Accelerating Adoption of Fire Science and Related Research

Final Report to the Joint Fire Science Program

JFSP Project # 05-S-07

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Executive Summary

Since its inception in 1998, the Joint Fire Science Program (JFSP) has funded over 350 projects. The Joint Fire Science Program has long recognized that the investments made in wildland fire science need to be accompanied by an emphasis on science interpretation and delivery. Program success is ultimately measured by how well information from research efforts is being conveyed to resource managers and end users, and whether this information is improving management decisions.

This project introduced a conceptual model for an adaptive process to improve the delivery of scientific information. We developed this process through these steps:

1. Creating a clear understanding of the existing set of knowledge, methods, and tools
2. Assessing whether these are useful and who needs them
3. Determining which scientists and managers will be helpful in the delivery process and which will avoid or resist it
4. Developing a plan to demonstrate a variety of science delivery techniques.

The overall goal was to promote organizational change through a two-way transfer of information between researchers and those who put new knowledge, methods, and tools into use. To accomplish this goal, the study undertook four distinct projects.

The first task was to create summaries of each JFSP-funded project. Each one presented a manager's perspective of the project and the applicability of the research. A total of 138 were drafted and sent out to the Principal Investigators for review. The final summaries have been posted to the Wildland Fire – Lessons Learned Center website.

The next task involved a survey of land managers from the various agencies that support JFSP, asking for their perspectives on the program and the effectiveness of current science delivery mechanisms.

The third task was a survey of Principal Investigators from JFSP asking for their perspectives on effective science delivery techniques.

We also conducted an evaluation of synthesis techniques and evaluated the proof of concept in relation to the our analysis of the completed JFSP studies

Table of Contents

Introduction

The establishment of the Joint Fire Science Program (JFSP) in 1997 substantially increased the volume of new knowledge, methods, and tools related to fire science, wildfire prevention and use, wildfire suppression, and the recovery of human communities and ecosystems from the effects of fire. Between 1998 and 2005 JFSP invested over $100 million in more than 300 fire-related research projects. The Joint Fire Science Program has long recognized that investments made in fuels management and wildland fire science need to be accompanied by science interpretation and delivery. Accordingly, the program has always required a technology transfer plan for funded studies. Program success is ultimately measured by how well critical information from research efforts is conveyed to resource managers and other end users, and whether it improves management decisions.

This study introduces a conceptual model (Figure 1) to improve the delivery of new scientific information to specialists and decision makers in management agencies and to field staff for regulatory agencies. It recognizes that adoption of new information or analytical methods (technology diffusion or science delivery) takes time. This process also provides for packaging information in ways that make it useful for people at different administrative levels (e.g., management specialists, decision makers, policy makers), and accounts for differences in the needs of federal, state, tribal, and private organizations.

Conceptual Model to Accelerate Adoption of Fire Sciences.

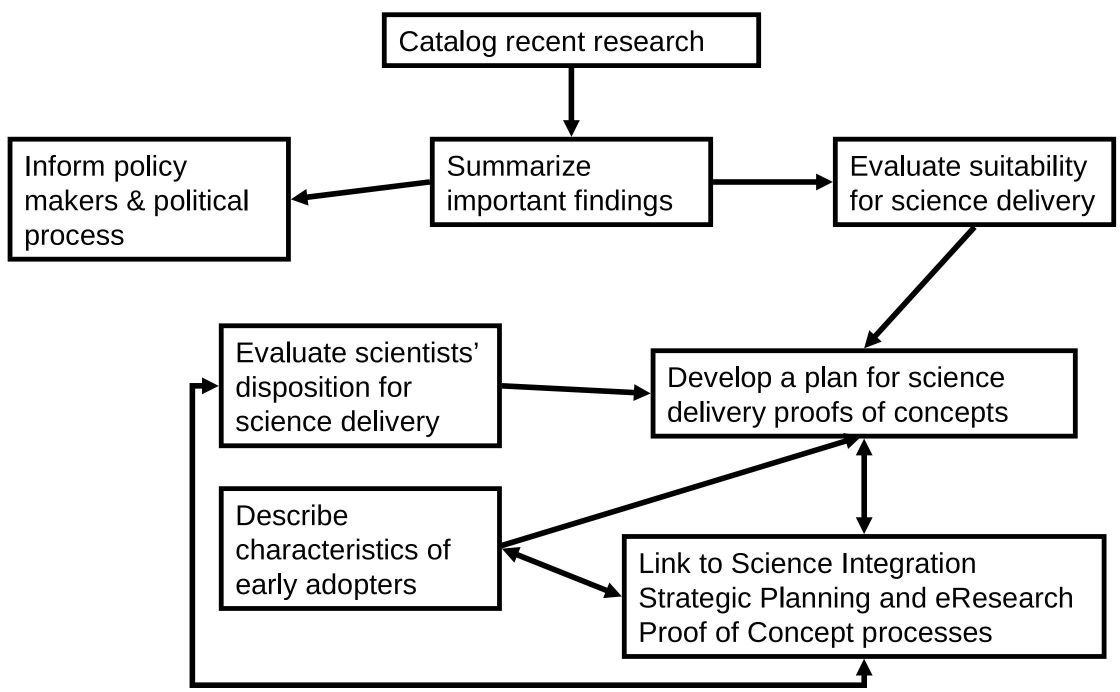

Figure 1

Incorporating the ever increasing knowledge base of science into forest policy and management creates a challenge for scientists, the public, and decision-makers (Joyce 2003). People who are overwhelmed with new information often overlook important innovations that could simplify their work. One way to improve this situation is to connect researchers and practitioners through a two-way dialogue, rather than sticking to the old model of scientists as teachers and practitioners as students. Organizational and social learning theories suggest that interactive relationships between practitioners and researchers are critical for effective learning (Hohl 2007).

Technology Diffusion/Science Delivery

Science forms the basis of many management actions. It is relied upon every day to inform and influence decisions. Therefore, getting new science and technology into use quickly is the key to the success of an applied science program. The process of disseminating information or products to clients, called technology diffusion or science delivery, can be illustrated by the knowledge pyramid (Figure 2).

