Developing Technology—A Forest Health Partnership

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Abstract.—Since the early 1960's Missoula Technology and Development Center (MTDC) and Forest Pest Management (FPM) have worked in partnership developing technology to support forest health and silviculture. Traditionally this partnership has included cooperators from other agencies, States, foreign governments, academia, industry, and individual landowners. The FPM sponsored projects have focused on engineering development of delivery systems and methods to mitigate environmental impact, protect personnel, and reduce costs while meeting resource manager forest health objectives. This paper summarizes program accomplishments, takes a look how the accomplishments were realized, and references the current 5-Year Forest Pest Management/Missoula Technology and Development Center Plan—Supporting Forest Health.

INTRODUCTION

The purpose of this paper is to review the role of the USDA Forest Service (Forest Service) Missoula Technology and Development Center (MTDC) in delivering technology to support forestry. To illustrate the technology development process, we will provide examples of delivered technology that supports forest health and silviculture. Through this review forest health managers and silviculturists should be introduced or reacquainted with MTDC capabilities that exist to meet needs of forest resource managers.

World competitiveness and the demand for resources are challenging our creativity, entrepreneurship, efficiency, and productivity in all sectors of the public and private economy. Survivors are blazing new trails into the unknown. To those of us in research and development the message is clear—fix it whether it's broken or not because if we don't someone else will.

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BACKGROUND

MTDC Mission

The mission of MTDC is the systematic applications of engineering principles and scientific knowledge to create new or substantially improved equipment, systems, materials, processes, techniques, and procedures that will perform a useful function or be suitable to meet the objectives of advanced forest management and utilization.

The Forest Service Technology and Development program began shortly after World War II. The program was originally established in Arcadia, CA and Missoula, MT in 1945 (Simila 1995). A forest pest management program was well established at MTDC by 1964 with some projects initiated in FY 1960 (USDA Forest Service 1974).

Program Management and Funding

MTDC is managed by a manager who reports to Director, Washington Office Engineering, currently through an assistant director. Most of the Forest Service traditional functional organizations are sponsors (customers) including Forest Pest Management (Forest Health Protection) and Timber Management. Funding is provided to MTDC by the sponsors and coordinated through the Washington Office; although FPM offices at Regional, Area, Forest, and District offices have provided project funding directly to MTDC. MTDC operates under industrial funding, that is its project funding comes from its sponsors. This funding is "zero-based," thus ending at fiscal year end. Each sponsor has one or more projects (collectively these are a program) at MTDC with each project assigned to an engineer or engineering technician (project leader). The project leader is responsible for delivering the technology (eg, hardware, methodology or manual) to the sponsor. In the case of FPM there is a single point of contact and coordination of the FPM projects. We refer to this person as the sponsor/coordinator.

Sponsor/Project Leader Relationship and Expectations

Critical to project success is the professional relationship between the project leader and the sponsor/coordinator. For the project to be successful, delivered in a timely manner, and implemented, the project leader and sponsor/coordinator must function as a team. As with any contract, the sponsor expects a quality product delivered at the time specified within the agreed price. In addition the sponsor expects status reports during the development. It is emphasized that the sponsor/coordinator share responsibility for these deliverables with the project leader.

Adaptive Engineering

A successful cost-effective approach to engineering development is adapting existing hardware and other technology to meet sponsor needs. Therefore one of the major efforts of MTDC engineers is researching new world-wide technologies; and establishing professional contracts within other agencies, academia, and private sector. These efforts often result in cost effective and mutually benefitting partnerships. Over the past decade, as an example, MTDC has established a long-lasting and productive partnership with Department of Defense in technology exchange and development.

TECHNOLOGY DEVELOPMENT PROCESS

Projects normally originate from a committee or even an individual representing one of the sponsoring groups, as opposed to the project being proposed by an MTDC engineer. Ideally, MTDC engineers, interacting in meetings at the field level, are alert to identifying needs and join actively in preliminary discussions on how the need might be addressed jointly with the potential sponsor. The other, but less common approach, is a direct call to MTDC from a field person who has a technical need. The key here is also for immediate follow up by MTDC to scope the need and discuss options with the potential sponsor. Responsiveness and enthusiasm are the essential elements and genesis of most successful projects.

