having to download them to a nine-track tape unit connected to the PC's and then having to reload the information back on the Data General for other processing." Or, "I would like to access general project information directly without having to rekey someone else's data base information into my data base in order to complete my reports."

By taking into account current needs and processes, trying to envision where the GSC will be headed during the next 5 to 10 years, and carefully analyzing the emerging commercial networking environments, our systems analyst proposed and then implemented an ethernet environment.

A LAN is, by nature, a very complex entity; it is imperative to document all phases of the design and implementation activities. After we documented the proposed cabling plant (jargon for where the cable is laid down and what type it is), workstation placement, LAN connection types, and both ethernet and internet addresses for each piece of equipment, we eliminated the potential conflicts which might occur during any subsequent enhancements to the LAN. Additionally, we keep a problem log for each piece of equipment which describe patterns of repair. This allows us to plan preventive maintenance procedures to ward off major catastrophes.

Ethernet was selected for its design flexibility and expandability. Two broadband backbone cables were installed: one large segment encircled GSC, while the second, smaller segment was confined to the AC unit to accommodate direct connections between Intergraph workstations and the DEC VAX minicomputer. Transmissions travel in digital form over a single transmission channel between machines connected by coaxial or twisted pair cable. Each message travels as a "packet" that contains both data and information about the source and destination machines.

The AC segment was established as a distinct entity. The large segment was enhanced with Bridge (later 3COM) Corporation's CS100 terminal servers, as well as with CS1 servers for consolidation of printer and terminal server functions. The CS100 terminal servers were connected to the backbone through 3COM transceivers attached with "vampire" taps; this type of tap allows connection to the main cable without creating a break in the backbone cable continuity.

One of the advantages of this first level of connectivity was the redistribution of printers throughout the building. Prior to the LAN implementation, printers were concentrated for easier connection to the minicomputers, and users had to walk half way across the building to retrieve a printout. By connecting the devices to the CS100 terminal servers, the printers were located where they were most beneficial to the users.

At this time, PC's were beginning to be included in the overall computing plan. Some of the users wanted Comprehensive Electronic Office (CEO) access to the DG's to avoid the need to search for an available DG terminal.

Many packages were tested, and we ultimately selected Communications Research Group's Blast product, an asynchronous communication package which allows terminal emulation and file transfer capabilities between DG and PC through RS-232 serial cable connections. This package allows basic file transfer of text and binary types between the PC's and the DG minicomputer; however, the excessive time it takes for file transfer through this asynchronous connection was unsatisfactory. Large files, a megabyte or more in size, are not uncommon in the mapping process, and to transfer even a half megabyte file often took 30 minutes or more using the asynchronous method. We were committed to utilizing a product that would allow us to take advantage of the 10 megabytes per seconds (mps) that the ethernet backbone would support.

After serious research and evaluation, we settled on the Transmission Control Protocol/Internet Protocol (TCP/IP) as the basis of our system integration plan. This protocol enables processes running on diverse platforms to exchange data at LAN speeds. As we planned the continued integration of our resources, we identified three primary goals:

- Allowing center-wide seamless access to the consolidated resources on the network from any network member. Transparent access allows the users to access any resource from any system without having to know where the resource is located.

- Providing PC users with access to a server environment in order to cost-effectively consolidate PC software and peripheral needs.

- Utilizing terminal emulation software that takes advantage of LAN speeds.

When we first implemented the LAN, users were disgruntled; they were required to learn new skills and to develop confidence with a nearly transparent technology. Once the users discovered the benefits of 10 mps data transfer, they demanded more connectivity, and we found that the user community was a driving force in the development and initiation of higher levels of network implementation.

The separation of the two GSC ethernet backbones became a hindrance to greater productivity. We installed a 3COM Corporation IB2 Bridge between the two backbones with single transceivers and thick ethernet cabling. This bridge opened the door to Service-wide connectivity for the AC segment of the center's LAN. By accessing the DG's mail and file transfer capabilities, information can be transmitted to regions, forests, and districts directly from the VAX environment.

The inclusion of PC workstations within the cartographic production loop was a double-edged sword; while the new devices effectively extended production capabilities, they amplified the problems associated with large data file transfer between distinct operating system platforms, as well as with terminal emulation, thereby severely escalating software costs. Initial implementation required that all operating systems provide TCP/IP drivers; the DG minicomputers use DG TCP/IP, the Santa Cruz Operation (SCO)

UNIX and Xenix PC Line Trace Plus (LTPlus) workstations run SCO TCP/IP, the VAX uses DEC TCP/IP with Network File Server (NFS) capabilities, while the DOS-based PC's run with 3COM's 3+ Open LAN Manager TCP/IP. (Some also offer SCO NFS in the UNIX partition as an additional connectivity resource.)

To fulfill our PC networking requirement, initially we chose 3COM's 3+ Open OS2 and LAN Manager software as our networking medium. The software runs on a 3COM 386-based 3/500 server with a 350-megabyte hard drive, a 250-megabyte tape drive, and 8 megabytes of Random Access Memory (RAM). Print services are provided by an HP Laserjet III connected to the server's parallel port. Users have access to software on the PC Server through 3COM's LAN Manager for workstations. We also chose as file transfer software 3COM's implementation of FTP (File Transfer Protocol), which is a user-loadable module running on TCP/IP. It unloads itself once the program is closed in order to reserve local memory resources.

At this point in our expansion, we realized that the number of PC's to be connected to the backbone outnumbered the possible connect points in one specific area of the building. On an ethernet backbone a transceiver may be placed only at specific intervals and no closer than 8 meters from another transceiver. To overcome this problem, we installed a 3COM Multiconnect Repeater. This device has the capability of driving 16 LAN subsegments. The Repeater requires a minimum of three internal cards to operate:

- A Network Interface Card (NIC) to connect to the ethernet backbone via an external transceiver and AUI cabling. AUI, previously referred to as a DIX connector, is thick transceiver cabling used to connect network resources with a drop cable and an external transceiver.
- A control card which routes the information to the segment NIC card.
- A segment NIC card.

Using this method, we saved an enormous amount of money. Thin ethernet cabling is less expensive and allows us to take advantage of the internal transceivers in the Etherlink II 503 NIC's installed in each PC workstation, rather than bypassing them and connecting the PC's with AUI cabling and external transceivers.

Upon installation of the first ethernet segment, we encountered several problems. The first problem was a lack of appropriate diagnostic tools to track down what turned out to be poor BNC cabling connections to the PC's in the segments. BNC is coaxial cable connector that locks when one connector is inserted into another and rotated 90 degrees. It is used with a NIC with an onboard or internal transceiver. Once the Multiconnect went on line, the five workstation segments crashed without any regularity. We would disconnect a workstation and then reconnect it, and the segment would come back up. After this happened numerous times, we finally removed all of the crimped BNC cable ends and replaced then with soldered ends. The problem never recurred. When installing two other segments, to support a total of 11 workstations, we used the same soldering method and encountered no problems.

While we were configuring the PC network, we encountered another obstacle: Users who were used to being autonomous were reluctant to relinquish some of their software or to learn a new process. This motivated us to develop another vision—helping others to see the resources they used as part of a whole system, rather than as an independent resource.

Another major problem in establishing the PC network was in determining the complexities and needs of the combined systems. Initially, we had some erroneous information that delayed implementation for several months. We were trained in the systems administration after struggling to set it up, rather than having the information beforehand. We also had to learn a new operating system, OS2, for administrative purposes.

Currently, the PC system works well as an overall component of the center's LAN. The development group recently tested SUN's NFS overlaying TCP/IP to allow a DOS workstation to access VAX files; however, the process is less than transparent. First, one must connect to an Intergraph workstation using NFS and remotely mount a VAX disk. Then, FTP overlaying TCP/IP must be activated to transfer the file. The Intergraph thinks the VAX disk belongs to it and allows the file transfer to the PC.

