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Report to Congressional Requesters

September 2003

GEOSPATIAL INFORMATION

Technologies Hold Promise for Wildland Fire Management, but Challenges Remain

GAO-03-1047

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Highlights

Highlights of GAO-03-1047, a report to congressional requesters

Why GAO Did This Study

Over the past decade, a series of devastating and deadly wildland fires has burned millions of acres of federal forests, grasslands, and deserts each year, requiring federal land management agencies to spend hundreds of millions of dollars to fight them. GAO was asked to assess opportunities to improve the way agencies manage fires through the use of geospatial information technologies, specifically, to (1) identify key geospatial information technologies for addressing different aspects of managing wildland fires, (2) summarize key challenges to the effective use of geospatial technologies in managing wildland fires, and (3) identify national opportunities to improve the effective use of geospatial technologies.

What GAO Recommends

GAO is making a series of recommendations to address specific challenges in effectively using geospatial information technologies and to improve the management of information resources and technologies in the interagency wildland fire management community.

Commenting on a draft of this report, the Departments of Agriculture and the Interior agreed with the report's conclusions and recommendations.

Note: The graphics in this report are in color and are best viewed electronically.

www.gao.gov/cgi-bin/getrpt?GAO-03-1047

To view the full product, including the scope and methodology, click on the link above. For more information, contact David Powner at (202) 512-9286 or pownerd@gao.gov.

What GAO Found

Geospatial information technologies—sensors, systems, and software that collect, manage, manipulate, analyze, model, and display information about locations on the earth's surface—can aid in managing wildland fires by providing accurate, detailed, and timely information to federal, state, and local decision makers; fire-fighting personnel; and the public. This information can be used to help reduce the risk that a fire will become uncontrollable, to respond to critical events while a fire is burning, and to aid in recovering from fire disasters.

However, there are multiple challenges to effectively using these technologies to manage wildland fires, including challenges with data, systems, infrastructure, staffing, and the effective use of new products. The National Wildfire Coordinating Group—composed of representatives from the five land management agencies and from other federal, state, and tribal organizations—has several initiatives under way to address specific challenges, but progress on these initiatives has been slow, and not all of the challenges are being addressed. A root cause of many of these challenges is the lack of an overall strategy guiding interagency management of information resources and technology. To improve interagency management of information resources and technology, different teams within the Coordinating Group plan to establish an interagency geospatial strategic plan, a strategy for information resources management, and an interagency enterprise architecture—a blueprint for operational and technical change in support of wildland fire management. However, these efforts lack the senior-level endorsement and detailed plans and milestones necessary for success. Until effective interagency management of information resources and technology is a priority, the wildland fire community will likely continue to face challenges in effectively using geospatial information technologies.

Effectively using geospatial information is of interest beyond the wildland fire management community. Detailed, accurate, and accessible geospatial information is critical in addressing homeland security and national preparedness, supporting our transportation infrastructure, and managing natural resources, among other activities. For decades, the federal government has tried to reduce duplicative geospatial data collection by coordinating activities inside and outside the federal government. Most recently, Geospatial One-Stop, one of 25 high profile e-government initiatives sponsored by the Office of Management and Budget, was initiated to develop national geospatial data standards and an Internet portal for locating geospatial data. While this and other initiatives hold promise, achieving a nationwide network of geospatial data remains a formidable challenge.

GAO focused on the five federal agencies that are primarily responsible for wildland fire management: the Department of Agriculture's Forest Service and the Department of the Interior's National Park Service, Bureau of Land Management, Fish and Wildlife Service, and Bureau of Indian Affairs.

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Abbreviations

BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
FGDC	Federal Geographic Data Committee
FS	Forest Service
FWS	Fish and Wildlife Service
GIS	geographic information system
IRM	information resource management
IT	information technology

MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NWCG	National Wildfire Coordinating Group
USGS	U.S. Geological Survey

Letter

September 23, 2003

The Honorable Mark Udall
House of Representatives

The Honorable Joel Hefley
House of Representatives

Over the past decade, there has been a series of devastating and deadly wildland fires on federal lands. Fires like these burn millions of acres of forests, grasslands, and deserts each year, requiring federal land management agencies to spend hundreds of millions of dollars to fight them. Wildland fires also threaten communities that are near federal lands. During the 2002 fire season, approximately 88,458 wildland fires burned about 6.9 million acres and cost the federal government over $1.6 billion to suppress. These fires destroyed timber, natural vegetation, wildlife habitats, homes, and businesses, and they severely damaged forest soils and watershed areas for decades to come. The 2002 fires also caused the deaths of 23 firefighters and drove thousands of people from their homes. Only 2 years earlier, during the 2000 fire season, approximately 123,000 fires had burned more than 8.4 million acres and cost the federal government over $2 billion.

Geospatial information technologies—sensors, systems, and software that collect, manage, manipulate, analyze, model, and display information about locations on the earth's surface—can aid in managing wildland fires by providing accurate, detailed, and timely information to federal, state, and local decision makers; fire-fighting personnel; and the public. This information can be used to help reduce the risk that a fire will become uncontrollable, to respond to critical events while a fire is burning, and to aid in recovering from fire disasters.

Concerned with recent wildland fires, you asked us to assess opportunities to improve the way agencies manage fires through the use of geospatial information technologies. Specifically, our objectives were to (1) identify key geospatial information technologies for addressing different aspects of wildland fire management, (2) summarize key challenges to the effective use of

geospatial technologies in wildland fire management, and (3) identify national opportunities to improve the effective use of geospatial technologies.

To accomplish these objectives, we focused our review on the five key federal agencies that are primarily responsible for wildland fire management on public lands: the Department of Agriculture's Forest Service and the Department of the Interior's National Park Service, Bureau of Land Management, Fish and Wildlife Service, and Bureau of Indian Affairs. To address the final objective, we also reviewed national efforts to improve the use of geospatial information, undertaken by the Office of Management and Budget and the Federal Geographic Data Committee. We conducted our work between October 2002 and September 2003 in accordance with generally accepted government auditing standards. Appendix I contains further details on our objectives, scope, and methodology. Key terms are defined in the glossary.

Results in Brief

Numerous geospatial information technologies are currently available, in use, or under development that can aid in wildland fire management. These technologies include remote sensing systems, the Global Positioning System, geographic information systems (GIS), and specialized software for modeling and visualizing locations and events. Land management agencies are using geospatial technologies in a number of different ways, ranging from mapping vegetation and dangerous accumulations of fuel, to identifying the perimeter and behavior of active fires, to mapping burned areas for rehabilitation. However, the extent to which these technologies are currently being used is not fully known.

There are multiple challenges to effectively using geospatial technologies—all complicated by the fact that wildland fire management extends beyond a single agency's responsibility and requires a collaborative interagency approach. Key challenges include issues with the following:

- **Data:** Geospatial data are not consistently available and are not compatible across different agencies, states, and local entities. As a result, decision makers often lack the timely, integrated information they need to make sound decisions in managing different aspects of wildland fire.

- **Systems:** Agencies have developed multiple, duplicative systems to address local or agency-specific needs. As a result, many similar systems are not interoperable. Also, there is no single comprehensive inventory of the systems used to support wildland fire management.

- **Infrastructure:** GIS specialists do not consistently have access to the equipment, communications infrastructure, and Internet when and where they need them to address wildland fires. As a result, these specialists often have difficulty in obtaining and manipulating geospatial data and in producing geospatial maps at remote fire sites.

- **Staffing:** The training and qualifications of the GIS specialists who work on wildland fires are not consistent, resulting in major differences in these individuals' capabilities.

- **New products:** While new products and services are available to support wildland fire management, commercial vendors expressed concern that the fire community is not aware of these products. Land management agencies noted that the cost of commercial products can be prohibitive and that licensing restrictions can keep local land units from sharing data with others in the wildland fire community.

  The National Wildfire Coordinating Group—comprising representatives from the five land management agencies and from other federal, state, and tribal organizations—has several initiatives under way to address specific challenges to using geospatial information technologies, but progress on these initiatives has been slow, and these initiatives do not address all of the challenges. A root cause of many of these challenges is the lack of an overall strategy guiding interagency management of information resources and technologies. Currently, different teams within the Coordinating Group are planning initiatives to improve the interagency management of information resources and technology. Focusing specifically on geospatial technologies, one interagency team has proposed developing an interagency strategic plan for using geospatial technologies to support wildland fire management. Another interagency team developed a draft Information Resource Management (IRM) strategy that provides high-level objectives for interagency IRM management. At a broader level, another interagency team plans to develop an enterprise architecture—a blueprint for operational and technological change in support of wildland fire management. However, these efforts lack the senior-level endorsement and the detailed plans and

milestones necessary for success. Until effective interagency management of information technologies becomes a priority, the wildland fire community will likely continue to face challenges in effectively using geospatial technologies.

Effectively using geospatial information is of interest beyond the wildland fire management community. Detailed, accurate, and accessible geospatial information is critical in addressing homeland security and national preparedness, supporting our transportation infrastructure, managing natural resources, and carrying out the national census—among other activities. For decades, the federal government has tried to reduce duplicative geospatial data collection by coordinating GIS activities within and outside the federal government. Most recently, the E-Government Act of 2002 called for common protocols for geographic information systems in order to reduce redundant data collection and information and to promote collaboration and use of standards for government geographic information.[1] To improve the use of geospatial data, the Office of Management and Budget initiated Geospatial One-Stop, a project to develop an Internet portal for locating geospatial data and to develop national geospatial data standards. While this and other initiatives hold promise, achieving the vision of a nationwide network of geospatial data remains a formidable challenge. We recently reported that a much more substantial effort will be required to attain the broader vision of seamless integration of GIS data nationwide—and that this effort will probably have to continue over an extended period of time.[2]

We are making recommendations to the Secretaries of Agriculture and the Interior to address specific challenges in effectively using geospatial technologies and to improve the management of information resources and technologies in the interagency wildland fire management community. In commenting on a draft of this report, the departments agreed with the report's conclusions and recommendations, and noted that staff from the two departments will be tasked with developing an action plan to address our findings and the broader issue of geospatial needs for wildland fire management.

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[1] Sec. 216, P.L. 107-347, December 17, 2002.
[2] U.S. General Accounting Office, *Geographic Information Systems: Challenges to Effective Data Sharing,* GAO-03-874T (Washington, D.C.: June 10, 2003).

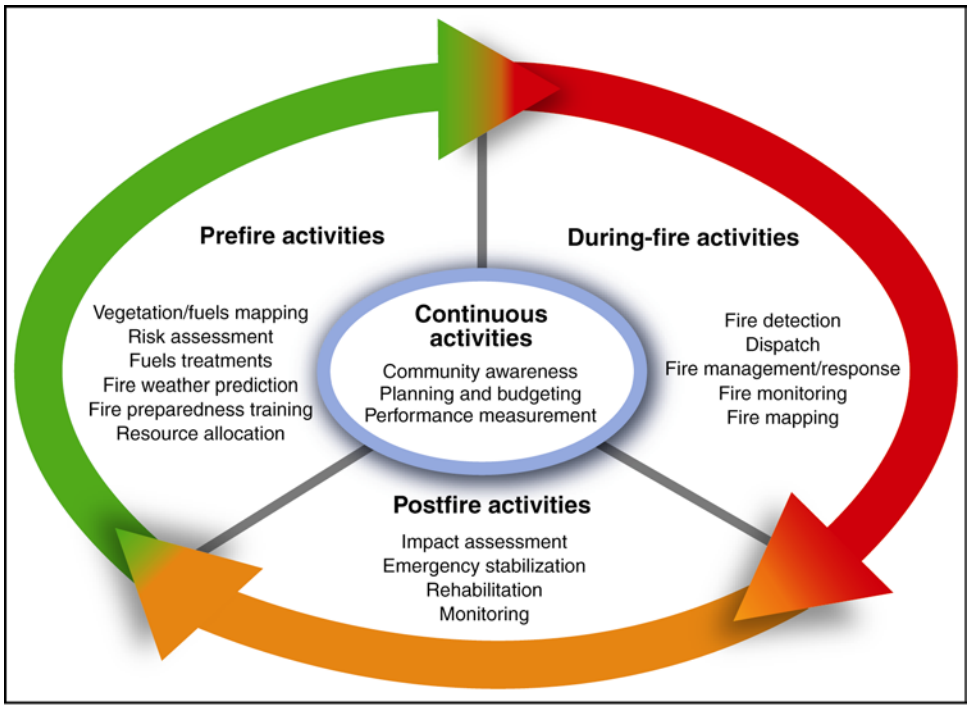
Background

Wildland Fire Management Life Cycle: An Overview

Effectively managing wildland fires can be viewed in terms of a life cycle—there are key activities that can be performed before a fire starts to reduce the risk of its becoming uncontrollable; other activities that can take place during a fire to detect the fire before it gets too large and to respond to it; and still others that can be performed after a fire has stopped in order to stabilize, rehabilitate, and restore damaged forests and rangelands. Prefire activities can include identifying areas that are at risk for wildland fire by assessing changes in vegetation and the accumulation of fuels (including small trees, underbrush, and dead vegetation), as well as these fuels' proximity to communities; taking action to reduce fuels through a variety of mechanisms (including timber harvesting, management-ignited or prescribed fires, mechanical thinning, and use of natural fires); and monitoring fire weather conditions. Other activities during this phase can include providing fire preparedness training and strategically deploying equipment and personnel resources to at-risk areas.

Activities that take place during a fire include detecting fires, dispatching resources, planning the initial attack on the fire, monitoring and mapping the fire's spread and behavior, and planning and managing subsequent attacks on the fire—if they are warranted. Postfire activities can include assessing the impact of the fire; providing emergency stabilization of burned areas to protect life, property, and natural resources from postfire degradation, such as flooding, contamination of a watershed area, and surface erosion; rehabilitating lands to remove fire debris, repair soils, and plant new vegetation; and monitoring the rehabilitation efforts over time to ensure that they are on track. Other activities—such as enhancing community awareness—can and should take place throughout the fire management life cycle. Figure 1 depicts a fire management life cycle, with key activities in each phase.

Figure 1: Wildland Fire Management Activities

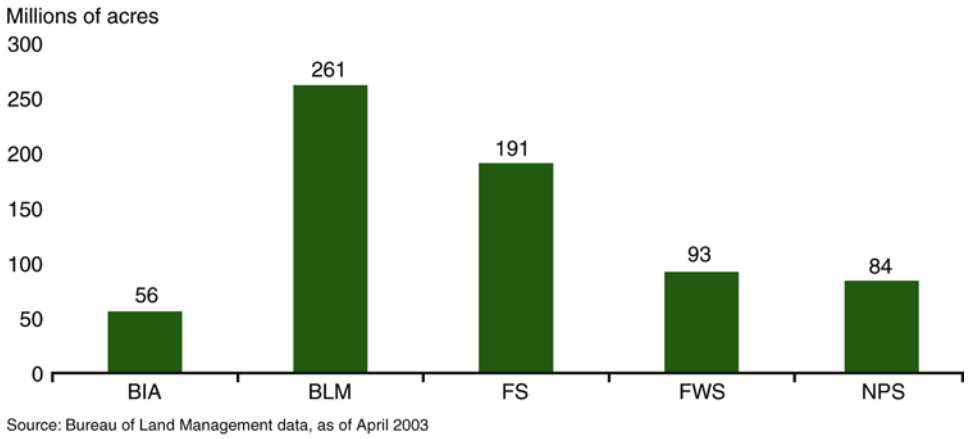


Source: GAO.

Federal Land Management Responsibilities

Five federal agencies share responsibility for managing the majority of our nation's federal lands—the Department of Agriculture's Forest Service (FS) and the Department of the Interior's National Park Service (NPS), Bureau of Land Management (BLM), Fish and Wildlife Service (FWS), and Bureau of Indian Affairs (BIA). While each agency has a different mission and responsibility for different areas and types of land, they work together to address catastrophic wildland fires, which often cross agency boundaries. In addition, state, local, and tribal governments and private individuals own thousands of acres that are adjacent to federal lands and are similarly susceptible to wildland fires. Figure 2 shows the number of acres of land managed by each of the five federal agencies.

Figure 2: Acres of Land Managed by Federal Land Management Agencies



Source: Bureau of Land Management data, as of April 2003

The National Fire Plan

After years of catastrophic fires, in September 2000, the Departments of Agriculture and the Interior jointly issued a report on managing the impact of wildland fires. This report forms the basis of what is now known as the National Fire Plan—a long-term multibillion-dollar effort to address the nation's risk of wildland fires. The plan directs funding and attention to five key initiatives:

- **Hazardous fuels reduction**—investing in projects to reduce the buildup of fuels that leads to severe fires.
- **Firefighting**—ensuring adequate preparedness for future fires by acquiring and maintaining personnel and equipment and by placing firefighting resources in locations where they can most effectively be used to respond to fires.
- **Rehabilitation and restoration**—restoring landscapes and rebuilding ecosystems that have been damaged by wildland fires.
- **Community assistance**—working directly with communities to ensure that they are adequately protected from fires.
- **Accountability**—establishing mechanisms to oversee and track progress in implementing the National Fire Plan, which includes developing performance measures, processes for reporting progress, and budgeting information.

