WILDLAND FIRE SCIENCE AND TECHNOLOGY TASK FORCE FINAL REPORT

PRODUCT OF THE
Committee on Environment, Natural Resources, and Sustainability
Subcommittee on Disaster Reduction
OF THE NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

NOVEMBER 2015

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Report prepared by
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1. EXECUTIVE SUMMARY

Large, intense wildland fires have become more frequent across the United States in recent decades. Risks to responders and citizens, property losses, response and recovery costs, and threats to communities and landscapes have increased significantly as a result. In order to address these formidable challenges, more-effective Federal agency coordination is needed among both wildland fire scientists and also between those who produce and those who use the science relevant to wildfire mitigation, response, and recovery.

To address this need, a Wildland Fire Science and Technology Task Force was chartered under the National Science and Technology Council's Subcommittee on Disaster Reduction. The Task Force analyzed the missions, portfolios, and existing coordination and application mechanisms employed by the relevant Federal agencies with respect to wildland fire science and technology, and assessed progress on the strategic actions set forth in the Subcommittee on Disaster Reduction's *Grand Challenges for Disaster Reduction Wildland Fire Implementation Plan*. From this examination, the Task Force identified several topics for high-priority attention and action on the part of the Federal fire research community and proposed mechanisms to improve coordination between fire science producers and the community of users of fire science.

The Task Force recommends that a standing Federal Fire Science Coordination Council be established to: ensure regular exchange among the leaders of those Federal organizations that either produce or use fire science; strengthen coordination and collaboration among the organizations that produce wildland-fire science and technology; establish mechanisms to systematically assess user needs and priorities for science, research, and technology support; and define national-level needs for Federal fire science in support of the fire-management community.

By working with the various interagency wildland fire management coordination and governance bodies, the Federal Fire Science Coordination Council can improve the diffusion of fire science and technology. It can also ensure alignment of scientific capacity with current and future science needs. As it does its work, the Council will serve as a formal, institutionalized mechanism to systematically link fire researchers with fire managers. It will also address the enhanced collaborative opportunities identified by the Task Force. Better articulation of needs by fire-science users and more effective communication on the part of fire-science producers will be a key component of resolving coordination gaps and identifying opportunities for enhanced fire science access, delivery, and application in the future.

2. INTRODUCTION: THE SCOPE OF THE PROBLEM

Statistics show that in nearly every area of the country – particularly in the western United States – the number of large, intense wildland fires has increased in recent years. Over the past decade, every Western state has experienced a rise in the number of large wildfires per year compared to the annual average from 1980 to 2000.[1] Also, the average length of the fire[2] season has been increasing. Comparing the period 1970 to 1986 with 1987 to 2003, the average season length

[1] http://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html

[2] Although the terms "wildland fire" and "wildfire" have different meanings as referenced in the terms glossary of this report (Appendix B), they are both often referred to from here on out as simply "fire."

increased 78 days.[3] According to the National Interagency Fire Center (NIFC) and the U.S. Fire Administration (USFA), nearly 68,000 wildfires burned over 9.3 million acres in 2012, making that year the third-highest in terms of the numbers of acres burned since national wildfire statistics began to be kept in 1960.[4] Property damage at the wildland-urban interface (WUI) has reached into the billions of dollars with more damage expected as more housing development is expected to occur in the WUI.

The recent historical trend of more frequently occurring, large wildfires is predicted to continue into the future as climate change causes temperatures to rise further and droughts to become more severe in the coming decades, particularly in the western United States.[5] The changing climate is driving up springtime temperatures and advancing the timing of snowmelt, vegetation green-up, and lengthening the duration of the fire season. These changes in fire seasonality increase the volumes of dry vegetation that can accumulate and hence the probability of larger fires.[6] At the same time, higher temperatures influence drought frequency, magnitude, and extent, and induce stress on vegetation and, hence, the susceptibility of vegetation to insects and disease. Changes in thunderstorm and lightning patterns can also increase ignition rates depending on time of year, areas of country affected by drought, and other factors.

While no single wildfire can be said to be caused by climate change, impacts of the changing climate contribute to longer fire seasons with more large fires in the United States.[7] According to the U.S. Global Change Research Program's most recent National Climate Assessment, hotter and drier weather and an earlier snowmelt mean that wildfires in the west start earlier in the spring and last later into the fall.[8] Since official recordkeeping began, the eight years with the largest area burned by wildfires in the United States have all occurred in the last 15 years.[9]

The environmental and occupational health costs of more-frequent and extensive wildfires are also considerable. Not only do wildfires threaten lives directly, but smoke from active fires and atmospheric particulates released from burned areas have the potential to increase local air pollution. These fire related pollutants can exacerbate lung diseases and cause breathing difficulties – even in healthy individuals – and the ash deposited in water from fires can affect municipal water supplies.[10] Public exposure to smoke has been shown to significantly increase health risks in the general population, including increased asthma, chronic obstructive pulmonary disease, pneumonia, acute bronchitis, cardiopulmonary symptoms, and heart failure.[11] The associated costs can be large. One study estimated that a single fire in rural North Carolina could yield costs in excess of $1 million for asthma and heart failure, $2 million in lost productivity, $100,000 in respiratory conditions in children, and $42 million due to excess mortality.[12]

As wildfires become more prevalent across the United States, investing in wildland fire-fighter

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[3] http://www.sciencemag.org/content/313/5789/940.short

[4] http://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html

[5] http://www.treesearch.fs.fed.us/pubs/46207

[6] http://www.sciencemag.org/content/313/5789/940.short

[7] *Ibid.*

[8] http://nca2014.globalchange.gov/report

[9] https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html

[10] http://www.fs.fed.us/ecosystemservices/FS_Efforts/forests2faucets.shtml

[11] http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3230437/?report=classic

[12] http://pubs.acs.org/doi/pdf/10.1021/es5012725

safety is an increasingly critical issue. Almost 300 on-duty wildland fire fighter fatalities occurred between 2000 and 2013.[13] Ensuring that wildland fire fighters have proper training, advanced personal protective equipment, adequate technical and operational support, and smart decision-making tools on the ground is imperative.

In order to address the daunting challenges presented by increasing wildland fire threats in a time of lean budgets, Federal agencies need to better align the activities of fire science and technology organizations (including those that deal with physical, social, and biological fire sciences) with the pressing needs of those organizations with responsibilities for fire management, mitigation, response, and recovery. More timely and effective communication of fire science findings, more efficient diffusion of effective new fire technologies, and better articulation of the needs of fire-science users to those who can study and innovate to meet those needs will all ensure better fire mitigation, response, and recovery. To achieve these objectives, it is important to resolve communication and coordination gaps and to identify opportunities for enhanced fire science access, delivery, and application.

3. THE CHARGE TO THE TASK FORCE

Recognizing the need to strengthen coordination and cooperation related to wildland fire science and technology, the White House Office of Science and Technology Policy (OSTP) asked the National Science and Technology Council (NSTC)'s Subcommittee on Disaster Reduction (SDR) to establish a Wildland Fire Science and Technology Task Force (Task Force). That Task Force was chartered in March 2014 to prepare a report that identifies opportunities and mechanisms for increased coordination and cooperation to support the development, access, and application of science and technology in wildland fire management, response, and recovery.

