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USGS REMOTE SENSING FOR FIRE SCIENCE APPLICATIONS: A STRATEGY

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(October 21, 2002)

Wildland fire is a major and potentially catastrophic disturbance affecting our nation's ecosystems and their interface with urban areas. As part of an overall fire management policy to restore fire-prone ecosystems and reduce fire hazard, the National Fire Plan calls for use of technologies such as remote sensing to assess risk and identify opportunities for reducing risk at multiple scales. Since the historic 2000 fire season, the U.S. Geological Survey (USGS) has repeatedly called for increased bureau-wide actions directed toward fire research and development opportunities. Fire research and applications are now prominently featured in USGS missions such as the Geographic Analysis and Monitoring Five Year Plan and regional initiatives such as the Central Region Integrated Science Partnership initiative.

In response to the national needs and action requests from the USGS and Department of Interior (DOI), the USGS EROS Data Center has initiated several fire research activities. These new projects (fire fuels assessment, fire danger forecasting, and post-fire mapping and analysis) are but an example of many efforts by USGS remote sensing scientists bureau wide. These individually developed research activities represent not only increased funding to USGS, but also critical science contributions to the fire science community and federal fire management agencies. However, it is proposed that current USGS activities could be organized into a more cohesive fire science structure in order to provide enhanced research efficiency and visibility both within USGS or other federal agencies such as Forest Service. This white paper is focused on USGS remote sensing roles in a potentially integrated fire science strategy by presenting a process and suggesting a project structure for a USGS fire science research agenda.

Assessment of Opportunities for USGS Remote Sensing

Fire management needs for remote sensing research and applications are clearly defined in the National Fire Plan (NFP), the Joint Fire Science Program (JFSP), U.S. Congress General Accounting Office (GAO) reports[1], and the Forest Service and DOI 10-Year Comprehensive Strategy. These documents stipulate that there is a consistent need to develop spatial technology and data about fires, fuels characteristics and burns. Table 1 lists NFP priorities in the next 10 years, and two possible remote sensing applications needed to implement these priorities.

Table 1. National Fire Plan priorities and corresponding remote sensing applications.

Firefighting	Rehab/restoration	Fuel reduction	Accountability
Fire fuels to simulate fire behavior	Rapid response burn severity mapping	Vegetation mapping (types and structure)	Mapping of controlled burns

[1] January 2002 GAO Report 02-259: "Currently, fire data are not yet available to make informed decisions and to measure progress."

Fire danger forecasting	Extended burn severity mapping	Fire fuels for fire spread models	Regional vegetation monitoring

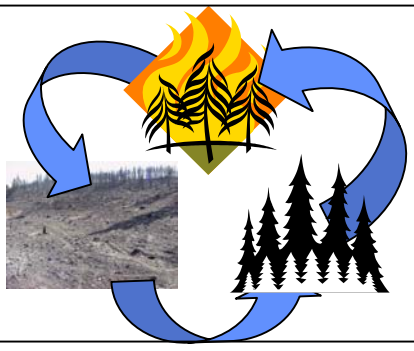
There are many other uses of remote sensing research and applications, in addition to those listed in Table 1. For example, to improve firefighting safety, agencies may need to map fire history (old burn scars) in order to 1) understand where further fuel reduction should take place, and 2) plot potential firefighter retreat routes. Almost any rehabilitation decision begins with accurate mapping of burn severity, including possibility of timber salvation. For fire directors, dependable fire danger forecasting is a tool for resource allocation and overall preparedness.

There are other government and non-government programs that conduct research and apply remote sensing techniques for monitoring live fire, fire spread and burn scars in various regions of the country and world. However, fire management needs at various levels require that remote sensing research and development cover large areas and produce results that can be used in large-area management applications. Such a program with national (or even regional) capabilities does not apparently exist. USGS (particularly EDC), with strong remote sensing research and production capabilities, is in a good position to step up its fire science efforts and meet the national fire needs in a systematic and programmatic fashion. An active responsiveness to land and fire management needs with increased R&D for fire issues on federal lands are clearly roles and responsibilities defined for federal research organizations such as the USGS.

Organization of USGS Remote Sensing for Fire Applications

Wildland fire is common natural process that occurs in many ecosystems of the US and the world. Such fire-adapted ecosystems go through natural cycles of fire risk and ignition of live fire, burn scar, recovery and vegetation succession, and accumulation of fire fuels posting fire risk again. Figure 1 is a simplistic rendition of natural fire cycle in three phases: live fire, burn scar, and accumulation of fire fuels.