Once all the PC's were on line and file sharing became a simple task, other system users wanted more. They wanted to use DG laser printers, to share a four-color printer that is connected to a workstation, and to use the scanner. They wanted terminal emulation with the DG's without having two cables running from their workstations.

As we were trying to envision another LAN enhancement, 3COM, the vendor source of our LAN, informed the world that they were selling their portion of LAN Manager software to Microsoft, thereby eliminating our technical support. We were faced with finding other software. Microsoft is promoting the Windows environment, and the expansion of LAN Manager and OS2 seemed in peril. We decided to implement new, technically supported software. Novell, a leader in networking software, appears to cover all the bases we envisioned when the center's LAN was conceived, including seamless user access to all resources on the network, complete print server sharing capabilities from independent workstations, and file transfers between disparate operating systems.

Additionally, UNIX, OS2, DOS, and Windows environments will be handled with the help of Netware's loadable NFS server module and SUN NFS on the UNIX systems. Basic file transfer is still supported by FTP and the TCP/IP suite. Novell also supports our current hardware investments by offering a migration from 3+ Open software to Netware kit. If our hardware changes in the future, Novell will be able to expand its capabilities. Once again, we feel that we are on the way to a total system integration.

The greatest benefits of installing this LAN have not been limited to the process portion of the system. Although files move quickly and systems are less restrictive, it is the people who are working more closely together; their information is dynamically linked by Oracle data bases, and they are aware of their place in the process and the effect their work has on others. Teams have developed which seek greater integration of processes and quality.

The key to a successful LAN implementation is short- and long-term planning. We have reached our initial goal and continue to strive to reach yet another, keeping in mind that those we support will be using technology to its fullest and that we need to stay aware and flexible. We pride ourselves at the GSC in providing "consistently superior map products and services to all of our customers." The LAN has proven to be a powerful tool in seeking this objective. The vision that the Computer Systems Group shared when the LAN was in its conceptual form is still valid: To enable all users of any system to access, use, share, and integrate their information in the quickest, most efficient, and easiest manner possible with current technology.

Special acknowledgement goes to H.L. Martin from Region 6, who took time to edit this article, Jim Rapp and Jerry Greer for encouraging me to write it, and Billy Reed and Carl Fonnesbeck for their input and comments.

Why I Did It!

Wendy S. Bertrand
RA Region 5, Engineering Staff
FTS 465-1880

Because I wanted to see the big picture.

> *When someone new comes in*
> *You try to teach them what is automatic*
> *When it is not that easy*
> *You are forced to look at why*
> *Things are the way they are.*

I joined the Engineering Budget Shop in Region 5 last year. Learning the basic elements of the Forest Service funding requirements was a challenge, because the pieces of the puzzle were so similar and there was no picture on the front of the box. Designing and developing a set of funding cards helped me learn. I didn't want that effort lost; that is why I did it.

We all like to know that our work counts. With these cards I wanted to connect each individual's work to the management codes used on time sheets. After all, not too many people in Engineering come in each morning because they care about the management codes they need to use; they come in to accomplish something, be part of a team, resolve a problem, make a contribution by surveying, prepare a right-of-way case, design a bridge, or administer a contract under construction.

I started by trying to keep the variables straight and building a structure of their relationships. It was imperative to describe the work so the worker could understand it and link it to the funding structure of management, funding, and activity codes. Cards provided the nonlinear flexibility needed to tie these together. I didn't invent anything or change anything. What I did was bring together graphically in one deck of cards the information now in four places. (See title card for sources.) My goal was to create a way for those working with the Forest Roads Program to understand funding requirements.

This set of 36 cards is for just 1 program in engineering. The activity codes in this program increased or changed by almost 50 percent in 1991 per the Washington Office file letter 2400/6500/7720 of July 11, 1991 (Timber Sale Program Information Reporting System [TSPIRS] Changes).

Realizing that people in the organization, from the district to the Washington Office, would be more or less interested in different aspects of the funding cards depending on the work for which they are responsible, I designed them so they could easily use only the parts they found useful, i.e., technicians might focus on a few cards with their names on them along with the forest's management code, while budget analysts might use the entire deck in setting up management codes and checking appropriate funding codes and units, and forest engineers might use the cards while reviewing reports, planning budgets, or explaining to subordinates why they need to follow the charge-as-worked policy. The cards can also be used as a training tool, a reference device, or a mechanism to introduce changes in the program.

Innovation is powerful. Why it is so rarely used is amazing. I share this deck of funding cards with you as I did with about 100 Recreation and Engineering employees attending the Facilities Academy Workshop on Program and Budget during February of this year in Region 5. You may be able to use it, or it may trigger an idea applicable to your work or perhaps inspire you to implement an idea you have incubating.

Workers and managers in the Forest Service, as in other work settings, are being asked to adapt to uncertain situations, changing directions, new technologies, fresh perspectives, and public opinion. There is a cry for more accountability, flexibility, and diversity and less wastefulness. Absorbing, integrating, and digesting new information is surely an uneven process within the work force. Producing these cards, in spite of the outward wonder of my superiors, was driven by my philosophy that one of management's responsibilities is to continuously search for processes that facilitate quality work.

The graphics were done with Harvard Graphics 3.0 which I wanted to learn. This self-made assignment became my subject matter. Knowing the workshop was scheduled in February gave me the audience, the target date, and the funding. A colleague of mine, in charge of program management, was very experienced in this area. He became my sounding board, editor, and advisor. Without his knowledge and cooperation, I could not have learned what I did in such a short period of time. These cards went to print 6 months after I arrived from the San Francisco Navy Public Works center, at which I had been an Engineering Division Director.

During this 6 months, I saw examples of how easy it was to get the numbers mixed up. As one senior engineer said during the workshop, "I just take the number on the top of the list; there are just too many numbers for me to learn." The average worker who has his/her mind on other things sees very little payback in getting the numbers right. No red light blinks if you err. No bell rings if you are correct. Maybe my funding cards will bring a renewed awareness of the complexity of our management systems. We must keep records and be accountable for what we are doing, without getting tangled up on the way, or the accuracy we base decisions on will be questionable.

The funding cards' LEGEND and INSTRUCTIONS follow as they appear with each package of cards. The funding cards have been adapted to the format of this magazine. The actual cards are color coded blue for reconstruction and yellow for construction. I have extra sets; if you would like one, please request by DG: W. Bertrand, R05A.

Happy shuffling! Make accuracy fun!

Forest Roads Program

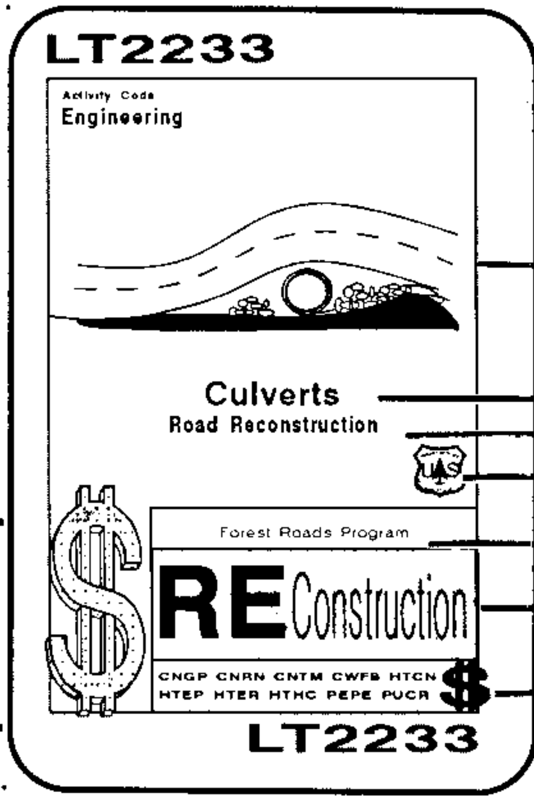
FUNDING CARDS

Legend

Instructions on back

FRONT

Activity Code for work
(Forest Service-wide)



