Wildland-Urban Interface Fire Research Needs

Workshop Summary Report

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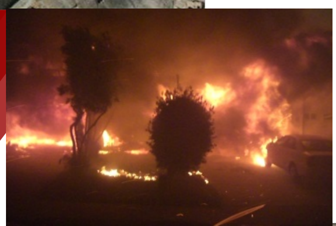

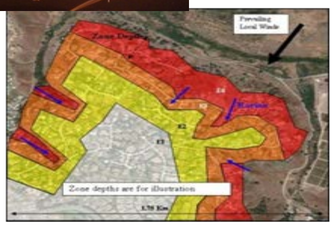

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Boulder, Colorado

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Steering Committee Co-Chairs

Nelson Bryner (National Institute of Standards and Technology)
Erik Johnsson (National Institute of Standards and Technology)

Steering Committee Members

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Contents

Figures

Tables

1 Workshop Overview

1.1 Wildland-Urban Interface Fire Problem

The wildland-urban interface (WUI) encompasses housing and other structures that are either co-located or abut wildland vegetation and forest.[1] WUI communities are especially susceptible to destruction from wildland fires. Several causes of WUI fires include the upsurge of structures in the WUI, long-term drought, climate change, and build-up of wildland fuel.[2] In the last 100 years, 6 of the top 10 fire loss incidents occurred in WUI areas (5 of the 6 occurred in California).[2] In the United States, more than 45 million homes in 70000 communities are at risk of WUI fires—which have destroyed an average of 3000 structures annually over the last decade—and this risk is rapidly increasing.[3]

WUI fires can also generate huge response and recovery costs. For example, the 1991 Oakland and 2007 Witch Creek fires in California resulted in property losses of $2.7 billion and $1.5 billion, respectively.[4] Federal funding for suppression and wildland fuel treatment has also risen significantly. In the period from 1996 to 2000 to the period from 2001 to 2005, this funding increased from $1.3 billion annually to $3.1 billion annually.[5] In addition, an average of 70 % more area was burned from 2000 to 2005 as compared to the 1990s.[6] Recent increases in funding, area burned, and fire occurrences in WUI communities imply an intensification of the WUI fire dilemma and require a review of the approaches to mitigating the issue.[7]

A traditional approach to mitigating WUI fires that has its roots in a series of massive wildfires in the early 1900s[*] has been to control or suppress a wildland fire as quickly as possible.[8] Wildland fire suppression operations successfully control 97 % to 99 % of all wildfires at initial attack.[9] Typically, the 1 % to 3 % of wildland fires that are not quickly suppressed involve extreme fire behavior such as high winds, prolonged dry conditions, and accumulated fuels. Although extreme fire behavior only occurs in a very limited number of fires, it can overwhelm firefighters and cause near simultaneous ignition of multiple structures within a community. Under extreme fire conditions, the suppression approach to mitigating the impact of WUI fires is less effective than under non-extreme conditions.

Another approach to mitigating WUI fires has been to improve the fire resistance or harden the structures within WUI communities.[10] Using principles of ignition and fire spread in the WUI, standards development organizations such as the National Fire Protection Association (NFPA)[11], the International Code Council (ICC)[12], and ASTM International[13] have developed building codes and standards for WUI communities. However, the range of actual exposures possible under different conditions has not been fully characterized or quantified. This has resulted in a very limited coupling between the potential exposure that a structure might experience and the

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[*] Including Hinckley, Minnesota 1894; Adirondack, New York 1903; and Big Blowup, Montana-Idaho 1910.

performance requirements in building codes and standards. For example, as a wildfire moves from the forest and into a community, direct flame contact may play a dominant role in the ignition of structures on the periphery of a community, but once a fire moves into a community, it is not clear whether direct flame contact or embers/firebrands[†] are causing most of the ignitions. Structures on the edge of a community may require increased resistance to ignition by flame contact while structures inside the community may need improved ignition resistance to embers. Other assessments include: 1) how wind and terrain affect ignition and fire spread within WUI communities, and 2) how to develop a representative performance test when the exposure has not been well characterized.

Realistic WUI fire and ember exposures over a wide range of fuel types (vegetative and structural), terrain, and weather conditions must be determined in order to consistently quantify the expected severity of WUI fire events. Once established, these technically based ember and fire exposures for the WUI will form a stronger technical foundation for the development of a realistic set of performance-based building code provisions aimed at providing a level of structure ignition protection commensurate with the expected fire and/or ember exposure.

Strategies or methodologies to improve the fire performance or hardening of structures and communities include ignition-resistant[‡] materials and construction, engineered fire-resistant[§] design, passive and active fire protection, risk assessment tools, implementable codes, stakeholder education and compliance, and firefighter safety and effectiveness.

1.2 Scope and Objectives

The "*Workshop on Wildland-Urban-Interface Fire Research Needs,*" held August 15–16, 2012, in Boulder, Colorado, provided a forum for WUI experts to discuss challenges, identify research needs, and establish research priorities to improve the fire resistance of WUI communities. Participants included professionals in WUI fire behavior, engineered fire protection technologies, ignition-resistant materials, wildfire-resistant design, standard test methods for building materials, fire suppression and response, and WUI building and fire codes, as well as representatives of authorities having jurisdiction.

1.3 Workshop Format

Discussions focused on identification and prioritization of current issues in mitigating WUI fires, ignition prevention ideas, and potential fire resistance improvements through implementation of measurement science to develop innovative technological solutions. Those ideas considered as the highest impact and highest priority were further explored and developed.

