

Advancing the Capabilities for Rapid Response Fire Monitoring and Intelligence

A proposal in response to AFP 2003-2 task 1.

Principle Investigators: Colin Hardy¹, Kevin Ryan¹, Wei Min Hao¹

Co-Investigators: Bret Butler¹, Bob Kremens²

Affiliations

¹Missoula Fire Science Lab, USDA Forest Service
PO Box 8089, Missoula, MT 59807

²Center for Imaging Science, Rochester Institute of Technology,
54 Lomb Memorial Drive, Rochester, NY 14623

Abstract

We propose to establish a consortium of experts in technology, remote sensing, fire behavior, and fire effects to develop and deploy an array of scientific equipment and personnel to specific fires to improve tactical intelligence on all future fires and strategic intelligence over the entire global landmass. The planned improvements to tactical intelligence will impact regional coordinators, incident commanders and every firefighter digging line. The strategic intelligence provides land managers with current fire activity and airshed information needed to implement prescribed and wildland fire use fires. We will mobilize aircraft, scientific grade thermal cameras, *in situ* heat flux instruments, disposable automatic “fire sentries” and personnel qualified to observe and meticulously record fire behavior and fire effects parameters. In addition, one aspect of our efforts will be the coordination of satellite-based intelligence with linkages to the local fire. Fires to which we deploy will benefit from enhanced fire reconnaissance via the fire sentries and near realtime (less than 2 hours acquisition-to-map) airborne fire perimeter maps. The end result will be a rapid response Team with proven technologies for acquiring data vital to the improvement of models of fire behavior, effects, post-fire succession, and area growth. The relation of 4 times daily MODIS satellite observations of active fire to fire effects and regional/national air quality will be described, and a new, field tested, low cost, high technology fire sentry will be demonstrated. Fire sentries, remote observations, and model estimates will all be refined and validated with independent, *in situ* measurements. The technological developments required to gather and integrate the data comprise a quantum leap in wildland fire intelligence acquisition, firefighter safety, suppression tactics, and management by means of tactical intelligence.

Telephone	406-329-4978
Fax	406-329-4877
Email	chardy01@fs.fed.us
Duration of Project	3 years
Annual funding requested	\$376,100;\$185,400; \$128,800
Total funding requested	\$690,300
Total in-kind funding	\$696,300



Introduction

This proposal addresses **AFP 2003-2, Task 1**; specifically, the call to: “...*obtain, document, and evaluate critical, time-sensitive information or data during or following wildland fire incidents...*” In this proposal we present a rationale, framework, and deployment strategy for a state-of-science Rapid-Response Team to facilitate both remote and *in situ* acquisition and integration of data on fire characteristics and behavior, first-order fire effects, and fire growth and spread. The proposed Team is a consortium of experts in instrumentation, remote sensing, fire behavior, and fire effects. It’s strength lies in the combined knowledge and resources made available through collaboration among all research units at the Missoula Fire Sciences Laboratory as well as the electrical engineering and imaging sciences departments at Rochester Institute of Technology (RIT). In addition to the technical, biological, and physical science credentials of the consortium, a high level of wildland fire experience, competence, training, and qualifications are also critical attributes of the Team. All field efforts by the proposed Missoula Rapid Response Team will be lead by a currently qualified Type II Incident Commander or, minimally, a Strike Team Leader. This proposal presents a hierarchical scheme of deployment for a suite of state-of-science technologies and field protocols. We plan and request funding for pre-season research, development and training activities, coordination with Incident Management Teams (IMT), and for acquisition of instrumentation and personal protective equipment (PPE). We provide a matrix of possible responses to actual wildland fire incidents.

Project Justification¹

Much of the data used to describe the behavior and characteristics of wildland fires have been derived from post-fire observations, anecdotal evidence, or modeling, rather than from *in situ* measurements of the fire phenomenon. When used to develop cause-and-effect relationships with respect to first- and second-order fire effects, these inferences frequently become circular. That is, the causal agents are described by measuring or observing the effects, and are then presented as independent variables with which to draw relationships. Several challenges confront the manager or investigator with respect to *in situ* measurements of the fire environment. First, it is often difficult to deploy field personnel to locations ahead of a wildland fire that could be expected to burn within the next several burning periods. Second, the technology required to characterize the fire environment in such a way as to provide robust thermodynamic data is neither well developed nor well understood. Finally, such technology that does exist has not been exploited even to the point that the transfer of technological methods can begin.

New technological tools are now being developed, however, that are intended to provide new data and insight to the relationships between the characteristics of wildland fire and the first- and second-order effects. By integrating data and information from a suite of tools, these new technologies can not only be used to demonstrate proof-of-concepts, but some may become readily adapted to operational fire monitoring and observations.

¹ Letters of support for this proposal are attached.

Project Objectives

This proposal addresses five primary objectives:

1. Create and implement a multi-disciplinary, state-of-science Rapid Response Team to develop, deploy, and advance new technologies in real-time fire monitoring and intelligence.
2. Develop and refine a suite of technological approaches for characterizing fire behavior, flame structure, and micro-climatic variables for field-deployment on wildland fires.
3. Install, operate, analyze data, and synthesize results from multiple field deployable instruments in a diversity of wildland fire situations ranging from an initial prescribed fire, wildland fire use for resource benefit incidents, and wildland fires.
4. Provide fundamental research data to investigators and modelers of fire behavior, flame dynamics, first-order fire effects, and longer-term second-order fire effects.
5. Refine instrumentation and provide technology transfer opportunities for operational application of promising technologies identified by the study.

Methods

Site selection Criteria

We have measured fuels and vegetation on 35 million acres in the Interior West/Rocky Mountain region (see Composite spatial data below, Table 3). We have used remote sensing and field verification to classify vegetative cover and structure and have created the terrain data necessary to run the FARSITE [8] model. And we can use these data to parameterize and run the NEXUS (www.fire.org) and FOFEM (www.fire.org) models. Previously sampled and classified areas provide the greatest opportunity to demonstrate model utility to fire managers, to validate model performance, and to gain new data to improve future versions of the models. Therefore, these areas (Table 3) are preferred areas for deployment of the Missoula Rapid Response Team. We anticipate that a number of fires are likely to occur within the 35 million acres within the next two fire seasons and that deployment to fires in these areas will provide ample opportunity to test all rapid response protocols as well as fire behavior and effects models. However, team members have frequently deployed to incidents where no previous data existed (e.g., Big Fish, Biscuit, Hayman, Missionary Ridge, Sanford) in 2002. Further, many of the areas sampled are largely wilderness areas. While the pace of fire management on wildfires managed for resource benefits (wildland fire use) is conducive to producing high quality fire behavior observations, the lack of accessibility makes extensive fire effects monitoring more difficult.

