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Wildland Fire and Fuels Research and Development Strategic Plan: Meeting the Needs of the Present, Anticipating the Needs of the Future

Large photo on front cover: Prescribed crown fires are being tested for stand replacement of Table Mountain pine communities in the southern Appalachian Mountains. This fire was on the Tallulah Ranger District, northeastern Georgia, in the late winter of 2003. Photo by Tom Waldrop, USDA Forest Service.

Left small photo: Research personnel clean out a sediment trap after a summer thunderstorm. These sediment traps are used to compare postfire treatment effectiveness after the Hayman Fire, Colorado, 2004. Photo by Pete Robichaud, USDA Forest Service.

Middle small photo: Crew inventories down and dead woody fuels for a natural fuels photo series site located on the Wallowa/Whitman National Forest. Photo by Roger Ottmar, USDA Forest Service.

Right small photo: Rapid Response Team researchers brief the incident command team on the Dragon Fire, a wildland use fire on the North Rim of the Grand Canyon in summer 2005. Photo courtesy Colin Hardy, USDA Forest Service.

Image on back cover: Old Fire, 25 October 2003, as viewed by the airborne FireMapper thermal-imaging radiometer developed and flown by the Pacific Southwest Research Station. The thermal image is color-coded by temperature (green/gray/red/orange/yellow) and shown on a post-fire image (with ash shown in blue). Image courtesy Phil Riggan, USDA Forest Service.

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Preface

Mission Statement

U.S. Department of Agriculture (USDA) Forest Service wildland fire and fuels research and development (R&D) provides the knowledge and tools that managers use to reduce negative impacts and enhance beneficial effects of fire and fire management on society and the environment.

Vision for the Future

Science, technology, and policy support management activities to protect life, property, infrastructure, and resources from the adverse effects of wildland fire, to protect the range of other values at risk, and to enhance the positive role fire plays in resource management.

The historic and ongoing role of wildland fire as a disturbance and the range of effects of fire and fuels management in various ecosystems are understood by the public, land managers, and policymakers. Land management practices and planning reflect the long- and short-term roles of fire at regional to global scales.

Through better understanding and awareness of fire processes and socioeconomic values, individuals and communities recognize their options regarding fire safety and living in fire-affected[1] ecosystems.

Fire management and suppression organizations, resource managers, communities, and policymakers are using knowledge, decision-support and predictive models, and other tools that incorporate state-of-the-art technology and science from fire R&D to achieve their goals.

Acknowledgments

We thank the many reviewers, including researchers, stakeholders, and other partners within and outside the USDA Forest Service who provided comments on earlier drafts of this document. This strategic plan has been greatly improved thanks to their input.

[1] Although the terms *fire-adapted* or *fire-dependent* ecosystems are often used, they are less inclusive than *fire-affected* ecosystems. Fire-affected ecosystems include those resilient to fire, although not specifically adapted to or dependent on it, as well as those that may be affected by fire but are *not* resilient to it or are adapted to it and therefore sustain damage that may require active restoration. We have chosen to use the term *fire-affected ecosystems* as inclusive of the range of ecosystems in which fire management is a concern.

Contents

Executive Summary

This document presents the U.S. Department of Agriculture (USDA) Forest Service Wildland Fire and Fuels Research and Development (R&D) Strategic Plan for the next 10 years (through 2015). The plan provides a framework to implement a national program of research and science application that aligns with and anticipates the needs of land managers and other clients and stakeholders. It recognizes the need to coordinate research activities with partners in other organizations and responds to fire and fuels management and research priorities identified in numerous reports. This plan takes an integrated and nationally coordinated approach to focus on the most important research needs by identifying priorities in three major strategic goal areas.

Strategic Goal 1. Advance the biological, physical, social, economic, and ecological sciences.

Research under this goal will improve the understanding of fire processes and interactions and deliver the basic scientific knowledge and understanding for developing the next generation of decision-support and predictive tools for fire and fuels management.

A. Core fire science. *Improved understanding of combustion processes, fuels, fire weather, fire behavior, and transitions.*

B. Ecological and environmental fire science. *Interactions among fire, other natural disturbance processes, and the physical and biological components of ecosystems and the environment.*

C. Social fire science. *Social and economic dimensions of fire and fuels management.*

D. Integrated fire and fuels management research. *Landscape analysis and integrated interdisciplinary research to quantify the interacting effects of management strategies on ecology, environment, and society.*

Strategic Goal 2. Develop and deliver knowledge and tools to policymakers, wildland fire managers, and communities.

Activities under this goal will ensure that knowledge generated by the USDA Forest Service and its cooperators is translated into a form that is useable by managers and the public and that is transferred to and adopted by the user community.

E1. Synthesis and tool development. *Accelerate and coordinate the development of science syntheses and decision-support and predictive tools that build on Strategic Goal 1 research.*

E2. Science application strategy. *Develop and implement a comprehensive strategy for moving science into application, supporting and maintaining tools and models resulting from wildland fire and fuels R&D, and for evaluating success.*

Strategic Goal 3. Provide Federal leadership for collaborative, coordinated, responsive, and forward-looking wildland fire-related R&D for all ownerships, now and in the future.

A new leadership structure and process for funding allocation in wildland fire and fuels R&D will support the development and implementation of a nationally coordinated program of USDA Forest Service wildland fire and fuels R&D to address the priorities identified in Strategic Goals 1 and 2. USDA Forest Service R&D will strengthen collaborations with other agencies and partners to ensure that Federal wildland fire and fuels R&D programs support the Nation's short-term priorities and long-term needs to reduce the negative economic, social, and environmental impacts of wildland fire while improving the health of our ecosystems, our environment, and our communities.

The priorities described above will guide the allocation of effort and resources for fire research, tool development, and delivering science-based knowledge and tools to managers and policymakers.

Introduction

This document presents the Wildland Fire and Fuels Research and Development (R&D)[2] Strategic Plan for the next 10 years (through 2015). The plan provides a framework for implementing a national program of fire-related R&D that aligns with and anticipates the needs of land managers and other clients and stakeholders.

The strategy described here for wildland fire R&D supports U.S. Department of Agriculture (USDA) Forest Service national priorities described in the USDA Forest Service Strategic Plan for fiscal years 2004–08 (USDA Forest Service 2004b). Wildland fire R&D primarily supports USDA Forest Service Strategic Plan's **Goal 1. Reduce the risk from catastrophic wildland fire.** *Restore the health of the Nation's forests and grasslands to increase resilience to the effects of wildland fire*. In support of this goal, the Wildland Fire and Fuels R&D Strategic Plan addresses specific needs in the four key point areas identified by the fire and fuels management communities in the interagency National Fire Plan (NFP), as outlined in "Managing the Impact of Wildfires on Communities and the Environment" (USDA and DOI 2000), "A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment: 10-Year Comprehensive Strategy" (USDA and DOI 2001), the implementation plan for the Comprehensive Strategy (USDA and DOI 2002), and "Protecting People and Natural Resources: A Cohesive Fuels Treatment Strategy" (DOI and USDA 2006). These documents identify four key needs for managing wildland fire and its impacts: (1) improve prevention and suppression, (2) reduce hazardous fuels, (3) restore fire-adapted ecosystems, and (4) promote community assistance. We anticipate that integrated approaches to wildland fire management will continue to be a high priority for the USDA Forest Service in future strategic plans.

Because fire is a natural process that interacts with other disturbances and land management activities and affects essentially all wildland ecosystems and their uses, research in other goal areas also often supports wildland fire R&D priorities, and wildland fire R&D also contributes to the other strategic plan goals:

Goal 2. Reduce the impacts from invasive species. *Restore the health of the Nation's forests and grasslands to be resilient to the effects of invasive insects, pathogens, plants, and pests.*

Goal 3. Provide outdoor recreational opportunities. *Provide high-quality outdoor recreational opportunities on forests and grasslands, while sustaining natural resources, to meet the Nation's recreational demands.*

[2] For explanation of the acronyms and abbreviations used in this document, please refer to appendix A.

Goal 4. Help meet energy resource needs. *Contribute to meeting the Nation's need for energy*.

Goal 5. Improve watershed condition. *Increase the number of forest and grassland watersheds that are in fully functional hydrologic condition*.

Implementation of the Wildland Fire and Fuels R&D Strategic Plan will focus research activities to provide the necessary science-based information and tools to support Federal, State, and local agencies, communities, and the broader user communities in achieving the overall societal and resource outcomes identified in the USDA Forest Service and U.S. Department of the Interior (DOI) proposed Wildland Fire Management Performance Logic Model (WFMPLM) (USDA Forest Service 2003) and the draft interagency Quadrennial Fire and Fuels Review (QFFR) (USDA Forest Service and DOI 2005):

- **Reduce** the **losses** to society (lives, property, infrastructure, resources) from wildland fire (WFMPLM). *Promote fire-adapted communities* (QFFR).
- **Improve** and **maintain** the resilience and sustainability of wildland ecosystems (WFMPLM). *Ensure fire management's role in ecosystem sustainability* (QFFR).

This strategic plan builds on the WFMPLM, which was used as input in stakeholder workshops to develop the Fire Research Logic Model (FRLM) (2004a). The FRLM outlines the research needed to support outcomes and goals of the the WFMPLM and provided a foundation for this strategic plan.

This strategic plan also responds to recognized national and international needs for research and technology to reduce the impacts of natural hazards, as outlined in two recent reports published by the Committee on Environment and Natural Resources (CENR) of the President's National Science and Technology Council. Both reports—*Reducing Disaster Vulnerability through Science and Technology* (CENR 2003) and the more recent strategy document *Grand Challenges for Disaster Reduction: Framing a Vision for the Future* (CENR 2005)—identify fire as one of the major hazards that needs to be addressed in reducing the impacts of disasters on U.S. and global societies, economies, and natural resources. These reports stress the need for better science-based knowledge, tools, and technologies for prediction, prevention, warning, mitigation, and recovery.

