5.1 ROADMAP FOR A NATIONAL WILDLAND FIRE RESEARCH AND DEVELOPMENT PROGRAM

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ABSTRACT

Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and the National Center for Atmospheric Research have formed a partnership to facilitate an innovative National Wildland Fire Research and Development Program. The ultimate purpose of the program will be to establish a deeper scientific understanding of the physics of fire than currently exists, to establish a solid scientific basis for strategic planning and policy making, and to develop and implement a set of advanced, scientifically based decision-making tools for the wildfire management community. The three main components of the program will be Wildland fire science, societal impacts, and operational applications. Smoke management, prescribed burns, wildfire mitigation and fuels assessment will be cross-cutting themes. We anticipate that this multidisciplinary, interagency program will bridge organizational and institutional barriers, and will be highly collaborative with numerous organizations and agencies, including other national laboratories; universities; federal, state, and county fire agencies; the Environmental Protection Agency; the Federal Emergency Management Agency; and the Western Governor's Association.

1. BACKGROUND

During the year 2000, 122,827 wildfires burned over 8.4 million acres of public and private lands[1], resulting in loss of property, damage to resources, and disruption of community services. Many of these fires burned in urban-wildland interface areas and exceeded the fire suppression capabilities available in those areas. For several weeks, the federal government was spending $15 million a day to support 20,000 civilian and military firefighters from 46 states and Canada.[2]

At the end of the fire season, fire experts expressed concern that the year 2000 experience could be the harbinger of an intensified wildfire cycle, caused in part by the ever-increasing fuel accumulations across the western United States. Those concerns have been reinforced by the events of the early 2001 fire season. From January 10 to August 22, more than 56,000 fires burned a total area in excess of 2.8 million acres[3], and in July, a fire claimed the lives of four firefighters in the state of Washington.

Many components of the wildland fire management system are being stressed to their limits. For example, the Chief of the USDA Forest Service recently questioned the adequacy of fuels management techniques. As reported in the New York Times on August 14, 2001, Mr. Dale Bosworth was quoted as saying, "I don't know if we can catch up. It may be impossible to ever catch up". The week before, the agency's National Fire Plan coordinator, Mr. Lyle Laverty, conceded that the federal government cannot possibly thin or burn 100 million acres; however, he also stated that his agency could not simply “let nature take its course.” The complex issues associated with vegetation management programs have been further complicated by recent problems with prescribed burns. Of course, when the fuel management is inadequate, the probability of large wildfires increases, further straining limited firefighting resources and putting lives and property at increased risk.

2. VISION: A BROADLY PARTICIPATORY WILDLAND FIRE R&D PROGRAM

We believe that key elements of more effective wildland fire management can be found within the nation's core scientific resources. The gains that could be realized by exploiting the largely untapped potential of our national laboratories and research centers include safer and more effective firefighting procedures, improved fuels management techniques, better long-term planning, reduced loss of property and natural resources, and most importantly, the protection of human lives.

We are well aware that an impressive wealth of knowledge, experience, and capabilities already exists within the national wildland fire community. The concept of combining these traditional wildfire management

[1] http://www.nifc.gov/stats/wildlandfirestats.html
[2] ABCNews.com, August 4, 2000
[3] http://www.nifc.gov/fireinfo/nfn.html

assets with complementary capabilities at the nation's major scientific research centers holds enormous potential for the advancement of wildland fire science and management.

As an initial step toward the realization of this potential, Los Alamos National Laboratory (LANL) Lawrence Livermore National Laboratory (LLNL)[4] and the National Center for Atmospheric Research (NCAR)[5] have formed a partnership, dedicated to the advancement of operationally-relevant wildland fire research and development. We propose a new national, multi-disciplinary, interagency program that leverages upon our country's best scientific and technological capabilities in order to develop and implement improved, scientifically based decision-making tools, services, and procedures for wildland fire managers.

We envision the program to be highly collaborative and interactive with land management research laboratories, universities and the wildfire management community at the national, regional, state, and county level. The scope of the program will be end-to-end, connecting advances in basic fire science with operational applications. It will provide benefits for operational organizations, even in the relatively short term. On a national scale, it will provide a rich source of information for major policy decisions.