A key tenet of the National Fire Plan is coordination between government agencies at the federal, state, and local levels to develop strategies and carry out programs. Building on this goal of cooperation, the five land management agencies have worked with

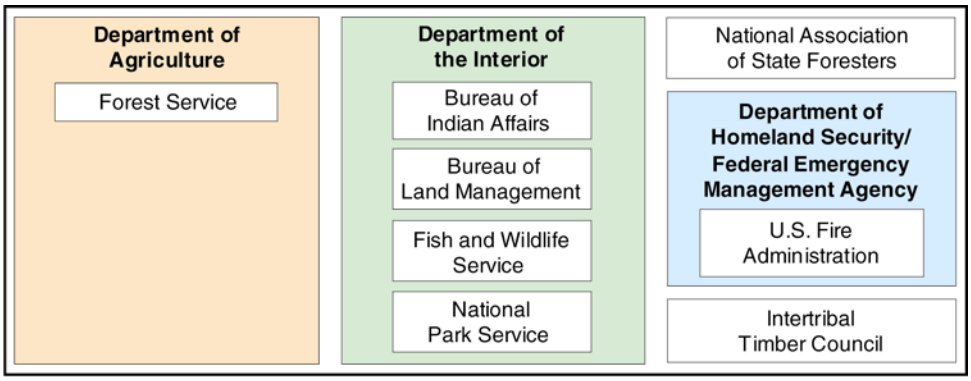
state governors and other stakeholders to develop a comprehensive strategy and an implementation plan for managing wildland fires, hazardous fuels, and ecosystem restoration and rehabilitation on federal and adjacent state, tribal, and private forest and rangelands in the United States. Appendix II provides a summary of the major federal policies, plans, reports, and initiatives on managing wildland fires and how they are related. In developing these integrated plans and initiatives, the land management agencies identified other federal agencies that have roles in wildland fire management: agencies that manage other federal lands, including the Department of Defense and Department of Energy; agencies that research, manage, or use technologies that can aid in wildland fire management, including the Department of the Interior's U.S. Geological Survey, the National Aeronautical and Space Administration, the Department of Commerce's National Oceanic and Atmospheric Administration, and the Department of Defense's National Imagery and Mapping Agency; and agencies with other fire-related responsibilities, including the Department of Homeland Security's Federal Emergency Management Agency and the Environmental Protection Agency. The integrated plans also identify key state and local organizations that may collaborate on wildland fire management. Appendix III identifies key federal, state, and local organizations and their roles in wildland fire management.

An Interagency Framework Supports the National Fire Plan

Over the past four decades, the Departments of Agriculture and the Interior have established an interagency framework to handle wildland fire management—a framework that currently supports the National Fire Plan. In 1965, the Forest Service and the Bureau of Land Management established the National Interagency Fire Center in Boise, Idaho. The Fire Center is the nation's principal management and logistical support center for wildland firefighting and now includes the five land management agencies, the National Weather Service, and the Department of the Interior's Office of Aircraft Services. The Department of Homeland Security's Federal Emergency Management Agency and the National Association of State Foresters also have a presence at the center. Working together, representatives from this mix of organizations exchange fire protection information and training services and coordinate and support operations for managing wildland fire incidents while they are occurring, throughout the United States.

In 1976, the departments established the National Wildfire Coordinating Group to coordinate government standards for wildland fire management and related programs, in order to avoid duplicating the various agencies' efforts and to encourage active collaboration among entities. This group comprises representatives from the five land management agencies and from other federal, state, and tribal organizations. Figure 3 identifies these member organizations. The coordinating group seeks to foster more effective execution of each agency's fire management program through agreements on common training, equipment, and other standards; however, each agency determines whether and how it will adopt the group's proposals. The group is organized into 15 working teams, which focus on issues that include information resource management (IRM), fire equipment, training, fire weather, and wildland fire education. Most recently, the coordinating group established the IRM program management office to further support the IRM working team by developing guidance and products. In addition, the IRM working team has established two subgroups to focus on specific issues involving geospatial information and data administration.

Figure 3: National Wildfire Coordinating Group: Member Organizations



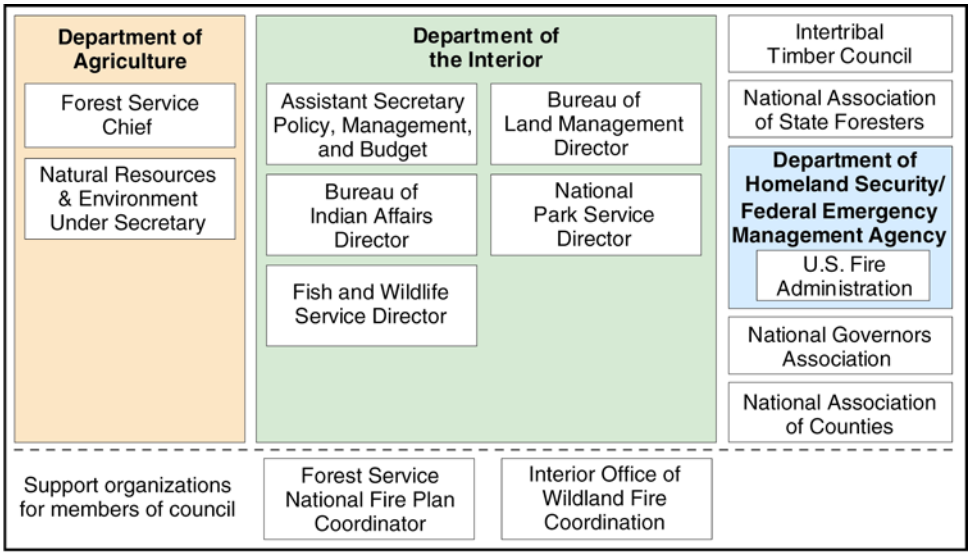
Source: National Wildfire Coordinating Group.

In recent years, we have reported that despite these interagency efforts, the Forest Service and the Department of the Interior had not established clearly defined and effective leadership for ensuring collaboration and coordination among the organizations that respond to wildland fires.[3] Further, the National Academy of Public Administration recommended that the Secretaries of

[3] U.S. General Accounting Office, *The National Fire Plan: Federal Agencies Are Not Organized to Effectively and Efficiently Implement the Plan*, GAO-01-1022T (Washington, D.C.: July 31, 2001); *Severe Wildland Fires: Leadership and Accountability Needed to Reduce Risks to Communities and Resources*, GAO-02-259 (Washington, D.C.: Jan. 31, 2002); *Wildland Fire Management: Improved Planning Will Help Agencies Better Identify Fire-Fighting Preparedness Needs*, GAO-02-158 (Washington, D.C.: Mar. 29, 2002).

Agriculture and the Interior establish a national interagency council to achieve more consistent and coordinated efforts in implementing national fire policies and plans.[4] In response to these concerns, in April 2002, the departments established the Wildland Fire Leadership Council. This council comprises senior members of both departments and of key external organizations; it is charged with providing active, visible interagency leadership and coordination and consistent, integrated policy direction to the land management agencies regarding wildland fire management. Figure 4 identifies members of the Leadership Council.

Figure 4: Members of the Wildland Fire Leadership Council



Source: Office of Wildland Fire Coordination.

Accurate information about specific locations is critical to all of the activities in wildland fire management. To manage information that extends beyond organizational boundaries in support of a common mission—such as the wildland fire mission—it is useful to view these activities within the context of the information technology management discipline of enterprise architecture management.

Enterprise Architecture: A Brief Description

If properly developed, an enterprise architecture provides a clear and comprehensive picture of an entity, whether it is an organization (for example, a federal department, agency, or bureau)

[4] Frank Fairbanks, Henry Gardner, Elizabeth Hill, Keith Mulrooney, Charles Philpot, Karl Weick, and Charles Wise, M*anaging Wildland Fire: Enhancing Capacity to Implement the Federal Interagency Policy* (Washington, D.C.: National Academy of Public Administration, December 2001).

or a functional or mission area that cuts across more than one organization (for example, grant management, homeland security, or wildland fire management). These architectures are recognized as essential tools for effectively and efficiently engineering business operations and the systems and databases that are needed to support these operations.

Enterprise architectures are systemically derived and captured blueprints or descriptions—in useful models, diagrams, and narrative—of the mode of operation for a given enterprise. This mode of operation is described in both (1) logical terms, such as interrelated business processes and business rules, information needs and flows, data models, work locations, and users, and (2) technical terms, such as hardware, software, data, communications, and security attributes and performance standards. They provide these perspectives both for the enterprise's current, or "as is," environment and for its target, or "to be," environment, as well as a transition plan for moving from the "as is" to the "to be" environment.

Using enterprise architectures is a basic tenet of effective information technology (IT) management, embodied in federal guidance and commercial best practices.[5] We recently issued an executive guide for improving enterprise architecture management.[6] When developed and used properly, these architectures define both business operations and the underlying IT infrastructure that supports these operations in a way that optimizes interdependencies and interrelationships. They provide a common frame of reference to guide and constrain decisions about the content of information asset investments in a way that can ensure that the right information is available to those who need it, when they need it. Employed in concert with IT investment management practices designed to ensure that new investments are compliant with the architecture, enterprise architectures can greatly increase an organization's likelihood of making successful and effective technology investments.[7] Our experience with federal

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[5]For example, see Office of Management and Budget, *Management of Federal Information Resources*, Circular No. A-130 (Washington, D.C.: November 2000) and U.S. General Accounting Office, *Executive Guide: Improving Mission Performance through Strategic Information Management and Technology: Learning from Leading Organizations*, GAO/AIMD-94-115 (Washington, D.C.: May 1994).

[6] U.S. General Accounting Office, *Information Technology: A Framework for Assessing and Improving Enterprise Architecture Management (Version 1.1)*, GAO-03-584G (Washington, D.C.: April 2003).

[7] U.S. General Accounting Office, *Information Technology Investment Management: A Framework for Assessing and Improving Process Maturity (Exposure Draft)*, GAO/AIMD-10.1.23 (Washington, D.C.: May 2000).

agencies has shown that investing in information technology without the context of an architecture often results in systems that are duplicative, not well integrated, and unnecessarily costly to maintain and interface.[8]

Numerous Geospatial Technologies Can Be Used to Address Different Aspects of Wildland Fire Management

Geospatial information technologies—sensors, systems, and software that collect, manage, manipulate, analyze, model, and display information about positions on the earth's surface—can aid in managing wildland fires by providing accurate, detailed, and timely information to federal, state, and local decision makers; fire-fighting personnel; and the public. This information can be used to help reduce the risk that a fire will become uncontrollable, to respond to critical events while a fire is burning, and to aid in recovering from fire disasters.

Specific examples of geospatial technologies include remote sensing systems, the Global Positioning System, and geographic information systems. In addition, specialized software can be used in conjunction with remote sensing data and geographic information systems to manipulate geographic data and allow users to analyze, model, and visualize locations and events. Table 1 describes key geospatial technologies.

[8] See, for example, U.S. General Accounting Office, *DOD Business Systems Modernization: Improvements to Enterprise Architecture Development and Implementation Efforts Needed*, GAO-03-458 (Washington, D.C.: February 2003); *Information Technology: DLA Should Strengthen Business Systems Modernization Architecture and Investment Activities*, GAO-01-631 (Washington, D.C.: June 2001); and *Information Technology: INS Needs to Better Manage the Development of Its Enterprise Architecture*, AIMD-00-212 (Washington, D.C.: August 2000).

Table 1: Key Geospatial Technologies

Technology	Description
Remote sensing systems	Remote sensing systems observe data that are either emitted or reflected by the earth and the atmosphere, collecting these data from a distance—such as from a satellite or an aerial platform. Remote sensing systems involve different observing technologies, including cameras, scanners, radar and sonar systems, radiometers, lasers, and thermal devices—to name a few—and are capable of collecting data from one or more bands of the electromagnetic spectrum.[a] Data from different bands provide different kinds of information. For example, data observed in the infrared band can identify heat sources that are not observable in the visible band of the electromagnetic spectrum. When data are collected from multiple bands, a more sophisticated analysis can be performed. Key factors that differentiate one sensor from another include the type(s) of data collected, the resolution[b] of the images, the width (or swath) of area covered on the ground, and the rate at which the sensor's platform revisits an area on the ground. Appendix IV provides more detail on types of sensors and identifies the characteristics of several remote sensing systems. After being observed, remotely sensed data need to be processed—a function that can include referencing the data to a position on earth, calibrating them, and then transforming them into a usable format. The resulting product can be an image or a quantitative data product, which can in turn be used as an input to other geospatial technologies, including geographic information systems and specialized software.
Global Positioning System	The Global Positioning System is a constellation of orbiting satellites that provides navigation data to military and civilian users around the world. These satellites orbit the earth every 12 hours, emitting continuous navigation signals. With the proper equipment, users can receive these signals and use them to calculate time, location, and velocity. Receivers have been developed for use on aircraft, ships, and land-based vehicles, as well as via mobile hand-held units. Data from the Global Positioning System can be used to reference remotely sensed aerial images or ground-based human observations to specific geographic coordinates, a process called geo-referencing.
Geographic information systems	A geographic information system (GIS) is a system of computer software, hardware, and data used to manipulate, analyze, and graphically display a potentially wide array of information associated with geographic locations. These systems can receive input from remotely sensed images from satellites and aerial platforms, as well as from other sources, including human observation, tabular data, and maps. These systems are capable of relating multiple layers of data (such as roads, vegetation, structures, and utilities) concerning the same geographical location and representing these multiple layers of information as one composite result.
Specialized software	Specialized software for modeling, decision support, and visualization complements the sensing, positioning, and GIS technologies described above by allowing analysts and managers to analyze data and explore different scenarios—and thereby make better informed decisions. For example, fire behavior specialists use such software to model fire behavior. Inputs to these models come from satellite images as well as weather data, tabular data, and on-the-ground observations.

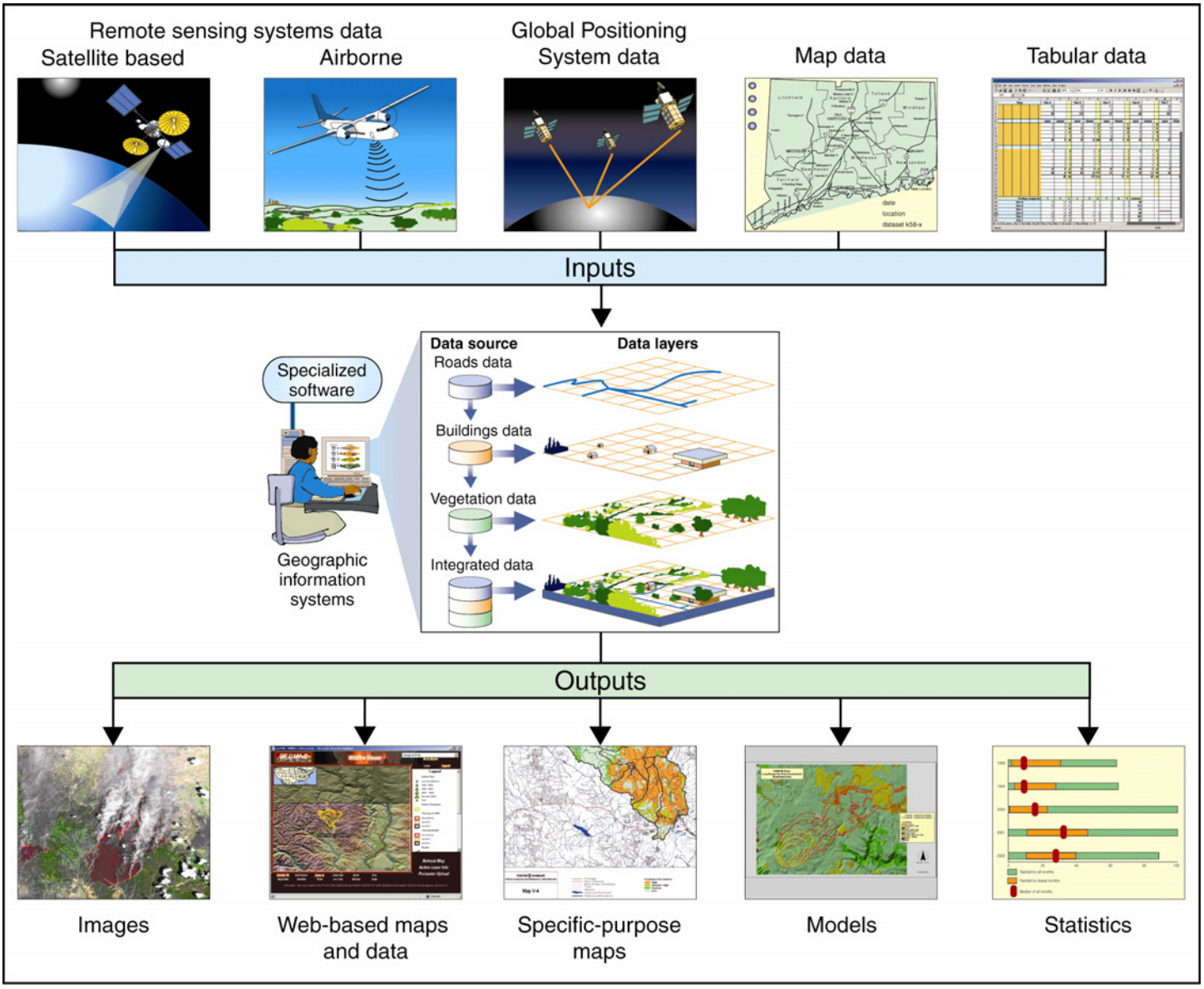
Source: GAO.

[a] A spectral band is a set of adjacent wavelengths in the electromagnetic spectrum. Examples include the ultraviolet, visible, near-infrared, mid-infrared, and thermal infrared bands.