Background

The combined effects of land use changes, landscape fragmentation, management practices, vegetation succession, climate, and spread of invasive species since the beginning of Euro-American settlement have led to widespread changes in fire regimes across the United States. Effects have ranged from increased fire frequency, and sometimes vegetation conversion, (e.g., in southern California coastal sage) to greatly decreased frequency and near fire exclusion (e.g., in dry forests of the interior West). In many areas where fire frequency has been greatly reduced and fuels have accumulated, the increase in the size and severity of wildfires has been sometimes dramatic, impacting lives, property, and natural resources. There is a growing recognition that aggressive fire suppression is only part of the solution and that wildland fire must be managed to protect values and resources while recognizing the essential role that fire plays in many natural ecosystem processes. The severity of the 2000 fire season brought these factors to the fore, and the implementation of the NFP, starting in 2001, ushered in a new era of fire management. The clear need for new approaches to managing fire and fuels, restoring and maintaining ecosystems that are adapted to or otherwise affected by wildland fire (fire-affected ecosystems), and working with the communities affected by wildland fire has greatly intensified the need for Federal land management agencies, tribes, States, and private constituents to apply science-based knowledge and decision tools to fire and fuels management. To meet this increased demand for new knowledge and products from wildland fire R&D, the USDA Forest Service has accelerated development of new tools and production of critical science and technology products for fighting fire, managing fuels, using prescribed fire, and restoring fire-affected and fire-adapted forests and rangelands.

In response to demand from agency managers, who are increasingly challenged by complex problems during fire and fuels planning and postfire restoration processes, wildland fire R&D has expanded programs on managing fire and fuels, predicting effects of fire, and understanding social and community processes while continuing research to support fire suppression or other appropriate management response to wildfires and address the global impacts of wildland fire.

Recent tools and products developed in response to these challenges include the following:

1. Fire growth simulators for assessing wildfire growth potential and fuel treatment priorities (FARSITE and FlamMap).
2. Modification of the USDA Forest Service stand growth simulator to incorporate effects of fire and fuel treatments (Fire and Fuels Extensions of the Forest Vegetation Simulator).

3. A new software package for fire behavior modeling that includes crown fire and other new models and greatly improved outputs and user interfaces (BehavePlus).
4. A modeling framework to predict cumulative smoke impacts from forest, rangeland, and agricultural fires (BlueSkyRAINS), which was piloted across the Western United States by the USDA Forest Service, DOI, and U.S. Environmental Protection Agency in FY 2005.
5. A multipartner, interdisciplinary effort to produce geospatial data on vegetation conditions, fire, fuels, risks, and ecosystem status at the national, regional, and local scales (LANDFIRE) that is being deployed operationally by USDA Forest Service, DOI, and The Nature Conservancy.

Both Congress (in USDA Forest Service R&D authorizing legislation) and the Department of State (in its environmental diplomacy goals) recognize that it is in the best interests of the United States to develop and maintain international collaboration in a broad range of research areas pertaining to natural resources and the environment. Fire is increasingly recognized as a process whose effects on air quality, atmospheric chemistry, carbon storage, and other factors can have international and global environmental and policy implications. The USDA Forest Service has a long, fruitful history of international collaboration in fire research, which has often led to direct benefits to United States and international fire management. USDA Forest Service wildland fire R&D must continue to respond to the challenges of increasing our understanding and modeling capabilities through research in the United States and in collaboration with colleagues around the world.

The purpose of this document is to articulate a USDA Forest Service wildland fire and fuels R&D strategy that will improve our ability to plan and implement a national program of federally supported fire-related research that is aligned with short-term priorities and long-term management and public needs. Activities taken under this plan must be integrated with both R&D and management activities of other Federal, State, and private entities. The strategic plan addresses current needs of managers and policymakers and anticipates future needs and opportunities in a world of changing fire regimes, climate, environment, land use, and social needs and priorities. It promotes the development of information and tools to support local and national decisionmaking and to apply on public and private lands at regional, national, and international scales.

A Brief History

USDA Forest Service wildland fire R&D has played a vital role in the agency's fire and fuels management program since the early 1900s and continues to do so today. USDA Forest Service research has collaborated with the management community to develop products that have guided the fire suppression and fire management activities of Federal, State, and local agencies and their partners.

- The Incident Command System (ICS), developed under the FIRESCOPE Research, Development, and Application (RD&A) Program in the 1970s, provides the management structure that all Federal agencies and many of their partners use for fighting unwanted wildfires. ICS guidelines are widely used in wildland fire and other emergency incident response around the world, including events as diverse as those of the terrorist attacks of September 11, 2001, response to earthquakes and hurricanes, and elimination of Newcastle disease epidemics in chicken populations.
- The National Fire Danger Rating System (Deeming et al. 1977) is a fundamental tool that fire managers still use today to assess seasonal progression of fire danger. It has been improved and added to over the years, but the basic concept of a consistent national system for monitoring seasonal changes in fire danger has not changed.
- The Behave system (Andrews 1986) has long been the standard model used in the United States for predicting fire behavior on wildfire incidents. This system has recently been improved substantially by incorporating new models, improved outputs, and more user-friendly interfaces into the BehavePlus fire modeling system. The Behave model has also served as the foundation for numerous other applications familiar to fire managers, such as the FARSITE landscape fire modeling system.

These products, which represent a direct result of long-term investments in wildland fire R&D, have changed the way the USDA Forest Service, DOI, and other agencies organized for fighting fires and fought fire and are examples of how the wildland fire R&D program has efficiently responded to users' needs. International collaborations have enhanced our understanding of fire processes and their regional and global environmental impacts, led to new approaches to fire behavior modeling, and informed fire management in the United States and in other countries. Tools developed by USDA Forest Service R&D (such as the ICS and fire behavior models) are used in the United States and other countries in many applications. Many of the products in use today were a direct result of strong agency support for wildland fire R&D during the 1970s. Support and staffing for wildland fire R&D declined

significantly in the 1980s. An increased awareness of the societal and resource impacts of increasingly large and severe fires starting in the late 1980s, along with implementation of the interagency Joint Fire Science Program in 1998 and the NFP in 2001, has led to the revitalization of wildland fire R&D within and outside the USDA Forest Service. Demand for new knowledge, services, and products to support wildland fire management continues to grow rapidly. Realizing the outcomes envisioned in this Wildland Fire and Fuels R&D Strategic Plan will require an ongoing investment in development and implementation of science-based knowledge and tools by the USDA Forest Service and our partners.

The Current Need

A clear strategy for intra-agency leadership and interagency collaboration at the national level is needed to ensure that our wildland fire R&D programs are able to keep up with the rapidly expanding demand for science-based decision-support and predictive tools and products, and to maintain the appropriate balance between meeting national and regional needs.

Managers and policymakers urgently need better information and tools to do their jobs more effectively. Our goal is to develop knowledge and tools responsive to current needs and to anticipated management and policy needs for wildland fire R&D over the next 10 years. The recently completed interagency QFFR report (USDA Forest Service and DOI 2005) identifies key mission strategies for fire and fuels management along with core capabilities needed to implement these strategies over the next several years. Capability of Federal and State agencies to implement two of these proposed strategies will benefit greatly from knowledge and products derived from wildland fire R&D. These mission strategies and their associated core capabilities include the following:

- Ensuring fire management's role in ecosystem sustainability.
    - Integrating planning.
    - Enhancing decisionmaking.
    - Ensuring seamless and integrated fuel programs.
    - Establishing monitoring.
    - Broadening the ability to respond.
- Promoting fire-adapted communities.
    - Strengthening community relationships.
    - Expanding community education.

Key Areas

We have identified four key areas in which managers most need improved knowledge and tools from R&D. These key areas support the needs identified in the WFMPLM and the QFFR and the broader land management community's needs concerning management of fire-affected ecosystems and communities. The key areas include the following:

- Programmatic fire planning.
- Fire decision support for appropriate management response to wildland fire.
- Fuel management and ecosystem restoration[3].
- Rehabilitation and restoration of severely burned landscapes.

A number of very important issues cut across several of these areas, including predicting fire behavior; understanding and predicting the environmental and ecosystem effects of fire; interactions between fire, weather, and climate; and effective use of social science information in fire management planning and program implementation. In all cases research can contribute to the ability of fire managers and land managers to adapt their approaches as new information, technology, and analysis capabilities emerge.

Programmatic Fire Planning

- Better R&D support for enhancing programmatic planning tools, including improved decision support, recordkeeping, and analysis tools that integrate economics, noneconomic values, suppression, and improved systems for fire hazard prediction and mapping.
- National monitoring systems for burned areas, fire severity, emissions, watershed impacts, property loss, and other factors that will support adaptive approaches to management as better data become available on the effects of management activities.
- A comprehensive analysis system for evaluating alternative mixes of wildland fire use, fuel management, and suppression—basing the system on economics, social impacts, ecological integrity, and environmental quality.
- Information and analysis capabilities that go beyond hazard assessment to incorporate actual risks of events occurring and risks to society and the environment if events do occur. Capabilities needed include fire severity, property damage, erosion potential, potential damage and benefits to resources or local economies, and health and safety.

[3] *Restoration* as used in this strategy means restoration to a desired healthy condition of the ecosystem; this may differ from the "historic" condition, which, for many sites, will be neither desirable nor sustainable.

