

A RETROSPECTIVE FOR THE JOINT FIRE SCIENCE PROGRAM

20 Years of Wildland Fire Research Supporting Sound Decisions

"No other program has a science-wide view of fire research, and no other program delivers science across the spectrum of users in the fire and land management community like JFSP."

- John Laurence, former JFSP Governing Board member



An Interagency Research, Development, and Science Delivery Partnership



July 2019



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PREFACE

Everyone remembers their first encounter with the Joint Fire Science Program (JFSP). It could have been a science presentation at a national fire meeting, with the JFSP logo indicating sponsorship. Perhaps you were a fire ecologist or land manager on a field tour hosted by one of the regional fire science exchanges. You may have been invited as an expert to participate in one of many roundtables, sessions, or workshops held over the years to address one of the essential facets of wildland fire science. If you are lucky, you were able to listen in on a plenary session at the 7th International Fire Ecology and Management Congress, where 20 years of the Joint Fire Science Program was highlighted almost with reverence by speakers and participants.

My first experience with the JFSP came from someone sharing a review of the effects of fire on fauna back in 2002. Part of the “Rainbow Series,” it was a well-written, peer-reviewed summary of the scientific literature and useful to a refuge manager such as myself that had just come into the National Wildlife Refuge System headquarters to support strategic planning. In 2006, I went back out to the field to manage an 875,000-acre refuge complex in the sagebrush steppe. The two refuges in the complex had several big wildfires and cheatgrass was getting worse, challenging the purpose of the two refuges to provide habitat for pronghorn antelope, greater sage-grouse, and other sagebrush-obligate species. Soon after, a coalition of scientists, supported with funding from the JFSP, approached me about hosting two experimental sites on Hart Mountain National Antelope Range as part of the SageSTEP study. I was impressed with the number and robustness of its experiments across the Great Basin, its use of an interdisciplinary approach, and

strong emphasis on sharing results with land managers during and after the study with field tours, fact sheets, field tools, and webinars.

Since then, I have become far more active in wildland fire management and science. I had the privilege of joining the JFSP Governing Board late in 2014, and I continue to be amazed as I keep learning more about the program, its people, and products. The JFSP’s approach to science is a model for all, with peer-reviewed and competitively funded research proposals, continuous review and improvement in program elements and overall program management, and strategic priorities lined out with an investment strategy and supporting science plans. The hundreds of funded research projects were completed collaboratively and with leveraged resources by scientists from many federal agencies, universities, and other institutions.

A very modestly funded program, the JFSP still has supported more than 800 research projects in its 20 years, resulting in thousands of publications. The impact, however, goes well beyond the number of government reports and journal publications. The knowledge produced underpins decisions made by wildland fire and land managers, field practitioners, and policymakers every day. Students and scientists alike grow and contribute to the body of science linked to our understanding of wildland fires. The Fire Science Exchange Network brings scientists and science users together, sharing knowledge and reality from both sides. This 20-year retrospective tells a little bit of the JFSP’s story but could never fully convey the importance of the many people that contributed and the value gained by everyone involved with the JFSP during the past 2 decades.

Paul F. Steblein

Wildland Fire Science Coordinator, U.S. Geological Survey
and Chair, JFSP Governing Board



HISTORY AND EVOLUTION OF THE JOINT FIRE SCIENCE PROGRAM

What is the Joint Fire Science Program?

Program vision statement: *The Joint Fire Science Program provides funding and science delivery for scientific studies associated with managing wildland fire, fuel, and fire-impacted ecosystems to respond to emerging needs of managers, practitioners, and policymakers from local to national levels.*

In 1998, Congress officially created a joint agency and interdepartmental research, development, and science delivery partnership between the U.S. Department of the Interior and the U.S. Department of Agriculture Forest Service called the Joint Fire Science Program (JFSP). The JFSP provides funding and science delivery for scientific studies associated with managing wildland fire, fuel, and fire-impacted ecosystems to respond to emerging needs of managers, practitioners, and policymakers from local to national levels.

Historian Stephen Pyne wrote about the JFSP in his book, *Between Two Fires: A Fire History of Contemporary America*, “For the first time, wildland fire had a funding source and a mandate not tied to any single agency—total mobility had finally come to fire science.” John Laurence, a former JFSP Governing Board member, said, “The JFSP serves as an overarching group that assesses research needs, prioritizes them, and delivers funding to achieve results that change the way we manage forests, grasslands, and fire on the ground.

The JFSP provides fire, fuel, natural resource, and land managers and “boots-on-the-ground” personnel needed information on how to treat hazardous fuels,

reduce the threat of severe wildland fires, address smoke issues, plan for post-fire recovery, and restore or maintain the appropriate role of fire in ecosystems through an annual cycle of open and competitive, peer-reviewed proposal solicitations.

Science delivery is as important to the JFSP as fire research results. Getting translated research findings into the hands of managers, practitioners, and policymakers is one of the main objectives of the program. The JFSP accomplishes most of its science delivery through an organized, national network of regional fire science exchanges named the Fire Science Exchange Network, which facilitates and enhances the adoption of new research and offers outreach mechanisms. The JFSP also conducts roundtables and workshops with partners to identify critical issues that research can inform.

More than 150 colleges and universities have collaborated on and partnered with JFSP-sponsored research projects through dedicated funding via the Graduate Research Innovation (GRIN) awards and Travel, Research, and Educational Experience (TREE) grants. By engaging graduate, undergraduate, and doctoral candidates in these projects, the JFSP trains the next generation of natural resource and fire managers and fire and fuel researchers. This collaboration extends to private and nonprofit organizations and tribal, state, county, and local governments. In all, nearly 300 organizations have become partners in JFSP-sponsored research (JFSP 2007).

The JFSP is a prime example of interagency collaboration and funding and is designed to address wildland fire and fuel challenges nationwide by providing efficient, timely, and relevant scientific

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- John Laurence, former JFSP Governing Board member

results (DOI 2018). Molly Hunter, a science advisor for the JFSP, summed it up best when she said, “JFSP is unique since it is an interagency program and its mission is delivering science directly to the managers in the field for direct application. It is hard to get work funded, and having this funding agency available is unique and special.”

Developing the Program

Origins and Congressional Mandates

In 1997, the idea for an innovative fire science program materialized during a discussion while driving home from a work field trip. Jim Douglas, a Department of the Interior fire manager, and Steve Botti, a fire program planning manager with the National Park Service, were discussing how helpful it would be to have access to science-based fuel treatment plans. They discussed how science could influence policy and plan development and what actually happens on the ground.

“During our discussion, we came up with the idea of having a funding organization that would fund research on fire monitoring and fuel treatments. And I decided then and there to pitch the idea to Capitol Hill,” Douglas said. After pitching the idea, the right people believed it was a good idea for the Department of the Interior agencies and the U.S. Forest Service to be involved. “It became a joint agency effort. My role was to set the strategy, and Bob Clark [a fire ecologist with the Bureau of Land Management] took over the setup of the program and became the initial architect of the request for proposal process to get the science started.”

Nate Benson, a former JFSP Governing Board chair, described Douglas and Botti’s accomplishment, “They created a program that is more robust than anyone imagined back then. The JFSP was started by the right people, at the right time. This is rare. And the alignment will never happen again. It fulfilled a needed mission, but no one realized then its full potential.”

In 1998, Congress officially provided a more flexible funding authority to support research needed for the aggressive use of prescribed fire and fuel treatments, with the goals of reducing the occurrence of high-

severity wildland fires and improving ecosystem health. In permitting this new funding authority, Congress expressed a concern that “both the Forest Service and the Department of the Interior lack consistent and credible information about the fuels management situation and workload, including information about fuel loads, conditions, risk, flammability potential, fire regimes, locations, effects on other resources, and priorities for treatment in the context of the values to be protected” (JFSP 1998).

The “Joint Fire Science Plan,” written in 1998 to respond to congressional direction, tasks the JFSP with the following principal purposes:

- Establish and implement a comprehensive approach for fuel mapping and inventory that involves the location and condition of fuels, the appropriate treatment frequency, potential effects on other resources, and priorities for treatment.
- Evaluate various treatment techniques for cost effectiveness, ecological consequences, and air quality impacts.
- Develop long-range schedules that describe sequencing of treatments, as appropriate, such as commercial or pre-commercial thinning and prescribed fire, based on priorities and consistent with forest plan and land management plan direction.
- Establish and implement a protocol for monitoring and evaluating fuels treatment techniques in a manner that measures performance over time and that allows conclusions to be drawn about the effectiveness and consequences of fuels management activities.

The JFSP mission and budget expanded in 2001. Funding doubled from fiscal year (FY) 2000 to FY 2001. This funding growth led to additional responsibility and a broadened mission. Benson describes this increase as allowing the “JFSP to focus on the full scope of wildland fire science, as a whole.” Becky Jenison, one of only two staffers in the program office at the time, said, “It really expanded our role. It was a big deal. We soon hired a part-time

school person due to the funding being doubled. A couple years later, we were able to hire a communications director, and an IT specialist came next.” In the long run, the funding increase really changed the program.

The 2001 appropriations, split evenly between the Department of the Interior and U.S. Forest Service, also included language that further directed the JFSP to expand its research efforts in the following areas:

- Restoration of fire-adapted ecosystems
- Post-fire stabilization and rehabilitation
- Remote sensing
- Development and integration of research information for local land managers and fire, fuel, and natural resource managers

Oversight and Management

When first created, the JFSP had a 10-member Governing Board (board) that provided all final decisions on funding priorities and oversight. The board consisted of five members each from the U.S. Forest Service and the Department of the Interior. Initial board members had a background in budget and a grounding in science and land management.

The number of board members increased to 12 in 2015 and now includes representatives from the U.S. Forest Service, Office of Wildland Fire, and the following Department of the Interior agencies: Bureau of Indian Affairs, Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and U.S. Geological Survey. Representatives come from fire research, fire management, and resource management positions and have national perspectives, experience, and responsibilities. The diversity of expertise in the board helps ensure that the program takes a

balanced approach to setting priorities and making funding decisions.

The board has gone through several phases during its lifetime. In the initial years of the program, it was mainly a “working or founding” board. During this phase, the board spent their time obtaining necessary funding and getting the program started and personnel in place. In approximately 2006, the board moved into the “managing” phase. At this stage, all procedures were already in place and the program had momentum. In 2010, the board moved into its current phase—strategic. In this phase, the board is better able to plan for the future.

The program office, located at the National Interagency Fire Center in Boise, Idaho, was initially staffed by two members—the program director and the administration position. Today, the program office is staffed by five personnel in the following positions: program director, deputy program director, communications director, program analyst, and information technology specialist.

Paul Langowski, former JFSP Governing Board vice chair and member, said, “When I first got there in 2002, we were a working board which meant that we had to do a lot of the day-to-day duties of running a program. But when staffing increased at the program office, we were able to eventually transition into a strategic board when the day-to-day duties were no longer our requirement. We could really start planning then.” The board continues to be adaptive and to work with the program office to efficiently and effectively execute the program.

In 1998, the JFSP developed a set of wide-ranging task statements in response to a stakeholder meeting it sponsored with representatives from the six cooperating agencies, five additional federal agencies, the Western Governors’ Association, and the National Association of

“My career with the Forest Service spanned over 35 years and, without hesitation, I would say that my time on the JFSP Governing Board was one of the best things I did in my career. The work was extremely meaningful to me and helped inform dialog and decisions.”

- Paul Langowski, former JFSP Governing Board vice chair and member

State Foresters. This group developed about 20 recommendations for initial actions by the JFSP. In general, the recommendations focused on determining the current status of wildland fuels and fuel management programs before conducting additional projects. The board authorized the issuance of a request for proposals that contained 11 separate tasks ranging from inventory and mapping of fuels to assessments of remote sensing needs and capabilities to begin addressing some of the recommendations (JFSP 1999).

When John Cissel became JFSP director in 2006, he decided to create a research proposal form that required more indepth information and a strict deadline. “The forms were due in May and no new ones would be accepted after May. In addition, we started asking the managers what they needed studied. We worked with fire management committees as well. The board still made the final decisions, but now we were asking the right questions.” The solicitation process started presenting a clearer picture of what questions needed answers and what tasks needed to be completed. The process offered an essential balance between short-term (for fire managers) and long-term (for researchers) research needs. Laurence describes Cissel’s changes by saying, “The program director implemented a rigorous peer-review program. Through his efforts...the documentation of reviews and selection for funding became clear and easy for users to track projects from funding to completion.”

Another added technique used in the proposal review process was the addition of board breakout sessions, work groups that help the speed and efficiency of writing task statements, and the addition of using “board advisors.” Langowski describes the board advisors as “board members that would be champions of particular statements. When proposals came in for those specific statements, ready for review, the advisors would rank each one and take the highest ranked ones to the full board for consideration.”

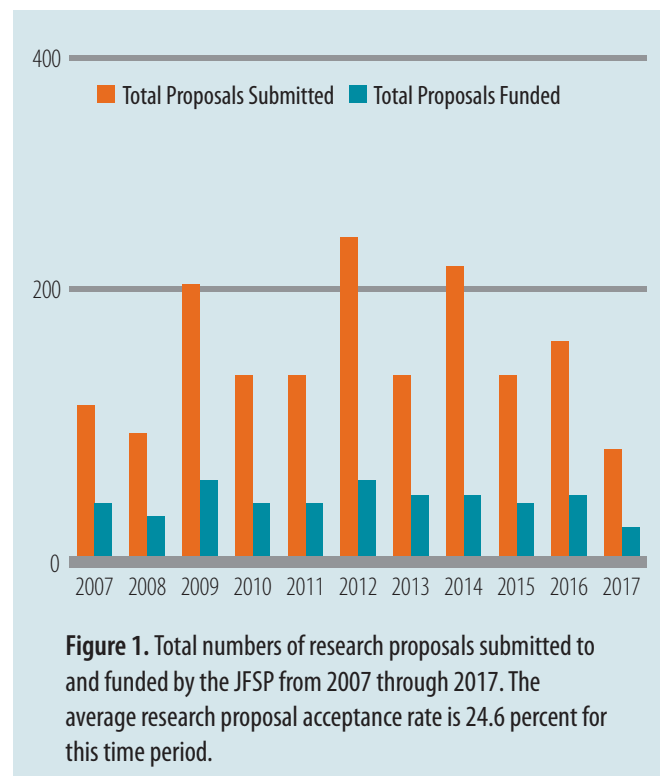
Today, the responsibility for task solicitation and processing falls to the program office. However, the board still makes the final decision on funded projects. Due to the process changes that started under Cissel and continue under John Hall, current

JFSP director, the annual solicitations are more focused, clear, and easier for users to track projects from funding to completion.

Hall said that the solicitation process was already in a good place when he arrived at the JFSP in 2016, but “I did make some small tweaks to the process. Mainly, I wanted to add more context to the proposal template by adding a technical background section. Don’t just tell me what you are going to do, but tell me why and your basis for how you are going to do it.”

The current peer review process is rigorous and completed by subject experts matched to the topic of the task statement. Figure 1 illustrates a comparison of the number of proposals that were received for funding consideration versus the number of proposals that were funded for the years of 2007-2017.

Laurence explains that as a member of the JFSP 2017 Program Review Committee, which reviews the program as a whole, he concluded that the “JFSP is on track to continue to support the highest priority research in a field where research funding is not sufficient.” To Langowski, the success of the JFSP shows itself in its “agility to react to fire



management issues in a relatively short time and have an answer/product that always comes out the other end.”

A Unique Mission

Responsive and Complementary

The strength of the JFSP has always come from its ability to listen. The program devotes an extraordinary amount of effort to listening and being responsive to the needs of the agencies it serves and the managers who implement the program’s findings (JFSP 2011b). Due to the experiences and wisdom of national and regional leaders, university and federal scientists, and managers throughout the nation, the JFSP anticipates the future needs of the fire management community and delivers research that supports sound decisions.

The need for science-based decisionmaking has always existed, but the demand for credible science information is increasing as fire and land management agencies take measures to restore fire-impacted ecosystems to healthy conditions. Today, the core mission of the JFSP is to provide leadership to the fire science community by identifying high-priority fire science research needs that will enhance the ability of fire, fuel, natural resource, and land managers to meet their objectives. The JFSP funds high-quality, peer-reviewed science proposals solicited through an open competitive process in response to research needs identified by extensive interactions with managers and leadership. The JFSP portfolio includes a balance of long-term and short-term science and science delivery and adoption activities targeted towards managers. A key part of the JFSP mission is to ensure research on wildland fire science is readily available to practitioners in a useful format so it can help support sound management decisions (LeQuire 2011).

Key elements of the JFSP’s mission are:

- Provide credible research tailored to the needs of fire, fuel, natural resource, and land managers.
- Engage and listen to clients and then develop focused, strategic lines of new research responsive to those needs.
- Solicit proposals from researchers who compete for funding through a rigorous peer-review process designed to ensure the most relevant projects are funded.
- Focus on science delivery when research is completed with an assortment of communication tools to ensure that managers are aware of, understand, and can use the information to make sound decisions and implement projects.

All JFSP research projects complement and build on other federal research programs, such as those in the U.S. Forest Service’s Forest and Rangeland Research Stations and the U.S. Geological Survey. The strength of the JFSP mission lies in its unique capability to quickly customize research and respond to the needs and issues of policymakers and fire, fuel, natural resource, and land managers (JFSP 2005, 2007).

Complementing JFSP efforts, the “National Fire Plan” also was initiated near the beginning of FY 2001 and supports management of wildland fire and accelerated fuel reduction treatments (USDA and DOI 2000). Also in 2001, the first JFSP research results were delivered. Since that time, practical research products have helped managers make informed decisions in federal and state agencies and local communities. Some of these nationwide products include the development of an index that describes the departure from historical fire regimes (Fire Regime Condition Class system); a wildland fire, vegetation, and fuel mapping system (LANDFIRE); and a fire effects monitoring and inventory system (FIREMON).

Investing Wisely

For a good portion of its early history, the JFSP had faced complex scientific and management issues. This had, at times, presented challenges to providing timely information to end users. In response, beginning in 2009, the program developed an investment strategy to help guide its research investments across a defined portfolio. The JFSP’s investment portfolio supports a range of research, such as applied research that is designed to provide managers needed information and tools within a couple of years and longer term research that must

Lines of work address complex management problems and require a coordinated multiyear approach to develop integrated solutions useful to managers. Lines of work are intended to guide JFSP investments over a period of 3 or more years.

first address the science questions underlying complex management problems.

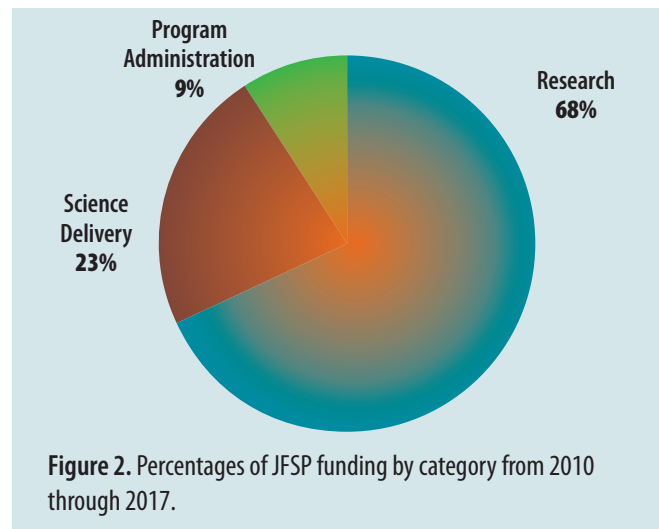
To support its long-term research investment, the program codified a lines-of-work approach to research planning that it had begun to use in 2007. Lines of work require a coordinated multiyear approach to develop integrated solutions useful to fire, fuel, natural resource, and land managers. Lines of work are intended to guide JFSP investments over a period of 3 or more years. The investment strategy for a line of work is developed by framing problems with managers and conducting subsequent planning and synthesis to develop an overall science plan. The science plans developed by the JFSP guide an integrated research approach and lead to a comprehensive and actionable set of deliverables. Some examples of lines of work with which the JFSP has been engaged include fuel treatment, smoke management and air quality, and software system integration.

Balancing Research, Science Delivery, and Program Administration

Since its origination, the JFSP has spent large amounts of money on fire and fuel research. For example, from FY 1998 through FY 2007, the JFSP spent approximately \$125 million on research to support fuel and fire management (Wright 2010). For the period 2010 through 2017, the JFSP's funding can be broken down into the following categories: science delivery, research (which includes lines of work and short-term applied research), and program administration (Figure 2). Most JFSP funding in this time period has gone toward research. Benson said the JFSP has been "effective in leveraging its dollars, helping support innovative research, and cultivating the next generation of fire professionals." Beginning in 2018, science delivery has become a more predominant portion of the funding mix.

Partners

Six different agencies are full partners in the JFSP



including the U.S. Forest Service and five Department of the Interior agencies: Bureau of Indian Affairs, Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and U.S. Geological Survey. Although agency missions are broad and varied, some issues, such as smoke management and air quality, are common across jurisdictions. The broad range and scope of agency missions require the JFSP to take broad approaches to many issues. For example, several of the agencies have designated wilderness areas. Because the use of mechanized equipment is generally prohibited in parks and wilderness areas, the JFSP must investigate multiple approaches and alternatives to fuel treatments rather than focus on selected approaches (such as mechanical thinning treatments) to meet the needs of all agencies (JFSP Governing Board 2000).

The JFSP's collaboration extends to private and nonprofit organizations; large and small universities; federal agencies; and tribal, state, county, and local governments. In all, nearly 300 organizations have become partners in JFSP-funded research. Figures 3 and 4 provide a nonexhaustive list of examples of partner organizations that are primary award recipients. Through these partnerships, the JFSP collaboratively coordinates to build capacity to meet research needs and perform outreach throughout the fire science community.



Arizona State University	University of Arizona-Tucson
Auburn University	University of Buffalo
Boise State University	University of California-Berkeley
Brigham Young University	University of California-Davis
California Polytechnic State University	University of California-Riverside
Carnegie Mellon University	University of Colorado-Boulder
Clemson University	University of Colorado-Denver
Colorado School of Mines	University of Edinburgh
Colorado State University	University of Florida
Desert Research Institute	University of Hawaii-Manoa
Duke University	University of Idaho
Eastern Kentucky University	University of Illinois-Urbana-Champaign
Florida Atlantic University	University of Kentucky
George Mason University	University of Maine
Georgia Institute of Technology	University of Massachusetts
Humboldt State University	University of Minnesota
Idaho State University	University of Missouri
Kansas State University	University of Montana
Michigan State University	University of Nevada-Las Vegas
Michigan Technological University	University of Nevada-Reno
Mississippi State University	University of New Mexico
Montana State University	University of North Carolina-Chapel Hill
North Carolina State University	University of North Carolina-Charlotte
Northern Arizona University	University of Oregon
Ohio State University	University of Tennessee-Knoxville
Oklahoma State University	University of Toledo
Oregon State University	University of Utah
Pennsylvania State University	University of Washington
Portland State University	University of Wisconsin-Madison
Prescott College	University of Wisconsin-Stevens Point
Purdue University	University of Wyoming
South Dakota State University	Utah State University
Southern Oregon University	Virginia Polytechnic Institute and State University
Stanford University	Washington State University
Stephen F. Austin State University	Wayne State University
Texas A&M University-College Station	Yale University
Texas A&M University-Kingsville	
University of Alabama	
University of Alaska-Fairbanks	
University of Alberta	

Figure 3. Examples of colleges and universities that have partnered in JFSP-funded research.



Arid Lands Project
 Business & Ecology Consulting
 Carolina Ecosystem Services
 Center for Natural Lands Management
 Ecostudies Institute
 Forest Stewards Guild
 International Association of Wildland Fire
 Independent Wildlife Researcher
 Institute for Applied Ecology
 Klamath Bird Observatory
 MacGregor-Bates, Inc.
 MarLynn Ecological Consultants
 Ministry of Forests and Range-British Columbia
 National Forest Foundation
 Native Plant Landscaping & Restoration, LLC
 Omi Associates
 Private Consulting
 Pyrologix
 Rancher Resource Management, LLC
 Resources for the Future
 Rocky Mountain Tree-Ring Research
 Tall Timbers Research Station
 Tanana Chiefs Conference
 The Nature Conservancy
 University Corporation for Atmospheric Research
 Weather Research & Consulting Services, LLC
 Western States Air Resources Council

Figure 4. Examples of nonprofit and tribal organizations that have partnered in JFSP-funded research.



A FOCUS ON MANAGEMENT-RELEVANT RESEARCH

***“The scientist is not a person who gives the right answers,
he’s one who asks the right questions.”***

- Claude Lévi-Strauss, anthropologist

The JFSP provides leadership to the fire science community by identifying high-priority fire science research needs that will enhance the decisionmaking ability of fire, fuel, natural resource, and land managers and others to meet their management objectives. The program also meets the needs of those involved in developing and implementing fire-related policy. The program’s range of stakeholders has broadened over the years along with its science mandate; however, the JFSP remains focused on actionable science and substantial outcomes that meet the needs of end users (JFSP 2018a).

“The JFSP not only helps us to accomplish research,” said Roger Ottmar, a research forester with the U.S. Forest Service Fire and Environmental Research Applications Team, “but they target research that will make a difference on how managers manage the land. They really bring a lot to the table. They develop models and make sure they are useful.”