The Task Force was led by two co-chairs – one each from the U.S. Department of the Interior (DOI) Office of Wildland Fire and the U.S. Forest Service (USFS) Office of Research and Development – and included members representing other relevant organizations from across the Federal wildland fire science-and-technology and wildfire-management communities. The departments and agencies represented on the Task Force were:

- Department of Agriculture
  - U.S. Forest Service
- Department of Commerce
  - National Institute of Standards and Technology
  - National Oceanic and Atmospheric Administration
- Department of Defense
- Department of Energy
- Department of Health and Human Services
  - U.S. Centers for Disease Control and Prevention
  - U.S. Public Health Service
- Department of Homeland Security
  - Federal Emergency Management Agency/U.S. Fire Administration
  - Science and Technology Directorate
- Department of the Interior

[13] http://www.cdc.gov/niosh/topics/firefighting/

    - Bureau of Indian Affairs
    - Bureau of Land Management
    - Office of Wildland Fire
    - U.S. Geological Survey
- Environmental Protection Agency
- National Aeronautics and Space Administration
- National Science Foundation

The Task Force charter also called for the group, among other functions, to measure and analyze progress on the implementation actions identified in the SDR *Grand Challenges for Disaster Reduction Wildland Fire Implementation Plan*, [14] to assess needs and opportunities, and to describe current and future national-level challenges for decreasing the undesired effects and increasing the desired effects of wildland fire.

In developing this report, the Task Force drew on the goals, objectives, and recommendations of three recently completed strategic efforts:

- The 2014 *National Cohesive Wildland Fire Management Strategy*[15] (Cohesive Strategy) developed jointly by the U.S. Department of Agriculture (USDA) and DOI, which focused on resilient landscapes, fire-adapted human communities, and safe and effective wildfire response.
- The SDR National Preparedness Science and Technology Task Force's assessment of wildland-fire core capabilities related to the prevention, protection, mitigation, response, and recovery mission areas as defined by Presidential Policy Directive-8 (PPD-8).[16]
- The 2014 *Quadrennial Fire Review,*[17] drafted jointly by the DOI Office of Wildland Fire and USFS Fire and Aviation Management, which offers a strategic assessment of current wildland fire management community strategies and capabilities compared against best estimates of future risks.

A Task Force kickoff meeting was held in April 2014, after formal approval of the group's charter by the NSTC. Task Force members then held a three-day workshop in June 2014 at DOI in Washington, DC, to establish a baseline set of missions, portfolios, and existing coordination and application mechanisms employed by the Federal agencies with respect to wildland-fire science and technology. The workshop involved 49 participants from 20 Federal entities that either produce or use fire science and technology. Workshop participants identified three goals for the report:

- Articulate the broad overarching needs of organizations that consume fire science and technology (i.e., wildland-fire management and wildfire response).
- Develop consensus on the main science and technology gaps that need to be addressed.
- Identify science and technology activities that have a high probability of addressing these gaps.

After the workshop, the Task Force issued a data call to those agencies represented on the Task

[14] http://www.sdr.gov/docs/185820_Wildfire_FINAL.pdf

[15] http://www.forestsandrangelands.gov/strategy/documents/strategy/CSPhaseIIINationalStrategyApr2014.pdf

[16] http://www.dhs.gov/presidential-policy-directive-8-national-preparedness

[17] http://www.forestsandrangelands.gov/QFR/documents/2014QFRFinalReport.pdf

Force requesting detailed program information on each agency's roles and responsibilities related to relevant fire-science activities. The input received is discussed in the following section.

4. DEFINING AGENCY ROLES AND RESPONSIBILITIES

Across the Federal government, many agencies develop science and technology to inform and support various aspects of fire management and response. An important function of the Task Force was to bring these organizations together to articulate their roles and responsibilities for providing relevant fire science and to develop a baseline of current science portfolios. The resulting comprehensive list of Federal programs that produce and use science related to wildland fire and wildfire mitigation, response, and recovery is provided in Appendix C of this report.

The Task Force also developed a list of fire science topic areas and asked agency representatives to estimate levels of effort within each topic area. The responses submitted by Task Force members can be found in Appendix D. They represent an inventory of current Federal capacity in wildland-fire science and technology research. The Task Force used these responses to characterize how Federal capacity aligns with current and emerging fire-management needs and knowledge gaps. This inventory should serve as a foundation for more effective and proactive exchange of fire science findings and technology tools with Federal fire management and response organizations.

Among the Task Force member agencies, the USFS has the broadest portfolio of fire science and technology, with programs focused on fire behavior, fire ecology and climatology, fire fuels, socioeconomics and human and programmatic performance, smoke and emissions, and geospatial and remote sensing applications. The U.S. Geological Survey (USGS), Department of Defense (DOD), and Department of Energy (DOE) have broad but focused fire portfolios ranging from fire behavior to fuels management to remote sensing, often targeted to specific landscapes. These programs are not duplicative of but often are conducted in collaboration with USFS efforts.

Organizations such as the U.S. Centers for Disease Control and Prevention (CDC), the Department of Homeland Security Science and Technology Directorate (DHS S&T), the U.S. Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA) have programs that are more topically focused. The CDC, EPA, and the National Institute of Standards and Technology (NIST) have programs focused on public and fire-fighter health and safety as well as the environmental health aspects of wildfires and their harmful effects on individuals and local communities. Programs at NASA and NOAA are more generally focused on geospatial and remote sensing applications, identification of fire ignition via satellite and lightning detection, and fire-weather analysis and forecasting.

Each of the Task Force departments and agencies has linkages with organizations that use fire science; however, these are often opportunistic and not comprehensive. Although the Task Force did not find evidence of duplication, there was recognition that there is also not a broad mechanism for coordination that pulls together all of these programs. It is the hope of the Task Force that the catalogue of baseline of Federal roles and responsibilities related to fire can serve as a foundation for more formal and inclusive collaboration between fire science producers and users in the future. Such collaboration is essential if Federal science and technology is to address the priorities for wildland-fire management discussed in the following section.

5. ALIGNING SCIENCE AND TECHNOLOGY WITH THE COHESIVE STRATEGY

The Cohesive Strategy describes a vision for future decades of Federal wildland fire management and operations as well as wildfire mitigation, response, and recovery "to safely and effectively extinguish fire, when needed; use fire where allowable; manage our natural resources; and as a Nation, live with wildland fire." Adopted by the intergovernmental Wildland Fire Leadership Council and the Secretaries of DOI and USDA in 2014, the Cohesive Strategy outlines three primary goals necessary to achieve this vision:

- Resilient landscapes: Landscapes across all jurisdictions are resilient to fire-related disturbances in accordance with management objectives.
- Fire-adapted communities: Human populations and infrastructure can withstand a wildfire without loss of life and property.
- Safe and effective wildfire response: All jurisdictions participate in making and implementing safe, effective, efficient risk-based wildfire management decisions.