- The development, testing, and implementation of improved landscape fire modeling systems (or one system) that can be used to reliably predict site-specific outcomes of prescribed fire, wildfire, and fuel or other vegetation treatments on ecosystem properties and fire behavior.
- An implemented national air quality prediction system that incorporates emissions from wildland fires on all lands and fine-scale meteorological, terrain, and fuel data to make national, regional, and local predictions of smoke patterns for assessing environmental and human health impacts from wildland fires and alternative fire and fuel management strategies.

Fire Decision Support for Appropriate Management Response

- A real-time fire behavior monitoring and prediction system that accurately identifies fire location and intensity and reliably predicts fire growth; extreme fire behavior transitions; and potential effects and consequences for resources, infrastructure, and safety.
- Information and tools that provide incident command teams with good estimates of costs, benefits, and resource (natural and infrastructure) effects of alternative fire suppression and fire management strategies.

Fuel Management and Ecosystem Restoration

- Information and tools to plan effective and cost-efficient fuel management and forest and rangeland health restoration treatments that are integrated into comprehensive landscape management, meet societal and economic goals, and contribute to community sustainability.
- Landscape-level planning that considers the relative effects of community action, zoning, building materials, landscape design, and fuel management on damage to communities and infrastructure from wildland-urban interface (WUI) fires.
- Information and decision-support and predictive tools for restoring health and sustainability in ecosystems impacted by fire exclusion, land use change, invasive species, conifer encroachment, insect and disease, and other disturbances that can increase the severity of and the extent of ecosystem damage from wildfires.

Rehabilitation and Restoration of Severely Burned Landscapes

- Improved data and predictive models of the effects of fire patterns, fire severity, and postfire rehabilitation treatments on vegetation, ecological recovery, site productivity, wildlife, erosion, and water quality to support decisionmaking for emergency rehabilitation of severely burned areas.

Progress in these areas will require enhancing current interactions with the fire and resource management community to identify changing needs and priorities. Progress will require a better understanding of social and economic systems and ecological responses to management. Meeting these needs will require a mix of basic research to develop new knowledge, synthesis of information from past research, improved models and decision-support and predictive tools, a national strategy for moving these tools into application, and rapid communication of new information to our stakeholders.

Wildland Fire and Fuels Research and Development Program Goals

This Wildland Fire and Fuels Research and Development Strategic Plan has three general strategic goals, which were identified in the fall of 2004 while developing the Fire R&D Logic Model (USDA Forest Service 2004a). The logic model process used regional meetings of stakeholders from the Eastern and Western United States to help develop recommended priorities for USDA Forest Service wildland fire and fuels research (see appendix B for stakeholder organizations that participated). The strategic plan also responds to priorities identified while developing logic models on invasive species, air and water research, and research program delivery. Many of the specific research and science application priorities articulated on the following pages have been identified by researchers and research stakeholders through numerous publications and workshops over the past several years. (See appendix C for a partial list of publications.)

Strategic Goal 1. Advance the biological, physical, social, economic, and ecological sciences.

Research under this goal will seek to improve the understanding of fire processes and interactions and deliver the basic scientific knowledge and understanding for developing the next generation of decision-support and predictive tools for fire and fuels management.

A. Core fire science. *Improved understanding of combustion processes, fuels, fire weather, fire behavior, and transitions.*

B. Ecological and environmental fire science. *Interactions among fire, other natural disturbance processes, and the physical and biological components of ecosystems and the environment.*

C. Social fire science. *Social and economic dimensions of fire and fuels management.*

D. Integrated fire and fuels management research. *Landscape analysis and integrated interdisciplinary research to quantify the interacting effects of management strategies on ecology, environment, and society.*

Strategic Goal 2. Develop and deliver knowledge and tools to policymakers, wildland fire managers, and communities.

Activities under this goal will ensure that knowledge generated by the USDA Forest Service and its cooperators is translated into a useable form for managers and the public, and that is transferred to and adopted by the user community.

E1. Synthesis and tool development. *Accelerate and coordinate the development of science syntheses and decision-support and predictive tools that build on Strategic Goal 1 research.*

E2. Science application strategy. *Develop and implement a comprehensive strategy for moving science into application, supporting and maintaining tools and models resulting from wildland fire and fuels R&D, and for evaluating success.*

Strategic Goal 3. Provide Federal leadership for collaborative, coordinated, responsive, and forward-looking wildland fire-related R&D for all ownerships, now and in the future.

A new leadership structure and process for funding allocation in wildland fire R&D will support the development and implementation of a nationally coordinated program of USDA Forest Service wildland fire R&D to address the priorities identified in Strategic Goals 1 and 2. USDA Forest Service R&D will strengthen collaborations with other agencies and partners to ensure that Federal wildland fire-related R&D programs support the Nation's short-term priorities and long-term needs to reduce the negative economic, social, and environmental impacts of wildland fire while improving the health of our ecosystems, our environment, and our communities.

Strategic Goal 1

Advance the biological, physical, social, economic, and ecological sciences

The knowledge and tools needed for landscape and national planning, implementation, and assessment require understanding and models that operate at a range of spatial and temporal scales and incorporate the complexity of the natural and human environment as it affects fire processes on the landscape. New computing and modeling tools, remote sensing and in situ observation capabilities, and databases have increased the capability for complex process and pattern analysis and modeling. Recognition of the need for multiownership, multidimensional, landscape-scale and national-scale planning and assessments has increased the demand for the understanding and tools to support more spatially and temporally refined predictions and analyses. Activities listed under Strategic Goal 1 will seek to build on a strong foundation of more than 75 years of past research on fire behavior, fire effects, fire and environment interactions, and socioeconomic aspects of fire management to meet these needs. Current knowledge and models are insufficient to predict complex fire processes and interactions and the effects of fire and management treatments across diverse landscapes and spatial and temporal scales. The basic scientific knowledge, principles, and process models developed under this plan will form the basis for the next generation of decision-support and predictive tools for fire and fuels management.

Research carried out under this goal will develop the information and knowledge needed to support improved fire and fuel management and planning and effective use of fire and fuel management treatments by the USDA Forest Service and its partners and clients to restore and maintain healthy, resilient, fire-adapted ecosystems. This research will produce a strong foundation of peer-reviewed science to support management activities and on which other research will build to further advance the science. Such information and knowledge are vital in predicting the environmental, ecological, and socioeconomic effects of fire and fuel treatments at stand, landscape, and broader levels; assessing the effectiveness of varying treatment strategies for restoring and maintaining fire-adapted ecosystems; supporting fire suppression decisionmaking; and understanding how to work more effectively with communities and collaborators.

Research priorities are identified for four broad topic areas that will be managed using a portfolio approach. Within each portfolio, we will strive to balance our program to address national needs and local managers' needs for site-specific information. This strategic plan identifies four research portfolio areas (A through D), as well as a science application portfolio described under Strategic Goal 2.

A. Core fire science. *Improved understanding of combustion processes, fuels, fire weather, fire behavior, and transitions.*

B. Ecological and environmental fire science. *Interactions among fire, other natural disturbance processes, and the physical and biological components of ecosystems and the environment.*

C. Social fire science. *Social and economic dimensions of fire and fuels management.*

D. Integrated fire and fuels management research. *Landscape analysis and integrated interdisciplinary research to quantify the interacting effects of management strategies on ecology, environment, and society.*

Major Fire Research and Development Needs

Portfolio A. Core Fire Science

Improved understanding of combustion processes, fuels, fire weather, fire behavior, and transitions.

Physical fire science is at the core of fire research. It advances the fundamental understanding of fire behavior, fire danger, and fire emissions in all fuels and fuel complexes. This understanding is critical for (1) developing timely, accurate, and complete predictions of fire behavior and effects; (2) improving assessments of fire hazards and risks; (3) designing and comparing fuel treatments and outcomes; and (4) prioritizing fuel treatment and response options. Current operational fire behavior models do not accurately reflect the complexity of combustion processes, the temporally and spatially variable physical environment in which they occur, or fire and atmosphere interactions. As a result, predictions are sometimes incomplete or inaccurate in ways that negatively affect fire planning and response. Improved basic understanding of physical and chemical fire processes and interactions is critical for developing the next generation of decision-support and predictive tools for fire and fuel management. Also critical is the ability to integrate this understanding into accurate spatial and temporal predictions of fire processes. This research will provide the foundation for incorporating improved understanding of fire behavior, combustion, fire weather, and emissions into tools to improve the efficiency and effectiveness of fire and fuel management decisions and will lead to enhancements in public safety, ecosystem integrity and sustainability, and environmental quality.

Three national priority program elements for core fire science research are described in the following paragraphs. This research will build on recent advances in fire behavior, atmosphere and and fire weather theory modeling capabilities, and monitoring to raise our understanding of physical processes governing fire hazard, fire behavior, combustion, and emissions at multiple scales, and will lead to substantial improvements in the capability to make accurate predictions needed for improved planning, decisionmaking, and firefighter safety.

Key Research Needs in Core Fire Science (Portfolio A)

1. Physical fire processes (Element A1). Improve our understanding of the fundamental, multiscale, physical processes that govern fire behavior, including combustion processes, heat and energy transfer processes, and fire-fuel-atmosphere interactions and dynamics in complex fuelbeds and environments.

- *Fire transitions.* Determine the physical processes responsible for major transitions in fire behavior, including initiation and cessation of surface spread, fire ignition extinction, transition to and from crown fire, and structure ignition.
- *Heat transfer.* Improve our ability to model and predict the level of heat transfer to and heat absorption by ground fuels, vegetation, the atmosphere, and the soil during all phases of combustion under varying fuel conditions.
- *Fire emissions.* Improve our understanding of the physical and chemical processes associated with fire emissions, including formation of primary combustion products and pollutants, chemical transformations in the smoke plume, and plume characteristics and behavior.
- *Complex fuels.* Characterize complex fuelbeds and determine their impacts on fire characteristics, including the impacts of different horizontal and vertical vegetation fuel structures, different live and dead fuel compositions, and complex fuelbeds composed of vegetation and buildings.