Symbol of work

Type of effort

Description of work

Agency

Funding program

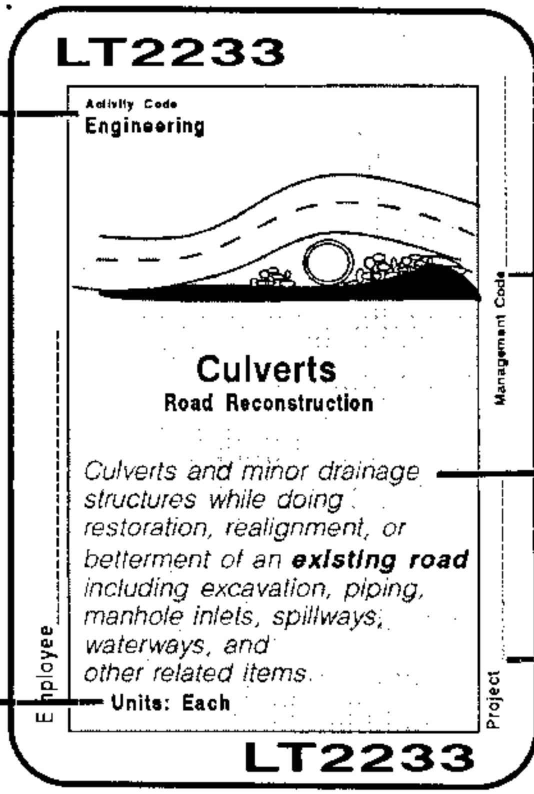
Funding Code Box:
(See Title Card for sources of information)

***Construction** (yellow)*
***Reconstruction** (blue)*

Funding code if dollars available
(Check your budget)

BACK

Staff doing work



Forests determine their own management codes
(They link to activity codes)

Activity Code definition

Project and employee names may be added
(Xerox card for individuals to personalize)

Units measured

Forest Roads Program

FUNDING CARDS

Instructions

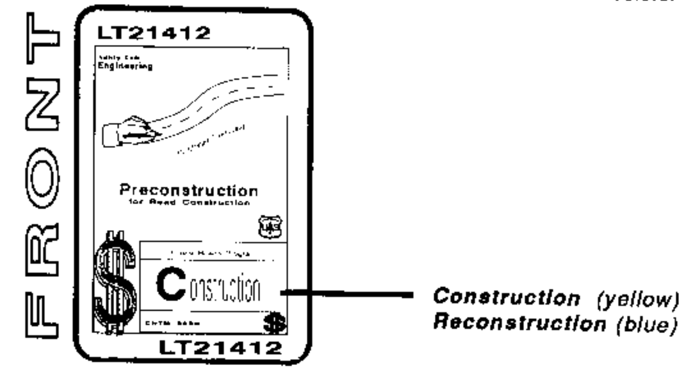
Legend on other side of this sheet

35 Activity Codes in this set

TITLE CARD
JL25
JL2511
JL2512
LT122
LT123
LT21411
LT21412
LT21413
LT21414
LT21415
LT21421
LT21422
LT21423
LT21424
LT21425
LT22111
LT22112
LT22113
LT22114
LT22121
LT22122
LT22123
LT22124
LT2221
LT2222
LT2223
LT2224
LT2231
LT2232
LT2233
LT2234
LT2731
LT2732
ML
PL132

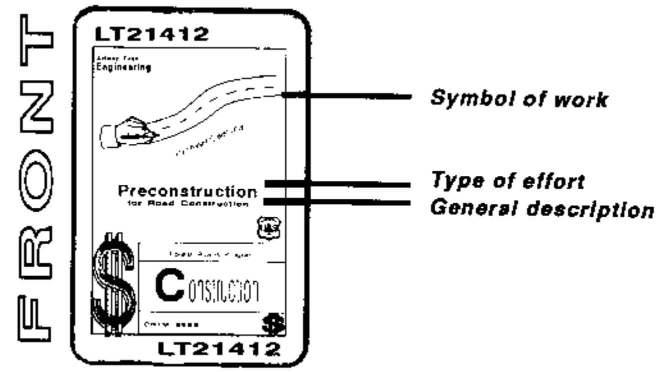
Step 1:

Separate cards by **color.** All the yellow, all the blue and those with both colors.



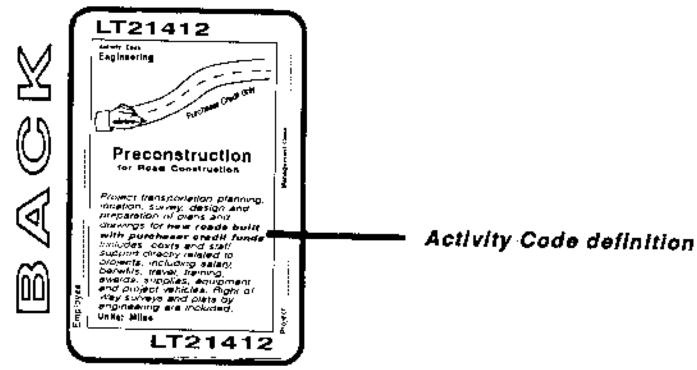
Step 2:

Using the cards with both colors and the color relating to your work, sort the cards by **type of effort** and then **symbol** of work. (For example there are six yellow preconstruction cards: three of them relate to roads only, one to roads and bridges and two to bridges.



Step 3:

Pick out the card you think describes best the work to be done then turn the card over to verify the **detailed description.**



Step 4:

Depending on your use, look for funding codes available on front of card or units measured on back.

Credits
Regional Engineer, Dick Deleissegues
Design and Development by Wendy Bertrand, R-5 Program Development
Encouragement from Gary Marple, WO Engineering Budget
Technical editing from Charlie Garrison, R-5 Program Management
Harvard Graphics introduction from Chuck Odorfer, Eldorado Nat Forest
Computer support from Burnhold Rankenburg
Feedback from Jeannie Duncan, AO Six Rivers Nat Forest and Carol Cooper, AO Modoc Nat Forest
Moral support from Jim Mandigo, R-5 Construction Engineering
Production support from Donna Del'Ano, R-5 Print Specialist

Joint Global Positioning System—Aerial Triangulation Project Final Project Report

Lee Whitmill
Geometrics Service Center

Phil Floor
Mapping Consultants, Inc.

In early September 1991, the USDA Forest Service, Geometronics Service Center (GSC), and Mapping Consultants (MAPCON), Inc., discussed the possibility of conducting a multiagency and private sector venture concerning the use of Global Positioning Systems (GPS's) to provide ground control for photogrammetric triangulation. On September 30, the parties involved with the proposal met and agreed to proceed with the proposed plan. On October 1, a letter of agreement was written and entered into by the Wasatch National Forest (WNF), GSC, and MAPCON. This agreement enumerated the areas of responsibility for the participants. The WNF would provide two GPS resource grade receivers and the post processing software. After this agreement was signed, the Bureau of Land Management (BLM) agreed to let us use their GPS resource grade receiver as well, thereby allowing us to have an additional unit in the field. The GSC would provide the transportation for the reconnaissance and data capturing portions of the project, as well as participate in the planning, data capturing, post processing, and written report aspects. MAPCON would supply the base station vehicle and antenna tripod, as well as participate in the planning, data capturing, mensuration, post processing, and final report aspects.

Geodetic information about the base station and other stations we were to occupy was gathered with the help of Salt Lake County (SLC), Davis County (DC), and the U.S. Geological Survey (USGS). Due to the possibility of impending bad weather, the preliminary planning, photo identification of likely points, field reconnaissance, and data capturing portion of the project was to be completed by October 11. The final report was to be completed and distributed to the parties outlined in the agreement.

The objectives of this joint venture were to:

- Use a low cost, simple-to-operate GPS system with easy post processing procedures to collect and apply the differentially corrected data within the photogrammetry process, and do so in a timely, cost-effective, and efficient manner.