However, even the most impressive research decreases in value if the consumer is not aware of it or does not use the project results and recommendations. Because the core mission of the JFSP is to fund and deliver research that meets managers’ needs and addresses problems associated with managing wildland fire, fuel, and fire-affected

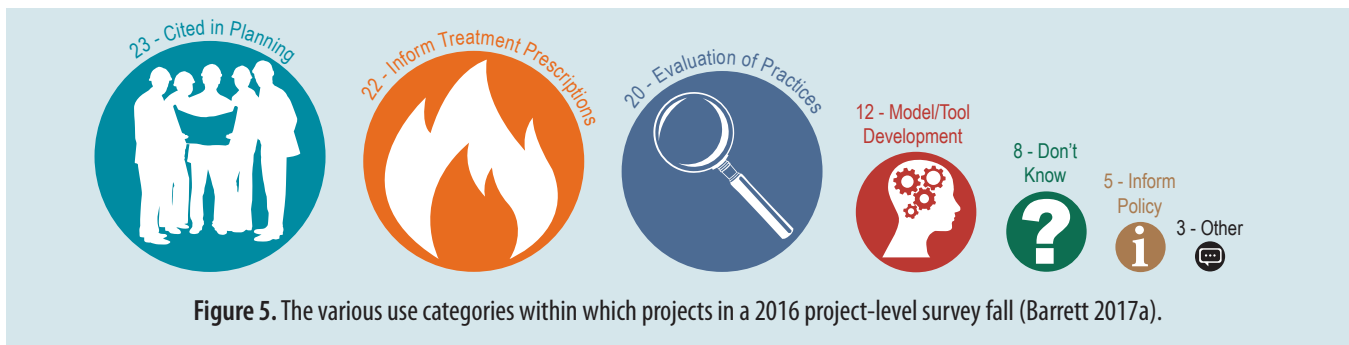
regions, the JFSP endeavors for the research to be understood and used. To date, the JFSP has awarded funding for more than 800 research projects. Even with this impressive number of completed projects, the program continues to address the question of whether funded research has successfully met the needs of the fire specialists, policymakers, and managers (Barrett 2017a).

Until about 10 years ago, the JFSP lacked detailed information about how much its fire research was used, who was using it, and how it was influencing wildland fire management decisions. The JFSP funded several projects to collect data and evaluate program and specific research outcomes to answer such key questions as: How relevant is the fire science supported by the JFSP? How many managers have been using it, how are they using it, and where? What factors influence managers’ decisions to use or not use fire science? How have outreach efforts increased awareness of fire science? Such work reflects the program’s ongoing desire to understand, monitor, and adapt to managers’ needs for high-quality, actionable fire science (Hunter 2016).

The JFSP uses adaptive management techniques to reduce the chances of its research going unused and unknown. For example, assessments funded by the JFSP provide the needed data about program

“The whole essence of what I tried to accomplish during my time at JFSP was to translate scientific information into a usable form for fire managers. I converted highly technical information into plain English and then demonstrated it, since I knew putting research into context is critical to its use. This way our science could be used immediately where it was needed.”

- Tim Swedberg, former JFSP communications director



strengths and inherent challenges with respect to science outreach and information exchange. A 2007 survey notes that managers find research that produces user guides and other tools to be some of the most useful and that managers seek out these tools (Barbour 2007). An example of a tool that resulted from specific research efforts is the “Digital Photo Series” (Wright et al. 2007; Barrett 2017a).

The manner in which the JFSP manages its investment portfolio provides another example of adaptive management in response to outcomes research to date. The JFSP has helped fund an increasing number of science syntheses in recent years, such as U.S. Forest Service general technical reports. Data syntheses sponsored by the JFSP, such as the U.S. Forest Service Rainbow Series (e.g., Ryan et al. 2012), are among the most highly valued products. Since 2006, the JFSP also has maintained a searchable database of past and current research projects on its website. The JFSP produced these and other technology-transfer tools in response to user suggestions, and these valuable tools help those seeking the latest fire science (Barrett 2017a).

On a project-level, assessments of the JFSP are highly informative. A 2008 study reviewed a sample of documents to determine to what extent JFSP-sponsored research is being incorporated into environmental analyses for fuel management-related projects within federal land management agencies. The study found that more than half of the fire and fuel management documents examined cite JFSP-funded research, mostly in relation to fuel treatment planning (Seesholtz 2008). Thus, the researchers found that JFSP-funded research is used by management on the ground.

A 2016 study found similar results to Seesholtz’s (2008) results, showing that managers tend to search

for applied science largely when it supports planning or when it informs or supports treatment practices (Hunter 2016). Fire, fuel, natural resource, and land managers and other fire professionals, as well as principal investigators, who responded to Hunter’s 2016 survey answered the question: “How has information from JFSP-funded projects been used by managers?” See Figure 5 for a breakdown of projects that fall within various use categories, including projects that are cited in planning and projects that inform treatment prescriptions and inform policy (Hunter 2016).

As a result of outcome assessment research, program managers and the Governing Board established the Fire Science Exchange Network in 2009, which provides an increasingly effective communication structure (see the section titled “Fire Science Exchange Network” in this report for more information). Recent studies (Sicafuse et al. 2011; Maletsky et al. 2015; Hunter 2016) have shown not only that managers use fire science but also that science outreach has improved since the network was established. According to Hunter’s (2016) study, “the JFSP is perceived by many in the wildland fire community as credible and legitimate and has been effective in sponsoring relevant science that has been used by managers to inform decisionmaking.”

To accomplish pertinent fire and fuel research so managers and end users can use it to inform decisions, the JFSP uses several general research methods. Several of these methods and related JFSP-funded research examples are described as follows:

1. **Case studies:** Method involving a personal, detailed, and comprehensive examination of a study subject, as well as its related background conditions. *Example:* “Effects of blowdown,

salvage logging, and wildfire on regeneration and fuel characteristics in Minnesota's forests" (Fraver et al. 2011). Results from this project guided management prescriptions intended to reduce fire risk and to ensure forest regeneration.

2. **Concept or product development:** Method that contributes to the development of products that both enhance the quality of analysis and provide valuable management tools. *Example:* "Effect of fuels treatment on wildfire severity" (Omi and Martinson 2002). Results from this study show that fuel treatment, including removal of the largest stems on trees, could be ineffective.
3. **Field experiment/data collection:** Method that applies the scientific method to test and examine variables in real-world settings rather than in laboratories. This method can add more validity to results but can have some disadvantages such as control and access difficulty. *Example:* "Piñon and juniper tree mastication effects in the Great Basin and Colorado Plateau" (Roundy et al. 2014). One management implication from this study is that shredding to reduce canopy fuels should increase ecosystem resilience by increasing returning grass cover, which is critical to withstanding weed dominance and erosion.
4. **Laboratory experiment:** Method that takes place in a controlled environment and is the main method used in the natural sciences. The method offers a controlled environment, which enables the researcher to measure precisely the effects of all variables to establish cause and effect relationships. This method may offer precise findings, but these results are coming from an artificial environment only. Many JFSP-funded research studies use both field and laboratory experiments for better conclusions. *Example:* "Masticated fuel beds: Custom fuel models, fire behavior, and fire effects" (Knapp et al. 2008). A management implication from this study is that dried crushed fuels are similar to uncrushed fuels in the same size class, indicating the process of crushing does not alter drying properties.
5. **Modeling study:** Method that aims to help make all types of fire and fire-related issues easier to understand, define, measure, imagine, or reproduce by referencing existing and commonly accepted knowledge or building on other existing models. *Example:* "Management options for reducing short and long-term fire risk in mountain pine beetle-infested forests" (Rhoades et al. 2013). This study informs management decisions based on the short- and long-term consequences of salvage logging in beetle-killed, gray-stage, lodgepole pine stands. This action will dampen the behavior and severity of potential future wildfires.
6. **Observational study:** Method in which a researcher simply observes the behavior of fire, fuel, smoke, etc., in an organized manner without affecting it or interfering. The researcher then records all observations. *Example:* "GOATS! To prevent or reduce wildland fire danger in shrub dominated wildland-urban interface areas" (Voth et al. 2003). This study found that in shrub-dominated environments, goats are effective at reducing fuels, but managers need to know that they do require additional effort due to training and fencing requirements. These animals demonstrated their ability to alter fire behavior more effectively than thinning.
7. **Syntheses:** Research documents that include a review and analysis of past and present information and research studies dealing with topics ranging from the effects of fire and extreme fire behavior to offering photos that provide a snapshot of different ecosystems for rapid assessment of fuel loads in the field (LeQuire 2007). *Examples:* The JFSP has funded several different series of these documents, including the Rainbow Series, Extreme Fire Behavior Series, and Natural Fuels Photo Series (discussed later in this section).

These and other methods are used by JFSP-sponsored researchers to conduct successful research. The following is a list of a few key research projects that fire, fuel, natural resource, and land managers and decisionmakers rely on every day:

- The **Fuel Characteristic Classification System (FCCS)** (Ottmar et al. 2005) is a software module that enables land managers, regulators, and

scientists to create and catalog fuelbeds and to classify those fuelbeds for their capacity to support fire and consume fuels. The fuelbed characteristics and fire classification from this tool provide inputs for current and future sophisticated models for the quantification of fire behavior, fire effects, and carbon accounting and enable assessment of fuel treatment effectiveness. The system was designed from requirements of land managers, researchers, and policymakers gathered through six regional workshops and supported in part by the JFSP.

- **Fire Emission Production Simulator (FEPS) (Sandberg 2004)** is a user-friendly computer program that calculates fuel consumption, emissions, and heat release parameters and is designed for researchers and resource managers. The objective of this program was to improve the usability, accuracy, and applicability of Emission Production Model software to predict air pollutant source strength, heat release rate, and plume buoyancy from all fire environments and all fuel types.
- **FIREMON (Fire Effects Monitoring and Inventory System) (Lutes et al. 2006)** is an agency independent plot-level sampling system designed to characterize changes in ecosystem attributes over time. The system consists of a sampling strategy manual, standardized sampling methods, field forms, Access database, and a data analysis program. FIREMON allows the consistent and comprehensive sampling of fire effects across all fire management agencies so data can be shared and used to update and refine fire management plans and prescriptions. In 2008, it was integrated with the Fire Ecology Assessment Tool (FEAT) (Sexton 2003) to form the FFI (FEAT/FIREMON Integrated) monitoring software tool, which is, at present, the tool of choice by the majority of fire monitoring practitioners.
- **CONSUME 3.0 (Ottmar et al. 2006)** is a user-friendly software application designed for resource managers to improve the understanding of fuel consumption in wildland fuels for shrublands, hardwood forests, and boreal forests. Land managers and researchers input fuel characteristics, lighting patterns,

fuel conditions, and weather attributes, and then CONSUME 3.0 outputs fuel consumption and emissions by category such as fuelbeds. CONSUME 3.0 allows managers to determine when and where to conduct prescribed burns or manage for wildland fire to achieve desired effects while reducing impacts on other resources.

Choosing the most relevant fire and fuel research takes strategy and planning. As discussed earlier, the JFSP uses a lines-of-work approach for program-level research and then considers past program reviews and end user recommendations for other research focus.

Program-Level Research and Outcomes

As previously discussed, lines of work are developed to address complex management problems that require coordinated, multiyear investments to develop useful solutions. The investment strategy for a line of work is developed by framing problems with managers and subsequent science planning processes. The program first asks researchers and managers to collaborate in assessing high-priority research needs, thereby creating a framework to guide research investments in a cohesive manner over a 3- to 5-year period and suggesting a future research agenda for an even longer timeframe (perhaps up to 10 years) (JFSP 2014). The program then executes the planned research through annual solicitations. For a good portion of its history, the JFSP has dedicated 40 percent of its funding to lines of work. The criteria for lines of work are as follows:

- The topic is of high priority to the fire, fuel, natural resource, and land management community and is within the JFSP's mission.
- The issue is enduring so that results obtained over 3 to 10 years will be relevant.
- The research questions have sufficient complexity that a focused, long-term approach involving a sequence of research is required.
- The need and potential of the topic builds toward a significant deliverable to improve management effectiveness.

This JFSP planning approach ensures that the initial framing of any potential line of work requires a focused definition of the scope of a problem and the advice of both managers and researchers, often using a roundtable approach. Once the problem has been defined and issues prioritized, a second step involves a thorough scientific assessment of the problem and what work already has been accomplished, followed by a prioritized sequence of research funding to accomplish the objectives raised in the roundtable. By defining broad issues of national concern, the lines-of-work approach ensures that important areas of research supported by the JFSP are coordinated (JFSP 2014). The JFSP has convened roundtables on biomass, smoke and air quality, and risk assessment. Other topics, such as fuel treatment effectiveness, were assessed via commissioned expert reviews.

Program-level research includes the JFSP lines-of-work projects focusing on fuel treatments and smoke management and air quality. Other recommended research focuses on the human dimension of fire management. The associated social science research has resulted in providing useful insight into factors including public acceptance of fuel treatments and smoke, communication strategies and planning processes to develop public support, and community fire planning.

Fuel Treatment

First Comes Fuel, Then Comes Fire

According to the National Interagency Fire Center, in 2017, the United States spent more than \$2.9 billion on fire suppression alone (NIFC 2017). It is generally understood that land management practices and indiscriminate wildfire suppression over the last 100 years have resulted in an accelerated increase of forest and rangeland fuels, though not to the same

degree everywhere. Fuel accumulation issues are extensive, and the situation has increased the potential for high-severity wildfires that are now being exacerbated by changing fire environments and increasing development in the wildland-urban interface (Zimmerman et al. 2014).

Treatment of wildland fuels to lessen the risk of severe wildland fire impacts to people, property, and valuable natural and cultural resources and to maintain and improve the health and quality of forests and rangelands is emerging as a key natural resource management process. With fuel treatment activities receiving greater attention and analysis, it is important to find ways to improve planning and operation. The importance of funding science to help understand the importance of fuel treatment and inform management cannot be overstated.

Zander Evans, the executive director of the Forest Stewards Guild, said of the JFSP's fuel treatment research efforts, "By competitively funding the best scientists (through awards) over a long period of time, the JFSP has contributed to a significant and convincing body of evidence that fuels treatment can change wildfire behavior. Importantly, the JFSP-funded research includes the nuances of when, where, how, and why specific kinds of treatment influence fire behavior. Building this scientific consensus is crucial for keeping communities and forests safe from unnaturally severe fires."

In the two decades that the JFSP has been funding research in fuel treatment effectiveness, much has been learned, and determined efforts have been made to assure that research findings are available to policymakers and fire, fuel, natural resource, and land managers. Because resources for research are limited, needs exist for careful research planning and addressing important management needs for the

Wildland-Urban Interface

From a wildland fire perspective, the wildland-urban interface is an area where human-made infrastructure is in or adjacent to areas prone to wildfire. On a community scale, the wildland-urban interface is an area where conditions can make a community vulnerable to a wildfire disaster (Hermansen-Báez et al. 2009).

future. For instance, JFSP science plans, including the “Fuel Treatment Science Plan,” are used to provide multiple benefits for management programs.

All JFSP science plans, including the “Fuel Treatment Science Plan”:

- Support planning focus for scientific efforts.
- Support JFSP objectives.
- Support the agencies that manage research and apply findings on the ground.
- Provide a basis for communication and increased collaboration with external research and management entities and the public, political, and governmental stakeholders and partners.

The JFSP-funded “Fuel Treatment Science Plan” was initiated in 2013 and completed in 2014. This plan supports the Governing Board and JFSP office in leading a national program of wildland fuel treatment research. Zimmerman et al. (2014) drafted the “Fuel Treatment Science Plan” and made sure to construct it with strategic and operational implications and to address the full scope of the fuel treatment program including assessments of

important program elements and central considerations and issues that influence and drive the program. This plan provides a detailed description of the state of fuel treatment research and identifies areas where additional work is needed. To Tom Zimmerman, senior consultant on this science plan, when written, this plan “[clarified] the current state of the fuels treatment program and needs.”

The “Fuel Treatment Science Plan” was developed in multiple phases, including: information acquisition using web-based questionnaires and interviews, information analysis, synthesis of the plan framework, and plan preparation. A second phase of the plan is ongoing to flesh out science needs associated with the fuel treatment research themes. Each research theme has an objective that provides vision and direction for the proposed work. The themes and objectives are listed in Table 1. As a self-learning program, the JFSP also intends to review, assess, and update the plan to ensure it meets the emerging needs of fuel management.

The JFSP’s “Smoke Science Plan” provided a strong template and example for Zimmerman and his colleagues while drafting the “Fuel Treatment Science Plan” and offered a necessary link between

Table 1. Research themes and objectives of phase two of the “Fuel Treatment Science Plan.”

Theme	Objective
Fuel treatment effectiveness	To develop new science and knowledge to establish viable fuel treatment effectiveness measures that (1) effectively evaluate fuel treatment programs and implementation activities in achieving both short- and long-term social, political, and ecological objectives at all spatial and temporal scales; and (2) provide ecoregion guidance to managers in planning and implementing fuel treatment projects and programs.
Ecological science	To develop new science and knowledge that provide effective, ecologically sound guidelines for regionally specific management of fuels and fire behavior based upon a better understanding of ecological responses and successional trajectories, including effects of natural disturbances and potential changing fire environments on vegetation distribution and fuel complexes.
Fuel treatment and society	To develop new science and knowledge that characterize the relationship of fuel treatments to human values; and promote improved communication and collaboration activities among governmental units, the public, and partner organizations.
Program implementation	To develop new science and knowledge that will improve planning, prioritizing, implementing, and evaluating effects of the implementation of fuel management treatments and programs, including attention to development and application of guidance and tools for managers.

fuel treatment and smoke science needs (Riebau and Fox 2010). Several other JFSP-funded efforts provided guidance, insight, and information on management implications that helped in the development of the plan as follows:

- **“Fuel treatments and fire regimes” (Omi and Martinson 2004):** This project found that the most effective fuel treatments support removal of small trees while leaving the largest and most fire-resistant trees behind. Also, treatments tend to be most effective where fire was historically most frequent. These trends suggest that the most appropriate fuel treatment applications are those that are consistent with the objectives of restoring historic ecosystems. A fire frequency model used in the study calculated geographic changes in historic fire frequencies and provides increased information for fire management objectives related to areas with frequent past fires, especially in areas where no fire history information currently existed.
- **“Synthesis of knowledge from woody biomass removal case studies” (Evans 2008):** This case study synthesis shows the importance of collaboration. Creating successful collaborative projects was found to be important since they can provide economies of scale, stimulate rural economies, reestablish natural fire areas, and reduce the risk of unexpected wildfire.
- **“Effectiveness of fuel treatments for mitigating wildfire severity: A manager-focused review and synthesis” (Omi and Martinson 2010):** The results from this synthesis document add practical support for the basic principles of fuel management that emphasize the reduction of surface fuels and the preservation of the largest trees in a stand, but also recognize the importance of opening the canopy to achieve the maximum benefits of hazard reduction. It also confirms that all treatments may not be beneficial in all locations.
- **“Synthesis of knowledge: Fire history and climate change” (Sommers et al. 2011):** This synthesis document shows how considerations for changing fire environments are important for all aspects of fire management as well as

for many other aspects of natural resources management impacted by fire. Advances and understanding in the science behind changing fire environments provide knowledge to help inform fire management about changes in historic fire activity resulting from longer, hotter, dryer fire seasons.

- **“Fire and climate synthesis (FACS)” (Swetnam et al. 2011):** This synthesis document indicates that managers need to learn to work with, not against, the time-varying influence of climate on widespread fire years. For managers, the implications are that widespread fire years are set up by local and regional climate variations and are unlikely to be controlled by local fire suppression efforts. An additional benefit of this project was a commitment to integrate climate information and support tools into the Wildland Fire Decision Support System to make the information more accessible to users.

Fuel treatment effectiveness and fire effects research has been a mainstay of JFSP research since its founding in 1998. In 2008, the JFSP refocused its efforts in this topic to investigate the overall success of fire and fuel treatments and to compare the treatment effectiveness and economics. Another area of interest is to develop a better understanding of how changing fire environments may influence treatment effectiveness (JFSP 2009b). The JFSP has funded almost 180 studies to evaluate the underlying scientific basis and effectiveness of fuel treatments throughout the United States.

Real-world examples of scientific evidence on the effectiveness of fuel treatments when subsequent wildfires encounter treated areas does exist. Fire managers have often seen crowning wildfires hit fuel treatment areas and drop to the ground. After the fire, the appearance of patches of green trees in blackened landscapes are examples of effective fuel treatments. But, as others have pointed out, fire behavior can vary for many reasons, such as changes in landscape or wind shifts (Rapp 2007).

Past studies of wildland fires burning treated areas used differing definitions, standards, and sampling designs, and many of the studies did not produce clear information on fuel treatment effectiveness and

the conditions that influenced it. However, with funding from the JFSP, scientifically sound management answers have been developed to show what happens when wildfires meet fuel treatments. Selected fuel treatment findings from JFSP-funded studies include the following:

- Appropriately designed fuel treatments substantially reduce fire intensity and detrimental ecological effects. In forest ecosystems that are adapted to frequent, low-intensity fires, the combination of tree thinning followed by the regular use of prescribed fire are most effective.
- Fuel treatments can improve wildlife habitat, increase biodiversity, and increase forage production when they are designed with these considerations in mind.
- Not all wildfires have negative impacts. A wildfire that burns under specific conditions can be an effective replacement for a fuel treatment.

The fuel treatment effectiveness line of work is positioned to complement any future science needs identified in the National Cohesive Wildland Fire Management Strategy (see the section titled “National Cohesive Wildland Fire Management Strategy” in this report for more information). This work has and will continue to produce information for a coordinated response to fuel management issues across the country (JFSP 2018b). The JFSP-funded research into different fuel treatment methods (e.g., prescribed fire, mechanical thinning, or a combination of both), along with remeasurements of past study findings and the creation of comprehensive resource guides, gives the fire, fuel, natural resource, and land management communities real-world fuel treatment implementation results.

Fuel Treatment Methods

Between 2001 and 2011, the United States spent approximately \$5.6 billion on hazardous fuel reduction to treat an average of 2.5 million acres per year across the nation (NIFC 2017). Fire, fuel, natural resource, and land managers use various treatments to reduce fuels. The most common fuel treatment

methods include prescribed fire, mechanical thinning, or a combination of both. The pace of implementing such fuel treatment methods have increased over the last several decades. As the “Fuel Treatment Science Plan” states, all of the scientific studies on fuel treatments supported by the JFSP highlight significant findings on the effectiveness of these treatments in various fuel types.

Fire, fuel, natural resource, and land managers use a variety of tools to create desired conditions within forests; the most common are prescribed fire and mechanical thinning. These two treatments may be used separately or in combination, depending on restoration goals for the forest stand.

Prescribed Fire

Reintroduction of fire to ecosystems, for the purpose of reducing fuels, is now a common management objective. Prescribed fires, or ignited fires allowed to burn under controlled conditions, are typically applied under a limited set of fuel and weather conditions. To minimize the risk of the fire escaping control, prescribed fires are often completed in a matter of hours or days. In addition, they are typically started in the spring or fall, when weather conditions allow for more moderate fire behavior and thus better control (Hunter et al. 2010).

The JFSP has funded many studies that show how prescribed fire is a successful method to reduce the amount of fuels that lead to the risk of high-severity fires and ultimately deliver valuable management outcomes. Swanson et al. (2006) found that prescribed understory fire, both alone and combined



with preburn crushing of vegetation, is the most effective method for reducing surface fuels, which can lead to high-severity fires. Understory vegetation includes the underlying layer of vegetation such as trees and shrubs located between the forest canopy and ground cover. Treatment effectiveness was evaluated using the fire modeling program Fuels Management Analyst, which provided not only fire behavior predictions but also assessments of tree-level fire severity (Swanson et al. 2006; Brown 2009). Results from this prescribed fire study could be immediately incorporated into adaptive management strategies to help managers reach fire hazard reduction goals.

Results from other JFSP-funded studies on prescribed fires show that it would likely be unwise for managers to adopt a more frequent burn schedule in changing fire environments, such as drought areas. Fraterrigo and Refsland (2016) found that in drier climates, prescribed fire may negatively impact the fitness of smaller seedlings under drought. In addition, the drier climate produced by annual burning may only make drought conditions worse. While fire suppression helps retain high shade that can improve drought stress conditions, it also results in greater light limitation for seedlings and allows fire-intolerant competitors to establish, slowing the annual growth rate of tree seedlings across all size classes. If a management goal is to increase oak recruitment as well as overall drought resilience of oak forests, then a low frequency, periodic burning schedule (e.g., 5- to 10-year return intervals) likely achieves the best balance between increasing resource availability, while also providing a large enough window for seedlings to grow into larger sizes with deep, drought-resilient root systems.

However, in eastern Oregon ponderosa pine (*Pinus ponderosa*) vegetation, Kerns et al. (2017) found that frequent reburning results in increases in invasive plant cover, decreases in cover for some plant functional groups, and decreases in total plant richness. Therefore, frequent reburning was meeting few management objectives associated with the reintroduction of fire and the restoration of fire-prone ponderosa pine forests in these regional stands. Even though the reintroduction of fire did not increase understory productivity and diversity, a common goal related to prescribed fire use, it did not

appear to be detrimental to the plant community, including spring burning. In their fire treatments, not allowing grazing in the area impacted total plant cover, although the magnitude of this exclusion may have depended on climate. One management outcome from these experiments includes the option of excluding grazing to increase understory production after fires.

In addition, managers should carefully consider several factors before implementing prescribed fire actions. Results from Wright and Vihnanek (2013) suggest that fire conditions designed to achieve a hotter fire may have the effect of retarding shrub coverage and fuel recovery. Managers should consider timing (hour, day), pattern, and method of ignition and also make sure to consider environmental conditions, including air temperature, wind speed, fuel moisture content, and fuel type.

Other studies funded by the JFSP have helped fill local knowledge gaps on prescribed fire significance to fire management plan development and implementation on lands that are managed by federal, state, and private agencies (Lafon and Grissino-Mayer 2006; Lafon et al. 2010). For example, resource managers in the southern Appalachian Mountains increasingly use prescribed fire to attempt to restore fire-dependent ecosystems and reduce hazardous fuel loads. Tools, such as Fire Regime Condition Class (FRCC) and LANDFIRE, were developed to guide restoration planning and implementation. Information about historic fire regimes and the departure of current fire regimes from historic conditions is essential for guiding and justifying management actions, such as prescribed burning programs for ecosystem process restoration and fuel reduction. Such information was noticeably lacking for the southern Appalachian Mountains, where human populations are encroaching more and more into wildland areas and where decades of fire exclusion have contributed to the decline of fire-adapted communities.