Work toward these goals has been in progress for several years by institutions around the world including each of the three collaborating organizations. For approximately three and one-half years, LANL and LLNL have been working together on the development of a national, supercomputer-based wildfire behavior prediction capability. This national resource will combine and leverage components of a multi-year wildland fire model development effort at LANL, atmospheric modeling research at LLNL, and the existing real-time operational capabilities of the National Atmospheric Release Advisory Center (NARAC, see Section 4.)

At NCAR two decades of work have contributed to a substantial body of knowledge and technologies that are directly applicable to a national wildland fire initiative. These include work on emissions from wildland fires, the role of wildland fire smoke on clouds and climate, social science focused on the effect of weather and climate changes on society, development of remote sensing technologies, development of coupled atmospheric-fire behavior models and the development of advanced decision support systems (DSS) for operational users requiring high resolution, accurate weather information. (See Section 4.)

[4] Lawrence Livermore National Laboratory and Los Alamos National Laboratory are operated by the University of California for the U.S. Department of Energy.

[5] The National Center for Atmospheric Research is operated by the University Corporation for Atmospheric Research under a cooperative agreement with the National Science Foundation.

3. MAJOR COMPONENTS OF THE PROGRAM

The three major components of the proposed program are wildland fire science, societal impacts, and operational applications. The program can be thought of as a three-legged stool with each of the components representing a leg. Each component depends on the other in a very interactive way and the program is not complete without all three.

3.1 *Wildland Fire Science*

The goal of the science component of the program we envision will be basic scientific understanding, particularly in areas that are needed to support and advance the other two components. Although this list is not exclusive or final, we consider several areas to be obvious worthwhile scientific investigations, as well as being a source of valuable knowledge to be included in DSSs and computer-aided tools for stakeholder interaction, problem solving and education.

3.1.1 Fire/Atmosphere Dynamics

Many fire-related issues are affected in one way or another by the complex, interactive dynamics of the fire-atmosphere system; yet much remains to be learned about these processes. Understanding their effects on fire behavior could lead to safer and more effective firefighting techniques, and will improve our knowledge and management capabilities for other fire-related issues. Field studies, numerical laboratory experiments, and numerical simulation research will contribute to a better understanding in this area.

For example, visible imagery from the U. S. Forest Service (Intermountain Fire Sciences Laboratory) of the spread of fire through a forest shows that the process is exceedingly complex. As the fire approaches, trees heat and begin to ‘smoke’ water vapor and other gases. When flames appear, it is as small ribbons of flame carried forward on the wind. Wind directions shift, and trees ignite in flame either from the bottom up or the top down. Such *in situ* observations of fires are valuable and should be expanded. High-speed photography of flames in wind tunnels (Latham, 1998) has been used to estimate the radiation from the fire front that falls on the fuel in front of the fire. Remote sensing using NCAR's infrared imager (Radke *et al.* 2000, Clark *et al.* , 1999) has exposed dynamic forward bursts from fire lines and allowed us to estimate wind velocities in the fire. Simulation studies using numerical models that represent the dynamical processes within fires (Linn et al., 2001, Clark *et al.* 1996a,b) provide insight into fire propagation mechanisms and the physics of fire behavior, and will play an important role in the program. We also envision advancing and validating methods to better represent fire spread rates in numerical models with widely ranging levels of complexity. These techniques, and other methods of investigation need to be expanded to add to the current understanding of processes such as spotting and crowning.

3.1.2 Fuels Assessment

The ability to characterize the wide variation in fuels and to model all types of fires for their potential to emit air pollutants is lacking for many fuel types across the continental U.S. and Alaska (Sandberg *et al.* , 1999). However, there is a great potential for (and desirability to) integrate observations to improve estimates of fuel quantity and conditions with remote sensing, particularly since a national identification of wildfire danger has begun (Dept. of Agriculture and Dept. of Interior, 2001). There is a need to advance methods for using satellite data to generate accurate, timely, updateable national wildland fire fuel maps and develop techniques for mesoscale atmospheric models, using dynamic land use concepts, to predict how such characteristics will change. This involves integrating data on land cover, weather, terrain, vegetation type, moisture level (live and dead), historic fire regimes, natural and man-made fuel breaks, and the locations of structures (in the wildland-urban interface). There is also a need to develop capability to map sub-canopy structure and quantify biomass loading. We envision progress on several of these topics using remote sensing of fuel characteristics with multi-channel radiometric sensors, both satellite and airborne, as well as integrating with land-based measurements where available.