2. Fire characteristics at multiple scales (Element A2). Assess how larger scale spatial and temporal processes and factors such as regional climate patterns and variability, terrain variability, landscape-level management strategies, and regional fuel variability influence fire behavior, fire severity, fire size, and burn patterns across landscapes.

3. Fire danger assessment (Element A3). Improve the scientific basis for new and improved fire danger assessments, including information on atmospheric conditions, fuel moisture interactions, physical and structural variability in fuels, fuel flammability and ignition probabilities, and critical atmospheric boundary layer and mesoscale processes associated with fire-weather development and evolution.

Portfolio B. Ecological and Environmental Fire Science

Research on interactions among fire, other disturbance processes, and the physical and biological components of ecosystems and the environment.

Improved ability to predict the effects of fire will enable better management of wildland ecosystems for public benefit. Changes that have resulted from altered fire regimes, past management practices, and climate variability threaten ecosystem health and sustainability. We need to better understand the interaction of fire with individual ecosystem components, how these interactions lead to an ecosystem response, and how drivers and effects vary in time and space. We need to understand and be able to predict, assess, and monitor the interactions among fire, soil, water, vegetation, insects, disease, fish and wildlife species and habitat, air quality, climate variability and change, invasive species, and other disturbances. These activities require evaluating the potential for positive outcomes and the risk of negative effects. Enhanced understanding will provide a sound foundation for managing wildland fire, developing and evaluating management prescriptions, modeling outcomes, and assessing the risks and benefits of alternative management strategies.

Existing research has shown that we can predict and quantify many types of individual changes in species or ecosystem components resulting from disturbance by fire. Future research needs to integrate this work across ecosystem components and processes, expand current knowledge into additional ecosystems and regions, and develop more comprehensive information on the effects of interactions between fire and other disturbances on key ecosystem processes and components. Improved understanding of basic processes and spatial and temporal variability is a prerequisite to developing predictive models for site-specific and landscape-scale fire and treatment effects. These models can support and improve almost all fire management decisions, including planning, incident management, and fuel treatment development and application.

We have identified two national priority research program elements in ecological and environmental fire science that are important to wildland fire management. Research in these areas will provide a necessary foundation for predicting and understanding the effects of variations in fire regimes and natural disturbances, invasive species, management strategies, and changing weather and climate on ecosystems and the physical environment.

Key Research Needs in Ecological and Environmental Fire Science (Portfolio B)

1. Fire effects on ecosystem components (Element B1). Better understand the relationships among varying fire behavior characteristics (e.g., energy release, residence time, flame length, and depth of burn) and fire regimes (e.g., fire size

distribution, severity, and return interval) and fire's effects on vegetation, soils, watersheds, insects and disease, fish and wildlife, and carbon and nutrient cycling.

- *Biophysical processes*. Describe and model the linkages between fire behavior and fire effects on flora, fauna, and soils. Whenever possible, use this basic knowledge as a means of understanding and predicting ecosystem responses to fire.
- *Fire-vegetation interactions.* Enhance basic knowledge of fire interaction with vegetation, including injury and mortality, recovery of vegetation and fuels, factors affecting postfire productivity and wildlife habitat, and the role of invasive species.
- *Watershed function.* Evaluate the effects of changing fire regimes on short- and long-term watershed processes, including water yield, water quality, erosion, fish habitat, and site quality or productivity.
- *Insects and disease.* Quantify the relationships between insects and disease and fire disturbance, including the effects of insect and disease damage on fire regimes and effects of fire on insect and disease levels.
- *Carbon balance.* Predict changes in carbon sequestration, storage, and release in relationship to changing climate, management, and fire regimes.

2. Fire and environment interactions (Element B2). Quantify the role of fire as an ecosystem process in a changing environment and the impacts of environmental change on fire regimes.

- *Weather and climate interactions.* Quantify and model interactions among fire regime, weather and climate variability (including extreme weather and changes in hydrologic regimes), other disturbances, and vegetation dynamics.
- *Fire history and fire regimes*. Determine the historic and present patterns of frequency, severity, and scale of wildland fires; their relationships with changing climate and human-induced disturbances; and their effects on vegetation structure, succession, and plant and animal species distribution and diversity, with an emphasis on ecosystems where such information is lacking.
- *Effects of introduced species.* Evaluate the interaction between introduced species, fire, and regeneration and dynamics of native vegetation. Evaluate potential effects of invasive species on future fire regimes.
- *Emissions and air quality*. Develop information necessary to predict and model fire effects on air quality, including smoke transport, regional haze, and atmospheric chemistry. Evaluate tradeoffs among prescribed fire, wildland fire use, and wildfire.

Portfolio C. Social Fire Science

Conduct research on social and economic dimensions of fire and fire and fuels management.

Society is positively and negatively affected by fire through effects on life, property, infrastructure, and the natural resources and ecosystems on which we depend. Federal, State, and local fire and land management organizations interact in a complex manner with communities to develop and implement responses to wildland fire, to manage fuel conditions near those communities, and to use fire to reduce potential losses and enhance social and ecological systems. These activities require balancing the monetary and nonmonetary costs and benefits in assessing tradeoffs of alternative actions. Our objectives are to emphasize research that leads to a broader understanding of the interactions between fire and fuel management and society; enhances understanding of costs and benefits of wildland fire; and provides guidelines and tools for improving safety, working with communities and other partners, and assessing, implementing, and achieving effective and efficient land management goals related to fire and fuel management. Social science research will be focused on decisionmaking practices to increase safety during incidents, improve collaboration with communities, build trust, and better inform and protect the public.

We have identified three national priority research program elements related to improving interactions with the public, understanding the social and economic effects of fire and fuels management, and improving the ability of wildland fire organizations to do their work safely, efficiently, and effectively.

Key Research Needs in Social Fire Science (Portfolio C)

1. Public interactions with fire and fuel management (Element C1). Understand how human attitudes, values, and beliefs influence fire and fuel management options and how individuals and communities respond to fire risks in the WUI and wildland ecosystem.

- *Public trust.* Develop and evaluate tools to assess and enhance public trust in land management agencies and the agencies' ability to carry out fire and fuel management consistent with land management objectives.
- *Public perceptions.* Improve understanding of public perceptions of fire and fuel management, including influencing factors and the way they affect management options.
- *Incentives.* Analyze the effectiveness of incentives (such as building codes and fuel reduction cost-sharing) on individual and community actions to reduce wildland fire risk.

- *Cooperation and planning.* Develop and evaluate processes to enhance communication, cooperation, and collaboration among local, State, and Federal fire organizations and communities.
- *Education.* Evaluate the effectiveness of alternative approaches for educating internal and external audiences (the public, collaborators, elected and appointed officials) on fire and fuel management.

2. Socioeconomic aspects of fire and fuel management (Element C2). Evaluate the social and economic impacts and risks of alternative fire and fuel management strategies.

- *Impacts of wildland fire.* Develop a framework for assessing the social and economic impacts of wildland fire and fuel management on natural resources and infrastructure at national, regional, and community scales.
- *Values at risk.* Improve estimates of values at risk from fire and develop tools to map and model these values to assist with decisionmaking for fire prevention, preparedness, suppression, restoration, and postfire rehabilitation, including decisionmaking for wildland fire use before, during, and after fire events.
- *Social and economic impacts of smoke.* Improve understanding of the social and economic effects of smoke on firefighter and the public health, assess the benefits and costs of mitigation methods, and compare smoke impacts from wildfire versus wildland fire use and prescribed fire.

3. Organizational effectiveness (Element C3). Develop knowledge, approaches, and tools to improve the organizational effectiveness of fire management programs.

- *Optimal fire management programs.* Develop models for forecasting and optimizing large fire costs and seasonal suppression costs and assessing initial attack priorities. Improve understanding of the interrelationships between fire management programs, including prevention, presuppression, suppression, and fuel management, and how changing allocations among programs affects fire management objectives.
- *Human factors in fire management.* Evaluate the role of individual psychology and group dynamics and identify effective tools and approaches to improve application of science, decisionmaking, and firefighter safety.
- *Fire management decisionmaking*. Evaluate incentives that fire managers face that influence safety, fire costs, and resource outcomes across the spectrum from wildland fire use to large suppression fires. Provide better tools for meeting national policy goals and determining appropriate management response on initial attack and at later stages of fire incident management.

Portfolio D. Integrated Fire and Fuels Management Research

Conduct landscape analysis and integrated interdisciplinary research to quantify the interacting effects of management strategies on ecology, environment, and society.

Providing a suite of approaches and techniques from which managers can select the most appropriate means for meeting their objectives requires integrated understanding and modeling, at landscape, regional, national, and international scales, of the following considerations:

- **Effectiveness** of treatments at achieving management goals.
- **Effects** of these treatments and other natural and human-induced disturbances or changes on the biophysical environment.
- **Economics** of alternative management strategies.
- **Social and policy context** in which management decisions are made and implemented.

Meeting societal goals for sustaining ecosystems where fire has played a historic role requires active management and planning based on the best available biological, physical, and social science. The knowledge and models developed in Portfolios A, B, and C will provide an essential foundation for developing integrated approaches to considering the impacts of environmental and human-induced changes on ecosystem function, landscape patterns, and other factors. Ensuring that long-term ecosystem and productivity goals are realistic and achievable and are being met as intended requires ongoing evaluation of effects of management strategies and other disturbances, not just on individual sites, but across landscapes and regions. In addition, managing ecosystem and productivity goals requires integrating into management decision-making an understanding of the social and economic environment in which management is being carried out. To meet these needs, research must quantify and model the interacting effects of spatial and temporal distributions of natural disturbances, human-induced landscape changes, and the sociopolitical environment at landscape and broader scales. Research must quantify and model the effectiveness of mechanical treatments and prescribed fire and wildland fire use for restoring and maintaining healthy, resilient, fire-adapted ecosystems and evaluate the potentially changing roles of fire and climate over time. We must improve the economics and efficiency of using biomass harvested for fuel reduction by developing new uses and better processing methods. We also must evaluate the effects of burned area rehabilitation and other postfire treatments on various resource components, including causes for variable response and effects. Providing a foundation for ecologically sound, effective, and efficient management practices requires that we evaluate tradeoffs of alternative treatments on fire behavior and characteristics, fire effects, long-term ecosystem health and productivity, and social and economic factors.