As a result of the completion of these two studies—Lafon and Grissino-Mayer (2006) and Lafon et al. (2010)—a regional network of fire chronologies in the Appalachian Mountains was developed. This network is important for several reasons. It is one of the largest forested areas, with an extensive network

of public lands, in the Eastern United States. It has a wide range of climate, terrain, vegetation, and human land uses. It also appears to provide some of the best locations remaining in the Eastern United States for finding fire-scarred trees (i.e., minimally disturbed sites where the fire-scarred trees have not been destroyed by forest clearing). These studies contribute to the understanding of the landscapes and ecosystems of Eastern United States temperate forests and offer managers the opportunity to use the results to inform their resource management plans.

In addition to traditional prescribed burning methods, the JFSP has supported the development of methods and tools aimed at incorporating the traditional ecological knowledge of indigenous peoples into standard science-based fire management (Wells 2014b). Indigenous peoples throughout the world sculpted their environment through distinctive burning patterns, developed in response to their material and spiritual needs and the ecosystem they lived in. In general, indigenous fires tended to be small, occurring sometimes yearly or twice a year (Wells 2014b). Prescribed burns using traditional ecological knowledge (the first was done in 2005) have been carefully planned to promote growth of important plants like hazel and tanoak, as well as to reduce fuels.

A project called ArcBurn aimed to quantify the effects of fire, both wild and prescribed, on cultural resources in a variety of ecological settings (Loehman et al. 2016). This project provided information critical to the integration of cultural resources and fire management decision processes. The results demonstrate that different artifact types have different responses (tolerances or sensitivity) to fire. Working with fire managers and cultural resource experts, Loehman et al. (2016) synthesized the findings into practical management guidelines for conducting prescribed burns in landscapes with ancient artifacts. These guidelines include best ignition practices that apply across sites (including nonarchitectural sites) in all vegetation types.

This research has assisted in deciding how and when to use prescribed burning as a method to reduce the amount of fuels that can lead to high-severity fires.

Mechanical Thinning and Mastication

Mechanical thinning methods are typically used to assist with fuel reduction or restoration of habitats. Treatments are intended to help fire, fuel, natural resource, and land managers avoid high-severity fires, protect people and their property, open overgrown canopy areas, and safely reintroduce fire to the landscape (Anstedt 2010a).

Several methods of mechanical thinning exist, and JFSP-funded research on this topic has helped managers discover the correct method to use in a given management situation. Understory thinning (also called low thinning or thinning from below) removes small trees from below the upper canopy layers; the smaller trees can act as ladder fuels for fires to move into the canopy. In drier, pine-dominated forests, low thinning typically favors fire-tolerant ponderosa pine, which is found in the upper canopy, and it removes fire-intolerant species (Graham et al. 1999). The trees removed are typically small to medium size (Bartuszevige and Kennedy 2009).

Ecological concerns exist in regard to thinning, such as the effect of these treatments on ecological processes, including fire, and on a wide range of animal species. To address these knowledge gaps, Coop and Magee (2016) measured vegetation and fuels and conducted bird point counts in piñon-juniper woodlands of the Arkansas River valley in central Colorado. Researchers used a suite of statistical approaches to assess treatment impacts on vegetation, fuels, and bird occupancy. Fire behavior models were also developed to examine expected



treatment impacts on fire behavior. This study found that in many other settings, such as persistent piñon-juniper woodlands, fuel treatments may not restore lost ecological functions and, instead, may move systems away from reference conditions. Researchers suggest that managers implement treatments prudently in light of persistent, negative ecological impacts that accompany woodland thinning in piñon-juniper ecosystems. Also, they encourage managers to critically consider whether or not treatments may even be necessary in any given setting. If treatments are likely to increase the presence of nonnative species in adjacent untreated stands, managers should reconsider prescribing the treatment, particularly in relatively pristine areas with no nonnative species present.

Muir and Hosten (2007) hoped to achieve a greater understanding of the effects of thinning treatments on nonconiferous ecosystems of southwest Oregon by studying plant communities and their relation to the environment such as slope, elevation, and soils. The researchers needed to gather information about the region's historical condition as well as observe how plant communities in the chaparral components of the area responded to thinning treatments. Above all, researchers sought to determine the effectiveness and consequences of these treatments—not only for the native and nonnative plant species but for ecosystem preservation and restoration. For this study, fuel reduction had been applied previously as part of routine treatments, and prescribed fire was not used. Study results indicate that compared to native perennials, native annual species respond favorably to thinning treatments. In fact, cover by native and nonnative annual species totaled more than 82 percent on thinned sites but only 44 percent on unthinned sites. By engaging in this JFSP-funded study, researchers gained a better idea of how thinning treatments affect the shrublands and oak woodlands of southwestern Oregon. This information also enables researchers to provide recommendations to managers on how to potentially reduce the expansion of nonnative species and domination of annual plant species within the herbaceous community after thinning treatments.

Managers masticate, or crush, fuels to reduce extreme fire hazards, but the impact on fire behavior

within the resulting compact fuelbeds in forests in the Interior West is poorly understood. Morgan et al. (2018) burned laboratory-based fuelbeds in one and two growing seasons after crushing and burned masticated fuelbeds in prescribed fires in one growing season after treatment in three replicated ponderosa pine stands. Researchers found that compared to fine mastication treatments, coarse treatments take less time to implement and are more cost effective. Results from this research and other projects clearly show that fires burn less intensely in masticated areas, though they smolder for longer, which can lead to soil heating and smoke. These findings support the use of masticating as a fuel treatment to alter fire behavior, especially when masticated fuelbeds burn when dry. Morgan et al. advised that masticated fuel depth should be limited to control soil heating. Where fires burn with higher intensity in masticated fuels, managers should expect trees to grow more slowly.

JFSP-funded research has offered new alternatives, clarified goals and objectives, and gathered more information for fire, fuel, natural resource, and land managers, so they can design thinning or mastication treatments that limit negative outcomes and enable greater success for ecosystem restoration where it is truly needed.

Combination Treatments

Wildland fire and fuel managers and policymakers require guidance about fuel treatment-type effectiveness, recommended amount of time between treatments, size of treatments, and area configurations to support strategic decisions about fuel management policy, planning, application, and maintenance. JFSP-funded research provides a wide-range of managers this needed information and informs on the use of combining prescribed burning and mechanical thinning to reduce fuel loading and therefore reduce the risk of high-severity fires.

In 2009, the JFSP funded a long-term study that contributed to the national Fire and Fire Surrogate Study, which was also funded by the JFSP. For this study, Bartuszevige and Kennedy (2009) assessed how ecological components or processes may be changed or lost if fire “surrogates,” such as cutting and mechanical thinning, are used instead of fire or



in combination with fire. Prior to this time, scientific reviews of literature already existed that documented the effect of fire (prescribed and natural fire) on both native and nonnative understory vegetation. However, no synthesis was available on the effects of thinning treatments on understory vegetation.

Bartuszevige and Kennedy showed that, in general, fire and thinning treatments increased the response of the understory. More intense treatments, such as combined thinning and burning treatments, and greater thinning intensity, had the highest increases in cover and production. One lesson learned from this project is that applying thinning and prescribed burning treatments in a mosaic pattern of treatment time and type across the landscape helps maintain a diversity of vegetation.

To learn more about using prescribed burning and thinning treatments together to reduce fire severity,

Prichard and Peterson (2010) evaluated fuel treatment effectiveness in the 2006 Tripod Complex Fire area. They provided strong evidence that, without treatment of surface fuels, thinning alone was not a viable replacement for prescribed fire in dry, mixed-conifer forests. In contrast, thinning followed by prescribed burning to reduce surface fuels appeared to be an effective strategy for easing wildfire severity. The results are applicable to many dry forests with low to mixed-severity fire regimes in the Western United States.

The researchers extended and expanded their analysis in another study (Prichard and Peterson 2012) on fuel treatment effectiveness in the same area, and findings suggest that prescribed burning effectively mitigated wildfire severity in a variety of harvest types and years since treatment. For managers, these findings show that lessening future wildfire severity is highly dependent on vegetation and fire area. Additionally, managing future wildfires to increase landscape diversity and resilience to extreme fire events are promising strategies at mid to high elevations.

Findings from the two Prichard and Peterson studies align with results from Omi and Martinson (2004), which highlight that thinning followed by removing branches and other residue was the most effective method for reducing fire severity, whereas thinning treatments alone failed to reduce fire severity and, in some cases, increased it. In another study, Omi and Martinson (2010) also found the importance of reduction of surface fuels and the preservation of the largest trees in a stand to lessen fire severity. They also recognized the importance of opening the canopy in order to achieve the maximum benefits of treatments. Thinning treatments demonstrated the most substantial reductions in wildfire severity, but only by those that produced substantial changes to canopy fuels, shifted toward larger trees, and were followed by controlled burning. For management, records of treatment boundaries, prescriptions, and fuel conditions are critical components of fuel treatment implementation to enable effective adaptive management.

Thanks to the many studies funded and disseminated by the JFSP, managers now have a better understanding of what a wildfire can do, what

it is likely to do, and what the odds are that it will do something unmanageable. “Those managers whom we might characterize as ‘risk-averse,’” said Tim Sexton, a U.S. Forest Service program manager for Research, Development, and Applications, “might not be risk-averse if they have a better understanding of what the real versus perceived risks are. JFSP research is providing better ways of assessing those risks. That’s the real payoff of JFSP work.”

Remeasurement Studies

Increases in high-severity wildfire in the Western United States have prompted widespread management concerns and questions about post-fire forest progression and fuel amounts. The JFSP funds remeasurement studies of previously established field experiments, plots, and surveys in areas burned by recent fire to find answers to these problems. The intent is to extend the usefulness of previous investments and capture unique opportunities provided by unplanned events. Remeasurement studies offer managers information on long-term trends that help with planning.

In one study, Smith et al. (2017) evaluated the long-term impact of forest restoration practices on soils and the mycorrhizal fungi associated with ponderosa pine on a field site in the Blue Mountains of northeastern Oregon. This site had been previously treated in 1998 and 2000 with mechanical thinning, prescribed fire, and a combination of both and was originally measured in 2014. Previous research indicated that mycorrhizal species richness, amounts of live roots, and plant levels were reduced significantly in the short-term by prescribed fire treatments compared to the nonburned treatments. After more than a decade of recovery, mycorrhizal

fungi in dry inland forests dominated by ponderosa pine returned to levels similar to the untreated areas. This research is valuable to fire, fuel, natural resource, and land managers since it provides evidence that fuel treatments seemingly have little long-term effect on ectomycorrhizal fungus and certain soil parameters, and this information improves confidence in various options for future management.

Skowronski et al. (2016) integrated field sampling, remote sensing methodologies, and numeric modeling of fire spread in their remeasurement study to test the principals and physics behind fuel reduction treatments. A large part of this study included remeasurements to directly determine the consumption of fuels during prescribed fires in three dimensions. Overall, this project contributes to remote sensing methodologies, better fire environment sampling methodologies, measurements of both forest floor and canopy fuel reduction treatments, and the identification of fundamental questions that will lead to the improvement of the Wildland-Urban Interface Fire Dynamics Simulator. The study’s findings on fuel treatment effects provide actionable and useful information for both operational fire and fuel managers and policymakers. These findings show the benefit of establishing and maintaining fuel treatments with multiple burns because of their increased effects on fuel reduction compared to the reduction amount found in single-entry burns.

In another remeasurement study, Donato et al. (2015) evaluated earlier findings from studies of the Biscuit Fire in southwest Oregon to see how they played out the first decade after the fire. From 2004 to 2006, field studies were conducted on vegetation and fuels in high-severity portions of the Biscuit Fire location. Reestablishment of tree cover is often a prime land management objective following large, severe fires; however, funding for tree planting and vegetation management over such large areas was limited during the time after the Biscuit Fire. After 10 years post-fire, researchers observed that in the unmanaged majority of the fire area, conifer establishment, survival, and growth were all proceeding well and meeting or exceeding typical objectives for density and occupancy. One management outcome that came from this study



includes information that some areas dominated by broadleaves and fire-dependent knobcone pine (*Pinus attenuata*) could be a priority for tree planting and other vegetation management activities.

Only by integrating new and historical data will researchers be able to truly answer remaining questions from managers regarding fuel treatment effects. These JFSP-funded remeasurement studies provide some of the answers.

Comprehensive Guides to Fuel Treatment Practices

Managing fuels is complex. To create fuel management consistency, the JFSP funded a series of comprehensive guides on fuel treatment practices in different areas of the United States (O'Brien et al. 2007). Over the years, the JFSP has produced more than 30 knowledge summaries for fire, fuel, natural resource, and land managers on fire-related issues. The publication series, also named the Black Series, includes the following:

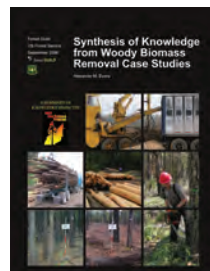
- “A comprehensive guide to fuels treatment practices for ponderosa pine in the Black Hills, Colorado Front Range, and Southwest” (Hunter et al. 2007)
- “Comprehensive fuels treatment practices guide for mixed conifer forests: California, central and southern Rockies, and the Southwest” (Evans et al. 2011)
- “Effectiveness of fuel treatments for mitigating wildfire severity: A manager-focused review and synthesis” (Omi and Martinson 2010)
- “Fire managers field guide: Hazardous fuels management in subtropical pine flatwoods and tropical pine rocklands” (O'Brien et al. 2007)
- “Synthesis of knowledge from woody biomass removal case studies” (Evans 2008)
- “Synthesis of knowledge of hazardous fuels management in loblolly pine forests” (Marshall et al. 2008)

In these guides, JFSP-funded researchers present existing knowledge from peer-reviewed literature and administrative studies and provide local knowledge gathered through a series of discussions with fuel treatment practitioners. The guides describe specific fuel treatments, the circumstances under which they could be applied, and treatment effects. They also provide recommendations related to where, how, and the frequency fuel treatments may be prescribed to achieve desired outcomes. Desired outcomes address social, political, economic, and ecological factors (Hunter et al. 2007).

Real-World Results of Fuel Treatment Implementation

JFSP-funded research shows how planning and implementation of fuel treatments and wildfire management strategies effectively reduce the risk and occurrence of high-severity fires. The following are real-world research results of fuel treatments (JFSP 2018b):

- **Tripod Complex Fire:** When the 2006 Tripod Complex Fire in Washington spread through untreated areas and areas treated with thinning only, it killed most of the trees in its path. However, in areas treated with both thinning and recent prescribed burning of surface fuels, most of the trees survived.
- **Appalachian Mountains:** Following prescribed fires in upland hardwood forests in the



Appalachian Mountains, small mammal and bird communities were either unaffected by the treatment or showed increases in abundance and number of species. As a result of this 2001 study and similar studies, fire managers increased the use of prescribed fire in the Appalachian region the last couple of decades.

- **Patch-Burn Grazing:** Rotations of prescribed fire and grazing, or “patch-burn grazing,” in grasslands can enhance biodiversity and improve livestock production. As a result of JFSP-funded research on this topic and similar studies, patch-burn grazing is commonly practiced worldwide.
- **Miller Fire:** The 2011 Miller Fire in the Gila Wilderness in New Mexico was allowed to spread with minimal suppression efforts. This fire produced beneficial effects by reducing fuels and limiting the spread of subsequent wildfires. Research from this area, which shows the beneficial effects of wildfire burning under moderate conditions, has led fire managers to adopt fire suppression strategies that allow the spread of wildfire under certain conditions.

Smoke Management and Air Quality

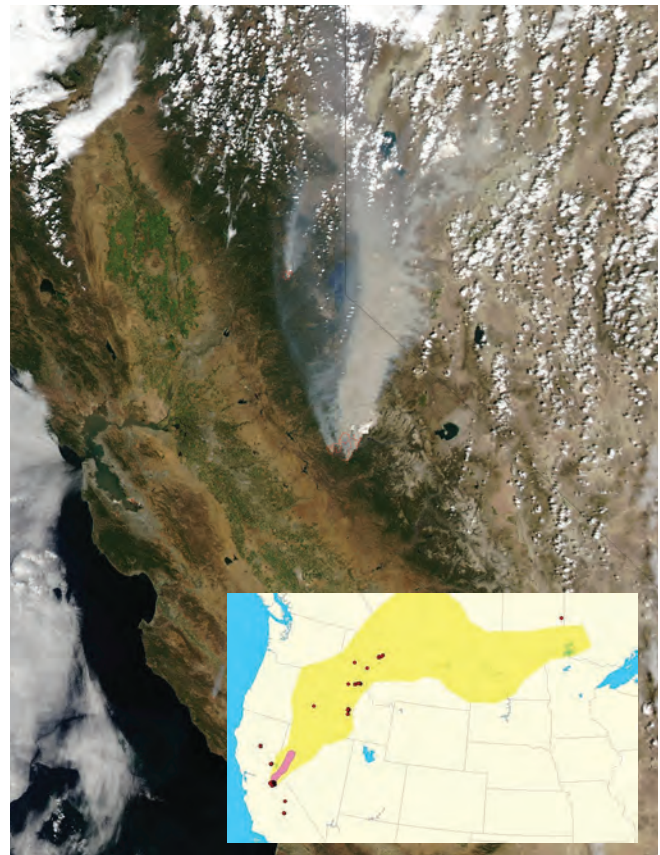
Where There's Fire, There's Smoke

Wildland fire smoke in the United States has been a controversial issue for air quality and fire management since the 1970s. Historically, the main air quality standard of concern has been particulates. However, other concerns include visibility for traffic safety and local haze. Current smoke management issues include adverse health effects to the public, long-term impacts on firefighter health, and smoke and changing fire environments (JFSP 2014).

Fire, fuel, natural resource, and land managers face increasingly steep challenges in order to meet air quality standards while planning prescribed fires and their inevitable smoke emissions. The goals of sound fire management practices, including fuel treatments through prescribed burning, are often challenged by the need to minimize smoke impacts on the public. Wildfires, of course, also produce smoke, so managers must constantly weigh the benefits and risks of prescribed fires against potential wildfires and must communicate those benefits and risks to

the public. Moreover, research on and the modeling of smoke emissions from fire is a rapidly evolving field. The JFSP has identified smoke management and air quality as a top priority area of research since the program started (LeQuire and Hunter 2012).

All wildland and prescribed fires produce gases and aerosols that influence air quality. The extent of their effects depends on fire size, fuel type, and the characteristics of the fire events themselves. Smoke is composed of hundreds of chemicals that undergo complex chemical reactions and transformations and includes critical pollutants such as ozone, nitrogen dioxide, and particulate matter, as well as other compounds of concern including carbon monoxide and dioxide, nitrogen oxides, and volatile organic compounds (Delwiche 2011). The JFSP smoke management line of work helps communities and managers predict and ease the impacts from these wildland and prescribed fire smoke emissions.

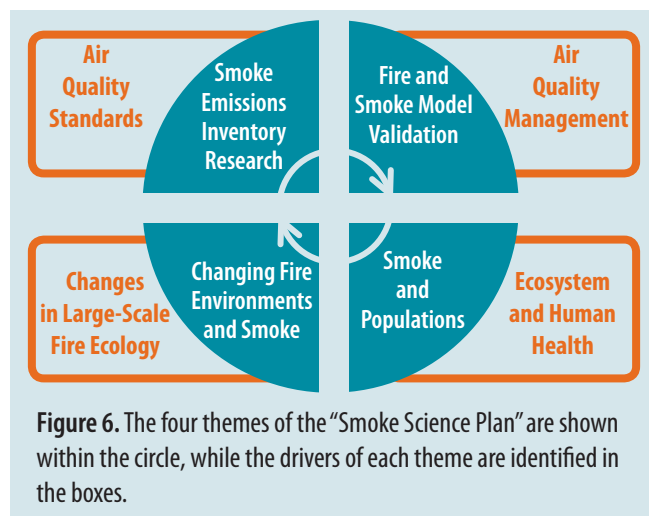


This satellite photo shows the extent of smoke deposited hundreds of miles away from the Rim Fire in California in 2013. However, the impact of the smoke emissions was felt across a much wider area of the Western United States and several Canadian provinces.

In 2007, the JFSP conducted a wildland fire smoke needs assessment and hosted two parallel roundtables (in the Eastern and Western United States) in which managers and researchers developed two lists of priorities. The outcome of the roundtables was then placed into a historical and regulatory context and synthesized into a cohesive national smoke science research plan. The resulting “Smoke Science Plan,” drafted by Riebau and Fox (2010), provided guidance for funding smoke research from 2011 through 2016.

Early in the process of developing the “Smoke Science Plan,” Riebau and Fox addressed the community of interest through a series of web-based questionnaires. Almost 900 people responded to the questionnaires, which, it is believed, was the largest and most diversified set of responses to smoke research needs ever collected in the United States. The completed plan also includes a series of meetings and interviews (JFSP 2011b).

Once the plan was developed and approved, it helped guide the funding and management of research and development projects under its four thematic areas: smoke emissions inventory research, fire and smoke model validation, smoke and populations, and changing fire environments and smoke (Figure 6). Since the plan’s inception in 2011, it helped guide the funding and management of 41 research and technology development projects (JFSP 2018e). Examples of several JFSP-funded smoke science research projects that further the themes of the “Smoke Science Plan” follow.



Research Theme 1: Smoke Emissions Inventory

Smoke emissions inventory research was completed to address the science needed to support an accurate national wildland fire emissions inventory system, improve emission factors, and apply improved emissions inventory tools to evaluate fire’s contributions to negative air quality (Riebau et al. 2017). A smoke emissions inventory accounts for the contribution smoke makes to the amount of specific chemicals in the atmosphere. An emissions inventory accounts for all smoke, including smoke from agricultural burning, prescribed burning, or wildland fires. In general, an inventory may include a number of variables, such as timing of burn, chemicals involved, and fire type. Inventories are constructed from “emission factors” which are the amount of the specific chemicals released into the atmosphere divided by the amount of “fuel” consumed by the fire.

JFSP-funded laboratory and field studies by Collett et al. (2013) and Benscoter et al. (2015) measured emission factors for prescribed fire and other fuels. They found that fine particulates in wildland fire smoke affect visibility and health. Since fine particle mass increases in smoke, managers need to weigh the effects on human health and visibility when considering the air quality impacts of fire management strategies.

In addition, Collett et al. (2013) and Kreidenweis and Pierce (2017) studied the complex nature of carbon emissions and their role in generating secondary organic aerosols. New understandings led to new chemical mechanisms for modeling smoke impacts on air quality. These mechanisms are currently being used in ongoing modeling studies on particulate matter and secondary organic aerosols. These studies indicate that modeling the impacts of fire on regional particulate matter and ozone, especially for some regulatory applications, must properly account for organic aerosol emissions and chemistry by the managers. Management outcomes from these studies benefit air quality modelers and fire, smoke, and air quality managers.

Also, Moore et al. (2013) and Moore (unpublished data) evaluated the relative contributions of fire smoke to ozone and particulate matter, respectively,

in the country and produced a ranking of counties where fire is most likely to contribute to exceeding the national air quality standards. The researchers developed tools that are currently being used at state and local levels to help in the air quality planning process (Huber et al. 2017).

Research Theme 2: Fire and Smoke Model Validation

The objective of this research theme was to identify the scientific scope, techniques, and partnerships needed to objectively validate smoke and fire models using field data (Huber et al. 2017). Completed projects address: (1) weaknesses in existing smoke models and data necessary to improve them, (2) the mechanisms of plume rise and superfog formation, (3) datasets and a framework that compare existing smoke model performance, (4) the smoke consequences from both low- and high-intensity burns, and (5) the groundwork of the development of an interagency plan for collecting field data for a multiyear series of field experiments.

One JFSP-funded study that benefits this research theme involves the Smoke and Emissions Model Intercomparison Project (SEMIP) (Larkin et al. 2012). By field testing fire and smoke models through post-fire scenarios, researchers verified that additional and better data were needed to evaluate the models. Researchers, managers, and policymakers needed information on how different model choices affected the resulting output and guidance on what choices to make in selecting the models that best represented their management requirements. SEMIP was designed to facilitate these comparisons. This project led to improvement in emission and smoke dispersion estimates.

Fire and smoke model evaluation and validation require multiple scientific disciplines and datasets. It became clear that to improve fire behavior models, which are an essential component of smoke modeling, work had to move to experimental fires of larger sizes, higher fuel amounts, and elevated burn intensities from previous efforts. Brown et al. (2014) found that for smoke modeling itself, such field work must also involve complex fuels with greater fuel amounts (than the grasslands previously studied) and higher intensity fires.

Superfog, a condition in which smoke and fog mix and reduce visibility enough to cause safety hazards, was researched by Princevac et al. (2013). This study made advances in understanding the atmospheric conditions necessary for such events to occur. A management outcome from this study includes information on the design of the Superfog Analysis Model (SAM), which assesses situations as favorable or unfavorable to superfog formation. To identify the specific location of superfog, SAM is coupled with other models, such as PB-Piedmont. This work was complemented by other studies, such as Heilman et al. (2013) and Strand et al. (2013), on low-intensity smoke dispersion.

A management outcome from these studies includes the finding that the potential for unwanted smoke impacts could be reduced by ending ignition earlier in the day. This allows for more mixing and movement of smoke away from the forest floor and lessens the amount of smoke trapped under the forest canopy.

Research Theme 3: Smoke and Populations

The purpose of this research theme was to determine the impact of wildland fire smoke on population centers and fire workers, as well as to clarify the mechanisms of public smoke acceptance in light of the needed balance between human smoke exposure risk and ecosystem health risk (Riebau et al. 2017).

The first objective of this research theme was to address the health impacts of wildland fire smoke on firefighters and the public. Gilmour (2018) investigated the toxicity of smoke emissions, marking the first research on cardiopulmonary toxicity and mutagenicity (or the ability of a chemical to cause permanent changes in DNA) from wildland fuel emissions. The findings prompted the Environmental Protection Agency to undertake further research into the effects of fire emissions on pulmonary function and toxicity, neurobehavioral changes, and cardiovascular function and toxicity from inhalation exposure of smoke.