We have a linked, but not co-dependent proposal (Assessing the Causes, Consequences and Spatial Variability of Burn Severity: A Rapid Response Proposal by Morgan, Hudak,

and Ryan, see attached letter), that proposes a rapid response project to: collect fire behavior, fire effects, and fuels data from five 2003 and five 2004 wildfires across the US. Their proposal intends that field and remotely sensed data be collected soon (two weeks to 1 year) after wildfires to understand the interactions and spatial variability in fire effects, fuels, fire behavior, local weather and topography and to assess the accuracy of current and alternative image analyses for remote sensing of burn severity. We strive to get the best data that the fire season and incident management system will allow. Many of the areas we've previously sampled contain substantial non-wilderness areas. Therefore, our site selection criteria will integrate prior availability of data, accessibility, and incident management team relationships. Considerable effort will be placed on developing working relationships with Incident Teams prior to the FY03 fire season. We have begun this process by contacting current Fire Use Management Team IC's (see attached letters).

Phased Deployment Schedule

In order to exploit the greatest range of deployment opportunities, while not constraining ourselves to an "all or nothing" approach, we propose a hierarchical deployment schedule. Further, the deployment schedule is stratified between pre-fire field activities (Table 1) and during-fire operations (Table 2) (figure 1).

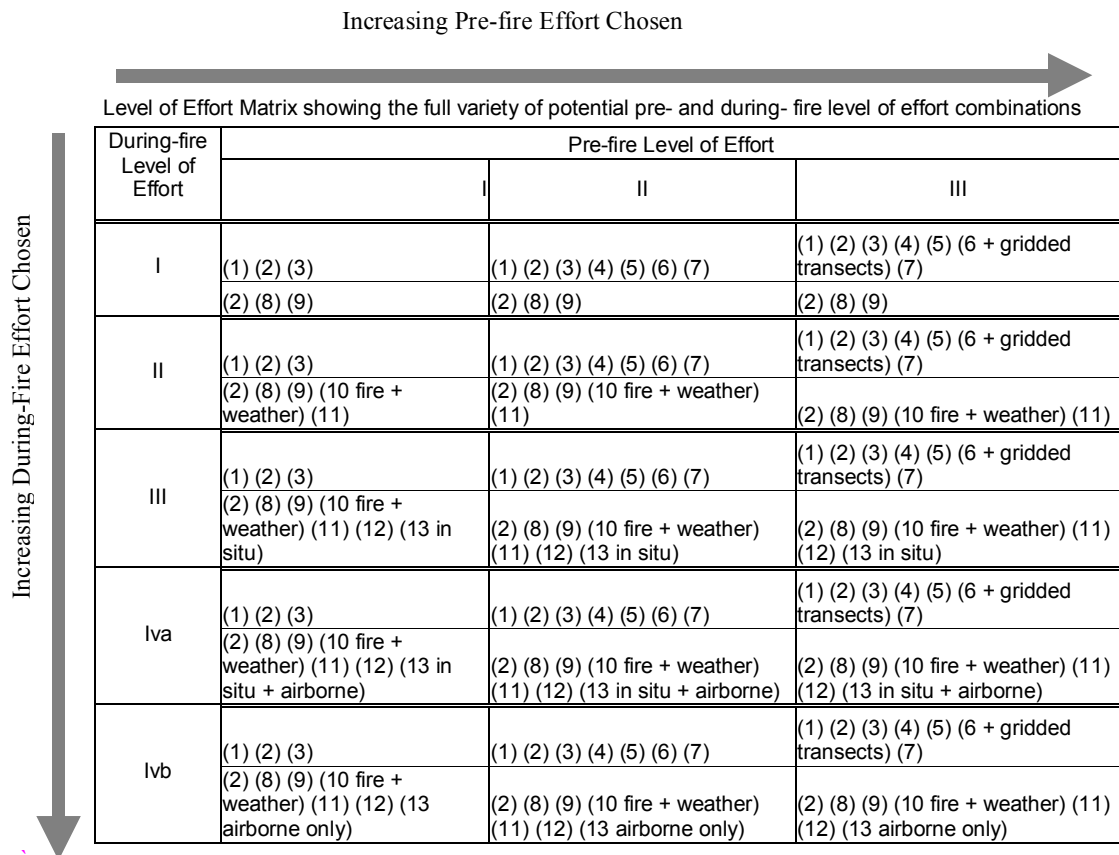


Figure 1. Matrix of Levels of Effort for pre-fire and during-fire activities. Numbers in brackets refer to the descriptions in tables 1 and 2 and in the narrative sections below.

This nested hierarchy of pre- and during-fire field efforts is intended to suggest that there is a matrix of combinations of respective pre- and during-fire levels of effort. That is, for example, we may find opportunities whereby time and/or access constraints limit us to a Level I pre-fire effort (Table 1), but also that it may be feasible to implement a Level II during-fire effort. We have therefore described each respective level of effort independently. Note in Tables 1 and 2, however, that each incrementally higher level of effort not only adds activities, but also inherits the activities from the respective subordinate level(s) of effort.

Table 1: *Pre-fire* field operations, by level of effort. A complete description of each operational method follows Table 1 and Table 2; each is cross-referenced in the tables using an italicized number within parentheses.

Effort Level	Description of Field Operations	
I	<u>General:</u> <u>Site-specific:</u>	Composite spatial data (1); Enhanced field observations and IMT intelligence(2); photo interpretation(3).
II	<u>General:</u> <u>Site-specific:</u>	[Level I]; Locate/monument plots(4); Fuel loading estimates(7); Site characterization estimates (6); photo panoramas(5)
III	<u>General:</u> <u>Site-specific:</u>	[Level I, II]; [Level I, II]; FIREMON fuel and site measurements on gridded transects(6)

Table 2: *During-fire* field operations, by level of effort. A complete description of each operational method follows Tables 1 and 2; each is cross-referenced in the tables using an italicized number within parentheses.

Effort Level	Description of Field Operations	
I	<u>Fire:</u> <u>Weather:</u>	Enhanced IMT intelligence(2) IMT weather intelligence(8); gridded weather streams(9)
II	<u>Fire:</u> <u>Weather:</u>	[Level I];RIT remote devices(10) [Level I];Micro-RAWS (11); RIT remote devices(10)
III	<u>Fire:</u> <u>Weather:</u>	[Level I, II]; Fire behavior/flux packages(12); <i>In situ</i> radiometry(13) [Level I, II];
IVa	<u>Fire:</u> <u>Weather:</u>	[Level I, II,III]; Airborne TIR(14) [Level I, II,III]
IVb	<u>Fire:</u> <u>Weather:</u>	Airborne TIR ONLY(14) [Level I]

Following are narrative descriptions of field methods and protocols corresponding to the Levels of Effort for both the pre- and during-fire operations shown in Table 1 and

Table 2, respectively. Items below are numbered with respect to the cross-references shown in the tables.

1. **Composite spatial data**— As a result of several years of research and development we have fuels, vegetation, and terrain data on approximately 35 million acres in the western US (Table 3). The data represent most of the vegetation types found in the region, and provide inputs to fire behavior and effects models. These areas provide the most suitable areas for rapid response to on-going incidents as we are able to ramp-up quickly to support the IMT, validate fire behavior and effects models, and develop new fire monitoring technology.

Table 3: Areas where the Fire Lab has available data to support rapid response efforts.