3.1.3 Fire Emissions

During combustion, particulates and gases are released that have a wide range of impacts on the environment. Fires release CO_2 and other greenhouse gases, and in some cases, are a significant portion of the global budget of these gases. Also of concern are toxics such as mercury, nutrients, and pollutants including SO_2 that are harbored in the biomass and soil but reintroduced to the atmosphere by the smokestack effect of wildland fires. Other gases produced by fires are photochemical precursors to pollutants such as ozone. Particulates readily serve as cloud condensation nuclei and affect cloud microphysical properties by narrowing the cloud droplet size distribution, likely reducing the clouds' precipitation efficiency, as well as making the clouds "brighter" in a radiative sense. The volume, concentration, and composition of these products are directly tied to the fire intensity and phase (flaming vs. smoldering) and fuel characteristics, thus are linked to other areas such as fire dynamics, combustion chemistry, and fuels assessment (Sections 3.1.1, 3.1.2 and 3.1.4).

Work in this area might involve numerical models, observations, and laboratory work. Specific examples include decomposition of fuel samples in ovens to determine combustion products (Brown et al, 2000), developing emission characteristics (known as "emissions models") for a range of fuel types, and implementing such components in atmospheric models, where atmospheric conditions, modeled fire behavior, fuel consumption, and local fuel characteristics together determine emission products and transport.

3.1.4 Combustion Chemistry and Physics

As an approaching fire heats fuel, the fuel begins to pyrolyze and water vapor begins to evaporate. As this happens, the fuel decomposes into combustible and inert gases, as well as solid substances that may later be part of combustion. This work involves investigating chemical constituents of fuel decomposition, including volatile organic compounds (VOCs) contained in biomass and their possible role in aspects of fire behavior. Further development of remote sensing techniques (such as Daily *et al.* (1999)) and *in situ* sampling to determine the composition of combustion products is envisioned.

3.1.5 Quantifying Wildland Fire Risks

The program will develop techniques to quantify the risk of fire to communities across the nation. This analysis could then be used for prioritizing the at-risk communities to stimulate methods of mitigation. This research includes methods to estimate the likelihood of ignition, severity, potential size of wildfires and the effectiveness of thinning and prescribed burns.

3.1.6 Climate-based Assessments

Climate research that relates to the prediction of wildland fire occurrence on time scales of a few weeks to a few years is highly relevant to this program. This information is highly effective as an input to strategic planning done by stakeholders at the federal, state, county and municipal levels. Notable researchers in this area, including Westerling (Scripps), Brown's group at DRI, and O'Brien at the Florida Climate Center have all begun to transfer their research into valuable operational tools.

3.2 *Societal Impacts, Policy, and Strategic Planning*

The second major component of the program is focused on analyzing and effectively communicating the societal impacts of wildland fire that are relevant to policymaking, strategic planning, and operational DSSs.

3.2.1 Definition of Specific User Requirements

This area of social science research will be focused on an assessment of user requirements within the wildland fire community. Social scientists will work interactively with stakeholders representing the spectrum of decision makers.

Many organizations likely have already performed some surveys of this type for a subset of the total stakeholders. The goal of the national initiative will be to collate these data, conduct any new surveys required for stakeholders that have not been assessed, and combine this information into one document for reference by all participants in the national program.

3.2.2 Quantitative Assessments

Social scientists will focus their efforts on quantifying public response to fire management strategies, particularly the 10-year comprehensive strategy, *A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment,* recently agreed to by the U.S. Department of Agriculture and Interior. Determining risks and costs associated with strategies of this type that affect broad segments of society will be a special focus of this work. This social science component will draw on the physical science research referenced in Section 3.1.5.