Scientists are generally more interested in the building blocks at the base of the pyramid (data). When data is analyzed and presented, it becomes information. Information is then evaluated and synthesized to become knowledge, which is where practitioners focus when they make management decisions. By this time, the science is often so embedded in their analysis and so mixed with past experiences that the root of the science is no longer recognizable. In fact, practitioners do not need to examine the data at the bottom to believe the information or accept the resulting knowledge, although they do need to trust that these data and interpretations are sound. One of the major challenges in science delivery is building and nurturing this trust in the scientific basis of new knowledge.

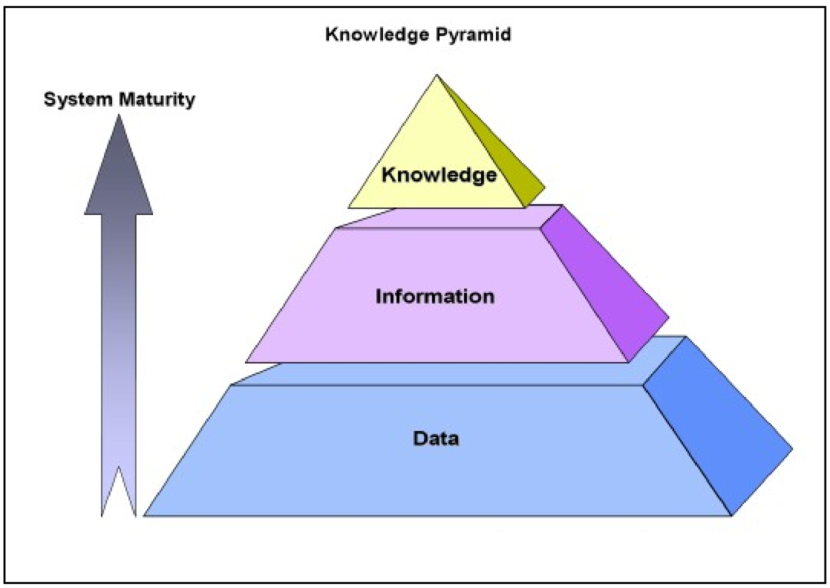

Figure 2

Over the past decade, the Joint Fire Science Program has built up a great deal of data and information. Identifying and addressing common human and technical barriers to transforming this information into knowledge can accelerate its adoption and use (Rogers 2003). This study investigates several different aspects of technology diffusion within the fire science and natural resources management communities. The work was divided into five interrelated yet distinct projects:

- Describing the portfolio of science for the Joint Fire Science Program
- Assessing how land managers assimilate new fire science
- Surveying Principal Investigators
- Examining synthesis techniques and delivery
- Examining proofs of concept

Describing the Joint Fire Science Program's portfolio of science

The JFSP has been so successful in developing new data and information that it can be a challenge to assimilate it in its entirety. We used a portfolio approach (Tartwijk et al. 2007) to summarize and catalog information about each of the more than 300 JFSP funded studies. Our intention was to organize the research and accomplishments of these studies so they would be a bit easier for practitioners to access.

Categorization of projects

We began by classifying studies funded between 1998 and 2005 according to the critical issues and priorities that guided the Joint Fire Science Plan, with a further breakdown into categories requested by practitioners. A total of 339 projects were identified, of which 306 were classified into the following themes and categories[1].

Direct Fire Science

- Fire Regimes – Projects in which the primary purpose was fuel mapping, inventory, or classification of fire-related ecosystems.
- Fuels – Projects in which the primary purpose was to evaluate and compare fuels treatment practices and techniques.
- Fire Behavior – Projects in which the primary purpose was to monitor, evaluate, or predict fire behavior variables.

Remote Sensing Technology

- Remote Image – Projects that advanced remote sensing technology supported by ground truthing and accuracy assessments to assist in development of a nationally consistent assessment of the fuels management situation.

Evaluation of Fuel and Fire Management and Environmental Resources

- Atmospheric – Fairly broad category encompassing the physical environment, including; weather, air quality, climate, and soil properties.
- Wildlife – Another broad category for terrestrial and aquatic wildlife species, including fisheries, insects, and macro-invertebrates.

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[1]The design of the remaining 33 studies did not permit classification into any of the categories yet they were unique enough not to warrant the establishment of another category. Many of the studies that were classified could have fit into two or more categories but a primary purpose was determined where possible to facilitate analysis.

- Botanical Related Resources – Projects covering a variety of plants and related systems, with a strong emphasis on the role and impact of invasives in fire systems.
- Social – Projects covering social and economic aspects and values, including public perceptions, trust, and collaboration.

Science Delivery

- Technology Transfer – Projects in which the main focus was improving how information is passed through the system. They Include database and web page development, training, and development of user or technical guides.
- Synthesis & Symposiums – Projects that dealt with gathering and distributing large volumes of information through written form or workshops.
- Decision Support – Projects that examined and enhanced decision processes.

Project awards and funding

Table 1 summarizes information on percentage of funded projects in each category and the amount of funding devoted to them. These results are also shown graphically in Figures 3 and 4.

Project Type	***Funding - $***	***% of Funding***	***% of Projects***
Fire Regimes	**$4,593,036**	**4.32**	**6.71**
Fuels	**$42,696,306**	**40.18**	**25.24**
Fire Behavior	**$8,334,214**	**7.84**	**8.31**
Remote Sensing	**$6,587,678**	**6.20**	**5.75**
Atmospheric, Climate, Soils	**$15,260,784**	**14.36**	**7.67**
Wildlife	**$7,129,504**	**6.71**	**10.54**
Botanical	**$8,619,269**	**8.11**	**16.61**
Social & Economic Aspects	**$3,045,486**	**2.87**	**4.79**
Technology Transfer	**$3,981,646**	**3.75**	**5.11**
Synthesis & Symposiums	**$606,584**	**0.57**	**2.56**
Decision Support	**$3,982,407**	**3.75**	**4.47**
Unclassified	**$1,414,233**	**1.33**	**2.24**
Total	**$106,251,147**		

Table 1: Distribution of funding and percent of project by project type or category.