The workshop began with a series of overview presentations from stakeholders:

- Authorities having jurisdiction:
  - Brett Lacey – Fire Marshal, Colorado Springs and Waldo Canyon Fire
- Standards development organizations:
  - Dan Bailey – International Code Council
  - Hylton Haynes – National Fire Protection Association

[†] Embers or firebrands are glowing or flaming fragments of fuel; these terms will be used interchangeably in this report. These fragments, which are lofted into the air and carried more than a mile by wind, may originate from either vegetative or structural fuel sources.

[‡] Ignition-resistant materials and construction incorporate material properties, chemicals, or configuration to prevent or limit ignition by embers or flame contact.

[§] Fire-resistant design utilizes material properties, construction, and assembly features to prevent or limit fire spread within design component and to other exposed structural and vegetative fuels.

- Fire service:
    - Rick Swan – International Association of Fire Fighters, California Department of Forestry and Fire Protection
- Industry:
    - Kuma Sumathipala – American Wood Council
- Research laboratories:
    - Steve Quarles – Insurance Institute for Business & Home Safety
    - Mark Dietenberger – U.S. Forest Service Forest Products Laboratory
    - Alex Maranghides – National Institute of Standards and Technology

These overview presentations laid the foundation for the workshop participants to split into three breakout discussion groups. Each of the three groups was charged with first identifying current issues and challenges of current WUI fire mitigation techniques, and secondly with identifying research needs to address those issues and challenges. After the breakout groups finished identifying issues and research needs, they reassembled to present their findings.

After consolidating similar issues and research needs, the workshop participants prioritized the research needs. The research needs that participants labeled as "high-priority" were then assigned to each breakout group for the group members to complete more detailed implementation plans.

1.4 Workshop Report

This workshop report describes and documents the contributions[**] of the workshop participants regarding issues in mitigating WUI fires (Section 2), research needs to address existing challenges to hardening communities (Section 3), prioritized research needs (Table 3-1), and implementation plans for selected research needs (Figures 3-1 through 3-9). The workshop contributors are listed in Appendix A. Acronyms and references are listed in Appendix B and Appendix C, respectively. Appendix D provides the workshop agenda. Appendix E provides overview presentations from the workshop.

[**] Contributions represent output of workshop participants and do not necessarily state or reflect those of the National Institute of Standards and Technology.

2 Mitigating WUI Fires

2.1 Overview of Current Issues and Challenges

The risk for forest fires spreading across the WUI increases year by year as communities continue to grow and more and more people build in forested areas. In 2007, "the WUI occupied 9 % of the surface and contained approximately 39 % of all housing units within the conterminous United States."[14] While there are a number of strategies in place to address wildland fires, including rapid fire containment and suppression and fuels management, wildfire mitigation strategies do not necessarily target WUI communities. It should not be surprising that these wildland fire strategies are less than effective in mitigating fires in WUI communities.[15] Fire protection is usually addressed by local fire service, which is often limited due to available resources and training. Educating the homeowners living in the WUI is essential to preventing fires and fire spread.[16]

The workshop discussed and identified current issues in mitigation techniques for WUI fires. These issues have been grouped into common themes or approaches: exposure quantification, ignition-resistant materials, fire-resistant design, response, recovery, public education, and other. Each of the major themes for mitigating WUI fires is discussed below. The corresponding challenges identified at the workshop are presented in each section[6].

2.2 Exposure Quantification

Exposure quantification seeks to measure the vulnerability of structures to ignition by fires. An exposure concept or scale[17] can be used to quantify expected fire and ember exposure and is applicable throughout new and existing WUI communities. A WUI exposure-scale can be used not only to identify WUI areas that may be exposed to wildfire, but also characterize the intensity of the exposure. This scale would link the potential exposure to a structure or community as opposed to the more traditional approach of identifying areas that simply meet housing density and wildland vegetation requirements for WUI areas. The scale can therefore be used to provide the boundaries where specific land use and/or building construction regulations would apply.

Improving the exposure quantification tests will ostensibly lead to more effective building codes and reduced risk of structural ignition.[18] Currently, standards development organizations (such as ASTM International, International Code Council, National Fire Protection Association, and others) are actively advancing WUI-related building and construction standards by compiling, organizing, and harmonizing the limited understanding of WUI fire exposure conditions for structures and communities. Better characterization of exposure conditions includes measuring

[6] Text generated during the workshop sessions was formatted and placed inside highlighted boxes within Section 2 of this report. This text which describes the challenges was a product of workshop participants working in different breakout groups. For a specific topic, text from different sessions was grouped together within a single box. Text was not edited for consistency between different breakout groups.

the critical roles played by burning embers, flame contact, and thermal radiation in structure ignition as well as understanding the importance of fuel package, terrain, and weather.

- Unknowns in ignition exposure
  - Susceptible ignition points/locations
  - Fire exposure on structures
- Limited comprehensive data and voluntary reporting – ignition, exposure, and related statistics
- Lack of representative exposure test methods inhibits innovation*
- Inadequate consideration of ember ignition as fire cause
  - Lack of effective coordination of research into codes
  - Lack of analysis on effectiveness
  - Lack of research and unbiased research funding; initiation bottle neck
  - Limited attribution of ember-cause ignition event in building/fire codes

*A set of exposure conditions that does not replicate realistic exposures will not encourage development of products/technology that will perform well under real exposure conditions (i.e., conditions not captured by the exposure test).

2.3 Ignition-Resistant Materials

Reducing the ignition potential and increasing the survivability of structural materials diminishes the severity of WUI fires. Through research, structural materials are constantly evolving to prevent ignition of the buildings and to slow fire propagation once the building is ignited. However, it will be critical to develop an effective implementation plan for incorporating advanced materials into both existing and new construction. Relevant laboratory-scale standard test methods for building materials also require an improved understanding of the exposure conditions faced by WUI structures. Effective WUI building materials (e.g., siding) or assemblies (e.g., vented eaves) require standard test methods that simulate exposure conditions that are as, or more, severe than those in an actual WUI fire.