Reich (2018) is in the process of characterizing the health and economic burdens of wildland fire smoke, representing the first attempt to quantify these data

“One of the reasons we study fire science like we do is because of the JFSP. They have built a great community of scientists, managers, policymakers, etc., that all work together.”

- Stacey Sargent Frederick, California Fire Science Consortium statewide program coordinator

across the continental United States over multiple years. Preliminary results find that although effects differ from year to year, wildland fires pose a significant burden to public health on an annual basis. Populations in California, Idaho, Oregon, Louisiana, and Georgia are most affected (Riebau et al. 2017).

Domitrovich et al. (2017) closely examined smoke exposure as well. The researchers began the study by combining a comprehensive literature review with extensive smoke exposure concentration data for wildland firefighters to estimate health risks specific to wildland fire smoke. Information from the literature review led the researchers to conclude that more research is needed on acute and longer term effects of wildland fire smoke exposure. The health effects experienced by wildland firefighters were largely unknown.

The second objective of this research theme focused on the public’s perception and tolerance of smoke. The JFSP funded three projects that represent the only existing social science research on wildland fire smoke for the United States. Hall et al. (2015) confirmed that effectiveness of public smoke messaging increases when the background of the audience, including the types of vegetation they are familiar with and past experiences with fire, align with communication goals. Research results provide managers with a framework from which to shape public engagement strategies based on building and maintaining agency trust and reinforcing beliefs about ecological and community protection benefits of prescribed fire practices. Results also identify the importance of being sensitive and proactive about regional and community perceptions of smoke impacts, especially those related to health impacts (Huber et al. 2017).

In addition, Toman et al. (2014) and Olsen and Frederick (2014) found that the two strongest

predictors of public tolerance of smoke from wildland fires are the public realizing the benefits of prescribed fire and the level of the public’s trust in local fire managers. These findings help frame wildland fire smoke messaging to the public. The findings also show that, for managers, careful consideration of the alternatives and the impacts of smoke remain a vital part of the planning process. Creating a system that readily incorporates these findings into management activities helps with future implementation.

The third objective of this research theme was to determine how to use information on health effects and public perceptions of smoke to develop public health smoke messages during large fire events (Riebau et al. 2017). To determine the best means of communicating smoke hazards to the public, the JFSP funded three collaborative projects to develop an operational smoke hazard warning system (Malm and Schichtel 2013; Jerrett 2018; Larkin 2018).

Research Theme 4: Changing Fire Environments and Smoke

The purpose of this research theme was to develop an understanding of the implications of changing fire environments on wildfire smoke and of wildfire smoke on changing fire environments using the United Nations Intergovernmental Panel on Climate Change emissions scenarios for guidance. One of the most important issues facing forest management today is changing fire environments. Research under this theme addressed black carbon generated from fire smoke, potential impacts from large fires on big urban areas, and simulation of future smoke impacts in future potential climates (Riebau et al. 2017).

In support of this theme, research was funded by the JFSP to find the amounts of potential contributions of fire smoke to ambient black carbon concentration and deposition in the Arctic and other regions.

Results from Larkin et al. (2011) and Chung et al. (2015) calculated: (1) fire emission's contributions to the black and brown carbon components of particulate matter and (2) source regions and meteorological situations leading to black carbon deposition. Larkin et al. (2011) provided findings and data on transport timing and injection heights to the Environmental Protection Agency for consideration in its "Report to Congress on Black Carbon" (EPA 2012). This study also provides information on preferable months for burn activities to land managers interested in lessening Arctic black carbon effects. Chung et al. (2015) simulated potential black carbon deposition patterns in the Northwestern United States. Managers and policymakers can use spatial maps provided by the researchers to identify locations and months for mitigation efforts.

Two additional research projects, Liu et al. (2014) and Larkin et al. (2015), estimated the potential for future large fires and their impacts, especially on urban areas. Based on Liu et al. (2014), a new model was developed to help predict large fire occurrence that better accounts for the extreme weather conditions associated with such fires. Results of Larkin et al. (2015) provide weather maps that offer a near-instant assessment of the potential for regional smoke impacts that are easily convertible into a simple assessment utility tool for regional area commands.

Overall, JFSP-funded smoke research has impacted fire, fuel, natural resource, and land management in significant ways. For example, research findings contributed to the BlueSky modeling framework (a modeling framework designed to predict cumulative impacts of smoke from forest, agricultural, and range fires), the "NWCG Smoke Management Guide for Prescribed Fire" (NWCG 2018), and improvements in the Environmental Protection Agency's triannual National Emissions Inventory and state smoke management plans.

In 2017, "A Compendium of Brief Summaries of Smoke Science Research in Support of the Joint Fire Science Program Smoke Science Plan" was released as part of the conclusion and wrap-up of the "Smoke Science Plan." This document (Huber et al. 2017) provides summaries and research results about each of the JFSP-funded projects under the plan.

Human Dimensions of Fire Management

JFSP-funded social science studies, which were recommended as a renewed focus after the 2008 program review, revealed what the public knows and thinks about fire and fuels and their management agencies. This research helped discover keys to successful communication in instructing the public and building support for all fire and fuel plans and programs (McDaniel 2014).

Communication is an important part of social science and science delivery. Communication between scientists and all management communities must occur to promote awareness of scientific information and products. Researchers have found, however, that communication often leads to misunderstandings, which then delay the acceptance of new ideas. Researchers have suggested that people are most likely to interact with others who they most identify with, based on personal and social characteristics, work experience, and educational background. Any differences may lead to misunderstandings about goals and intended messages.

Wright (2010) suggested after her study that science communicators were more successful if they kept in mind the intended audience for the communication. For example, all information on fire improvements and fire research should be tailored to the fire, fuel, natural resource, and land management communities as well as policymakers, stakeholders, and the public (Anstedt 2010b). People tended to let



personal beliefs and attitudes (i.e., positive or negative feelings about people, objects, or issues) dictate how open they were to new ideas and scientific discoveries. These attitudes greatly influenced personal behavior and decisions, such as whether to experiment with new approaches.

“The adoption of research products is a complex process that takes time. Research relevance, while critical, is just one factor that influences whether and when research is used. By better understanding individual managers’ perspectives on using research and on working with scientists, science communicators can tailor delivery to be more effective with different groups of potential users,” said Wright.

To improve science delivery and application, Wright (2010) recommends increases in scientist-manager interaction. Personal contact through small workshops, field trips, demonstration sites, and interpretive programs was the most effective way to reach people and change attitudes. Since the completion of Wright’s (2010) study, the JFSP’s Fire Science Exchange Network significantly increased these types of interactions and communications (see the section titled “Fire Science Exchange Network” in this report for more information on the types of communication and interaction approaches) (Anstedt 2010b).

Research surveys found that public acceptance of fire and fuel management activities increased when a community had trust and confidence in the responsible agencies and individuals applying the treatments (McDaniel 2014). Shindler et al. (2009) found that the most common reasons given for increased trust were improved personal interactions, increased fuel reduction activities, and successful suppression of recent fires. Bruce Shindler, principal investigator, said of his findings, “Getting everyone together to work on fire solutions is important. It is important to build trust between the public, agency personnel, and land managers. Everyone is concerned with wildfire, whether you live near public lands, forests, farmland, or other open spaces.” Several fire and fuel management outcomes from this study include capitalizing on existing public awareness and support, tailoring outreach programs to the local level, focusing on relationships with local

citizens, and emphasizing trust-building. One JFSP-funded project captured the views of trust with communities from the perspectives of fire and fuel experts, with an international-level comparison of views. The first JFSP-funded international project, Shindler et al. (2014a), met the following two goals: (1) examine fire and fuel experts’ perspectives on trust, how it developed, and actions that promoted trust between community members and agencies; and (2) develop a planning guide for fire and fuel experts and agencies that addresses trust in fire-susceptible communities. To accomplish these goals, workshops were conducted with experts in the United States, Australia, and Canada. The research team included social scientists with considerable fire research experience in one or more of the study nations. At each site, they completed semistructured workshops to collect nonnumerical information about trust between agencies and communities in a fire management context. Several key findings from this research include:

- Trust is highly relevant to management agencies, and fire and fuel experts believe that trust is critically important to accomplishing their work.
- Trust in management situations is complex and, since it is dynamic, it does not have an end point.
- Trust operates at many levels and in many directions.

Researchers realized that how people and communities prepared for and responded to fire was greatly influenced by trust between the local community, the agencies, and fire and fuel experts responsible for managing fire and reducing fire risk. Shindler said, “We did find that the best work gets done at the local level. Local people solving local problems.” He went on to say, “Relationships matter. With better relationships comes better communication. Agencies can’t do everything themselves, they need local help.”

The planning guide completed as a result of this research is titled “Trust: A Planning Guide for Wildfire Agencies and Practitioners.” It represents a collaborative effort by researchers and fire and fuel experts from all three countries. This guide is very popular among the management community. It

clearly discusses and provides examples of the three main elements to building trust: ability, goodwill, and integrity. In addition, the guide includes trust-building assessment tools that management agencies and experts can use to assess their own situations (Shindler et al. 2014b).

Other JFSP-funded human dimensions research focuses on the economics of large wildfires. The purpose of this research was to fill the gap of knowledge on fire suppression and local economies to help fire, fuel, natural resource, and land managers and policymakers and community leaders better understand, predict, and plan for the local economic effects of wildfires. Large wildfires disrupt the lives of all people living and working near the fires. However, fire suppression and recovery efforts may provide economic opportunities. Little research existed on how wildfires affect local economies. Moseley et al. (2012) analyzed the effects of large wildfires on labor markets and examined how fire suppression spending could resolve these effects. One major finding from the project is that both local employment and average wages increased in affected communities during large wildfires. Cass Moseley, the project's principal investigator, explains, "We discovered that large fires increase labor insecurity. Lots of economic activity during the fire, but that activity goes down after the fire is put out. It takes 2 years to recover."

It is important that these social and economic research findings are made available to managers, fire scientists, researchers, experts, policymakers, and the public. They offer valuable insight into the impacts of fire and fire suppression on communities. The JFSP has provided an avenue to better and more broadly provide and communicate these findings with all relevant audiences.

Moseley is thankful to the JFSP and said, "No other agency funds this kind of [social science] research on a consistent basis. They realized the importance of social science research and ways to engage in interesting social science questions. The JFSP is the only one that funds competitive research in this field, and we are very thankful for them."

Resilient Landscapes and Fire-Adapted Communities

Resilient landscapes can be defined as landscapes that maintain fire resistance and integrity due to natural vegetation existing in specific conditions in forests, rangelands, and other ecosystems. The National Wildfire Coordinating Group defines a fire-adapted community as "a human community consisting of informed and prepared citizens collaboratively planning and taking action to safely coexist with wildland fire" (FACC 2018). Both "resilient landscapes" and "fire-adapted communities" have become two of the three goals of the "National Cohesive Wildland Fire Management Strategy" (see the section titled "National Cohesive Wildland Fire Management Strategy" in this report for more information on this strategy).

One way the JFSP has been actively supporting resilient landscapes and fire-adapted communities is by funding research in support of Secretarial Order 3336, titled "Rangeland Fire Prevention, Management, and Restoration." The main purpose of the order is to implement enhanced policies and strategies for managing rangeland fire and restoring sagebrush (*Artemisia* spp.) landscapes impacted by fire across the West. This order established the Rangeland Fire Task Force, which, guided by the order, is designed to ensure that land managers and other interested parties have access to the best available science and tools to conserve sagebrush ecosystems, protect greater sage-grouse habitat, reduce the threat of wildfire, and restore degraded areas (Barrett 2016). The JFSP played a pivotal role in



both providing a scientific underpinning for the establishment of Secretarial Order 3336 and subsequent strategic planning by the Rangeland Fire Task Force through previous and ongoing research it funded relative to sagebrush ecosystems and fire (Barrett 2016).

Since achieving fire-adapted communities was established as a national goal by federal strategies, orders, and plans, as well as by federal agencies involved in wildland firefighting, the JFSP has funded several studies to improve the understanding of how adaptive capacities can be productively applied to communities with high fire risk. These studies show how communities and individuals acted or adapted in ways that allowed them to experience a wildland fire without it becoming a disaster.

In one such JFSP-funded study, researchers studied individuals' and communities' abilities to adapt to change driven by events such as wildland fire (Jakes et al. 2010). For this study, researchers reviewed literature on natural hazards, political ecology, and globally changing fire environments to develop a model that identifies the categories or types of social elements critical to adaptive capacity for wildland fire. In addition, they reviewed documents from communities involved in the Firewise Communities/USA program, fire safe councils, or community wildfire protection planning to determine the conditions that contribute to a community adapting to living with fire. In addition, Jakes et al. (2010) expanded and modified a research model based on findings from focus groups composed of emergency managers and stakeholders in two wildland-urban interface communities and of natural resource and hazards social scientists.

This study shows how diverse communities require different motivations to change and become more fire adapted. The ability for community members to interact was key to adaptive capacity, and the researchers found that, in order to help motivate residents, managers should provide forums, in the form of field trips, open houses, and discussion groups, that create a sense of community between local residents.

In addition to studying how groups of people interact to create fire-adapted communities, JFSP-

funded research also focused on how individuals in communities react to fire risk. In a study by Champ et al. (2017), researchers found that wildland-urban interface residents underestimate wildfire risk on their properties when compared to wildfire professionals. Researchers concluded that community education programs should focus on general wildfire risk. When residents had a more accurate understanding of both the nature and threat of fire hazards on their property, they could make better decisions about how to lessen that risk. Taking action to safeguard property against risk of fire, such as creating defensible space, spilled over to neighboring properties and started a path to create a fire-adapted community (Champ et al. 2017).

Achieving resilient landscapes and fire-adapted communities is a continual process with no defined end point. In addition to contributing to the expanding social science knowledge base regarding these communities, JFSP-funded research continues to inform strategic planning and regional stakeholders about present and future science needs for these communities.

Public Perceptions of Fire-Related Communications

In recent years, wildland fires have increased in scope and significance. At the same time, more and more people are living in harm's way. This has not only resulted in more lives and property being impacted by fire or fire risk, but also an increased number of people who may not agree with or are negatively impacted by fuel reduction efforts.

Given the nature of smoke, emissions from fuel treatments have the potential to affect residents far beyond the treated area. Many fire managers and residents claim that smoke concerns limit the development of fuel treatment programs and plans. Although several studies have identified a variety of concerns with fuel reduction treatments, including the potential for increased smoke for various reasons (Shindler and Toman 2003; Brunson and Shindler 2004), relatively little was known about public perceptions of smoke, because most of the prior information came from questions established within broader studies of fuel treatment acceptability.

With JFSP funding, Toman et al. (2014) attempted to fill this knowledge gap by examining the social acceptability of smoke management practices, factors influencing this acceptability, and the effectiveness of different communication approaches. Management outcomes from this study include the following recommendations: (1) focus communication efforts on developing strategies that help improve the public's ability to control exposure to smoke emissions; (2) prioritize communication and relationship-building; and (3) enhance interagency coordination in communication efforts with the public. Such an approach could potentially lead to the development of a unified message in which responsibilities and objectives overlap.

With support from the JFSP, this and other public perception studies show that specific informational messages influence public acceptance and alleviate public concerns over fire-related issues, including smoke. Prioritizing communication and building relationships help fire, fuel, natural resource, and land managers achieve their objectives with public acceptance.

Science Syntheses and Review Series

The JFSP funds series research or synthesis documents that focus on improving the knowledge available on varying topics to inform management and policy decisions that support federal, tribal, state, and local agencies and their partners. These documents include a review and analysis of past and present information and research studies addressing topics ranging from the effects of fire and extreme fire behavior to a collection of photos that provides a snapshot of different ecosystems for rapid assessment of fuel loads in the field (LeQuire 2007).

The synthesis documents are an asset to the scientific and fire, fuel, natural resource, and land management communities. Tom Zimmerman, president of the International Association of Wildland Fire, said that the synthesis documents funded by the JFSP have "provided an abundance of information that have the potential to dramatically improve management capability." The JFSP has funded various series documents, including the Black Series (detailed in this report in the section titled "Comprehensive Guides to Fuel Treatment

Practices"), the following Rainbow Series, Extreme Fire Behavior Series, and Natural Fuels Photo Series.

Rainbow Series

The Rainbow Series began in the year 2000 and was completed in 2012. The different volumes within the series provide substantial synthesis and review of tangible fire effects on fauna, flora, air, soil, water, nonnative invasive plants, and cultural resources. The volumes of the Rainbow Series encompass the United States and Canada in geographic coverage, but many of the principles can be applied to other regions that experience wildland fires. These volumes provide technical support to fire and resource managers for carrying out interdisciplinary planning, and the series is helpful to planners and managers in many aspects of ecosystem-based management.



The Rainbow Series includes the following six volumes:

“Wildland fire in ecosystems: Effects of fire on fauna” (Lyon et al. 2000): This synthesis document provides information on how fire affects animals. The chapters address regional variation in fire regimes, direct effects of fire and animal responses, fire effects on animal populations and communities, fire effects on fauna at landscape scales, fire effects on wildlife foods, and management and research implications.

“Wildland fire in ecosystems: Effects of fire on flora” (Ansley et al. 2000): This synthesis document provides information on the effects of fire on flora and fuels and can assist fire, fuel, natural resource, and land managers with ecosystem and fire management planning. Chapter topics include fire regime classification, autoecological effects of fire, fire regime characteristics and post-fire plant community developments in ecosystems, changing fire environments, ecological principles of fire regimes, and practical considerations for managing fire in an ecosystem context.

“Wildland fire in ecosystems: Effects of fire on air” (Sandberg et al. 2002): This synthesis document provides information on the effects of fire on air quality and assists fire, fuel, natural and air resource, and land managers with fire and smoke planning. Chapter topics include air quality regulations and fire; characterization of emissions from fire; the transport, dispersion, and modeling of fire emissions; atmospheric and plume chemistry; air quality impacts of fire; social consequences of air quality impacts; and recommendations for future research.

“Wildland fire in ecosystems: Effects of fire on soil and water” (Beyers et al. 2005): This synthesis document provides information on the effects of fire on soils and water and can assist managers with information on the physical, chemical, and biological effects of fire needed to successfully conduct ecosystem management. Chapter topics include the soil resource, soil physical properties and fire, soil chemistry effects, soil biology responses, the hydrologic cycle and water resources, water quality, aquatic biology, fire effects on wetland and riparian systems, fire effects models, and watershed rehabilitation.

“Wildland fire in ecosystems: Fire and nonnative invasive plants” (Zouhar et al. 2008): This synthesis document provides information on relationships between wildland fire and nonnative invasive plants and can assist managers concerned with prevention, detection, and eradication or control of nonnative invasive plants. The chapters address ecological and botanical principles regarding relationships between wildland fire and nonnative invasive plants, identify the nonnative invasive species currently of greatest concern in major bioregions of the United States, and describe emerging fire-invasive plant issues in each bioregion and throughout the nation.

“Wildland fire in ecosystems: Effects of fire on cultural resources and archaeology” (Deal et al. 2012): This synthesis document provides information on the effects of fire on cultural resources and can be used by managers, cultural resource specialists, and archaeologists to more effectively manage wildland vegetation, fuels, and fire. The chapters provide a conceptual fire effects framework for planning, managing, and modeling fire effects; a primer on fire and fuel processes and fire effects prediction modeling; a synthesis of the effects of fire on ceramics, lithics, rock art, historic-period artifacts/ materials, and below-ground features; the importance of cultural landscapes to indigenous peoples and actively involving native people in the development of collaborative management plans; and the use and practical implications of this synthesis.

Extreme Fire Behavior Series

In 2008, the National Wildfire Coordinating Group Fire Behavior Committee asked the JFSP to fund a synthesis and review of the scientific information related to extreme fire behavior. In 2008, the JFSP announced a call for proposals that included a request for “an examination of the state of the science underlying predictions of extreme fire behavior, and an assessment of the appropriate uses and limits of this information.” The Extreme Fire Behavior Series began as a result of that request.

The objective of this series was to synthesize existing extreme fire behavior knowledge in a way that connects the weather, fuel, and topographic factors that contribute to the development of extreme fire

behavior. The synthesis documents focus on the state of the science but also consider how that science is presented to the fire, fuel, natural resource, and land management community, including incident commanders, fire behavior analysts, incident meteorologists, National Weather Service office forecasters, and firefighters. The synthesis seeks to clearly define the known and unknown research and areas of research with the greatest potential impact on firefighter protection.

The Extreme Fire Behavior Series includes the following publications:

“Synthesis of knowledge of extreme fire behavior: Volume I for fire managers” (Werth et al. 2011): The primary goal of this synthesis is to summarize known scientific information about extreme fire behavior for use by fire, fuel, natural resource, and land managers and firefighters and fire researchers. This document distills scientific information and provides references to the many research papers related to the topic.

“Crown fire behavior characteristics and prediction in conifer forests: A state-of-knowledge synthesis” (Alexander et al. 2013): This synthesis document offers a review and analysis of the literature that addresses certain features of crown fire behavior in conifer forests in the United States and adjacent regions of Canada. The key findings are organized by the following topics: types of crown fires; crown fire initiation; crown fire propagation; crown fire rate of spread; crown fire intensity and flame zone characteristics; crown fire area and perimeter growth; crown fire spotting activity; models, systems, and other decision aids for predicting crown fire behavior; and implications for fire and fuel management.



“Synthesis of knowledge of extreme fire behavior: Volume 2 for fire behavior specialists, researchers, and meteorologists” (Werth et al. 2016): This synthesis document covers most of the same topics as volume 1 but in more detail and includes information necessary for fire behavior analysts to understand what is scientifically known, the science behind the tools they have, and limitations on scientific knowledge and tools. It also includes more references to scientific literature. In contrast to volume 1, this volume includes a chapter on fuel dynamics.

Natural Fuels Photo Series

Originally developed as a field guide for managers, the Natural Fuels Photo Series emerged in the late 1980s (Ottmar and Vihnanek 2005), well before the JFSP existed. After performing logging operations, timberland managers then developed photographic assessments to show situations in which fuels posed wildfire risks and for which prescribed fire may be used to reduce the hazard and prepare for replanting (LeQuire 2007).

In 2006, the JFSP began funding the next step of the Natural Fuels Photo Series, the Stereo Photo Series, which includes locations that were left out of the original logging photo project and more information with each photo, such as the georeferenced location, forest type, species inventory, understory characteristics, estimates of the size of saplings and trees, amount of debris on the forest floor, and the loading of woody material measured in tons per acre (Ottmar 2006a). These photos were designed to help a fuel manager accurately assess conditions in the field without having to do extensive calculations. They offer a quick, easy way to discover existing fuel properties (LeQuire 2007).

The Stereo Photo Series is used by managers from all over the United States ranging from Alaska, Hawaii, the Southeast, and the Southwest. This is an important land management tool to ecologically assess landscapes through appraisal of living and dead woody material, fuels, and resource characteristics. Once an assessment is completed, treatment options such as prescribed fire or thinning are planned and implemented to better achieve desired effects while minimizing negative impacts

on resources. Fire managers find these data useful for predicting fuel consumption, smoke production, fire behavior, and fire effects during wildfires and prescribed fires. In addition, the series is used to appraise carbon sequestration and to link remotely sensed signatures to live and dead fuels on the ground.

In 2007, the JFSP funded another expansion of the photo series. Material from the Natural Fuels Photo Series was digitized and is known as the Digital Photo Series (Wright et al. 2007). The database created from this expanded project offers managers a quick way to access the photos and their information online. The database is searchable by fuel type, forest, location, and more descriptors. The 17 volumes published in the series cover more than 48 fuelbed types, from mixed conifer and sagebrush in the Pacific Northwest to the longleaf pine (*Pinus palustris*), mixed pine, and hardwood of the Southeast. Also, one photo series volume was published for Brazil and one for Mexico.

Another expansion of the Natural Fuels Photo Series, the Hurricane Photo Series, covers a range of post-hurricane fuels in forest types of the southeastern United States—the Gulf Coast dominated by mixed forest species and the Atlantic Coast dominated by a heavy shrub understory (Ottmar and Vihnanek 2010). The Natural Fuels Photo Series continues to evolve and grow as land managers, researchers, and policymakers identify ecosystems for which vegetation and fuel inventory data are needed. The Digital Photo Series is available at <https://depts.washington.edu/nwfire/dps/>.

Research in the Spotlight

Interagency Fuels Treatment Decision Support System (IFTDSS)

Fuel specialists often have to be persistent in accessing and learning about the various fuel and fire planning models, not to mention learning the specifics of running, adjusting, and inputting data distinct to each model and its underlying software. In addition to these challenges, inputs/outputs among these models previously did not have the capability of being shared and thus required each model to be used separately rather than in an integrated manner (Wells 2014b). In 2006, the JFSP conducted an extensive set of informal and formal meetings with agency managers and practitioners across the nation to better understand the nature of the preceding issues that were limiting progress on the ground. Based on the information obtained from this effort and the JFSP Governing Board's own knowledge and experience, the board determined that a solution to the cost in resources and lost productivity from the proliferation of independent, stove-piped model software applications warranted a major coordinated investment from the JFSP. In sum, due to the lack of coordination and planning from agency model software developers and partly as a response to the JSFP's own piecemeal model development funding processes, several dozen decision support models and data applications had been developed that were partially redundant, failed to address significant information gaps, used their own unique user interfaces, had haphazard technical support, and



contained no provision to share data with other models/applications. This last point is particularly critical to fuel treatment planning, which is typically conducted as a series of steps in which each step involves some analysis and modeling using model outputs from previous steps.

To address this problem, the JFSP engaged Carnegie Mellon University's Software Engineering Institute to conduct an initial assessment of the problem in 2007 (phase 1) (Wells 2009b). Results confirmed the magnitude of the problem and recommended that the wildland fire community move toward a small set of centralized computing platforms designed in a service-oriented architecture, labeled as a "system-of-systems." This involved creating a single user interface that accessed core modeling and data handling tools and passed data from one application to the next with minimal work required from end users. Results and recommendations from the phase 1 assessment were shared widely with the JFSP Governing Board, interagency fire leadership at the National Interagency Fire Center and in Washington DC, and the practitioner community. All supported further work by the JFSP to help agencies address this problem.

