2009 BFRL Project Description

Project Title: Experimental Investigation of Structural Ignition in Wildland-Urban Interface (WUI) Fires

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

Objective: Develop an experimental database to support the development of risk assessment and mitigation tools, including test methods and computer models, for application to structural ignition in WUI fires; field, full scale, and reduced scale experiments will be conducted to investigate the ignition of structures.

Problem:

What is the problem? The Wildland-Urban Interface (WUI) is defined as a location where structures meet or intermingle with undeveloped wildland. There is a lack of quantitative information on the processes of structure ignition in WUI fires. Anecdotal evidence suggests that spotting is the major source of structural ignition in WUI fires. Spot fires are defined as new fires that propagate away from the main fire line due to lofted firebrands. Understanding how these hot firebrands can ignite surrounding structures is an important consideration in mitigating fire spread in communities. The proposed experimental effort will develop the knowledge required to reduce the number of structures lost during WUI fires. Improved understanding as to how structures ignite in WUI fires was listed as one of the major recommendations in the GAO report (2005)[1].

Why is it hard to solve? Without physical knowledge regarding how firebrands ignite structures in WUI fires, it is impossible to develop risk assessment and mitigation tools intended to reduce structure losses in these fires. Specifically, building codes and standards are needed to guide construction of new structures in areas known to be prone to WUI fires in order to reduce the risk of structural ignition in the event of a firebrand attack. For these standards to be relevant, a thorough scientific methodology must be developed to understand the types of materials (*e.g.* roofing and siding materials) that can be ignited by firebrands as well as vulnerable points on a structure where firebrands may easily enter (*e.g.* building vents); this project will develop these

[1] 'Technology Assessment: Protecting Structures and Improving Communications During Wildland Fires.' GAO-05-380 (Washington, DC).

methodologies. It is difficult to develop measurement methods to replicate a firebrand attack on structures that occur in actual WUI fires. Entirely new experimental approaches are required to address this problem. In particular, the capability to generate and engineer specific firebrand size and mass distributions (based on distributions measured from burning vegetation and structures) and direct this firebrand flux towards full scale components of structures is required. Furthermore, the generation of firebrand flux must be done in a full scale wind tunnel facility designed to conduct fire tests since wind plays a key role in WUI fire spread.

How is it solved today, and by whom? Fire risk to WUI communities is currently mitigated by either reducing wildland fuel loading or by following a number of homeowner risk reduction practices. The various fuel treatment methods used are based on very limited scientific study, leaving their effectiveness largely unproven, especially with regard to preventing structure ignition. Most of these risk reduction practices follow rule-based and empirically determined checklists that lack testing and are not the result of a coordinated scientific based effort. Accordingly, scientifically based test methods are required and need to be tied to realistic WUI fire conditions to understand structure ignition in WUI fires. Universities (UC Berkeley) have developed some standard test methods for radiant ignition but scientifically based test methods are lacking and are needed with regard to structure ignition due to firebrand attack on structures.

Why NIST? BFRL has an international reputation in developing unbiased scientific methodologies necessary for new building codes and standards. Developing test methods to understand structure ignition in WUI fires is consistent with BRFL's core competency of fire protection and fire spread within buildings and with the measurement science for innovative fire protection strategic priority. The proposed team has the requisite expertise to tackle this important problem.

Approach:

What is the new technical idea? The new technical ideas include both field scale, full scale, and reduced scale experiments that will be conducted to quantify the vulnerability of structures to ignition in WUI fires. The full scale and reduced scale experiments will make use of a unique, one of a kind experimental apparatus developed in support of the project; the BFRL-NIST Firebrand Generator (or BFRL-NIST Dragon). The BFRL-NIST Dragon can generate a controlled flux of firebrands on a realistic scale and direct this firebrand flux onto components of a structure to ascertain their resistance to ignition as a part of a full scale structural system. In addition to this, the investigators have co-developed unique field deployable instrumentation that can be used to quantify the ignition of structures during actual fires in field scale experiments. The field deployable instrumentation can image structures under fire attack and provide quantitative information on heat flux, firebrand size and mass distribution, local wind speed and direction, local temperature, and humidity.