[b] Spatial resolution is a measure of the size of the smallest feature that can be distinguished in an image. That is, in a 30-meter resolution image, one can discern objects 30 meters and larger. Images with smaller discernable objects are considered to have higher resolutions.

While individual technologies can be used to obtain information and products, the integration of these technologies holds promise for providing even more valuable information to decision makers. For example, remote sensing systems provide images that are useful in their own right. However, when images are geo-referenced and combined with other layers of data in a geographic information system—and then used with specialized software—a more sophisticated analysis can be performed, and more timely and sound decisions can be made. Figure 5 provides an overview of the relationships among the different technologies and some resulting products.

Figure 5: Overview of the Flow of Data Among Key Geospatial Information Technologies and Resulting Products of These Technologies



Source: GAO, Art Explosion, U.S. Geological Survey, Forest Service.

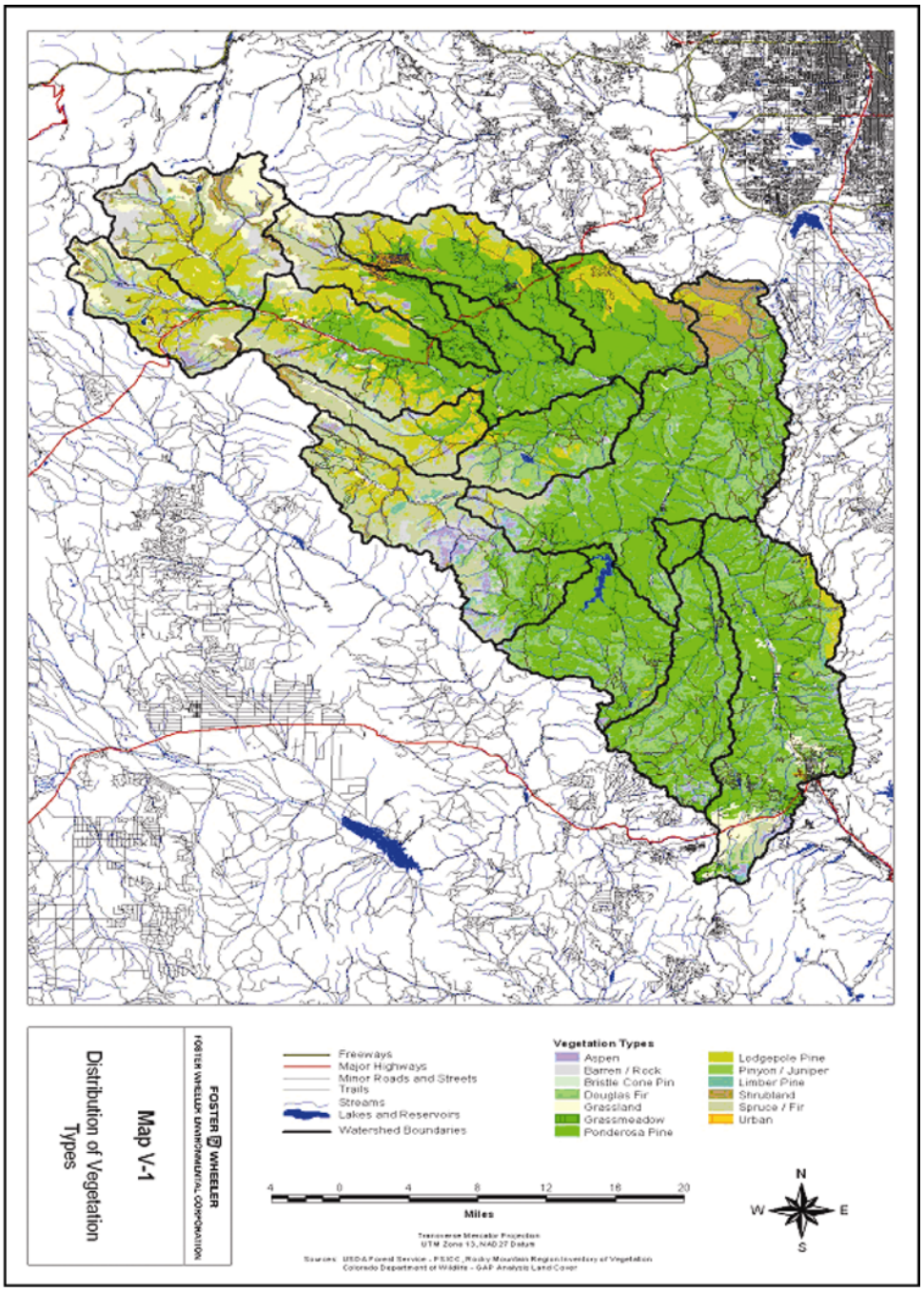
Federal Land Management Agencies Are Using Geospatial Technologies to Support Wildland Fire Management

The geospatial information technologies mentioned above—remote sensing systems, the Global Positioning System, geographic information systems, and specialized software—are being used to some extent in managing wildland fires. These technologies are used throughout the wildland fire management life cycle. Key examples follow.

Examples of Geospatial Technology Use: Prefire

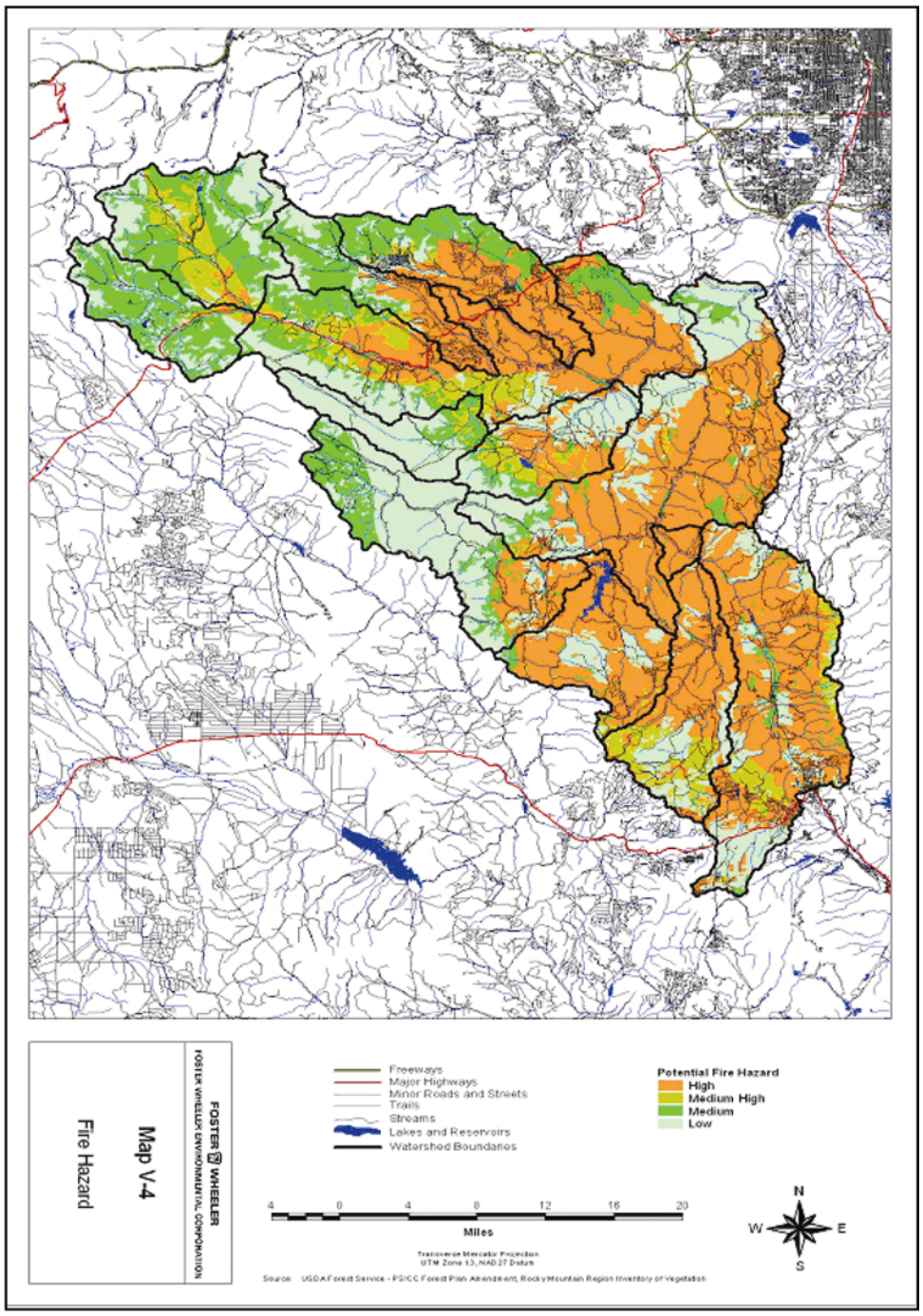
Before a fire starts, local and regional land managers often use vegetation and fuels maps derived from remote sensing data in conjunction with a geographic information system to understand conditions and to identify areas for fuels treatments. Some land management offices have also developed software to help them assess risk areas and prioritize fuels treatment projects. For example, figure 6 depicts a vegetation map, and figure 7 depicts a map showing areas with increased risk of fires. Interestingly, an area that the map identified as being at high risk of fire later burned during the Hayman fire of 2002.

Figure 6: Vegetation Map, Rocky Mountain Region, Colorado, August 1999



Source: Forest Service, Colorado State Forest Service.

Figure 7: Fire Hazard Map, Rocky Mountain Region, Colorado, August 1999



Source: Forest Service, Colorado State Forest Service.

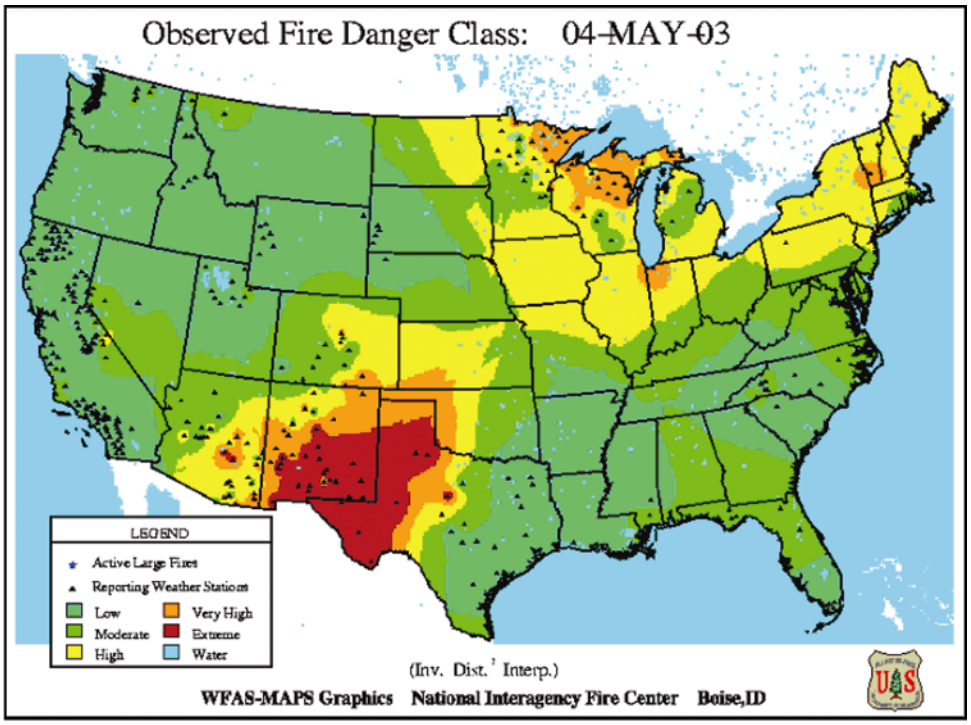
Land management agencies also use geospatial products related to the weather to aid in fire planning, detecting, and monitoring activities. Weather-based products are derived from ground-based lightning detection and weather observing systems, as well as from fire-related weather predictions from the National Weather Service.

Figure 8 depicts a seasonal fire outlook, and figure 9 depicts a fire danger map that is based on daily weather predictions.

Figure 8: National Wildland Fire Outlook

Source: National Interagency Coordination Center, Boise, Idaho.

Figure 9: Fire Danger Map

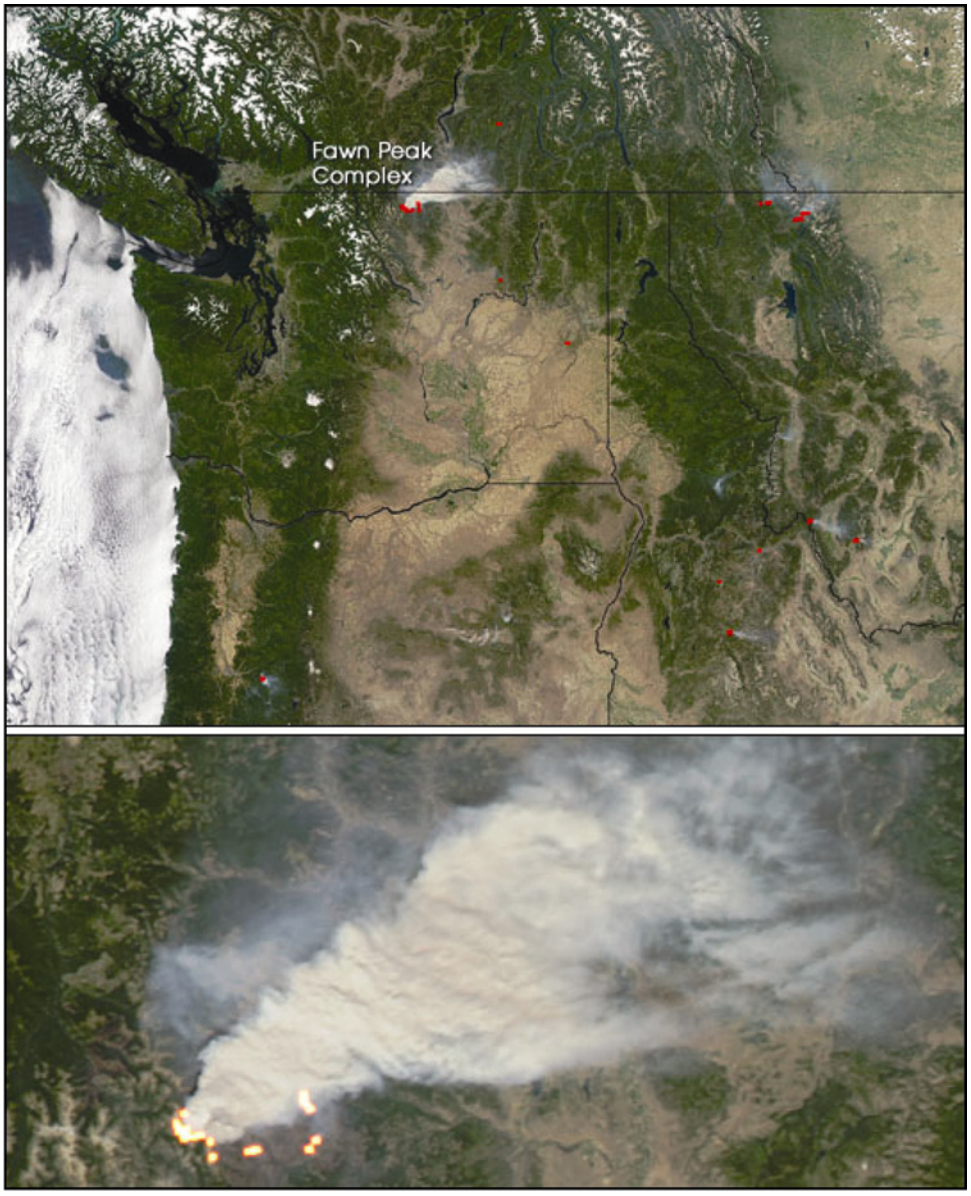


Source: National Interagency Fire Center.

Examples of Geospatial Technology Use: During Fire

During a fire, some fire responders use satellite and aerial imagery, in combination with Global Positioning System data, geographic information systems, and specialized fire behavior modeling software, to obtain information about the fire and to help plan how they will respond to it. For example, the Forest Service uses satellite data to produce images of active fires. Also, the National Interagency Fire Center manages an aerial infrared program that flies aircraft equipped with infrared sensors over large fires to detect heat and fire areas. These images contribute to the development of daily fire perimeter maps. Figure 10 depicts a satellite image of active fires. Figure 11 depicts a satellite image of a fire perimeter, and figure 12 depicts an aerial infrared image and a fire perimeter map based on that image. Some incident teams also use fire growth modeling software to predict the growth of wildland fires in terms of size, intensity, and spread, considering variable terrain, fuels, and weather. Using this information, incident managers are able to estimate short- and long-term fire behaviors, plan for potential fires, communicate concerns and needs to state and local governments and the public, and request and position resources. Figure 13 shows the output of a fire behavior model.