Accordingly, the JFSP contracted in 2008 with a software developer (Sonoma Technology) with experience in this field to develop a conceptual and system design for a prototype system to serve the fuels treatment community and its domain of work (phase 2) (Wells 2009b). The JFSP and Sonoma Technology were guided in this effort by a steering group of field practitioners and modelers convened by the JFSP. Again, results were widely shared, and the JFSP was encouraged to keep pressing forward.

For phase 3, the JFSP contracted with Sonoma Technology from 2009 to 2011 to develop a prototype service-oriented computing platform to serve as a data handling and modeling system known as the Interagency Fuels Treatment Decision Support System (IFTDSS) (Wells 2009b). The IFTDSS would become a web-based application designed to integrate a variety of fuel management planning and analysis tools (fire behavior, smoke, prescribed burn planning, and risk assessment). It organizes and manages the most used software and database tools according to the functions most needed by fire and

fuel specialists. It actively links models and data (Wells 2009b). The system uses workflows to guide fuel treatment planners in performing the main tasks of fuel treatment planning and management (Bennett et al. 2013). The vision of the system is to allow users to work through the planning process for all segments of fuels management: evaluate, plan, implement, monitor, and report.

Development proceeded rapidly through a series of iterations in an agile development environment. Provisional releases were regularly provided to a group of test users and feedback was collated and used to inform future work. At the end of the contract, IFTDSS existed as a functioning computing platform with substantial capabilities, and it also had a substantial base of users that encouraged further development and support. Simultaneously, leadership of the interagency fire community developed an involved process to approve software development and information technology. To support the fire community's consideration of IFTDSS as a potentially approved and supported software application, and to conclude the JFSP's investment in this line of work, the JFSP again engaged with the Software Engineering Institute to independently evaluate IFTDSS (phase 4) (Wells 2014b). The intent of phase 4 was to assess how well the software functioned and to what degree the phase 1 recommendations had been fulfilled. In short, did IFTDSS meet its expectations, and did it make sense for the fire community to invest in IFTDSS as an official, supported computing platform? The assessment included a series of workshops held across the country with end users testing the software in a series of exercises to determine the usefulness of the system.

Results from the phase 4 assessment confirmed the value of IFTDSS and the potential savings to the community from a fully supported and centralized fuels treatment decision support system. Potential savings derive from the efficiency of users learning only one software interface and having one source of analytical direction and guidance, consistent user support and training, and efficient tools for data handling and transformation. Potential savings also accrue to the model-development community as it offloads interface development and support to a centralized computing platform. Model developers

can focus on developing, testing, and improving core algorithms rather than on software development and maintenance. Phase 4 formally concluded the JFSP's role in IFTDSS (Bennett et al. 2013; JFSP 2014; Wells 2014b).

IFTDSS was one of the first software systems to be submitted to the new Wildland Fire Information and Technology Executive Board in 2013. The executive board formally approved IFTDSS in 2014 for further planning, development, and eventual operational deployment (JFSP 2014; Wells 2014b).

Developing the Next Generation of Fire and Smoke Models to Advance Science and Meet Operational Needs

Through two major efforts, the JFSP has played an instrumental role in advancing science underlying the understanding of fire and smoke behavior and using that understanding to develop and advance associated models to meet operational needs. Brief descriptions of these two efforts follow.

Prescribed Fire Combustion-Atmospheric Dynamics Research Experiments (RxCADRE)

To help advance fire behavior and fire effects model development, the JFSP helped fund the Prescribed Fire Combustion-Atmospheric Dynamics Research Experiments or RxCADRE. This project was planned to provide an opportunity for leading researchers to team up and collect fire datasets on seven large prescribed fires in 2008 and 2011 at Eglin Air Force Base and the Joseph W. Jones Ecological Research Center in the southeastern United States. In 2012, the JFSP funded the extension and expansion of this project to include six small replicates and three operational prescribed burn blocks in longleaf pine ecosystems at Eglin Air Force Base. The researchers represented a range of fire-related disciplines—fire ecology, fire behavior, fire effects, meteorology, and smoke science (Ottmar et al. 2014; Wells 2013).

“To validate the models,” Roger Ottmar, principal investigator, said, “you have to know not only what goes into the model, but what comes out—not only how much fuel was out there, for example, but how

much of it was actually burned. You can't evaluate your model with the same data you used to build it.” When the program first started, it was an ad-hoc endeavor. Ottmar said, “Whoever was available could work on it. We learned to really work together.” Soon, the JFSP Governing Board pushed for more formal work to be done with their available funding. “They put out proposals, selected it, and pushed it into a formal effort. This was when the project became known as RxCADRE.”

In 2012, data from the nine prescribed burns were being studied, and close to 100 scientists from many different disciplines were collaborating on the effort. The JFSP also funded data repository for the project. The RxCADRE researchers processed the mountain of data that came out of the prescribed burns. “We collected 10 terabytes,” said Ottmar. “That's huge.” The goal was to make the data available and useful to any modeler or scientist who wanted them. The RxCADRE team built a verifiable dataset—a collection of organized measurements taken before, during, and after a set of prescribed fires.

The team captured the same burn event from different perspectives and with different instruments. “I really appreciated this comprehensive approach,” said Bret Butler, a U.S. Forest Service research forester. Butler's team used ground-based instruments placed within the fire to measure air temperature, flow, and radiant and convective heating, and they also placed an array of instruments around the burn site to measure wind direction and speed. “I've worked on many research burns in the



past, and it seems like I nearly always come away wishing we'd measured something more," Butler said. "I haven't had that feeling with this project. I believe it represents the most complete characterization ever of wildland fire in a natural setting" (Wells 2013).

RxCADRE organized its data collection around six core research discipline areas and their associated variables (fuel, meteorology, fire behavior, energy, smoke emissions, and fire effects) as defined by the fire modeling community. All variables for each discipline were measured on the same experimental burns, so there was a collaboration developed between the disciplines as all data were shared among all the researchers (Ottmar et al. 2016).

RxCADRE proved that it is possible to bring many scientists together to successfully and efficiently complete several large research campaigns. Furthermore, this project provided quality assured datasets for development and evaluation of fire models. Implementation of the project and preliminary analysis of the data has led to important science and management implications. One management implication for fire behavior managers and researchers is that data represent an important first step in building a comprehensive dataset and support evaluation and development of fire behavior, effects, and emissions models (Ottmar et al. 2014).

According to Ottmar, this successful and collaborative project never would have happened without funding from the JFSP. "They brought all these scientists together. The JFSP helped us focus on collaboration and how to efficiently use the money for the project." Because of the success of RxCADRE, several cooperating agencies continue the advancement of measurement techniques and observational data to further evaluate, validate, and advance fire and smoke modeling systems (Ottmar et al. 2016).

Fire and Smoke Model Evaluation Experiment (FASMEE)

The Fire and Smoke Model Evaluation Experiment (FASMEE) is a large-scale interagency effort to (1) identify the critical measurements necessary to improve operational wildland fire and smoke

prediction systems; (2) collect observations through a coordinated field campaign; and (3) use these measurements and observations to advance science and modeling capabilities (Ottmar et al. 2017). FASMEE is targeted to support the data and validation needs of operational modeling systems in use today, as well as the development and advancement of the next generation of modeling systems expected to become operationally useful in the next 5 to 10 years.

The overall goal of FASMEE is to evaluate and advance operationally applicable fire and smoke modeling systems and their underlying scientific models and frameworks. The overarching science question for FASMEE is: How do fuels, fire behavior, fire energy, and meteorology influence the dynamics of near-source plumes and the long-range transport of smoke and its chemical evolution?

FASMEE is designed to take place in three phases:

- Phase 1: An analysis and planning process to review and assess the current state of fire-plume-smoke modeling and scientific understanding to determine the critical data gaps and knowledge needs and to identify realistic pathways to address these needs.
- Phase 2: Implementation of a set of field campaigns initially envisioned to occur from 2018 to 2022 to collect data valuable for model evaluation and improvement.
- Future improvements: Based on the data collected in phase 2, identify additional sets of analyses and improvements to the models.

Phase 1 is complete and resulted in a comprehensive study plan (Ottmar et al. 2017) that is scheduled to be published as a U.S. Forest Service general technical report in 2019. Given the focus on fire-plume-smoke-chemistry system linkages, the study plan includes four discipline areas: (1) fuels and consumption; (2) fire behavior and energy; (3) plume dynamics and meteorology; and (4) smoke emissions, chemistry, and transport. The data collection emphasis is on measurements of high-volume smoke production from burning in heavy

fuels that produce multiple plume cores and significant vertical plume development.

Reductions in JFSP funding starting in 2018 preclude full implementation of FASMEE's phase 2 vision. To compensate in part, the FASMEE project leads have been working closely with other federal agencies and partners to leverage the following ongoing efforts.

- **Western Wildfire Campaign:** FASMEE is providing, via JFSP and U.S. Forest Service funding, pre- and post-fuel inventories, fire behavior and energy measurements, and plume development characterization measurements in support of aircraft- and satellite-based platform measurements of western wildfire smoke chemistry and transport studies by the National Science Foundation. Planned for 2019, FASMEE will provide the same support to the Fire Influence on Regional and Global Environments and Air Quality (FIREX-AQ) study, which is a joint effort of the National Oceanic and Atmospheric Administration and National Aeronautics and Space Administration.
- **Southwest Campaign:** Stand replacement prescribed burns on the Fishlake National Forest in Utah in 2019 will involve data collection efforts by FASMEE and FIREX-AQ.
- **Southeast Campaign:** Large, 3- to 4-year rough southern pine units on the Fort Stewart and Fort Jackson military installations in the Southeast U.S. in 2021 will involve data collection efforts by FASMEE and the Department of Defense Strategic Environmental Research and Development Program.

In addition, a fifth discipline area has been added—fire effects—in which scientists willing to participate using their own funding can take advantage of the data collection already planned. Data collection will occur through three different campaigns extending into 2021.

Sagebrush Steppe Treatment Evaluation Project (SageSTEP)

The Sagebrush Steppe Treatment Evaluation Project (SageSTEP) is an ongoing, collaborative, long-term research program that evaluates ways to improve the health of sagebrush areas across the cold desert region of the Western United States, comprising most of Nevada and parts of California, Idaho, Oregon, Utah, and Wyoming (this area is also known as the Great Basin). Sagebrush communities have been identified as one of the most threatened land types in North America, and as much as half of this land type has already been lost in the Great Basin (SageSTEP 2012).

The purpose of SageSTEP is to conduct research and provide improved information about restoring sagebrush rangelands degraded by conifer encroachment or nonnative grassland species invasion. This information will help resource managers make restoration management decisions with reduced risk and uncertainty. The project is a collaborative effort among researchers and land managers in a variety of disciplines from five universities, six federal agencies, and one nonprofit organization in the Great Basin (SageSTEP 2013).

The JFSP started the project in 2003 by first funding an initial planning step, which researchers, including Jim McIver, an ecologist and the SageSTEP science lead, used to design the study and develop a proposal in collaboration with the land management community. The proposal was approved and funded in 2005, and the study was fully implemented by 2011. According to McIver, "The JFSP helped greatly with their full-time outreach arm, which ensured that initial scientific results were effectively delivered. In addition to science delivery, the JFSP also funded tours and assisted us in setting longer term funding arrangements with other partners such as NIFC and BLM. JFSP staff was always very helpful and responsive, especially throughout the early phases of the study."

Project investigators say JFSP funding also was crucial for building an infrastructure that set the stage for an unprecedented long-term study that provides needed information on sagebrush steppe restoration and fuel treatment effectiveness. The

research provided information on how to restore sagebrush degraded by conifer advancement or the spread of nonnative invasive grasses, such as cheatgrass (*Bromus tectorum*) (McIver and Brunson 2014). Treatment options (i.e., prescribed fire, mechanical thinning of shrubs and trees, and herbicide applications) were evaluated to learn how to create resilient and diverse plant communities.

McIver said, “The main goal of this project was to explore methods that were effective at controlling cheatgrass.” Cheatgrass is not native to the area and will take over the habitat and the available water at many sites. McIver explained that “cheatgrass can be burned but will still come back, whereas some other plants, such as sagebrush, do not. In some places, cheatgrass can come to dominate a site with repeat fires, becoming an invasive monoculture [Figure 7]. To help prevent this kind of monoculture, it is better to have other grasses in the system, particularly native perennials, as they also will come back after fire, expand with the presence of water, and compete with cheatgrass. So one of the principle SageSTEP questions is: How do treatments influence the balance between the invasive cheatgrass and the native perennial bunchgrasses?”

The SageSTEP project is providing information to fire, fuel, natural resource, and land managers to help address significant changes that have occurred on sagebrush areas over the past 150 years: cheatgrass growth, pinyon (*Pinus* spp.) and juniper (*Juniperus* spp.) woodland encroachment, and the resulting changes in fire environments. So far, SageSTEP has offered many findings from each experiment and in general. One finding is that under high stress, such as inappropriate livestock grazing, native perennial grasses tend to be restricted to growing underneath sagebrush. This tips the balance of the grass community to cheatgrass when fires occur, because native grass mortality is much higher when growing under a sage canopy. Managers should try to reduce the manageable stressors (e.g., cattle grazing), when other stress (e.g., water, heat) levels are high in the area (McIver et al. 2011; Reisner et al. 2013).

Another accomplishment of this project is the completion of an economic analyses on fuel treatments, including valuation of ecological goods and services and impacts to ranches. The project has

amassed a great amount of data for analysis, resulting in more than 125 scientific publications (McIver 2018). For all sites, data exist on every layer of vegetation and can be tied to weather, soil chemistry, moisture, and temperature. Most data are available pretreatment, and up to 10 years post-treatment, which allows for a reasonably long-term assessment of treatment effects.

Since the beginning of the SageSTEP study, researchers and managers knew that they would need to continue measuring treatment responses for many years after treatment. Long-term monitoring of the SageSTEP study plots is essential to understanding the full implications of fuel treatments on native grasses and other vegetation, fuels, water runoff and erosion, soils, wildlife, and more. This monitoring provides baseline data relevant to the effectiveness of management treatments and to future responses associated with changing fire environments. As a significant aid to data management, data analysis and interpretation, and collaboration with others, SageSTEP researchers have input information into an online database for quality control, downloading, and reporting. The long-term plan is to continue measuring for up to 25 years post-treatment. This length of time should be sufficient to show how these cold desert ecosystems respond to land management treatments, in the context of a generally warming and drying climate (McIver 2018). In summary, it is now more than 15 years past the original 2003 funding from the JFSP. A

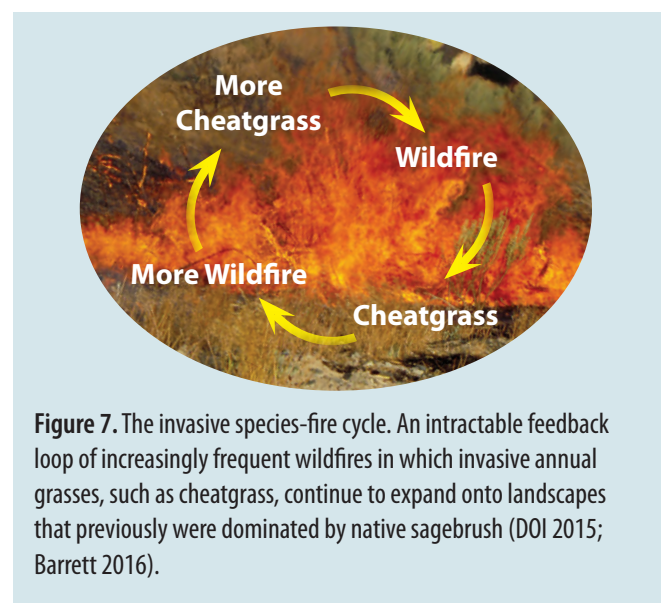


Figure 7. The invasive species-fire cycle. An intractable feedback loop of increasingly frequent wildfires in which invasive annual grasses, such as cheatgrass, continue to expand onto landscapes that previously were dominated by native sagebrush (DOI 2015; Barrett 2016).

total of nearly \$22 million has now been invested in SageSTEP, including the cost of setting up the infrastructure, applying the treatments, and measuring variables throughout that time period. The JFSP's original investment of \$13 million has paid off significantly to make SageSTEP the most comprehensive research/monitoring project ever conducted in the Great Basin.

One approach of SageSTEP was to evaluate alternative treatments designed to accomplish similar objectives. This approach is similar to the one followed by the national Fire and Fire Surrogate (FFS) study (McIver et al. 2009), which also was funded by the JFSP from 2000 to 2006. In the case of the FFS study, alternative treatments, such as prescribed fire and mechanical methods, were evaluated in seasonally dry forests nationwide. Similar to SageSTEP, the FFS study delivered robust scientific information to managers, which enabled them to decide among alternative treatments in particular cases.

Firefighter Safety Zone Effectiveness

For many years, the JFSP has funded the wildfire safety zone work of Bret Butler, a U.S. Forest Service research forester. As a result of Butler's initial work in developing flat terrain safety zone recommendations for firefighters (Butler 2006), the JFSP then funded Butler's additional research, which focuses on safe separation distances on slopes (Butler 2014).

The term "safety zone" was first introduced in official literature in 1957 in the aftermath of the Inaja Fire that killed 11 firefighters in California. More than 50 years after the Inaja Fire, firefighters continue to be injured or killed by fire entrapments. Identification of safety zones has been an integral task for all wildland firefighters. A safety zone, as defined by the U.S. Forest Service, is "a preplanned area of sufficient size and suitable location that is expected to protect fire personnel from known hazards without using fire shelters" (NWCG 2004).

Current U.S. safety zone guidelines are based on radiant heating, flat ground, and no wind. Butler's

primary objective in his 2014 study was to analyze current safety zone guidelines within the context of wind and slope. Butler completed four tasks to accomplish the analysis: (1) summarize current understanding of energy transport in natural fires; (2) collect measurements of heating from fires specifically on slopes; (3) use the measurements as a basis to perform computer simulations of energy transport for different slopes and fire intensities; and (4) based on the results from the simulations, recommend a modified safety zone size rule to account for slope and wind (Butler 2014).

A literature review was completed in the first year of the project. During the second and third years, Butler focused on the collection of measurements of energy transport from fires in Alaska, California, Florida, Georgia, Idaho, Montana, Oregon, and Texas. During the third and fourth years, Butler used computer simulations to explore relations between energy release, wind, slope, and fire intensity. Data and findings were analyzed from the fourth to the sixth years.

Funding from the JFSP for this project has led to advances in understanding how energy is released from fires, the impact of atmospheric humidity on that energy, the relative contribution of radiant (electromagnetic waves) and convective (transfer of heat energy by molecule movement) energy transport, and the impact of slope and wind on energy release. The measurements, analysis, and simulations completed as part of this work provide new information about the characteristics of an adequate safety zone. U.S. Forest Service scientists Russ Parsons and Ruddy Mell also collaborated on the project by assisting in computer simulations.

Analysis of firefighter entrapments over the past 90 years suggests that advances in understanding fire, changes in fire management policy, and better firefighter work practices will save lives. The work performed, with support from the JFSP, in this project results in new understanding of how energy is released from fires and its implications to firefighter safety.

INNOVATION IN WILDLAND FIRE SCIENCE DELIVERY

“Creating knowledge isn’t enough. The customer needs to know how to use it.”

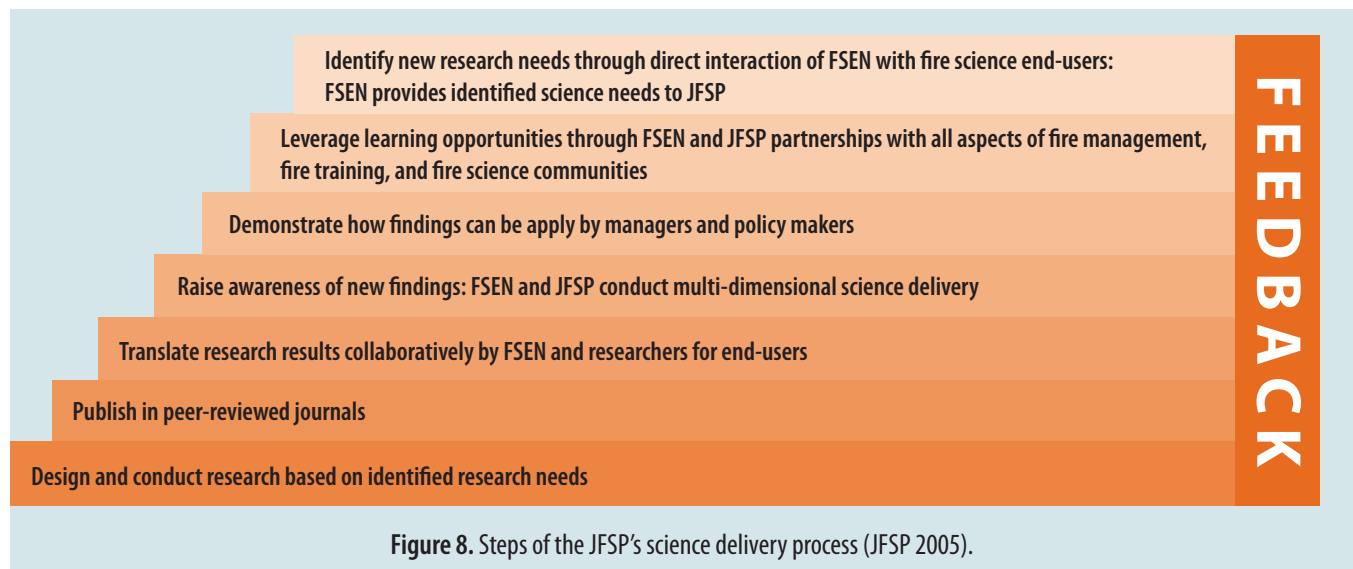
- Tim Swedberg, former JFSP communications director

The JFSP has established itself as a catalyst for accomplishing wildland fire-related research. Since the JFSP was formed in 1998, the number of completed projects has accumulated to more than 800. According to a 2008 project report, the JFSP “has long recognized that the investments made in wildland fire science need to be accompanied by an emphasis on science interpretation and delivery” (Seesholtz 2008). Program success is ultimately measured by how well information from research efforts is communicated to fire, fuel, natural resource, and land managers and end users and whether this information is improving management decisions.

One important goal of the JFSP is to support an effective and efficient structure for translating scientific information into usable data that promote communications among managers, on-the-ground personnel, and researchers. The JFSP encourages dialogue in which researchers and managers help frame problems together before the research even starts (LeQuire 2011). This channel of communication

leads to defining the manager’s expectations and how the research team can fulfill those expectations. The process ends with the delivery and application of information, models, and tools designed for the manager. Feedback is solicited throughout all steps of this process to refine and clarify outcomes. See Figure 8 for more information on this process. In order to meet this science delivery goal, the JFSP funds the development of science delivery projects and uses other techniques to reach their diverse customers.

A significant science delivery endeavor supported since the start of the program includes the development and marketing of summaries of scientific information translated into suitable formats for fire, fuel, natural resource, and land managers. These syntheses are a cornerstone of the JFSP science delivery effort. Some of these synthesis documents are discussed in this report under “Science Syntheses and Review Series.” The JFSP initiated these “state-of-the-science” syntheses as



another way to focus on integrating existing knowledge and interpreting research findings in terms relevant to managers.

Throughout the years, the JFSP has continued to support this summarization work by prioritizing new publications to meet the information needs of managers. As these summaries are published, the JFSP takes them directly to managers at “roadshows,” where scientists travel to central locations across the nation to offer “state-of-the-art” science information (JFSP 2007). For example, in 2008, the JFSP sponsored four roadshows of scientists and managers in the field to discuss their topics of choice. Two-day field tours were held in the Black Hills of South Dakota, the Front Range of Colorado, and the ponderosa pine forests of northern New Mexico and Arizona. Managers at the South Dakota and Colorado roadshows asked for information on how to effectively manage a bark beetle outbreak, and as a result, the JFSP solicited proposals for funding in FY 2009 to address this emerging need.

In 2007, the JFSP launched their website to provide a trusted source of reliable wildland fire science information for managers, practitioners, and policymakers across the nation. The program continually adds publications and other useful information to the site (more details about the website are provided in this report under “Program Tools”).

Social media and webinars are other successful methods used by the JFSP to deliver new scientific knowledge and instruction. The program uses both Facebook and Twitter to provide updates on social media, and in 2012, partnerships with the Wildland Fire Lessons Learned Center (LLC) and the International Association of Wildland Fire produced several webinars and online trainings. All webinars are archived and available on the WildlandFireLLC YouTube channel, a knowledge resource center for the entire wildland fire community. This channel has more than 4,600 subscribers, and many of its webinars average greater than 10,000 views.

Generally, the JFSP-funded projects that appear to have been the most successful regarding science delivery share common characteristics: (1) the projects were successful at framing the problem,

which then enabled focus on the pertinent management issues; (2) the research was performed in a timely manner, so it remained relevant upon completion; (3) the research was presented in a way that directly addressed a management issue; and (4) communication with end users occurred throughout the process, which increased the ease of technology transfer (Barbour 2007).

Overall though, the biggest achievement in science delivery for the JFSP is the development, implementation, and support of the Fire Science Exchange Network. This increasingly useful technology-transfer tool and collaborative organization has taken wildland fire science delivery to a whole new level.