Study Area	Location	Areal Extent	Major Veg Types
Selway-Bitterroot Wilderness Complex [11]	Central Idaho, Western Montana	2.9 MM	Whitebark Pine, Spruce-Fir, Douglas-fir, Lodgepole Pine, Ponderosa Pine
Salmon-Challis National Forests ¹	South Central Idaho	8.5 MM	Whitebark Pine, Spruce-Fir, Douglas-fir, Lodgepole Pine, Ponderosa Pine, Sagebrush
South Fork Sun River, Lewis and Clark National Forest ⁴	Western Montana	0.3 MM	Whitebark Pine, Spruce-Fir, Douglas-fir, Lodgepole Pine
Madison Range, Gallatin National Forest	Southwest Montana	0.5 MM	Whitebark Pine, Spruce-Fir, Douglas-fir, Lodgepole Pine
Gravelly Range, Beaverhead-Deerlodge National Forest	Southwest Montana	2.0 MM	Whitebark Pine, Spruce-Fir, Douglas-fir, Lodgepole Pine, Sagebrush
Southern Utah Fuel Management Project Dixie, Fishlake N.F Cedar City, Richfield, and Arizona Strip ¹ - JFSP	Southern Utah	15.3 MM	Aspen, Spruce-Fir, Douglas-fir, White Fir, Pinyon-juniper, Oak, Ponderosa Pine, Sagebrush, Desert Shrub
Gila Wilderness Gila National Forest [10]	Western New Mexico	2.4 MM	Aspen, Spruce-Fir, Douglas-fir, White Fir, Pinyon-juniper, Oak, Ponderosa Pine, Sagebrush, Desert Shrub
Idaho Panhandle N.F. ²	North Idaho	0.4 MM	Douglas-fir, cedar, hemlock, grand fir, western larch, Engelmann spruce
Owyhee Mountains ³	Southwest Idaho	2.5 MM	Pinyon-juniper, Sagebrush, Desert Shrub

¹ Data on file at Missoula Fire Sciences Laboratory

² Data on file at Idaho Panhandle National Forest

³ Data on file at University of Idaho

⁴ Data on file at Lewis and Clark National Forest

2. **Enhanced field observations and IMT intelligence**— Team provides a minimum of two research observers to support the Field Observer (FOBS) and Fire Effects Monitor (FEMO) duties, with specific emphasis on local conditions in proximity to identified study area(s). We are aware of JFSP requirements and NWCG 310-1 qualifications system documentation needs for FOBS and FEMO positions, as well as those required of personnel restricted to incident command center support (i.e., fire camp), e.g. Technical Specialist, GIS and modeling. Team member Ed Mathews, a Type 2 IC and Type 1 FBAN through 2001 is responsible for assuring that all Missoula Rapid Response Team members have red-card qualifications and PPE required for their assignment.

Team membership varies by the level of incident support. At the minimum fire modeling and GIS team members will support the local incident management team by providing access to existing data and aid in running and interpreting fire behavior models, while the FOBS and FEMO team members collect traditional fire weather, fire behavior, and fire effects information using standard methods [12,13,14] that is often lost when the incident is turned over to local managers. At “during-fire” levels of effort 2 and higher (Table 2) the Missoula Rapid Response Team IC (see Missoula Rapid Response Team description, below) will be responsible for coordinating instrument deployment and insuring strict observance to all LCES principles. Our goal is to enhance fire observations in order to test and validate current predictive models. For example, on a wildland fire the management team focuses on areas critical to managing the incident. We want to validate predictive relationships. Therefore our team will select areas to model and observe fire behavior and effects such that we test/validate in a wide range of fuel models, habitat types, cover types, and structural stages. We will work with the IC to locate field plots that maximize their information content and minimize potential conflicts with fire management.

3. **Photo interpretation**— When we arrive at an incident we will acquire and exploit any pre-fire aerial photography resources to improve or validate the composite spatial data for the specific area identified by the Team.
4. **Locate/monument plots**— Permanent plot markers will be fixed, georeferenced with differentially corrected GPS (DGPS), and augmented with bearing and distance where needed. These markers will designate the plot centers and study area perimeters for all field estimates and/or measurements. We will locate plots for fire behavior and effects monitoring using FIREMON procedures (www.fire.org/firemon).
5. **Photo panoramas**— The minimum FIREMON procedure is for one digital photo looking east and north from plot center. It is preferred that digital panoramic photo documentation be acquired at each plot center. Focal length and photo methods will be constant among all plots to facilitate use of the photo panoramas for supplementing information with respect to site characteristics. If time permits the

field observer will photograph plots using Hall's methods [9]. As a minimum we will take digital photographs to the north and east of plot center (www.fire.org/firemon).

6. **Site characterization**— We will use FIREMON (www.fire.org/firemon) procedures to characterize plots. The minimum procedure will be to use ocular assessments of general site characteristics (Similar to the ECODATA general form (GF) to characterize habitat type, cover type, and structural stage to validate or improve the pre-fire vegetation classification (in Composite spatial data areas) [see *relevé* approach in FIREMON Integrated Sampling Strategy, Level 1 sampling (www.fire.org/firemon)]. When time permits, and for all sites where we are able to do Level II, or higher instrumented real time fire behavior monitoring, we will use FIREMON Level III sampling.
7. **Fuel loading estimates**— At our Level I pre-fire sampling effort, fuel loadings will be estimated using the Photo Series resources and methods. In rapid response mode (ahead of expected fire spread) estimates of fuel loadings will be made at as many points within the study perimeter as is feasible within safety and operational standards. When time permits we will augment photo series with standard fuel inventory using methods in FIREMON (i.e., “Brown’s” transects and vegetation sampling). FIREMON protocol will be followed for measurements of fuel loadings and vegetation profiles at each plot (www.fire.org/firemon).
8. **IMT weather intelligence**— Standard weather intelligence acquired by Incident Management Team (IMT) will be archived and exploited by the Missoula Rapid Response Team for real-time monitoring and post-fire effects measurements.
9. **Gridded weather streams**— The Team will acquire supplemental gridded weather products for spatial application over the study area. These data can be utilized by FARSITE and can also be used to infer local weather characteristics.
10. **RIT remote devices**— Scientists at Rochester Institute of Technology have developed, under separate contract (NASA Grant NAG-10051), compact data collection equipment for measurement of fire parameters and for use as alarms and data sentries for fire fighting [5,6] and environmental data recording [7]. These are ideal sentries for positions ahead of the fire front, as shown in Figure 2. Cognizant of location via a GPS and inexpensive enough to be considered disposable, they radio temperature, windspeed, and TIR radiometer data back to a central command. The central command is responsible for alerting Missoula Rapid Response Team to sentry position turnovers, on-site data analysis and data archival operations.