- Incomplete characterization and performance discrimination among combustible materials
- Limited new construction design and materials (e.g., roofs, decks, and siding)
- Inadequate knowledge of construction materials: combustible or noncombustible
- Limited research and development and use of new technologies (e.g., nanotechnology)

2.4 Fire-Resistant Design

In concert with ignition-resistant material improvements, engineered wildfire-resistant design and construction of WUI communities can improve fire performance by reducing exposure to the fire and decreasing the likelihood of fire spread. The geometry of the building may play a role. If a corner or seam allows embers to accumulate, a group of embers may transfer enough energy to cause the fire to spread to the exposed component and, subsequently, the structure. A fire-resistant design strategy would minimize the accumulation of embers through layouts that reduce or eliminate geometries with internal corners, for example, which allow thermal radiation to be re-radiated from one surface to another. For communities, thermal radiation exposure and flame contact exposure to an adjacent surface can be reduced by designing noncombustible zones between adjacent structures or vegetation. These design principles can be incorporated in the initial development phases of a community or during retrofitting or home improvements.

- Inconsistent recommendations regarding adequate defensible space (e.g., walls or retaining walls)
- Defining standards allowing the use of new/economical products or vegetation clearing
- Limited community-wide fuels treatments: surrounding versus within
- Current focus is fire suppression instead of mitigation in the built environment
- Limited intermediary solutions (e.g., removing mulch)
- Aesthetics of overgrown land
- Inappropriate landscaping choices: vegetation in relation to homes/windows
- Legacy infrastructure parcels and land use
- Inadequate vegetation and forest management
  - Vegetation burns hotter and faster these days
- Inadequate WUI design codes and poor enforcement of them
- Focus on protection, not design: fire blankets, water external systems, etc.
- Fuels reduction: need to reduce supply
  - Use of non-native vegetation for landscaping
  - Reliance on irrigation in arid or semiarid areas
  - Code enforcement and ensuring compliance
  - Need information based on type of vegetation and location from structure
- Limited consistent resources for effective long-term management

2.5 Response

Destructive WUI fire events usually occur in severe conditions (e.g., high winds or dry fuels) resulting in large, rapidly spreading fire perimeters. WUI fires differ from structural fires; they are more complex and require different equipment and operating procedures. The ability to suppress a wildfire depends on the energy release rate of the fire, the availability of fire service and equipment, staff training, quality of communications and organization efforts, and response times. Limited resources—manpower and infrastructure—are the norm and can be easily overwhelmed during WUI events. Because existing standards are directed to either wildland or structural firefighting scenarios, WUI-specific standard equipment and operating procedure standards need to be developed to effectively fight fires in the WUI.

- Poorly established firefighting tactics for WUI
- Inadequate access for response
- Limited understanding of the impact of engine crew size on initial attack effectiveness
- Unified command on WUI fires is lacking
- Fire response capacity is limited
- Evacuations are not optimal
- Too much emphasis and money on suppression strategies

2.6 Recovery

Guidelines for rebuilding communities need to incorporate advanced ignition-resistant materials, improved methods of construction, and enhanced fire-resistant designs. As previously described, the limited exposure information currently available does not address the full range of realistic WUI exposures and offers little context for the design and construction of ignition-resistant landscapes and buildings. It is difficult to implement a more fire-resistant design if one does not understand whether the exposure is to embers, radiant heat, and/or flames. In addition to a lack of understanding regarding the exposure threat, the performance of current structural and community designs is not well documented. Standardized post-fire data collection methods are not widely implemented. Post-fire (and pre-fire) WUI community data collection could also identify shortcomings or unnecessary redundancies in recommended mitigation actions for ease of implementation or clarity. This would help determine what improvements are needed in terms of community education and incentives. Analysis of post-fire data and sufficiently accurate WUI fire behavior and economic models could also support the development of rehabilitation guidelines (e.g., site planning, landscaping, vegetation choice and maintenance, building placement, and construction choices and prioritization) for damaged communities.

Rebuilding homes also requires homeowners to overcome the emotional response to the loss of their home and belongings, find competent design professionals to prepare housing plans that adhere to existing codes and planning requirements, navigate the permit process for rebuilding, and find an acceptable builder, among other details.[19]

- Rebuilding a community after a WUI fire without determining effectiveness of existing mitigation strategy
    - Unclear long-term impacts: lacking a holistic evaluation of long-term impacts
- Post-event mitigation tactics are seldom maintained – communities, legislation, etc.

2.7 PUBLIC EDUCATION, OUTREACH, AND PERCEPTION

Education and effective information delivery is essential to the implementation of homeowner and community guidelines. Education and outreach must include the residents of WUI communities, government officials, community developers, firefighters, and other stakeholders. Each of these groups requires tailored and targeted information on regular intervals through a variety of venues and vehicles. There are a number of existing web-based resources that can be used to promulgate improved guidelines. Public education and awareness programs such as Fire Safe;[20] Firesmart;[21] Firewise;[22] Fire Free;[23] Ready, Set, Go;[24] Fire Adapted Communities;[25] and Living with Fire[26] educate communities where potential hazards exist and provide steps to minimize those hazards. These programs typically draw on the requirements and recommendations in WUI building codes such as the ICC International Wildland-Urban Interface Code (IWUIC)[27] and standards such as Reducing Structure Ignition Hazards from Wildland Fires.[28] Although the Ready, Set, Go program does mention the importance of hardening structures and the Fire Adapted Communities and Living With Fire programs present information on embers, typically embers are either not discussed or when discussed, not presented as a major ignition source.. The approaches described by these programs need to be expanded to more adequately describe the role of embers in structure ignition and need to include additional risk factors based on the attributes of adjacent structures and surrounding vegetation. Communities differ in the amount of financial resources available for landscape and residential fuel treatments.