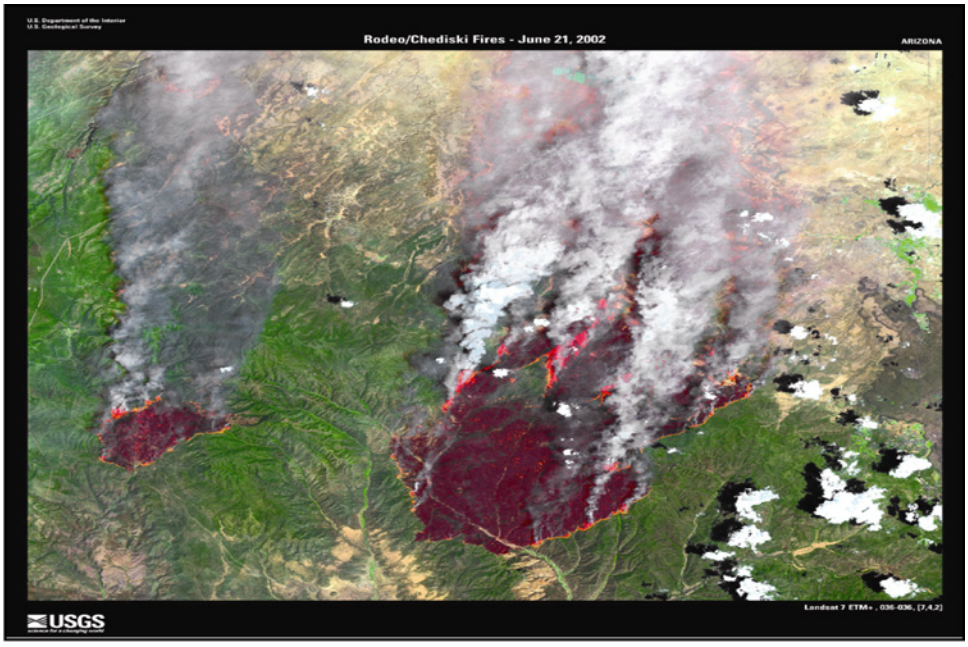
Figure 10: Satellite Images of Fires in the Northwestern United States, July 21, 2003



Source: National Aeronautics and Space Administration.

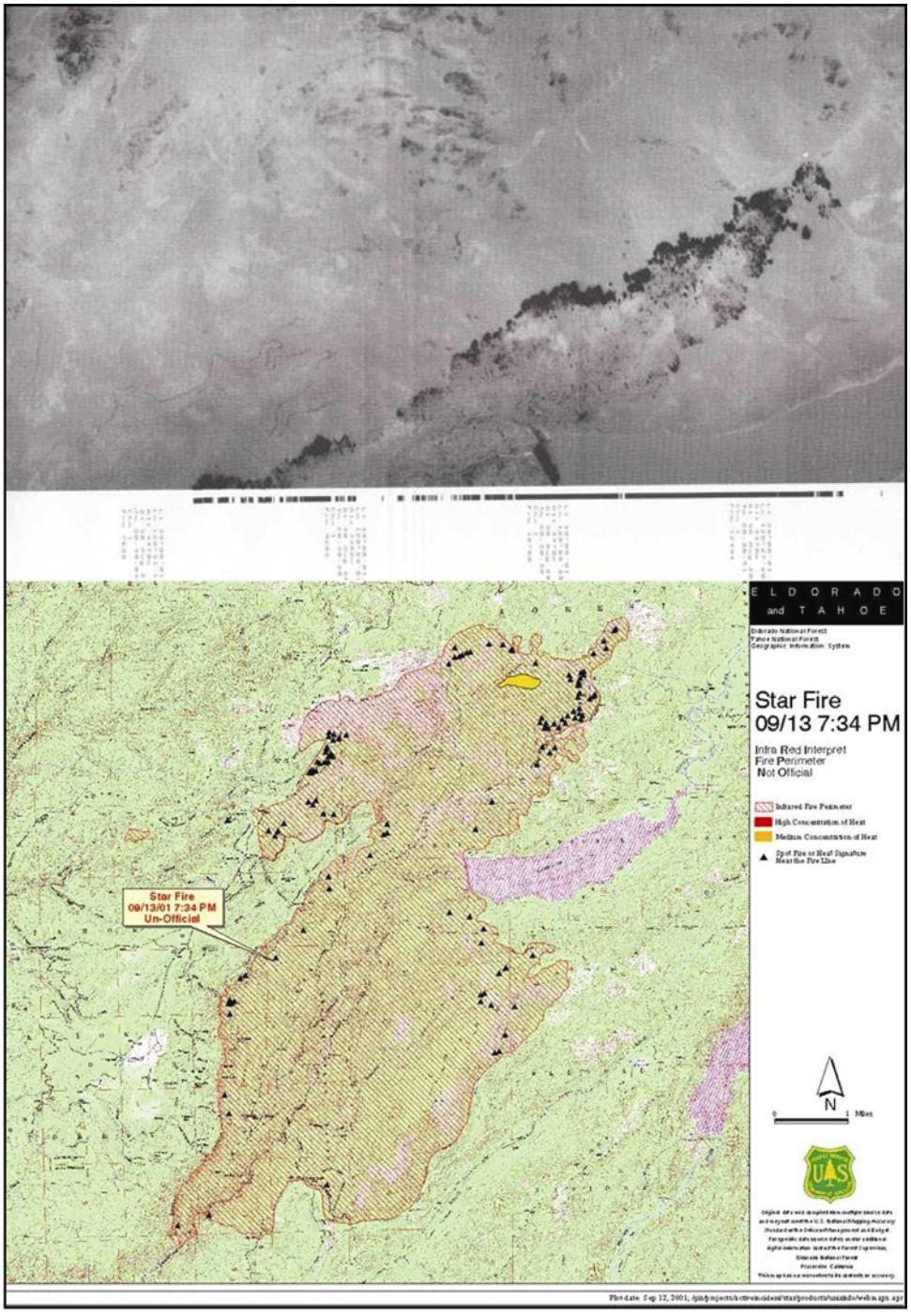
Note: Images from NASA's Aqua satellite, Moderate Resolution Imaging Spectroradiometer (MODIS).

Figure 11: Landsat Satellite Image Showing Early Fire Perimeters for the Rodeo and Chediski Fires, Arizona, June 2002



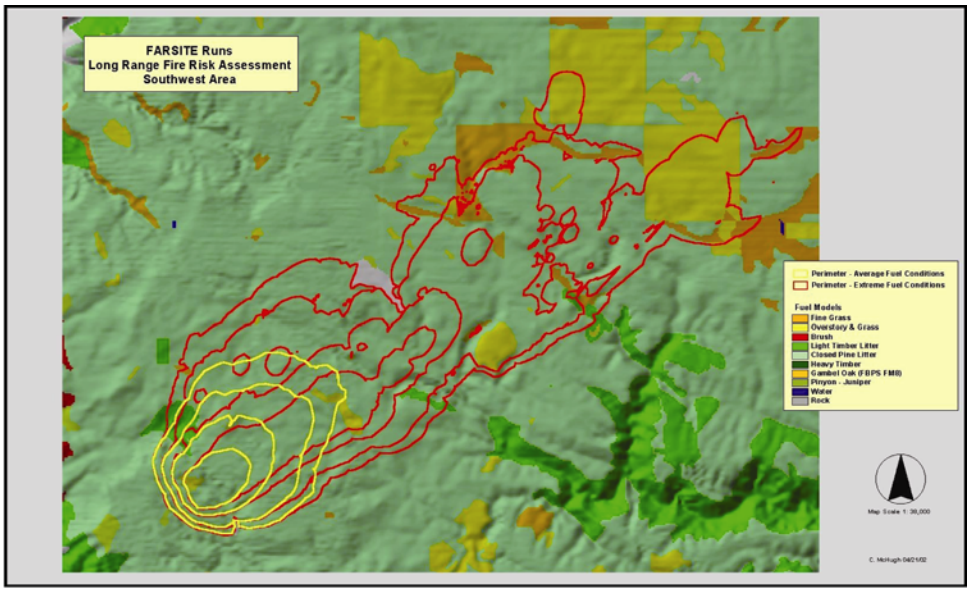
Source: U.S. Geological Survey.

Figure 12: An Aerial Infrared Image and Resulting Fire Perimeter Map, September 2001



Source: Forest Service, Remote Sensing Applications Center.

Figure 13: Output of a Fire Behavior Model



Source: Forest Service, Fire Sciences Laboratory, Missoula, Montana.

Geospatial technologies are also used to provide information on active fires to the general public. The wildland fire community and the U.S. Geological Survey established an Internet Web site, at www.geomac.gov, to provide access to geospatial information about active fires. This site allows visitors to identify the location of wildland fires on a broad scale and then focus in to identify information on the location and status of specific fires. Figure 14 shows images from the Web site.

Figure 14: Internet-Based Maps of Active Fires

Source: U.S. Geological Survey.

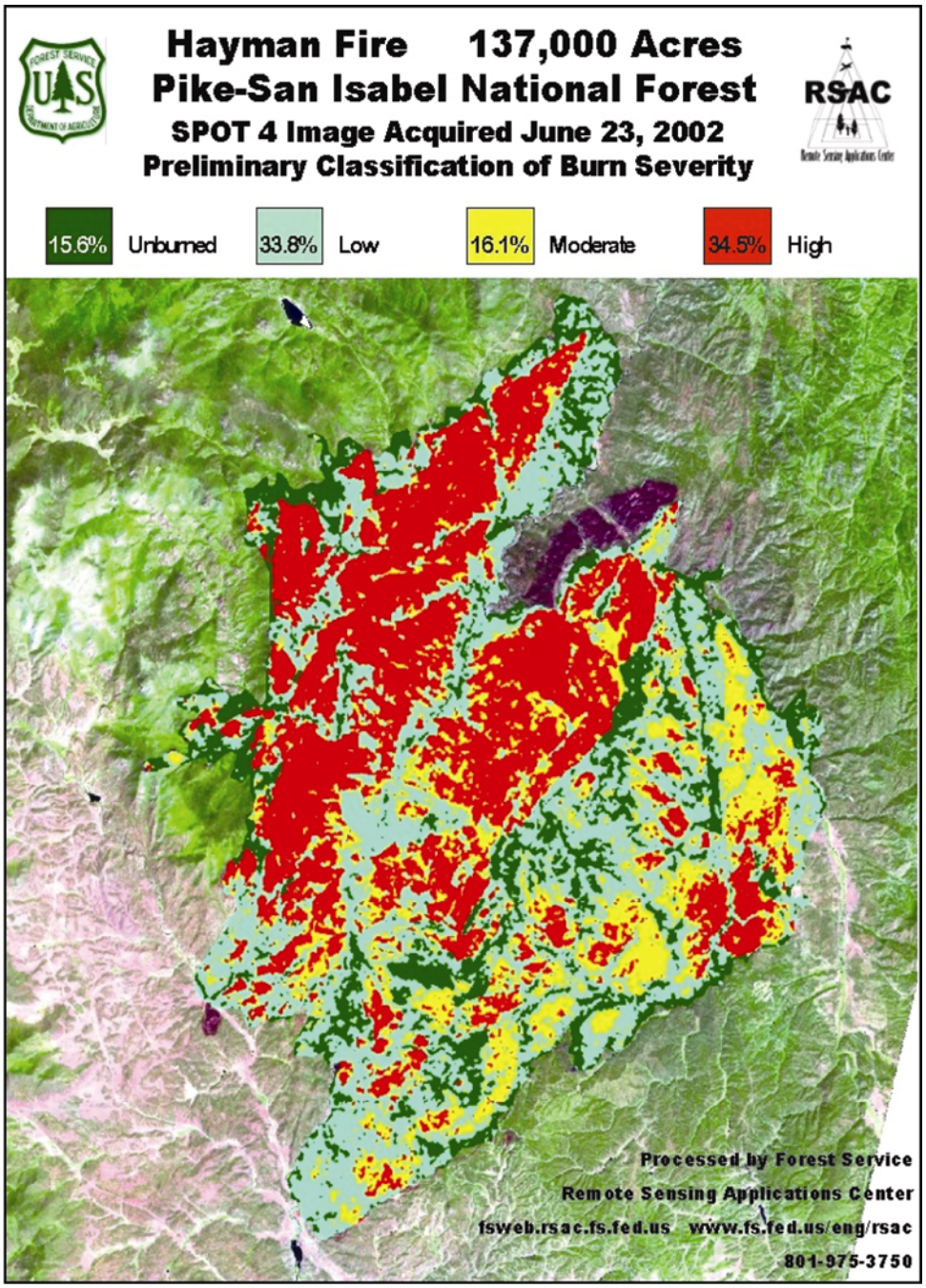
It is important to note that there are many commercial products and services available for use during a fire—ranging from high-resolution aerial and satellite imagery, to handheld Global Positioning System devices, to enhanced visualization models, to on-site geographic information systems, equipment, and personnel.

Incident commanders responsible for responding to fires often choose to purchase commercial products and services to supplement interagency resources.

Examples of Geospatial Technology Use: Postfire

After a fire occurs, burned-area teams have recently begun to use remote sensing data in conjunction with geographic information systems to determine the extent of fire damage and to help plan and implement emergency stabilization and rehabilitation efforts. Typical products include burn severity and burn intensity maps. Figure 15 depicts a satellite image and a burn severity map showing areas that have a high priority for emergency stabilization measures. Geospatial technologies also aid in monitoring rehabilitation efforts for years after a fire to ensure that restoration plans are on track.

Figure 15: Burn Severity Map, Hayman Fire, June 2002



Source: Forest Service, Remote Sensing Applications Center.

New Uses of Geospatial Information Technologies to Aid in Wildland Fire Management Are under Development

The Forest Service and Interior are researching and developing new applications of geospatial information technologies to support business needs in wildland fire management. In addition, the Joint

Fire Science Program, a partnership of the five land management agencies and the U.S. Geological Survey, funds numerous research projects each year on fire and fuels management. Once again, these initiatives vary greatly—ranging from research on remote sensing systems to the development of interagency information systems with geospatial components, to improvements in existing software models. Examples of these efforts include the following:

- **Sensor research.** Several new research projects are under way on LIDAR and hyperspectral sensors.[9] For example, a BLM state office is researching the use of high-resolution hyperspectral and LIDAR imaging technologies for improving the identification of vegetation; planning hazardous fuels projects; and monitoring wildland urban interface projects, the effects of wildland fires, and fire rehabilitation efforts. Additionally, the Forest Service is exploring the use of mobile LIDAR systems for assessing smoke plumes, and it is conducting research on using LIDAR data, satellite data, and modeling techniques to forecast air quality after a fire.

- **Vegetation data and tools.** The five land management agencies and the U.S. Geological Survey are working together to develop a national geospatial dataset and a set of modeling tools for wildland fire planning. This effort, called LANDFIRE, is to provide a comprehensive package of spatial data layers, models, and tools needed by land and fire managers. The system is expected to help prioritize, plan, complete, and monitor fuel treatment and restoration projects on national, regional, and local scales. A prototype of the system covers central Utah and Northwestern Montana and is expected to be completed by April 2005.

- **Interagency information systems.** The five land management agencies are developing information systems for use by Interior and Forest Service offices to track efforts under the National Fire Plan. The National Fire Plan Operations and Reporting System is an interagency system designed to assist field personnel in managing and reporting accomplishments for work conducted under the National Fire Plan. It is a Web-based data collection tool with GIS support that locates projects and treatments. It consists of three modules—hazardous fuels reduction, restoration and rehabilitation, and community assistance. While the agencies are currently using the system, it will not be fully operational until 2004. Another information system, the Fire Program Analysis

[9] LIDAR sensors measure the reflection of emitted light; hyperspectral sensors observe data in multiple contiguous channels of the electromagnetic spectrum. A more detailed discussion of these and other types of sensors is included in appendix IV.

system, is an interagency planning tool for analysis and budgeting to be used by the five federal wildland fire management agencies. The first module—preparedness—is scheduled for implementation in September 2004 and will evaluate the cost-effectiveness of alternative initial attack operations in meeting multiple fire management objectives. Additional system modules are expected to provide geospatial capabilities and to address extended attack, large fires and national fire resources, hazardous fuels reduction, wildland fire use, and fire prevention.

- **Improvements in existing systems.** There are multiple efforts planned or under way to improve existing systems or to add geospatial components to systems that are currently under development. For example, researchers at a federal fire sciences laboratory are exploring possible improvements to the Wildland Fire Assessment System, an Internet-based system that provides information on a broad area of national fire potential and weather maps for fire managers and the general public. Specifically, researchers are working to develop products that depict moisture levels in live fuels, which will aid in assessing the potential for wildland fires.

Extent to Which Geospatial Technologies Are Used to Support Wildland Fire Management Is Not Fully Known

While many land management entities are using geospatial technologies in support of their wildland fire-related activities, the extent to which geospatial technologies and tools are being used in support of wildland fire management is not fully known. In an effort to get a more accurate picture of how extensively geospatial information technologies are being used, the Geospatial Task Group, a subgroup of the National Wildfire Coordinating Group's (NWCG) IRM working team, is conducting a survey of wildland fire personnel to determine what technologies are being used and how they are being used. Group members stated that this information would help them to develop interagency standards for equipment and training and would allow land managers to learn from others' experiences in using some of the geospatial information technologies. For example, some incident teams use fire modeling software during active fires, while some land management offices are using the software in planning prescribed fires. The group initiated its survey in June 2003 and expects to complete its assessment by September 2003.

The Wildland Fire Community Faces Numerous Challenges in Using Geospatial Information Technologies Effectively; More Must Be Done to Address These Challenges

There are numerous challenges in using geospatial information technologies effectively in the wildland fire community. Key challenges involve data, systems, infrastructure, staffing, and the effective use of new products and technologies—all complicated by the fact that wildland fire management extends beyond a single agency's responsibility. NWCG has several initiatives under way to address specific challenges to using geospatial information technologies. However, progress on these initiatives has been slow, and the initiatives do not address all of the challenges.