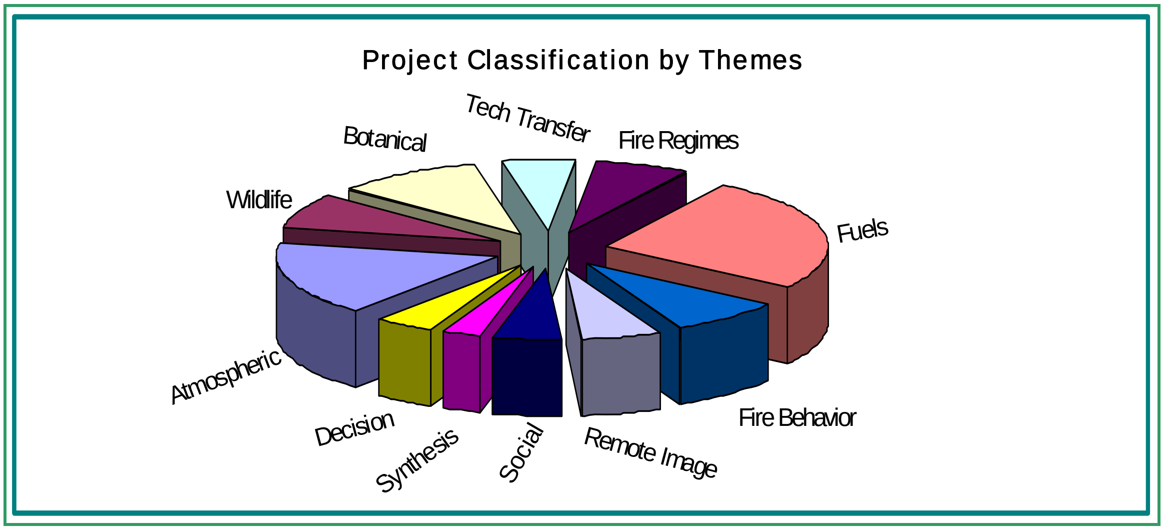

Figure 3: Percentage of projects by category 1998 - 2005.

Not surprisingly, the greatest piece of the pie went to the Direct Fire Science theme, with over 50 percent of the funding committed to the Fire Regimes, Fuels, and Fire Behavior categories. These same categories accounted for 40 percent of the total number of projects. The Science Delivery theme received the least investment. The Atmospheric category had the highest unit costs. This may reflect the amount of uncertainty surrounding these issues in regards to fire management.

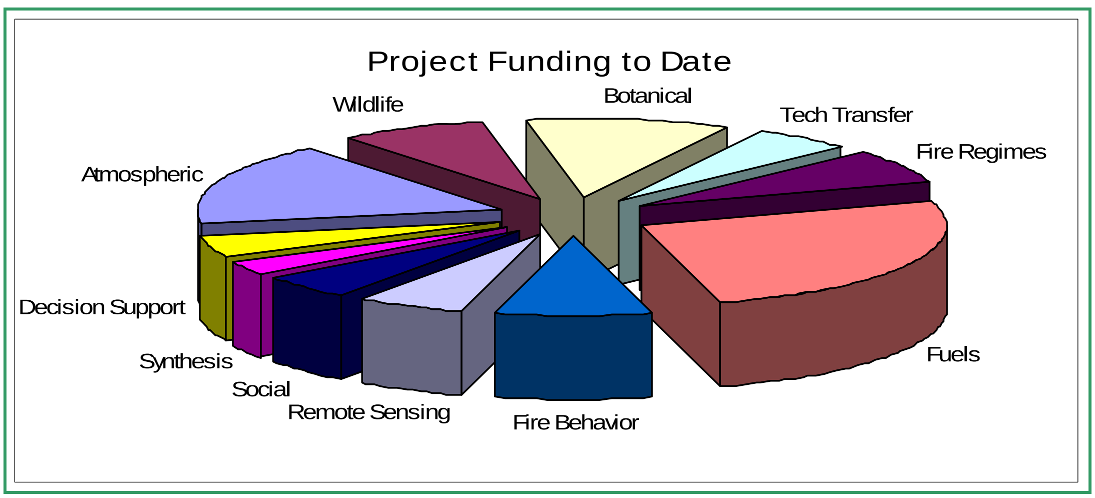

Figure 4: Percent of funding by category projects awarded 1998 – 2005.

Project summaries

A small team of scientists, managers, and a science writer reviewed completed projects and produced concise summaries for each, explaining methods and findings. In total, 138 project summaries were drafted and sent out to the Principle Investigators for review.

We received responses on 44 percent, with a better return rate for more recently completed projects. The project summaries were posted on the JFSP website to provide easier access by practitioners to the material contained in project reports and related publications. Through feedback on the summaries we realized that practitioners related better to summaries written by people with similar jobs and backgrounds to their own than they did to the summaries written by scientists. At the request of the JFSP Program Office staff and with concurrence of the JFSP Governing Board, we initiated a new study in FY07 that used a group of field level resource specialists to develop a new product known as ***Managers' Viewpoints*** and discontinued production of summaries.

The summary team also inventoried the types of technology transfer techniques used on completed projects (n=100, Figure 5). The most commonly reported techniques were fairly standard methods scientists use to share information with each other. Activities like seminars, presentations, and publications dominated, with only 23 percent of the projects using activities like field trips that might have greater appeal to practitioners. Web pages also were quite common but we did not assess their quality or how well they related to practitioners' needs.