We have identified three national priority research program elements for improving basic understanding of interacting effects of treatments and other disturbances at landscape and larger scales. This research will provide an essential foundation for developing management-oriented models and decision-support and predictive tools that integrate socioeconomic and biophysical considerations to support integrated planning and implementation for fire and fuel management programs and policies.

Key Research Needs in Integrated Fire and Fuels Management Research (Portfolio D)

1. Effects of landscape management strategies at multiple scales (Element D1). Assess the effects of spatial and temporal treatment strategies at multiple scales on attributes such as distribution of fire regimes, vegetation dynamics and health, vegetation structural and compositional diversity over time, effects of interacting disturbances, and socioeconomic effects and tradeoffs in space and time.

- *Treatment effects on fire and fuel characteristics.* Assess and model the effects of various stand and landscape-scale strategies and patterns of fuel treatment and their interactions with other human or natural disturbances on wildland fire behavior, fire size, burn severity, fuel consumption, and smoke production.
- *Community protection.* Assess the effectiveness of landscape and localized fuel treatments in meeting community wildfire protection objectives.
- *Information integration.* Develop methods to integrate geospatial and temporal information on the effects of alternative management strategies on ecosystems and on landscape-scale fire regimes, fire hazards, and site conditions with information on economic and social impacts and benefits of treatments.
- *Treatment tradeoffs*. Develop information and tools for analyzing the economic, social, and resource tradeoffs among fuel and forest health restoration treatments and effects of different spatial and temporal scales and patterns of treatments. Improve understanding of the relationship among the costs of treatments, the effects of those treatments on future fire behavior, future costs of fire suppression, and protecting values at risk over time.
- *Homeland security implications of fuels management*. Assess the role and effectiveness of wildland fuels management as a means of enhancing homeland security by reducing potential human-caused disasters.
- *Policy implications and impacts*. Develop integrated approaches to evaluating the potential policy impacts of alternative fire and fuels management strategies. Consider issues such as the effects of fire management, changing fire regimes, or changing climate on carbon storage, vegetation structure and distribution, and the economics of biomass removal and use at a national or global level.

2. Effects of treatments and other human impacts on ecosystem components (Element D2). Determine the effects of human-induced disturbance and land-management treatments on key ecosystem components and their interactions, including vegetation, wildlife, insects, diseases, watershed characteristics, and air.

- *Effects of fuel treatments.* Evaluate and integrate the individual and cumulative effects of single and multiple fuels treatments, including biomass use and wildland fire use, on key ecosystem components (vegetation, wildlife, insects, diseases, soils, water, watersheds, and air) at stand and landscape scales.
- *Effects of postfire treatments on ecosystem components.* Evaluate the effects of burned area rehabilitation and other postfire treatments on soil properties, soil biota and site productivity, long-term watershed properties (including water yield and water quality, potential for erosion and landslides, terrestrial and aquatic wildlife habitat and connectivity), and future fire size and severity.
- *Invasive species.* Evaluate the effects of site and landscape treatments on invasive species management or control and on susceptibility to invasion.

3. Biomass utilization, product development, and forest operations associated with fire and fuel management activities (Element D3). Develop new products, markets, and harvesting techniques for small-diameter materials. Evaluate the economics of use as a component of hazardous fuel reduction treatments.

- *Small-diameter product development.* Develop new products and processes that make use of small-diameter material removed for fuel management, including uses for bioenergy.
- *Harvesting techniques for mechanical fuel treatments*. Develop systems to treat fuels in proximity to the WUI.
- *Economics and markets*. Assess the economics of and potential markets for biomass use and the role of subsidies and other incentives in developing economically feasible alternatives for use of these materials.
- *Economic and social impacts.* Evaluate the long-term and regional sustainability of alternative fuel treatment and biomass use strategies in terms of economic feasibility and impacts on the welfare of local communities.

Relationship of Priority Research Areas to Fire Management Needs

All the proposed research supports the needs of managers for improved tools or information in several of the four key fire management needs areas identified in the preceding pages. Table 1 summarizes these relationships.

Table 1. *Relationship of research priority areas to fire management needs: summary.*

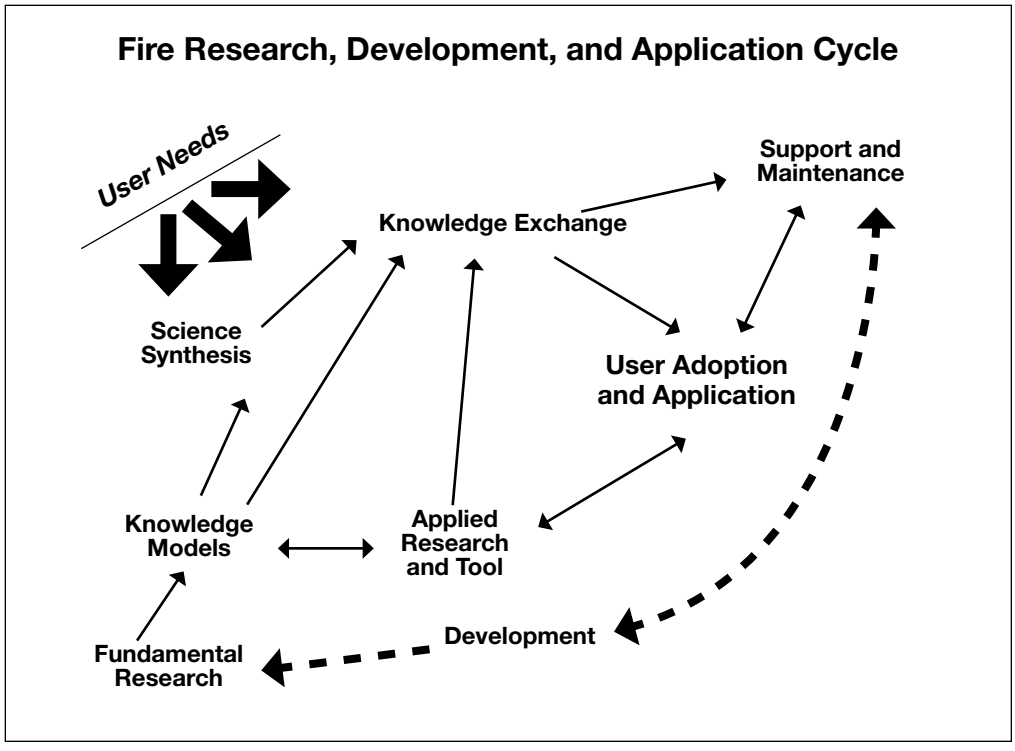
Research portfolio element	Fire management need			
	Programmatic fire planning	Decision support for appropriate management response	Fuel management and restoration	Severe fires—rehabilitation and restoration
Core fire science				
A1. Physical processes	X	X	X	X
A2. Multiple scales	X	X	X	X
A3. Fire danger	X	X	X	
Ecological fire science				
B1. Ecosystem fire effects	X	X	X	X
B2. Fire/environment	X	X	X	X
Social fire science				
C1. Public interactions	X	X	X	
C2. Socioeconomic aspects	X	X	X	X
C3. Organizational effectiveness	X		X	
Integrated management				
D1. Landscape strategies	X	X	X	X
D2. Treatment effects	X	X	X	X
D3. Biomass utilization	X		X	

Strategic Goal 2

Develop and deliver knowledge and tools to policymakers, wildland fire managers, and communities (Portfolio E)

Interaction with the community of users is critical at all stages of the research, development, and application cycle, from the identification of information gaps and users' needs to the processes of science delivery and application. We must ensure that we are producing information and tools of value to the user community; that information is synthesized and translated into models, decision-support and predictive tools, or other forms that are useable by managers and the public; and that knowledge and tools are transferred to and adopted by the user community. It is important to evaluate to what extent the science-based knowledge and tools are applied or adopted, where they are in the adoption and diffusion process, whether the methods of transferring information were effective, and what the barriers are to adoption. Feedback between users and researchers can point to needs for future research and tool development. Figure 1 illustrates this complex cycle of RD&A. Note the many feedback paths to ensure an "adaptive management" approach to RD&A.

Figure 1. *The fire research, development, and application cycle.*



We will develop improved mechanisms to ensure that models and decision-support and predictive tools developed under this strategy are integrated with existing products and with those still under development, and that their development is fully coordinated with external partners. A critical need in science application is development and implementation of mechanisms to accomplish the following:

- Determine when tools are ready to move from development into application.
- Partner with management to determine which tools should be adopted for national/interagency (corporate) application and support.
- Recommend needed improvements and additions to the "toolkit."
- Provide adequate staff and financial resources to support training courses, tutorials, help desks, and other mechanisms for transferring and delivering knowledge and tools.
- Partner with management to provide adequate infrastructure and funding for the maintenance, evaluation, and improvement of science-based decision-support systems and tools that are adopted.
- Proactively engage user communities in the development of science.