- Limited/inadequate outreach education of homeowners on wildfire risks
  - Large lots (low number of homes/acre)
  - Neighborhood (lower density housing)
- Multiple public education initiatives are not clearly differentiated
- Lack of community awareness/planning (local government and citizens) regarding WUI fire risks
- Homeowner desires conflict with best practices (e.g., rustic cabin look inconsistent with best practices)
- Lack of community motivation until the event happens
- Politics
  - Inadequate communication with politicians on the problem
  - Weak political will/apathy – government officials and citizens
  - Culture shift required: required codes versus lack of cooperation from some homeowners
- Lack of personal accountability and responsibility
- Homeowner often unaware of benefits of implementing fire prevention best practices
  - Cost – unwilling to pay
  - Lack of initiative by homeowners and communities

2.8 OTHER

There are many other issues that are challenging to categorize but are valid considerations in the attempt to mitigate WUI fires. These issues are no less important than those previously mentioned. In this report these issues have been grouped into one category that includes social, economic, jurisdictional, and environmental factors, among others.

- Inadequate definition of adequate clearance for diverse materials, topographies, and regional conditions
- Poor attitudes: wildfires are capricious, so hard to justify time, effort
- Economic limits
    - Cost of special building materials and fuels management. Cost to responsible parties executing mitigation strategies.
    - Lack of cost-benefit analysis for fire mitigation
    - Best practices are not always cost effective for homeowners to implement
    - Owner buy-in to WUI protective action through reduced insurance rates
- Government issues
    - Jurisdictional issues – problem is complex combination of publicly owned wildlands where a wildfire may start and WUI communities where privately owned structures are destroyed. Cost and responsibility for fuels management, response, and recovery must be apportioned across involved public and private parties
    - Multi-jurisdictional problems
    - Limited funding at all levels – local, state, and federal (should be predominantly a federal concern)
- Environmental constraints
    - Invasive species
    - Sensitive habitats
    - Endangered species
    - Erosion and sedimentation, nutrients, climate change, etc.
- Beyond "replace wood shake roofs" and other simple tasks, the importance of subsequent mitigation measures in unknown
- Duplication of efforts by different authorities and parties
- Mitigation efforts are fragmented – the entire system needs consideration

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3 HARDENING THE WUI COMMUNITIES

3.1 OVERVIEW

The Waldo Canyon fire near Colorado Springs, Colorado, in the summer of 2012 was the most destructive in state history—the wildfire decimated more than 18,247 acres(7380 ha or 2990 m^2), killed two people, and destroyed nearly 350 homes. The total property damage is estimated at more than $110 million; the cost to fight the blaze is approximated at more than $16 million.[29] The myriad of issues in mitigating WUI fires identified in the previous chapter suggests that wildland fires will continue to inflict a high level of destruction unless new science-based fire protection strategies are developed and existing mitigation tactics are fully implemented. Concepts to prevent ignition and retard fire spread, as well as methods to increase wildfire resistance in WUI structures and regions—all ways to harden the WUI community against fire—are presented below.

3.2 IMPORTANT WUI FIRE RESISTANCE RESEARCH NEEDS

Workshop participants identified a number of important research needs to aid in hardening the WUI community and address existing challenges; these needs are summarized below. The needs have been grouped into the following areas: exposure quantification, materials, fire-resistant design, response, recovery, and education.

3.3 EXPOSURE QUANTIFICATION

Test methods that represent realistic problems: The limited characterization of actual exposures coupled with an incomplete understanding of the roles played by fuels, weather conditions, and terrain makes developing performance-based and material-neutral test methods more difficult. Although WUI communities have a limited number of standard test methods and design requirements such as California State Fire Marshal standards and several ASTM International standards, most are not performance based and material neutral. These methods should be more representative of realistic exposures. Standards should provide a path to discriminate performance of materials and increase the resistance of buildings to wildfire by providing a systematic and exposure-based method of evaluating the performance of vulnerable designs, materials, and constructions features. Because it would be too costly and impractical to conduct full-scale tests on every design and material combination, a more limited set of standard test methods must be developed. This set of exposure-based test standards will still need to capture the full range of potential exposure to flames, thermal radiation, and embers. Current test standards largely focus on fire resistance. Future test standards must emphasize ignition resistance applied at the building and community levels. New software may aid in the development and implementation of new testing. Design requirements must be developed and incorporated into new codes that are effectively enforced.

Understand ignition phenomena: A key part of increasing the fire resistance of WUI communities includes augmenting the existing knowledge of ignition and fire spread (underlying and primary causes). Although WUI fires are initiated (started) by either "human caused" actions or lightening, these fires can be propagated or spread in a number of ways—embers, heat radiation from a nearby fire, direct fire contact, and/or fire jump.[30] In addition, there are a number of points/locations on or near a building where ignition can occur. These points could also be a vulnerable component that could facilitate fire spreading to other components or the interior of the structure. These locations include the roof, windows, vents, eaves, soffits, siding, trees, bushes, and combustible mulch, among many more points.[31] A comprehensive knowledge of how fires initiate in different building materials, building components, and communities is necessary. Further, causes can be organized into a hierarchy by their severity or impact, enabling prioritization of mitigation or prevention strategies.

Specification of performance standards and needs: While hardening of the structures is an important part of WUI fire prevention and defense, specific ignition resistance and fire propagation considerations need to be further explained and clarified based on relevant circumstances and materials. With a more fully developed understanding of these interactions, WUI standards can be updated and/or created against which materials and methods of construction can be tested using relevant conditions.