Fire Science Exchange Network

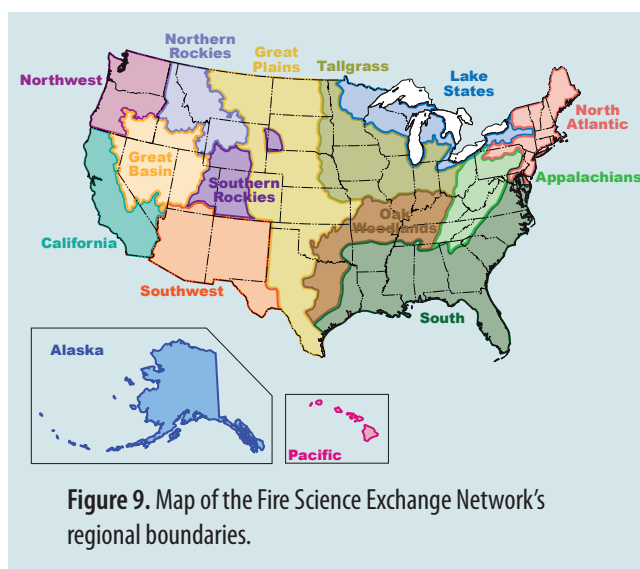
The JFSP’s science delivery strategy that existed prior to 2009 produced several positive outcomes such as the production of high-quality science, positive recognition by the scientific community as a successful program, research that represented management outcomes and implications, and support for fire science education. However, Barbour (2007) found that the program was not recognized enough by the management community. Often, managers did not know that the JFSP was the sponsor of major products that they used on a consistent basis, such as the Natural Fuels Photo Series, FARSITE, and Fire and Fire Surrogate Study. The JFSP had been using an ad-hoc or unfocused approach to science delivery. A study completed by Barbour, as well as prior recommendations from the Governing Board’s 10-year program review, revealed that the program needed a regional technology transfer tool. So, the JFSP decided to break the “conventional mold” of science delivery by creating ecologically coherent, regionally based consortia, or exchanges, and encourage fire science experts to take part in driving the research agenda and translating research results into useful and actionable information.

Since 2009, the JFSP has established a network of 15 regional fire science exchanges across the United States to facilitate information exchange between

fire researchers and fire, fuel, natural resource, and land managers (Figure 9). All personnel working in these exchanges, as well as the network itself, serve as so-called “boundary spanners,” which are essential for enhancing science delivery and maintaining open communication between managers and researchers (Barrett 2017a).

Paul Langowski, vice chair of the Governing Board during the development of the network, said, “The initial efforts of the first exchanges were so well received by both the management and science communities, the board decided to solicit proposals for additional exchanges in 2010 rather than wait until a formal evaluation of the initial network.” In 2009, to ensure that the goals of increased science delivery and development of a two-way communication process between researchers and managers was achieved, the Governing Board outlined a roadmap to increase the funding for science delivery. As a result, by 2016, science delivery and outreach investments had nearly tripled and represented one-quarter of the total JFSP budget. In 2018, it is the majority of the program’s funding.

The Fire Science Exchange Network has become a powerful tool for relaying information among many types of fire and fuel professionals and other participants interested in wildland fire science, including research principal investigators, fire ecologists, cooperative extension specialists, educators, managers, program funders, and decisionmakers. To date, the exchanges have fostered communication and collaboration by providing access to the latest publications, offering webinars and workshops, sponsoring field tours, hosting discussion forums, and promoting other interactions between managers and researchers. For instance, the Northern Rockies Fire Science Network sponsors the Network of Fire Science Champions, a



community of researchers and land managers who interact through periodic conference calls to share experiences and learn about the latest scientific knowledge and tools for fire, fuel, natural resource, and land management. In addition, participants discuss potential research and science delivery needs with the exchange’s development team (Barrett 2017a).

The exchanges were created by the same open solicitation and competitive peer review process used for research proposals. They were set up with a local “bang for the buck,” customer-first structure that finds the best local fire science information and puts it in context for their area. It is one thing to make managers aware of information, but the exchanges do more by demonstrating the research findings in the field (JFSP 2011b).

“The [exchange network] acts like a filter to weed out information that is not relevant to different ecoregions,” said Tim Swedberg, former JFSP

BOUNDARY SPANNER

Boundary spanners are fire personnel who specialize in fire and fuel management and interact frequently with both managers and fire researchers. These personnel are science knowledge brokers in the wildland fire community and are relied upon by managers often for relevant fire science (Hunter 2016).

“While the JFSP has funded research for 20 years during many of the greatest challenges in wildland fire management, its unique contribution is the Fire Science Exchange Network. The network is an important source of feedback on future science needs and is unique in that the exchanges provide coverage in all 50 states.”

- Paul Steblein, JFSP Governing Board chair

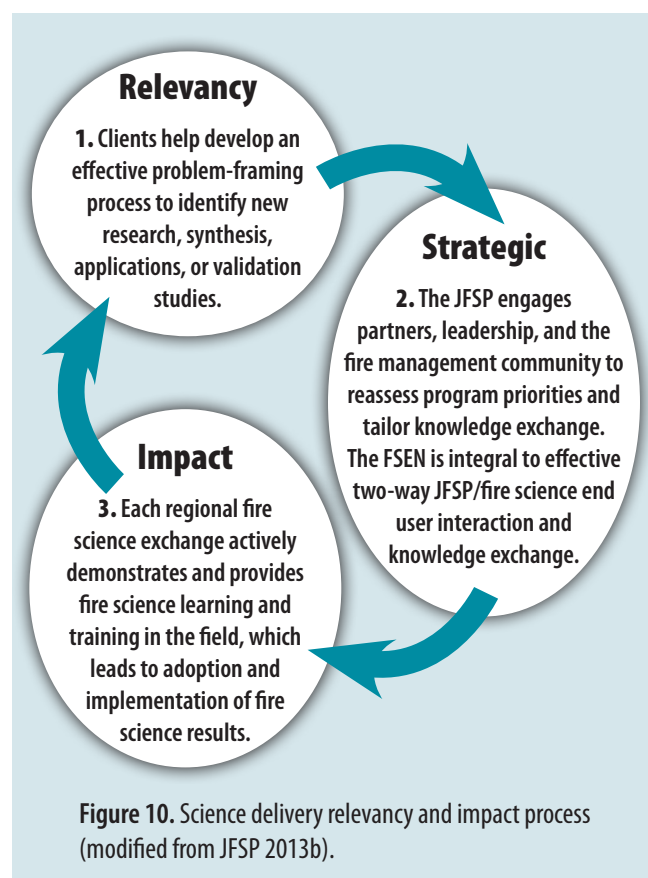
communications director. People in the Southwest Fire Science Consortium do not need copious information on conditions in the Lake States Fire Science Consortium, for example. “There is a lot of information out there,” said Swedberg. “Filtering creates a trusted conduit that vouches for the information and delivers it in the best way possible” (LeQuire 2011). Simply put, translating and delivering research in context is critical to its use.

The foundation of each exchange is the establishment of relationships and trust necessary for effective science delivery, adoption, and implementation. Every exchange is focused on establishing relationships and discovering the priorities of participants interested in wildland fire and fuel management in their region (JFSP 2013b). Active knowledge exchange involves a kind of courtship phase between researchers and managers. “Passive delivery is a science push. If the managers are dictating what they need, it becomes a pull,” said Swedberg (LeQuire 2011).

Recent evaluations of the Fire Science Exchange Network indicate that the exchanges are enhancing perceptions of wildland fire science and its use, increasing interactions among fire science professionals, and providing valuable and easily obtained translated fire science through their websites, social media accounts, and events (JFSP 2016). Molly Hunter, a science advisor for the JFSP, describes how important the network has become to fire research. “Because of the network, we are starting to see managers becoming more engaged and having more input in proposals. Their input helps in getting the right questions produced which leads to much needed research. This engagement is all attributed to the network.”

The JFSP is continually focused on developing new knowledge, building applications that are useful to

managers, validating existing research, and integrating management needs and research discoveries. First and foremost, the Fire Science Exchange Network was created to demonstrate and teach these discoveries so they can be implemented by management or inform policy decisions. See Figure 10 for information on the process used to achieve relevancy and impact (JFSP 2013b).



Network Goals and Objectives

A common phrase is “use the best available science.” However, managers often do not know what information is already available or how relevant that

research is to their management needs. Another problem is the research may not be translated into a context meaningful to them. And although the research may be of the highest quality and peer reviewed, demonstration of science findings in the field often is lacking.

Since one goal of the JFSP is to accelerate the awareness, understanding, and adoption of wildland fire science information by federal, tribal, state, local, and private stakeholders within ecologically similar regions, the Governing Board established six broad guiding principles for the Fire Science Exchange Network to help achieve this goal (JFSP 2018d). These following principles apply to all network planning, funding opportunities, and outcomes and were created through discussions with federal, state, tribal, and local governmental and nongovernmental organization representatives.

The guiding principles are:

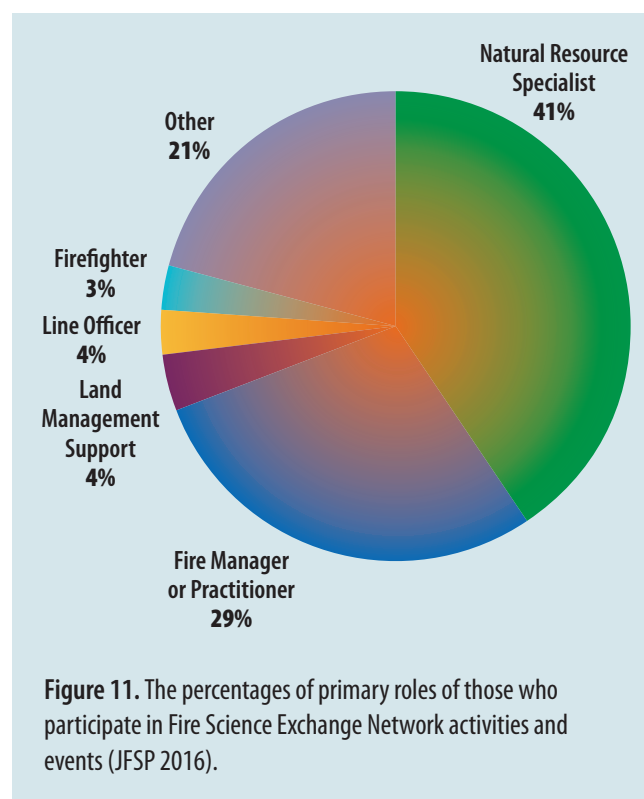
1. Be inclusive, making sure all relevant partners have the opportunity to be involved.
2. Serve as neutral science partners.
3. Be customer driven, both in how they are structured and how they function.
4. Operate collaboratively, fostering joint management and science communication.
5. Be innovative, pursuing new and creative ways to disseminate knowledge.
6. Facilitate the flow in fire science information, dialogue of new science findings, and needs of resource managers and policymakers.

In addition to the guiding principles, the JFSP created six key objectives that were crafted with supporting activities to assist in reaching their goal (Table 2) (JFSP 2018d).

Network Science Delivery Techniques

Fostering trust, communication, and collaboration among fire science researchers and managers is a key purpose of the Fire Science Exchange Network. The overarching goal of enhancing wildland fire science delivery depends upon fire researchers' understanding and openness to managers' needs, as well as managers' willingness to trust resulting products and apply the most current information

and tools in the field. Relations between researchers and managers remain complex in many regions, and changing perceptions and attitudes takes time. Many signs show that significant achievements have been made in promoting positive interactions between these two groups (Sicafuse et al. 2013). Figure 11 illustrates a breakdown of the participants most likely to take part in network activities and events. In 2016, the main participants were natural resource specialists, followed by fire managers or practitioners. This shows that positive interactions are happening between specialists and managers.



The advantage of interactive communications within all exchanges is that it goes both ways. The experts are able to answer questions and provide clarification to exchange participants. The participants are then able to express their concerns and judge on their own the knowledge and candor of the experts. Interactive events also help build trust by demonstrating openness in interactions with the public (McDaniel 2014).

Important types of Fire Science Exchange Network science delivery techniques that help promote

Table 2. Key objectives of the Fire Science Exchange Network and supporting activities.

	Key Objective 1: Dissemination of information and building relationships	Key Objective 2: Listing and describing existing research and synthesis information	Key Objective 3: Methods to assess the quality and applicability of research	Key Objective 4: Demonstrating research on the ground	Key Objective 5: Adaptive management (ideas for a coherent program)	Key Objective 6: New research, synthesis, or validation needs
ACTIVITIES	Complete periodic alerts or newsletters	Develop and maintain a regional, quick- reference web catalog of existing fire and fuel research results	Complete systematic evidence reviews that address important regional fire and fuel management questions	Develop and conduct regional in-the- field discussions to showcase recent fire research findings, demonstrate innovative practices, or highlight a fire research need	Create innovative project and/or landscape planning processes that illustrate application of recent fire science findings	Have each exchange develop mechanisms in which stakeholders can provide input about future fire and fuel research needs to the Governing Board
	Publish and disseminate publications to all stakeholders	Develop and maintain a regional, geospatial web catalog of new and ongoing research projects		Develop and manage an exchange of regional demonstration areas that highlight application of recent research findings	Apply innovative practices based on new science findings	Have regional exchanges develop and conduct stakeholder roundtables to identify regional fire and fuel research needs, or identify specific questions and topics that might be included in systematic evidence reviews
	Develop, promote, and manage regional communities of practice to support peer-to-peer networking and knowledge exchange	Develop regional specific information in the Fire Effects Information System database			Monitor project effectiveness and effects	
	Develop and manage a regional, web- based National Environmental Policy Act aid that allows quick access to relevant research results				Manage experiments implemented through ongoing fire and fuel management programs	
					Complete outreach efforts to share results through field tours, workshops, publications, websites, or other means	

needed transparency and open dialogue are as follows:

1. Collaborative activities, including face-to-face and multiexchange activities
2. Online and direct communications
3. Partnerships
4. Use of a research needs database

Collaborative Activities

Collaborative activities in the form of face-to-face and multiexchange events that encourage the exchange of information between wildland fire management and the fire science community are important priorities for the Fire Science Exchange Network and include workshops, field trips, tours, presentations, and exhibits. Many exchanges use all or most of these activities to promote trust, communication, and collaboration with their participants.

Face-to-face Collaboration and Personal Connections

Nearly 12,000 participants took part in network face-to-face collaborative activities in FYs 2016 and 2017. These activities included more than 600 field trips and consultations. In addition, nearly 200 leadership briefings took place that informed approximately 1,100 decisionmakers during this time period (JFSP 2018e).

One example of successful face-to-face collaboration was conducted by the Northern Rockies Fire Science Network. In 2017, this exchange partnered with a JFSP-funded research team led by Monica Turner, a professor of ecology, to host two workshops, which brought together a diverse group of participants who shared their thoughts about which social and ecological factors will be important for landscape resilience in the coming decades (NRFNS 2017).

Another example of face-to-face collaboration was a 2-day field trip in 2017 hosted by the Southwest Fire Science Consortium to visit various locations within the perimeter of the 2011 Horseshoe 2 Fire (including Chiricahua National Monument and Coronado National Forest) in Arizona. Topics discussed included wildlife impacts, rangeland impacts, watershed and hydrology effects, and historic fire regime and reburn issues (SFSC 2017).

For the Alaska Fire Science Consortium, workshops are popular and help reach a large variety of personnel in the fire and fuel community. Sarah Trainor, director of the consortium, said of the workshops, "The specialty workshops are especially popular. Workshops such as the recent 'Applying the Canadian Forest Fire Danger Rating System to Alaskan Ecosystems and the Remote Sensing Workshop' in 2017 attracted top-notch people to attend and help. We had researchers and fire managers working together to complete research that is directly relevant in Alaska."



Another form of collaboration that brings a positive, personal touch to science delivery is the use of creative and informative exhibits. These exhibits add a personal connection to foster relationships with end users. An example of these exhibits is the Fire Learning Trail in the Appalachian Mountains. The Consortium of Appalachian Fire Managers and Scientists designed an enhanced interpretive trail with several locations throughout the mountains. This trail introduces visitors to the role of fire in the area, as well as wildland firefighters and local history. Many educational signs occur along the trail, which contain basic information and photos, as well as a podcast-style audio tour that is available as a download or on free CDs. They also are working with another exchange to help them set up their own learning trail (CAFMS 2018).

To find out if these and other techniques were assisting in science delivery in the exchanges, a qualitative evaluation was conducted in 2013 that included exchange network personnel, including principal investigators and co-principal investigators. During this evaluation, Sicafuse et al. (2013) found that the interviewees had plenty of positive feedback to share regarding the face-to-face collaboration techniques used in the network, such as the following:

- These interactions continue to build relationships between fire, fuel, natural resource, and land managers and researchers.
- Several exchanges use creative ways to increase positive interactions. For example, one exchange held workshops during which attendees were encouraged to visit and talk with fire science experts on a particular topic. Another exchange regularly scheduled potluck-style interactions in personal homes so that managers and researchers could meet in a more casual setting. Another exchange utilized an internship program which was intended to bring managers and researchers together.
- One exchange participant described how honest, direct communication helped resolve issues between managers and researchers. In this case, management-level Advisory Board members felt excluded by members on the research side and

expressed these concerns. The researchers took those concerns to heart and began to include all the management board/team members in decisionmaking activities.

Face-to-face interactions, along with the use of creative delivery techniques, among fire science professionals are adding a great value to the fire science community by providing the most recent scientific information through activities, events, and other personal connections.

Multiexchange Collaboration

During the evaluation study mentioned earlier, Sicafuse et al. (2013) found that each of the exchanges are unique, many have different cultures and political and organizational structures that set them apart from one another, and some target different user groups. Yet, the data also highlighted many general similarities. For instance, multiple exchanges cited a focus on prescribed fire and private lands as a unique characteristic. More than one exchange discussed issues related to acceptance of prescribed burning in their region. Some have patches of similar forest and ecologies, although they are geographically spread out. Overall, it seems that many of the exchanges share similar successes and challenges. Given current barriers (e.g., limited time, funding, resources), increased communication and collaboration may be one of the most useful strategies for the exchanges to further the goals of both the fire science professional and the network as a whole.



Multiexchange collaborative (i.e., the entire exchange network working together) activities currently used by the Fire Science Exchange Network include co-sponsoring workshops, field trips, presentations, and other events with other exchanges. One example of a multiexchange collaboration is an all-exchange conference call that is hosted by the JFSP. This conference call takes place approximately six times a year and is very helpful to network personnel for planning purposes and relaying pertinent information across all exchanges.

Sicafuse et al. (2013) listed the following examples as other success stories regarding multiexchange collaboration techniques used in the exchange network:

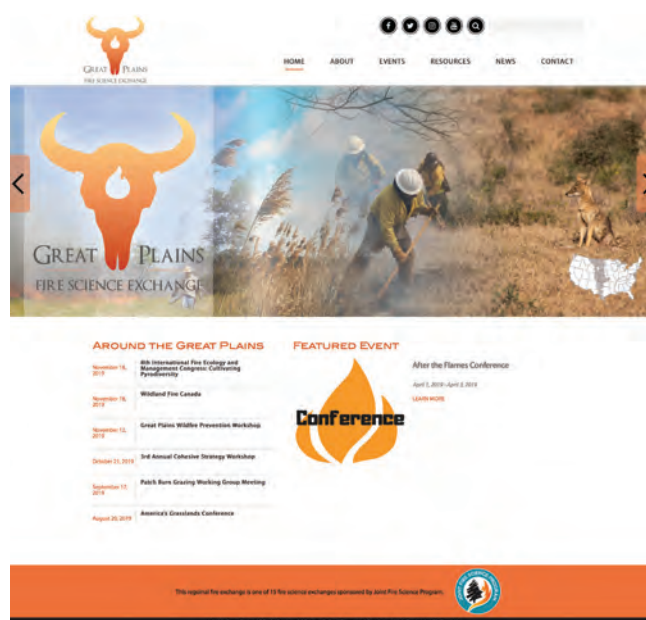
- Learning from and collaborating with other exchanges is important. For example, the more recently established exchanges seem to learn from the shared experiences of the initially established exchanges. Overall, the exchanges appreciate these interactions. One evaluation interviewee said, “One of the things I like about this project is that the [exchanges] are not competitors. So, most of our interactions with others have been supportive and helpful. It’s sort of like we have a network of people who are helping each other.”
- Sharing information with other exchanges is helpful. Most exchanges collaborate with one or more of the other exchanges on some level.
- Co-sponsoring workshops and other events with neighboring exchanges were found to be successful and should continue.

Online and Direct Communications

The use of online and direct communications, which include websites, social media messages, e-newsletters, fire event communications, webinars, and others, offers networking opportunities and helps remove cultural barriers (e.g., organizational, racial, and gender) (White 2004).

Individual Websites and Social Media

Individual websites are perhaps the most critical science delivery tool for the exchanges. These sites



aim to enhance wildland fire science delivery by providing a wide variety of regionally relevant fire science information that can be quickly accessed by fire, fuel, natural resource, and land managers and other targeted populations (e.g., landowners, community members). Exchange websites are critical in advertising and maximizing participation in network events, notifying users of other funding and continuing education opportunities, and keeping users informed of the most current happenings in the fire community. In addition, social media has become an increasingly important means of disseminating current fire science information and advertising learning opportunities.

Sicafuse et al. (2013) shared success stories pertaining to individual exchange websites and use of social media as follows:

- Across the network, individual website development and establishment is an achievement. This accomplishment required a large amount of time and effort among key exchanges. Even though some described a relatively smooth transition from website planning and development to the actual launch, most encountered and had to handle numerous bumps along the way (e.g., platform/host challenges and changes, inadequate support personnel or turnover). Most website

builders had no prior experience with website development and thus took the initiative to learn how to construct and maintain their exchange's site independently.

- The exchanges increasingly attract and retain site users. This accomplishment suggests that exchange websites provide relevant products for visitors that keep them coming back. As one coordinator said, "I think the fact that we have a lot of research briefs and webinar recordings on our website does bring people back."
- The increasing number of new visitors indicates that the network also has been successful in creatively marketing their websites. For instance, one exchange markets their website through "swag" products such as pens, folders, and hats that have the exchange logo and website address printed on them.
- Many exchanges use social media platforms (mainly Facebook and Twitter) to promote various fire science-related issues and advertise their exchange and associated events. At the start of using social media, a few exchange members may have been resistant, but became more enthusiastic over time. The target audiences for the social media accounts are all managers and fire researchers/scientists.

Webinars, Blogs, and Online Discussions

Exchanges offer webinars and trainings directly from their websites. Lack of consistent Internet access and busy schedules can make real-time, remote attendance at webinars difficult. These topic-focused webinars are conveniently available to participants seated at their office or home computers and available for later viewing by those unable to attend trainings at a given time.

Because the number of available recorded webinars and videos continue to increase for all exchanges and can be difficult to find, searchable databases are often needed. For example, in 2017, the Northern Rockies Fire Science Network added 104 webinar and video recordings to their online database. They now provide access to 443 webinar recordings and videos, which are searchable by topic and ecosystem. According to Google Analytics, there were 509 page

views of their webinar and video archive database in 2017 (NRFSN 2017).

Several exchanges are also creating blogs and online discussions through their websites. Others are implementing an "ask an expert" corner in which managers can find quick answers from a specialist in their area (LeQuire 2011).

Another trend in science delivery within the exchange network is using thematic approaches. These approaches include building on one theme of fire science and incorporating that theme into collaborative activities such as webinars and monitoring workshops. For example, the California Fire Science Consortium utilizes the theme of "fire in the wildland-urban interface" and then provides several publications, webinars, and field tours/workshops based on this theme. These activities and assets help reach more exchange participants.

Partnerships

Partnerships are the relationships and associated sharing of resources (e.g., funding, personnel, or information systems) within agencies and among external groups. Interagency partnerships include relationships between agency managers and researchers; external partnerships include relationships among other agencies, tribes, communities, universities, the public, policymakers, and others (White 2004). Partnerships help exchanges with collaborative activities, events, webinars, and other science delivery duties. Without them, meeting their goals would be more difficult.



Colleen Haskell said of these partnerships within the exchanges, “Some of the new partnerships that the exchanges are engaging in today include state involvement, more emphasis on prescribed fire councils, and forest fire compacts. Others may include more interaction with LLCs [Landscape Conservation Cooperatives], USGS climate hubs, and NOAA [National Oceanic and Atmospheric Administration] RISA [Regional Integrated Sciences and Assessments] teams, among others.”

Some participants in the exchanges already had existing partnerships prior to the creation of the exchanges. Since the creation of the exchange network, these partnerships have only gotten stronger. For example, the Great Basin Science Delivery Project has benefited from longstanding partnerships in the region. “Many of us have been working together for more than a decade,” said Mike Pellant, former principal investigator for the project. “We are not just in the initial courtship phase.” Partners include the Great Basin Cooperative Ecosystems Studies Unit, Great Basin Research and Management Partnership, Great Basin Landscape Conservation Cooperative, and Great Basin Restoration Initiative (LeQuire 2011).

In another exchange, the California Fire Science Consortium, partnerships include a wide range of

organizations. This exchange must handle extensive land issues due to the distinctive geographical areas within the region, so their diverse partnerships reflect this need. These partnerships include: National Fire Protection Association; University of California-Los Angeles La Kretz Center for California Conservation Science; Desert Fire, Mammal, and Plant Studies; California Klamath-Siskiyou Fire Learning Network; CALFIRE Wildland Urban Interface Resources; Living with Fire-Nevada; and Northern California Prescribed Fire Council.

Research Needs Database

The Fire Science Exchange Network’s Research Needs Database was established by the JFSP to manage research needs identified by the network. When this database is fully functional, it will allow the JFSP to solicit research needs from participants in the fire management community and enter them into the database. Once in the database, the program office and the science advisor can review and explore research for development with the Governing Board. Eventually, the database is envisioned as a “conduit” that connects the federal wildland fire research community across agencies and programs to assist in identifying national and regional research priorities.

What People Are Saying about the Exchanges

“The exchanges are very important. They are the communication between the researcher and the manager.”

- Andi Thode, Southwest Fire Science Consortium chair

“The network represents the boundary spanning space to help make sure science moves beyond just journal articles.”

- David Godwin, outreach coordinator for the Southern Fire Exchange

“The network delivers good and applicable science to managers and helps them apply it.”

- Robert Ziel, fire analyst

“Taking part in the workshops that are hosted locally via the network is time well spent.”