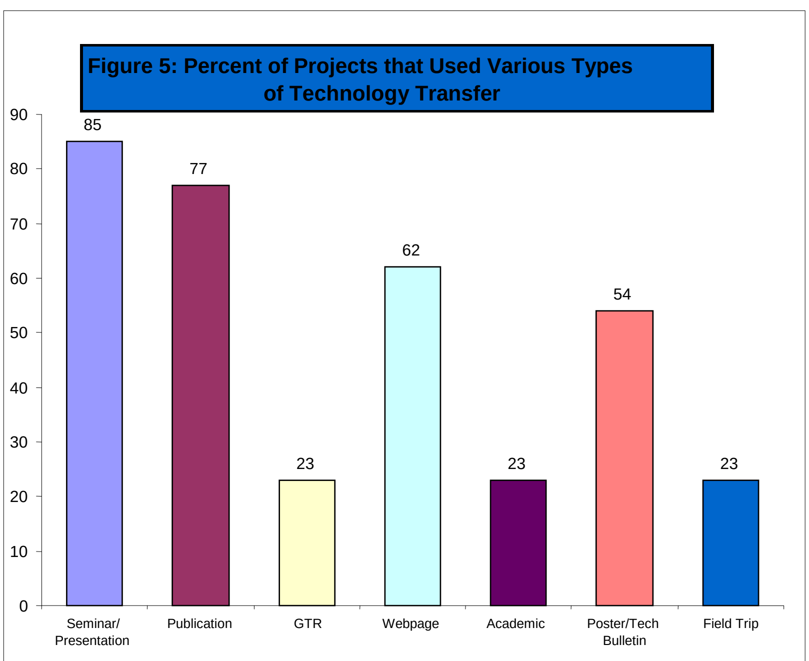

Figure 5: Percent of Projects that Used Various Types of Technology Transfer

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Figure 5

The JFSP Governing Board has been reasonably flexible in allowing PIs to adapt to the uncertainty inherent in research, and our analysis of completed studies bears this out. About 69 percent of the completed projects we examined deviated from their original set of proposed deliverables. The majority (57%) of projects that revised their expectations went on to meet or surpass their newly stated obligation (Figure 6). Overall, 62 percent of projects met or surpassed their anticipated deliverables. About a third (32 %) did not fully meet the stated expectations of the proposal. Most of these still produced high quality scientific products that were related to their primary purpose.

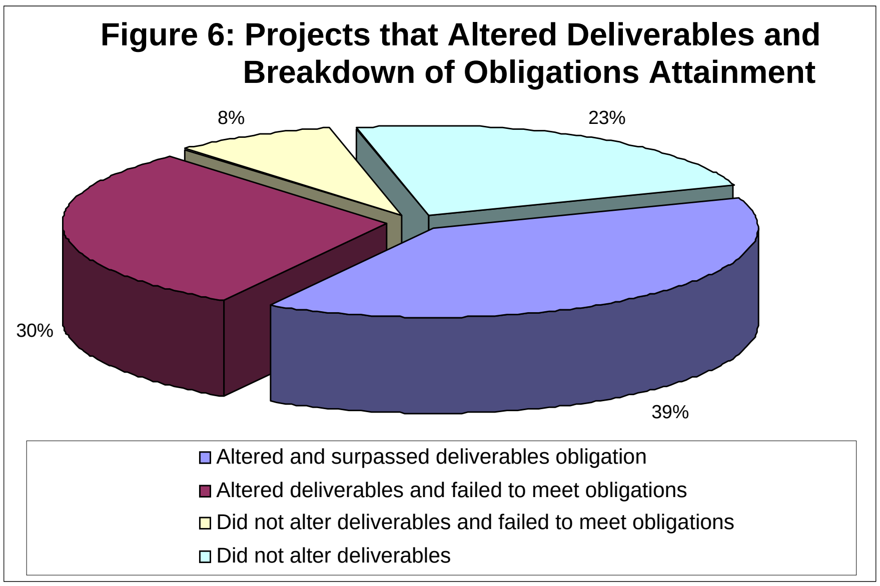

Figure 6

Conclusions for the Portfolio of Science

For the most part, the studies funded by the JFSP are producing high quality scientific information. Applying this information may still be a challenge to practitioners, as the information and knowledge is usually published in traditional scientific outlets, and many of the individual studies are not linked. This means that a field resource specialist might have to read many traditional research papers to get an idea of what the JFSP has accomplished in a particular category of work or thematic area. On the other hand, when managing a portfolio, whether of investments or of science, diversity is an important consideration. The JFSP has done a good job of diversifying its scientific portfolio and in doing so it has developed a body of science related to many of the Joint Fire Science Plan and program priorities[2]. The JFSP is now faced with the challenge of making this portfolio more useful to their customers, which will require finding ways to make it easier for practitioners to access the contents of the portfolio and adapt them to their own needs.

[2] Joint Fire Science Plan. Available on line at http://www.firescience.gov/documents/JointFire.cfm.

As the amount of new information and tools in the JFSP portfolio continues to grow, the program needs to decide what role it will play in turning this information into management knowledge and helping practitioners apply that knowledge. Making new science findings useful often requires developing applications that directly address a practical problem or issue (Figure 7). The JFSP has begun to focus more resources on synthesis products that will combine results from individual studies both funded by the JFSP and funded by other sources, and to combine them in ways that enhance their utility to practitioners.

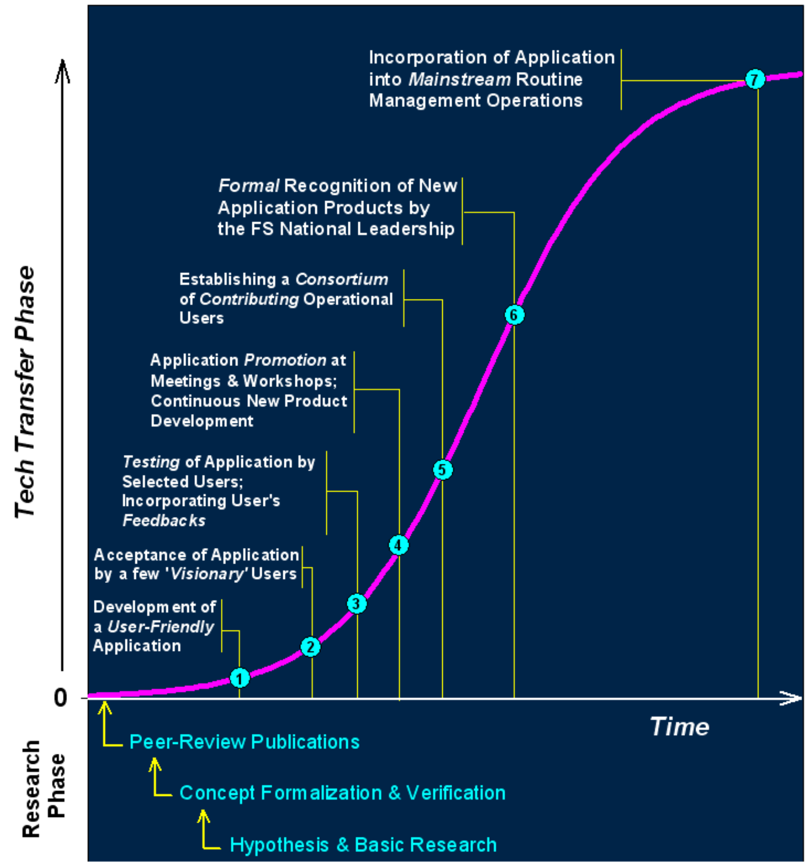

Figure 7: The science technology transfer process and its relationship to research according to the USFS Rocky Mountain Research Station.