3.2.3 Computer-aided tools

Social scientists working with developers in information technology will focus on the development of computer-aided tools to assist in planning for fire mitigation at the urban-wildland interface. One of the components of such a system could be the full physics model developed by LANL/LLNL and the associated visualization software. The proposed tools will enable communities to go through simulated exercises based on actual case studies and over time, utilize the collective knowledge of all stakeholders. Knowledge-based systems of this type are being developed for many other applications; wildland fire applications are the next step. Experts in this area reside at the national collaborating laboratories, universities and in the private sector.

3.2.4 Applications of GIS-based technologies

Exploitation of GIS technologies to focus on pre-fire, prescribed burns and wildfire decision processes will be a strong focus within the national initiative. This tool can be quite effective in assessing information from diverse sources including precision weather information, fire behavior, terrain, land use and fuel assessments.

3.3 *Operational Applications*

The third core objective of the program will be the development of new, scientifically based decision-making tools, services, and procedures for the wildland fire management community.

It is envisioned that the program will "go to school" on the problem of adequately managing prescribed burns. These fires have some similarity to research field experiments in that they are planned far in advance, they are not initiated until the desired atmospheric conditions are attained, they are logistically much simpler than the wildfire problem, and they normally allow the opportunity to put adequate environmental sensors in place. Experience established in addressing the prescribed burn problem will cascade forward to be applied to smoke management and wildfire DSSs.

3.3.1 Prescribed Burn Decision Support System

Prescribed burns sometimes do not behave as expected, due to insufficient information or incorrect impact assessments. One of the goals of this initiative is to develop a decision support system to assist decision makers prior to and during the prescribed burn. Specific user requirements in terms of decision horizons, risk assessment, societal impact, resource allocation and costs will be factored into the prototype systems. Numerical models will supply one primary source of information, but many other sources of information will be processed. The system will be designed to work in real time with frequent updates based on user requirements. It is also desirable to have interactive functionality with the system from the fire site in order to measure last minute changes and changes in weather conditions during the fire. The technologies exist today at several laboratories to build such a prototype. Most of these technologies have been applied to other user communities like aviation and defense.

3.3.2 Smoke Management Decision Support System

Smoke is a hazard that is becoming an ever-increasing problem for many sectors of society. For example, the State of Florida registers more fatalities each year from vehicle crashes caused by low visibility due to smoke than they do from the effects of hurricanes. Smoke can be particularly dangerous when combined with other meteorological factors like fog. Health effects on local residents are also significant issues.

A prototype smoke management decision support system will be a component of the development effort within this initiative. This DSS will be designed to give land managers and other users affected by the smoke (State departments of transportation for example) definitive information about the three-dimensional domain of the current smoke plume and forecasts over several hours in the future. It will also detect and predict the intensity of the smoke in terms of visibility and particulate matter.

Numerical models will be one of the components of the smoke management DSS in addition to terrain data, ground-sensed data, aircraft and satellite remote-sensed data. There are various options for the type of numerical models that should be used. This can range from so-called coupled atmospheric and dispersion models, up the scale to full physics models that create and transport the smoke during the model run. Part of the research will be focused on sorting out the best modeling approach for the short, mid and long term.

The prototype will be designed for real-time use with frequent updates to detect short-term changes in the plume that can, for example, affect new stretches of highway. The system could automatically trigger variable message signs to warn drivers of the hazard. Exploitation of remote sensing techniques (particularly those that can be used in real time) will be crucial to this development effort.

3.3.3 Wildfire Decision Support System

This decision support system will be considered the “Holy Grail” of the development effort; it is also the most difficult to develop. Although much can be learned from developments associated with prescribed burns, the raging wildfire poses many more challenges – more difficult logistical support, less data overall on the ground and from remote sensors, and a crisis-mode environment requiring decisions on an hour-to-hour basis. In extreme wildfires undergoing large environmental changes, the decisions may be required on a scale of every few minutes. The current understanding of wildfire dynamics is limited, and there is virtually no capability to predict the behavior of this hazard; currently there are only rough estimates of fire spread rates and intensity.