A root cause of many of these challenges is the lack of an overall strategy guiding interagency management of information resources and technologies. Currently, different IRM-related teams within NWCG are planning initiatives to improve the interagency management of information resources and technology. Focusing specifically on geospatial technologies, the NWCG's IRM working team's geospatial task group has proposed developing an interagency strategic plan for using geospatial technologies to support wildland fire management. Additionally, the IRM working team has developed a draft IRM strategy to guide information technology development and use by the interagency fire community. At a broader level, NWCG's IRM program management office plans to develop an enterprise architecture to guide and integrate business operations for wildland fire management. However, these efforts lack the senior-level endorsement and the detailed plans and milestones necessary for success. Until effective interagency management of information technologies becomes a priority, the wildland fire community will likely continue to face challenges in effectively using geospatial technologies.

Many Challenges Affect the Usefulness of Geospatial Information Technologies

As the use of geospatial information technologies has become more common in wildland fire management, the challenges to effectively using and sharing geospatial information have become more apparent. Key challenges include the following:

- **Data issues**. Users of geospatial information have noted problems in acquiring compatible and comprehensive geospatial data. For

example, GIS specialists involved in fighting fires reported that they did not have ready access to the geospatial data they needed. They noted that some local jurisdictions have geospatial data, but others do not. Further, they reported that the data from neighboring jurisdictions are often incompatible. GIS specialists reported that the first days at a wildland fire are spent trying to gather the geospatial information needed to accurately map the fire. While concerns with data availability and compatibility are often noted during fire incidents, these issues are also evident before and after fire incidents. For example, we recently reported that the five land management agencies did not know how effective their postfire emergency stabilization and rehabilitation treatments were because, among other reasons, local land units do not routinely collect comparable information.[10] As a result of unavailable or incompatible data, decision makers often lack the timely, integrated information they need to make sound decisions in managing different aspects of wildland fire.

On a related note, the development and implementation of data standards is a well-recognized solution for addressing some of the problems mentioned above, but there are currently no nationally recognized geospatial data standards for use on fires. GIS specialists frequently cited a need for common, interagency geospatial data standards for use with fires. They noted that the land management agencies and states do not record information about fires—such as fire location, fire perimeter, or the date of different fire perimeters—in the same way.

System issues. In 1996, NWCG reported that there was a duplication of information systems and computer applications supporting wildland fire management, noting that agencies were using 15 different weather-related software applications, 9 logistics applications, and 7 dispatch applications.[11] Since that time, the number of applications has grown—as has the potential for duplication of effort. Duplicative systems not only waste limited funds, but they also make interoperability between systems more difficult.

This issue is complicated by the fact that there is no single, comprehensive inventory of information systems and applications that could be of use to others in the interagency wildland fire

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[10] U.S. General Accounting Office, *Wildland Fires: Better Information Needed on Effectiveness of Emergency Stabilization and Rehabilitation Treatments*, GAO-03-430 (Washington, D.C.: Apr. 4, 2003).

[11] National Wildfire Coordinating Group, *Information Resource Management Strategy Project: Wildland Fire Business Model* (National Interagency Fire Center: August 1996).

community. A single comprehensive inventory would allow the wildland fire community to identify and learn about available applications and tools, and to avoid duplicating efforts to develop new applications. We identified five different inventories of software applications—including information systems, models, and tools—that are currently being used in support of wildland fire management. While these listings are not limited to geospatial applications, many of the applications have geospatial components. The most comprehensive listing is an inventory managed by NWCG. This inventory identifies 199 applications used in support of wildland fire, but even this inventory is not complete. That is, it did not include 45 applications that were included in the other inventories. Additionally, it did not include 24 applications that we had identified. Appendix V provides information on applications with geospatial components.

Infrastructure issues. Many GIS specialists noted that there are problems in getting equipment, networking capabilities, and Internet access to the areas that need them during a fire. For example, at a recent fire in a remote location, these specialists reported that they were unable to produce needed information and maps because they had problems with networking capabilities. Again, this issue is critical during a fire, when incident teams try to set up a command center in a remote location. However, it is also an issue when federal regional managers try to obtain consistent information from the different land management agencies' field offices before or after fires. The majority of local field offices have equipment to support geospatial information and analysis, but some do not.

Staffing issues. GIS specialists noted that the training and qualifications of the GIS specialists who support fire incidents is not consistent. Specifically, officials noted that skills and qualifications vary widely among those who work with geographic information systems. For example, some GIS specialists are capable of interpreting infrared images as well as developing maps, but others are not. Some have experience working with GIS applications but are not specifically trained to develop GIS maps for fires.

Use of new products. While many commercial vendors are developing geospatial products and services that could be of use to the wildland fire community—including advanced satellite and aerial imaging; GIS software and equipment; and advanced mapping products, including analyses, visualization, and modeling—many have expressed concern that the wildland fire community is not aware of these advancements or has little

funding for these products. Land managers acknowledged the value of many of these products, but noted that acquiring these products needs to be driven by business needs. Agency officials also expressed concern that the cost of these products and services can be prohibitive and that licensing restrictions could keep them from sharing the commercial data and products with others in the wildland fire community.

National Wildfire Coordinating Group Has Initiated Efforts to Address Some Geospatial Challenges, but Progress Has Been Slow and Not All Challenges Are Being Addressed

Different NWCG teams (including the IRM working team, the IRM program management office, the IRM working team's geospatial task group, and the IRM working team's data administration working group) are undertaking efforts to address specific challenges to effectively using information technologies. Specifically:

- Focusing on geospatial data issues, NWCG teams are working to share geospatial data and to define geospatial data standards. To date, an NWCG team has established an Internet site where geospatial data can be provided and obtained. NWCG teams have also begun developing data standards for daily and final fire perimeters with a goal of implementing these standards across the land management agencies.

- Recognizing the large number of systems supporting fire management, an NWCG team is managing the development of five new interagency systems to replace several similar systems that are currently being used by different agencies. For example, the team has developed a resource ordering and status system to replace four existing systems and is developing an integrated system for tracking the qualifications of individuals assigned to fire incidents (such as incident commanders and firefighters), which should replace separate tracking systems that are currently used by the five land management agencies. NWCG is also working to improve the inventory of information systems and applications that are used to support wildland fire management. This team is seeking validation of the information already in the inventory and adding new items to the inventory as they become known.

- Focusing on the development of GIS specialists' skills, an ad hoc group not associated with NWCG developed a training course for GIS technical specialists who work on fires, to provide them a

minimum set of qualifications, with the intent of obtaining a consistent level of GIS skills among the specialists. An NWCG team is evaluating this training for use throughout the wildland fire community. Also, this NWCG team has proposed a minimum set of qualifications for GIS specialists who work on fires.

However, progress on these geospatial initiatives has been slow. Although these initiatives have been under development for over 14 months, senior NWCG IRM officials have not yet endorsed proposals for a data standard on fire perimeters, the GIS specialists' qualifications for incident support, or the GIS specialists' training. NWCG officials were unable to estimate when they would evaluate or implement these proposals; they explained that they have multiple competing priorities.

Further, these initiatives do not address all of the challenges to effectively using geospatial information technologies. The initiatives do not address issues associated with infrastructure and the use of new technologies, and they do not comprehensively address all of the issues with data, systems, and staffing. For example, other geospatial data standards are needed to achieve consistency in the geospatial data used to support wildland fire management.

Effective Interagency IT Management Could Help Address Challenges

Effective interagency IT management could help address the challenges faced by the wildland fire community in using geospatial information and technologies. Such an approach could address the implementation and enforcement of national geospatial data standards for managing wildland fires, an interagency strategic approach to systems and infrastructure development, a plan for ensuring consistent equipment and training throughout the wildland fire community, and a thorough evaluation of user needs and opportunities for meeting those needs through new products and technologies.

Acknowledging many of the geospatial and information management challenges, in September 2002 the National Academy of Public Administration reported that a national information technology/information management framework is needed to guide future development and deployment of systems and information sources to support more cost-effective fire

suppression.[12] Such a framework would provide an architecture for systems, applications, data, and networks, based on user-identified needs. The academy recommended that the agencies involved work together under the guidance of the Wildland Fire Leadership Council to describe what the desired system and data sources should accomplish in fire management and how individual components and data sources can become functioning parts of the overall system. The academy also recommended that the framework provide uniform data policies and standards to ensure the interoperability needed among federal, state, and local systems to maximize the utility and maintenance of available geographic information.

National Wildfire Coordinating Group Plans to Improve Interagency IT Management, but Efforts Lack Senior-Level Endorsement and Detailed Plans and Milestones

Three different teams within NWCG are planning initiatives to improve the interagency management of geospatial information and information resources and technology. However, these initiatives lack the senior-level endorsement and detailed plans and milestones necessary for success.

Focusing specifically on geospatial technologies, the Geospatial Task Group (a subgroup of NWCG's IRM working team) has proposed developing an interagency strategic plan for using geospatial technologies to support wildland fire management. Officials proposed that this geospatial strategic plan would evaluate the use of technologies in support of the wildland fire mission, assess the need for these technologies, explore opportunities to improve these technologies, and contribute to developing an interagency geospatial infrastructure. However, NWCG has not approved funding for this initiative, and as a result, there is as yet no schedule for developing this geospatial strategic plan.

Focusing on IRM management, NWCG's IRM working team developed a draft IRM strategy to help guide information technology development and use by the interagency fire community. However, this plan has been in draft form since March 2002, and officials could not estimate when it would be finalized. Further, the draft plan includes high-level objectives, but does not

[12] Frank Fairbanks, Elizabeth Hill, Patrick Kelly, Lyle Laverty, Keith F. Mulrooney, Charlie Philpot, and Charles Wise, *Wildfire Suppression: Strategies for Containing Costs* (Washington, D.C.: National Academy of Public Administration, September 2002).

include detailed action items or schedules for accomplishing these objectives. For example, the draft IRM strategy lists objectives such as leveraging existing technologies, incorporating emerging technologies, and developing and obtaining a workforce that is fully trained and skilled in the use of IRM applications. However, the plan does not identify any activities or schedules for accomplishing these objectives.

At a broader level, NWCG's IRM program management office plans to develop an interagency enterprise architecture to guide and integrate business operations for wildland fire management. According to federal guidance on developing enterprise architectures, one of the most important initial steps is to obtain and demonstrate senior-level support for the architecture effort.[13] Another critical element is to demonstrate a clear plan, or roadmap, for developing the architecture. Such a plan would include critical steps, deliverables, and estimated time frames for the deliverables. Critical activities in the plan would include a description of the current IT environment (hardware, software, data, communications); an assessment of user needs and technological opportunities for meeting those needs; a target environment; and a transition plan to get to the target environment. Finally, for an enterprise architecture to be effective, it needs to be tied to investment processes and controls. That way, decision makers can ensure that new investments in technology are consistent with the target environment.

NWCG's IRM program management office is beginning to work on an interagency enterprise architecture. To date, the office has established a goal of developing an enterprise architecture for the interagency wildland fire community and has designated an IRM program manager, data architect, and applications architect to help build it. Further, the data and applications architects expect to be certified in the development of federal enterprise architectures by October 2003.

However, the planned interagency enterprise architecture lacks senior-level support, detailed plans and milestones, and a link to investment control processes. The Wildland Fire Leadership Council was established in April 2002 to provide senior-level leadership in the wildland fire community. However, the Leadership Council has not formally endorsed NWCG's interagency enterprise architecture effort. Without this senior-level support, the

[13] Chief Information Officer Council, *A Practical Guide to Federal Enterprise Architecture*, Version 1.0 (February 2001).

interagency wildland fire community runs the risk that its components will continue to invest in duplicative "stovepiped" systems and will perpetuate the existing situation of limited interoperability and unnecessarily costly operations.

Additionally, although the IRM program management office has established the goal of developing an enterprise architecture, it has not yet defined exactly what it will deliver and by when. NWCG officials could not provide estimates for when they would develop a thorough understanding of the current "as is" interagency environment, identify user needs and technological opportunities for meeting those needs, identify a target architecture, or complete a plan for transitioning to that target architecture. NWCG officials explained that "to successfully implement anything across two departments, five federal agencies, and 50 states is difficult and takes years of planning and preparation."

Further, once it is developed, it is not clear how this enterprise architecture would be linked to the interagency geospatial strategic plan, the interagency IRM strategy, or the different agencies' investment control processes.

Given the complexity of interagency wildland fire operations, it is clear that effectively managing IT (including geospatial IT) in support of the wildland fire mission is a challenging task. However, it is also clear that without senior-level endorsement and clear plans for achieving results, efforts to address geospatial IT challenges and to improve IT management may never be successful. Until effective management of information resources and technology in support of the wildland fire mission becomes a management priority, the wildland fire community will likely continue to face significant challenges in effectively using geospatial technologies.

New National Efforts to Improve the Use of Geospatial Information Are Promising, but Challenges to Effective Data Sharing Remain

Effectively using geospatial information is of interest beyond the wildland fire management community. Detailed, accurate, and accessible geospatial information is critical in addressing homeland security and national preparedness, supporting our transportation infrastructure, managing natural resources, and performing the

national census—among other activities—and the federal government has long recognized problems in duplicative collections of geospatial data.

We recently reported that the federal government has tried for years to reduce duplicative geospatial data collection by coordinating geospatial activities both within and outside the federal government.[14] In 1953, the Bureau of the Budget first issued its Circular A-16, encouraging expeditious surveying and mapping activities across all levels of government and avoidance of duplicative efforts. In 1990, the Office of Management and Budget revised this circular to establish a Federal Geographic Data Committee (FGDC), chaired by the Department of the Interior, to promote coordinated use, sharing, and dissemination of geospatial data nationwide. In 1994, an executive order called for coordinating geographic data acquisition and access through a National Spatial Data Infrastructure.[15] The order defined this infrastructure as the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve the utilization of geospatial data. In 2002, the Office of Management and Budget issued revised guidance for agencies that create, use, or store geospatial data and established a coordinated approach to the National Spatial Data Infrastructure.[16] Additionally, the E-Government Act of 2002 called for common protocols for GIS in order to reduce redundant data collection and information, and to promote collaboration and use of standards for government geographic information.[17] Most recently, the Office of Management and Budget issued guidance on implementing the act.[18]

Various efforts are now under way to implement this guidance and legislation. Under the framework of the National Spatial Data Infrastructure, the FGDC coordinates efforts to develop national standards for geospatial data, develop a national framework for sharing geospatial data collections, and establish a portal on the Internet—called the Geospatial One-Stop initiative—for accessing geospatial information.

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[14] U.S. General Accounting Office, *Geographic Information Systems: Challenges to Effective Data Sharing*, GAO-03-874T (Washington, D.C.: June 10, 2003).
[15] Executive Order 12906, *Coordination of Geographic Data Acquisition and Access: The National Spatial Data Infrastructure* (Apr. 13, 1994).
[16] Office of Management and Budget, *Coordination of Geographic Information and Related Spatial Data Activities,* Circular A-16 Revised (Washington, D.C.: Aug. 19, 2002). The Circular applies to any agency that collects, produces, acquires, maintains, distributes, uses, or preserves paper maps or digital geospatial data to fulfill its mission.
[17] Sec. 216, P.L. 107-347, December 17, 2002.
[18] Office of Management and Budget Memorandum, "Implementation Guidance for the E-Government Act of 2002," M-03-18 (Aug. 1, 2003).

The status of these efforts follows.

- **Geospatial Data Standards**. FGDC is developing standards for data documentation, collection, and exchange so that data can be shared across state and local boundaries on many different hardware platforms and with many different software programs. To date, FGDC has established 20 different standards, including standards for classifying vegetation and for documenting information about the collected data, called metadata.

- **National Geospatial Data Clearinghouse**. The clearinghouse is a decentralized system of Internet servers that contain field-level descriptions or metadata of available digital geospatial data. The clearinghouse allows individual agencies, consortia, and geographically defined communities to coordinate and promote the use of their available geospatial data. Currently, the FGDC Clearinghouse server connects to over 250 nodes around the world.

- **Geospatial One-Stop**. One of 25 high-profile Office of Management and Budget-sponsored e-government initiatives, this project builds upon the data clearinghouse to develop an Internet portal for one-stop access to geospatial data. This effort is expected to develop national geospatial data standards, increase the inventory of data holdings, and encourage greater coordination among federal, state, and local agencies about existing and planned geospatial projects. The Department of the Interior expects to complete this initiative in early 2004.

While these initiatives hold promise, much remains to be done to achieve effective sharing of geospatial data. We recently reported that progress has been made on these initiatives, but that achieving the goals of the National Spatial Data Infrastructure remains a formidable challenge.[19] Despite a series of mandates and directives over many years requiring the use of standards and cooperation among federal agencies and other entities, not all governmental entities are fully cooperating on a nationwide basis. As a result, significant geographic data standardization and data sharing have not been realized. We also noted that a much more substantial effort will be required to attain the vision of seamless integration of GIS data nationwide. Specifically, existing draft standards may need further revision, and more extensive coordination efforts may be required to ensure broad adoption of the standards at all levels of government. Further, attaining this goal is likely to require a continuing effort over an extended period of time. Clearly,

[19] GAO-03-874T.

compliance with the mandate of the E-Government Act will advance the goal of obtaining standardized geographic data.

Although these national efforts are not at the level of detail that the wildland fire community needs for fire-related geospatial data standards, it will be important that the efforts are coordinated. As the interagency wildland fire community moves forward with its plans to develop an overall strategy for geospatial information technology and data standards, it will be important to incorporate national data standards, to participate in national initiatives such as the Geospatial One-Stop, and to comply with the purpose and requirements of the E-Government Act.

