2009 BFRL Project Description

Project Title: Fires in the Wildland-Urban Interface – Development of an Outdoor-Scale Fire Model.

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BFRL Program: Reduced Risk of Fire Spread in Wildland-Urban Interface Communities

Objective: Construct models for predicting the behavior of wildland-urban interface (WUI) fires in order to better assess and mitigate a WUI community's fire risk. Working suite of WUI fire models and WUI fuels database building methods will be completed.

Problem:

What is the problem? Fires in the wildland-urban interface (WUI) are an international problem with significant ongoing costs (see program description). Current firespread models capable of operating over WUI community scales (1000s meters) are limited to vegetative fuels and rely heavily on empirical relations. Physics-based models are needed that adequately capture firespread through WUI fuels (vegetation and structures) over neighborhood (100 s meters) to community (1000s meters) scales. Such models can be used improve our understanding of fire behavior in WUI communities and assess and advance risk assessment and mitigation methods. Existing methods of risk assessment and mitigation are rule based and do not take into account the range of conditions that represent realistic WUI communities (e.g., the range of housing densities and environmental conditions).

This project addresses problems raised by the Western Governors Association[1], the Office of the Federal Coordinator for Meteorological Services (OFCM) and Supporting Research[2], and the National Science and Technology Council report on disaster reduction[3] all of which call for increased research leading to a greater understanding of wildland and WUI fire behavior.

Why is it hard to solve? The physical processes in WUI fire behavior exist across a large range of scales: from the ignition event (sub-meter) to smoke transport through communities and interactions with larger scale atmosphere dynamics (1000s meters). This presents a significant

[1] Western Governor's Association Policy Resolution 05-04, June 14, 2005 (www.westgov.org/wga/policy/05/fire-weather.pdf) (last accessed 5/27/08)
[2] National Wildland Fire Weather: A Summary of User Needs and Issues, Office of the Federal Coordinator for Meteorological Service and Supporting Research, July 3, 2007
[3] "Wildland Fire" Grand Challenges for Disaster Reduction, National Science and Technology Council, Subcommittee on Disaster Reduction, www.sdr.gov (last accessed 5/27/08)

challenge to numerical modeling since computer resources (memory capacity and processor speeds) can not support models of equal physical fidelity across all the relevant spatial and time scales. Modeling approaches that adequately capture the small scale physics (1 cm) of combustion can not, in practice, be applied to fires that are 100s meters long. Also, observations and measurements relevant to WUI fire behavior are needed (both at the field scale and in the laboratory) in order to validate and develop a WUI fire model. An effective method for creating a community-wide database of WUI fuels (structures and vegetation) and terrain is needed to supply model inputs. This database has the potential to be very large. The key components of this community database need to be identified in order to make data collection more practicable.

How is it solved today, and by whom? Currently no WUI fire behavior model exists that includes realistic WUI fuels and environmental conditions. NIST is currently developing WUI models at both the structural and community scales. These models, and a methodology for obtaining WUI fuels information from remote sensing data, are in their early stages. The US Forest Service (USFS) has an established, empirically based, wildland (not WUI) suite of firespread models[4]. NOAA has a fire weather prediction system that provides weather predictions relevant to fire behavior, but does not model fire behavior. The European Union's Fire Paradox[5] project was organized recently to, in part, develop new methods of reducing the risks of WUI communities from wildfires.

Currently, the most prominent fuels database is LANDFIRE[6], which is nationwide and Geographic Information System (GIS) based but for wildland fuels only. Neither a WUI fuels database, nor a proven methodology for creating such a database, for the purposes proposed exists.

Why NIST? The objectives of this project supports BFRL's mission and vision by providing measurement science and technology that will enable the development of new standards and risk assessment tools that reduce the destructive impact of wildfires on WUI communities. Thus, the project directly supports BFRL's strategic priority of Measurement Science for Innovative Fire Protection. The proposed work is consistent with, and advances, BFRL's core competency in fire protection and fire spread in communities.