- Tami Parkinson, lead fire application specialist

Successful Integration of Science into Policy and Management

In 2013, the JFSP issued a request for proposals to create a national policy-oriented fire science exchange. Review and evaluation of submitted proposals led the Governing Board to conclude that there was not enough understanding of the existing situation, and further assessment was needed to determine an effective plan forward for integrating wildland fire science into policy. As a result, the JFSP entered into an interagency agreement with the U.S. Institute for Environmental Conflict Resolution and its contractor, EnviroIssues, in 2015. The purpose of the agreement was to explore approaches through a multiphase effort that would eventually integrate wildland fire science into policy development, implementation, and evaluation in timely and effective ways (EnviroIssues 2018).

For phase 1, Hayman and Thomson (2016) conducted an assessment to determine key needs and interests for true integration of wildland fire science into policy by interviewing 45 experts in wildland fire science and land and resource management. The assessment findings were used as a basis for the collaborative development of recommendations to the Governing Board for establishing a productive policy-focused science exchange.

During the course of the assessment, many interviewees suggested that policymakers most actively look for and use science in times of crises and that the application of science to support policy decisions is inconsistent and not always strategic. Consistently, the interviewees said that policymakers have limited time for decisionmaking, which often does not allow for the purposeful use of science. In addition, policymakers rarely have time to access and use initial science (e.g., research papers). Instead, they rely on syntheses of scientific information, presentations at conferences and meetings, online webinars, and, most importantly, the advice from their key staff who function as facilitators. In particular, study interviewees noted the key role of facilitators, or those specific individuals who provide a bridge between science and policy, that help

policymakers understand and apply relevant science (Hayman and Thomson 2016).

Hayman and Thomson (2016) made it clear that existing mechanisms do not fully meet the needs for those seeking science information to support policy development, particularly related to synthesis of information and incorporating all impacts. Key suggestions for new or improved mechanisms included creating a dialogue between those generating knowledge and those making decisions, potentially through annual conferences, workshops, or existing meetings. Others suggested creating an independent body tasked with connecting science and policy. Still others suggested creating training sessions for scientists to better communicate with policymakers or education programs that increase the visibility of fire science in the public eye. Finally, it was suggested to convene task groups or teams, including researchers, management, academia, and others across a wide span of disciplines, to address high-priority policy issues. According to this study, high-priority issues include social science, air quality, changing fire environments, and management-related issues.

During phase 2, EnviroIssues added to phase 1 assessment findings and convened a Science/Policy Work Group. This group met several times to fully develop specific, actionable suggestions (i.e., “mechanisms”) that had strong support from key stakeholders potentially involved in implementation (EnviroIssues 2017).

During phase 3, JFSP office staff, Governing Board members, Fire Science Exchange Network representatives, senior fire professionals, and others with key science/policy expertise participated in a workshop in 2018 to contribute to the development of an action plan. The action plan includes overarching guidance and detailed implementation steps for mechanisms identified by the workshop participants as high priority and particularly suitable for the JFSP to lead and/or convene (EnviroIssues 2018). Using the action plan, the JFSP office and Governing Board will seek opportunities to implement the priority mechanisms in the years to come.

In addition to implementing the priority mechanisms from the action plan, the JFSP continues to take

steps to make sure policymakers receive the science information they need to make policy decisions. For example, the program continues to fund the following:

- Synthesis documents written for fire managers, such as the “Synthesis of knowledge of extreme fire behavior: Volume 1 for fire managers” (Werth et al. 2011).
- Popular publications, including the Friday Flash e-newsletter and Fire Science Digests, which offer updated manager-relevant information on many subjects, such as “Preparing Tomorrow’s Fire Professionals: Integration of Education, Training, and Experience through Science-Management Partnerships” (Wells 2011).
- A website and searchable database that both offer valuable on-demand information.

Through the Fire Science Exchange Network, which is extremely useful in providing policymakers with regional issues that can be applied to other areas (e.g., California synthesis papers), the JFSP sponsors the following:

- Workshops, conferences, and field trips that focus on specific subjects and themes. These in-person interactions offer a deeper understanding of the issues in a concentrated timeframe.
- Lessons-learned webinars and online training courses. These presentations are succinct, easily accessible, and applicable to fire and fuel manager needs.

National Cohesive Wildland Fire Management Strategy

A good example of successful integration of wildland fire science into policy includes the “National Cohesive Wildland Fire Management Strategy” (cohesive strategy). This cohesive strategy is an example of how to create a connection between researchers and policymakers in fire and fuel management. The purpose is clearly communicated by policymakers, and the strategy reflects science purposefully designed by the science community (Hayman and Thomson 2016).

The following are the three primary goals of the cohesive strategy for making a positive difference in addressing wildland fire problems and costs (JFSP 2013b):

- **Restoring and maintaining resilient landscapes.** The strategy recognizes the current lack of ecosystem health and the variability from geographic area to geographic area. Because landscape conditions and needs vary depending on local climate and fuel conditions, among other elements, the strategy addresses landscapes on a regional (more localized) scale, instead of a single model.
- **Creating fire-adapted communities.** The strategy offers options and opportunities to engage communities and to work with them to become more resistant to wildfire threats.
- **Wildfire response.** This goal considers the full spectrum of fire management, from preparedness to full suppression to managing fire for multiple objectives. The strategy recognizes differences in missions among local, state, tribal, and federal agencies and offers collaboratively developed methodologies to move forward.

As shown in Figure 12, science is the unifying element of the cohesive strategy. For 20 years, the

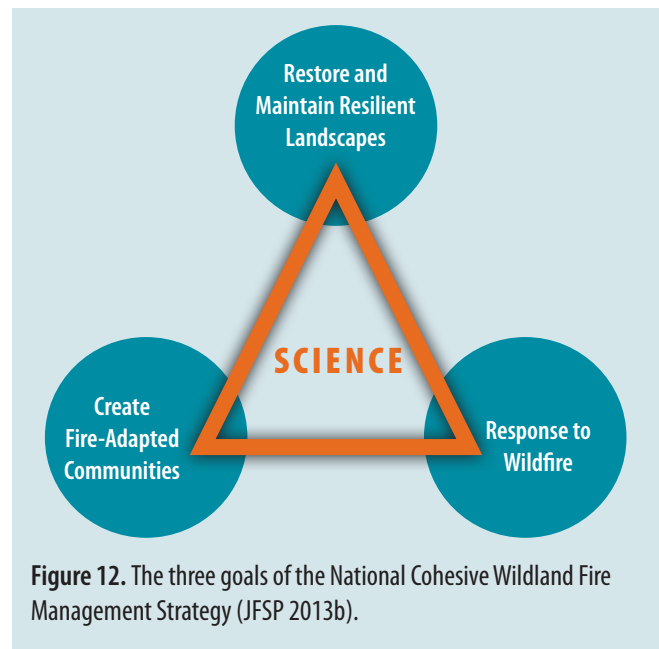


Figure 12. The three goals of the National Cohesive Wildland Fire Management Strategy (JFSP 2013b).

JFSP has been producing the highest quality science information to inform both management actions and policy strategies and thus offering “Research Supporting Sound Decisions.”

Linking JFSP Research to the Cohesive Strategy

In 1998, the first year of funding for the JFSP, 19 projects were selected that focused on different aspects of wildland fire and fuel issues. From the very beginning, the program funded projects, such as (JFSP 2013b):

- A risk-based comparison of potential fuel treatment trade-off models
- Risk assessment of fuel management practices on hillslope erosion processes
- Assessing values at risk in the United States from wildfire
- Assessing values of air quality and visibility at risk

The program has consistently led the nation to find solutions to the fire issues that managers have deemed important for the past 2 decades and is now supporting the management needs as described in the cohesive strategy. Although it is important to understand the JFSP has been working on these issues for a long time, it is also currently providing the highest quality peer-reviewed research in support of the cohesive strategy goals.

According to Tom Zimmerman, it is important that the JFSP funds studies to inform the cohesive strategy since “the cohesive strategy represents the best strategic plan for wildland fire we have ever had. Since we will always have fires that need to be put out, there are also fires that need to be managed and used for restorative purposes. This strategy helps

with both.” Zimmerman is an important figure in affecting fire management policy. He worked on the 1995 Federal Wildland Fire Management Policy and has been a strong advocate and influencer for fire and fuel policy throughout the years.

Zimmerman was recently a host and presenter at both the 2017 and 2018 National Cohesive Wildland Fire Management Strategy Workshops. These workshops were presented by the International Association of Wildland Fire in partnership with the Wildland Fire Leadership Council and the regional cohesive strategy strategic committees. Zimmerman brought the idea of these workshops to the JFSP and asked to get the Fire Science Exchange Network engaged. The workshops have since become very successful and well attended. “The popularity and great feedback we have received from these workshops really shows that people are interested in the cohesive strategy and what it offers in scientific and implementation information,” Zimmerman said.

Historically, all JFSP-funded research topics, directly or indirectly, have supported one or more of the goals of the cohesive strategy. Currently, the JFSP is funding research projects on comanagement of risk. This research will be used to inform the second and third goals of the cohesive strategy and produce actionable recommendations to improve communication about respective responsibilities for wildland fire risks, align management objectives, and coordinate actions before, during, and after fires.

Program Tools

The JFSP continues to organize roundtables, roadshows, and other forms of client interaction throughout the country, as well as actively manage and update the JFSP website, database, and social media accounts and produce numerous publications.

“One of the best accomplishments of JFSP is our database, which was set up in 2009. This database is a real success, since it allows us a good way to manage all the different proposals in an efficient manner. Principal investigators and others can upload their proposals and final reports themselves. It has become a great technology-transfer tool.”

- Becky Jenison, program analyst for the JFSP

Website and Database

In 2008, the JFSP launched an addition to their www.firescience.gov website that allows users/researchers to submit proposals into a database via an electronic form, along with other related information, such as post-research publications. The public-access portion of the website went through a major redesign in 2012. The goal was to develop a source of reliable wildland fire science information to meet the needs of the wildland fire management and science community. This website presents the latest JFSP fire-related news, events, publications, and more.

In addition, the JFSP developed a search engine that allows approved users to find information easily. The purpose is to present JFSP-funded research and to offer supporting documentation on the best fire-related information from the JFSP and other sources. At the end of each research project, metadata and data are archived. Within 2 years, the data are made available to the research community.

Social Media

The JFSP has both Twitter and Facebook accounts to meet its social media needs. The JFSP started its Twitter presence (@Firescience.gov) in 2011 with a handful of followers. Since then, the account has grown to nearly 8,000 followers and has sent more than 3,900 tweets. Followers of the account include agencies, media outlets, smokejumper and hotshot crews, community wildfire safety groups, research organizations, individuals, and others.

The JFSP's Facebook account (Firescience.gov) began in 2011 and now has more than 10,000 likes from people, agencies, organizations, and wildland fire-related businesses. The JFSP has fans from more than 10 countries. New JFSP e-newsletters and publications are automatically posted to the Facebook page and are regularly shared on the pages of the people and organizational accounts that follow the content.

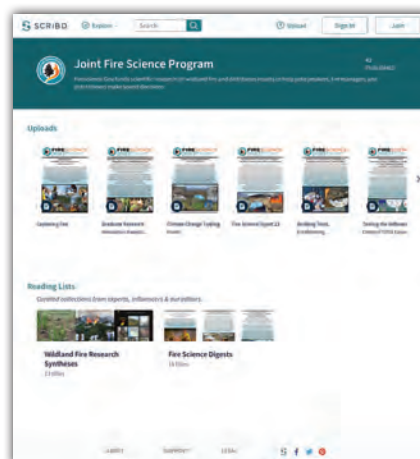
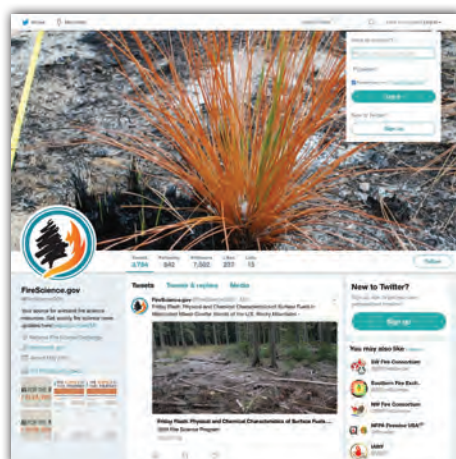
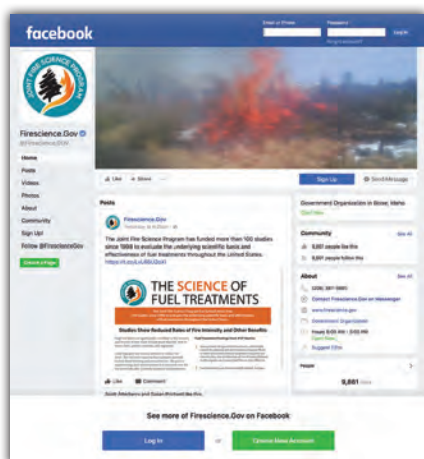
Publications

The JFSP launched a public, online multiplatform library in 2012. This platform allows visitors to easily read official publications on smartphones and tablets and view them as ePubs on desktop and laptop computers without having to download large portable documents. The format also allows readers to easily annotate, highlight, bookmark, save, recommend, and comment on the material. It also allows for easy sharing on social media.

Examples of JFSP publications are as follows:

Fire Science Briefs

Each brief is a four-page summary of a completed JFSP-funded project that provides the reader with a quick understanding of the project. The main goal of the publication is to help managers find and use the best available wildland fire science information. These publications were distributed monthly from 2007 to early 2012. All briefs are available for download on the JFSP website.



Fire Science Digests

Each digest provides an indepth summary of several related JFSP-funded research projects. Issues are printed and mailed to subscribers several times a year and are archived online. The main goal is to help managers find and use the best available wildland fire science information. All digests are available for download on the JFSP website.

Fire Science Fact Sheets

These two-page documents are available on the JFSP website and provide stakeholders with a quick overview of the program's roles and accomplishments. Recent fact sheets define and discuss topics such as the science of fuel treatments, the Fire Science Exchange Network, and the program itself.

Friday Flash e-News

This short newsletter is sent to subscribers every Friday and linked to JFSP social media accounts (i.e., Facebook, Twitter). This newsletter highlights new publications, research topics, conferences, funding opportunities, and more. Visitors can subscribe to the Friday Flash e-News from the JFSP website home page.

JFSP Progress Reports

Each report is a published summary of the JFSP for a specified timeframe (previous 1 or 2 years). The report updates readers on the status of the program's lines of work, research outcomes, latest projects, and general news.

Barriers to Science Delivery

Some JFSP-funded studies have identified barriers that prevent greater use of fire science information by the broader fire, fuel, natural resource, and land management communities. These studies are an important tool to help the JFSP address these barriers and continue to make program improvements.

Researchers and managers are more likely to collaborate if they do not encounter barriers. The top

barriers found in studies are as follows (Barbour 2007):

- Lack of adequate funding for collaborative projects in the field.
- Insufficient time to develop partnerships with field personnel.
- Differences in the cultures of science and management.
- Risks of drawing conclusions from a limited science base to the real world.

Coleen Haskell, former JFSP communications director, said, "Today at the JFSP, the main barrier is competition for resources, including time and funding. There is limited time allocated for training and continuing education for fire and fuels managers, so messaging needs to be direct and effective. Also, there is competition for dollars, where funding toward short-term fire management needs often takes priority over longer term goals in fuels management."

As for other potential barriers, managers often have a difficult time keeping up to date on recent or ongoing science. However, this issue has become less of a barrier due to the increase of user-friendly, searchable databases available at the JFSP and Fire Science Exchange Network websites. The JFSP produced these and other technology transfer tools to serve as key sources for the latest fire science (Barrett 2017a).

Perhaps the most effective instrument for removing barriers to science delivery has been the ongoing improvements within the Fire Science Exchange Network. These boundary spanners have worked diligently to maintain open lines of communication between fire, fuel, natural resource, and land managers and researchers, and the network has provided increasing educational opportunities and other well-received delivery techniques. The JFSP now encourages principal investigators to work in conjunction with their respective exchanges to develop science delivery plans. Barriers to effective dissemination and use of science information still exist. However, the JFSP will continue to address those issues to improve program quality and outreach.

TRAINING AND SUPPORTING THE NEXT GENERATION OF FIRE AND NATURAL RESOURCE SCIENTISTS AND MANAGERS

“The challenges we face today in the fire management and science communities demand broad-based thinking and cross-disciplinary investigation.”

- John Cissel, former JFSP director

To support the next generation of scientists and managers, the JFSP offers direct funding and other opportunities to enable graduate and at times undergraduate students to conduct research that supplements and enhances the quality, scope, or applicability of their work, thesis, or dissertation to develop information and products useful to fire, fuel, natural resource, and land managers and decisionmakers. Student research opportunities through the JFSP and its partners encourage students to apply science to identify best practices to manage land and water resources and adapt to changes in the environment related to wildland fire. This is accomplished through funding studies that provide science-based information that ensures the health and safety of public and other lands and protection of life, critical infrastructure, and natural and cultural resources through cost-efficient and cost-effective fire and fuel management and fire prevention strategies. These studies also directly and indirectly support the goals of the cohesive strategy.

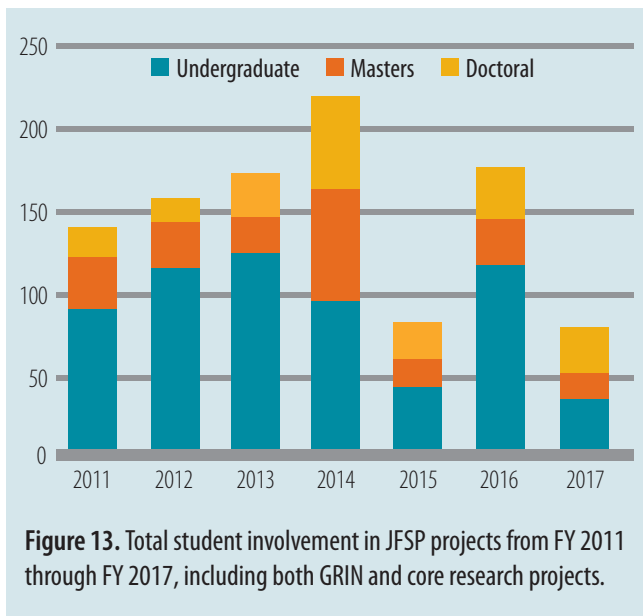
To make this happen, the JFSP partners with universities and colleges around the country. To John Cissel, former JFSP director, the partnerships the JFSP has developed and maintained with colleges and universities is a major success story for the program. He said, “Without this peer-reviewed science, there would be no avenue for the students in fire science. These universities provide the most scientists and the most proposals for studies.”

These partnerships, which involve more than 150 colleges and universities, have led to many institutions starting their own fire programs and

increasing the capacity for more innovative fire research (Wells 2010). JFSP-funded research has been able to reach students all around the country including Alaska and Hawaii.

Penelope Morgan, University of Idaho professor and strong advocate for student training, said that many current fire scientists earned their graduate degrees while conducting JFSP-funded research and communicating it to those who use it. In addition, many have gone on to establish effective research and teaching programs at universities or work in federal, state, or county land management agencies or nongovernmental organizations. “They are all making a difference as society faces growing wildland fire and fuels challenges. The science that JFSP has funded has helped to address these growing fire challenges—the challenges we face would be greater if we didn’t have the people and knowledge fostered through the 20 years of JFSP. The rippling effect through natural resources education and management is beyond calculation—far more than the dollars, for you’ve enabled people to follow their dreams, to collaborate with each other, and to make a difference” (JFSP 2018e).

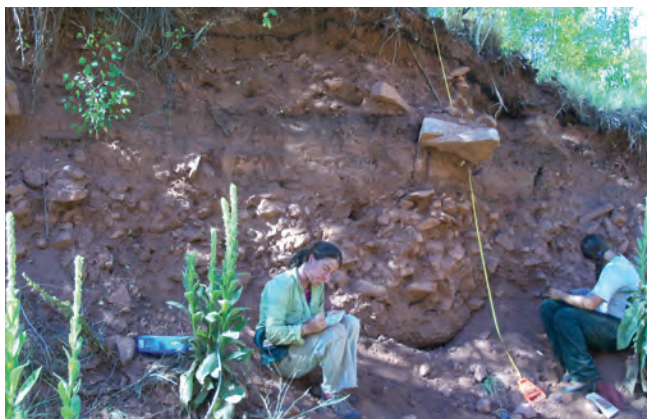
In addition to the program’s core research offerings in which students participate on research teams, the JFSP also offers two funding opportunities for qualified graduate student applicants: Graduate Research Innovation (GRIN) awards and Travel, Research, and Educational Experience (TREE) grants. Figure 13 illustrates the total number of students involved in JFSP research opportunities (core and GRIN) between FY 2011 and 2017. On average, the



JFSP has approximately 130 students per year involved with the program. Through these efforts, the JFSP is helping develop the next generation of wildland fire leaders (JFSP 2009b).

Graduate Research Innovation (GRIN) Awards

Since 2011, the JFSP, in partnership with the Association for Fire Ecology, has invited current master and doctoral students enrolled at colleges or universities within the United States in the fields of wildland fire and related physical, biological, and social sciences to compete for a GRIN award, which provides one-time funds up to \$25,000 through a university, tribal government, nongovernmental organization, or federal agency. These awards allow



students to conduct research that will supplement and enhance the quality, scope, or applicability of their thesis or dissertation and to build skills needed for independent inquiry.

The purpose of a GRIN award is to enhance student exposure to the management and policy relevance of their research to achieve beneficial outcomes of funded work. These awards:

- Enhance student exposure to and interaction with fire and fuel managers.
- Develop appreciation and understanding of fire and fuel managers' information and research needs.
- Augment already planned and funded master or doctoral research to develop information and/or products useful to managers.

Proposals for GRIN awards must demonstrate relevance to fire, fuel, natural resource, or land management and include a means to directly communicate with managers, when applicable, regarding project outcomes. Proposals must describe new, unfunded work that extends ongoing or planned research that is the subject of a thesis or dissertation and has been approved by the student's advisory committee. Succinct proposals, authored by the student and reviewed and submitted by the student's advisor who acts as the project's formal principal investigator, must be directly related to the mission and goals of the JFSP to be considered (BLM 2013).

In 2018, GRIN proposals were directed to address management- or policy-related questions associated with one or more of the following topic areas (JFSP 2018c):

- Fuels management and fire behavior
- Emissions and air quality
- Fire effects and post-fire recovery
- Relative impacts of prescribed fire versus wildfire
- Human dimensions of fire

Since the award's inception through 2017, the JFSP has received 184 GRIN proposals, with 50 proposals approved for funding. As of 2017, the total GRIN funding was approximately \$1.2 million (JFSP 2018e). Leda Kobziar, co-developer of the GRIN award, said, "The establishment of the GRIN awards underscores the commitment of JFSP to the future of fire research for fire management applications. The JFSP has set the mold for targeted support of graduate student research." Kobziar describes how some of the resulting benefits were unpredictable and surprising. "Not only did GRIN produce a broad array of highly applicable, high-quality, and cost-effective scientific products, it provided professional development that benefitted both the students and the fire management community... Feedback to the students provided an invaluable learning experience to prepare students for future proposal writing" (JFSP 2018e).

All applicants receive detailed and supportive feedback on their proposals. Standards are high, said Morgan. "A successful proposal has to be clearly and concisely written, because it has to cover everything in four [now five] pages. Students have to propose

innovative research and justify its value." Proposals are evaluated on scientific merit, the applicant's credentials, extent to which the proposed work extends or enhances an approved thesis or dissertation, and relevance of the research to the JFSP's goals.

In securing letters of support from fire management practitioners, students learn the importance of their science being applicable to real-world questions and of strategic planning to communicate and disseminate the knowledge they hoped to gain. In this way, the GRIN proposal process prepares future fire scientists to conduct high-quality research with a clear pathway for that research making a difference in wildland fire management. "The GRIN experience is akin to the first year of a post-doctoral position: students who have been supported by GRIN are far ahead of their peers," Kobziar concludes (JFSP 2018e). The GRIN program has attracted quality proposals and projects on a wide variety of subjects and from many universities and organizations from all over the country. See Table 3 for examples of the variety of funded GRIN projects.

Table 3. Examples of JFSP-funded GRIN projects.

GRIN Project Title	Research Management Outcomes	Academic Institution/ Organization	Student Name
"Exploring how deliberation on scientific information shapes stakeholder perceptions of smoke and forest management" (Hall and Blades 2014)	Credibility in climate science decreased and more uncertainty was involved when models were based on more variables and when complex relationships existed among those variables.	University of Idaho	Jarod Blades
"Sensitivity analysis of air quality to meteorological data in fire simulations" (Odman and Garcia-Menendez 2013)	The ability of current air quality models to replicate the impacts of wildland fires may be limited by the capabilities of existing numerical weather prediction systems.	Georgia Institute of Technology	Fernando Garcia Menendez
"Impacts of changing fire regimes in the alpine treeline ecotone" (McKenzie and Cansler 2015)	Changing fire environments may cause treelines to expand upward and trees to infill previously snow-dominated sites, and increased wildfire is most likely to cause mortality at sites with older trees and lower fuel moistures.	University of Washington	Courtney A. Cansler
"Can the arrangement of pine barrens mediate the spread of wildfires under various climate change scenarios?" (Kashian and Tucker 2017)	Prioritization of open barrens within the typically dense structure of Kirtland's warbler habitat plantations could restore landscape structural diversity while providing a tool for fire management within the context of a changing climate.	Wayne State University	Madelyn M. Tucker
"A low-cost sensor network for wildfire smoke detection and monitoring" (Volckens and Kelleher 2017)	Air quality data at more locations would enhance the accuracy of land-use regression models, yielding a more comprehensive estimate of exposure and health hazards.	Colorado State University	Scott M. Kelleher

"The JFSP is essential to fire science across the country. They partner with universities, nonprofits, agencies, etc., to complete a range of science. Their role on the national level is critical to advancing the knowledge of fire science."