Planning is basic to success—it provides for delivering the product that's needed, it helps to avoid misunderstandings, it builds rapport between project leader and sponsor, it supports timely delivery, and it helps to avoid cost overruns. Problems in planning are more likely to occur when project leaders, engineers, and sponsors are inexperienced. A solid and detailed project work plan supported by the sponsor is basic to a well planned project. Experience plays a major role in successful development but a work plan is a must. Development is laced with surprises, disappointments, and unanticipated outcomes, both favorable and unfavorable. Development is also risky and rewarding. The inexperienced developer, sponsor, or manager might be tempted to give up at the brink of success. Sponsors and managers need to realize the risks and uniqueness of development, while the project leader must be empowered with flexibility to exercise creativity in meeting unexpected challenges.

Accountability, if lacking on part of either party, might doom the project. Accountability, like technology transfer, should be laced throughout the project and includes delivering, as specified, within the project scope and contract.

Completion of the project by meeting sponsor customer expectations (quality, timely, and fullness) should be the project leader's guiding principles. Team recognition will help to promote future successes.

TECHNOLOGY TRANSFER

Implementing new technology is one of the major challenges of the technology development process. It's probably a greater challenge in the public sector, where unlike the private sector, it's not driven by competition and profits nor supported by marketing expertise. The public technology developer is, therefore, driven by fewer motivators—a challenge to the federal manager. The Chief, Forest Service, recognizing the lack of public incentives, established a major recognition award for technology transfer. Congress has established policies to encourage private and public cooperation in technology transfer. The FPM program at MTDC has generated technology transfer agreements between the Forest Service and its partners including Canada, New Zealand, and the major agricultural chemical companies in the US.

Technology transfer is threaded throughout the development process. It begins when the potential sponsor first proposes the idea and begins to establish rapport between the sponsor and project leader —the team responsible for technology transfer. Technology developed without a sponsor and without the spirit of cooperation is the most difficult to transfer and implement. Technology transfer should be part of the entire development process—beginning at first discussions and continued until all the potential users have adapted the technology.

"The Forest Service approaches technology transfer as a continuing process that ideally begins during the conceptual phase of product development, and continues through product adoption and improvement. The end user's needs and participation should be in the forefront and incorporated into the process to enhance product acceptance. Sharing ownership in and during the process are key to successful technology transfer. Previously, the Forest Service failed to implement promising research and development simply because the end use was not part of the process.

However, the Forest Service is committed to the process of technology transfer to improve productivity and competitiveness. This commitment promotes the development of new technologies within the Forest Service, stimulates the use of federally funded technologies by others, and encourages the recognition and exchange of scientific and technical personnel among academia, industry and the Forest Service" (Barry, et al. 1991).

FPM FOREST HEALTH PROGRAM

MTDC/FPM Program

The present FPM program is guided by a 5-year plan (Thistle 1995) that was initially prepared jointly by MTDC and FPM and approved by the Director, FPM in December 1991. The program describes processes, describes projects and deliverables, and lists budget estimates. The plan is a living document for use in managing the program and supporting technology transfer, and a reference document for conducting program review to include project deletion, modification, additions, or cancellation.

National Steering Committees

FPM sponsors eight national steering committees that have the role of identifying technology development needs. The committees, composed of members that represent the Forest Service and its cooperators, meet annually to review and identify technology needs and agree on priority for funding. The committee process has worked well since its inception in 1988. MTDC is a participant in these committees interacting directly with potential technology users. Several of the projects in the MTDC/FPM 5-Year Program originated during various committee discussions.

Examples of Successful Projects

Two examples of successful projects are given—one a long-range development effort, the other a short-range. FPM and MTDC joined efforts in the mid–1970's along with sponsorship of the USDA Douglas-fir Tussock Moth Research and Development Program (Brookes, Stark, and Campbell 1978) to develop a computer model that predicted the dispersion drift, deposition and fate of aerial sprays (Teske et al. 1993). The US Army provided the base computer model and remained cooperating partners during development. In addition several Forest Service cooperators, universities, and the National Aeronautical and Space Administration provided assistance. Significant developmental challenges were successfully met and with funding support from the US Army and FPM, we developed a model that has become the accepted spray model by forest and agricultural practitioners and regulators in Canada, New Zealand, and US. The US-EPA is in the process of accepting a version of this model for use in satisfying registration and labeling of pesticides.