The development initiative will focus on specific user requirements to determine a detailed concept of operations used by the decision makers on scene. Functional characteristics of the prototype system will then be designed to meet these operational requirements. Design topology issues like the mix of centralized processing versus distributed processing (down to the fire location if necessary) will be addressed. It is essential that such a system operate in real time and that it is directly accessible by the incident commanders on scene.

3.3.4 Collaboration on an Advanced National Fire Danger Rating System

Many of the new technologies that now exist in the national laboratories and universities are excellent candidates for the development of an advanced national fire danger rating system. Most of these advancements are applicable to the period t=0 to about 10 days; however, on-going research shows great promise in leading to much improved monthly and seasonal assessments (See 3.1.5 – 3.1.6)

New intelligent forecasting algorithms have been developed for temperature and other wildland–fire-related parameters (See Section 4.3.4). NASA has developed several new remote sensing algorithms, including one that detects fire boundaries and previously burned areas that could contribute to the assessment of fuels, soil moisture, and land use changes. If these new technologies are combined with advancements in numerical modeling, GIS capabilities at LLNL and other laboratories and the climate-related research cited above, the potential is high to create a very advanced fire danger rating system. It is envisioned that the Intermountain Fire Sciences Laboratory (Bradshaw et al) will lead this development initiative with routine feedback and guidance from the National Wildfire Coordination Group’s special working group on the fire danger rating system, and participation by several of the collaborating laboratories.

4. RELEVANT CORE CAPABILITIES AVAILABLE AT LANL, LLNL, and NCAR

The material in this section is presented to facilitate the exploration of potential collaborations within the proposed program. It provides an overview of capabilities at LANL, LLNL, and NCAR that appear to be complementary to capabilities of other organizations involved in wildland fire research and management.

4.1 *Wildland Fire Science*

Fire/Atmospheric Dynamics

Concurrently, LANL and NCAR have been developing coupled atmosphere-fire models that simulate two-way interactions between fires and the weather, an essential capability for predicting complex fire behavior, but which are computationally intensive and currently cannot run faster than real time.

FIRETEC is a high-resolution fire behavior model, developed by Rod Linn at LANL, that predicts fire spread based on a fundamental treatment of combustion, turbulence and other physical processes. FIRETEC runs fully interactively with the HIGRAD atmospheric model (which solves the compressible Navier Stokes equations of motion for fluid flow) thus accounting for important, complex fire-atmosphere feedback mechanisms. Because it represents the actual physics of combustion and the two-way interactions between the fire and the atmosphere (processes not fully accounted for by the tools currently in use), FIRETEC can simulate wildfire behavior in realistic environments characterized by complex terrain and changing weather conditions. A new FIRETEC capability, the simulation of fire spread by airborne burning fuel (“spotting”) is currently being developed at LANL.

A research team at LLNL, under the direction of Mike Bradley, is examining the important physical and numerical issues involved in coupling the HIGRAD/FIRETEC system with an operational regional weather prediction model. The weather prediction model (COAMPS, the Coupled Ocean-Atmosphere Mesoscale Prediction System[6]) is run routinely to support NARAC operations at LLNL (see Section 4.3), and can be quickly relocated to predict the weather at any location on Earth. The LLNL team is also conducting model

[6] COAMPS was developed by the Naval Research Laboratory, and has been enhanced in several ways by the LLNL Atmospheric Sciences Division.

evaluation studies and case studies of specific wildfires, and integrating the models with a Geographical Information System (GIS). The underlying goal of the project is to advance the science of interactive wildfire/atmosphere simulation toward the realization of an operational capability.

NCAR's Mesoscale and Microscale Meteorology Division also has been developing a coupled atmosphere-fire model. The Clark atmospheric model has been coupled with a fire model such that heat and water vapor from the fire is released into the atmosphere, creating updrafts and winds that in turn direct the later propagation of the fire. This model does not treat the details of combustion *per se*, but uses a tracer code developed by Terry Clark (Clark et al, 1996b) to define the burning regions, and applies BEHAVE to estimate fire spread rates with local fire winds as input to predict spread rate, and a routine based on BURNUP, an algorithm that describes how a mixed fuel is consumed over time. Studies to date have sought to explain some aspects of fire behavior by examining the interactions of fires with their atmospheric environment, leading to behaviors such as the bowing of firelines into conical shapes, fire vortices, and the acceleration of fires on slopes, and testing the effect of certain atmospheric temperature and wind structures on fire behaviors that are believed to be causes of extreme behavior.