We have identified two major strategic research program elements that are necessary to ensure the application of science to meet the needs of managers and policymakers:

E1. Synthesis and tool development. *Accelerate and coordinate the development of science syntheses and decision-support and predictive tools that build on Strategic Goal 1 research (Element E1).*

E2. Science application strategy. *Develop and implement a comprehensive strategy for moving science into application, supporting and maintaining tools and models resulting from wildland fire and fuels R&D, and for evaluating success (Element E2).*

Strategic Actions

Element E1. Synthesis and Tool Development

Accelerate and coordinate the development of science syntheses and decision-support and predictive tools that build on Strategic Goal 1 research.

Develop a variety of improved science synthesis products, models, and decision-support and predictive tools and models that are coordinated to avoid unnecessary duplication, enhance functionality and target specific user needs. These products will be available to Federal, State, and local managers and to private landowners. We will inventory the current products to determine their adequacy, level of use, and range of applicability (scale and topical) so that plans for future products can avoid duplication.

Future work will emphasize the development of decision-support and predictive tools that are national in scope, except where regional differences clearly warrant building products that are more specific. The intent of this approach is to build fewer tools, but ones that are better integrated across disciplines (e.g., incorporate biological, physical, and social science) and have broad geographic coverage.

a. Decision Support for Appropriate Management Response and Programmatic Fire Planning

- Support implementation of improved and validated landscape modeling systems for fire behavior that fully use existing and expected capabilities for incorporating fuel structure and condition, surface winds and weather, fire and atmosphere interactions, and fire transitions in wildland and WUI settings to predict fire intensity and spread rate, fire severity, emissions and smoke dispersal, and ecosystem and community impacts.
- Facilitate application of improved decision-support systems for incident preparedness and management to support appropriate management response and assist in integrating potential resource effects of alternative incident management strategies into land management planning.
- Use increased knowledge of fire, weather, and climate interactions with fuels and other factors to develop new systems for risk assessment and tracking and predicting fire danger and fire severity.
- Support adoption of effective and affordable ground-based and remote sensing systems and analysis tools for monitoring and mapping fuels, burned areas, fire behavior, fire severity, emissions, and fire effects and for quantifying trends and effects of fire and fuel management treatments on landscape to national scales.

b. Fuel Management, Postfire Rehabilitation, and Ecosystem Restoration

- Develop techniques and models for assessing fire risk, disturbance patterns, and effects of fuel treatment strategies at landscape and national scales.
- Develop models and tools based on the synthesis of existing science to increase the capability of predicting effects of prefire and postfire treatments on soils, watersheds, vegetation, wildlife habitat, fisheries, and cultural values.
- Create risk assessment systems (including necessary databases) to help determine fuel treatment priorities and make wildland fire management decisions, including fire behavior, effects on communities and natural values, and tradeoffs between suppression and future risks.
- Develop and improve models and tools that integrate geospatial and temporal information on effects of alternative management strategies on ecosystems and on landscape-scale fire regimes, fire hazards, and site conditions with information on economic and social impacts of treatments.

Element E2. Science Application Strategy

Develop and implement a comprehensive national strategy for moving science into application, supporting and maintaining tools and models resulting from wildland fire and fuels R&D, and for evaluating success.

a. Implement a corporate, interagency decision process to evaluate and select models and decision-support and predictive tools for further development and recommend those tools that should be adopted for operational use

For decision-support and predictive tools (including modeling systems and databases) that are developed as outputs of Strategic Goal 1 research, the USDA Forest Service will develop an internal review process, coordinated with DOI and other relevant agencies, to supplement the current process used by the interagency National Wildfire Coordinating Group (NWCG)[4]. This process will ensure that new products are evaluated both at the prototype stage and as additional development is pursued. Such evaluations will lead to the development of tools that are more closely matched to end users' needs and minimize the proliferation of multiple products to serve the same needs.

This approval process must address information technology requirements and must build on existing processes used by USDA Forest Service Fire and Aviation Management, DOI Office of Wildland Fire Coordination, Information Technology organizations, and the NWCG. We strongly recommend that this process involve collaboration among all deputy areas, other Federal agencies, and State and local partners as appropriate. It is critical to ensure that research and land management organizations are full participants, because many of the applications and tools being developed are incorporated into integrated, multiresource modeling or planning systems in support of landscape-scale planning, National Environmental Policy Act development, and other activities. Planning for national implementation of R&D products should address where the decision-support or predictive tool will be housed organizationally and how it is to be funded and maintained once it becomes operational. It is also important to ensure that new and updated fire models and fire management tools are quickly integrated into training programs. To accomplish these goals, we believe that evaluation and decision processes must be coordinated among agencies and other partners and between R&D and management at a national level. We believe such coordination can be accomplished by modifying some existing processes. We recommend articulating more clearly the existing decision

[4] The National Wildfire Coordinating Group is an operational group established to coordinate programs of the participating wildfire management agencies. Members include the U.S. Department of the Interior (DOI) National Park Service, DOI Bureau of Land Management, DOI Bureau of Indian Affairs, U.S. Department of Agriculture, Forest Service Fire & Avaiation Management and Research & Development, Intertribal Timber Council, National Association of State Foresters, the U.S. Fire Administration, and the National Fire Protection Association.

and analysis processes for moving tools and products into application, modifying these processes as necessary to ensure adequate involvement of R&D at the national level, and regularly and collaboratively evaluating models and tools that are proposed for potential national application to determine when products are ready for national adoption and to recommend appropriate processes for maintenance and training.

b. Develop a corporate approach within the USDA Forest Service to ensure effective application of research results to management problems

The two major components for addressing this problem are as follows:

1. Define and implement a dedicated infrastructure for science application and technology transfer. We recommend that the USDA Forest Service component of this infrastructure be housed largely within USDA Forest Service R&D and designed explicitly to meet the needs of all three deputy areas and external stakeholders. An essential component of science application occurs at the level of individual researchers and research groups. A desirable structure will ensure that the USDA Forest Service has the necessary capacity and technical expertise for science delivery, technology transfer, and science application at local, regional and national levels to supplement existing capacity in individual research stations. This infrastructure should address the needs for long-term training on, and maintenance of, predictive models and decision-support tools, preferably through service centers such as the Forest Management Service Center and the National Interagency Fire Center Help Desk. USDA Forest Service R&D will engage with interdeputy partners to develop an improved nationally coordinated science application function. This effort will incorporate Washington Office oversight, the Forest Service Wildland Fire Research Development and Application unit in Boise, ID, and regional nodes of expertise that are linked to stations, to research and extension organizations in universities and other agencies, to the USDA Forest Service Technology and Development Centers (San Dimas, CA, and Missoula, MT), and to the wildland fire and land management communities.

2. Develop a stable funding structure to ensure adequate staffing and long-term commitment. Moving science into application is a function that bridges the science and management communities. An effective science application program responds to the needs of the user communities for acquiring information and tools in a timely, understandable manner. It is a collaborative effort that interfaces between the delivery of information and tools from the science community (“push”) and the demands for new information and tools from the user communities (“pull”). One goal of this strategic plan is to recognize the importance of this concept of science application. This “pull” from the user community is as important a component of successful science application as the more traditional “push” from the science

community (the outdated one-way "technology transfer" model of providing information to users). Recognizing that successful application of science is a mutual responsibility of the science community and the management/user community leads to a collaborative model of support for these activities. The science community and the user community both stand to benefit from a strong science application program. Commitment of agency resource managers and the interagency fire management community is necessary to ensure that science delivery and adoption take place in a reasonable time, that approved applications and tools are adequately supported, and that users and researchers provide each other adequate feedback to influence the direction of future work.

c. Foster partnerships for science application and delivery

The previous section addresses a USDA Forest Service strategy for science application. We operate, however, in an interagency, collaborative, multistakeholder environment—both in our research and in our management activities. Many benefits and economies are to be gained by a collaborative approach to science application. Wherever possible we recommend joint planning with agency, university, and other partners outside the USDA Forest Service for science application. Existing networks of Federal and State agencies, universities, tribal governments, and nongovernmental organizations and new, nontraditional partnerships can contribute greatly to furthering the adoption of science by targeted users. Potential partners include organizations like the USDA Cooperative State Research, Education, and Extension Service; external partners, such as Tall Timbers Research Station, The Nature Conservancy, and other nongovernmental organizations and universities; other agencies such as the U.S. Geological Survey and the USDA Natural Resources Conservation Service; and the interagency Geographic Area Coordination Centers. The goal of this approach is to make sure that a cadre of experienced science communicators exists who have the strategic and technical skills to interact effectively with the science and management communities in moving science into application.

d. Develop improved approaches for effective science delivery and application

Improving the effectiveness of science delivery requires us to identify and evaluate existing approaches to science delivery and learning within target audiences. We will use knowledge from communication studies, organizational research, decision science, social psychology, education, and other relevant sources to improve agency capacity to integrate science both at individual and organizational levels.

- We will conduct periodic reviews of wildland fire R&D delivery and application

efforts. In an effort to improve integration and efficiency in delivering science and technology products, review teams should examine the potential roles of the USDA Forest Service technology centers and other organizations within and outside the USDA Forest Service in developing and delivering fire research information. Reviews should include a multidisciplinary team of scientists, users, and communications and education professionals.

- In conjunction with activities under Portfolio C, we will evaluate the effectiveness of various delivery mechanisms (e.g., publications, training sessions, conferences, and online systems) for communicating information and achieving successful implementation of science-based knowledge and tools so that efforts can focus on those approaches most likely to succeed. This evaluation includes developing an understanding of different target audiences, the factors that influence their use of new knowledge and tools, and their preferred communication styles and networks.
- In making plans for implementing tools and models for decision-support, we will weigh the advantages of electronic tools compared to hard-copy distribution or maintaining applications on agency computer systems. Appropriate marketing approaches need to be developed and implemented for all products to ensure use by the target audiences.