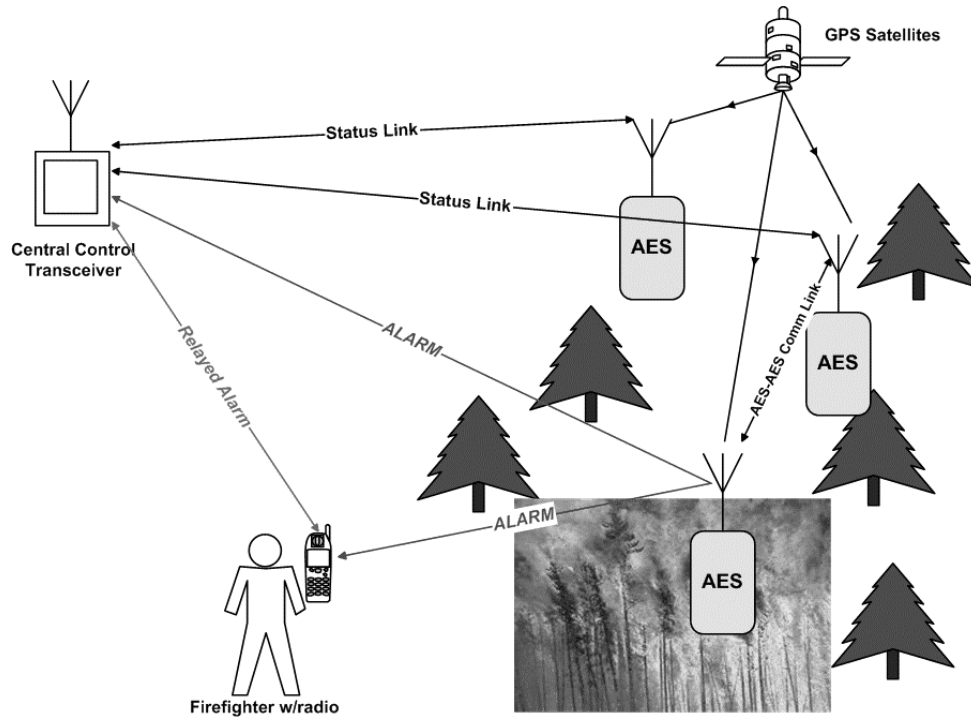


Figure 2: Networked implementation of the autonomous environmental sensor (AES) package used as a fire sentry or alarm device

A matrix of these fire sensors can be networked via radio to extend their usable range beyond line-of-sight. We anticipate a nominal turnover attrition rate of 30% per deployment. Due to the construction of the devices, careful deployment may engender a less than complete turnover loss (i.e., the sensor or antenna may be lost, but the computer and radio may survive). We anticipate deploying 20-25 stations in front of the fireline and have calculated provisional replacement costs accordingly.

11. **Fire-RAWS**— Two portable, radio frequency-reporting weather stations (NIFC Fire Raws) will be deployed in the field in relatively fire-safe areas (using safety-zone criteria, where possible) to acquire site-specific weather data. The Fire Raws stations monitor wind speed and direction at 6 feet, air and fuel temperature, fuel moisture and relative humidity, solar radiation, and associated threshold warnings. The data are collected, stored, and forwarded to the BLM/NIFC website and are also collectable in the field by interrogating a voice radio. Additionally, existing weather stations will also be monitored and their data archived.
12. **Fire behavior/flux packages**— Measurements of fire intensity will be obtained by deploying arrays of radiometers (devices that measure radiant energy emitted by the fire). The sensor packages will be deployed ahead of a spreading fire. Deployment can occur as long as three to four hours ahead of the arrival of the fire front. The sensors and cameras are enclosed in fireproof packages that permit measurement throughout the burning period (Figure 3). These sensors are positioned to measure the vertical distribution of radiant energy emitted by the approaching flames. Small-

gauge shielded thermocouples will provide measurements of flame and air temperatures during passage of the flame front. Pitot-static type velocity probes (devices designed to measure air flow direction and magnitude) will be positioned to sense the magnitude and direction of airflow before, during, and after the fire passes. A second set of energy flux sensors will measure the total and radiant energy that is arriving at the sensor location. This information provides direct measurement of the relative magnitudes of the radiant and convective energy emitted during the fire--information needed for an accurate evaluation of fire behavior models. Flame geometry will be obtained by analysis of video images of the fire collected from visual and infrared video cameras (thermal infrared acquired during fire at effort level III) mounted in fire proof enclosures located inside or near the burned area. Analysis of the visual video images provides a relatively objective method for measuring flame height, flame length, flame depth, flame angle and fire rate of spread.

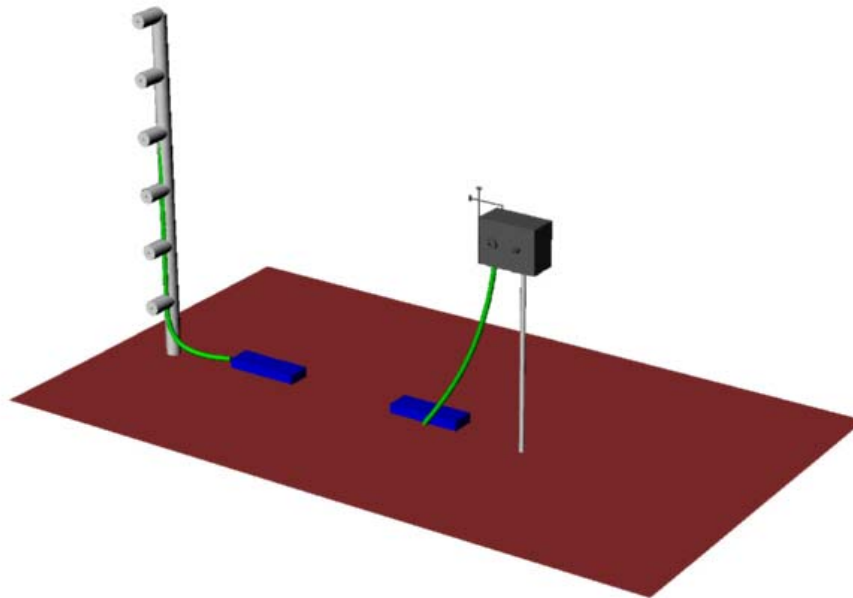


Figure 3: Illustration of a fire behavior/flux sensor fireproof package



Figure 4a.-- Visual video-capture of the test tree. Bole is instrumented with thermocouples and MedTherm bolometer.

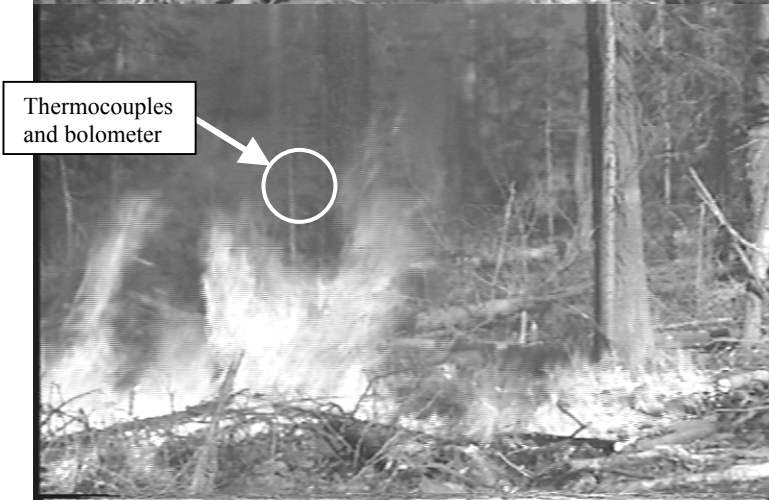


Figure 4b.-- Visual video-capture of a the test tree exposed to fire. Note the obscuration of the tree bole by the visible wavelength energy from the flames..