3.4 Materials

Research ignition-resistant and noncombustible materials: Even though some noncombustible and ignition-resistant building materials exist—stucco, fiber cement, wall siding, fire-retardant-treated lumber, and fire-retardant-treated wood shakes and shingles[32]—research and development (R&D) into improving existing designs, materials, and methods of construction and increasing the number of wildfire-resistive choices should be continued. This will add to the options available to designers, builders, and residents when constructing structures in the WUI communities, thereby reducing the chance for fire ignition.

Classifications for combustible materials to complement WUI exposures: National Institute of Standards and Technology (NIST) researchers are currently augmenting their definitions for building exposure to embers, radiant heat, and flames, leading to an exposure classification system (ECS) as a common industry resource.[33] To design more wildfire-resistant buildings, designers will also need a clear, science-based understanding of the relative efficacy of construction material treatments (the combustibility of various materials and the relative combustibility of the same materials with different coatings or treatments). To complement the ECS, research is needed to develop (via consistent methodology and terminology) a similar classification system for specific materials with various treatments or coatings and methods of construction. In addition, there is a need to better understand the exposure thresholds posed by various types of vegetative embers that could land on or near a structure, taking into account expected variations by region and climate.

Effective accelerated weathering protocol for materials and coatings: The choice of materials and coatings can significantly affect the fire resistance of homes and other structures in WUI communities, yet the relative efficacies of the various treatment options, particularly their durability over time, are not well understood. Some coatings provide more lasting protection on some surfaces than others, depending upon the design and application as well as moisture and ultraviolet exposure. Research is needed to evaluate the accuracy of existing accelerated weathering models for these materials and coatings and determine how closely these models match long-term "aging" conditions in each climate type. Ultimately, a clear and accurate protocol is needed to effectively guide design professionals, homebuilders, homeowners, standards developing organizations, and others in a position to influence critical choices affecting fire resistance.

3.5 Fire-Resistant Design

Hardening of structures (exteriors including decks, siding, roofs, windows, and vents, as well as interiors, and intra- and inter- community features): Hardening of structures entails reducing the potential for ignition from direct flame, firebrand showers, and radiant heat coming from outside of the defensible zone.[34] Furthermore, hardening also entails the ability to slow the propagation of the flame should ignition occur. Ignition resistance and retarded fire-spreading structures and communities can be achieved with careful building planning, selection of fire-resistance construction materials, active and passive barriers, reflective materials, non-louvered shutters, sprinkler installations, and inclusion of quality defensible space surrounding individual houses and neighborhoods.[35] Where relevant standards exist they need to be enforced, and new standards are needed where none currently exist. For many measures, however, maintenance is critical. Homeowners should be held accountable for keeping roofs and gutters free of debris; maintaining defined defensible spaces; and not storing firewood on, near, or under decks.

New codes that focus on ignition resistance and fire resistance independently: Novel codes must continue to be developed that focus on ignition resistance and fire resistance as separate, but complementary approaches. The majority of past studies, knowledge, and codes are based on the fire resistance, heat release rate, propensity to drop burning debris, ability to self-extinguish, flame spread rating, ability to generate embers, or endurance a material possesses rather than the issue of how easily that material will catch fire or ignite. Additional research cognizant of this distinction is required for the development and implementation of appropriate, effective WUI codes.

Ecosystem health and fuel management: Various fire jurisdictions conduct regular and prescribed fuels management activities, but these are most often done on publicly accessible lands. An emphasis on controlling and reducing fuels on other lands, such as private residences and businesses and parkland, would benefit the fire resistance of communities and aid in retaining a healthy ecosystem. Creating more fuel breaks, implementing more controlled burns, harvesting timber, expanding chipping programs, and clearing brush and invasive species would improve the chances of survival for the WUI community during a wild fire event. Better planning and design to limit the availability of fuels within the community is another approach that could impact survivability.

Codification of Class A fire-rated roofs as a system, including vulnerabilities of complex roofs: After WUI fires, firefighters have found Class A roofs lying on the ground—while the homes they once covered were largely destroyed. Such occurrences highlight the importance of looking at a roof not as a standalone unit but as part of a larger system designed to protect the home. WUI code provisions that regulate roof construction and replacement should take into account the entire assembly system, including construction and joining techniques, materials, attics, crawl spaces, and vent systems. In addition, codes should contain requirements to mitigate the various vulnerabilities created by some complex designs and systems, including gutters, vents, fans, dormers, and other junctures between roof sections.

Simulation software to compare trade-offs between vegetation and structure hardening options: Development of this software tool will likely require considerable initial research, yet the effort holds significant promise as a way to help homeowners make informed decisions and move forward with investments to harden their homes and properties against WUI fires. Many homeowners today have balked at the multitude of protective devices, equipment, and other approaches available on the market with varying price tags—putting off any action until they better understand the options. The proposed tool would enable them to weigh the costs and benefits and to prioritize the available strategies, approaches, and products in terms of effectiveness for a given level of investment. It should be designed for use by owners of both existing and new homes in WUI areas as well as other stakeholders.

Strategic incorporation of greenbelts, parks, and defensible spaces into new developments: Regulations, codes, and community design standards should require that WUI communities strategically plan and locate open space and recreational areas so that they can also serve as defensible spaces—where WUI fires can be stopped before they reach a community. Placed around the outside of a community and between adjacent sections of a community, golf courses, ball fields, parks, walking/bike paths, and similar spaces can be developed and maintained as firebreaks to effectively limit fire spread. Appropriate dimensions and relative distance from the community should be determined by taking into consideration the terrain, climate, prevailing winds, and other relevant factors. Designers may need to be innovative in their designs and materials to optimize these spaces to serve the dual purpose. Depending on water pressure, hydrants (or surface water sources) may be strategically placed on the outer perimeter of these areas.