- Compare the differences of the GPS with quad-derived control methods, while learning the GPS process at the same time.
- Promote a healthy mutual cooperation between several Federal agencies and the private sector.
- Show that the photogrammetric triangulation process could be made easier and faster by minimizing error propagation.
- Improve final triangulation accuracy so that the bridged photography can be utilized for, not only better orthophoto production but, other purposes such as the base for Geographic Information System (GIS) digitizing instead of tablet digitized quads, as well as to incorporate with larger scale projects.
- Evaluate other uses within the Federal and private sectors, such as cadastral or automated cartography.

The seven phases of the project were preliminary planning, field data collection, analytical photogrammetry mensuration, bundle adjustment, summary, conclusions, and report.

The project was divided into two different blocks (figure 1). The west block consisted of six quads just west of Grantsville, Utah, covering the Deseret Peak Wilderness within the Stansbury Mountain range and east of Skull Valley. The east block consisted of 14 quads covering most of the Salt Lake Valley from Draper to south Ogden and extending east as far as Midway. This area covered most of what is called the Wasatch Front Range of the WNF. The photography for this project was black and white, 9 x 9 inch format, 1:40,000 photo scale prints and diapositives, originating from color infra-red (IR).

Preliminary Planning and Field Data Collection

The preliminary planning phase was conducted by MAPCON and the GSC. The areas of access were determined from the photos and the Wasatch-Cache National Forest visitors map. Maps and blue lines from the county, showing section corners with surveyed values, were obtained. The USGS was contacted about the locations of first and second order control networks on the north and south limits of the project, as we wanted to occupy these stations if possible. Access to the compound, to our main base station "YARD," was obtained from BLM. Field reconnaissance was conducted to verify access, location, and condition of the various monuments to be occupied as well as the photogrammetric image points to be used as extended control for the triangulation process. They were then annotated on the forest map to act as a guide for field occupation and data gathering. Route planning was completed on the forest map as well. A numbering system was derived for the west and east blocks of the project. GPS satellite planning was conducted to determine visibility of satellites on the days of our field work and their respective Positional Dissolution of Precision (PDOP). The coordination and use of the Pathfinders with the WNF was arranged for 1 week. In order to not be affected by the Selective Availability (SA) and chance any degradation of the accuracy desired, we employed a base station and differentially corrected the data.

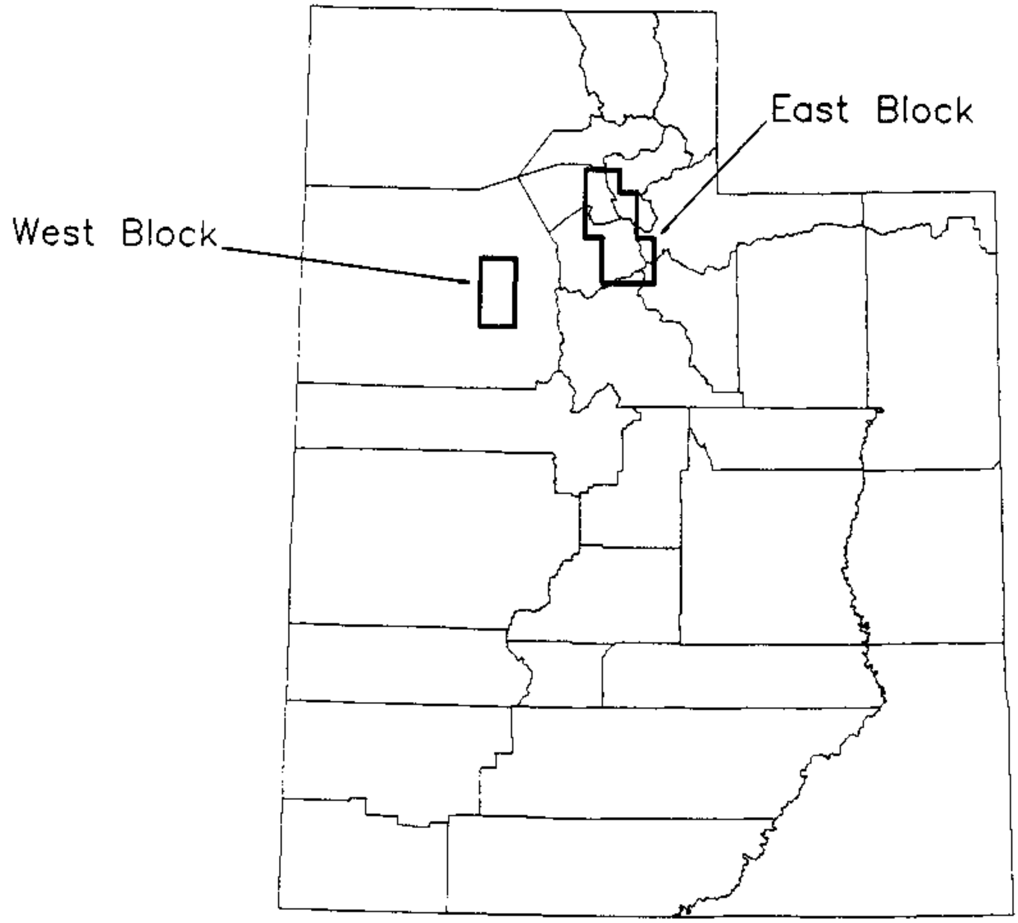


Figure 1.—Project Location Diagram

On the first day, the GPS field data collection phase started, covering the area from the middle of the Salt Lake Valley south to Draper on the eastern block. Because the PDOP was not conducive to a full day's data capturing, we were limited in the time and area of coverage for this first day's field work. The second day, we captured data from the middle of the Salt Lake Valley north to the top of the project near south Ogden on the east block. On the third day, all of the data for the west block was collected by one party, while the other party concentrated on the northeast quarter of the east block. On the fourth day, we collected data on the southeast portion of the east block. On the fifth and final day, we downloaded the information that had been gathered, began the differential corrections, and started the evaluation of the data that would be used for the ground control.

Three Trimble Pathfinder Professional six-channel GPS receivers were used to collect positional data. The receivers were supported by Omnidata Polycorder data collectors. One receiver was set over a known point located inside of a fenced equipment yard in Salt Lake City. This receiver acted as the reference or base station in the differential correction process. The remote receivers were set up in automobiles, such that the antenna was placed on the roof of the vehicle directly above the driver. This permitted the driver to position the antenna over the control point location without leaving the vehicle. For locations where this was impractical, the antenna was attached to a survey range pole and placed upon the point of reference. The 4-meter-long antenna cable allowed for most locations to be collected without removing the receiver unit from the vehicle.

For each control point location, data was collected for 3 minutes at 1-second intervals. The majority of points were collected in a 2D mode with the operator inputting the initial altitude. As the control point features corresponded to features on USGS quad maps, an elevation was interpreted from the map if the position did not correspond to a map spot height. These elevation values were used as the initial altitude input. This procedure allowed for operation during times of inadequate 3D satellite coverage. Along with the control point locations, various NGS and county survey control points were occupied in order to provide an assessment of the accuracy of the GPS values prior to the photogrammetric process.