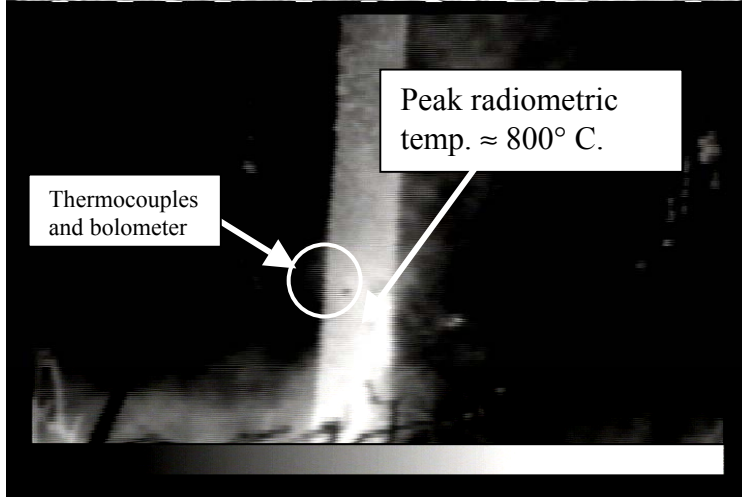


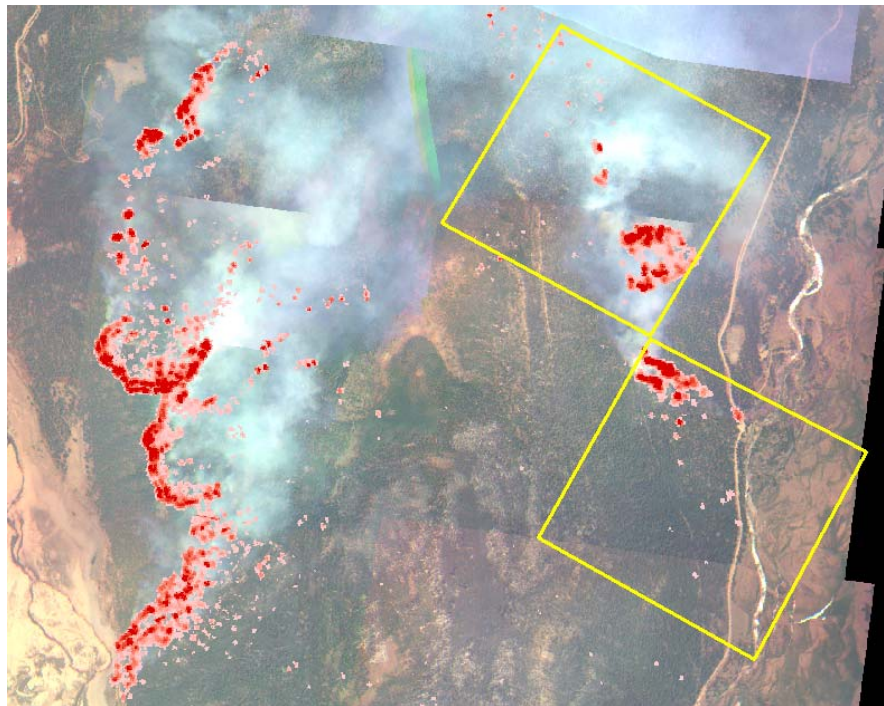
Figure 4c.-- Video-capture of a thermal infrared (TIR) image acquired in the 8-14 micron bandpass. Image was acquired simultaneously with figure 4b. Radiometric data can be converted to heat flux and temperature values by measuring the TIR energy emitted from the tree bole. Flames are transparent in this bandpass.

13. ***In situ* radiometry**— Thermal infrared (TIR) remote sensing of radiant heat flux can be done *in situ* using a TIR radiometer. Electromagnetic energy (EM) emitted from burning wildland fuel in the TIR wavelength range (bandpass) of 8-14 micrometers is

an ideal bandpass from which to derive radiometric temperatures in the presence of otherwise visibility obscuring flame structure (figures 4b and 4c). Radiometric temperature profile can then be analyzed across the entire two-dimensional space of the image. This is a significant improvement to both the quality and extent of data heretofore acquired from contact-type kinetic temperature measurements such as those from thermocouples. When integrated with data from other instruments such as those described in items #10 and #12, above, these data can then be used to invoke, calibrate, and verify models of both fire effects and fire behavior. The TIR radiometer is field-portable, can be set up in minutes, and can utilize optics of various focal lengths to establish an appropriately safe and feasible distance from fire to observer.

The Team will deploy a longwave (8-14 μm), sterling-cooled, radiometer to acquire TIR radiometric data. The instrument will be located coincident with other Level III instrumentation to enable integration of multiple observations at the same point.

14. **Airborne TIR**— Airborne operations shall consist of mapping the fire with an airborne IR camera from approximately 10000 feet above ground level. Canister samples of smoke will be taken from the smoke plume by the mapping aircraft downwind of the fire (to allow for the plume to mix). These samples are collected immediately prior to and after a mapping cycle by opening a valve on a canister containing a vacuum. The outside air is drawn in and the valve is closed. The canister is labeled and taken to the Fire Chemistry lab for analysis.



15.

Figure 5: Missionary Ridge fire on June 23, 2002. RGB backdrape and red fire intensity are from the Airborne Data Systems five band camera. The boxes are the MODIS fire detections. MODIS and the plane were over the fire within 30 minutes of each other.

Daily global satellite observations demonstrate potential for measuring local, regional, continental and global scale wildfire impact. Due to promising simulations [2, 3] and laboratory results [4], fire intensity merits consideration as a proxy both for burn severity and combustion efficiency. Burn severity measures the local impact of the wildfire, and combustion efficiency relates to the emissions (and hence the extension of the wildfire’s impact across regional and higher scales.) The dominant conundrum when attempting to measure fire intensity from space is that combustion processes occur in a fraction of a 1km² pixel. From the large satellite pixel, one must deduce the combination of fire intensity and fire area within that pixel. Once this combination is determined, fire intensity may be tested for correlation with measurable environmental and ecological parameters.

Figure 5 shows the Missionary Ridge fire on June 23, 2002 at approximately 12:30 PM MDT. The size of a typical MODIS pixel is indicated by the boxes. The boxes represent MODIS fire detections. Dark blobs are red in a color representation and represent areas of excess heat (probable fires). Fire detections are an indication that fire is present “somewhere inside” the MODIS pixel. For each MODIS fire detection, a total fire energy (intensity) for the pixel is computed. The process of finding the actual fire area and the fire intensity which was localized to that area is the conundrum mentioned above. Our pilots reported the conflagration to the west started sometime between their first and second pass over the fire (passes were ~30 minutes apart). Apparently, MODIS just missed those burns.

Several procedures for determining the subpixel mixture of burning, smoldering, cooling, and unburned ground have been proposed [1]. Some are operationally used in the production of satellite fire products and fire radiative energy. Our approach shall be to circumvent this process to the maximum extent possible. We will map fire intensity with a 3-5 micron airborne infrared camera at better than 10 m x 10 m spatial resolution seven times per day.