Fire Emissions

The Atmospheric Chemistry Division (ACD) of NCAR has been involved with emissions in the global atmosphere for several decades and more recently has focused on emissions from wildland fires. The Biosphere-Atmosphere Interactions group is focused on the analysis of volatile compounds contained in different plant types to determine the contribution to combustion physics. The long-term goal is to use these data in dynamic models to better understand fire behavior. ACD, in collaboration with other divisions, is also strongly focused on identifying the sources and amounts of mercury emissions from wildland fires. As part of the NCAR fire initiative, Alex Guenther (NCAR/ACD) is currently working on quantifying the effects of wildland fire emissions on regional pollution for the EPA, and Hans Friedli is expanding his assessment of mercury release from fires in different regions of the world to compile a global estimate of its importance.

Climate-Based Assessments

NCAR's Climate and Global Dynamics division has been a leader in climate modeling and assessing the potential impacts on society (global warming and El Nino – Southern Oscillation for example). A new NCAR-wide initiative on Biogeosciences includes an assessment of the effect of wildland fires on climate, studies of the urban-rural interface, and the effect of emissions from several natural phenomena on general health within our society.

4.2 *Societal Impacts*

The Environmental and Societal Impacts Group (ESIG) at NCAR has a mission of focusing research on interactions between society and the environment. Their social science research over the past 30 years has had the following components: a) protection of life, health and property, b) improving strategies for natural resource and environmental management, c) use of weather and climate information in decision-making and policy, and d) fostering the integration of knowledge and action in education and societal services. ESIG has recently turned its attention to the issues associated with wildland fires.

User Requirements

NCAR's Research Applications Program and ESIG have two decades of experience in assessing detailed user requirements. Each group has conducted this work for different purposes, but the combined expertise can contribute significantly toward building a research program that is operationally relevant.

Quantitative Assessments

NCAR's ESIG has twenty years of experience in assessing environmental data to derive scientifically-based information that can be used by policy makers in many disciplines and regions of the world.

Computer Aided Tools

NCAR's ESIG, Research Applications Program, and the Cooperative Program for Operational Meteorology, Education, and Training have many years of collective experience building computer-aided tools used by educators, students and stakeholders in various user communities.

GIS Technologies

The LLNL Energy and Environment Directorate GIS Center provides a combination of commercial software, custom applications and user interfaces, geographically referenced data, and analytical and other procedures. GIS provides a structure to organize, manipulate, analyze, and visualize data and modeled results describing features and phenomena that have specific geospatial locations. The GIS has a full suite of analytic geometry functions and statistical capabilities that are used to assess spatial relationships, trends, and correlations among relevant factors. This is particularly useful for organizing spatial data and pre-processing it as required for various models. The LLNL GIS Center supports LLNL's wildfire simulation project by providing the models with gridded terrain elevation and gridded spatial distributions of fuel loads attributed by type and condition. GIS is also being used for wildfire consequence analysis, e.g., estimating the dollar value of structures destroyed by potential fires, estimating the number and demographic composition of persons affected by fire or smoke, infrastructure (fire mains, reservoirs) affected by fires, and identifying areas subject to post-fire events such as increased runoff or erosion.

4.3 Operational Applications

Decision Support Systems (Prescribed Burns, Wildfire and Smoke Management)

NARAC at LLNL is a national resource that supports federal, state, and local emergency response managers by predicting the atmospheric dispersion of hazardous materials. NARAC has substantial expertise using its suite of fast-running models to predict the atmospheric transport and diffusion of smoke, and the concentrations of smoke particles at specific locations and times. The capability was used during the planning stages of Operation Desert Storm. Later, for six months after the war ended, NARAC provided numerous countries and international agencies with daily predictions of the smoke concentrations from the oil well fires in Kuwait. NARAC also supported local and state agencies and emergency operations centers during two extremely large tire fires in the San Joaquin Valley of California in 1998 and 1999. Recently, NARAC has predicted the smoke dispersion for prescribed burns for the Los Angeles County Fire Department and the LLNL Fire Department.