Approach:

What is the new technical idea? There are two main technical ideas. The first is to construct physics-based models for predicting WUI fire behavior. These models will cover the range of appropriate WUI scales, can be used to advance our understanding of fire behavior in the complex WUI fuels system, and will lead to improved risk assessment and risk mitigation approaches for WUI communities.

The second new technical idea is to develop and test methodologies for managing and using information on the fuels and terrain in WUI communities using state-of-the-art GIS tools. The resulting database of WUI community information will provide inputs for fire behavior

[4] US Forest Service suite of wildland firespread models (2008) www.fire.org (last accessed 5/27/08)
[5] FIRE PARADOX (2008) www.fireparadox.org (last accessed 5/27/08)
[6] Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) (2008) www.landfire.gov/ (last accessed 5/27/08)

models and will also be valuable for risk assessment tools that do not rely on fire behavior models. This work will be done through a continued collaboration with the Coeur d'Alene Indian Tribe GIS program (a NIST grantee) and, potentially, new collaborations with academic partners at San Diego State University.

Why can we succeed now? Continuing advances in affordable computational resources (especially multiprocessor computers), advances in remote sensing technologies for obtaining wildland and WUI fuel information, and end-user interest and commitment (as reported by the WGA[1] and OFCM[2]; and evidenced by external funding) to improve WUI and wildland fire behavior models all support a successful effort. The proven synergies with, and complementary aspects of, the other projects in the WUI program at NIST also significantly raise the chances for success.

What is the research plan? Work will continue on extending NIST's Fire Dynamics Simulator (FDS) to handle fire spread in the WUI. The resulting computer simulation code has been named WFDS for WUI Fire Dynamics Simulator. Three major areas of WFDS development will occur simultaneously, each is addressed individually in the following paragraphs.

The first area of WFDS development is to add and test the capability of simulating fire spread at laboratory (meters) to the neighborhood scale (100s meters). This directly builds upon the current form of FDS. Model testing and refinement will occur in collaboration with the USFS and with the structure ignition and post-fire analysis projects in the WUI program. Project Outcome: a working firespread model that is well tested on laboratory scale problems, with proven capabilities at the community scale; established beta-user base of USFS researchers.

The second area of WFDS development is to add the capability of simulating firespread at community scales (1000s meters). Due to the much larger spatial scales of interest, this modeling approach will be distinctly different from the first area of model development. A new collaboration with NOAA, NCAR, and the University of Utah will facilitate the development of community-scale fire modeling in WFDS. This collaboration will be two-way, as NIST will help implement and validate simple fire models within NOAA's fire weather model. Project outcome: a working prototype community-scale fire spread model in WFDS and in NOAA's fire weather prediction system.

The third area of WFDS model development will initiate the use of adaptive mesh refinement (AMR). This approach has the potential to simulate, with one "solver", fire spread processes across a wider range of scales (i.e., from the structure to the community scale), thus encompassing the first two approaches. This could allow very computationally efficient firespread simulations over large spatial scales while retaining a higher degree of physical fidelity in fire and fire-atmosphere physics. Project outcome: a working prototype of an AMR based fire behavior model.

With regard to a WUI database (fuels and terrain), NIST, in collaboration with the Coeur d'Alene Indian Tribe GIS program (a NIST grantee), will identify a representative high risk WUI community. Methodologies for developing a GIS based WUI community database will then be developed and tested. The San Diego area is a probable location and initial progress has been made already by redirecting FY2008 funds and effort after the October 2007 fires. Project

outcome: A working methodology and GIS based tool for creating a WUI database of information relevant to both the firespread behavior models and community risk assessment methods (i.e., vegetation and structure properties, terrain, and roads).

All areas will require new visualization capabilities in BFRL's visualization tool, Smokeview.