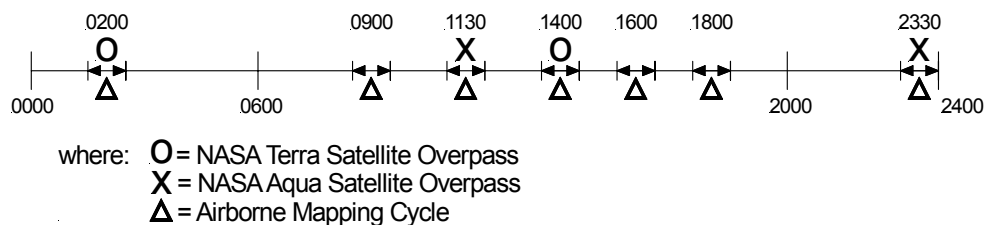


Figure 6: Airborne and satellite sampling over the diurnal cycle.

Our intent is to completely map our target fires from the air at definite intervals. Four mapping cycles per day will be concurrent with MODIS instrument overpasses. The remainder of the mapping cycles shall be distributed over the diurnal fire cycle. These remaining mapping cycles should target changes (sudden or otherwise) in fire behavior, insofar as this can be done safely and in accordance with IMT aviation procedures. A nominal mapping schedule is included in Figure 6; the actual mapping schedule will respond to the fire behavior on the scene. For this reason, there is a

synergy between our scientific interests and the vital concerns of the incident commander on the scene.

Missoula Rapid Response Team

The Missoula Rapid Response Team (MRRT) is comprised of fire professionals, scientists, and technicians. The personnel proposed for our Team are shown below in Table 4. The rapid response team leader will act as an IC for the team. He will be responsible for developing working relationships with Incident Commanders, ensuring that team members are fully trained, qualified, and equipped. During deployment on incidents, he will be in command of the rapid response team and will be responsible for team activities and coordination with the IMT.

Two key positions under the MRRT IC are the fire behavior observer and the fire effects monitor. In Level I response, they and their assistants will be responsible for plot location, site characterization, and fire behavior monitoring. At level II and higher responses, they will supervise the instrumentation crew and the site characterization/fire effects crews, respectively.

Table 4: Missoula Rapid Response Team Members and Fire Qualifications; Affiliation: 1: Fire Science Lab, USDA Forest Service, Missoula, MT; 2: Rochester Institute of Technology, Rochester, NY; 3: SEM,

NAME	TITLE	FIRE QUALIFICATIONS
Ed Mathews ^{1,I-IV}	Forester	ICT2, OSC2, FBAN, RXB1
Jason Forthofer ^{1,II-IV}	Mechanical Engineer	ICT4, CRWB, ENGB, FFT1
Kevin Ryan ¹	Project Leader	FFT2
Colin Hardy ¹	Project Leader	FFT1, RXI2
Bob Kremens ^{2,II-IV}	Senior Scientist	FFT2
Sharon Hood ^{1,I-IV}	Forester	FFT2
Bryce Nordgren ^{1,IV}	Physical Scientist	FFT2
J Meghan Salmon ^{1,IV}	Physical Scientist	FFT2
Don Long ^{1,I-IV}	GIS Analyst	THSP-GIS
Maureen Mislivets ^{1,I-IV}	GIS Analyst	THSP-GIS
Bret Butler ^{1,I-IV}	Research Mech Engineer	THSP-Fire Behavior
Dan Jimenez ^{1,II-IV}	Mechanical Engineer	FFT2
Kyle Shannon ^{1,II-IV}	Phys. Sci Technician	FFT2
Rick Stratton ^{1,I-IV}	Modeling Analyst	FFT1

Project Duration

This is a three year project. Data collection activities comprise the majority of the effort in the first two years.

Budget

Year 1

This budget sheet is for fixed costs to establish and maintain a rapid response team. Per AFP 2003-2 task 1 instructions, deployment costs will be approved with the program manager at the time of

		Total	In-Kind	Requested
			RMRS	RIT
				JFSP
		--- Thousand dollars ---		
Personnel	GS-11 Fire Behavior Analyst	36.4	36.4	
	GS-9 Image Analyst	12.0		12.0
	GS-9 Forester/IC	26.0		26.0
	GS-11 Remote Sensing Analyst	36.4		36.4
	GS-9 GIS analyst	25.0		25.0
	GS-7 Field Monitor (2 x 13 PP)	41.6		41.6
	GS-13 Research Forester (6PP)	23.4	23.4	
	GS-14 Research Forester (6PP)	25.2	25.2	
	GS-14 Research Chemist (2PP)	8.0	8.0	
	Staff Training (14 people-variable 1-4 PP)	83.0	20.0	63.0
	Subtotal	317.0	113.0	0.0
Equipment:	RMRS			
	FireRaws (2)	31.6	15.8	15.8
	TIR shortwave Camera (1)	85.0	85.0	
	TIR longwave Camera (1)	45.0	25.0	20.0
	GPS Rx (8)	3.6	1.8	1.8
	Laptop PC, ruggedized	4.0		4.0
	Laptop PC, dataloggers (4)	8.0	8.0	
	Pers. Prot. Equip. (6)	7.7	3.7	4.0
	Subtotal	184.9	139.3	0.0
Vehicles:	One crewcab; one PU	8.5		8.5
Travel/PerDiem	Coordination (6 trips)	12.0		12.0
	Training	4.0		4.0
	Subtotal	24.5	0.0	0.0
Lab Operating Costs		63.0	63.0	
Totals (RMRS)	Direct	589.4	315.3	0.0
	Indirect Cost (15%)			41.1
RIT Subcontract (development and deployment of fire sentries)		132.0		30.0
				102.0
Grand Totals				417.2

Year 2

This budget sheet is for fixed costs to establish and maintain a rapid response team. Per AFP 2003-2 task 1 instructions, Deployment costs will be approved with the program manager at the time of

		Total	In-Kind RMRS	Requested RIT	Requested JFSP
-- -- Thousand dollars -- --					
Personnel	GS-11 Fire Behavior Analyst	36.4	36.4		
	GS-9 Image Analyst	12.0			12.0
	GS-9 Forester/IC	26.0			26.0
	GS-11 Remote Sensing Analyst	36.4			36.4
	GS-9 GIS analyst	25.0			25.0
	GS-7 Field Monitor (2 x 13 PP)	41.6			41.6
	GS-13 Research Forester (6PP)	23.4	23.4		
	GS-14 Research Forester (6PP)	25.2	25.2		
	GS-14 Research Chemist (2PP)	8.0	8.0		
	Staff Training (14 people-variable 1-4 PP)	15.0	0.0		15.0
	Subtotal	249.0	93.0	0.0	156.0
Equipment:	RMRS				
	TIR shortwave Camera (1)	85.0	85.0		
	TIR longwave Camera (1)	25.0	25.0		
	GPS Rx (2)	0.9			0.9
	Laptop PC, ruggedized dataloggers (2)	4.0			4.0
	Subtotal	118.9	114.0	0.0	4.9
Vehicles:	One crewcab; one PU	8.5			8.5
Travel/PerDiem	Coordination (6 trips)	12.0			12.0
	Training	4.0			4.0
	Subtotal	24.5	0.0	0.0	24.5
Lab Operating Costs		63.0	63.0		
Totals (RMRS)	Direct	455.4	270.0	0.0	185.4
	Indirect Cost (15%)				27.8