Strategic Goal 3

Provide Federal leadership for collaborative, focused, coordinated, responsive, and forward-looking wildland fire-related R&D for all ownerships, now and in the future

Our overall goal is to have the USDA Forest Service contribute to and foster a national program of federally supported wildland fire-related R&D that is aligned with the Nation's short-term priorities and long-term needs. This includes reducing the negative economic, social, and environmental impacts of wildland fire while improving the health of our ecosystems, environment, and communities. To accomplish this will involve addressing a wide range of issues at local, regional, national, and international levels. Success will depend on strengthened collaboration with R&D partners in other agencies and universities and with stakeholders in the management and policy communities, including States and other partners. We must foster an efficient and effective interagency approach to planning and conducting the needed research and support the development of a program and infrastructure adequate to meet users' demands for fire management R&D knowledge and tools applicable to all ownerships.

Program Planning and Coordination

Ensuring that the wildland fire R&D program does the best job possible of identifying, articulating, and meeting national and regional needs requires national mechanisms for interagency and intra-agency coordination, planning, and client interaction, along with a strategic approach to balancing regional and national needs in program and budget development. As one of the largest natural resource research programs in the country, USDA Forest Service R&D is prepared to take a leadership role in these activities in collaboration with our many partners in Federal agencies, universities, and other organizations.

Other agencies provide critical funding or infrastructure support for wildland fire R&D (table 2), and they often have capabilities and perspectives that complement those of the USDA Forest Service. Much of the federally funded R&D is carried out by university partners, who play key roles in both the success of national wildland fire R&D programs and the training of our next generation of scientists and managers. Both interagency and USDA Forest Service teams are needed to support coordinated interagency and intra-agency program development, budget planning, and program oversight of wildland fire R&D. Coordinated strategic planning and

efforts to align programs across agencies and within the USDA Forest Service with priorities at regional to national and international scales will improve the efficiency and effectiveness of U.S. wildland fire R&D. The result will be a more efficient and effective wildland fire R&D program that brings together the skills and capabilities of USDA Forest Service R&D and other agencies and collaborators to develop the necessary knowledge and tools to improve the science basis for fire and fuels management.

Table 2. *Major current and anticipated areas of collaboration or financial support for wildland fire R&D in other Federal agencies and the university community.*

	Core fire science	Ecosystem effects	Social/ economic	Integrated management	Science application
Cooperative State Research, Education, and Extension Service/National Research Initiative		X	X		X
Department of Defense	X	X			
Department of Energy	X			X	
Environmental Protection Agency		X	X		
National Aeronautics and Space Administration	X	X		X	X
Nongovernmental Organizations e.g., The Nature Conservancy	X	X	X		X
National Institute of Science and Technology	X				X
National Oceanic and Atmospheric Administration	X	X		X	X
National Science Foundation	X	X	X	X	
Universities	X	X	X	X	X
U.S. Geological Survey	X	X		X	X

Information and Program-Level Reporting

NFP and Joint Fire Science Program R&D programs work together to prepare annual accomplishment reports that provide an overview of program activities and the application of results by management. No similar capability or product exists for fire-related R&D funded out of base appropriations. We will move toward reporting that addresses all USDA Forest Service-supported fire and fuels R&D programs. A new USDA Forest Service R&D program budget reporting process under development for FY 2007 will enable better articulation of program investments in wildland fire R&D. The USDA Forest Service R&D is developing performance measures for wildland fire R&D. As these measures are incorporated into reporting, they will provide a quantitative basis for synthetic accomplishment reporting of outputs and outcomes from wildland fire R&D that is tied to strategic goals and progress at meeting users' needs.

International Leadership and Collaboration

USDA Forest Service R&D has a long history of collaboration and leadership through international fire-related R&D projects; information exchange at international conferences, workshops, exchanges, and study tours; and participation in key international policy processes related to wildland fire. International R&D collaborations have addressed topics such as fire behavior modeling, the role of fire in global carbon cycles and atmospheric chemistry, and fire effects in ecosystems similar to those in the United States. Tools developed by USDA Forest Service R&D (such as the Incident Command System and fire behavior models) are used nationally and internationally in many applications. The results of these collaborative efforts have enhanced our understanding of fire processes, led to new approaches to fire behavior modeling, and improved fire management in the United States and other countries.

Wildland fire as a process crosses national boundaries (e.g., smoke movement between Mexico, Canada, the United States, and other countries; effects on global atmospheric chemistry and carbon storage; even the need for sharing firefighting resources during severe wildfire episodes). Solutions for addressing many issues can apply worldwide. Knowledge and understanding gained from other countries can improve the quality of wildland fire R&D and fire management in the United States. For example, high-quality fire behavior research is under way in Canada, Australia, Europe, and Brazil. International collaboration can help strengthen wildland fire R&D, inform fire management in the rest of the world, and help build consistent approaches to fire monitoring and to evaluating the impact of fire on key global processes. Research results can contribute to international policy discussions on the role and impacts of fire and fire management in forums such as the North American

Forestry Commission Fire Management Working Group, the United Nations Forum on Forests, the International Union of Forest Research Organizations, and the Global Observation of Forest Cover and Land Disturbance program. Methods pioneered for the LANDFIRE project were used recently in a global assessment of changes in fire regimes by the The Nature Conservancy. As we develop future programs it is important to consider the benefits of ongoing investment in international collaboration on certain aspects of USDA Forest Service wildland fire and fuels R&D programs in the portfolio areas.

Balancing Regional and National Needs

Maintaining an appropriate balance among national, local, regional, and international research efforts will help ensure the maximum benefits from wildland fire R&D for managers and policymakers at all levels. We anticipate that NFP R&D funding will be focused primarily on meeting national needs within the portfolio areas, with some emphasis on addressing specific regional needs such as understanding fire or treatment effects in specific ecosystems. We also recognize and support the importance for the broader wildland fire and fuels R&D programs to address both regional needs and the global impacts of fire and fire management on factors such as carbon storage, atmospheric chemistry, biodiversity, sustainable management, and wood supply.

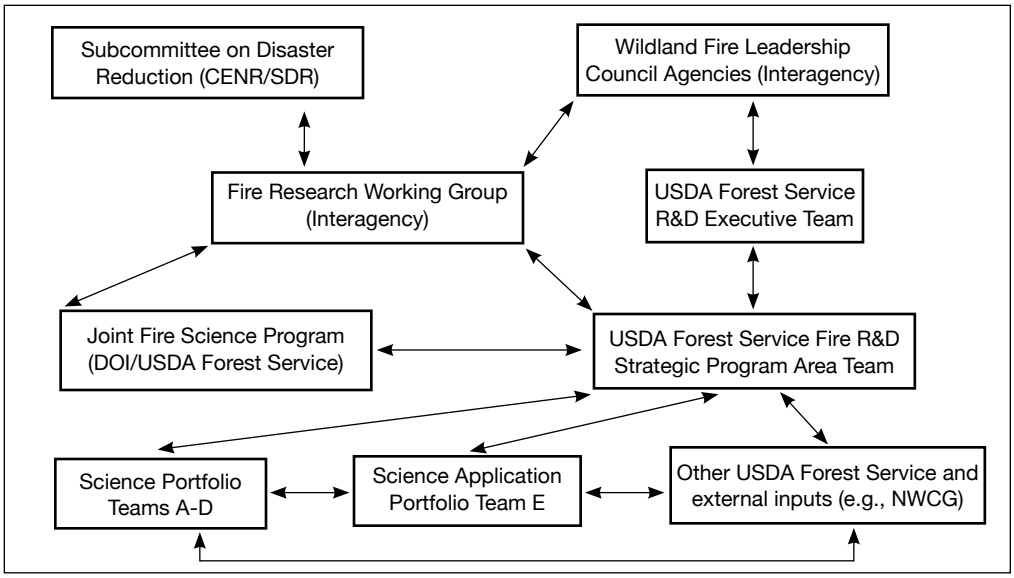
Strategic Actions

A. Organize To Do the Job

Several levels of organization and collaboration are needed. (See figure 2.)

- **Interagency.** Coordinate among Federal and State agencies and other partners and recommend priorities for interagency collaboration on fire-related R&D.
- **USDA Forest Service national coordination and planning.** Improve national coordination and mid- to long-range program planning of wildland fire R&D within the USDA Forest Service.
- **Topical (portfolio management).** Improve coordination among USDA Forest Service research stations and research collaborators within the national R&D portfolio areas.
- **Science application.** Improve the coordination and implementation of science application.

Figure 2. *Proposed structure and interactions for coordinated program planning.*



1. Interagency Coordination

Develop an interagency Fire Research Working Group (FRWG) in 2006 to foster improved interagency coordination and communication on wildland fire R&D and to develop integrated budget initiatives consistent with agency and interagency strategic planning efforts relevant to wildland and WUI fire management. The FRWG would provide a forum for the USDA Forest Service and DOI to work with other agencies to assess current programs and expenditures on wildland fire-related R&D, expenditures on fire and fuel management, costs of community protection and coordination, and economic losses due to wildland fire. This information will provide a strong basis for coordination within and among agencies during program and budget planning and development. Evaluate the potential to formally charter the FRWG under the interagency Subcommittee on Disaster Reduction (SDR). The FRWG would support information needs of the SDR and the member agencies, including Wildland Fire Leadership Council (WFLC)[5] agencies. Coordination with other agencies will help build interagency initiatives aligned with the priorities in the USDA Forest Service R&D strategy and those of Grand Challenges for Disaster Reduction R&D and other interagency strategy documents (CENR 2003, 2005). Interagency collaboration (between DOI and USDA Forest Service) will also continue in management of the

[5] The Wildland Fire Leadership Council provides leadership and oversight to ensure policy coordination, accountability, and effective implementation of the National Fire Plan and the Federal Wildland Fire Management Policy. Membership includes the U.S. Department of Agriculture (USDA), U.S. Department of the Interior (DOI), USDA Forest Service, DOI Bureau of Land Management, DOI Bureau of Indian Affairs, DOI National Park Service, DOI Fish & Wildlife Service, National Governors Association, and Intertribal Timber Council.