The control for the west block of photography had been previously collected using the tablet digitizing method, conforming to normal procedures. The field effort for this photography consisted of identifying these positions in the field, then collecting the GPS data on each (figure 2). The east block of photography differed from this approach in that features which were not shown on the quad maps, but were readily identifiable on the photography,

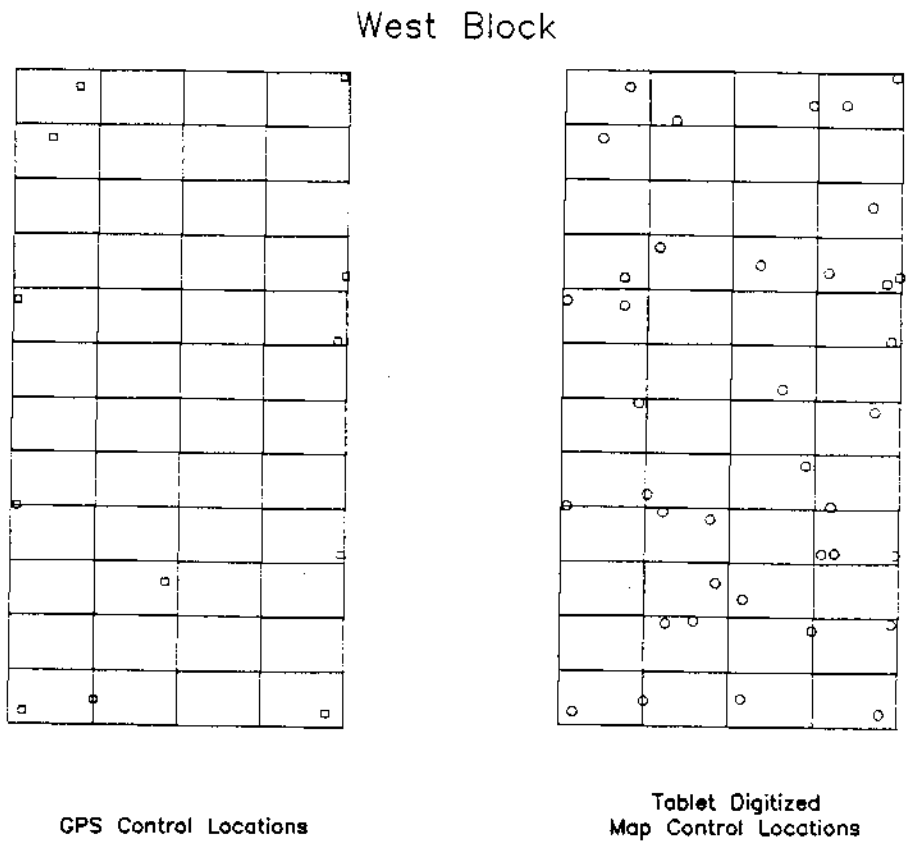


Figure 2.—The Locations of the GPS and Tablet Digitized Control Points Shown in Respect With the Nominal Stereo Model Coverage

would be controlled. The types of features which fell into this category were sidewalks, road and parking lot stripes, fence lines, and utility poles (figure 3).

The data was downloaded from the Polycorders to an AT style personal computer. The files were differentially corrected utilizing the respective base station files. ASCII files were generated which listed the readings (approximately 180 for each point location) in latitude and longitude. These files were then used in a spread sheet program for averaging and translation to the Utah State Plane, North American Datum (NAD) of 1927, Central Zone coordinate system.

Analytical Photogrammetry Mensuration and Bundle Adjustment

The analytical photogrammetry preparation and mensuration phase was accomplished by MAPCON. Locations for pass and tie points were selected, marked, and numbered in accordance with the GSC Numbering System Guide. The photos were marked for measurement in a model system with 5 points per cross-section and a minimum of 10 points per stereo model. The side lap of the photography allowed for two points from each photo to be transferred to the adjoining strip. The location of the quad map corner is first identified from the appropriate USGS map sheet. Quad corner points are then selected so as to fall within 7,000 feet inside of the actual quad map

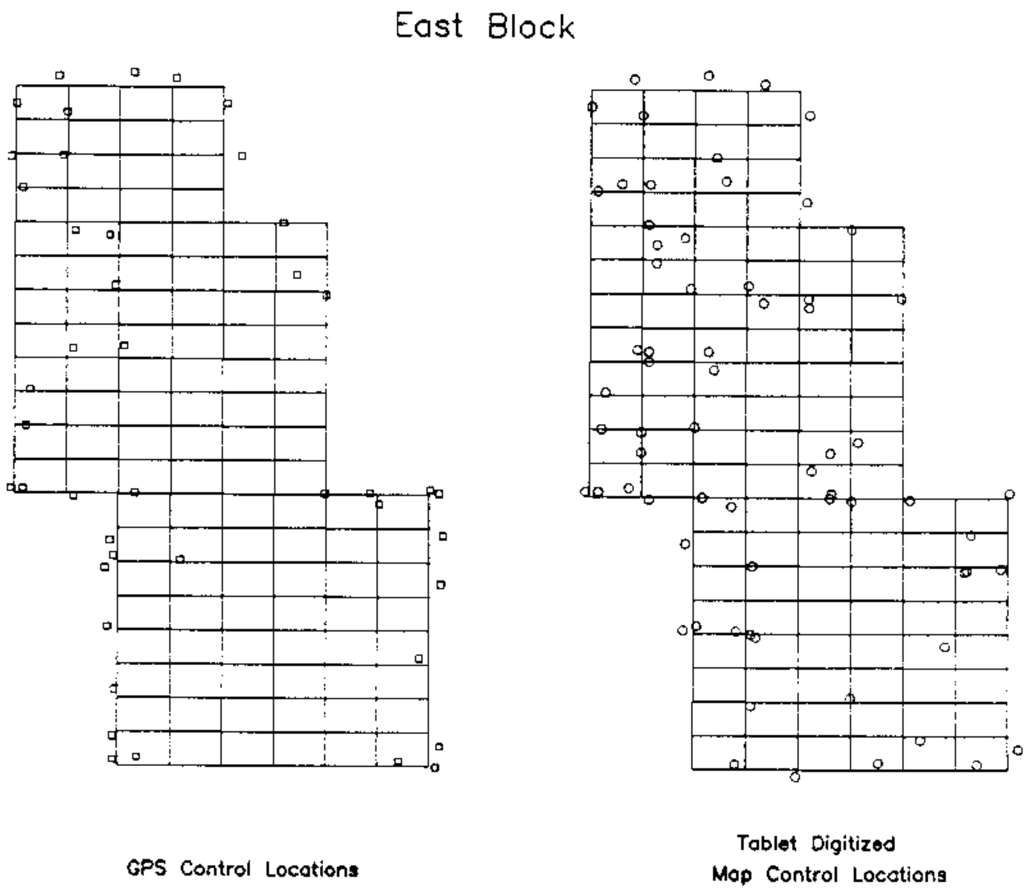


Figure 3.—The Locations of the GPS and Tablet Digitized Control Points Shown in Respect With the Nominal Stereo Model Coverage

corner while avoiding the extreme or apex of any feature. A Bausch and Lomb Micromark point transfer device was used for the preparation of the diapositives. A luminous floating mark is employed for parallax removal, and a thermal marking system molds the selected marks into the photographic emulsion of the film diapositive. The optical system allows continuous magnification change from 4.5 to 40 times enlargement for use with photography having scale differences as great as 9:1. The pneumatically controlled marking system permits marking of either stage. The map locations which were used for control are well defined features, not subject to an inordinate amount of cartographic generalization. Road intersections and road and stream intersections constitute the majority of the selected features used for horizontal control. USGS field-verified spot heights make up most of the vertical control point locations. The position and density of these control points were chosen so as to limit the vertical bridging distance to four stereo models and to provide, as nearly as possible, full perimeter horizontal control.

The selected map locations were digitized on a Kurta 36 x 48 inch, high resolution digitizing tablet. The tablet is interfaced to ESRI PC/ArcInfo software for the conversion of tablet coordinates to terrain coordinates. State Plane values for all 16 geographic ticks shown on the USGS map sheets were calculated using MAPCON's in-house software and then used for input into PC/ArcInfo. A minimum of six geographic ticks were digitized for the registration of the map sheet to the tablet.

The control point locations, including points intended for vertical control only, were digitized in PC/ArcInfo and then translated to Autodesk AutoCAD software for the purpose of attributing the point locations with name and elevation data. The final output of this phase was a coordinate list showing point name, X value, Y value, and Z value (if appropriate) in the given terrain system. The digitized horizontal position for vertical control points is used for gross error determination during the initial adjustment and is not included in the final control list.

A Kern DSR1 analytical stereoplotter was utilized for all of the photogrammetric measurements. These measurements were made in a model space system and corrections were applied for film deformation and lens distortion based upon the USGS Camera Calibration Reports associated with this photography. The output of the measurement process was refined plate coordinates in the camera fiducial coordinate system.