Grand Totals
213.2

Year 3

This budget sheet is for fixed costs to establish and maintain a rapid response team. Per AFP 2003-2 task 1 instructions, Deployment costs will be approved with the program manager at the time of

		Total	In-Kind RMRS	Requested RIT	Requested JFSP
-- -- Thousand dollars -- --					
Personnel	GS-11 Fire Behavior Analyst	36.4	36.4		
	GS-9 Image Analyst	12.0			12.0
	GS-9 Forester/IC	26.0			26.0
	GS-11 Remote Sensing Analyst	36.4			36.4
	GS-9 GIS analyst	25.0			25.0
	GS-13 Research Forester (6PP)	23.4	23.4		
	GS-14 Research Forester (6PP)	25.2	25.2		
	GS-14 Research Chemist (2PP)	8.0	8.0		
	Subtotal	192.4	93.0	0.0	99.4
Equipment:	RMRS				
	TIR shortwave Camera (1)	85.0	85.0		
	TIR longwave Camera (1)	25.0	25.0		
	GPS Rx (2)	0.9			0.9
	Laptop PC, ruggedized	4.0			4.0
	dataloggers (2)	4.0	4.0		
Subtotal	118.9	114.0	0.0	4.9	
Vehicles:	One crewcab; one PU	8.5			8.5
Travel/PerDiem	Coordination (6 trips)	12.0			12.0
	Training	4.0			4.0
	Subtotal	24.5	0.0	0.0	24.5
Lab Operating Costs		63.0	63.0		
Totals (RMRS)	Direct	398.8	270.0	0.0	128.8
	Indirect Cost (15%)				19.3

Grand Totals
148.1

Summary

	Total	In-Kind RMRS	Requested RIT	Requested JFSP
	-- -- Thousand dollars -- --			
Personnel	317.0	113.0	0.0	204.0
Equipment:	184.9	139.3	0.0	45.6
Travel/PerDiem	24.5	0.0	0.0	24.5
RIT (pass-thru)	132.0		30.0	102.0
Indirect				41.1
Year 1 Total	658.4	252.3	30.0	376.1
Personnel	249.0	93.0	0.0	156.0
Equipment:	118.9	114.0	0.0	4.9
Travel/PerDiem	24.5	0.0	0.0	24.5
Indirect				27.8
Year 2 Total	392.4	207.0	0.0	185.4
Personnel	192.4	93.0	0.0	99.4
Equipment:	118.9	114.0	0.0	4.9
Travel/PerDiem	24.5	0.0	0.0	24.5
Indirect				19.3
Year 3 Total	335.8	207.0	0.0	128.8
Grand Total	1386.6	666.3	30.0	690.3

Deliverables

1. A Rapid Response Team that can deploy to wildland fires to monitor time sensitive fire environment (i.e., fuels and weather), fire behavior (i.e., radiant energy and temperature), and fire effects information.
2. New approaches for characterizing fire behavior, flame structure, and micro-climatic variables for field-deployment on wildland fires (e.g., fire sentries).
3. Provide fundamental research data to investigators and modelers of fire behavior, flame dynamics, first-order fire effects, and longer-term second-order fire effects. These fire behavior and weather data will allow scientists to validate current fire behavior and first- and second-order fire effects models (i.e., FARSITE, NEXUS, FOFEM), and identify proxies for satellite observations of fire behavior and airshed parameters (e.g., see linked proposal letter). Within four months, these data will be posted on the Fire Behavior website.
4. Refined instrumentation and technology transfer opportunities for operational application of promising technologies identified by the study.
5. Within two hours of acquisition, a fire perimeter map based on the airborne IR data will be produced and delivered to incident command's designee.

6. Within four months, the airborne fire perimeters, measured combustion efficiency from the grab samples and MODIS data shall be analyzed for correlations. These results shall be posted on the Fire Chemistry group's website.
7. Within seven months, a comparison of the observed fire growth and FARSITE predicted fire growth shall be posted on the Fire Chemistry website.
8. At the end of the project, a process shall be developed by which MODIS data are ingested into FARSITE. This will contribute to our capacity to predict wildfire smoke production and transport in real-time, enabling land managers to make informed decisions about their own smoke events. This process will be delivered to the Fire Chemistry Group. In addition to improving FARSITE modeling, this process will be used to enhance the reliability of "Automated Forecasting of Smoke Dispersion and Air Quality Using NASA Terra and Aqua Satellite Data", a Joint Fire Sciences funded project.
9. Critically evaluate the instruments, methods, and sampling protocols and make appropriate recommendations for next generation fire behavior and fire effects monitoring (e.g., fire sentry field users manual).

Technology Transfer

The cornerstone of this research and development is to improve fire behavior and effects modeling and fire monitoring. Results will be reported in the refereed literature (e.g., International Journal of Wildland Fire, Remote Sensing of Environment, and Journal of Geophysical Research) and conference proceedings. As appropriate, these results will be integrated into national and regional fire training courses for fire behavior analyst (FBAN), fire effects monitors (FEMO), field observers (FOBS), and long-term fire analyst (LTAN). A field user's manual will be developed for the deployment and operation of the disposable fire sentry units. FIREMON (www.fire.org/firemon) procedures will be upgraded as appropriate.

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Qualifications of Investigators

COLIN HARDY

Education: B.S.: *Resource Conservation*; University of Montana, School of Forestry, 1977
Master's: *Forest Resource Management*; University of Washington, College of Forest Resources, 1983
Currently: PhD Candidate, *Remote Sensing*, University of Montana, School of Forestry.

Experience:

Currently Project Leader, *Fire Behavior*, USDA Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory, Missoula, MT.

1996-2002 Supervisory Research Forester; Team Leader, *Fire Effects--Prescribed Fire and Wildfire*, USDA Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory, Missoula, MT.

1992-1996 Research Forester; *Fire Behavior*, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT.

1988-1992 Research Forester; Team Leader, *Fire and Environmental Research Applications*, USDA Forest Service, Pacific Northwest Research Station, Seattle, WA.

1984-1988 Research Forester; *Fire and Air Resource Management*, USDA Forest Service, Pacific Northwest Research Station, Seattle, WA.

1981-1983 Research Assistant; *Fire and Fuels*, University of Washington, College of Forest Resources, Seattle, WA

Committee Appointments and Special Assignments:

Standing Member; National Wildfire Coordinating Group--*Fire Use Working Team* (Interagency)
Lead Editor-Compiler, National Wildfire Coordinating Group's revisions to the *Smoke Management Guide for Prescribed and Wildland Fire—2001 edition*.

Selected Publications:

Burgan, R.E.; Hardy, C.C.; Ohlen, D.O.; Fosnight, G. 1997. Landcover groundtruth sample data. CD. Gen. Tech. rep. INT-GTR-368CD. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. CD.

Ferguson, S.A.; Hardy, C.C. 1994. Modeling smoldering emissions from prescribed broadcast burns in the Pacific Northwest. *International Journal of Wildland Fire*. 4(2): 135-142.