The vision and goals of the Cohesive Strategy frame the targets for science and technology investment to address the significant, long-standing needs for mitigating, responding to, and recovering from the ever-growing fire risks facing the Nation. In particular, the Cohesive Strategy identifies four national-level fire challenges that science and technology can help address:

Managing Vegetation and Fuels: Wildland fire from both natural and human causes shape many of the landscapes of the United States, with periodic fires maintaining landscapes that are resilient to wildfires. The primary purpose of fuels management is to reduce the extent, intensity, and severity of wildfire over the lifespan of the treatments to reduce the risk of undesired fires. To be effective, fuel treatments must reduce fire intensities under the conditions most likely to result in harm; that is, they have to work across a range of weather conditions during which a wildfire is likely to occur. For some ecosystems, reduced fire extent, intensity, and severity can have beneficial ecological effects. For example, wildfires burning less intensely may mimic historical fire effects more closely, helping to restore or enhance native, fire-adapted vegetation. Thus, fuel treatments are an important part of land management plans that emphasize resilient landscapes. Strategically placed fuel treatments can have broader landscape effects that extend beyond the perimeter of the area physically treated, either through affecting fire behavior directly or by allowing response strategies that involve less aggressive suppression tactics. Reduced intensity also means that suppression efforts are more likely to be effective and can be conducted more safely around communities. Fuel treatments near homes and communities are also an effective way to reduce the likelihood of structure ignition and enhance the safety of fire fighters and the public. With so many variables and options, maximizing the effectiveness of fuel treatment is a major challenge, and additional research is needed to explore the full range of conditions and consequences.

Protecting Homes, Communities, and Other Values at Risk: Fire risks to communities result from multiple factors, including the frequency and extent of wildfires, the distribution and density of homes within the WUI, and components of social vulnerability. Many fire managers who strive to reduce losses to homes and communities from wildfires focus on the immediate vicinity of the home or the surrounding community and the building materials recommended for new construction. Reducing the likelihood that a wildfire burning in adjoining vegetation will ignite homes or other structures is one of the more effective avenues to reducing losses. Individual homeowners can take many actions, but other actions require concerted effort at the community

and even the political level to be effective. Similarly, community efforts without commensurate attention by local home and business owners are unlikely to succeed. Therefore, actions by property owners to reduce the ignitability of homes and other structures are prudent wherever structures are near flammable vegetation. To this end, research is needed to improve the current mitigation guidelines and regulations, both for new construction and for retrofitting existing communities. Improving building resilience should be a high priority, along with parallel science-based fuel treatments.

Managing Human-caused Ignitions: Human ignitions are the predominant cause of wildfires throughout the United States. In the 48 coterminous states, between 2002 and 2011, more reported fire incidents began with human-caused ignitions than natural ignitions in 98 percent of counties and, in 94 percent of counties, the fires that were human caused burned a greater area than fires that began with natural ignitions. Furthermore, human-caused wildfires often occur adjacent to communities and are frequently more dangerous for fire fighters. Programs that target the prevention of human-caused ignitions have the potential to substantively affect wildfire occurrence and extent in essentially every county. There is a need to support fire prevention educational efforts as well as for states and local jurisdictions to develop adequate and enforceable ordinances related to wildfire prevention. There is clear evidence that small investments in fire prevention help reduce the high cost of fire suppression, as well as associated wildfire damages.[18] Such programs are most effective when they focus on the underlying causes of these human-caused ignitions in each location and tailor the prevention programs to specific causal factors and community dynamics.

Effectively and Efficiently Responding to Wildfire: The United States benefits from extensive and sophisticated fire response organizations composed of thousands of separate local, state, tribal, and Federal entities. Each organization has specific responsibilities for the initial response to wildfires occurring within their jurisdiction. They also coordinate and share resources and responsibilities as fires become larger and exceed the local response capacity, requiring a more extended suppression response. Such preparedness does not come cheap; Federal suppression response expenditures alone in 2005 to 2012 exceeded on average $1.5 billion per year.[19] The relatively small percentage of fires that escape initial response account for a disproportionate percentage of the area burned, damage to homes and communities within the WUI, and injuries and fatalities. Relatively few large fires also account for a major portion of total suppression costs nationwide, and the variation in large fires from year-to-year results in significant swings in total suppression expenditures. This variability creates major challenges from both a planning and funding perspective. As with any large, complex endeavor, there are opportunities to increase efficiency (e.g., by using communication, coordination, and resources to maximum advantage). Finding innovative ways to contain large wildfires more efficiently is an ongoing and continuous struggle for both fire-science producers and users, and it represents a significant research priority going forward.

Within these broad goals, the Task Force identified several topics for high-priority attention and action on the part of the Federal fire research community. These include:

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[18] G. Snider, P.J. Daugherty, P.J. and D. Wood, D. (2006). "*The Irrationality of Continued Fire Suppression: An Avoided Cost Analysis of Fire Hazard Reduction Treatments Versus No Treatment.*" ***Journal of Forestry****,* 104 (2006): 431-437.

[19] https://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf

- **Continued Expansion of the WUI in All Vegetation Types:** Expansion of the WUI and all it entails – homes, citizens, transportation and power corridors, and local economies – presents a variety of challenges – related to all three goal areas – for all stakeholders, including land owners, business and commerce leaders, the wildland fire-management and science-and-technology communities, tribes, and governments.
    - *Research Recommendation:* Federal fire science producers and users should focus efforts on protecting life and property and reducing risks to WUI property, residents, and responders.

- **Changing Climate and the Effects on Wildland Fire Extent and Seasonality:** Climate contributes to shaping fire regimes and, through changing weather, influences fire behavior. The impacts of a changing climate are clearly seen in the form of changes in growing seasons, extended drought periods, longer fire seasons, increased emissions from fire, increased susceptibility of landscapes to insect infestation, invasive species, and increased frequency of large fires – all of which contribute to larger and more complex and costly incidents as noted in the National Climate Assessment.[20] Additionally, changing climate affects the post-fire recovery of landscapes, altering resilience to future disturbances. Together, these impacts are challenging the fire management community to provide more annual coverage and response capability for a longer period of time, as well as maintain a high initial attack success rate on faster growing fires while managing incidents of unprecedented size and complexity.
    - *Research Recommendation:* Understanding and anticipating trends in, and impacts from, climate change is necessary in order to most effectively manage changes in fire regimes and fire behavior and meet all three national goals of the Cohesive Strategy.

- **Vegetation Stressed by Insects, Drought, Disease, Invasive Species, and Legacy Management:** Many of our Nation's forests and rangelands have been adversely affected by a variety of factors, such as fire exclusion, droughts, livestock grazing, insect infestations, invasive species (such as annual grasses in arid landscapes), and accumulations of hazardous vegetative fuels, resulting in stressed vegetation that is more susceptible to fire-induced mortality and less likely to regenerate in its previous form. Stand dynamics such as composition, age distribution, and structure influence fire behavior, as well as the risk of other stressors.
    - *Research Recommendation*: Understanding interactions among stress factors and minimizing their impacts is necessary to achieve desired healthy vegetation and wildlife habitat.

- **Disturbance-Sensitive Species of Concern:** Many species of concern are sensitive to fire-related disturbance, and the changing climate can affect this sensitivity. Managing fire's contribution to deteriorating habitats requires an understanding of species and habitat requirements and how these disturbances interact to affect them.
    - *Research Recommendation*: To avoid further habitat degradation, action must be taken by Federal fire-science users and producers to improve capabilities to effectively suppress fire as well as actively manage vegetation, including fuels treatment, post-fire stabilization, and habitat restoration actions.

[20] http://nca2014.globalchange.gov/report

- **Dynamic Landscape Management:** Landscapes are dynamic and the pace of change is accelerating. Going forward, both private land owners and public land managers will be faced with managing increasingly dynamic landscapes for the continued provision of goods and services.
    - *Research Recommendation*: Developing, testing, and implementing management options, systems, and practices for effective restoration activities is necessary to serve the needs of a rapidly expanding human population from our changing forest landscapes.