Much of the work funded so far by the JFSP falls into the bottom two levels of the knowledge pyramid (Figure 2). It represents many individual pieces of information and synthesis is an appropriate way to aggregate this data and information into more accessible knowledge. There is, however, a more comprehensive set of JFSP-funded products that are already useful without synthesis.

Approximately 30 of the studies we reviewed either developed or enhanced the application of various fire management tools. Some of these could provide tangible benefits to users. Two examples are development and advancement in fuels characteristic and classification, such as FCCS and the Fuels Photo Series.

Overall, the projects that appear to have been the most successful with science delivery share some common characteristics. They did a good job of problem framing, which enabled research to focus on the pertinent land management issue. The work was performed in a timely manner, so it remained relevant to the audience upon completion. The information obtained through research was synthesized and presented in a way that directly addressed a management issue. A true collaborative effort existed, so the end users were involved throughout the process and may have even helped in collection of data or played other roles in the study. Communication with end users occurred throughout the process, which increased the ease of technology transfer. The internet was used as both a storehouse of information and a communication channel. Dissemination of information to larger audiences occurred through a variety of mechanisms, but there was an understanding of the hierarchical nature of the delivery systems that exists for management.

Land managers survey on fire research

Research is an important element for sound resource management decision making. Federal resource management agencies, such as those associated with the Joint Fire Science Program, spend considerable effort developing new scientific knowledge in support of the information needs of field managers. Just how well and to what degree such information meets the management decision making needs of field managers is an open question.

The purpose of this exploratory study was to inform our understanding of how field units incorporate science and research into their unit management activities. The study takes conceptual guidance from Rogers' "Diffusion of Innovations" (2003) theory by which new knowledge, information and concepts are moved or "diffused" according to a process that is characterized by (a) differences between people in terms of their stance toward adopting innovation, and (b) a five-stage sequential decision process by which individuals go from initial exposure to implementation of an innovation. Conceptual elements of Rogers' theory were used to guide the development of a protocol for conducting interviews with field-level resource managers.

Data for the study were obtained from interviews with selected individuals from a range of resource management specialties and across five resource management agencies: USDA Forest Service, USDOI BLM, USDOI NPS, USDOI F&WS, and USDOI BIA. Individuals selected for the study were drawn from four position categories: Line Officers (e.g., park superintendents, refuge managers, forest supervisors), Fire Staff (e.g., FMOs, prescribed-fire specialists), Environmental Planners (e.g., ID team leaders, NEPA specialists), and Biologists (e.g., Wildlife, Plant).

A total of 45 interviews were completed. The interview process was guided by a protocol that provided a structure in terms of probes relevant to key research questions. General topic categories included:

- Interviewee and unit characteristics
- Unit issues and decision drivers
- Sources of information
- Role of research in decision making
- Changes in resource management practices
- Accessing research
- Meaning of science-based resource management
- Knowledge and perception of the Joint Fire Science Program and its products.

A five-category model of information access and utilization was used to provide conceptual guidance for the interviews:

- *Access* – From what sources and by what pathways does science/research come into the organization? What process guides how science/research is accessed?
- *Accumulation* – How does the unit store, organize and/or accumulate science and research? Are there specific individuals or sub-units inside the organization that accumulate science or serve as internal science/research agents?
- *Aggregation* – By what means does the unit summarize or synthesize multiple pieces of research into overall, unit-relevant information?
- *Integration* – How does the unit integrate science across disciplinary lines?
- *Application* – How do management decision processes incorporate science/research? What role does science/research play in the decision processes on the unit?

Key conclusions from the land managers survey

At all levels, land and resource managers have a strong appreciation and value for the role of science and research in unit management. Capacity problems at the unit level may be a potential barrier to the incorporation of new research into management activities. The human resources needed for accessing, maintaining currency, and translating research into meaningful management direction may not be available on many units. In many units, research accumulates in the form of "core science frameworks" or bibliographies that represent key sources of information and reference used by the unit as part of, for example, NEPA documentation

Access to the printed products of research, particularly through online, centralized databases tended to be reported as high across all agencies and all specialties. Peer-reviewed journal articles and research papers provide an important link between the science and the field community. However, research papers alone may not provide sufficient direction for use in resource management decision making. Research papers and reports that aggregate the results of multiple studies were reported as an information need that remains under addressed.

Many field-level interviewees reported that the most important source for accessing research was "informal information networks" or key individuals that they know personally at, for example, the regional level. These networks and individuals tend to screen and/or select research and send it to unit-level staff those papers, studies, etc., that they believe are relevant to their information needs. Line officers tended to access research through their local resource staff members, and rarely through outside contacts, centralized databases or symposia and/or conferences.

Some interviewees reported difficulty identifying meaningful resource management direction applicable to their local unit based on written research papers and reports. Research conducted on the local unit is an important source of management information. Relevance to the local situation may, in many cases, be judged as a more important indicator of the value of research than its scientific validity. Local, "informal experiments" and other monitoring studies in the form of "little r" research often provides more valuable management information than scientist-conducted research. Interviewees tended to express a lack of confidence in extrapolating the results of research to the particular unit management decision problems they faced.

Interviewees tended to see the research interests of scientists as developing from their unique disciplinary interests and as relatively disconnected from the problems and research needs of field units. In many cases, research was perceived as being done in a context and circumstances that differ from those of a particular unit attempting to use the research for management decision making. Some interviewees indicated they did not have the knowledge to understand how these differences influence the applicability and relevance of the science to their local needs.

Direct contact with scientists tended to be mixed. Some units had little direct involvement with scientists, while others had a great deal. Problems or difficulties managing the activities of outside scientists were noted, including:

- Orienting scientists' activities toward research questions that have direct relevance for management decision making,
- Involving scientists in local unit-management decision problems,
- Managing the day-to-day activities of scientists while on the local unit.

Periodic regional-level conferences and workshops were reported by many interviewees as an important source of new science and research. Opportunities at such meetings to interact with scientists were sometimes noted as an important source of additional information.

Most interviewees were aware of the Joint Fire Science Program, though relatively few had participated as a collaborator or cooperator. However, none of the interviewees could name a particular piece of research that they associated with the Joint Fire Science Program.