During the bundle adjustment phase, plate coordinates, together with the ground control files, were used with Erio Technologies analytical simultaneous bundle block adjustment program (ALBANY). This program allows for corrections for earth curvature and refraction, as well as error detection, through the use of polynomial adjustments for tie point analysis and block adjustment. A series of adjustments were performed, leading to a final adjustment which utilized the GPS positions for the horizontal control and the map positions for the vertical control. The tablet digitized positions became check values in the final adjustment which facilitated the evaluation of the results.

Comparisons

The initial aerial triangulation adjustments, using the map control only, indicate a root mean square error (RMSE) of approximately 35 feet horizontally and 15 feet vertically. These results would be found acceptable for the normal application of orthophoto generation. The introduction of the GPS control allowed for further error detection in both the horizontal and vertical map control which, when accounted for, resulted in a horizontal RMSE of 28.8 feet for the west block and 32.6 feet for the east block, improving the vertical RMSE to 7.0 feet and 6.5 feet, respectively. The time spent in analysis of the adjustment, checking for errors, was decreased by approximately 30 percent with the use of more accurate ground control.

The final triangulation adjustment for the west block, which used 12 GPS points for the horizontal control and 34 points interpreted from the quad maps for vertical control, showed a horizontal RMSE of 12.9 feet and a vertical RMSE of 7.0 feet. The east block adjustment showed similar improvement when utilizing 44 GPS points for the horizontal solution and 103 map vertical control points. The final RMSE for the east block was 16.9 feet horizontally and 6.5 feet vertically.

In order to verify the accuracy of the GPS locations, six published control points were occupied, and data was gathered using the same procedures as those used for the photogrammetric control. These points were spaced randomly throughout the east block and consisted of SLC and DC section corners, along with NGS third order control points. The average radial error between the published values and the differentially corrected GPS values was 12 feet (3.6 meters), which is within the stated accuracy of 2 to 5 meters for the GPS receivers (as shown below).

Station	Delta E (Feet)	Delta N (Feet)	Source
MIDWAY	5.3	-12.7	NGS
N1/4 5N/1W	1.0	1.9	DC
SE 8 1N/1W	-2.6	-0.4	SLC
3410 1N/2E	-6.9	14.1	USFS
SW31 1S/1E	-1.1	16.5	SLC
SE32 3S/1E	11.2	-2.5	SLC

The GPS locations were compared to the same locations derived from tablet digitizing methods. A direct comparison was made of those points (as shown below) which were collected in the field via GPS and also digitized from the USGS quad maps. The average radial distance between these points was 35 feet.

Station	Delta E (Feet)	Delta N (Feet)
519	-7.1	-4.7
529	-11.5	42.8
531	-3.3	-40.7
502	-24.3	27.3
517	40.1	36.8
523	-52.1	35.2

Station	Delta E (Feet)	Delta N (Feet)
506	-18.8	-34.5
503	25.7	50.0
620	9.6	10.8
1718	22.0	61.5
1716	53.9	-18.2
1721	25.0	30.2
1713	-4.5	-28.9
1711	34.7	-18.5
2723	-3.3	-28.0
3714	27.8	-19.8
4723	12.8	-0.7
4722	3.3	15.6
4711	12.5	-8.3
4713	-4.6	-0.6
4717	21.8	-8.2
4714	23.3	-47.2
4720	6.8	-39.1

As a test of the overall photogrammetric accuracy, the photogrammetric readings were made from the east block of aerial photography on published, surveyed control locations, using final adjusted control files.

The Salt Lake County Surveyors Office was contacted and data was gathered as to which section corners within the east block would correspond to centerline road intersections. A ground control file was generated from the final GPS controlled aerial triangulation adjustment and used to perform an absolute orientation on the analytical stereoplotter. The operator then digitized the interpreted road intersections, producing a digital file of X, Y, and Z locations. The results, as shown below, have a standard deviation of 5.1 feet in easting and 4.8 feet in northing with an average radial error of 8.2 feet.

Station		Delta E (Feet)	Delta N (Feet)
23E	62S	-6.0	-2.8
20E	66S	5.4	-8.0
27E	70S	-1.1	-0.8
7E	78S	6.9	-1.1
10E	78S	7.3	-5.0
13E	78S	-3.6	3.2
35E	78S	9.1	7.3
7E	86S	5.8	-7.5
10E	86S	9.5	0.2
13E	86S	3.8	-0.7
17E	86S	5.9	0.4
7E	98S	4.8	-6.6
17E	98S	12.0	4.5
7E	106S	9.2	4.5
13E	106S	11.3	7.1

There was significant radial error improvement, by a factor of two, of the GPS controlling method over the tablet digitizing method as indicated by the final adjustment results.

Summary and Conclusions

The project consisted of 792 square miles on the east block and 341 square miles on the west block. Total hours, both in the field as well as the post processing, were 64. (This is somewhat higher because we included the learning curve for the system and the post processing into this total.) We have not included in this report any equipment costs, its maintenance, or any normally associated depreciations. Field work on the west block was completed in one day. The east block was completed in 3 days.

It was noted, when collecting data all day on the base station polycoder with a 15-second collection interval, that it was possible to overload it and lose data at the end of the day. The receivers interval settings and time usage were followed as was recommended by the manufacturer. An accurate elevation needs to be entered in the system when collecting in a ID mode. A horizontal error will approach a one-to-one ratio with the vertical error.

It was noted that a base station closer to the area being worked, particularly on the same side of the mountain range, is preferred when differentially correcting the data. This is primarily due to a different satellite constellation being observed.

Quad elevations are still needed for vertical input when collecting the data and when checking for blunders and the overall fit of the project. Also, when conducting triangulation for orthophoto purposes, quad control is adequate but can be improved on with the addition of GPS control. When conducting similar mapping projects, it is recommended that you incorporate in the planning a GPS network of selected sites, even if they are few in number. This will certainly be a cost-effective plus for the project in its present and future uses.

Our six initial objectives were achieved to our satisfaction. A relatively low cost, simple-to-operate resource grade GPS system was used, and a successful collection and application of the differentially corrected data was added to the photogrammetric process. Comparisons of the GPS acquired control locations to the quad-derived control positions were accomplished. We did learn the GPS process and what it involves. A healthy mutual cooperation between Federal, State, and county agencies and private firms has been promoted. It has been shown that the overall triangulation process can be made easier and faster when utilizing GPS control, considering the error propagation that takes place in any adjustment. Error detection is easier to analyze, hence faster to isolate, when more accurate ground control is used in the adjustment, even if the errors are few in number. The overall net affect is that you can minimize error propagation and speed up the adjustment process. It has been shown that accuracy within the triangulation adjustment can be improved when using GPS in this fashion, and that better results can be witnessed in the production of orthophotos. The use of black and white diapositives produced from original color IR photography results in poor resolution and possibly leads to a degradation of the photogrammetric results.

Any previous triangulation adjustment can most likely be enhanced with the insertion of a few strategically placed GPS ground control points. It is relatively safe to assume that, when compared to a quad only controlled project, as good, and probably better results can be achieved when using photography, even 1:40,000 photo scale, that has been triangulated with ground control originating at least in part from a GPS source.

Other purposes, such as the base for GIS digitizing as well as for bridging down to a variety of large scale mapping projects, can also be visualized. It should be recognized that other uses for this type of triangulation and ground control can have positive influence in areas such as cadastral boundary line and land line plotting. Automated cartography methods can be enhanced when using GPS or GPS integrated sources. Land resource management and site planning are certainly up and coming areas where these techniques can be utilized. Overall time and cost savings for almost any mapping need will undoubtedly be evident.

The authors would like to express their appreciation to all of the respective agencies and firms for supporting and participating in this worthwhile and successful effort and to all those individuals who took an active part in making it happen.