Figure 1. Three phases in a wildland fire cycle: 1): fire ignition and spread, 2) burn lands altering ecosystem components and conditions, and 3) accumulation of fire fuels



Fire management issues, corresponding to different phases of a fire cycle, require different but related research approaches and technologies. For example, fire fuels reduction require mapping of the spatial distribution of vegetation characteristics and fuel models, whereas the monitoring and forecasting of fire ignition danger primarily depends upon coarse-resolution satellite data and weather models. However, the use of accurate fuel models will make fire danger forecasting more consistent and accurate.

In fact, many USGS geospatial fire applications are issue-driven research and development activities, including those of the EROS Data Center, Rocky Mountain Mapping Center, and USGS BRD. These current efforts, such as the Rocky Mountain Mapping Center's web-based fire and burn application GEOMAC and BRD's long-term research sites, offer excellent partnership opportunities to demonstrate the effectiveness of an integrated Fire Science Program. A common characteristic of these fire activities is their responsiveness to identified fire science and management needs (such as fire fuels and burn monitoring) at the project level and beyond, using strong USGS capabilities in remote sensing, GIS and spatial modeling. Still, we should ask whether an established and integrated fire science program would underscore USGS commitment to fire community needs for spatial information and technology, and streamline management, operation, and funding opportunities of both active and potential fire projects in USGS bureau-wide.

As an example, Table 2 below illustrates how current fire applications at EDC are organized according to phases of the fire cycle (therefore to distinctive management concerns). It may also be noted from the table that these projects are mostly funded on a reimbursable basis and operated in partnership with many other federal agencies.

Table 2. USGS EROS Data Center fire applications using remote sensing, organized on the basis of fire management issues.

Issues	Project	Funding source	Partners
Fire danger monitoring and forecasting	Greenness Mapping and fire danger monitoring	USGS and USFS	USFS
	Improved Fire Potential Index model as a tool for fire danger forecasting	Proposed to USGS	USFS, University
Post-fire mapping and analysis	Validation of burn severity mapping	Joint Fire Science Program	NPS, BRD
	Burn severity mapping production	NPS, BLM	NPS, BRD, BLM
	Relating fire effects with burn severity mapping	USGS	
Fire fuels assessment	Characterizing fire fuels parameters using new vegetation mapping methods	JFSP	BRD, USFS
	Mapping vegetation types and structure at 30-m resolution (LANDFIRE)	DOI and USFS	USFS, DOI

Organizing fire research activities by natural fire cycle has obvious programmatic advantages. First, it forces our research to be issue driven, thus linking research topics and results directly with the concerns of fire managers. Second, it could help strengthen future funding requests by clearly demonstrating the value of USGS remote sensing research to specific areas of fire management. In addition, as in the case of the EROS Data Center, remote sensing R&D is often a team effort.

Fire and Fire-Adapted Ecosystem Research Needs[2]

Wildland fires present many complex issues that bring with them challenging research needs. USGS remote sensing scientists should conduct studies that are relevance to fire management issues and compatible with USGS technical capabilities, long-term vision (such as the National Map) and research plans (e.g. Geographic Analysis and Monitoring Five-Year Plan). Based on these criteria, EDC should focus on the following research topics:

- Fuels mapping techniques and strategies. Mapping fire fuels requires data and information about vegetation types, structure, and aboveground biomass. How can we design mapping and modeling research to measure canopy height, stand size, canopy closure, and understory vegetation in an operational mode? Can we effectively integrate field data with satellite imagery to derive desired variables? Will modeling of ecological principles be effective for deriving vegetation types and structure classes? Will the overall mapping strategy be repeatable? Can re-measured field plot data drive updating of land/vegetation maps? There is also a critical need to incorporate LIDAR, IFSAR technologies and expertise at EDC to applications of land and vegetation mapping and characterization.

- Improvement in monitoring and forecasting risk factors using tools such as Fire Potential Index (FPI). Here the focus should be on studies that lead to a better understanding of 1) vegetation conditions such as moisture content, percent green vegetation, and fuel models; and 2) the impact of climate and weather variability, spatially and temporally, on fire risks.