The second example is a project that delivered operational technology to the field within 3 months of its inception compared to years in the case reviewed above. Need for a single tree spray system was originated by an FPM steering committee and by Tom Catchpole, silviculturist, Pineridge Ranger District, Sierra NF, CA, who expressed interest in protecting critically needed and high value sugar pine seed from insect damage. Tom contacted Nancy Rappaport, research entomologist, Pacific Southwest Research Station. The question was how to apply the spray to sugar pine that tower over 100 feet, do it without the aid of a helicopter, and insure minimal contamination of adjoining trees. Nancy's husband, Harvey Rappaport, suggested mounting lawn type sprinklers in the tree crown and pumping the insecticide from a mobile ground system. The need for repeated insecticide application and its estimated low cost made the idea theoretically practical. Immediate follow-up prototype testing by MTDC, PSW, and Sierra NF personnel was conducted on the Pineridge District. Another test was conducted at the Forest Service Coeur d' Alene Nursery, ID. Continued success with this technology has encouraged its evaluation in eastern seed orchards operated by Weyerhaeuser, the Forest Service, and Florida Department of Forestry. MTDC designed the system, however, it was the enthusiastic support and hands-on participation and team approach that caused this idea to be a success and the system to become operational technology within a few months.

Everyone was a winner in these two contrasting projects.

REGENERATION AND FOREST HEALTH PROJECTS

Regeneration Projects

Over the years, MTDC has been involved in many aspects of forest regeneration. This section gives a few examples of projects related to regeneration which MTDC has conducted in the past 2 years. The nature of the projects ranges from statistical evaluation of methods to the actual development of electromechanical systems to reduce labor and improve efficiency in regeneration practices. The project topics cover activities from seed protection through site preparation, storage, and transport to planting and establishment. The brief descriptions given here can be reviewed in given references or by contacting MTDC.

Steep Slope Site Preparation

Mechanical site preparation is generally restricted to slopes of less than 35 percent. With a mind to ecological considerations, more residual matter is being left after timber harvests. New methods are needed to adequately treat brush and logging debris and to prepare planting sites on slopes of more than 35 percent with heavy slash. MTDC conducted a market and literature search to seek equipment and techniques available for steep slope work. All applicable equipment from large excavators to small four wheel drive ATVs was considered for Forest Service tasks. Results of the MTDC investigation revealed a variety of equipment that would satisfy these needs (Karsky 1993).

Mulch for Seedlings

Ground mulch is commonly used in the ornamental and landscape business to reduce vegetative competition and improve soil moisture around newly planted trees and shrubs. Forest Service researchers determined that ground mulch could significantly improve seedling survival and promote early growth. As part of a nationwide cooperative research effort, MTDC collected data on various types of mulch material, current techniques, and equipment used to place the material around newly planted trees. MTDC has also helped collect the final data on a cooperative mulch test project with the Lolo NF. Results of this project will be published in a report which is intended to serve as a reference for field foresters. The report will include information on commercial mulches, suggested installation techniques, a quick overview of past mulch study results including the cooperative mulch test and recommendations, and a comprehensive bibliography (Windell 1995a).

Root Pruner

Tree seedlings are pruned in the packing shed to provide seedlings with a uniform root length. This is currently done with hand operated, office type paper cutters. This system has a number of problems. The hand cutting is difficult and workers tire quickly. The operators are subject to carpel tunnel injury and are at continuous risk of laceration from the cutters. The work is slow and typically requires that temporary personnel and equipment be brought in to keep up with production. Finally, contractors have difficulty meeting USDA Forest Service root length specifications.

MTDC was asked to develop a root pruner to automate the pruning process and increase packing shed safety and efficiency. The prototype MTDC developed accommodates up to an 8-inch diameter seedling bundle and carries it to the cutting area on plastic conveyor chain. When these bundles enter the cutting area, the shear is activated and the bundles are pruned to the correct length. The bundles are then transported to the end of the unit and then packed in boxes. The cutting area is completely enclosed with a Lexan guard, which provides a barrier between the operator and the cutting mechanism, yet still allows the necessary visibility. The system has been refined based on field tests (Lowman 1995).

Seedling Protection

MTDC has been working with the Southern Region to evaluate commercially available devices that can be used to protect seedlings from animal damage and to promote growth. Seedling protectors have been successfully used in Europe and in some parts of the US for years. Along with protecting the young plant from animal browsing, these devices can create a microclimate around the seedling that will improve survival and promote early growth (Windell 1995b).