There may be critical events, times and periods when science and research becomes a significant part of a unit's focus. These potentially provide opportunities for science delivery. Five categories of opportunities are identified based on the content of the interviews:

- ***Large-scale, routine planning efforts.*** These are times when significant, periodic planning cycles occur. During the beginning of these planning cycles units may seek an infusion of new science and/or to update their "core science frameworks"
- ***Project development involving NEPA requirements.*** These types of projects occur according to local planning and local opportunities. The role that science plays here is part of the justification for the EA or EIS. Periodically, if it is important enough, the local unit will want to enhance its science background.
- ***Unit transitional decisions or "meta decisions."*** These occasions tend to involve major changes in a unit's management practices. Although NEPA analyses and documentation may play a role in this transition, its significance and scope will typically go beyond that of a unit's normal NEPA requirements. In general, this is as a category of decisions involving fundamental changes to the management practices of the unit.
- ***Response to unusual or significant events.*** Units are sometimes faced with unusual or significant events. Although these events are difficult to anticipate, they often lead to a need to (a) mobilize or engage existing science, (b) also develop new science, and/or (c) focus research tightly on a geographic area, a particular set of environmental conditions, and/or a particular management problem.
- ***Monitoring and evaluation.*** Most natural resource management units engage in local research activities that support their needs for management information. In cases where local units need "consultation" and advice on how science should be applied in the field; they need the involvement of scientists and researchers to help "tailor" the science to the needs of the local unit.

Principal Investigators survey

In the USDA Forest Service and the USDOI resource management agencies (i.e., BLM, FWS, NPS & BIA), science delivery and technology transfer are elements of a systematic process in which research and field units collaborate to achieve scientifically rigorous and applicable research results. Science plays a fundamental role in resource management by providing new knowledge and techniques to field managers. Individual scientists are central to this process by contributing their expertise and science delivery skills. Research programs depend upon scientist-initiated research proposals to begin the process of creating new knowledge and delivering it to the field. The quality of the science delivery process and the usability of research results depend in large part upon collaborative partnerships between scientists and field managers that serve to define the needs of the field in terms that can be addressed through research.

But how do scientists view the science delivery process? What are their attitudes and predispositions toward science/field partnerships and collaborations? What do they perceive as the barriers and opportunities for them to engage in productive applied research relationships with field managers? Answers to these questions are critical for understanding how science delivery and science/field partnerships can be improved.

To this end, a study of scientists' views about collaboration with the field was done using a web-based protocol. The protocol contained 67 items relevant to science delivery, including (1) science/field partnership experience, (2) attitudes about the application of science to field problems, (3) professional interests and activities, (4) perceived barriers to science/field collaborations, (5) effectiveness of science delivery methods, and (6) incentives for science/field collaborations. Additional information on work location, educational background, and disciplinary specialty was also collected.

Respondents were scientists identified through the Joint Fire Science Program. An electronic letter was sent to all scientists in the JFSP database indicating that a study of scientists' experience with science delivery was being done and that they would be contacted in the coming weeks. A second electronic letter was sent on March 24, 2006, introducing the study in more detail and giving a URL to access the website containing the protocol. A follow-up reminder e-mail was sent three days later; the protocol remained accessible on the host website until April 17th, a period of approximately 3 ½ weeks. A total of 320 completed protocol responses were obtained. Almost all respondents (90.2%) held at least a Masters Degree with about two thirds (66%) holding a Ph.D. A wide number of scientific specialties were represented including Forestry (29.6%), Biology (19.2%), Ecology (17.0%), and Social Science (7.5%). Slightly under half (41.2%) worked at a Federal research station, and about a quarter (28.3%) were associated with a university. The rest were located at regional offices, research work units, Federal projects and research institutes.

Science/field partnership experience

After a brief introduction to the study, respondents were asked "Have you ever been a Principal Investigator, Co-PI, or collaborator in a science/field collaboration?" Of the total sample, 278 (86.9%) indicated "Yes." Of these, the vast majority (97.5%) indicated that the collaboration was successful in their own terms. This high level of experience with collaboration is expected, given that Joint Fire Science Program places explicit emphasis on science delivery, technology transfer, and field collaboration as criteria for project selection and funding.

The 13.1 percent of respondents who had never been involved in a science/field collaboration were given the opportunity to indicate reasons by selecting up to three reasons from a list provided. The most common reason given was "not enough funding." The next three most common reasons all related to facets of field experience, particularly "right field person hasn't come along", "right field problem hasn't come along", and "very little contact with field personnel." The least endorsed reason was "not interested in field problems."

Application of science to field problems

Respondents were asked: "How applicable is your scientific work to field problems?" Almost half (44.4%) judged their research to be "highly and directly" applicable to problems in the field. Over three-quarters (86.5%) judged their research to be either "very" or "highly and directly" applicable.[3] In general, respondents viewed the field as:

- Interested in their research (97.5%),
- Improving the quality of their research through collaboration (95.3%), and
- Having problems that are interesting to them as scientists (99.1%).[4]

The majority of respondents indicated that field personnel were able to understand science well enough to work with them (76.6%), though a moderately sizable minority tended to disagree (23.4%).

Overall, respondents tended to see their supervisors as supportive of their interests in science/field collaboration (88.8%). Most (73.4%) disagreed that they would rather work in one location than travel around, an attitude generally conducive to establishing and promoting field collaboration.

However, respondents tended to be split in how comfortable they were with "making definitive conclusions from single studies in (their) area of specialty to directly support management decisions in the field." Some scientists indicated they were comfortable making such conclusions (37.5%), but well over half (62.5%) indicated that they were not. This result suggests that some scientist respondents are less conservative than others and more willing to exercise their expert judgment in applied management situations than others.

Professional interests and activities

This module of the protocol probed respondents' experience and interest in a range of professional activities associated with science and science/field collaboration. For each activity, respondents indicated whether they had participated; if not, they indicated whether or not they were interested in participating in the future.

In general, participation rates were very high for activities associated with the science culture, such as attending scientific conferences (99.0%), working with fellow scientists to develop new

[3] "Applicable" was defined for respondents as "to what degree can (your research) be used directly to solve management problems and aid management decisions in the field without your direct guidance or involvement."
[4] All responses made on a "strongly disagree, disagree, agree, strongly agree" scale. Percentages shown are "strongly agree, agree" responses combined or "strongly disagree, disagree" combined as appropriate.

studies (96.6%), answering telephone questions about research from others scientists (91.0%), and publishing in a peer-reviewed journal (86.9%).