Why can we succeed now? Progress is now possible due to the unique BFRL-NIST Firebrand Generator coupled to an extended stay by Manzello at the world-class Fire Research Wind Tunnel Facility (FRWTF) at the Building Research Institute (BRI) in Japan. Manzello was awarded a fellowship in engineering sciences from the Japan Society for the Promotion of Science (JSPS) in 2008. This fellowship will allow for detailed experimental studies to be

conducted at BRI's unique FRWTF. Furthermore, targeted Firebrand Generator experiments are now possible due to input from BFRL-NIST's post-fire analysis of WUI fires effort (Maranghides is the PI). Post-fire analysis has identified potential vulnerabilities that common ceramic roofing assemblies may have due to firebrand attack; experiments will be targeted to these as well as other potential vulnerabilities. The collaboration among Manzello and Maranghides guarantees that the experiments delineated below are relevant to observations from actual WUI fires. This range of collaboration, in conjunction with Mell's modeling of WUI fire behavior and Butry's WUI economic analysis, is unprecedented in WUI research.

What is the research plan?

Firebrand Generator Testing

Full scale laboratory experiments will be conducted to investigate the ignition of structures due to firebrand attack using the BFRL-NIST Firebrand Generator. BFRL-NIST's Post-Fire Analysis (Maranghides is the PI) will provide key input to these experiments. During Manzello's stay at BRI, this work will investigate vulnerable roofing designs to firebrand attack; different roofing designs will be constructed at BRI for testing. In the proposed experiments, the Firebrand Generator will be used to direct various firebrand fluxes towards the constructed roofs. For a fixed wind tunnel flow sufficient to loft firebrands produced from the generator, a specific roof will be constructed using a certain type of roofing material (*i.e.* shingles and substructure). The firebrand fluxes generated using the firebrand generator will be tuned to include those from vegetation (*e.g.* trees) and extended to include those from structures. In addition to engineering the size and mass distribution of firebrand fluxes generated, the duration of the firebrand exposure (on the order of tens of seconds) and its impact location can be controlled using the Firebrand Generator. During WUI fire spread, firebrands produced from structures become important as well; the firebrand generator will be tuned to produce structural firebrands based on upon previous work conducted in the USA and Japan. The influence of roofing materials, such as asphalt shingles, ceramic tile shingles, and wood shingles will be investigated. While ceramic tile shingles are clearly not ignitable; gaps exists where tile shingles overlap and firebrands may accumulate in these crevices and ignite the roof substructure. For wood shingles, not only will the material be varied but commercial wood coatings designed to prevent ignition will be tested. Once the vulnerabilities of roofing types have been identified, it will be possible to provide guidance for new and improved roofing design. For existing structures, it will be possible to retrofit roofing constructions to provide enhanced fire resistance. In addition to ignition testing at BRI, experiments designed to investigate firebrand transport for WFDS model validation will be conducted. Finally, a reduced scale wind tunnel has been designed and completed at BFRL-NIST in FY08. Extensive testing will be conducted by coupling a reduced scale Firebrand Generator to this device. In addition to ignition testing, a full suite of measurements will be performed investigating drag from vegetation.

Rapid Response Instrumentation

A second generation rapidly deployable system will be developed to be used during actual WUI fires to quantify structural ignition mechanisms. In FY08, a first generation deployable measurements system was co-developed and tested successfully in a prescribed fire in the New Jersey Pine Barrens. The second generation system will be used to quantify structure ignition in a variety of prescribed fires in the Western USA. The second generation system will allow far more measurement stations to image multiple structures exposed to fires as well as incorporate

improvements to collect quantitative information on heat flux, firebrand size and mass distribution, local wind speed and direction, local temperature, and humidity for a longer duration. Potential collaborative opportunities are being explored with University of Idaho, USFS in Alaska, and CALFIRE in California.

Recent Results:
A total of six archival journal articles, six conference proceedings, six invited lectures, international research fellowship (JSPS), guest scientists (2) as well as NRC post-doctoral applicants (1), and MOU with Building Research Institute in Japan.

Output

Output: S.L. Manzello, T.G. Cleary, J.R. Shields, A. Maranghides, W.E. Mell, J.C. Yang, "An Experimental Investigation of Firebrands: Generation and Ignition of Fuel Beds", *Fire Safety Journal*, 43:226-233, 2008.

Output: S.L. Manzello, A. Maranghides, W.E. Mell, Firebrand Generation from Burning Vegetation, *Int'l J. Wildland Fire*, 16:458-462, 2007.

Output: S.L. Manzello, T.G. Cleary, J.R. Shields, A. Maranghides, W.E. Mell, J.C. Yang, Y. Hayashi, D. Nii, T. Kurita, "On the Development and Characterization of a Firebrand Generator", *Fire Safety Journal*, 43:258-268, 2008.

Output: S.L. Manzello, A. Maranghides, W.E. Mell, Y. Hayashi, D. Nii, "Mass and Size Distribution of Firebrands Generated from Burning Korean Pine Trees", *Fire and Materials*, accepted in press, 2008.