Standardization of defensible spaces in wildfire-prone states: All states with existing or new developments within or encroaching on areas prone to wildfire should clearly define "defensible space" so that homeowners, firefighters, government agencies, and other key stakeholders have a uniform understanding of the term. The definition would specify how the space will be maintained to serve its intended purpose and be consistent with the climate, type of terrain, and dominant type of vegetation. Wherever defensible space is an issue, housing densities should be strictly limited.

3.6 Response

Standards for unified command and cooperative tactics to improve attack effectiveness: An effective response to WUI fires requires swift and coordinated action by all available firefighting units and other emergency responders. Multiagency and multi-jurisdiction responses have sometimes led to significant initial confusion and the loss of valuable time in getting control of the fire. Some WUI areas have greatly enhanced the ability of diverse units to quickly coordinate by conducting joint training exercises and establishing a single point of command to issue orders, order resources, make plans and decisions, and serve as a clearinghouse for updates and information. Pre-planning across agencies to establish roles, priorities, evacuation routes, and other essential procedures saves valuable time in a real event. This concept can be effectively expanded across all response agencies by creating standards for unified command and cooperative tactics. Further, response methods can be standardized as much as possible while incorporating proven cutting-edge technologies (e.g., foams) when relevant. Older, less-effective techniques (e.g., "throwing dirt on fire") can provide additional response as appropriate.

Expanded fire engine crews to vastly increase efficiency: Restricting the initial spread of a wildfire to 10 acres or less can significantly reduce the final damage, underscoring the importance of launching an effective initial attack. Analyzed firefighter staffing data suggests that the efficiency of a three-person crew in fighting a wildfire increases 50 % with the addition of a fourth crew member.[36] On this evidence, a clear economic case can be made for expanding all three-person fire crews to four members.

3.7 Recovery

Improved tools for post-fire evaluation: Implementation of improved post-fire evaluation tools is necessary for forensic purposes in order to understand exactly what transpired during a WUI fire event. This can improve scientific understanding of how fires ignite structures and move throughout a community. Armed with this knowledge, building and community design can be engineered to restrict future ignition and fire spread.

3.8 Education

Public education for improved ignition prevention: More and more families are relocating into WUI communities;[37] however, these residents may not understand the steps and proven measures they should undertake to protect themselves and their property from WUI fires. A recommitment to educating the public on ignition prevention techniques is necessary. Homeowner education efforts can play a key role in fostering compliance, and homeowner associations and community boards can assist in enforcement. "Smokey the Bear – Only you can prevent forest fires,"[38] was an effective public outreach tool to educate and instill a feeling of accountability in the public for preventing ignitions. Revamping the Smokey Bear campaign would be simple, straightforward, and effective. In addition, any education plan should also include the tried and tested practices in fire mitigation. This same knowledge should be shared with elected and appointed officials, with a focus on the local jurisdictions.

Social/local grassroots inspections and self-enforcement: Rules, regulations, and codes exist to help reduce the potential for fires in WUI communities. However, inspectors that enforce such rules are few in number and are often overwhelmed due to workload and/or budget constraints. The rise of social networking and the use of grassroots initiatives to empower citizen activists to act locally could be used to encourage neighbors to abide by regulations without engaging the authorities.

3.9 Prioritized Research Needs and Implementation Plan

The previous sections provided a list and short summary of the important desired research topics for WUI fire resistance. Of those, the most pressing research needs or those that will have the most impact in mitigating the hazards associated with WUI fires were selected and designated as research priorities. The selection results are presented in Table 3.1 below. The implementation of the high-prioritized research needs was explored in depth with respect to specific tasks, timing, milestones, and performance targets. Figures 3-1 through 3-9 outline the results of these discussions[7].

[7] Text generated during the workshop sessions was formatted and placed inside highlighted boxes within Figures 3-1 through 3-9 within Section 3. This text which describes possible implementation plans was a product of workshop participants working in different breakout groups. Text was not edited for consistency between different breakout groups.

TABLE 3-1: PRIORITIZED WUI RESEARCH NEEDS		
Rank	**Topics Areas**	**Votes**
1.	Hardening of structures	(19)
2.	Specify performance standards and needs	(16)
3	Understand ignition phenomena	(13)
4.	Educate stakeholders on ignition prevention	(11)
4.	Improve tools for post-fire evaluation	(11)
4.	Unify and improve effectiveness of response teams	(11)
4.	Enhance fuels management	(11)
8.	Develop realistic and material-neutral test methods	(9)
8.	Codify Class A fire-rated roofs	(9)
10.	Strategically build greenbelts, parks, and defensible spaces into new developments	(8)
11.	Develop accelerated weathering protocol for materials and coatings	(7)
12.	Create simulation software to model trade-offs between vegetation and structure hardening options	(6)
13.	Develop and adopt classifications for combustible materials	(5)
13.	Produce new codes focused on both ignition and fire resistance	(5)
13.	Increase fire engine crew size to vastly increase efficiency	(5)
13.	Standardize defensible spaces in wildfire-prone states	(5)
17.	Research fire-resistive materials	(3)
18.	Organize social or local grassroots inspections and self-enforcement	(0)

Note: Each dot represents a participant-identified priority with the greatest potential to improve the fire resistance of WUI communities.

- Blue represents a research (academic and federal agency) participant vote.
- Green represents a standards development organizations and authorities having jurisdiction participant vote.
- Orange represents a fire service participant vote.
- Red represents an industrial participant vote.

Figure 3-1: Hardening of Structures

A hardened building is one that can resist wildfire exposures including ember/firebrand, radiant heat, and direct flame contact. When home spacing is close, extended exposures to radiant heat and flames must be considered. An effective structure hardening program must have viable defensible space and a vegetation management component (parcel level and community). An effective community hardening program will consider existing defensible space (including topography) and building spacing.

Short- or Long-Term Priority

Both short and long term: Homes are an important financial investment for homeowners.