Machine Vision Computerized Sorting and Grading System for Tree Seedlings

Forest Service tree nurseries tailor their seedlings to specific Forest and District needs. In doing so, these nurseries must have an effective quality control system. Currently, lifted seedlings are delivered to packing sheds for grading and packing. In this process graders sort seedlings by hand, cull the unacceptable plants, and sort the others by stem diameter, top length, root area, and overall quality. They then place the acceptable seedlings on a packing belt for final processing and packaging. Quality control checkers further monitor this operation by picking samples and overseeing grader performance. This is a labor intensive and expensive process. MTDC was asked to automate the quality control and grading in an effort to reduce these costs.

Under contract to MTDC, Oklahoma State University delivered a machine vision quality control inspection station to the J. Herbert Stone Nursery in February 1994. The system utilizes high resolution line-scan camera technology and an IBM/AT bus compatible personal computer. Ten tree seedling morphological features are measured at rates up to ten seedlings per second. Initial performance tests demonstrated measurement precision equal to or greater than manual measurements. The seedling inspection station can be expanded upon for automating production line grading. Several related aspects of defect detection and seedling handling must, however, be addressed to achieve a comprehensive automated system. Investigation of color detection of defects such as chlorotic foliage and stripped root laterals showed promising results. Also a positioning and sorting mechanism for handling the seedlings after grading was found to be marginally suitable to support automated root pruning (Gasvoda 1994).

FOREST HEALTH PROJECTS

Complex Terrain Droplet Dispersion

The Forest Service Cramer-Barry-Grim (FSCBG) model is a modeling system used to simulate the dispersion, deposition, and drift of pesticides into the atmosphere (Teske et al. 1993). The modeling approach focuses on describing the movement of particles or drops (typically 5–500 microns in diameter) released from an airborne spray system. In the near field the approach is to solve a Lagrangian trajectory equation, in the far-field the Lagrangian model is used to provide a source term to either a Gaussian dispersion algorithm or a phenomenological valley drift model (VALDRIFT) which utilizes conservation of mass and momentum to calculate material moving in flow tubes parallel to the axis of a valley. It had long been observed that the upslope (anabatic) winds that often occur in mountain valleys during the day and downslope (katabatic) winds which often occur at night, control the movement of spray material released in these valleys. VALDRIFT models these mountain wind cells. In the FSCBG modeling approach, the near field equations are solved analytically based on detailed descriptions of the release scenario (aircraft type, weight, number of nozzles, nozzle spacing, initial droplet size distribution, release height, and others). The near field solution is used to a distance where the source momentum is a small percentage of the total momentum. In the first case, the material not 'depleted' from the plume in the near field is available as the source term of a Gaussian line source or as the initial concentration in a valley flow-tube.

The VALDRIFT model is the result of cooperative work between the Forest Service and Battelle PNL Laboratories. Since much of the domain of the Forest Service operations is mountainous, it is critical to consider the effects of the mountains on the dispersion field. This model was initially developed by Battelle for the US-EPA and has been substantially modified to suit Forest Service applications (Allwine et al. 1995).

Thermal Insect Control

The objective of this project is to control insect larvae in seed orchards before they emerge from the cones or from the duff layer. It has been shown that this is an opportune time in the insect's life cycle to lessen the effect of the insect. Historically, prescribed fire has been found effective in controlling larvae but ideal burning conditions do not always occur prior to emergence. If the insect emerges during the rainy season, prescribed fire is useless because it will not propagate through the orchard. This project investigates the use of burner equipment (adapted or developed) for the control of seed cone and duff layer pests during their vulnerable larvae stage. The exact temperature and duration of heat required to control different pests is unknown. This project was given priority by FPM's National Steering Committee for Management of Seed, Cone, and Regeneration Insects. This approach could offer a non-chemical, relatively economical method to control insects in seed orchards. Results of tests in the spring of 1995 indicate that target temperatures can be met in the duff layer under dry conditions. Concerns remain regarding the dependence of the effectiveness of the equipment due to weather, since there is a narrow entomological time window available. Also, human safety and fire control are concerns (Thistle 1995).

Orchard Sanitation

Non-chemical orchard sanitization techniques such as sweeping, vacuuming, and steaming may be safe, effective means of controlling cone and duff pests from seed orchards. Infestations such as cone beetle have a substantial economic impact on Forest Service seed orchards and orchard pests. Seed orchard managers are becoming more and more reluctant to use chemicals. Various non-chemical sanitization approaches have been proposed. This project has evolved out of the Thermal Insect Control Project. While recent tests have shown promising results for thermal control, they have not conclusively demonstrated its effectiveness and there are safety concerns with burning regarding explosions, smoke exposure, and wildfires. Sanitation may offer a viable alternative and this technique is already used by the lumber industry in the southeast. The Non-chemical Orchard Sanitization Project addresses needs reported by one of the FPM steering committees. As costs associated with the use of chemical pesticides increase, orchard managers are left with fewer and fewer tools to combat economically important pests. This project has potential of providing managers with efficacious and economically feasible tools to combat pests in seed orchards (Thistle 1995).