In order to effectively deliver science that addresses the issues raised by the Cohesive Strategy, fire-science providers need to support three overarching requirements of organizations that use fire science and technology: the ability to make risk-based decisions at multiple scales in order to reduce uncertainty; the ability to measure outcomes and effectiveness of wildland-fire management activities; and the ability to manage for landscape resiliency, fire-adapted communities, and safe and efficient operations. The Task Force identified a number of gaps in both understanding and translation that stand in the way of meeting these requirements:

- Lack of coordination, collaboration, and integration of fire science and technology, both among the various producers and between the producers and the community of users.
- Poor understanding of wildland fire in the context of changing baseline conditions such as climate change as outlined in the National Climate Assessment.
- Poor understanding of the human elements of wildland fire, including firefighter safety, long-term health effects of smoke, individual and organizational performance and risk perception, and public perceptions and attitudes towards both fire and fire management.
- Implementation of new technologies for situational awareness, communications, and protective equipment to improve safety during wildfire response activities.
- Lack of organized and systematic ways to forecast future requirements and research opportunities.
- A need to build capacity and understanding of public perceptions and attitudes about wildland fire (e.g., changing perceptions that all fire is bad).
- Lack of ability to measure programmatic outcomes at various scales.
- Poor understanding of the relationship between wildland fires and adjacent structures and a lack of science-based building codes, standards, and guidance.

To mitigate the escalating risks posed by unwanted wildfire and to safely and successfully manage natural and prescribed wildland fire, Federal agencies with wildfire mitigation, response, and recovery responsibilities must work together more productively with Federal organizations with fire science and technology functions. Aligning innovative science and technology resources with pressing management and operational needs – as well as more effective communication of those needs by the fire-science user community and on the part of fire-science providers – will be a key to resolving existing gaps and identifying opportunities for enhanced science access, delivery, and application for these challenges into the future.

6. MARKING PROGRESS ON GRAND CHALLENGES FOR DISASTER REDUCTION

Just as the Cohesive Strategy lays out challenges for wildland-fire management, the NSTC Subcommittee on Disaster Reduction identified a set of challenges that, when addressed, would

reduce community vulnerability to disasters and thus create a more disaster-resilient Nation. These were set forth in a 2005 report, *Grand Challenges for Disaster Reduction*,[21] which formulated a ten-year strategy for disaster reduction through science and technology. The six broad challenges were:

- Provide hazard and disaster information where and when it is needed.
- Understand the natural processes that produce hazards.
- Develop hazard mitigation strategies and technologies.
- Recognize and reduce vulnerability of interdependent critical infrastructure.
- Assess disaster resilience using standard methods.
- Promote risk-wise behavior.

The report acknowledged that addressing these challenges would require sustained Federal investment as well as collaborations with state, local, and tribal governments, professional societies and trade associations, the private sector, academia, and the international community in order to successfully transfer disaster-reduction science and technology into common use.

The SDR subsequently developed a series of 15 hazard-specific Implementation Plans – released in 2008, 2009, and 2010 – that contained priority science and technology interagency strategic actions to improve the Nation's capacity to mitigate, respond to, and recover from disasters. As one of the functions laid out in its charter, the Task Force assessed progress on addressing the 32 strategic actions contained in the SDR *Grand Challenges for Disaster Reduction Wildland Fire Implementation Plan*.[22] Task Force member-agency representatives self-reported their assessments of levels of progress with respect to attaining these actions (Appendix E). On an agency-by-agency basis, improvements in some fire-related areas were less than anticipated, while gains in others were steady. To accompany the table in Appendix E, the following four examples provide a snapshot of priority actions that stood out in terms of both progress made and ongoing work that remains:

- **"Develop and deliver real-time decision support tools during fire incidents to help managers identify wildlands, communities, and structures most at risk and the most appropriate tactical responses."** The Wildland Fire Decision Support System (WFDSS)[23] project evolved from the need to streamline and improve decision-making processes as well as take advantage of improvements in technology, fire modeling, and geospatial analysis. The WFDSS has the following capabilities: develops a scalable decision support system for agency administrators; uses appropriate fire behavior modeling, economic principles, and information technology; and supports effective wildland-fire decisions consistent with resource and fire-management plans. Despite this capacity, the WFDSS does not yet meet the need for real-time data to support the wildland-fire fighter on the ground who has to make fast and informed decisions.

- **"Link fire-safe community information with geospatial data for evaluating and predicting local to national impacts of fuel and fire management and community design."** Federal fire science producers are making strides to enhance capabilities to

[21] National Science and Technology Council, Committee on Environment and Natural Resources, *Grand Challenges for Disaster Reduction: A report of the Subcommittee on Disaster Reduction*, June 2005. http://www.sdr.gov/docs/SDRGrandChallengesforDisasterReduction.pdf

[22] http://www.sdr.gov/docs/185820_Wildfire_FINAL.pdf

[23] http://wfdss.usgs.gov/wfdss/WFDSS_About.shtml

show some types of fire information in a geospatial form by using the Integrated Reporting of Wildland Fire Information (IRWIN) system.[24] IRWIN provides capabilities for exchange of data between existing geospatial and remote-sensing applications used to manage data related to wildland-fire incidents. The system aims to reduce redundant data entry, identify authoritative data sources, and improve the consistency, accuracy, and availability of operational data. Although IRWIN provides a tool to collect and collate data from many different sources, movement to the next phase is needed in order to help predict the impacts of fuel management and better apply geospatial and remote sensing technology to assist in decision-making, increase safety, and reduce losses. Comprehensive data needs to be collected at the incident level to quantify exposure (fire and embers) and system response, including defensive actions, for vegetative fuels and structures. This type of data will provide insight into the effectiveness of hazard-mitigation technologies such as fuel treatments and hardening of buildings in the WUI. The concept of fire-adapted communities needs to be supported by data documenting the performance of risk-mitigation technologies for wildlands, communities, and structures.

- **"Integrate with multi-hazard risk communication systems for emergency warning."** Throughout areas of the United States where wildfire risk exists, there are many different types of emergency systems to warn fire fighters, fire management, and the public about critical fire conditions. At the Federal level, the National Weather Service issues Red Flag Warnings and Fire Weather Watches to alert local fire departments of the onset, or possible onset, of critical weather and dry conditions that could lead to rapid or dramatic increases in wildfire activity. A Red Flag Warning is issued for weather conditions that are conducive to extreme fire behavior within 48 hours, and a Fire Weather Watch is issued when Red Flag Warning conditions might occur within the next four days. The Red Flag Warning is intended to inform fire management and fire-fighting resources of critical conditions, not the general public. Yet the public still requires actionable information during critical fire periods via appropriate products and communication systems. Other warning methods and systems are used at the state and local levels that are not readily compatible with these Federal mechanisms. There has been little research from the fire science community into how to improve the interconnectedness of these systems or to characterize the overall effect on enhanced safety for the public.

- **"More fully integrate across hazards to identify and illustrate interactions, including environmental benefits of natural wildland fires."** There is a need to more effectively communicate to the public the benefit of fire from the management perspective with regards to watersheds, wildlife habitat, and controlling unwanted vegetation. Often, the public does not understand that wildland fire is a necessary natural process that plays a critical role in shaping ecosystems by serving as an agent of renewal and change. The ecological benefits of wildland fire often outweigh the negative effects, and as such, prescribed fire is one of the most effective means for controlling the rate of spread and severity of undesired wildfire. A more unified and effective messaging strategy among the fire- and health-management agencies is needed to relay these benefits to the public in a clear and understandable way. Investigations concerning the integration or combined effects of various natural disturbances

[24] http://www.forestsandrangelands.gov/WFIT/applications/IRWIN/background.shtml

including extreme weather, earthquakes, pathogens, and invasive vegetation are also important to understanding their interaction with fire for optimizing treatments and preparations.