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Asphotac, A Demonstration of a Dust Palliative

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Background

The Fremont National Forest demonstrated a new dust palliative product, Asphotac, on a recent timber sale. Asphotac is a proprietary asphalt emulsion that is distributed by Actin, Inc., East Chicago, Indiana, telephone: (219) 397-5020, and formulated by John Chabria, Xtalonix, Columbus, Ohio, telephone: (614) 488-5915. Asphotac has been used to control dust problems at industrial steel production companies in northwest Indiana. Michael Lopez, President of Actin, solicited the Forest Service for the opportunity to demonstrate its product on Forest Service roads.

The demonstration was on the Silverlake District on Road 2901, the primary haul route for the timber sale. The sale volume was 2 million board feet. The road was 10.7 miles long and 16 feet wide with turnouts approximately every 500 feet. Its elevation varied from 4800 to 6800 feet, with an average grade of 6 percent, a third of it flat, and maximum grade of 12 percent. Prior to the Asphotac application, the road had 4 inches of 1/2-inch or less crushed aggregate base course. The rock had been compacted until visual displacement ceased, and the road had a smooth running, out-slope surface (figure 1). Water was suppose to have been the original dust abatement material, but it is not an abundant resource because the Fremont National Forest is on the dry side (east side) of the Cascades. The forest had been investigating different methods of dust abatement other than using water. This product would satisfy that requirement and would better protect the forest resources and road investment, as well as maintain traffic safety better than water.

Asphotac Application

Asphotac arrived at the job site in a concentrate and was mixed on the job site (figure 2). On this project, the concentrate was diluted one part concentrate to five parts water. Almost any water source may be used for mixing with the concentrate. The forest's water sources were a spring fed pond at the end of the project and the district compound. Since the road had been shaped, no other preparation was necessary. A total of 0.60 gal/yd^2 of mixture was applied (or 0.10 gal of concentrate) in three applications: the

Figure 1.—Road Before Asphotac Application

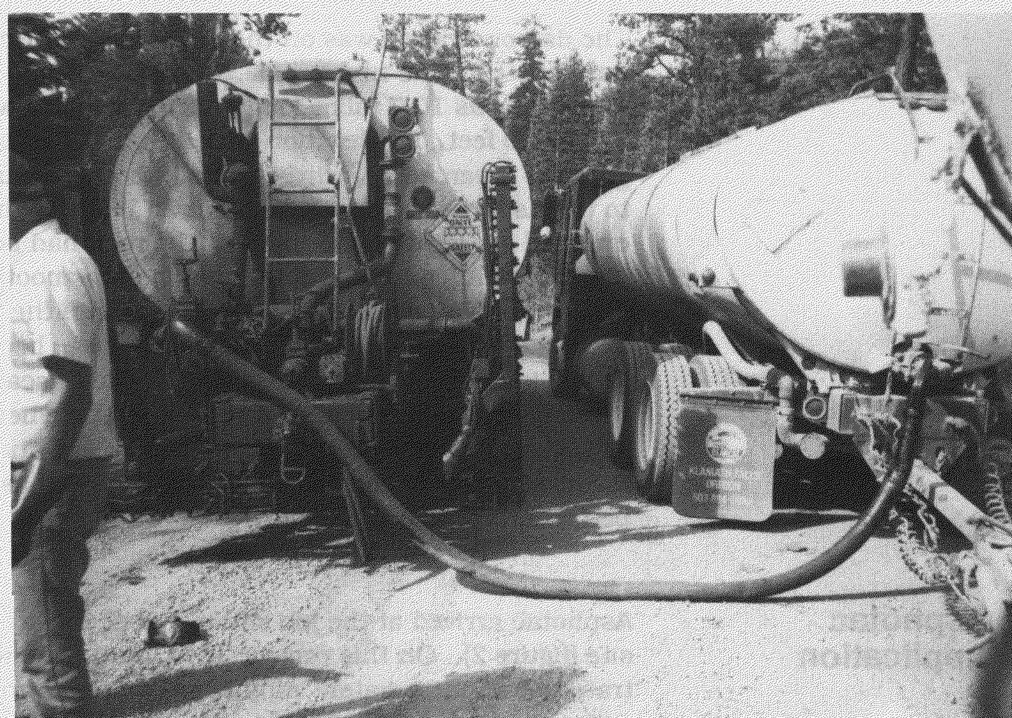

Figure 2.—Mixing Asphotac and Water on the Job Site

first was 0.30 gal/yd², and the second and third were both 0.15 gal/yd² (figure 3). The road's moisture content needs to be less than optimum moisture for compaction, which will allow the mixture having a high water content to penetrate fast and deep. After the first application, bubbles formed on the road surface, indicating that the voids in the road were being filled (figure 4). Penetration was 1 to 1-1/2 inches after the first application; the other two applications did not penetrate as much but developed a thin surface crust. Traffic, because of Asphotac fast penetration and curing time, can resume almost immediately after application without harm to vehicle or road.

Test Sections

Four 300-foot control sections, not treated with Asphotac, were established to determine the effectiveness of Asphotac. The forest decided that this would be a good opportunity to compare other dust palliatives that are normally used on the forest. The products that were used were lignin sulfonate (lignin), magnesium chloride (MgCl), and DOPE 30 (an emulsified asphalt). These products were applied about a week after the Asphotac application according to Forest Service specifications or to the suppliers recommendations. The remaining section was not treated.

The lignin-treated section was located at milepost (MP) 0.6 on a 12-percent grade. Prior to applying the lignin, 2 to 3 gal/yd² of water were applied. The lignin was applied to a wet surface in three applications of 0.25 gal/yd² each. Traffic was not allowed for 6 to 8 hours after the final application. Typically, two applications at 0.25 gal/yd² are used. The DOPE 30 section

Figure 3.—Applying Asphotac

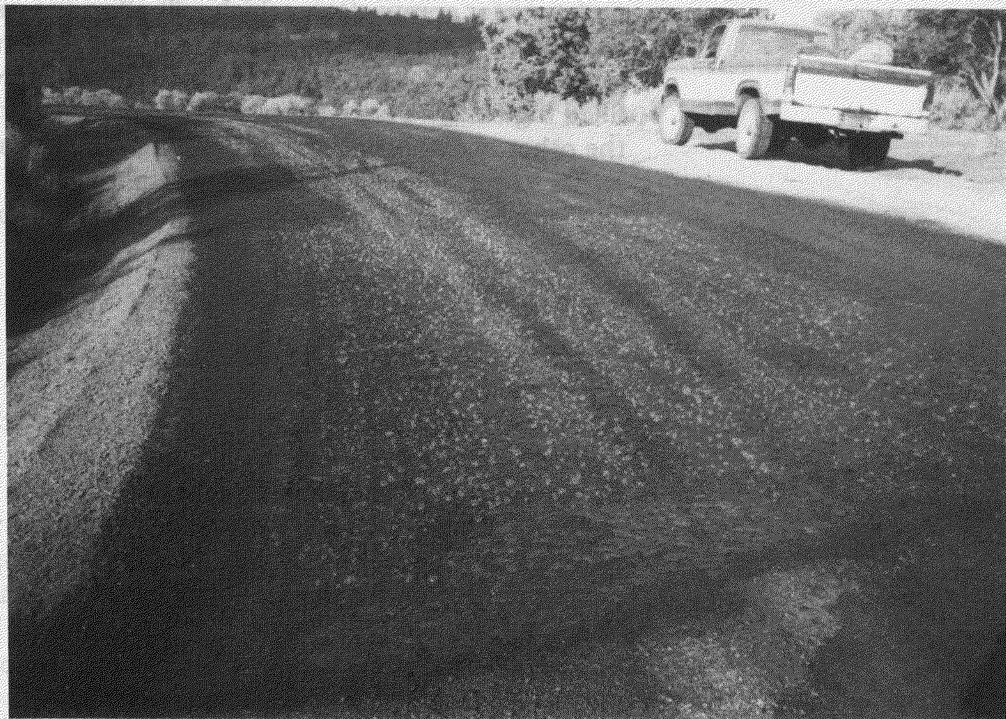

Figure 4.—Bubbles Forming After First Application

was located at MP 3.0 on a 6-percent grade. Before DOPE 30 application, 1 to 2 gal/yd^2 of water were applied. For this project, two applications of 0.35 gal/yd^2 were applied, and no traffic allowed for 24 hours. The DOPE 30 was applied too heavy and runoff occurred in the ditches. The amount of DOPE 30 which should be applied varies with timber volume and traffic passes, and only one 0.35 gal/yd^2 application should have been used. The MgCl section was located at MP 5.7 on a flat grade. Water, 1 to 2 gal/yd^2, was applied before the two applications of 0.5 and 0.25 gal/yd^2, respectively, of MgCl. As soon as the brine is absorbed, traffic can resume (about 6 to 8 hours). Typically two applications of 0.25 gal/yd^2 each are used.