Participation rates were somewhat lower for activities associated with field personnel, such as receiving and answering e-mails from field personnel who want help solving a problem (85.3%), participating in a working group of scientists and field personnel to solve a field-related problem (80.6%), and giving a workshop to field personnel at a field site (59.1%).

Although most of these percentages appear high, the sample of scientist respondents represents those who have already demonstrated a strong interest in field-relevant research through their involvement in Joint Fire Science Program.

Barriers to science/field collaboration

Science and field collaborations are more likely to occur and to succeed if they do not encounter barriers. Respondents were asked to judge a number of factors that could pose potential barriers. Their top four were:

- Lack of adequate funding for field collaboration projects (77.5%)
- Insufficient time to develop partnerships with field personnel (50.9%)
- Differences in the cultures of science and the field (42.8%)
- Risks of extrapolating from a limited science base to the real world (42.8%).[5]

The lowest three perceived barriers were:

- Lack of field problems amenable to scientific solution (8.1%)
- Lack of interest on the part of field personnel in science solutions (21.3%)
- Lack of background field personnel have in scientific research (21.6%).

Setting aside the adequacy of funding, scientists in this study saw time, culture, and extrapolation risks as the major barriers to science and field collaboration. Characteristics of field personnel such as interest and ability in science, were seen as significantly lower barriers, as was applicability of science to field problems.

Incentives for science/field collaboration

Incentives play a key role in how individual scientists focus their research activities and how they use science in a field context. Scientist respondents in this study tended to view field collaborations as an important source of ideas for their research (95.3%). In addition, they tended to see field collaborations as both personally and professionally rewarding (95.9%), and of sufficient value to their career to warrant the time and effort they require (81.9%).

However, on other incentive issues respondents tended to be split:

- Slightly more than half (55.0%) indicated that doing science/field collaboration projects counts adequately toward promotion, but the remainder (45.0%) disagreed;
- Over half (58.4%) *disagreed* that the process their organization uses to make promotions decisions gives adequate weight to science/field collaboration projects compared with peer-reviewed journal publications;

[5] Percentage of respondents indicating either an "Important Barrier" or a "Very Important Barrier."

- Slightly less than half (48.4%) indicated that publishing in peer-review journals is the form of science delivery they are able to do best; slightly more than half (56.6%) disagreed;
- For most respondents (65.0%) funding for science/field collaboration was considered adequate, while for others (35.0%) it was not.

Scientist respondents were also somewhat split on how much science is needed to address field issues. A majority (60%) indicated that a cumulative body of research evidence is needed before science can be used as a basis for making sound management decisions in the field; a sizable minority (40%) indicated the opposite.

With regard to their understanding of science delivery, about half (54.7%) indicated that Joint Fire Science Program was helpful to them in knowing how to do science delivery, but for the remainder (45.3%) it was not.

Effectiveness of science delivery methods

Respondents rated the effectiveness of various science delivery methods. Almost every method presented was rated as at least minimally effective. Those judged most effective were:

- Face-to-face interactions and consultations with field personnel (95.9%);
- Scientists and field personnel directly collaborating on projects (94.0%);
- Workshops and seminars conducted by scientists for field personnel (92.5%); and
- Focused meetings involving scientists and field personnel to work on a field problem (89.9%).[6]

The least effective methods were Scientific Advisory Boards (54.4%), general scientific and technical conferences (47.5%) and papers published in peer-reviewed journals (37.4%). General Technical Reports (GTRs) and the "gray literature" were rated as more effective than peer-review journal papers (59.8% vs. 37.4% respectively).

The effectiveness of websites and web-based communications had a fairly broad distribution with about half of the respondents (52.5%) rating it highly. This result may be related to the differing content of scientists' work and its amenability to distribution and delivery via the Internet.

Conclusions pertaining to Principal Investigators survey

The Joint Fire Science Program places a high value on innovative research that has direct application to field units. The scientists who responded to this study and who were drawn from JFSP participants reflect these values in their strongly positive experience with science/field collaboration and their positive attitude toward the relevance of the field to their research. We expect that these responses represent an upper bound on the predispositions of scientists toward valuing productive working relationships with field units. This is a group of respondents who have self-selected themselves into a funding and research profile that emphasizes science delivery and technology transfer.

[6] Ratings were made on a scale of "Not Effective, Slightly Effective, Effective, Highly Effective." Percentages are based on "Effective" and "Highly Effective" responses combined.

Nonetheless, even among this homogeneous group of scientists patterns and trends emerge that have value for improving the science delivery process. Although respondents tended toward unanimity in some areas, it is clear from the results that not all scientists are the same. Distinct differences emerged in their views about the value of science and field collaborations as part of the promotion process, with approximately half expressing the attitude that too little weight is placed on this aspect of their research. This may reflect a tendency for scientists who are in the earlier part of their career to be more concerned about the panel/promotion process and their publication record than scientists who are late career. Although scientists in the study tended to be generally positive about field managers and the value of working on field problems, they also tended to be individualistic in their concerns about the risks and challenges of extrapolating from research to field problems. Differences emerged as well in the amount and kind of experience scientists have had with the field as they attempt to forge meaningful and productive working relationships, including the problems of bridging the gap between the culture of the scientific community and that of the field.

The results tend to support a conclusion that these scientists see themselves as doing science delivery according to the goals and standards of the scientific community of which they are members. For the most part, their ideas and concepts about science delivery appear to come from outside of the Joint Fire Science Program and are likely based on suppositions and generalizations that derive from broader agency or institutional values, such as teamwork, collaboration and cooperation. Graham and Kruger (2002) found that: "Those scientists who hold a fairly traditional view of science place a lower value—and thus focus less time, money, and energy—on work-related relations and collaboration. Those who have more nontraditional or alternative views of science (nonlinear, intuitive, integrative, holistic, flexible, synthesizing) place a higher value on interpersonal relations and collaboration." Because science/management interactions appear to be important aspects of successful science delivery, it appears that a scientist's view of science does affect their ability to implement effective technology transfer.