Conclusions

The federal wildland fire management community is using a variety of different geospatial technologies for such activities as identifying dangerous fuels, assessing fire risks, detecting and fighting fires, and restoring fire-damaged lands. These technologies run the gamut from satellite and aerial imaging, to the Global Positioning System, to geographic information systems, to specialized fire models.

Local land managers and incident teams often acquire, collect, and develop geospatial information and technologies to meet their specific needs, resulting in a hodgepodge of incompatible and duplicative data and tools. This problem is echoed throughout the fire community: Those who work with different aspects of fire management commonly cite concerns with unavailable or incompatible geospatial data, duplicative systems, lack of equipment and infrastructure to access geospatial information, inconsistency in the training of GIS specialists, and ineffective use of new products and technologies. These challenges illustrate the need for a new, integrated, strategic approach to managing information systems and data in the wildland fire community. Different teams within the National Wildfire Coordinating Group have proposed developing an interagency geospatial strategy to help define and plan how to address geospatial challenges, drafted an interagency IRM strategy to identify high-level goals, and proposed developing an interagency enterprise architecture to more effectively manage information resources and technology. However, the plan to develop a geospatial strategy has not been approved, and the draft IRM strategy lacks detailed activities and schedules for accomplishing key objectives. Further, the NWCG

team responsible for developing the architecture has not yet begun the effort, and the initiative lacks the senior management endorsement, the detailed plans and schedules, and the link to an investment control process that are critical to any architecture's success.

Looking beyond the wildland fire community, effective use of geospatial information is a national priority. The federal government has been working for years to use geospatial data more effectively and efficiently. New initiatives to develop nationwide standards, a geospatial data clearinghouse, and an Internet portal for accessing geospatial data holdings offer much promise. However, significant challenges remain. It will be important, as NWCG moves forward with its efforts to develop an interagency geospatial strategy, an interagency IRM strategy, and an interagency enterprise architecture, that these efforts comply with the requirements of the E-Government Act and incorporate national standards for geospatial data.

Recommendations

In order to better manage the use of geospatial information in support of wildland fire management, we recommend that the Secretaries of Agriculture and the Interior direct the Wildland Fire Leadership Council to endorse and oversee the National Wildfire Coordinating Group's efforts to develop an interagency geospatial strategy for effectively using geospatial information technologies in all phases of wildland fire management. We also recommend that this geospatial strategy

- address challenges to effectively using geospatial technologies, including issues associated with data, systems, infrastructure, staffing, and the use of new products;
- establish deliverables and milestones for completing key initiatives; and
- be incorporated in interagency efforts to improve IT management, including the interagency IRM strategy and the interagency enterprise architecture effort.

In order to ensure effective interagency IT management, we recommend that the Secretaries of Agriculture and the Interior immediately endorse development of an interagency IRM strategy

and an enterprise architecture for wildland fire management. Further, we recommend that the Secretaries ensure senior-level oversight by directing the Wildland Fire Leadership Council to oversee the National Wildfire Coordinating Group's efforts to

- establish detailed plans and schedules for implementing the interagency IRM strategy for wildland fire management;
- establish a detailed plan for developing the interagency enterprise architecture for wildland fire management, and ensure that it includes clear interim steps and implementation milestones;
- ensure that the interagency geospatial strategic plan and the interagency IRM strategy are integrated with the enterprise architecture for wildland fire management;
- establish a link between the architecture and the investment control processes at the land management agencies; and
- ensure that the architecture incorporates E-Government Act requirements and national standards for geospatial data.

Agency Comments

We provided a draft of this report to the Secretaries of Agriculture and the Interior for review and comment. The departments provided a consolidated, written response to our draft report, signed by the Under Secretary, Natural Resources and the Environment, Department of Agriculture, and the Assistant Secretary, Policy, Management and Budget, Department of the Interior. The departments' response is included in appendix VI of this report. The departments agreed with the report's conclusions and recommendations, and noted that developing an interagency IRM strategy and interagency enterprise architecture is an ambitious undertaking. They stated that it makes sense to incorporate our recommendations into ongoing agency and departmental e-government enterprise architecture strategies, and that doing so will enable them to modernize various lines of business in manageable components. The departments also stated that as a result of these initiatives, the agencies will gain incremental integration of information and shared use of information technology, but noted that these improvements will be both time and resource intensive.

The departments commented that our findings will be discussed by the Wildland Fire Leadership Council at their October 2003 meeting and that, based on that discussion and direction provided by the Council, staff from the two departments will be tasked with developing an action plan to address our findings and the broader issue of geospatial needs for wildland fire management. The departments also stated that the recommendations we provided will help the departments move forward to establish a better coordinated, interagency architecture for geospatial wildland fire management information requirements. The departments also provided technical corrections, which we have incorporated as appropriate.

We are sending notification of this report to the Chairman and Ranking Minority Members of the Subcommittee on Public Lands and Forests, Senate Committee on Energy and Natural Resources; the Subcommittee on Forests and Forest Health, House Committee on Resources; and other interested congressional committees. We will also send notification of this report to the Secretary of Agriculture; the Secretary of the Interior; the Chief of the Forest Service; the Directors of the Bureau of Land Management, the National Park Service, and the Fish and Wildlife Service; the Deputy Commissioner, Bureau of Indian Affairs; the Director, Office of Management and Budget; and other interested parties. In addition, this report will be available at no charge on GAO's Web site at www.gao.gov.

If you have any questions on matters discussed in this report, please contact me at (202) 512-9286 or Colleen Phillips, Assistant Director, at (202) 512-6326. We can also be reached by E-mail at pownerd@gao.gov and phillipsc@gao.gov, respectively. Other contacts and key contributors to this report are listed in appendix VII.

David A. Powner
Director (Acting), Information Technology
Management Issues

Appendix I: Objectives, Scope, and Methodology

Our objectives were to (1) identify key geospatial information technologies for addressing different aspects of wildland fire management; (2) summarize key challenges to the effective use of geospatial technologies in wildland fire management; and (3) identify national opportunities to improve the effective use of geospatial technologies. To accomplish these objectives, we focused our review on five key federal agencies that are responsible for wildland fire management on public lands: the Department of Agriculture's Forest Service and the Department of the Interior's National Park Service, Bureau of Land Management, Fish and Wildlife Service, and Bureau of Indian Affairs. To address the final objective, we also reviewed national efforts to improve the use of geospatial information by the Office of Management and Budget and the Federal Geographic Data Committee (FGDC).

To identify key geospatial information technologies for addressing different aspects of wildland fire management, we assessed policies, plans, and reports on wildland fire management and technical documents on geospatial technologies. We assessed information on Forest Service and Interior efforts to develop and use geospatial technologies. We also interviewed officials with the Forest Service and the Interior, interagency organizations, commercial vendors, and selected states to determine the characteristics and uses of different geospatial technologies in supporting different phases of wildland fire management. In addition, we met with officials of other federal agencies, including the Department of the Interior's U.S. Geological Survey, the Department of Defense's National Imagery and Mapping Agency, the National Aeronautics and Space Administration, the Department of Commerce's National Oceanic and Atmospheric Administration, and the Department of Homeland Security's Federal Emergency Management Agency, to identify their efforts to develop geospatial information products in support of wildland fire management.

To compile a list of geospatial applications used in support of wildland fire management, we identified five inventories of software models, applications, and tools used to support wildland fire activities. We combined the five inventories to compile a more complete list of applications, and we added geospatial applications

that were not on any of the inventories. We learned about these other applications through discussions with agency officials and by searching Forest Service and Interior Web sites. Additionally, Forest Service and Interior officials provided input on which applications have geospatial components and provided supporting information where it was available. We did not validate the accuracy of the information in the five separate inventories.

To summarize key challenges to the effective use and sharing of geospatial technologies, we reviewed key reports and studies on these challenges. These include the following:

Burchfield, James A., Theron A. Miller, Lloyd Queen, Joe Frost, Dorothy Albright, and David DelSordo. *Investigation of Geospatial Support of Incident Management.* National Center for Landscape Fire Analysis at the University of Montana. November 25, 2002.

Committee on Earth Observation Satellites, Disaster Management Support Group. *The Use of Earth Observing Satellites for Hazard Support: Assessments & Scenarios.* National Oceanic and Atmospheric Administration, n.d.

Department of Agriculture (Forest Service) and Department of Interior. *Developing an Interagency, Landscape-scale Fire Planning Analysis and Budget Tool.* n.d. [December 2001].

Fairbanks, Frank, Elizabeth Hill, Patrick Kelly, Lyle Laverty, Keith F. Mulrooney, Charlie Philpot, and Charles Wise. *Wildfire Suppression: Strategies for Containing Costs.* Washington, D.C.: National Academy of Public Administration, September 2002.

Fairbanks, Frank, Henry Gardner, Elizabeth Hill, Keith Mulrooney, Charles Philpot, Karl Weick, and Charles Wise. *Managing Wildland Fire: Enhancing Capacity to Implement the Federal Interagency Policy*. Washington, D.C.: National Academy of Public Administration, December 2001.

National Oceanic and Atmospheric Administration. *Wildland Fire Management: Some Information Needs and Opportunities.* Working paper, National Hazards Information Strategy, July 2002.

National Wildfire Coordinating Group. *Information Resource Management Strategy Project: Wildland Fire Business Model.* National Interagency Fire Center. August 1996.

National Wildfire Coordinating Group, Information Resource Management Working Team, Geospatial Task Group. *Geospatial Technology for Incident Support: A White Paper*. April 12, 2002.

We also interviewed federal officials from interagency wildland fire groups, including the national fire directors, the National Wildfire Coordinating Group's (NWCG) Information Resource Management (IRM) working team, NWCG's IRM program management office, the IRM working team's geospatial task group, and the Wildland Fire Leadership Council to discuss challenges and ongoing efforts to address these challenges. In addition, we reviewed postfire reports on the Hayman, Biscuit, and Cerro Grande fires to identify how geospatial technologies were used on these fires and to evaluate any challenges the incident teams may have encountered in using these technologies. We attended federal and commercial conferences on geospatial information technologies, interviewed representatives from selected states and commercial vendors, and observed group discussions on challenges in effectively using these technologies and plans for addressing them.

To identify national opportunities to improve the effective use of geospatial technologies to address wildland fire management, we identified key national efforts to set geospatial data standards, to reduce duplication of effort, and to increase collaboration among the federal government, states, and private entities. Specifically, we evaluated the history of legislation and guidance from the Office of Management and Budget on geospatial information, and identified the status and plans of efforts under the National Spatial Data Infrastructure, including FGDC's efforts to develop geospatial data standards, a data clearinghouse, and an Internet portal (called Geospatial One-Stop). We discussed the status of these initiatives with the Office of Management and Budget and committee officials. We also reviewed the land management agencies' progress in implementing and enforcing key elements of these national efforts by assessing the FGDC progress reports and by determining the status of the agencies' efforts to adopt geospatial data policies.

We conducted our review at the federal agencies' headquarters in Washington, D.C.; the Forest Service's Remote Sensing Applications Center and Geospatial Service and Technology Center in Salt Lake City, Utah; the U.S. Geological Survey's Rocky Mountain Mapping Center in Denver, Colorado; the U.S. Geological Survey's Earth Resources Observation Systems Data Center in Sioux Falls, South Dakota; the National Interagency Fire Center in Boise, Idaho; and the Forest Service's Rocky Mountain Research Station, Fire Sciences Laboratory in Missoula, Montana. We conducted our work between

October 2002 and September 2003 in accordance with generally accepted government auditing standards.

Appendix II: Major Wildland Fire Policies, Plans, Reports, and Initiatives

The following table provides a chronology of the policies, plans, reports, and initiatives that form the national approach to wildland fire management over the past decade.

Document or initiative	What it does	Relationship to other initiatives
Federal Wildland Fire Management Policy and Program Review, December 1995	This policy responded to the tragic fires of 1994. Among other things, the report • reaffirms the protection of life as the first priority, • recognizes wildland fire as a critical natural process, • requires that fire management plans be developed for all burnable acres, • requires that fire management decisions be consistent with approved land and resource management plans, • requires that agency administrators conside r a full range of fire management actions, and • clarifies the role of federal agencies in the wildland-urban interface.	Provides the overarching fire policy framework for the Department of Agriculture's Forest Service (FS) and the Department of the Interior's National Park Service (NPS), Fish and Wildlife Service (FWS), Bureau of Indian Affairs (BIA), and Bureau of Land Management (BLM).
A Report to the President: Managing the Impact of Wildfires on Communities and the Environment, September 2000 Web site: www.fireplan.gov/content/reports/	This report was developed in response to a Presidential request. It provides recommendations to the Departments of Agriculture and the Interior on how best to respond to the severe fire season of 2000. Among other key recommendations, the report recommends that the departments • provide additional firefighting resources; • restore damaged landscapes and communities; • increase investment to reduce fire risk (emphasis on multi-jurisdictional efforts that give better landscape protection); • work directly with local communities that are at risk, to improve community fire-fighting capacity and coordination, implement restoration and fuel reduction projects, and expand education and risk mitigation efforts in the wildland urban interface; and • establish accountability.	Provides the basis and conceptual framework for the National Fire Plan and the *10-Year Comprehensive Strategy*.

Document or initiative	What it does	Relationship to other initiatives
The National Fire Plan Initiative, October 2000	This initiative is a long-term, multifaceted program designed to manage the impacts of wildland fire on communities and ecosystems and to reduce wildfire risk. It encompasses the Departments of Agriculture (FS) and the Interior (NPS, FWS, BIA, BLM). The program focuses on • improving fire preparedness, • restoring and rehabilitating burned areas, • reducing hazardous fuels, • assisting communities, and • accountability.	Implements the recommendations in the *Report to the President* through the Departments of Agriculture and the Interior, with increased funding provided by Congress.
Protecting People and Sustaining Resources in Fire-Adapted Ecosystems: A Cohesive Strategy, October 2000	This strategy is the Forest Service's response to GAO report RCED-99-65,[a] which found that fuel buildup was a major problem in the interior west and recommended that the Forest Service develop a cohesive strategy for reducing fuel buildup. The strategy establishes a framework to restore and maintain the health of fire-adapted ecosystems on National Forest System lands. It focuses treatments in "short-interval" fire-adapted ecosystems—ecosystems where frequent lower-intensity ground fires historically occurred and were a powerful force in shaping the makeup and structure of vegetative communities. The strategy identifies as priority areas for treatment • wildland urban interface, • municipal watersheds, • threatened and endangered species habitats, and • the maintenance of low risk Condition Class I areas.	Identifies priorities and focus for hazardous fuel treatments on national forest system lands, as called for in the *National Fire Policy* and the *10-year Comprehensive Strategy*.
Review and Update of the 1995 Federal Wildland Fire Management Policy, January 2001 Web site: www.nifc.gov/fire_policy/index.htm	This policy • reviews the status of 1995 Fire Policy implementation and provides recommendations for full implementation, • addresses specific issues raised in the Cerro Grande Prescribed Fire Investigation report, • recommends creating a senior level interagency mechanism to oversee fire policy implementation, • recommends a series of strategic implementation actions that are essential for wildland fire management, and • recommends establishing a new mechanism for ensuring coordinated implementation of the policy.	Reaffirms the relevance of the 1995 Federal Fire Policy; provides a contemporary and comprehensive interagency federal fire management policy to support long-term implementation of the National Fire Plan and the *10-year Comprehensive Strategy*.
A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment: 10-year Comprehensive Strategy, August 2001 Web site: www.fireplan.gov/content/reports/	This coordinated 10-year strategy to comprehensively manage wildfire, hazardous fuels, and ecosystem restoration was developed in collaboration with governors and in consultation with a broad range of stakeholders. Its scope includes federal and adjacent state, tribal, and private lands. Its primary goals are to • improve fire prevention and suppression, • reduce hazardous fuels, • restore fire-adapted ecosystems, and • promote community assistance. The core principles of the strategy are collaboration, priority setting, and accountability.	Extends the concepts of the Report to the President and focus of the National Fire Plan into a broader, longer-term, collaborative effort.