Recent Results:

Outputs

- Three peer reviewed papers[7-10] (co-author and first author) and approximately 15 conference presentations (four invited[11-14]), all WUI related.
- Reports from national panel activity[15-18].
- Two fire grants were issued: (1) FY2006 Coeur d'Alene Indian Tribe's GIS program (currently near completion). They developed a first generation approach for developing WUI fuels database via remote sensing data acquisition and GIS-based data storage and analysis; (2) FY2007 University of Utah Meteorology Department. Currently in first year. Objective is to support the extension of WFDS to include necessary atmospheric physics.
- As a result of interactions with the USFS, an Interagency Agreement was established with funding to NIST in FY2008.
- FY 2006 to present: Member of a number of influential national panels (OFCM Fire Weather Needs Assessment (completed), Subcommittee on Disaster Reduction (ongoing), WUI National Blue Ribbon Panel (completed), USFS Research Assumptions Panel (completed), FEMA Wildfire Panel (ongoing), NOAA Fire Weather Science Advisory Board Working Group (ongoing)) all of which have (or will) produced nationally disseminated reports or working documents.

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[7] Mell, W.E. Charney, J.J. , Jenkins, M.A., Cheney, P. , Gould J., "Numerical simulations of grassland fire behavior from the LANL-FIRETEC and NIST-WFDS models," *Remote Sensing and Modeling Applications to Wildland fires*, to appear

[9] Mell, W.E. M.A. Jenkins, J. Gould, P. Cheney, "A physics-based approach to modelling grassland fires," *Intnl. J.Wildland Fire*, Vol. 16, pp. 1-22 (2007)

[10] Rehm, R.R. Mell, W.E. "A Simple Model for Wind Effects of Burning Structures and Topography on WUI Surface-Fire Propagation," *Intnl. J. Wildland Fire*, to appear

[11] Mell, W.E. & Maranghides, A. "Wildland-Urban Interface Fires," invited seminar, San Diego State University Dept. of Mechanical Engineering, March 27, 2008.

[12] Maranghides, A. & Mell, W.E., "Fire Investigation – Determining Fire Behavior from Post-Fire Analysis," invited talk, Joint NASA/USDA Forest Service Wildfire Recovery Initiative, CalTech, November 28, 2007

[13] Mell, W.E., Maranghides, A., Forney, G., "NIST's Wildland-Urban Interface Fire Project," invited talk, National Blue Ribbon Panel Meeting, October 23, 2007

[14] Mell, W.E. & Maranghides, A., "Modeling Wildland and Wildland-Urban Interface Fires," invited talk, Eastern States Section of the Combustion Institute, Univ. of Virginia, Charlottesville, VA, October 21, 2007

[15] "The Future of Wildland Fire Management, Advance Briefing Report for the Quadrennial Fire Review Working Panels," The Brooking Inst., January 15, 2008

[16] "Grand Challenges for Disaster Reduction," (wildland fire element), National Science and Technology Council report of the Subcommittee on Disaster Reduction, February 1, 2008.

[17] "National Widland Fire Weather: A Summary of User Needs and Issues," Office of the Federal Coordinator for [19] [18] Meteorological Service and Supporting Research, July 3, 2007.

"The Blue Ribbon Panel on Wildland/Urban Interface Fire," International Code Council, April 7, 2008

Outcomes

- A collaborative effort with NOAA and NCAR was initiated with the objective of improving NOAA's Fire Weather Predictions, which are used by incident commanders in response to large wildfires.

Standards and Codes: Both the fire spread models and the WUI database are expected to support the development of WUI related standards. Both the PI and Co-PI Maranghides are members of the NFPA Forest and Rural Fire Protection Standards Committee.

Anticipated Impact

Adoption of new codes and standards (e.g., via the NFPA Forest and Rural Fire Protection Standards Committee) developed with support from measurement science (e.g., computer tools) outputs of this project. Implementation of new model-based strategic risk assessment tools by city and state fire officials and communities.

Future Impacts

- Adoption of improved risk assessment and mitigation methods, including codes and standards, leading to reduced damages and improved safety in communities affected by WUI fires.
- Improvements in NOAA's Fire Weather Prediction System improve situational awareness in WUI and wildland fires, resulting in more effective and safe disaster response.