For many, if not most, of the strategic actions identified in the implementation plan, success will require the work of multiple agencies working in concert. This will take an enhanced level of coordination – and coordination mechanisms – which is the subject of the next section.

7. IDENTIFYING OPPORTUNITIES FOR INCREASED COORDINATION

Although individual organizations maintain strategic plans that stress external coordination (e.g., U.S. Forest Service 2006)[25] and many excellent examples of functional peer-to-peer relationships between scientists and practitioners exist, there are no formal entities charged specifically with the coordination of wildland-fire science among all Federal fire-science producing organizations. The Joint Fire Science Program (JFSP) comes closest, serving as a focal point for Federal fire research strategy and coordination.[26] However, USFS and DOI are the only formal partners of JFSP. Many opportunities exist for increased coordination among other relevant agencies to avoid duplication of effort and increase return on investment in relevant fire science. These opportunities include joint or partnered solicitations, increasing science-delivery capacity within the JFSP, and establishing a national fire-science delivery capacity focused on integrating and synthesizing science from across the Federal fire-science community.

In contrast to the situation with science coordination, there are numerous Federal entities charged with coordinating the adaptation and implementation of science and technology into the businesses of wildland fire-management and wildfire response. These include the National Wildfire Coordinating Group, the NIFC in Boise, Idaho, and numerous interagency governance groups that develop and implement policy and standards for both technology and applications. These entities include representatives from Federal science- and technology-producing organizations that are charged to identify requirements for fire science and supporting groups that address these requirements. In addition, the JFSP, DOD, the USFS research stations, NIST, and USFA have active programs dedicated to the accessibility and delivery of relevant wildland- and WUI-fire science to the user community.

Generally, the alignment of annual Federal budget allocations within fire science-producing departments and agencies with the needs of fire-science users could be more effective. The JFSP has adopted a strategic framework for funding fire science that continuously identifies requirements for relevant science and adapts these into a flexible investment strategy that balances resource allocation among fundamental and applied and short- and long-term scientific lines of work. The approach used by the JFSP could serve as a model for improving the broader alignment between Federal fire science capacity and science requirements if it were applied across the Federal fire science community beyond the current JFSP participating agencies.

To this end, the Task Force recommends the establishment of a formal Federal Fire Science Coordination Council that will address scientific, technological, and programmatic gaps in the context of the current, national-level challenges from the Cohesive Strategy identified in Section 5.

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[25] http://www.fs.fed.us/research/pdf/2006-10-20-wildland-book.pdf

[26] http://www.firescience.gov/

The Task Force recommends that the roles and responsibilities of this group include:

- Provide a forum for science exchange and communication between the leadership of Federal fire-science producers and users.
- Establish and enhance mechanisms to strengthen coordination and collaboration among the Federal wildland fire science- and technology-producing organizations.
- Establish mechanisms to systematically assess user requirements and priorities for Federal fire science, research, and technology support.
- Identify national-level needs for Federal fire science in support of the fire management community to ensure alignment of capacity with current and future science requirements.

Membership of the Federal Fire Science Coordination Council should largely parallel the membership of the Task Force, including representatives from the fire-science user community such as the USFA, USFS Fire & Aviation Management, and the DOI Office of Wildland Fire. The Council should be chartered by the Fire Executive Council, which consists of fire-management executives in DOI, USDA, and FEMA and provides executive-level fire program coordination within those agencies. The Federal Fire Science Coordination Council should have appropriate representation to enable well-informed decision-making, and its leadership should be linked back to the NSTC through *ex officio* membership on the SDR.

8. CONCLUSION: LONG-TERM OUTLOOK

Wildland fires involve numerous interacting and complex social, ecological, and physical factors, of which a thorough understanding is essential. The considerable variation that exists across the Nation as well as the shifting conditions due to factors such as the changing climate, political constraints, and social considerations all complicate the ability of fire-science producers and users to address the risks – and benefits – of wildland fire. The wildland-fire challenges that we currently face are not going to become less complex in the future. To become as effective as possible in dealing with them, as quickly as possible, we need to draw together the disparate components of the Federal fire community – science and technology users and producers alike – towards better communication, coordination and integration of purpose.

The overriding goals of the Federal fire-management community for the immediate future are enumerated in the Cohesive Strategy. Whether considering resilient landscapes, fire-adapted communities or operational response, managers need to operate within a probability-based, risk management framework. The decision environment has become much more complex over the last several decades from changes in WUI expansion, increased frequency of large fires, and an increasing diversity of stakeholder interests in the values at risk. Operating effectively requires the use of complex, accurate, and easy-to-use models to provide information to better allow for proactive action when possible, and well-considered reactive action when necessary.

Scientific knowledge is a cornerstone of these complex models, from design fundamentals to output interpretation. In order to support management needs, the Federal fire-science and technology research community needs to be aware of the Cohesive Strategy goals. This will enable the members of the community to align themselves in such a way as to maximize understanding of where scientific progress is most needed, improve the delivery of science and technology products that meet wildfire managers' needs, and increase efficiency in the development of science products.

Cross-boundary communication – building understanding among scientists about what fire managers need, and among managers about what scientists can offer – is a key to successful collaboration between the two communities. Coordination and cooperation presume communication and this principle provides a starting point. A newly established Federal Fire Science Coordination Council is expected to strengthen a communication network among the participants as its first objective. The result of that effort will likely reveal further opportunities for coordination, cooperation and efficiencies throughout the fire community.

The long-term vision for future decades of Federal wildland-fire management and operations as well as wildfire mitigation, response, and recovery hinges upon five objectives: safely and effectively extinguishing fire, when needed; using fire where allowable; managing our natural resources; helping communities and homeowners prepare, mitigate, and recover from WUI fires; and as a Nation, living with wildland fire. A commitment to carrying out these principles in practice must begin with effectively harmonizing the innovative resources of Federal organizations that produce fire science with the pressing needs of the Federal fire-science user community per the recommendations laid out in this report. When these missions are aligned and fire-science coordination, collaboration, and integration with fire management is optimal, a major step will have been taken towards fulfilling our Nation's commitment to reducing the impacts of fire and enhancing the safety and economic well-being of every individual and community.

APPENDIX A: KEY ACROYNMS

CDC – Centers for Disease Control and Prevention
DHS – Department of Homeland Security
DHS S&T – Department of Homeland Security Science and Technology Directorate
DOC – Department of Commerce
DOD – Department of Defense
DOE – Department of Energy
DOI – Department of the Interior
EPA – Environmental Protection Agency
FEMA – Federal Emergency Management Agency
HHS – Health and Human Services
IRWIN – Integrated Reporting of Wildland Fire Information
JFSP – Joint Fire Science Program
NASA – National Aeronautics and Space Administration
NIFC – National Interagency Fire Center
NIST – National Institute of Standards and Technology
NOAA – National Oceanic and Atmospheric Administration
NSF – National Science Foundation
NSTC – National Science and Technology Council
PPD-8 – Presidential Policy Directive 8
OSTP – Office of Science and Technology Policy
OWF – Office of Wildland Fire
SDR – Subcommittee on Disaster Reduction
SERDP – Strategic Environmental Research and Development Program
USDA – U.S. Department of Agriculture
USFA – U.S. Fire Administration
USFS – U.S. Forest Service
USFS F&A – U.S. Forest Service Fire and Aviation
USFS R&D – U.S. Forest Service Research and Development
USGS – U.S. Geological Survey
WUI – Wildland-Urban Interface

APPENDIX B: TERMS GLOSSARY

Burn Severity – The effects of wildland fires on the biophysical characteristics of a site. Includes soil, vegetation, and broader effects on ecosystem composition, structure, and function.