Test Results

The hauler took 2-1/2 months, from September to November, to complete the haul. This demonstration was to determine the effectiveness of Asphotac and to learn if there were other benefits that it might have. Important properties of successful dust palliation, according to "An Evaluation of Dust Abatement Material Used in Region 6" by Brian Langdon, are as follows:

"a. The product should penetrate.
b. The product should leave a useful residue.
c. The useful residue should resist leaching.
d. The useful residue should impart cohesion to dust particles.
e. The useful residue should resist aging."

These properties were considered to determine the effectiveness of Asphotac. The other products' effectiveness was known and was used as a comparison to the Asphotac. The test sections were short, and only dust suppression was compared. No other comparisons—i.e., washboard prevention, leaching, etc.—were made. The observations and comparisons were made by the forest geotechnical representative, John Crumrine, and the project engineer, Joe Acosta. Some of those observations of effectiveness and benefits of Asphotac are as follows:

- Rain occurred the day after the Asphotac application and there was no apparent leaching.

- Dust that occurred on the Asphotac-treated portion seemed to settle quickly. Halfway through the haul, the observers noticed that the Asphotac had penetrated the first 2 inches of depth and lightly coated the aggregate. This added weight caused this short airborne time.

- Traffic can start using the road soon after application; therefore, no road closure is necessary.

- The contractor's crew that applied Asphotac seemed pleased with the material because it did not plug their equipment and spreader bar.

- Water used is a measured amount; with the other materials, water used is an approximation or a guess; the Asphotac application used the least water.

- Washboard started to occur on the grades and sharp curves in 2 weeks, and it started on the flat portions after 4 weeks.

- Washboard had occurred on 80 to 90 percent of the road by the end of the haul.

- Road maintenance had to be accomplished because of excessive washboarding. The Forest Service Force Account Crew noticed that the Asphotac-treated roadway was easy to scarify and repair, making the crew's work faster to accomplish.

The observations taken on the test sections were more difficult to obtain, because the sections were shorter and application rates were about twice the normal amount. Some of those observations were the following:

- The lignin did not perform well for the first 2 weeks. The observers thought that it had leached out of the roadway. After 2 weeks this section became less dusty. The observers concluded that the lignin had penetrated below the surface, leaving loose material on top. When that material "blew" away, the lignin controlled the dust to a satisfactory level for the remaining haul (figure 5).

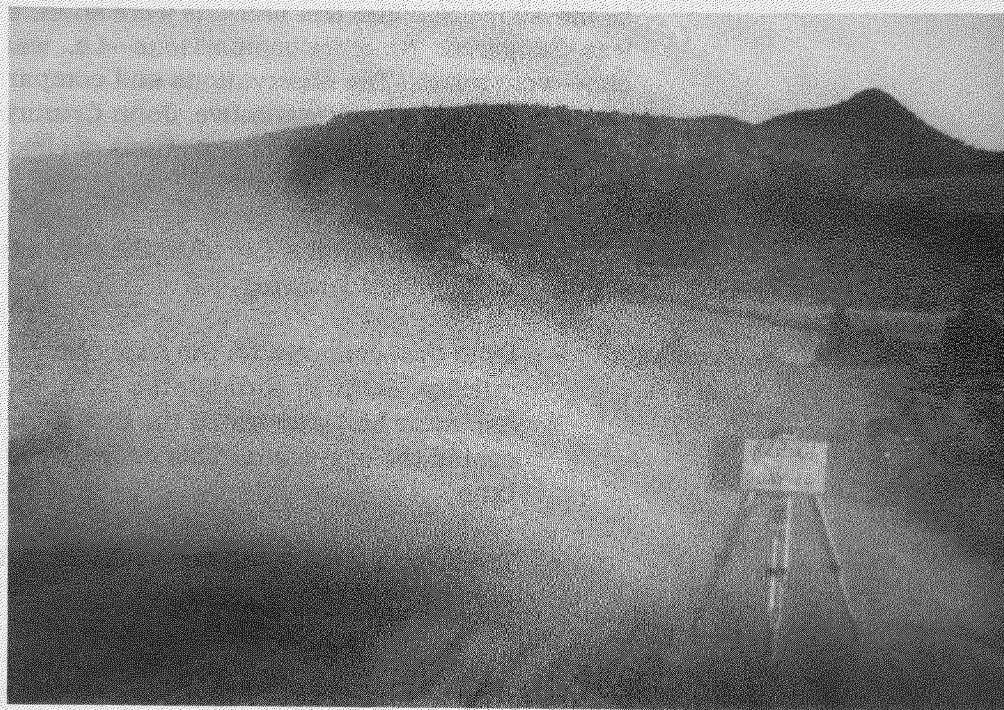

Figure 5.—Lignin Section on Day 20, One-Third of Timber Haul

- DOPE 30 controlled the dust throughout the project. DOPE 30 had twice the amount applied than required and had runoff in the ditch during the application. Even with the "double" amount, some dust was present, but it was never significant (figure 6).

- The MgCl controlled dust satisfactorily throughout the project. The location of the MgCl was a friendly site, because it was flat and was shaded most of the time; therefore, it did not have to release all of its "stored" moisture (figure 7).

- The section that was not treated was at the end of the haul and, consequently, had less traffic. When it was traveled, there was a notable amount of dust generated.

Figure 6.—DOPE 30 Section on Day 30, One-Half of Timber Haul

Figure 7.—MgCl Section on Day 30, One-Half of Timber Haul

Project Cost

The equipment (with operators) required for Asphotac application was a tanker truck for the Asphotac, a water truck to dilute it, and a spreader truck. The actual project cost of the Asphotac application for the 10.7 miles was:

	Actual Appl. Rate (Gal/Yd²)	Unit Cost (Incl. Transp. and Appl.)	Product Cost	Water Cost	Total Project
Asphotac	0.1	\$2.00/Gal	\$23,000	\$1,200	\$24,200

The estimated cost, including all equipment and operators, of the other dust palliative products as typically applied is as follows:

	Actual Appl. Rate (Gal/Yd²)	Unit Cost (Incl. Transp. and Appl.)	Product Cost	Water Cost	Total Project
Lignin Sulfonate	0.50	\$0.42/Gal	\$24,500	\$5,400	\$29.900
DOPE 30	0.35	\$0.62/Gal	\$25,200	\$5,400	\$30,600
MgCl	0.50	\$0.39/Gal	\$22,500	\$5,400	\$27,900

Based on the above cost, Asphotac is the most economical for this project.

Conclusions

The observers concluded that Asphotac met the requirements for a successful dust palliation. Asphotac required less than half the water of the other products. For the same amount of dust palliation, Asphotac used less than a third of the asphalt used by the DOPE 30. Asphotac demonstrated good resilience after the maintenance crew reworked the road; it was still controlling dust. Asphotac for this project did not prevent washboarding or potholing, but that is not a requirement of dust palliation.

All of the products used in this demonstration were satisfactory. Because the Lignin, MgCl, and DOPE 30 were applied in at least twice the amount necessary and the Asphotac applied in the specified amount, no rating of the products will be made. All are judged satisfactory, and Asphotac succeeded as a dust palliative (figure 8).

Figure 8.—Asphotac on Day 40, Three-Quarters of Timber Haul

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