NCAR's Research Applications Program has established a reputation over the past 20 years for developing user-specific decision support systems . In particular, a technology referred to as Intelligent Weather System (IWS) design has been shown to significantly improve detection and forecasts of many atmospheric parameters (Wagoner 1998). This design taps intelligent sources of information from numerical models, real-time data, climatology, forecaster knowledge bases, and human input. This combined information is processed using a fuzzy-logic technique to extract a highly accurate, high-resolution estimate of any atmospheric or user-defined, non-atmospheric variable.

National Fire Danger Rating System

Research at NCAR has resulted in an IWS derivative technology referred to as NextCast that has been demonstrated to equal or exceed human forecasting expertise for several meteorological parameters (temperature for example) out to 10 days. Work is underway to extend this capability to most of the parameters relevant to wildland fires. The forecast parameters will be available as absolute values or probability density functions.

5. PROGRAM DEVELOPMENT ISSUES

There are several categories of issues associated with spinning up a national initiative of this breadth. It is a difficult process at best and one that takes several years to reach maturity. Discussion of some of the key issues follows.

5.1 Philosophy of Program Development

This program is designed to be highly collaborative in nature as pointed out previously. The three laboratories that have joined forces in this initiative should be considered facilitators, not owners of the program; they have stepped up to the plate to get the process of organization underway. It is understood by all that the full expectation is that many research organizations will eventually sign on to benefit from the collaboration offered by the program and to benefit from funding opportunities brought about by the leverage and critical mass of the participants. In this sense, the intent of this paper is to send an *invitation*, not to make an *announcement*. The program is seen as dynamic, long-term and ever evolving by all who participate.

5.2 Preliminary Scope of Collaborators

Other than the three research organizations that have signed on initially, it is very difficult to predict just how many total organizations will join the team; however, it is fairly easy at this point to list the *desired* participants. The fire research laboratories in the land management agencies are considered critical to the program. Their baseline of previous and on-going research should play a significant interactive role in most of the elements of the program. This would include the Intermountain Fire Sciences Laboratory, the Riverside Fire Sciences Laboratory, the Pacific Northwest Research Stations (Ferguson and Sandberg), and experts on fuels assessment, like Carl Edminster of the USFS. The breadth of combustion research (modeling and experimental instrumentation) occurring at Sandia National Laboratory under the direction of Louis Gritzo would add significant depth to the program in a number of ways. Similarly, university investigators at DRI (Brown, et al), U. of CO (Daily and Milford), U. of AZ (Moorehouse), and U. of MT (Running) to name only a few, would be excellent additions. NOAA's Office of Atmospheric Research and National Environmental Satellite and Data Information Service are hoped-for participants. The EPA, NASA, and the NSF round out the research organizations that hopefully will join.

Collaborators on the operational side are also considered critical to the success of the program. The National Wildfire Coordinating Group, the National Interagency Fire Center, the new Geographical Area Coordination Centers, the National Weather Service, and fire response organizations at the state, county and municipal level will hopefully join the initiative to provide direction for the research. The Western Governors' Association could play a significant role in supporting the program, as could organizations in the private sector, environmental sector and foreign countries.

5.3 *Management of the Program*

Given that the program by definition is broad in scope and potentially could have several dozen participants, it is essential that some effective management entity be created to provide oversight, advocacy and determination of R&D priorities. Some type of governing board is envisioned that will consist of representatives from the research community and the operational community. These representatives will serve terms of 2-3 years for continuity.

5.4 *Funding*

The governing board in association with the members of the program will collectively serve as advocates for acquiring funds. Such a group will serve as a formidable force to interact with operational stakeholders, state organizations, federal organizations, and the Congress. The general idea is that the governing board will sort the priorities for R&D, strongly influenced by the operational sector. As funds are acquired, they will be allocated in accordance with the priorities, and *all* organizations' boats will rise simultaneously with the incoming funding tide.

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