Carbon Cycle – The biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of the earth.

Climate Change – A long-term change in the earth's climate, especially an increase in the average atmospheric temperature, largely attributed to increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.

Communications – The technology (hardware and software) necessary to maintain situational awareness when working-on and responding-to wildland fires.

Data Management/Storage – The process where required data are acquired, validated, stored, protected, and processed; further, ensuring their accessibility, reliability, and timeliness to satisfy the needs of stakeholders.

Decision Support – A decision support system is a process or application that supports tactical and strategic decision-making in the business of wildland fire management and response.

Economics – Economics is the social science that studies economic activity to gain an understanding of the processes that govern the social, organizational, and political activities related to wildland fire management and response.

Emissions – Smoke, particulates, gases, and aerosols emitted into the atmosphere by wildland fires. Wildland fire emissions include black carbon, brown carbon, greenhouse gases, and several criterion pollutants that impact regional haze, human safety, health and welfare, and feedback to the climate system.

Fire Ecology – Fire ecology is the science focused on the historical, current, and future effects of wildland fires on the structure, composition, and function of ecosystems and landscapes.

Fire Behavior – The physical processes of wildland fire occurrence, intensity, and spread defined by fuel structure and composition, topography, and weather.

Fire Weather – Weather characteristics that govern wildland fire ignition, occurrence, behavior, effects, and suppression.

Fuels – Any combustible material; for wildland fires, primarily living and dead biomass.

General Modeling – Mechanistic and empirical algorithms and applications that simulate and predict wildland fire behavior and effects.

General Workforce – The labor pool, diversity, demographics, experience and qualifications, and human resource management involved in the business processes and planning coordination of wildland fire mitigation, response, and recovery.

Health/Safety Impacts – The short- and long-term effects of wildland fire on fire fighters and the public.

Human Factors – The behavior of organizations, fire fighters, and the public relevant to wildfire business, response, and recovery.

Human Ignition – Wildland fires that are initiated by humans; including arsons, prescribed fires, agricultural fires, and accidents.

Measuring Effectiveness/Success – Processes, metrics, and trends that define the accomplishments of wildland fire management and response programs.

Model Validation – The process of using independent information to define the relative uncertainty in the outputs of models and applications.

Remote Sensing – Acquiring information about landscapes using instruments that do not make physical contact with the object or process of focus. In wildland fire management, remote sensing includes: mapping wildland fuels and values at risk of wildland fires; wildland fire detection; mapping spread, extent, and intensity; measurement of effects, and mapping landscape composition, structure, and function.

Restoration/Rehabilitation – The business and activities of mitigating the effects and recovering from wildland fires in communities, landscapes, ecosystems and watersheds.

Risk Management – The identification, assessments, and mitigation of the risk of wildland fire includes the characterization, valuation, and prioritization of landscape and community components affected by wildland fires.

Smoke Modeling – The simulation and forecasting of wildland fire emission of particulates and compounds into the atmosphere by wildland fires.

Technology Transfer – The process of delivering and implementing the results and products of research and development in wildland fire management and response.

Watershed Response – The effects and reaction of landscapes to wildland fire characteristics; specifically landscape response that affects water supply and quality.

Wildfire – An unplanned, unwanted wildland fire including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, and all other wildland fires where the objective is to put the fire out.

Wildland Fire – Any non-structure fire that occurs in vegetation or natural fuels. Wildland fire includes prescribed fire and wildfire.

Wildland-Urban Interface Issues – Any mitigation, response, and recovery measurement, modeling, or wildland management or response activity that takes place in the interface between wildland fuels and the built environment; includes the socioeconomic and human factors that affect the mitigation, response, and recovery components of wildland fire management.

APPENDIX C: PROGRAMS THAT PRODUCE AND USE FIRE SCIENCE

Programs that produce fire science as provided at the June 2014 Task Force workshop:

DHS S&T:

- Early Fire Detection Project
- Wildland Fire Fighter Advanced Personal Protection System

DOC/NIST:

- Engineering Laboratory, Disaster and Failure Studies Program
- National Fire Research Laboratory
- Reduced Risk of Fire in Communities Program and Disaster-Resilient Buildings, Infrastructure, and Communities Program

DOC/NOAA:

- Chemical Sciences Division, Earth System Research Laboratory
- Global Systems Division, Office of Atmospheric and Oceanic Research
- Incident Meteorologist Program
- National Environmental Satellite, Data and Information Service, Hazard Mapping System and Fire and Smoke Program
- National Weather Service, Analyze, Forecast, and Support Office
- National Weather Service, Office of Science and Technology Integration
- National Weather Service, Environmental Modeling Center
- National Weather Service, Storm Prediction Center

DOD:

- Environmental Security Technology Certification Program
- National Geospatial-Intelligence Agency
- Naval Research Lab Fire Storm Detection, Analysis, and Prediction
- Strategic Environmental Research and Development Program

DOE:

- Los Alamos National Laboratory, Earth and Environmental Sciences Division
- Office of Biological and Environmental Research

DOI/USGS:

- Climate Research and Development Program
- Environments Program
- Land Change Science Program
- Land Remote Sensing Program
- Landscape Fire and Resource Management Planning Tools Project
- Landslide Hazards Program
- Mineral Resources Program
- National Geospatial Program
- Science Applications for Risk Reduction
- Science Synthesis, Analysis, and Research Program
- Water National Research Program

EPA:

- Environmental Public Health Division, Human Studies Facility
- Office of Research and Development
- Office of Air and Radiation
- Office of Air Quality Planning and Standards
- Sustainable and Healthy Communities Research Program

HHS/CDC:

- Fire Fighter Fatality Investigation & Prevention Program
- National Institute for Occupational Safety and Health
- National Personal Protective Technology Laboratory
- Wildland Fire Fighter Occupational Safety and Health Program

Interagency Programs:

- Fire Predictive Services
- Joint Fire Science Program

NASA:

- Applied Remote Sensing Training Program
- Applied Sciences Program
- Atmospheric Composition Program
- Carbon Cycle and Ecosystems Program
- Distributed Active Archive Centers
- Land-Cover/Land-Use Change Program
- Rapid Response and Novel Research in Earth Science Program
- Terrestrial Ecology Program

NSF:

- Grants for Rapid Response Research
- Hazard Sciences Education Engineering and Sustainability Program
- National Center for Atmospheric Research
- University Corporation for Atmospheric Research

USFS/Other:

- Active Fire Mapping Program
- Missoula and San Dimas Technology and Development Centers
- National Infrared Operations
- Remote Sensing Applications Center
- Smoke Management Program

USFS/Research & Development:

- Fire Fighter Safety Zones
- R&D Portfolio A: Core Fire Science
- R&D Portfolio B: Ecological And Environmental Fire Science
- R&D Portfolio C: Social Fire Science
- R&D Portfolio D: Integrated Fire and Fuels Management
- R&D Portfolio E: Science Delivery
- Wildland Fire Research, Development, and Application Centers

Programs that use fire science as provided at the June 2014 Task Force workshop:

DHS/FEMA:

- Office of Response and Recovery and Public Assistance Program
- U.S. Fire Administration, Fire & Emergency Services Higher Education
- U.S. Fire Administration, National Emergency Training Center
- U.S. Fire Administration, National Fire Incident Reporting System

DOD:

- Air Force Wildfire Center
- Army Installation Management Command

DOE:

- Laboratory Site Management Programs

DOI/Office of Wildland Fire:

- Bureau Fire Management Programs
- Burned Area Emergency Response
- Burned Area Rehabilitation
- Preparedness
- Suppression
- Hazardous Fuels Reduction

Interagency Programs:

- Firewise Communities
- National Interagency Coordination Center
- National Wildland Fire Coordinating Group

USFS/Fire & Aviation Management:

- Aviation Management
- Hazardous Fuels
- National Coordination System
- Predictive Services
- Preparedness
- Prescribed Fire Program
- Prevention Program
- Risk Management
- Smoke Management
- State Fire Assistance
- Suppression
- Volunteer Fire Assistance
- Wildland Fire Decision Support System
- Workforce Development

APPENDIX D: AGENCY ROLES AND RESPONSIBILITIES MATRIX

The SDR Wildland Fire Science and Technology Task Force was tasked with assessing current roles and responsibilities and establishing a resource baseline for Federal wildland fire science and technology agencies. Each agency was asked to assess their organizational involvement on a scale of "1-2-3" (low-moderate-high) for each of the science and technology topic areas listed. "N/A" indicates that the science and technology topic area does not apply to a particular agency's mission.

Roles and Responsibilities Metric Key

1 = Low-Level Involvement
2 = Moderate-Level Involvement
3 = High-Level Involvement
N/A = Area Not Applicable

Wildland Fire Science and Technology Topic Areas	DHS/FEMA	DHS/S&T	DOC/NIST	DOC/NOAA	DOD/SERDP	DOE	DOI/OWF	DOI/USGS	EPA	HHS/CDC	JFSP	NASA	NSF	USFS/F&A	USFS/R&D
Burn Severity	N/A	N/A	N/A	1	1	1	3	3	N/A	N/A	3	2	N/A	3	3
Carbon Cycle	N/A	N/A	N/A	1	3	2	1	3	3	N/A	3	3	N/A	2	3
Climate Change	N/A	1	N/A	3	2	2	1	3	3	2	3	3	N/A	1	3
Communications	N/A	2	N/A	2	N/A	1	2	1	2	1	3	2	N/A	2	3
Data Management/Storage	1	2	N/A	3	N/A	1	3	3	1	N/A	3	3	N/A	2	3
Decision Support	2	3	N/A	3	3	N/A	3	3	1	N/A	3	1	N/A	3	3
Economics	N/A	N/A	N/A	2	N/A	1	3	1	2	N/A	2	N/A	N/A	2	2
Emissions	N/A	N/A	N/A	2	3	1	2	3	3	N/A	3	2	N/A	2	3
Fire Ecology	N/A	1	N/A	1	3	1	3	3	1	N/A	3	2	N/A	3	3
Fire Behavior	N/A	1	2	3	3	3	3	2	N/A	N/A	3	1	N/A	3	3
Fire Weather	N/A	1	2	3	2	2	2	N/A	N/A	N/A	2	3	N/A	2	3
Fuels	N/A	1	N/A	2	3	1	3	3	1	N/A	3	3	N/A	3	3
General Modeling	N/A	1	3	2	N/A	3	3	2	1	N/A	N/A	3	N/A	3	3
General Workforce	N/A	3	N/A	1	N/A	1	3	N/A	N/A	2	N/A	N/A	N/A	3	3
Health/Safety Impacts	N/A	2	N/A	3	N/A	1	3	2	1	3	2	2	N/A	2	3
Human Factors	N/A	2	N/A	2	N/A	N/A	3	1	N/A	N/A	3	N/A	N/A	2	3
Human Ignition	N/A	1	N/A	1	N/A	N/A	1	1	N/A	N/A	1	N/A	N/A	2	3
Measuring Effectiveness/Success	N/A	2	2	2	3	1	3	1	N/A	N/A	3	3	N/A	2	3
Model Validation	N/A	1	2	2	3	2	3	2	N/A	N/A	3	3	N/A	2	3
Remote Sensing	N/A	2	N/A	2	1	2	2	3	1	N/A	2	3	N/A	2	3
Restoration/Rehabilitation	N/A	1	N/A	1	2	1	2	3	1	N/A	3	2	N/A	2	3
Risk Management	N/A	2	N/A	1	N/A	1	3	1	2	2	2	N/A	N/A	3	3
Smoke Modeling	N/A	N/A	2	2	3	1	2	1	N/A	N/A	3	2	N/A	3	3
Technology Transfer	N/A	2	2	2	3	N/A	3	3	N/A	N/A	3	2	N/A	1	3
Watershed Response	N/A	1	N/A	2	2	2	1	3	1	N/A	2	2	1	2	3
Wildland-Urban Interface Issues	2	2	3	2	N/A	2	2	2	2	1	2	1	N/A	2	3

APPENDIX E: GRAND CHALLENGES STRATEGIC ACTIONS PROGRESS MATRIX

The SDR Wildland Fire Science and Technology Task Force was tasked with measuring and analyzing progress on the strategic actions identified in the SDR *Grand Challenges for Disaster Reduction Wildland Fire Implementation Plan* document that was developed in 2008. Each agency was asked to assess their organizational progress on a scale of "1-2-3" (low-moderate-high) for each of the short-, medium-, and long-term actions listed. "N/A" indicates that the strategic action does not apply to a particular agency's mission.

Strategic Action Key

□ = Short-Term Action (1-2 Years)
○ = Medium-Term Action (2-5 Years)
◊ = Long-Term Action (5+ Years)

Progress Metric Key

1 = Low-Level Progress
2 = Moderate-Level Progress
3 = High-Level Progress
N/A = Action Not Applicable