These results also support those findings from Clark and others (1998) when looking at how to integrate science with policy:

- Scientists frequently advocate the importance of specific kinds of research. Choosing one over the other is a value judgment with the result often affecting scientific capacity to support responsive public policy about complex issues.
- Scientists assert that their proposed research will do more to solve important problems than competing research.
- Scientists often disagree sharply about the implications of uncertainty. Uncertainty is a pervasive attribute of science. Regardless of whether it can be meaningfully quantified, scientists will always be faced with how to deal with uncertainty (Thompson 1986). The view one takes, however, has major policy implications.
- Some of the most important work in natural resource science involves developing unifying concepts. Examples include ecosystem integrity, sustainability, community stability, social resilience, ecosystem health, and the like.
- Considerable evidence supports the proposition that scientists may have to successfully advocate policy proposals before they will have any chance of proving or disproving their hypotheses (Latour 1987).

Whether the same pattern of responses we see in scientists drawn from the Joint Fire Science Program community would be evidenced from a sample of scientists drawn from a larger population of agency scientists and their non-Federal colleagues remains to be seen. Examination of such a study population would reveal more about (1) how scientists and science organizations see their role with respect to field management processes, (2) how characteristics of scientists influence their approach to technology transfer and science delivery, and (3) the meaning of science-based resource management as a collaborative relationship between scientists and field managers.

Examination of synthesis techniques and delivery

Effective dissemination of scientific knowledge to stakeholders and decision makers contributes to forest policy and on-the-ground management. What tools are most effective in improving the delivery process? To answer this question, we examined the effectiveness of research synopses in reaching an audience of land managers—largely program managers and/or line officers who have very limited time to invest in acquiring technical information but tend to control budget and program priorities, which in turn affect the rate of adoption or science delivery by members of their staff.

Topical themes were used to organize and classify the existing Joint Fire Science Program research projects. Approximately 275 projects were examined and assigned into seven different research categories. Many of the projects were classified as interdisciplinary and assigned two or more codes.

Table 2: Thematic categories for potential research synopses.

1	Ecology/Biology – terrestrial and aquatic
2	Social/Values/Economics
3	Fire fighting
4	Fuels and fuel reduction
5	Fire behavior/Models of fire behavior/ Historical fire regimes/Weather
6	Physical effects/Erosion/Atmospheric inputs
7	Other: Demonstration sites, Landscape models, Published volumes, Mapping, Symposia

To appeal to a broader audience of land managers we elected to focus on projects that were categorized under Ecology/Biology. We further divided this category into subcategories of soils, invasives, vegetation, wildlife, aquatic, and ecosystem processes, again assigning projects into two or more subcategories as appropriate. This classification was based on information from the proposals, and any reports available at the time. We then selected soils and invasives as our initial topics.

Based on proposals, final or annual reports, published and in press manuscripts, and information obtained directly from Principal Investigators, information was selected and distilled based on whether it was new information and on its relevance to management. To organize the information, a series of key questions on invasives and soils were posed and any project findings that addressed these questions were included in the write ups.

Conclusions associated with synopses as a delivery method

These synopses integrate findings for 15 invasive projects and 17 soil projects in a very concise and reader friendly format. Responses from the correlated Principal Investigators have been very positive: in fact, one has asked to use the Soil Synopsis in his course offering. The final versions, which are currently in review and draft, will be posted to the Joint Fire Science website and distributed to other Principal Investigators and managers. Additional work is needed to do evaluate in a quantitative sense the success of delivery associated with this tool. The Invasive Plant Species and the Joint Fire Science Program synopsis will be published as a USDA Forest Service, Pacific Northwest Research Station General Technical Report (PNW-GTR-707).

Examination of proofs of concepts

We evaluated the findings from the recent USDA Forest Service eResearch Technology Transfer proof of concept in relation to the our analysis of the completed JFSP studies. One of the major recommendations of the Technology Transfer POC concerns the recognition of the importance in organizational management decisions of shaping the outcomes from technology transfer activities. The Technology Transfer POC describes two fundamentally different approaches to technology transfer. Ad hoc or scientist driven technology transfer relies on the judgment of individual scientists about what information is ready for dissemination and who to transfer it to. This type of technology transfer is highly dependent on the scientist's personal relationships and how well each scientist can judge what is needed by practitioners. Two important aspects of an ad hoc technology transfer system are that the scientists involved develop strong personal relationships with practitioners and practitioners see individual scientists not their organizations as solving their problems.

Corporate technology transfer relies on priorities set by research managers or policy makers, often in cooperation with high level representatives of recipient organizations. It takes into account what is important to those organizations and how innovations diffuse through them. Two important aspects of a corporate technology transfer system are that it focuses resources more efficiently on problems that policy makers agree are important, and that it causes practitioners to see the organization not the scientist as providing answers to their problems.

The JFSP has relied almost exclusively on ad hoc technology transfer and this could at least partially explain the proliferation of computer models and other tools within the JFSP portfolio of science. It could also explain why so few of those tools have found widespread use among natural resource practitioners. The JFSP Governing Board, through their modeling evaluation project and adoption of Focused Lines of Work, is considering moving to a more corporate technology transfer model for some of its work. This probably makes sense for an organization that depends on annual funding decisions from its sponsoring agencies, needs to demonstrate its relevance on a regular basis, and uses what is for all intents and purposes a contract research staff with no real loyalty to the JFSP beyond their desire to continue to receive funding. By relying on an ad hoc system the JFSP tends to build support for individual scientists and their home organizations rather than for the JFSP itself.

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Appendix A-1: Crosswalk between Proposed and Delivered Activities

Proposed	Delivered	Status
Catalog of recent fire related research	Database that classifies 350 JFSP projects into one of 11 categories.	Done
Summary of Recent Research	138 summaries were completed and delivered to JFSP. They are also posted at http://www.wildfirelessons.net/Additional.aspx?Page=76	Done
	2 synposes were completed for soils and invasives.	In Press
Survey of Scientists	Survey completed. 320 responses were obtained compared to the 50 in the proposal. Publication in works: MacGregor, D., Seesholtz, D., and Barbour, J. *Scientists' Attitudinal Predispositions Toward Science/Field Partnerships: Results From A Web-Based Protocol Approach*	Paper in preparation Winter 2007
Identify managers disposed to adopt new ideas	Survey completed. Preliminary results analyzed. Paper is in preparation.	Paper Spring 2008
Proof of Concept Plan	This is related to preparing for Phase II of the original proposal. Without expectation of pursuing the next phase the plan is not needed.	Future Opportunity
Recommendation of steps for adoption	Found within Final Report	Done