- David Godwin, GRIN recipient and outreach coordinator for the Southern Fire Exchange

The GRIN awards also foster professional development by putting a young scientist fully in charge of a research project. These students are responsible for managing the budget, hiring staff, arranging for data collection and laboratory time, and producing the promised deliverables. This task is an immeasurable feature of these awards.

One of the first GRIN recipients is David Godwin, who was in his second year of a doctoral program at the University of Florida. In 2012, Godwin was hired as the outreach coordinator for the Southern Fire Exchange, one exchange in the JFSP's Fire Science Exchange Network. He is currently conducting workshops, field tours, and sharing his research and management findings with a variety of interested parties such as forest landowners, nonprofit organizations, and federal agencies. Godwin said of the award, "The GRIN award ended up being my gateway into the JFSP and the fire science community at large. It increased the value and relevance of my graduate studies and my opportunities to interact with fire scientists."

Another GRIN recipient is Stacey Sargent Frederick, who won the award in 2012 while studying at Oregon State University. Since this project, Frederick has become the statewide program coordinator of the California Fire Science Consortium, an exchange in the Fire Science Exchange Network. Frederick said of the GRIN award, "Since the program is so straightforward and competitive, it is a great [award] to win to help with graduate school costs, which can be tricky. This also offers a great start to fire science careers since you are instantly brought into the fire science community network. You also can't help but feel that once you are done with school, you want to hit the ground running and start making a difference in the field."

Travel, Research, and Educational Experience (TREE) Grants

In 2011, another program funded by the JFSP through the Association of Fire Ecologists was initiated: Travel, Research, and Educational Experience (TREE) grants. This program assists graduate and undergraduate student scientists to attend and present their work at professional conferences, symposia, and workshops or to travel to conduct laboratory research in fire science (Wells 2014a).

The objective of the TREE program is to nurture excellence in student research by facilitating active



student participation in conferences and laboratories where they can meet other fire researchers and managers who may provide opportunities for future jobs, internships, or collaborations on research and management projects. TREE funds are an investment in the next generation of professional researchers, managers, and educators.

Like the GRIN awards, the TREE program is highly competitive. The grants cover transportation, lodging, conference registration fees, and cost of preparing presentation materials. Individual sums are not large; they range from about \$650 to \$1,200, but they can make a difference for students who

might otherwise miss the opportunity to interact with peers and get to know the leaders in their fields (Wells 2014a).

In 2014, Timothy Ingalsbee, then co-director of the Association for Fire Ecology, said, “TREE is a really wonderful opportunity. These grants enable students to attend what may be their first professional event; to give their first presentation; to network with peers and researchers, managers, and other fire professionals. These students are the researchers and managers and educators of tomorrow, and the TREE grants help to introduce them to their professional community” (Wells 2014a).





CONTINUED IMPROVEMENT THROUGH SELF-EVALUATION

"I always believe that every one of us is working hard not only for our own performance but also to give something significant back to the societies we live in."

- Yani Tseng, professional athlete

Throughout the past 20 years, the JFSP has grown, evolved, and managed a variety of challenges. Periodic assessments—external and internal—of the program's progress, status, and direction provide the Governing Board, partner agencies, and Congress with necessary information and analysis to sustain and improve the program, as well as make any adjustments based on changing needs and issues. In addition to external program-level evaluations, the Governing Board has completed its own internal assessments of progress and direction in 2013, 2015, and 2017. Whether externally or internally conducted, the JFSP uses several types of reviews to accomplish necessary and informative assessments: 5-year program reviews, project outcomes evaluations, and self-evaluations of the Fire Science Exchange Network.

Five-Year Program Reviews

Initiated by the Governing Board and JFSP office staff as part of the program's ongoing adaptive management philosophy, an interagency and interdisciplinary review team is convened every 5 or so years to review and evaluate the program. This review team is charged with assessing the status, effectiveness, relevance, and future direction of the program, as well as reviewing progress made following prior assessments. These program reviews

were completed in 2003, 2008, 2013, and 2017. Stemming from these reviews, some major changes to the program have occurred. Two examples of important program reviews are the 2008 and 2013 reviews.

In 2008, the purpose of the review fell into two primary areas. The first purpose was to assess the progress made since the prior review that was conducted in 2003. The second was to evaluate the current status of the program; its relevance; the effectiveness of its products, science delivery, and governance; and to consider future direction and challenges (JFSP 2009a).

When this review took place, there had been more than 400 research projects funded that led to an increase in knowledge applicable to fire and fuel management. An additional result, though not an explicit objective of the original program, was the support of a new generation of well-trained fire scientists and fuel managers.

The review team, consisting of eight members representing a cross-section of government and nongovernment disciplines and chosen by the JFSP director and Governing Board, also found that the program had made good progress in addressing the recommendations presented in the prior review and made strides in improving all aspects of the

"I've never seen a program as self-reflective and responsive as the JFSP. They are systematically introspective to ensure accountability and responsiveness, and that's extremely rare in agency environments where programs view their budget as a sinecure."

- Calvin Joyner, U.S. Forest Service

program's mission, including governance, the range and quality of research questions asked, outreach, science delivery, and technology transfer. In addition, the team found that a primary strength of the program was its ability, demonstrated over the years, to capture a wide range of relevant science and maintain a useful focus on applied questions.

In the course of this review and evaluation, the review team repeatedly heard that the quality of the program management and staff were among the JFSP's strengths. The team commended the JFSP staff for its high degree of responsiveness to critical issues of concern to fire and fuel managers and for being open, accessible, and responsive. While the findings and recommendations in the report acknowledged the work done by the JFSP, the report also noted where improvements could be made.

From this review, the review team recommended that the JFSP should:

- Target specific social science research topics relevant to the mission and goals of the JFSP.
- Conduct a systematic analysis of outcomes as well as outputs to determine the actual implementation and impact on fuel and fire management activities on the ground.
- Continue to expand the synthesis work, and solicit input from the field regarding topics to be analyzed.
- Consider developing an even more comprehensive outreach program that might include a web portal and/or community of practitioners with one-stop science application shopping for specific issues. Additionally, the JFSP should work with agencies and partners to develop training programs that specifically target users and applications of new methods developed from the JFSP.

All of these recommendations were taken to heart by the JFSP staff. The program increased its social science research support, conducted recommended outcomes evaluations, and developed more synthesis products. And last, but not least, the final recommendation led to the creation of the Fire

Science Exchange Network. This boundary spanning addition to the program has drastically helped with science delivery, communication, and collaboration.

In the 2013 program review, the third in the series of voluntary reviews, the purpose was to take stock of the JFSP and help the Governing Board and departmental and congressional leaders confirm or alter the strategic direction of the program. The review helped the Governing Board and program staff evaluate the effectiveness of program components and suggest refinements or new directions the program should pursue (JFSP 2013a).

The 2013 review team elected not to produce a long list of recommendations but rather consolidated the findings into a few substantive recommendations. One main recommendation was that the JFSP should include greater emphasis on describing the value of program outcomes in addition to outputs. The team believed that more clearly describing the impacts that the JFSP had on fire management and the understanding of fire ecology would encourage continued future investment. From this recommendation, the JFSP funded an assessment by Hunter (2016) to find out if research from projects funded by the JFSP were being used to inform fire, fuel, natural resource, and land management and policy decisions and to find the circumstances that enable the use of fire science. One finding from this assessment was that managers are not always aware of new research. Thus, detailing the management outcomes and implications from JFSP-funded research became the norm in JFSP-sponsored publications, workshops, webinars, etc. The JFSP made it a priority to ensure managers would have easy access to all research.

The overall finding from this review was that the Governing Board and program staff continue to operate a highly targeted and well-run program to meet the needs of managers by building the involvement of the science community in proposal-driven research. As these two review examples show, the JFSP reviews have been a useful tool to measure the effectiveness and success of the JFSP over the years.

Program Outcomes Evaluations

Program evaluations show key personnel and stakeholders the usefulness of the time and effort they apply to the program. Since the start of the program, the JFSP has funded many fire science research projects and made substantial steps in delivering science findings to managers. Thus, it is important that the program knows where, when, how, and why its research results and products are being used, studied, disseminated, and applied. Program evaluations are conducted in two ways. One way is through data collection from important stakeholders regarding how to improve the program using an informal method such as one-on-one interviews. The second method is to utilize surveys, interviews, and/or focus groups from a larger group of individuals to gather data. The JFSP used the second method to conduct several evaluations of program outcomes through the years on different topics:

- **“Accelerating adoption of fire science and related research” (Barbour 2007):** This research was conducted to find out the relevance of JFSP-funded research, as a whole. Meaning, whether it has contributed positively to management. This study showed that land managers often did not use delivered science as intended by principal investigators or use some delivered products at all. Also, the study found that many land managers had a difficult time keeping up with the latest fire science findings, and there was a real desire for additional research syntheses such as general technical reports. Barbour’s research findings also emphasized the important role of boundary spanners to assist in science delivery and communication between principal investigators and managers. As a result of this research, the JFSP established the Fire Science Exchange Network in 2009.
- **“Evaluation of science delivery of Joint Fire Science Program research” (Seesholtz 2008):** This research examined a sample of planning and other documents derived from three agencies—the Bureau of Land Management, National Park Service, and U.S. Forest Service.
- The objective was to document how often and to what extent JFSP users incorporated research into local planning efforts and to identify factors contributing to the adoption of new science at the project level. This study found that projects funded by the JFSP often were not effectively linked in such a way that potential end users could readily access similar bodies of work. This study proved how important the current user-friendly tools such as the searchable online databases of the JFSP and the Fire Science Exchange Network are today. Also, this study emphasized the importance of the creation of data syntheses and how they were some of the most highly valued products. Recommendations from this research also assisted in the development of the Fire Science Exchange Network.
- **“Influences to the success of fire science delivery: Perspectives of potential fire/fuels science users” (Wright 2010):** Wright designed the research to help the JFSP evaluate program-level effectiveness during the 2008 program review. She stated that without these assessment data, the JFSP, boundary spanners in the Fire Science Exchange Network, and principal investigators would likely have a difficult time identifying the science delivery and application needs of prospective end users. In addition, the study survey of land managers revealed that fire management subgroups differ in how open they are to research. For example, some fire ecologists and fire analysts were more likely to have positive beliefs and attitudes about research and to use research than other subgroups. Wright also emphasized that a boundary spanning system would be essential for science delivery and communication. The establishment of the Fire Science Exchange Network coincided with Wright’s work, and the exchanges adopted some of the research recommendations to improve the network.
- **“Final report of the Interagency Fuels Treatment Decision Support System (IFTDSS) evaluation study” (Bennett et al. 2013):** In 2012, the JFSP chartered the Software Engineering Institute of Carnegie Mellon University to independently evaluate the IFTDSS prototype

along multiple dimensions. The institute recommended IFTDSS be implemented in a limited manner while preparing the system and its users to more effectively use IFTDSS.

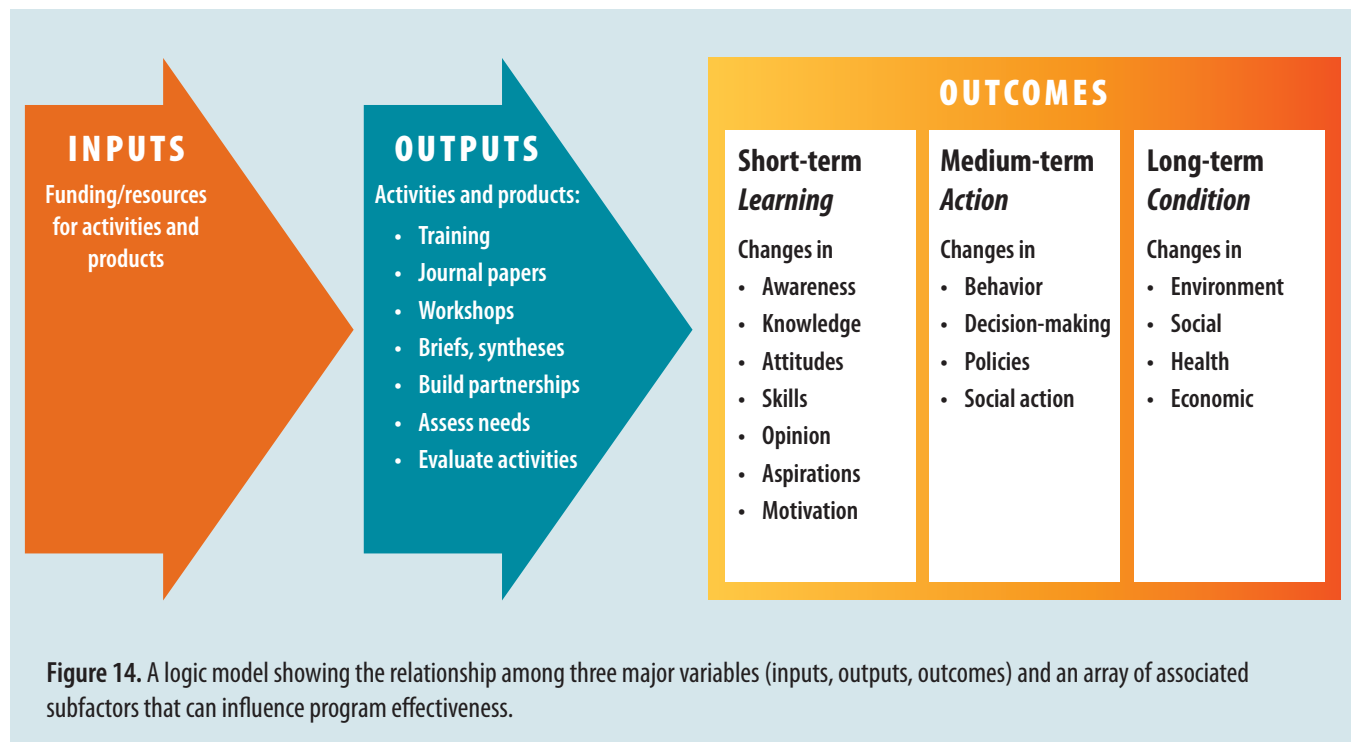
- **“Outcomes of fire research: Is science used?” (Hunter 2016):** This study pointed out that, when research projects are completed, there can be a tendency in the fire science community to stress outputs (e.g., numbers of journal articles) over outcomes (e.g., contributions to land management policies). Managers tended to search for applied science largely when it supported fire or fuel planning or when it informed or supported treatment practices. This research concluded that managers not only had used fire science but also that science outreach had improved greatly due to the establishment of the Fire Science Exchange Network.

Evaluations of program outcomes will continue. These evaluations offer compelling information that validates the JFSP’s approach to executing a management-relevant research program and assesses the degree to which the program is succeeding with science delivery and product development and meeting management needs.

Fire Science Exchange Network Annual Self-Evaluations

In 2010, the JFSP set out to analyze and improve program outcomes by funding a multiyear evaluation study that was conducted by a team of social researchers from the University of Nevada Cooperative Extension (e.g., Sicafuse et al. 2011; Maletsky et al. 2015; Copp et al. 2017). As criteria for receiving continued funding every year and to improve fire science delivery, measuring and reporting program impacts was required of the network. These comprehensive evaluations included online surveys, a webmetrics component, an evaluation resource guide, and an interview portion that explored the experiences of key network personnel (Maletsky et al. 2015).

The researchers used a graphic representation called a logic model, which is a conceptual tool for evaluating program effectiveness (Barrett 2017a). This tool showed the logical relationships between inputs (e.g., funding for products and program activities), outputs (e.g., activities and products such as training, journal articles, and workshops), and



CONTINUED IMPROVEMENT THROUGH SELF-EVALUATION

outcomes (e.g., changes in opinions, behavior, policies, and environment). See Figure 14 for a logic model of JFSP objectives relative to the Fire Science Exchange Network.

Results from the latest evaluation reports reveal that the developmental goals initially outlined for the network are materializing. On a national scale, the network is achieving the intended outcomes. The network continues to increase awareness of fire science and its use within the fire science community. Personal interactions within the network are creating a big impact on the fire science community through social media, websites, workshops, and other outreach. These outreach tools

offer information in accessible, flexible, and useful ways. More people are becoming familiar with their regional exchanges, which then leads to better understanding of the fire science information and its use (Copp et al. 2017).

As stated earlier, based on these evaluations, not only are fire and fuel managers using fire science, but science outreach itself has improved since the network was established. While the evaluations provide the necessary feedback for the program to improve, the essential fact is that the JFSP quickly responds to advice by implementing the recommendations that come from these evaluations.





APPRECIATING THE SUCCESS OF THE JFSP

“Without the JFSP, there would only be baby steps in fire science.”

- Pete Robichaud, research engineer

For 20 years, the JFSP has succeeded at producing and delivering wildland fire research that supports sound decisions. Due to its emphasis on competitively solicited and peer-reviewed research proposals, a successful investment strategy approach, a collaborative and regionally distributed science delivery system in the Fire Science Exchange Network, and a strategic method for cultivating future fire researchers and managers, the JFSP continues to bring leadership and credibility to wildland fire science.

This unique extramural research program has been instrumental in advancing wildland fire science and bringing the fire science, fire management, and land management communities together. It has provided the fire management community with knowledge and solutions on wide-ranging research topics, such as where and when to use prescribed fire in the Appalachian Mountains or the Pacific Northwest or how the public truly perceives smoke in the wildland-urban interface. Because of JFSP research findings, the operational community has improved access to fire and smoke models and emission inventory tools that predict air quality changes that can affect public health. In addition, practitioners and managers can use an improved understanding

of wildland fire science to provide multiple benefits for fire, fuel, natural resource, and land management plans. Without this program, wildland fire research and science delivery would be far behind the needs of the practitioner and management communities. Without this program, knowledge about managing fire would slow in growth and maturity, yielding far fewer sound answers and comprehensive fire management solutions.

Everyone can agree that wildfire is a common concern, and solutions and methods for managing and living with fire are increasingly needed. The JFSP focuses limited resources on the most critical issues and on rapidly delivering information and tools that make a difference in people's lives. With optimism for the future, the JFSP will continue bringing wildland fire science to the forefront and being a clear example for other programs to emulate. As John Laurence said, “I see the JFSP as a shining example of a program that takes the best researchers with good ideas, sets them to work on a practical problem, insists on an aggressive timeline, and delivers results to the field that are used.”

“One of my fondest memories during my time with JFSP was at the November 2017 AFE Fire Congress plenary session which opened up the conference for the week. When the audience was asked how many of their projects had been funded through JFSP over the years, an alarming number of scientists and managers stood up to show their support. I was truly amazed by the number of individuals who were affected by this small sample of scientists and fire professionals.”

- Coleen Haskell, former JFSP communications director

Thoughts about the Program

“The program provides practical analysis to managers and creates a community of fire professionals across disciplines.”

- Jim Douglas, former DOI fire manager

“JFSP’s real success story is their competitive research. No one else funds this kind of research.”

- Cass Moseley, University of Oregon, associate vice president for research

“JFSP’s role on the national level is critical to advancing knowledge of fire science. They educate the country on how to understand and live with wildland fire.”

- David Godwin, outreach coordinator for the Southern Fire Exchange

“The JFSP helps us with our science delivery. Their outreach capability is critical.”

- Jim McIver, ecologist

Looking toward the Future

The JFSP, like most research programs, must be adaptive to changing circumstances: whether these are changes in the “fire environment” and how they affect future research needs and agency information priorities; changes in skill sets and technology (e.g., social media and database management) that affect program management; or changes in funding priorities and desired oversight by agencies, administrations, and Congress. Some of the science, and its delivery, challenges faced by the program at its inception in 1998 still remain—though in many cases, significant progress has been made. The nation’s relationship to wildland fire and the new challenges also are significantly different and will continue to evolve. Amidst such change, the JFSP must remain proactive and continue to show value to the preceding audiences, as well as the wildland fire science, fire management and policy, and land management communities.

The JFSP can accomplish this by first remaining true to its core values as a program:

- The needs of managers and policymakers guide and frame research questions.
- Open solicitation and fair competition are a hallmark of the program.
- All research proposals receive an independent peer review to ensure scientific merit, applicability of outcomes, and feasibility of execution.
- Maximum science adoption is achieved by sharing, synthesizing, interpreting, and demonstrating/validating results.
- Regular self and external evaluations of program activities are routinely conducted.

“The JFSP provides science you can use.”

- Tim Swedberg, former JFSP communications director

Second, the JFSP must extend its work with current and new partners. The wildland fire science community is diverse and includes not only federal science programs but also academic, nonprofit, and other communities that produce and translate science. End users of science also extend beyond the traditional land management agencies and include managers, practitioners, and policymakers in other federal agencies, as well as states, tribes, and private interests. The JFSP must show (1) how it complements and integrates with the work of other science producers and in many cases acts as a catalyst for their efforts and (2) how its science delivery activities reach a broad diversity of end users and include not only its own funded research but that of its partners—such as U.S. Forest Service research stations and U.S. Geological Survey science centers.

Third, the JFSP must continue to innovate. Its fire science exchanges do not only “deliver” science: They are constantly innovating (1) in the way that science is interpreted, translated, and made accessible to a variety of end users and (2) in the way they solicit future research needs from the end user community. The Fire Science Exchange Network is a

well-respected “boundary-spanning” organization and model for other such organizations or networks. Even so, it must continue to assess and innovate in the manner in which it shares knowledge. Even the manner in which research is conducted, especially when striving for management and policy relevance is subject to innovation. As the JFSP moves forward, it will develop and implement new models of conducting research and its application as a coproduced effort between scientists, practitioners, and managers.

As a joint interagency program, the JFSP is uniquely positioned. By working closely with partners, it can take a broad look at the wildland fire science needs and priorities across the nation, while staying attentive to regional and individual agency needs and priorities. By convening and coordinating across the different interests, the JFSP can assist other agencies and research programs in identifying a coordinated response to the nation’s wildland fire science needs that avoids unnecessary duplication of effort while promoting complementary efforts, integration, and synergy in a manner that best serves to advance scientific understanding and meet end user needs.



“Fire is an agent of change. Moreover, the changing environmental and societal conditions under which wildland fire occurs are their own agents of change and will challenge [the nation’s] future ability to adapt to and live with fire. In a similar manner, the JFSP has adapted to change. In response to reduced funding over the last couple of years, [the program is] focused on accomplishing a leaner mission—one that concentrates on a high return on investment and our core strengths. These are science delivery, workforce development, and strengthening partnerships” (JFSP 2018e).

- John Hall, current JFSP director



TIMELINE OF KEY EVENTS

- 1998** Congress creates the Joint Fire Science Program and establishes its mission.
JFSP receives initial congressional funding.
In response to congressional direction, the “Joint Fire Science Plan” is developed.
JFSP Governing Board and peer-review process for research proposals are established.
Program office is staffed with its first two employees.
- 2000** JFSP completes development of the program’s implementation plan and operating guidelines.
- 2001** Congress expands the JFSP mission and budget.
- 2003** The first “Five-year Program Review” is completed.
- 2004** JFSP establishes a communications director position for the program office.
JFSP hires the first communications director.
JFSP hires a new program director.
SageSTEP proposal receives funding.
- 2005** JFSP hires a new communications director.
- 2006** JFSP establishes a webpage database manager position and fills the position.
JFSP hires a new program director.
- 2007** JFSP establishes initial lines of work.
JFSP initiates group peer reviews.
Program director creates more focused task statements.
JFSP revises operating guidelines.
JFSP begins smoke line-of-work task statements.
JFSP conducts smoke biomass and risk roundtables.
JFSP initiates Fire Science Digests and Fire Science Briefs.
JFSP establishes the science delivery strategy.
- 2008** The second “Five-year Program Review” is completed.
Peer review is restructured to emphasize technical review by scientists.
Researchers begin Interagency Fuels Treatment Decision Support System (IFTDSS) design.
JFSP adds electronic proposal submission capability to website.
- 2009** JFSP adopts the investment strategy.
JFSP reviews and accepts first online proposal submissions.
Governing Board triples science delivery funding and initiates the Fire Science Exchange Network.
JFSP creates findings database.
JFSP sponsors symposium on 10 years of JFSP-funded research at the 4th International Fire Ecology and Management Congress.

TIMELINE OF KEY EVENTS

- 2010** JFSP revises process by which potential task statement topics are identified and selected.
Researchers complete development of IFTDSS.
JFSP converts all records to electronic storage.
Eight exchanges in the Fire Science Exchange Network receive funding.
JFSP initiates webinar series.
JFSP releases and implements the “Smoke Science Plan.”
- 2011** DOI is selected as interim managing partner of IFTDSS.
SageSTEP funding ends.
JFSP launches GRIN awards and TREE grants.
JFSP initiates Friday Flash e-newsletters on website.
JFSP begins social media program.
Fire Science Brief publication ends.
- 2012** RxCADRE extension and expansion receives funding.
JFSP completes major redesign of website.
JFSP launches public, online multiplatform library.
- 2013** The third “Five-year Program Review” is completed.
JFSP initiates development of the “Fuel Treatment Science Plan.”
IFTDSS sponsorship ends.
International Journal of Wildland Fire publishes special issue titled “Ten Years of Fire Research: The US Joint Fire Science Program.”
- 2014** JFSP releases and implements “Fuel Treatment Science Plan.”
Fire Executive Council charters the program.
IFTDSS prototype transferred to USFS Wildland Fire Management Research, Development, and Application Program for further development and implementation.
RxCADRE funding ends.
- 2015** The number of Governing Board members increases from 10 to 12 members.
JFSP initiates assessment of policymaker needs for wildland fire science.
- 2016** JFSP hires a new program director.
Governing Board revises operating guidelines to reflect a strategic board.
- 2017** The fourth “Five-year Program Review” is completed.
Phase I planning for the Fire and Smoke Model Evaluation Experiment (FASMEE) is completed.
JFSP updates research proposal and final report guidelines.
- 2018** JFSP completes action plan for policymakers to receive necessary wildland fire science.
JFSP completes assessment of Fire Science Exchange Network vision and business model.
JFSP celebrates 20 years.

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