SDR Wildland Fire Grand Challenges	DHS/FEMA	DHS/S&T	DOC/NIST	DOC/NOAA	DOE	DOI/OWF	DOI/USGS	EPA	HHS/CDC	JFSP	NASA	NSF	USFS/F&A	USFS/R&D
Grand Challenge #1: Provide hazard and disaster information where and when it is needed.														
□Develop national databases of burn severity and fire perimeters for both wildland and wildland-urban-interface fires.	1	1	1	1	N/A	2	3	N/A	N/A	N/A	2	N/A	3	3
□Implement continuity missions for moderate-resolution satellite data (15-30 m) for characterizing fuels and burn severity and for active fire remote sensing.	N/A	N/A	N/A	2	1	N/A	3	N/A	N/A	N/A	3	N/A	2	1
○More fully integrate across hazards to identify and illustrate interactions, including environmental benefits of natural wildland fires.	N/A	2	N/A	1	2	2	2	N/A	N/A	2	N/A	N/A	1	3
○Develop national geospatial coverage and modeling systems for fuel types, fire regimes, and condition classes appropriate for a new generation of fire models.	N/A	N/A	N/A	N/A	N/A	2	3	N/A	N/A	2	2	N/A	2	3
○Use Earth observation systems (ground and remote sensing) to develop and regularly update fuels, weather, and other data bases needed for fire prediction and monitoring.	N/A	N/A	N/A	2	1	N/A	3	N/A	N/A	2	1	N/A	2	3
○Develop and support analysis, computing, and communication capabilities to improve risk-informed assessments and analysis.	N/A	2	N/A	1	2	2	2	1	N/A	3	N/A	N/A	2	2
◊Create geospatial data layers and integrated information, decision support systems, and models to support fire management planning and incident response.	N/A	3	1	2	2	3	3	1	N/A	2	1	N/A	3	3
Grand Challenge #2: Understand the natural processes that produce hazards.														
□Develop an interagency coordinating group for wildland and wildland-urban-interface fire research and development.	1	2	N/A	2	N/A	3	N/A	2	N/A	3	N/A	N/A	1	1
○Improve understanding of the processes of wildland fire events to accurately model and predict the potential occurrence, behavior, and impacts of wildland fire on resources, the environment, and physical infrastructure.	N/A	1	1	2	2	3	2	N/A	N/A	2	2	N/A	2	3
◊Integrate new process understanding into improved 3-D fire behavior models that incorporate complex fuels (including structures), terrain, and fire/atmosphere interactions into predictions of fire probability, fire behavior, fire severity, fire emissions, smoke transport, and ecosystem fire effects.	2	N/A	1	2	3	2	2	N/A	N/A	1	1	N/A	2	2
Grand Challenge #3: Develop hazard mitigation strategies and technologies.														
□Assess the benefits of fuel treatments, other preparedness activities, societal attitudes and decision-making processes in reducing potential impacts.	N/A	1	N/A	1	1	3	2	N/A	N/A	3	1	N/A	2	2
○Improve understanding of costs and benefits of wildland fire and fuel management.	1	1	N/A	1	N/A	3	1	1	N/A	3	N/A	N/A	2	2
○Develop and implement integrated landscape and larger-scale modeling and analysis systems for wildland fire planning and wildland-urban-interface community design that incorporate risk mitigation, fuels, fire behavior, smoke transport, resource and social values.	N/A	N/A	N/A	1	1	2	2	N/A	N/A	2	1	N/A	1	3
○Use remote sensing and burn severity mapping to monitor fuel treatment effects and effectiveness.	N/A	1	N/A	2	1	2	2	N/A	N/A	2	1	N/A	1	2
◊Develop risk-based methods for deciding on the best strategies for mitigating the negative effects of wildland fire on ecosystems and communities.	N/A	1	N/A	1	1	3	2	N/A	N/A	2	N/A	N/A	2	3
◊Understand the factors that motivate individuals to undertake risk mitigation activities.	2	1	N/A	1	N/A	1	N/A	N/A	N/A	3	N/A	N/A	1	2
Grand Challenge #4: Reduce the vulnerability of infrastructure.														
○Assess the fire safe characteristics of community designs, including layout, landscaping, and structure design and building materials, and make recommendations for improved fire safety. Improve information and tools for homeowners and planners on fire-safe construction, landscaping, and community planning.	2	1	1	1	1	2	1	N/A	N/A	1	N/A	N/A	2	2
○Develop data and validated models to assess how well different community and landscape designs and post-fire restoration activities mitigate fire risk and damage, including offsite effects such as flooding and erosion, and damage to transportation and energy infrastructure.	N/A	1	N/A	1	1	1	2	N/A	N/A	N/A	2	N/A	1	2
◊Develop improved approaches to increase the resistance of infrastructure and communities to damage from wildland fire and its aftereffects.	1	2	1	1	1	2	1	N/A	N/A	N/A	N/A	N/A	1	1
Grand Challenge #5: Assess disaster resilience.														
□Assess logistical needs and evacuation plans for a variety of fire scenarios, including wildland and wildland-urban-interface fires.	2	1	N/A	1	2	N/A	1	N/A	N/A	N/A	N/A	N/A	1	2
□Understand why individuals evacuate or choose to stay.	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	2	2

○Link fire safe community information with geospatial data for evaluating and predicting local to national impacts of fuel and fire management and community design.	N/A	2	N/A	N/A	1	2	1	N/A	N/A	1	N/A	N/A	1	2
○Establish methods to assess the adequacy of community resources for a successful response to a likely fire hazard.	2	1	N/A	1	3	N/A	N/A	N/A	N/A	1	N/A	N/A	2	2
◊Improve and apply validated methods to enable consistent, rapid, and accurate fire severity mapping and assessment of the benefits of natural wildland fire and the risk of severe erosion, flooding, and other ecosystem damage.	N/A	1	N/A	1	2	3	3	N/A	N/A	1	1	N/A	2	3
◊Develop methods to model recovery of fire-impacted ecosystems under various climate change scenarios.	N/A	N/A	N/A	1	1	1	2	N/A	N/A	1	1	1	1	1
◊Develop improved systems to assist homeowners and communities to recover from impacts of wildland fire.	2	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2
◊Create common tools for assessing impacts of wildland fire as well as validated methods to enhance resilience to wildland fire and restore fire-impacted ecosystems and communities.	N/A	2	N/A	1	N/A	2	1	N/A	N/A	3	1	N/A	2	2
Grand Challenge #6: Promote risk-wise behavior.														
□Evaluate effectiveness of alternative approaches to risk communication, emergency warning, and decision-making on fire management, prevention, and mitigation.	1	1	N/A	1	1	N/A	N/A	N/A	1	1	N/A	N/A	1	2
○Study the effectiveness of resource management and firefighter response and alternative management strategies at altering outcomes, including benefits to safety, costs, natural resources, and communities.	2	1	N/A	N/A	1	3	N/A	N/A	1	1	N/A	N/A	2	2
○Develop and deliver real-time decision support tools during fire incidents to help managers identify wildlands, communities, and structures most at risk and the most appropriate tactical responses.	N/A	3	N/A	1	2	3	2	N/A	1	1	N/A	N/A	1	3
◊Develop national and global capabilities and tools to effectively illustrate and communicate immediate to long-term risks from wildland and wildland-urban-interface fires to managers, decision-makers and individuals.	N/A	3	N/A	1	1	2	1	N/A	1	1	1	N/A	2	2
◊Integrate with multi-hazard risk communication systems for emergency warning.	1	2	N/A	2	1	N/A	N/A	1	N/A	1	N/A	N/A	1	3

APPENDIX F: DOCUMENT REFERENCE LIBRARY

National Cohesive Wildland Fire Management Strategy:
http://www.forestsandrangelands.gov/strategy/documents/strategy/CSPhaseIIINationalStrategyApr2014.pdf

Quadrennial Fire Review:
http://www.forestsandrangelands.gov/QFR/documents/2014QFRFinalReport.pdf

Subcommittee on Disaster Reduction *Grand Challenges for Disaster Reduction*:
http://www.sdr.gov/docs/SDRGrandChallengesforDisasterReduction.pdf

Subcommittee on Disaster Reduction *Grand Challenges Wildland Fire Implementation Plan*:
http://www.sdr.gov/docs/185820_Wildfire_FINAL.pdf

Wildland Fire and Fuels Research and Development Strategic Plan: Meeting the Needs of the Present, Anticipating the Needs of the Future:
http://www.fs.fed.us/research/pdf/2006-10-20-wildland-book.pdf