Document or initiative	What it does	Relationship to other initiatives
A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment: 10-year Comprehensive Strategy Implementation Plan, May 2002 Web site: www.fireplan.gov/content/reports/	The plan identifies 22 specific tasks supporting four goals identified in the *10-year Comprehensive Strategy* and performance measures that are interagency and interdepartmental in scope. It was developed in collaboration with governors and in consultation with a broad range of stakeholders. It emphasizes a collaborative, community-based approach to address issues related to wildland fires.	Translates the conceptual framework of the *10-year Comprehensive Strategy* into specific actions, identifying time frames for completion.
Healthy Forests: An Initiative for Wildfire Prevention and Stronger Communities, August 2002 Web site: www.whitehouse.gov/infocus/healthyforests/toc.html	This presidential initiative is to better protect people and natural resources by lowering the procedural and process hurdles that impede the reduction of hazardous fuels on public land, and to fulfill the original objectives of the Northwest Forest Plan. The initiative has legislative and administrative components. The administration will propose to (1) facilitate timely reviews of high priority forest health restoration and rehabilitation projects, consistent with agency procedures and land and resource management plans; (2) amend rules for project appeals to hasten the process of reviewing vital forest health projects while encouraging meaningful public participation; (3) improve the Endangered Species Act process to expedite decisions to allow timely completion of fuels treatment projects while providing protection for wildlife and restoring habitat; and (4) establish improved and more focused process for environmental assessments of forest health projects. All these actions will make it easier for land managers to restore forest and rangeland health, while also engaging communities early, frequently, and in a meaningful way in these decisions. These changes will bring about more timely actions to restore forest and rangeland health. The initiative emphasizes using collaborative processes in identifying projects and priorities.	In facilitating fuels reduction projects, the healthy forest initiative would speed implementation of projects, improving implementation of the *National Fire Plan* and the *10-year Comprehensive Strategy*. It is a legislative proposal that requires the use of a collaborative process consistent with the *Implementation Plan* for the *10-year Comprehensive Strategy*.
Memorandum of Understanding for the Development of a Collaborative Fuels Treatment Program among the Department of Agriculture (FS), the Department of the Interior (BLM, FWS, and NPS), the National Association of State Foresters, and the National Association of Counties January 2003 Web site: www.fireplan.gov/content/reports/	The memorandum provides the framework of a process for the federal land management agencies, the National Association of State Foresters, and the National Association of Counties to collaborate on the annual selection of a fuels treatment program within their respective jurisdictions, in order to provide for community protection and enhance the health of forests and rangelands. Concentration on high priority areas will be facilitated by • collaborating by notification and discussion of an annual program of work for fuels treatment, • completing a proposed program of work by May 1 of each year, • placing priority on treating acres within states that are actively incorporating projects into a joint program of work, • taking into account multiyear landscape-level projects across ownerships, and • considering long-term investments and sequencing of projects and building on prior year programs to ensure that projects are strategically located and implemented across landscapes.	Consistent with the goals, performance standards, and collaborative framework outlined in the *10-Year Comprehensive Strategy* and *Implementation Plan*.

Document or initiative	What it does	Relationship to other initiatives
Protecting People and Natural Resources: A Cohesive Fuel Treatment Strategy (Draft) February 2003	The strategy outlines a coordinated approach to fuels treatment to be adopted by the five major federal land management agencies in the Departments of Agriculture and the Interior. The strategy provides considerations for local prioritization in project planning to ensure that areas that present the greatest risk to communities and cultural, historical, and natural resources receive the highest priority for funding. These considerations include • quality interagency planning, • evidence of active community participation, and • development of partnerships and other collaborative efforts with stakeholders. It also explains and clarifies the common goals of fuel treatments. It • reiterates the mission of the fuels treatment program, • clarifies priorities for selecting projects, and • spells out the strategy for reducing the risk of wildland fire.	Emphasizes goals two and three in the *Implementation Plan* for the *10-year Comprehensive Strategy*. Uses performance measures outlined in the *10-year Comprehensive Strategy* to measure success.
2001 Fire Policy Implementation Plan (in development)	This implementation plan will develop a common code for fire management organizations within the five major federal land management agencies in the Departments of Agriculture and the Interior. It is to ensure unified implementation of the 2001 Fire Policy.	Provides uniform implementation of federal fire policy to enable effective collaboration with states, tribes, and communities in implementing the *National Fire Plan*, the *10-year Comprehensive Strategy*, and the *Interagency Cohesive Treatment Strategy*.

Sources: Department of the Interior, Department of Agriculture.

[a] U.S. General Accounting Office, *Western National Forests: A Cohesive Strategy Is Needed to Address Catastrophic Wildfire Threats*, GAO/RCED-99-65 (Washington, D.C.: Apr. 2, 1999).

Appendix III: Federal, State, and Local Entities with Land Management, Technology, or Other Fire-Related Roles

Under the National Fire Plan, five federal land management agencies lead the efforts to develop wildland fire policies and initiatives. However, many other federal agencies and nonfederal associations also have a role in wildland fire management. The federal entities include agencies that manage other federal lands; agencies that research, manage, or use technologies that can aid in wildland fire management; and agencies with other fire-related responsibilities. The nonfederal entities include key state, local, and international organizations, which collaborate with the federal agencies on wildland fire management. Key federal, state, and local organizations and their roles in wildland fire management are identified below.

Federal Departments and Agencies

Five federal agencies have key responsibilities for managing more than 90 percent of all federal lands.[20]

- The Department of Agriculture's Forest Service manages 191 million acres of national forests and grasslands; its mission is to sustain the health, diversity, and productivity of these areas to meet the needs of present and future generations.
- The Department of the Interior's Bureau of Land Management manages 261 million acres of public domain lands. Its mission is to sustain the health, diversity, and productivity of these public lands for the use and enjoyment of present and future generations. Most of the land managed by Bureau of Land Management is located west of the Mississippi.
- The Department of the Interior's Bureau of Indian Affairs administers and manages 56 million acres of land that is held in trust by the United States for American Indians, Indian tribes, and Alaska natives. Its mission includes developing forestlands, leasing assets on these lands, directing agricultural programs, protecting

[20] Several of these agencies also provide scientific research, technology, and products in support of the land management missions.

water and land rights, developing and maintaining infrastructure, providing for health, human services, and economic development.

- The Department of the Interior's Fish and Wildlife Service manages 93 million acres of national wildlife refuges and wetland areas. Its mission is to work with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people.

- The Department of the Interior's National Park Service administers over 80 million acres of national parks, monuments, historic sites, natural areas, and other federal lands. Its mission is to preserve the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of present and future generations.

In addition to the five federal land management agencies, three other federal departments manage extensive tracts of federal land.

- The Department of Defense manages about 38 million acres at bases and installations around the country and has fire management responsibility for these lands.

- The Bureau of Reclamation manages about 9 million acres of land.

- The Department of Energy manages about 2.4 million acres of land.

Other federal entities research, manage, or use technologies that can aid in wildland fire management.

- The National Aeronautics and Space Administration, through its Earth Science Enterprise research and development efforts, partners with federal agencies with fire management responsibilities to provide satellite remote sensing images and other science and data products.

- The Department of Commerce's National Oceanic and Atmospheric Administration operates satellites, manages the daily processing and distribution of data and images produced by these satellites; conducts research, develops innovative technologies and observation systems, and prepares weather and fire weather forecasts—all of which provide useful information to fire management officials who plan and manage wildland fires.

- The Department of Defense's National Imagery and Mapping Agency provides imagery and geospatial information in support of the national security objectives of the United States. At the request

of the National Interagency Fire Center, through the Forest Service, the agency uses multiple sources of imagery and geospatial data to provide map products to assist the fire community with fire suppression efforts.

- The Department of the Interior's U.S. Geological Survey contributes to wildland fire management by conducting fire-related research to meet the varied needs of the fire management community and to understand the role of fire in the landscape. This research includes fire management support, studies of postfire effects, and a wide range of studies on fire history and ecology. In addition, the U.S. Geological Survey supports the wildland fire community by providing earth science information through (1) receipt and archiving of remotely sensed land data and (2) geographical scientific information that describes and interprets the nation's landscape.

Other federal entities also have fire-related responsibilities.

- The Department of Homeland Security's Federal Emergency Management Agency, the lead agency for emergency management in the federal government, provides financial assistance for the mitigation, management, and control of fires burning on publicly or privately owned forests or grasslands. The agency also provides maps of geologic and flood hazards to support fire management.

- The Environmental Protection Agency develops and enforces regulations regarding the environment, including the effects of wildland fire on air quality.

State, Local, and Other Associations and Committees

Many state, local, international, and private organizations participate in wildland fire management.

- The National Association of State Foresters, the largest nonfederal firefighting partner, is a nonprofit organization that represents the directors of the state forestry agencies from all 50 states, 8 U.S. territories, and the District of Columbia. The state foresters provide management assistance and protection services for over two-thirds of the nation's forests. The association is a member of both the National Wildfire Coordinating Group and the Wildland Fire Leadership Council.

- The Intertribal Timber Council is a nationwide consortium of Indian Tribes, Alaska Native Corporations, and individuals dedicated to improving the management of natural resources of importance to Native American communities. The Council is a member of both the National Wildfire Coordinating Group and the Wildland Fire Leadership Council.

- The National Fire Protection Association's mission is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating scientifically based consensus codes and standards, research, training, and education. The association's membership totals more than 75,000 individuals from around the world and more than 80 national trade and professional organizations.

- The Fire Control Officers Group is an umbrella organization consisting of fire control officers from the forest fire management agencies in all Australian states and New Zealand, with additional representation from industry, research, and education. The group develops and maintains international relationships with fire management agencies in the United States.

- The National Governors' Association deals with issues of public policy and governance relating to the states. The association's ongoing mission is to support the work of the governors by providing a bipartisan forum to help shape and implement national policy and to solve state problems.

- The National Association of Counties seeks to represent the nation's 3,066 counties; its membership totals more than 2,000 counties, representing over 80 percent of the nation's population. As a member of the Wildland Fire Leadership Council and in working with the National Association of State Foresters, the association is a lead collaborator on such wildland fire issues as (1) assessing the training, equipment, and safety awareness of and services provided by rural, volunteer, and other firefighters who work in the wildland urban interface and (2) annually selecting fuel treatment and ecosystem restoration projects within jurisdictions.

- The Western Governors' Association, composed of the governors of 18 states and 3 islands in the Pacific, addresses important policy and governance issues in the West—in particular wildland fire issues, because of the prevalence and severity of fires and grassland fires in these states.

- The International Association of Fire Chiefs is a network of more than 12,000 chief fire and emergency officers. The association's mission is to provide leadership to chief fire officers and managers of emergency services organizations. The International Association of Fire Chiefs also prepares awareness and training information on the use of minimum impact suppression activities.

- The National Volunteer Fire Council, a nonprofit membership association, represents the interest of the volunteer fire, emergency medical, and rescue services.

- The International Association of Wildland Fire is a nonprofit, professional association representing members of the global wildland fire community. The purpose of the association is to facilitate communication and provide leadership for the wildland fire community.

- The Nature Conservancy's mission is to preserve the plants, animals, and natural communities that represent the diversity of life on earth by protecting the lands and waters they need to survive. One of the Nature Conservancy's five priority conservation initiatives is to play a leading role in restoring fire-altered ecosystems by working to counter the threats posed to both human and natural communities where the role of fire is severely out of balance.

- The Wilderness Society seeks to save, protect, and restore America's wilderness areas through the combination of scientific expertise, analysis, advocacy, and education. The Wilderness Society's Wildland Fire Program is an interdisciplinary program designed to return fire to fire-dependent ecosystems in a socially acceptable manner.

Appendix IV: Remote Sensing Systems

Remote sensing systems observe data in one or more bands of the electromagnetic spectrum, including the visible, near-infrared, mid-infrared, thermal infrared, and microwave bands. Data from different bands provide different kinds of information. For example, data observed in the thermal infrared band can identify heat sources that are not observable in the visible band of the electromagnetic spectrum. When data are collected from multiple bands or from multiple channels within a band, a more sophisticated analysis can be performed.

Remote sensors are often characterized by the type of observations they perform and their resulting products. Common types of sensors include panchromatic imaging sensors, multispectral imaging sensors, hyperspectral imaging sensors, radio detection and ranging (radar) sensors, and light detection and ranging (LIDAR) sensors. A definition of each type of sensor follows.

- **Panchromatic imaging sensors** collect data in a single band of the electromagnetic spectrum. These data are then processed to provide a black and white image.
- **Multispectral imaging sensors** collect data in multiple, noncontiguous, wide-wavelength bands, which are then combined to create color images.
- **Hyperspectral imaging sensors** collect data in multiple, contiguous, narrow-wavelength bands. Because different materials absorb and reflect light differently, analysis of detailed hyperspectral data can identify different materials, minerals, and species.
- **Radar** sensors emit a high-frequency radio wave to determine a remote object's velocity, position, or other characteristic by analyzing the radio wave reflected from the remote object. Radar sensors can acquire images through clouds, fog, and darkness.
- **LIDAR** sensors emit a light beam and analyze the reflected and scattered light that is returned to the collection instrument. This measured change enables LIDAR to penetrate a forest canopy to map the floor and can aid in the determination of topographic elevations.

Remote sensing systems can be placed on satellite and aerial platforms. These platforms can be government-owned or commercial. Currently, there are numerous government-owned and commercial remote sensing systems—used on both satellite and aerial platforms. Table 2 identifies characteristics of several different remote sensing systems that are currently operational. Key characteristics that help distinguish one system from another include image resolution (the size of the objects that can be depicted in an image) and revisit rate (the rate at which a platform returns to an area).

Table 2: Characteristics of Selected Remote Sensing Systems

Sensor	Platform	Sensor type	Image resolution (meters)	Revisit rate
Thematic Mapper	NASA Satellite: Landsat-5	Multispectral (Observed spectral bands: visible, near infrared, short wave infrared, and thermal infrared)	30–120	16 days (offset 8 days from Landsat-7)
Enhanced Thematic Mapper+	NASA Satellite: Landsat-7	Panchromatic, multispectral (Observed spectral bands: visible, near-infrared, short-wave infrared, and thermal infrared)	15–60	16 days (offset 8 days from Landsat-5)
Advanced Very High Resolution Radiometer	NOAA Satellites: Polar-orbiting Operational Environmental Satellites	Multispectral (Observed spectral bands: visible, near-infrared, and thermal infrared)	1,100	0.5 days
Advanced Spaceborne Thermal Emission and Reflection Radiometer	NASA Satellite: Earth Observing System/Terra	Multispectral (Observed spectral bands: visible, near-infrared, short-wave infrared, and thermal infrared)	15–90	16 days
Moderate Resolution Imaging Spectroradiometer	NASA Satellites: Earth Observing System/Aqua and Terra	Multispectral (Observed spectral bands: visible, near-infrared, short-wave infrared, and thermal infrared)	250–1,000	1–2 days
Panchromatic Multispectral, Low Resolution	Indian Satellite: IRS-1C, IRS-1D	Panchromatic, Multispectral (Observed spectral bands: visible, near-infrared, and short-wave infrared)	5.8–188	5–24 days

Sensor	Platform	Sensor type	Image resolution (meters)	Revisit rate
High Resolution Geometric, Visible and Infrared	French Satellites: SPOT 4 and 5	Panchromatic, multispectral (Observed spectral bands: visible, near-infrared, and short-wave infrared)	2.5–20	1–4 days
High resolution imaging sensors	Private sector satellites (Ikonos, Quickbird)	Panchromatic, multispectral (Observed spectral bands: visible and near-infrared)	0.6–4	Varies by vendor: 3–5 days
High resolution imaging sensors	Aircraft	Panchromatic, multispectral (Observed spectral bands: varies by vendor)	Varies by vendor: often 0.5–1	As warranted
Phoenix infrared scanner	National Interagency Fire Center aircraft	Multispectral (Observed spectral band: thermal infrared)	0.25–1	As warranted

Sources: Forest Service, Remote Sensing Applications Center, GAO.

Appendix V: Examples of Applications with Geospatial Components Supporting Wildland Fire Management

The following tables provide examples of different applications with geospatial information components that are used in support of wildland fire management activities. Table 3 provides examples of operational applications, and table 4 provides examples of developmental applications.

Table 3: Examples of Operational Applications

Name and description	Lead entities	Users	For more information
Automated Flight Following: transmits geographic positions of aircraft for graphical display	Forest Service (FS)	Bureau of Indian Affairs (BIA) Bureau of Land Management (BLM) Forest Service (FS) Fish and Wildlife Service (FWS) National Park Service (NPS)	https://aff.nifc.gov
Automated Lightning Mapping System: downloads and maps near-real-time lightning location information from the BLM lightning data server	FS	BIA BLM FS FWS NPS	http://www.fs.fed.us/fire/planning/nist/alms.htm#ALMS
California Fire Plan Assessment System: assesses weather, fuels, and assets at risk to identify areas to target for mitigation projects	California	California	http://www.fire.ca.gov/fireemergencyresponse/fireplan/chapter3.html
Coarse Scale Spatial Data for Wildland Fire and Fuel Management: provides nationwide coarse-scale vegetation and fire regime mapping	FS	Multiple users (including federal, state, and local governments as well as the public)	http://www.fs.fed.us/fire/fuelman
Ecosystem Management Model: simulates ecosystem processes and evaluates resource management actions before their implementation	Canada		
Fire and Fuels Extension to Forest Vegetation Simulator: simulates effects of treatment alternatives on fuel dynamics and fire potential into the future	FS	FS (regional use)	http://forest.moscowfsl.wsu.edu/4155/ffe-fvs.html

Name and description	Lead entities	Users	For more information
Fire Area Simulator (FARSITE): simulates and maps fire growth and behavior under complex terrain, fuels, and weather conditions	FS	BLM FS NPS State governments Local governments	http://www.farsite.org
Fire Potential Index: provides national fire potential mapping based on vegetation and weather data	FS U.S. Geological Survey (USGS)	Multiple users (including federal, state, and local governments as well as the public)	http://www.fs.fed.us/land/wfas/experment.htm
FirePac: provides tools for a variety of fire management applications, including fire perimeter mapping	NPS	BIA BLM FS FWS NPS	http://www.fs.fed.us/fire/gis/incident-support/firepac.htm
Forest Vegetation Information System: stores, retrieves, and analyzes data used to inventory and monitor vegetation on forested lands	BLM	BLM	http://www.blm.gov/nstc/resourcenotes/rn48.html
FX-Net: provides portable weather forecasting	National Oceanic and Atmospheric Administration (NOAA)	BIA BLM FS FWS NPS National Weather Service	http://www-id.fsl.noaa.gov/fxnet.html
GeoMAC: provides Internet-based national fire monitoring and perimeter mapping	USGS	BIA BLM FS FWS NPS Public	http://www.geomac.gov
Immediate Response Burn Severity Mapping for Burned Area Emergency Response Teams: provides preliminary burn severity mapping to FS fires and provides support to other agency fires on request	FS	BIA BLM FS NPS	http://www.fs.fed.us/eng/rsac/baer
Immediate Response Burn Severity Mapping for Emergency Stabilization and Rehabilitation Teams: provides preliminary burn severity mapping	USGS	BIA BLM FWS NPS	http://edc2.usgs.gov/fsp/severity/fire_main.asp
Initial Attack Management System: records, monitors, and reports aviation hazards and restrictions	BLM FS	BLM FS	http://www.nifc.blm.gov/nsdu/aviation
Initial Attack Management System Maps Viewer: provides graphical representation of various kinds of geographic data	BLM	BLM FS	Alaska Fire Service version at http://fire.ak.blm.gov/scripts/maps/maps.asp