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Hardy, C.C.; Burgan, R.E. 1999. Evaluation of NDVI for monitoring live moisture in three vegetation types of the western U.S. *Photogrammetric Engineering and Remote Sensing*. 603-610.

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Hardy, Colin C.; Ottmar, Roger D.; Peterson, Janice L.; Core, John E. Seamon, P. eds., comps. 2000. *Smoke management guide for prescribed and wildland fire—2000 edition*. Boise, ID: National Wildfire Coordinating Group. 226 p.

Hardy, Colin C.; Hermann, S.M.; Core, J.E. 2001. The smoke management imperative. In: Hardy, Colin C.; Ottmar, Roger D.; Peterson, Janice L. [and others], comps., eds. *Smoke management guide for prescribed and wildland fire: 2001 edition*. PMS 420-2. Boise, ID: National Wildfire Coordinating Group: 21-24. Chapter 2.2.

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KEVIN C. RYAN**Education:**

1993 Ph.D. Forest Ecophysiology, U. of Montana, Missoula, MT

1976 M.S. Forest Ecology, Colorado State U., Ft. Collins, CO

1973 B.S. Forest Biology, Colorado State U., Ft. Collins, CO

Experience:

1976 - 1979: Research Forester/Fire, Forest Residues and Energy Program, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Seattle, WA

1979 - 1992: Research Forester, U.S.D.A. Forest Service, Fire Effects Project, Intermountain Fire Sciences Laboratory, Missoula, MT

1992 - 1995: Supervisory Research Forester, Team Leader, Fire and Ecosystem Processes, U.S.D.A. Forest Service, Fire Sciences Laboratory, Missoula, MT

October 1995 - Present: Project Leader, Fire Effects: Prescribed Fire and Wildfire, U.S.D.A. Forest Service, Intermountain Fire Sciences Laboratory, Missoula, MT

Society Affiliations:

Society of American Foresters: Student Mentor, Fire and Forest Ecology Working Groups; International Association of Wildland Fire: Associate Editor, *Int. J. Wildland Fire*; Association for Fire Ecology

Reviewer:

European Economic Commission's Fire Research Program; Science; Forest Science; Canadian Journal of Forest Research; International Journal of Wildland Fire; Western Journal of Applied Forestry; U.S.D.A.'s Competitive Grants and Forest Service; McIntyre-Stennis; Joint Fire Sciences Program

Publications (68 publications, 26 refereed and 42 non-refereed including):

- Ryan, K.C. 2002. Dynamic interactions between forest structure and fire behavior in boreal ecosystems. *Silva Fennica* 36(1):13-39.
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- Ryan, K. C., D. L. Peterson, and E.D. Reinhardt. 1988. Modeling long-term fire-caused mortality of Douglas-fir. *Forest Science* 34(1):190-199.

Honors and Awards:

Certificate of Merit, U.S. Forest Service, 1997, 2000, 2002; George M. Bright Memorial Fellowship, University of Montana, 1986; Sigma Xi, 1974; Xi Sigma Pi Forestry Honor Society, 1972

WEI-MIN HAOEducation

- 1986 Ph.D. Harvard University, Division of Engineering and Applied Sciences
1981 S.M. Massachusetts Institute of Technology, Dept. of Nutrition and Food Sciences
1979 S.M. Massachusetts Institute of Technology, Dept. of Earth, Atmospheric, and Planetary Sciences
1976 B.S. Fu Jen Catholic University, Taiwan, Dept. of Chemistry

Experience

- 1998- Project Leader, Fire Sciences Laboratory, Rocky Mountain Research Station, USDA Forest Service, Missoula, Montana
1994-1998 Research Chemist, Fire Sciences Laboratory, Rocky Mountain Research Station, USDA Forest Service, Missoula, Montana
1993-1994 Associate Professor (Research), Department of Chemistry, University of Montana
1991-1993 Assistant Professor (Research), Department of Chemistry, University of Montana
1986-1990 Research Scientist, Max-Planck-Institute for Chemistry, Mainz, Germany

Selected Publications

Hao, W.M., D.E. Ward, R.E. Babbitt, R.A. Susott, B.L. Nordgren, Y.J. Kaufman, B.N. Holben and D.M. Giles. Comparison of aerosol optical thickness measurements by MODIS, sun photometers, and hazemeters in Southern Africa during the SAFARI 2000 campaign, *Int. J. Remote Sensing* – SAFARI 2000 Special Issue, in press.

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BRET BUTLER

Bret Butler works in the Fire Behavior Research Work Unit at the Rocky Mountain Research Station's Intermountain Fire Sciences Laboratory in Missoula, MT. His research focuses on fundamental heat and combustion processes in wildland fire. Applications for his research include fire behavior models, links between fire behavior and effects, and firefighter safety. He came to the Forest Service in 1992 after receiving a Ph.D. in Mechanical Engineering from Brigham Young University where he studied energy transport in particle laden flames.

Relevant Publications:

Butler, B.W.; R.A. Bartlette; L.S. Bradshaw; J.D. Cohen; P.L. Andrews; T. Putnam and R.J. Mangan. 1998. Fire behavior associated with the 1994 South Canyon Fire on Storm King Mountain. USDA RMRS Res. Pap. RP-9.

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Competitive Grants:

Safety Zone Standards. October 1994. \$17,300; 1 year; Interior Fire Coordinating Committee. Resulted in publication of theoretical model for safety zone size.

Guidelines for effective fire shelter deployment. April 1997. \$39,960; 2 years; Interior Fire Coordinating Committee. Due to anticipated major shift in shelter design these funds were used to obtain measurements on only two fires, one in Alaska and one in high elevation sage brush. Remaining funds were used to develop guidelines for firefighter escape routes.

A Proposal for Development and Implementation of a System for the Prediction of Fire-Induced Shrub and Tree Mortality. November, 2000. \$396,950; 3 years; Joint Fire Sciences Program. This effort is just completing year 1 of a three year study. A two dimensional theoretical model of energy transfer through a plant stem has been formulated. A parallel effort is directed at laboratory studies to obtain data for evaluation of the model.

BOB KREMENS**Professional Experience**

Senior Research Scientist 2000 - Present
Digital Imaging and Remote Sensing
Rochester Institute for Technology
Rochester, N.Y.

Senior Principal Consultant 1998 - 2000
Special Projects
Questra Consulting
Rochester, N.Y.

Scientist 1988 - 1998
Group Leader, Nuclear Diagnostics
University of Rochester
Laboratory for Laser Energetics
Rochester, N.Y.

Education

MS Environmental Studies, University of Rochester, Rochester, NY, 2000
Ph.D. Physics, New York University, New York, NY, 1981
MS Physics, New York University, New York, NY, 1977
BS Physics, The Cooper Union, New York, NY, 1975

Publications

Low Cost Autonomous Field-Deployable Environment Sensors, Robert L. Kremens, Andrew J. Gallagher, Adolph Seema, American Institute of Physics Proceedings of the Unattended Radiation Sensor Systems for Remote Applications Symposium, Vol. 632, July 2002

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R. L. Kremens, A. Vodacek, A. J. Fordham, S. C. VanGorden, D. Luisi, J. R. Schott, International Journal of Remote Sensing Vol.23 2721-2726.

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