JFSP. We will continue to ensure coordination of this program with other agency and interagency fire R&D through overlapping memberships with other committees and coordination groups.

2. USDA Forest Service National Coordination and Planning

Formalize a USDA Forest Service Fire R&D Strategic Program Area Team (SPA Team). The main role of this team will be program planning and coordination relative to the USDA Forest Service NFP and base wildland fire R&D and recommending wildland fire R&D allocations to the Deputy Chiefs for Research and Development and State and Private Forestry (S&PF). Allocations will focus NFP R&D on the four R&D portfolios and the science application portfolio identified in this strategic plan. The SPA team will also be expected to coordinate with JFSP, and with DOI fire R&D. The SPA Team will focus on maintaining the appropriate balance between meeting national and regional needs, ensuring collaborative approaches to meeting key R&D needs, and recommending overall allocations and priorities among and within the portfolio areas. The SPA Team will report to the USDA Forest Service Research Executive Team (FSRET) through the FSRET co-leads for fire R&D. The Wildland Fire SPA Team will include representatives from WO R&D, S&PF, and potentially other WO program staffs, as well as research station representatives. The SPA Team will work closely with USDA Forest Service research stations (both directly and through Portfolio Teams) in determining where the best capacity is available to meet specific needs. Out-year budget proposals within the USDA Forest Service will emphasize ensuring that programs are better aligned to address priorities described in Strategic Goals 1 and 2 of this strategic plan and to balance risks with expected benefits of investments.

3. Portfolio Management

We are building on the success of existing ad hoc teams such as the Core Fire Science Caucus, the Fire Economics Research Group, and the oversight group for the Fire Consortia for Advanced Modeling of Meteorology and Smoke to develop national, cross-station teams for each of the fire RD&A portfolio areas (Portfolio Teams). These cross-station teams, including station representatives and SPA Team liaisons, are assigned to plan and coordinate research in each of the four program areas following guidance from the Wildland Fire SPA Team. Each portfolio team will report periodically to the SPA Team on progress and recommendations for future activities in the research elements within their program areas. These teams may consult subject matter experts from collaborating Federal and State agencies, universities, and other key cooperators as needed to enhance planning. Benefits will include achieving critical mass on key research questions and better coordination

of R&D activities across stations and agencies. These teams will be chartered in consultation with WO and station leadership. The Portfolio Teams will develop annual plans and 5-year plans for recommended R&D priorities in their portfolio areas.

4. Science Application

In addition to the science area Portfolio Teams (Strategic Goal 1), a Portfolio Team will be established to coordinate and make recommendations to the SPA Team on priorities and improved coordination for science application (Strategic Goal 2). This team will consult with fire science application and technology transfer specialists from other agencies and universities to increase interagency awareness and coordination of science application activities. The USDA Forest Service will also support analyses of science application activities and of future needs for science application in recognition of the critical need to move forward with improving delivery of new products from wildland fire and fuels R&D. These reports, which will be completed in FY 2006, will provide additional inputs and recommendations to the Science Application Portfolio Team. Similar efforts will be undertaken as needed in the future. The Science Application Portfolio Team will also coordinate with the USDA Forest Service R&D science applications group, which will be working to implement recommendations from the Science Application Logic Model.

B. Internal and External Communication

1. Develop Common Messages and Briefing Materials

Within both the USDA Forest Service and the interagency R&D community, it is important to develop consistent messages on the accomplishments and capacity of wildland fire and fuels R&D and on future program needs and priorities. Fire R&D will coordinate USDA Forest Service materials with other SPA Teams as appropriate, and will work with other agencies to improve coordination of accomplishment reporting and program descriptions.

2. Build Understanding and Support Within and Outside the USDA Forest Service

- We will develop a coordinated strategy within the agency to ensure that upper management (staff directors, associate deputy chiefs, deputy chiefs, regional leadership, and the chief) are well informed on these programs and to develop support for initiatives to enhance investments in wildland fire and fuels R&D to more closely meet the demand.
- We will work with collaborators to develop a coordinated interagency effort to ensure that our external clients (other Federal agencies, funding

agencies, cooperator institutions, and States) are well informed on program accomplishments, capabilities, and priority needs; to solicit feedback from clients; and to help build USDA Forest Service and interagency initiatives in wildland fire R&D to better support our research and management partners.

C. Program and Capacity Development

We will work within the agency and with WFLC agencies to maintain and develop the capacity to meet the goals of this strategic plan. Budget and program development should include (1) maintaining and building the necessary human capital and infrastructure to meet the needs, and (2) supporting and strengthening university, interagency, and other external collaborations. The science application strategy should include recommendations for the level of support required to achieve agency and interagency objectives for effectively moving science into applications and maintaining essential tools and databases.

Appendix A. Abbreviations and Acronyms

CENR	Committee on Environment and Natural Resources (a committee of the President's National Science and Technology Council)
DOI	U.S. Department of the Interior
FSRET	USDA Forest Service Research Executive Team
ICS	Incident Command System
JFSP	Joint Fire Science Program
NFP	National Fire Plan
NWCG	National Wildfire Coordinating Group
QFFR	Quadrennial Fire and Fuels Review
R&D	Research and Development (USDA Forest Service deputy area); also refers to research and development in general)
RD&A	Research, Development, and Application
S&PF	State and Private Forestry (USDA Forest Service)
SDR	Subcommittee on Disaster Reduction (subcommittee of CENR)
SPA Team	Strategic Program Area Team
USDA	U.S. Department of Agriculture
WFLC	Wildland Fire Leadership Council (interagency coordination group for wildland fire management; the chief of the USDA Forest Service is a member)
WFMPLM	Wildland Fire Management Performance Logic Model
WUI	Wildland-urban interface

Appendix B. Participants in the Wildland Fire Research and Development Logic Model Process

Non-Federal Participants

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American Forests, Washington, DC
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Colorado Department of Health, Colorado Air Pollution Control Division, Denver, CO
Colorado State Forest Service, Fort Collins, CO
Colorado State University, Fort Collins, CO

- Department of Agricultural and Resource Economics
- Department of Forest, Rangeland, and Watershed Stewardship
- Department of Natural Resource Recreation and Tourism

Environmental Systems Research Institute, Broomfield, CO
Florida State University, Department of Meteorology, Tallahassee, FL
George Mason University, Center for Earth Observation, Fairfax, VA
Joseph W. Jones Ecological Center, Newton, GA
Los Alamos National Laboratory, Los Alamos, NM
Michigan State University, Park, Recreation and Tourism Resources, East Lansing, MI
National Center for Atmospheric Research, Boulder, CO
National Council Air and Stream Improvement, Naperville, IL
National Fire Protection Association, Quincy, MA
National Institute of Standards and Technology, Gaithersburg, MD
Northeast Forest Fire Protection Compact, China Village, ME
Ohio University, Department of Environmental and Plant Biology, Athens, OH
Risk Prediction Initiative, Garrett Park, MD
Rochester Institute of Technology, Center for Imaging Science, Rochester, NY
St. Johns Water Management District, Palatka, FL
State Farm Insurance, CO
The Watershed Research and Training Center, Hayfork, CA
University of California, Department of Mechanical Engineering, Riverside, CA
University of Florida, Wildlife, Ecology & Conservation, Gainesville, FL
University of Montana, College of Forestry & Conservation, Missoula, MT
Virginia Tech, Department of Forestry, Blacksburg, VA

Federal Agency Participants

USDA Forest Service

- Fire and Aviation Management, Washington, DC
- Forest Management, Washington, DC
- Forest Products Laboratory, Madison, WI
- Intermountain Region, Ogden, UT
- Monongahela National Forest, Elkins, WV
- National Forests of Florida, Tallahassee, FL
- North Central Research Station, Evanston, IL
- Pacific Northwest Research Station, Portland, OR
- Pacific Southwest Research Station, Boise, ID
- Pacific Southwest Research Station, Portland, OR
- Pacific Southwest Research Station, Riverside, CA
- Resource Valuation and Use Research, Arlington, VA
- Rocky Mountain Region, Golden, CO
- Rocky Mountain Region, Lakewood, CO
- Rocky Mountain Research Station, Flagstaff, AZ
- Rocky Mountain Research Station, Ft. Collins, CO
- Rocky Mountain Research Station, Missoula, MT
- Southern Region, Tallahassee, FL
- Southern Research Station, Athens, GA
- Tallulah Ranger District, Chattahoochee-Oconee National Forest, Clayton, GA
- Umatilla National Forest, Pendleton, OR
- Vegetation Management and Protection Research, Arlington, VA

U.S. Department of the Interior (DOI) Bureau of Indian Affairs, National Interagency Fire Center (NIFC), Boise, ID

DOI Bureau of Land Management

- Colorado State Office, CO
- Fire Science Laboratory, Missoula, MT
- Joint Fire Science Program, Boise, ID
- National Science & Technology Center, Denver, CO
- NIFC, Boise, ID
- Northwest Coordination Center, Portland, OR
- Planning & Resource Group, NIFC, Boise, ID
- Salt Lake City, UT

DOI Fish and Wildlife Service

- National Wildlife Refuge System, Arlington, VA
- NIFC, Boise, ID

DOI Geological Survey

- Biological Resources Division, Reston, VA
- EROS Data Center, Sioux Falls, SD

DOI National Park Service, Fire Ecology Program, Lakewood, CO

DOI Office of the Assistant Secretary, Land and Minerals Management, Washington, DC

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