Name and description	Lead entities	Users	For more information
Integrated Forest Management System: integrates vegetation/fuels data and tools for fuels reduction analysis	FS	FS (regional use)	http://www.fs.fed.us/foresthealth/technology/products/informs/INFoverview.html
Landscape Fire Model: provides for land use planning		BLM (Alaska)	
Landscape Simulation Model: provides spatially explicit landscape dynamics simulation modeling for southern Utah	FS	FS (regional use)	http://www.firelab.org/fep/research/sufm/studyplan/ls.htm
Lightning Data: displays real-time lightning information and provides tracking capability	BLM	BLM FS	http://www.nifc.blm.gov/nsdu/lightning/
Meteorology for Fire Severity Forecasting: provides monthly forecasts of weather-induced fire potential for the continental United States	FS		http://met.rfl.psw.fs.fed.us/met/MFWF.html
MODIS Active Fire Mapping: provides coarse-scale mapping of current wildfire locations and fire perimeters	FS National Aeronautics and Space Administration (NASA)	BIA BLM FS FWS NPS Public	http://activefiremaps.fs.fed.us
Multi-Resource Analysis and Geographic Information: schedules treatments to meet resource and management objectives and computes trade-offs associated with the treatment schedule	FS	Multiple users (including federal, state, and local governments as well as the public)	http://www.forestry.umt.edu/magis
National Fire Danger Rating System: uses fuels, topography, and weather to derive national maps of potential fire occurrence and behavior	FS	Multiple users (including federal, state, and local governments as well as the public)	http://www.fs.fed.us/land/wfas/wfas23.html
National Fire Plan Maps: provides Internet-based mapping of hazardous fuels program projects in relation to wildland urban interface communities	USGS	BIA BLM FS FWS NPS	http://www.fireplan.gov
National Fire Plan Operations & Reporting System (NFPORS): provides Internet-based mapping and data collection for restoration and rehabilitation, hazardous fuels reduction, and community assistance projects	Department of the Interior FS	BIA BLM FS FWS NPS	http://www.nfpors.gov

Name and description	Lead entities	Users	For more information
National Wildland Fire Outlook: provides seasonal and monthly maps and narratives of the national wildland fire outlook	National Interagency Coordination Center	Multiple users (including federal, state, and local governments as well as the public)	http://www.nifc.gov/firemaps.html
NFSPUFF: models smoke dispersion for complex terrains in the western United States	FS	FS (western U.S.)	http://www.frames.gov/tools/html/NFSPUFF.detailed.html
Normalized Difference Vegetation Index: provides national vegetation greenness mapping	USGS	Multiple users (including federal, state, and local governments as well as the public)	http://www.fs.fed.us/land/wfas/wfas11.html
NPS-USGS National Burn Severity Mapping: provides extended assessment burn severity mapping for long-term monitoring of fire effects	NPS USGS	NPS	http://edc2.usgs.gov/fsp/severity/fire_main.asp
Personal Computer Historical Analysis: analyzes historical wildland fire occurrence for wildland fire planning	FS	BIA BLM FS	http://www.fs.fed.us/fire/planning/nist/pcha.htm
Phoenix Digital Signal Processor: provides infrared fire detection and mapping	FS	BIA BLM FS FWS NPS	http://nirops.fs.fed.us
Real-time Observation Monitor and Analysis Network: provides current fire weather conditions nationwide	BLM University of Utah		http://www.met.utah.edu/roman
Resources Ordering and Status System: automates resource ordering, dispatching, and reporting; geospatial component is planned	FS	BIA BLM FS FWS NPS Federal Emergency Management Agency State governments	http://ross.nwcg.gov
Risk Assessment and Mitigation Strategies: provides a process for developing prevention and fuels management programs	BLM	BIA BLM	http://www.nifc.blm.gov/nsdu/fire_planning/rams
SAM Sensitive Area Program: provides spatial analyses for mapping complex resource issues for overflight planning	NPS	NPS	http://www.nps.gov/gis/applications/new_apps.html
Southern State Fuel Hazard Mapping: provides a map of fuel hazards and a fuel model for all southeastern states	FS	FS (regional) FWS State governments Local governments	

Name and description	Lead entities	Users	For more information
Tool for Exploratory Landscape Scenario Analysis: helps resource managers and planners assess the consequences of alternative management scenarios at the scale of landscape units	FS	FS	http://www.eessa.com/downloads/telsa
Utah Wildfire Initial Attack Dispatch Application Cedar City Support Center: provides dispatching of fire personnel and geospatial information system capabilities	Utah	BIA (regional use) BLM (regional use) NPS (regional use) Utah	
Ventilation Climate Information System: assesses risks to values of air quality and visibility from historical patterns of ventilation conditions	FS	Multiple users (including federal, state, and local governments as well as the public)	http://www.fs.fed.us/pnw/fera/vent
Wildfire Hazard Identification and Mitigation System: combines wildfire hazard assessment, prevention, and suppression expertise with fire and forest management knowledge	Boulder County, Colorado	Local government	http://www.co.boulder.co.us/lu/wildfire/whims.htm
Wildland Fire Assessment System: provides Internet-based national fire potential and weather mapping	FS	Multiple users (including federal, state, and local governments as well as the public)	http://www.fs.fed.us/land/wfas
Wildland Fire Management Information System: provides Internet-based weather, lightning, fire reporting, and aviation information	BLM	BLM	http://www.nifc.blm.gov

Sources: NWCG, FS, BLM, GAO.

Table 4: Examples of Developmental Applications

Name and description	Lead entities	Planned users	For more information
Fire Behavior Mapping and Analysis: is to map potential fire behavior characteristics and environmental conditions using topography and fuels data layers	FS	FS (local use)	http://fire.org/cgi-bin/nav.cgi?pages=JFSP&mode=11
Fire Effects Assessment Tools: is to provide fire ecology and vegetation data collection, data handling, and data analysis	NPS	NPS	http://ftp.nps.gov/incoming/fire/feat_cbi
Fire Effects Monitoring and Inventory Protocol: is to provide standards for implementing a monitoring program before and after a burn	FS USGS	—	http://fire.org/firemon

Name and description	Lead entities	Planned users	For more information
Fire Internet Map Server: is to provide a spatial display of current fire intelligence information	BLM	BIA BLM FS FWS NPS	http://www.fs.fed.us/fire/gis/Documents/FIMS_FINAL_RPT.doc
Fire Program Analysis: is to conduct analyses for fire management planning and budgeting	FS	BIA BLM FS FWS NPS	http://fpa.nifc.gov
FireSat: is to provide national wildland fire detection (formerly called the Hazard Support System and the Integrated Hazard Information System)	USGS (1997) NOAA (2001) Federal Emergency Management Agency (late 2002)	—	
Incident Based Automation: is to automate management activities during a fire incident	FS	BIA BLM FS FWS NPS	
Landscape and Fire Management Planning Tools (LANDFIRE): is to provide nationwide vegetation/fuels mapping and predictive models needed for fuel treatment and restoration projects	FS USGS	BIA BLM FS FWS NPS	http://www.landfire.gov
National Land Cover Data 2001: is to provide nationwide intermediate-scale land cover mapping	Environmental Protection Agency FS NOAA USGS	—	http://landcover.usgs.gov/nationallandcover.html
National Park Service Vegetation and Fuels Mapping: is to provide vegetation/fuels mapping of NPS lands	NPS USGS	NPS	http://biology.usgs.gov/npsveg
Southern Wildfire Risk Assessment: is to provide tools to help analyze mitigation options and estimate their impact on wildland fire risk for 13 southern states	Southern state governments	Southern states FS	http://corp.spaceimaging.com/swra/

Sources: NWCG, FS, BLM, GAO.

Appendix VI: Comments from the Departments of Agriculture and the Interior

WASHINGTON

THE DEPARTMENT OF AGRICULTURE

THE DEPARTMENT OF THE INTERIOR

August 21, 2003

David A. Powner
Director (Acting), Information Technology
Management Issues
United States General Accounting Office
441 G. Street N.W.
Washington, D.C. 20548

Dear Director Powner:

Thank you for the opportunity to review and comment on the draft copy of GAO-03-1047, "Geospatial Information; Technologies Hold Promise for Wildland Fire Management, but Challenges Remain."

Overall, the Departments agree with the report conclusions and recommendations. Minor factual and technical corrections were identified and conveyed to the GAO investigators during conference calls on August 20, 2003, for the Department of the Interior and on August 21, 2003, for the Department of Agriculture.

In reference to the conclusions and recommendations provided in the report, we offer the following comments:

- The GAO recommendations involve some ambitious undertakings, such as developing an interagency IRM strategy and interagency enterprise architecture. Both of these significantly support not only wildland fire management but also every other line of business in which the agencies and Departments are involved. It makes sense to incorporate the GAO recommendations into ongoing agency and Departmental e-Gov enterprise architecture strategies. This would enable us to modernize our various lines of business in manageable components, using enterprise architecture as a framework and tool. As a result, agencies would gain incremental enterprise-wide integration of information and shared use of information technology. These enhancements will, however, be both time and resource intensive.
- While the lack of comprehensive Information Technology (IT) and enterprise architecture contribute as potential barriers to more effective use of geospatial applications, experience demonstrates that core issues also include data availability and associated funding mechanisms. The use or non-use of specific technologies is not the issue. The

central concern is whether the delivery of appropriate information can be made in a timely, cost effective manner to address specific business driven needs.

- Information technology and geospatial information management have evolved both independently of and within wildland fire management. The successful use of geospatial technologies in wildland fire management requires the existence of basic geospatial technologies, data, and skills within land management agencies. Geospatial information supports all disciplines within these agencies. The applicability and utility of these tools for aiding in decision-making and achieving wildland fire management objectives makes them essential.

  Inconsistencies among agencies in terms of data content, availability, systems, and infrastructure are often beyond the control of the agencies' wildland fire management programs. This is particularly true with data standards. Wildland fire perimeter data standards will be easy to complete compared to interagency standards for roads, vegetation, and other crucial wildland fire mission data. There must be disciplined, purposeful cooperation outside of wildland fire management programs within the agencies, as well as with state and local governments, to have effective geospatial support for wildland fire management.

- Most of the recommendations listed in the report are currently under consideration by the wildland fire agencies. These GAO findings will be presented to the Wildland Fire Leadership Council at their October 2003, meeting. Based upon discussions and direction provided by the Council, staff from the two departments will be tasked with developing an action plan to address the GAO findings and the broader issue of geospatial needs for wildland fire management.

The Departments continually evaluate new and emerging technologies in their attempt to apply the best practices to support their missions. This is particularly true in the wildland fire management program where public and firefighter safety and the health of forests and rangelands is highly dependant upon multiple layers of data that must be quickly and accurately translated into information for decision making. In this effort, the wildland fire management community has been a leader. The recommendations provided by the GAO will help the Departments move forward to establish a better coordinated, interagency architecture for geospatial wildland fire management information requirements.

MARK REY
Under Secretary
Natural Resources and the Environment
U.S. Department of Agriculture

P. LYNN SCARLETT
Assistant Secretary
Policy, Management and Budget
U.S. Department of the Interior

Appendix VII: GAO Contacts and Acknowledgments

GAO Contacts

David A. Powner, (202) 512-9286, (303) 572-7316 or pownerd@gao.gov

Colleen M. Phillips, (202) 512-6326 or phillipsc@gao.gov

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Glossary

The following terms are used in the geospatial and wildland fire communities.

Aerial Photography Taking photographs from the air, such as a photograph of part of the Earth's surface, with a camera mounted in an aircraft; usually involves taking strips of overlapping prints for mapping purposes.

Burn Severity A qualitative assessment of the heat pulse directed toward the ground during a fire. Burn severity relates to soil heating, large fuel and duff consumption, consumption of the litter and organic layer beneath trees and isolated shrubs, and mortality of buried plant parts.

Burned Area Rehabilitation The full range of postfire activities to rehabilitate and restore fire-damaged lands, including protection of public health and safety.

Digital Aerial Data A computer representation of imagery acquired from an aircraft. This type of data is produced either by digitizing aerial photographs or through direct acquisition by electronic sensors such as digital cameras or Forward Looking Infrared (FLIR) thermal imaging sensors.

Duff The layer of decomposing organic materials lying below the litter layer of freshly fallen twigs, needles, and leaves and immediately above the mineral soil.

Fire Prevention Activities, including education, engineering, enforcement and administration, that are directed at reducing the number of wildfires, the costs of suppression, and fire-caused damages to resources and property.

Fire Suppression All work and activities connected with fire-extinguishing operations, beginning with discovery and continuing until the fire is completely extinguished.

Fuel Combustible material.

Fuel Condition Relative flammability of fuel as determined by fuel type and environmental conditions.

Fuel Reduction	Manipulation or removal of fuels to reduce the likelihood of ignition, to lessen the potential damage and resistance to control, or both (e.g., lopping, chipping, crushing, piling, and burning).
Fuel Treatment	(See fuel reduction.)
Geographic or Geospatial Information	Information about a phenomenon that can be referenced to a specific location relative to the earth's surface.
Geographic Information System (GIS)	A system of computer software, hardware, and data used to manipulate, analyze, and graphically display a potentially wide array of information associated with geographic locations. Typically, a GIS is used for handling maps of one kind or another. These maps might be represented as several different layers, where each layer holds data about a particular kind of feature (e.g., roads). Each feature is linked to a position on the graphical image of a map.
Geographic or Geospatial Information Technology	A broad term encompassing all forms of technology to gather, display, sample, and process geographic or geospatial information, including in particular GIS, remote sensing, and use of the Global Positioning System.
Global Positioning System (GPS)	A system of navigational satellites operated by the U.S. Department of Defense and available for civilian use. The system can track objects anywhere in the world with an accuracy of approximately 40 feet.
Hyperspectral Imaging	Type of imaging that records many tens of bands of imagery at very narrow bandwidths.
Infrared Imaging	Producing images using the thermal infrared spectral band; used for fire detection, mapping, and hotspot identification.
Initial Attack	The actions taken by the first responders to arrive at a wildfire to protect lives and property, and prevent further extension of the fire.
LIDAR	(From "light detection and ranging.") An instrument capable of measuring distance and direction to an object by emitting timed pulses of light in a measured direction based on the time between when a pulse is emitted and when its echo is received. Three-dimensional information is computed by relating these distances and direction measurements to the location and orientation of the instrument. Airborne LIDAR instruments are used to develop three-dimensional data, such as digital elevation models, tree and building heights, and feature geometry.

Multispectral Imaging	Acquiring optical images in more than one spectral band.
Preparedness	Condition or degree of being ready to cope with a potential fire situation.
Prescribed Fire	Controlled application of fire to wildland fuels, in either their natural or modified state, under specified environmental conditions, which allows the fire to be confined to a predetermined area and produces the fire behavior and fire characteristics required to attain planned fire treatment and resource management objectives.
Presuppression	Activities in advance of fire occurrence to ensure effective suppression action. Includes planning the organization, recruiting and training, procuring equipment and supplies, maintaining fire equipment and fire control improvements, and negotiating cooperative or mutual aid agreements.
Prevention	Activities directed at reducing the incidence of fires, including public education, law enforcement, personal contact, and reduction of fuel hazards (fuels management).
Radar	(From "radio detection and ranging.") An instrument that emits a narrow beam of electromagnetic pulses (radio waves) in a specific direction and measures the time, intensity, or other characteristics of the energy that returns from targets or objects. Radar imagery can be obtained at night or through clouds and smoke. Radar images provide a unique visual impression, and advanced analysis of radar imagery usually requires specific experience, knowledge, and facilities.
Rehabilitation	The activities necessary to repair damage or disturbance caused by a wildfire or the wildfire suppression activity.
Remote Sensing	Process of determining properties of objects without contact, usually by measuring and recording images based on the electromagnetic energy that has interacted with the objects. Remote sensing also involves the manipulation of images to derive useful information. Remote sensing traditionally involves aerial photography but now includes many electronic sensors on both airborne and space-based platforms.
Satellite	A space-based platform for sensors that measure, image, receive, and transmit data from an orbital path above the earth.
Spatial Resolution	Spatial resolution is a measure of the size of the smallest feature that can be distinguished in an image. That is, in a 30-meter

	resolution image, one could discern objects 30 meters and larger. Images with smaller discernable objects are considered to have higher resolutions.
Suppression	All the work of extinguishing or confining a fire, beginning with its discovery.
Thermal Imaging	(See infrared imaging.)
Wildfire	A fire occurring on wildland that is not meeting management objectives and thus requires a suppression response.
Wildland	An area in which development is essentially nonexistent, except for roads, railroads, power lines, and similar transportation features, and structures, if any, are widely scattered.
Wildland Fire	Any fire occurring on the wildlands, regardless of ignition source, damages, or benefits.

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