Major Tasks

- Review existing documents related to hardening buildings (NFPA, Chapter 7A[CA], IWUIC [ICC], other research) for adequacy and deficiencies
- Review and evaluate adequacy of current defensible space requirements in minimizing radiant heat exposure and opportunity for flame contact exposure
- Separate mitigation issues specifically related to new versus existing homes
- Improve building, lot, and community design
- Enhance construction material

Major Milestones

- Conduct critical review of key publications: current codes, standards, and defensible space requirements (0 to 3 years)
- Define exposures (0 to 3 years)
- Slow propagation by improving new subdivision separation distances and greenbelts (0 to 3 years)
- Identify and collect baseline data on building ignition and fire spread in the community (0 to 3 years)
- Decrease ignition of lot vegetation by embers (0 to 3 years) and by flame (>3 years)
- Reduce ignition of building exterior by embers and flame (>3 years)

Performance Targets

- Reviewed building codes and standards
- Vetted homeowner document (for existing homes)
- Vetted new home or building document in use
- Educational materials in hands of end users
- Reduced building ignition by 25 % in 3 years; 50 % in 5 years
- Slowed propagation rate by 25 % in 3 years; 50 % in 5 years

Figure 3-2: Performance Standards and Needs

Increase the possibility that structures within the WUI will survive exposure to wildfire by creating and implementing ignition and fire-resistance needs that can be translated into testing standards. These standards are applicable for new development and remodeling of existing structures within the WUI.

Short- or Long-Term Priority

Long term: New development and structural retrofitting are longer-term projects.

Major Tasks

- Involve public in code development and review
- Develop building code specifications to meet outcome
- Design materials that comply with the set performance standard

Major Milestones

- Increase the percentage of survival of structures exposed to WUI event (>10 years)

Performance Targets

- Increased survival to multiple exposures over time under various conditions over the life of the structures
- Improved survivability without suppression efforts

Figure 3-3: Understanding the Ignition Phenomena

The knowledge surrounding the generation and propagation of embers is incomplete. Additional research will advance understanding of how vegetation, topography, climate, and construction cause structure ignition and spread of fires.

Short- or Long-Term Priority

Short term: Short-term action is needed to develop codes and standards, catch the coding wave of development, and decide where research is needed.

Major Tasks

- Develop data gathering methods
- Initiate interaction between topography, climate, and fuel causes
- Determine the contribution of burning structures to fire spread (e.g., wind, location, materials, configurations)

Major Milestones

- Complete testing to determine ember generation based on vegetation and from structure fuels (0–3 years)
- Develop a fire model to validate behavior (>3 years)
- Determine contribution of landscaping (>3 years)

Performance Targets

- Changed use of building material and building configuration based on findings
- Acceptance of findings to change codes, standards, and acceptance by authorities having jurisdiction and community

Figure 3-4: Education of Stakeholders on Ignition Prevention

Education is a critical component of WUI fire prevention. Increased educational outreach to the general public and officials at all levels, especially in local jurisdictions, will help reduce WUI fire occurrence.

Short- or Long-Term Priority

Long term: Cultural change such as this does not happen easily. In addition, politics plays a critical role in successfully resolving WUI fire issues, but the role and impact of politics has not been adequately addressed.

Major Tasks

- Identify target audience
- Use social research to define media
- Develop media based on available technology
- Research and develop relevant and applicable content and delivery methods

Major Milestones

- Increase number of jurisdictions adopting WUI risk reduction codes (3 to 5 years)
- Raise the number of communities developing wildfire protection plans (3 to 5 years)
- Grow and expand the use of existing educational programs (5 to 8 years)

Performance Targets

- Adoption of WUI codes by more homes; possibly 50 % of new construction in WUI areas in 10 years
- Better survivability of structures after a WUI event; possibly 99 % of new construction

Figure 3-5: Improved Tools for Post-Fire Evaluation

After abatement of the wildfire, the post-fire evaluation provides much information that is useful for future planning, reduction of fire risk, and comparison between fires. Improving tools and standardizing methodology will enhance the amount and quality of data collected and response timing.

Short- or Long-Term Priority

Both short and long term: Short-term activities include informing research initiatives. Long-term commitments are needed to maintain value and the integrity of data.

Major Tasks

- Identify initial priorities
- Find local contacts
- Produce software, hardware, training, and standard operating procedures for post-fire methodology
- Develop consistent methodology
- Create standards for continuing education deployment
- Provide incentives for timely completion of evaluation

Major Milestones

- Develop and test tool kit (0–3 years)
- Test software/hardware on three fires (2 years)
- Establish performance targets and incentives (3 years)
- Train local and regional teams ready to deploy (5 years)

Performance Targets

- Completed a satisfactory number of drills (3 to 4 per year)
- Enlisted additional participating agencies (25 %, 1 to 2 years)
- Collected acceptable amount of useful data (3 years)

Figure 3-6: Unified and Efficient Response Teams

To improve the effectiveness of WUI response resources and technology, standards should be developed for a unified command.

Short- or Long-Term Priority

Short term: The fire departments must be able to communicate and have the standard operating procedures during WUI fire events.

Major Tasks

- Continue analysis of cost effectiveness
- Develop and streamline training standards
- Establish common terminology

Major Milestones

- Usage of the Incident Command System (ICS) by all departments (3 years)

Performance Targets

- Trained fire departments with respect to WUI fires
- Properly staffed fire engines
- Common radio communications
- Nationwide buy-in to the ICS

Figure 3-7: Fuels Management

Managing the fuel available to fires at the WUI serves to reduce the potential fire intensity. Fuel management should be integrated into the design and planning of communities through strategic placement of greenbelt parks and golf courses. Ongoing maintenance of these vegetation management areas inside and outside the community is essential.