DGPS Aircraft Guidance

The field of Global Positioning System (GPS) based navigation is rapidly growing and is positively impacting the effectiveness of Forest Service and cooperator operations. This technology is based on the reception of signals from a constellation of satellites. These satellites were originally intended for military use but the capabilities of civilian applications of GPS technology are increasing rapidly. Currently, instrumentation using the signals from this satellite constellation can yield positions on the surface of the earth with less than two meters absolute error under optimal conditions. (A technology known as carrier phase DGPS increases this accuracy to 2 centimeters and is now the state-of-the-art in surveying.) The applications of this type of accurate positioning are numerous. Of great interest to FPM (investigation and implementation of this technology has been noted as a priority by the Forest Pest Management National Spray Model and Application Technology Steering Committee, the National Steering Committee for Gypsy Moth and Eastern Defoliators, and other groups within the Forest Service) is the ability to accurately know and log to a stored file the exact position of an aerial or ground spray system during an application event. This ability can: (1) help eliminate the problem of treating the wrong area, consequently reducing the need for flaggers and block marking; (2) provide aircraft tracking and guidance, allowing the spray material to be applied more evenly; (3) provide detailed position vs time records for quality control and post spray environmental and legal challenges; (4) eliminate need for flaggers and associated safety and cost factors; (5) reduce or eliminate lost pilot time due to finding home and costs associated with returning to base for reloading and returning to the exact position where application ceased; and (6) indicate misses or gaps immediately by the applicator or operational manager allowing corrective action to be taken in a timely manner.

In general, costs can be lowered, safety improved, and efficiency increased when GPS navigation systems are integrated into FPM pesticide application operations (Thistle et al. 1994). There was substantial interest within FPM to see this technology demonstrated and to have the manufacturers and developers' claims independently verified. Demonstrations and tests held on the Ninemile Ranger District west of Missoula, MT indicated that the accuracy claimed for these systems can be demonstrated. However, a further observation was that the systems have been designed for crop work and face a substantially different set of circumstances when deployed on forestry projects in mountainous terrain. Some further development by system developers will greatly benefit forestry. This technology is making a major impact on the way in which Forest Service personnel perform various resource management tasks.

Computer Assisted Sketchmapping

The advent of GPS positioning and high speed computer based GIS systems is influencing many established, hard map based procedures. In forest health aerial survey work, it may be feasible to replace hand marking of topographic maps by the direct entry of data into a GIS system which scrolls over a map based on input from a GPS unit. This type of moving map display exists but the logistical considerations involved in integrating, installing, and operating this type of airborne system are substantial. Currently, FPM conducts an aerial survey of the national forest land annually and compiles statistics relating to infestation and general forest health. The current method is to fly at low altitude with a pilot and a FPM specialist who marks directly onto a paper map. The correct location on the map is generally found using drainages in Region 1, while Region 6 uses a regular flight path and a map grid to determine the map location. GPS and GIS technology combined now offer a possible alternative which would eliminate the encumbrances of maps in the aircraft and then reducing data off maps after the survey flight. Spatial statistics and graphics could be produced directly from the GIS. The GPS interface would also improve survey accuracy in areas where the surveyor does not have topographical or other features to determine accurate map location.

This project was initiated directly from the Regions via FPM sponsor/coordinator. The state of the technology will allow the aerial survey sketchmapping to be done more efficiently. The computer file which is produced should download directly to Forest Service Project 615 systems. The number of systems that perform similar applications is growing daily and thorough examination of available technology will be a critical part of this project (Thistle 1995a).

SUMMARY

- Engineers are available to assist field practitioners in support of forest health needs to meet advanced technical needs of natural resource managers.
- MTDC has a long-term and productive relationship with FPM, TM, and other staffs in developing forest-use technologies.
- Partnerships in technology transfer are critical to success.
- Future of the MTDC type organization is dependent, as in the private sector, upon customer satisfaction through delivery of a quality product at a competitive unit price, delivered in a timely manner.

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