Output: S.L. Manzello, J.R. Shields, Y. Hayashi, D. Nii, Investigating the Vulnerabilities of Structures to Ignition From a Firebrand Attack, *Fire Safety Science, 9* accepted in press, 2008.

Output: S.L. Manzello, S. Park, and T.G. Cleary, Investigation on the Ability of Glowing Firebrands Deposited Within Crevices to Ignite Common Building Materials, in review, *Fire Safety Journal*, 2008.

Output: S.L. Manzello, S.H. Park, T.G. Cleary, and J.C. Yang, Determining Conditions for the Ignition of Building Materials in Contact With Glowing Firebrands, Poster Presentation, *Proceedings of the Combustion Institute*, Montreal, 2008.

Output: S.L. Manzello, "Firebrand Generation from Vegetation and Ignitability of Fuel Beds by Firebrands", 2nd Fire Behavior and Fuels Conference, Destin, FL, March 2007.

Output: S.L. Manzello, A. Maranghides, W.E. Mell, Y. Hayashi, D. Nii, "Mass and Size Distribution of Firebrands Generated from Burning Korean Pine Trees", 2nd Fire Behavior and Fuels Conference, Destin, FL, March, 2007.

Output: S.L. Manzello, Y. Hayashi, D Nii, "Firebrand Generation from Vegetation and Ignitability of Fuel Beds by Firebrands", Annual Meeting of the Japan Association for Fire Science and Engineering, Tokyo, Japan, May, 2007.

Output: S.L. Manzello, J.R. Shields, J.C. Yang, Y. Hayashi, D Nii, "On the Use of a Firebrand Generator to Investigate the Ignition of Structures in Wildland Urban Interface (WUI) Fires", 11th Int'l Conference for Fire Science and Engineering (INTERFLAM), London, UK, September, 2007.

Output: S.L. Manzello, J.R. Shields, A. Maranghides, W.E. Mell, Y. Hayashi, D. Nii, "Measurement of Firebrand Produdction and Heat Release Rate (HRR) from Burning

Korean Pine Trees", 7th Asia-Oceania Symposium (IAFSS), Hong Kong, September, 2007.

Output: S.L. Manzello, Firebrand Generation from Burning Vegetation and Ignition of Fuel Beds by Firebrands, Kanazawa Institute of Technology, Kanazawa, Japan, May 26th (2007).

Output: S.L. Manzello, Structure Ignition in Wildland-Urban Interface (WUI) Fires, Mechanical Engineering Department, UC Berkeley, November 16th, 2007.

Output: S.L. Manzello, Structure Ignition in Wildland-Urban Interface (WUI) Fires, University of California-San Diego, November 15th, 2007.

Output: S.L. Manzello, On the Use of a Firebrand Generator to Investigate the Ignition of Structures in Wildland-Urban (WUI) Fires, Kyoto University, October 22nd, 2007.

Output: S.L. Manzello, On the Use of a Firebrand Generator to Investigate the Ignition of Structures in Wildland-Urban (WUI) Fires, University of Tokyo, April 16th, 2008.

Output: S.L. Manzello, On the Use of a Firebrand Generator to Investigate the Ignition of Structures in Wildland-Urban (WUI) Fires, OSFM (California), July 2nd, 2008.

Output: Manzello was one of only 16 people awarded a fellowship in engineering sciences from the Japan Society for the Promotion of Science (JSPS) in 2008.

Output: MOU developed with BRI in Japan; make use of Fire Research Wind Tunnel Facility.

Outcomes

Outcome: First generation rapid response instrumentation co-developed and tested.

Outcome: Unique, one of a kind experimental apparatus developed in support of the project; the BFRL-NIST Firebrand Generator (or BFRL-NIST Dragon).

Standards and Codes: CAL FIRE recently created WUI building standards (California Code of Regulations, Title 24, known as the 2007 California Code of Regulations) focused on reducing risk of building fires. CAL FIRE has expressed an interest in collaborating with NIST on assessing these existing standards and extending them to reducing risk from firebrand initiated structural fires. The effort proposed will directly influence their findings.

Impacts: Measurement science developed will provide the scientific basis for new WUI building codes/standards regarding structure ignition from firebrands.

Impacts: Measurement science developed will provide the scientific basis for retrofitting strategies for existing structures pertaining to roofing/vents/siding to resist ignition from firebrands.

Impacts: State of New Jersey Fire Warden is using video from our experiments ineducational sessions

Future Impacts

Impacts: Adoption of new WUI building codes/standards regarding structure ignition from firebrands.

Impacts: Adoption of retrofitting strategies for existing structures pertaining to roofing/vents/siding to resist ignition from firebrands.