- Post-fire mapping and analysis. Many research questions must be addressed before remote sensing can be used consistently to provide data for burn severity and link burn severity to physical and biogeochemical processes. Performance (sensitivity, robustness) of burn-area mapping algorithms under different ecosystem and fire history conditions should be studied and calibrated. Can burn severity mapping be used to monitor land cover change regimes such as vegetation succession and invasive weeds? How is mapped fire severity related to post-fire water yield, soil erosion, vegetation succession, and carbon emission to atmosphere? These research areas need to be studied before EDC can effectively implement operational post-fire remote sensing support.

EDC Fire Science Goal and Objectives

Improving our understanding of the current and historical spatial dynamics of fire and its effects should be a foundation for a comprehensive USGS and EROS Data Center remote sensing fire science direction. Research, data production, and applications should be emphasized as important components at EDC. To accomplish this goal, EDC scientists will:

- Focus on fire science priorities that are identified by national and international fire programs (such as the National Fire Plan and the Interagency Fire Science Program) and that can be addressed by using remote sensing, GIS, and landscape ecology principles and tools.

[2] Although the following sections are primarily devoted to EROS Data Center – the largest center of USGS, most of the discussion should also apply to USGS remote sensing.

- Develop techniques, models and datasets at varying scales depending on applications. Emphasize landscape-scale applications to match project-level fire management needs, but also play an active role in coarse-resolution fire applications such as fire risk forecasting and burn scar mapping.

- Focus on DOI agencies and other management and science community needs for fire data. In particular, EDC will develop production capabilities to meet data needs for fire fuels and post-fire rehabilitation and restoration.

- Relate fire research to other environmental problems where fire plays an important role, such as land cover and land use change and carbon emission.

Operating Principles for EDC Fire Science

The key to success for EDC (and USGS) Fire Science may be responsiveness to the needs and issues of federal fire management agencies and programs. Therefore, project organization, operation, and deliverables should be directly related to fire science, fire/land management, and funding objectives. Project scientists should carefully select and conduct research that addresses important issues defined by the fire community.

Future studies should be proposed with goals to improve monitoring efforts for fire hazard and to improve data exchange capabilities.

It is very important that fire research and development at EDC is conducted on the basis of broad cooperation, both with existing USGS programs in land cover and remote sensing, and with other federal agencies and universities. Without such cooperation, the probability of success could be very low. As the current fire projects at EDC show, fire R&D goes 'hand-and-hand' with land cover mapping and characterization. Thus, it is imperative that the two activities work closely with each other, including coupling of project design and implementation.

Lastly, EDC fire science management must be given high attention. The level of effort by EDC scientists and customer expectations require that we manage EDC fire science carefully and effectively. Projects should be staffed with qualified research scientists. Principal investigators should have overall responsibly for their projects.

Conditions for Success

The scope of the integrated EDC Fire Science Project is to conduct research and development in the three focus areas: fire fuels assessment, fire danger monitoring/forecasting, and post-fire mapping and analysis. Currently for these areas, we operate on the basis of reimbursable funding obtained as the result of competitive grant writing and interagency cooperation (the NPS and LANDFIRE projects). Available to these projects are several experienced EDC scientists.

These cooperative projects (with the USGS BRD, other DOI agencies, other federal agencies) reflect a mixed funding situation, including direct funding by federal agencies and competitively

funded projects. While most such projects are typical for a three-year duration, the longevity of EDC fire science will depend on our abilities to respond to fire community needs, select research areas, and show results.

Additionally there will be an early need for a web-based interactive user interface with functionalities including: live fire monitoring in a geospatial framework, user identification of fire locations and geographic coordinates, posting map results for downloading, and long-term archival of fire histories and atlases.

Cutting edge research should be pursued whenever possible while operational, practical methods are employed in order to achieve data production goals. Scientists should look into the state-of-the-art technologies, including SAR applications, LIDAR applications, integration of field inventory plots with satellite imagery, the use of vegetation ecology rules and principles, and incorporation of meteorological models in monitoring.

Staff scientists should actively pursue publication and conference opportunities. Ability to write and synthesize research results will be promoted within EDC Fire Science. We will emphasize writing skills and encourage publications and grant writing.

EDC Fire Science should not overlook technology transfer. When given the opportunity, we should do our best to transfer research results and data to land management agencies, non-governmental organizations and Native American communities.