Short- or Long-Term Priority

Short-term: The activity is able to directly impact the intensity of the fires when they occur.

Major Tasks

- Identify benchmark (geographically selected) communities that have implemented fuel management practices
- Evaluate NFPA standards and determine available regulatory mechanisms
- Observe the mechanical fuel reduction efficacy and prescriptive burn efficiency in relation to the community
- Determine critical distances relative to the community where implementation of fuel management would be most effective
- Understand how different practices give different results—potentially using modeling and simulations to inform decision making
- Reduce fire intensity in the wild lands, community, and lot vegetation

Major Milestones

- Conduct literature review with respect to fuel management in relation to structures (0 to 2 years)
- Identify federal land management policy that restricts community resilience (0 to 2 years)
- Identify benchmark communities (0 to 2 years)
- Collect baseline data on wildland fire intensity, community, and lot vegetation (0 to 3 years)
- Reduce the fuel loading in the wildland, communities, and lots through prescribed burns, fuel mosaics, mastication projects, and healthy forest programs (0 to 3 years)
- Identify areas where fuel management or community planning has worked (1 to 2 years)
- Develop best management practices and adaptive management programs based on unique circumstances (2 to 5 years)
- Develop model(s) for designing fuel breaks based on fire history and fuel modeling (>3 years)
- Effectively maintain fuel management programs (>3 years)
- Evaluate ember generation and ignition properties of different fuel types (>5 years)
- Identify community design and planning strategies for WUI (>5 years)

Performance Targets

- Better synergy among state, local, and federal regulations promoting community resilience
- Established guidelines
- Increased number of benchmark communities
- Reduced fuel loading by 15 % in 3 years and 30 % in 5 years and in 20 % of target (i.e., maintained) areas
- Creation of a model to design fuel breaks that incorporate fire history and lot vegetation
- Identification of saved communities
- Decreased homes lost per year

Figure 3-8: Realistic and Material-Neutral Test Methods

Repeatable standardized test methods are needed that realistically simulate WUI events and conditions, irrespective of material. Standardized test methods would ensure scientific and statistical rigor.

Short- or Long-Term Priority

Both short and long term: Short-term activities include investigating current standards and identifying gaps within those standards. Long-term challenges involve filling in the identified gaps.

Major Tasks

- Engage all relevant parties
- Investigate existing WUI codes and standards
- Centralize collected data
- Develop an iterative and adaptive process that encourages an open process

Major Milestones

- Create a clearinghouse of testing information (1 to 2 years)
- Identify gaps in testing methods (2 to 3 years)
- Fill gaps (2 to 3 years)
- Develop testing protocols (3 to 5 years)
- Conduct testing (ongoing)

Performance Targets

- Increased understanding of ignition resistance versus fire resistance
- Protocols to test WUI standards

FIGURE 3-9: CODIFIED CLASS A FIRE-RATED ROOFS

Class A fire-rated roofs offer the highest resistance to fire. The codes and tests to classify roofs should view the roof as a system, including other assemblies and components. To incorporate and evaluate the roof's performance, vulnerabilities of complex roofs should be considered.

Short- or Long-Term Priority

Short term: The roof component of a structure is deemed the most vulnerable to ember exposure.

Major Tasks

- Identify vulnerabilities
- Evaluate solutions for vulnerabilities
- Develop recommendations
- Retrofit guidelines
- Recommend intermediary measures (without changing the whole roof)

Major Milestones

- Establish retrofit guidelines (3 years)
- Propose intermediary recommendations without changing the whole roof (3 years)

Performance Targets

- Creation of a Class A roof rating based on a systems approach

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4 Summary

In response to the increasing losses due to WUI fires and to ensure that measurement science keeps pace with needed improvements in materials, fire-resistant design, mitigation response, and building and fire codes, NIST sponsored the *Workshop on Wildland-Urban Interface Fire Research Needs* on August 15–16, 2012, in Boulder, Colorado. The workshop provided an opportunity for experts in WUI fire behavior, protection, codes, and mitigation to collectively determine the areas of research that will have the most impact in mitigating the hazards associated with WUI fires.

Workshop participants identified the following high-priority research areas for WUI fires:

- Hardening of structures
- Specifying performance standards and needs
- Understanding ignition phenomena
- Educating stakeholders on ignition prevention
- Improving tools for post-fire evaluation
- Unifying and improving effectiveness of response teams
- Enhancing fuels management

This report summarizes the results of the workshop and will serve to guide NIST in pursuing a portfolio of programs that are focused on providing the measurement science needed to enable communities that are exposed to WUI fires to become more fire resistant. It can also be used by both the public and private sectors to guide policy, R&D, and other decision making relevant to this important area.

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APPENDIX A: CONTRIBUTORS

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Appendix B: Acronyms

ECS	Exposure classification system
ICC	International Code Council
ICS	Incident Command System
IWUIC	International Wildland-Urban Interface Code
NFPA	National Fire Protection Association
R&D	Research and development
NIST	National Institute of Standards and Technology
WUI	Wildland-urban interface

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APPENDIX C: REFERENCES

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Appendix D: Workshop Agenda

Wednesday, August 15, 2012

8:00 am **Registration Opens**

8:30 am **Opening Plenary Session** – Room 1107

Welcome and Introductions ~ Nelson Bryner, National Institute of Standards and Technology

9:00 am **Wildland-Urban-Interface Fire Overview Presentations**

- **Authorities Having Jurisdiction**
  Brett Lacey, Fire Marshal, Colorado Springs – Waldo Canyon Fire
- **Building and Fire Codes**
  Dan Bailey, International Code Council
  Hylton Haynes, National Fire Protection Association
- **Fire Service**
  Rick Swan, California Department of Forestry, International Association of Fire Fighters
  Dan Bailey, International Association of Wildland Fire
- **Industry, Testing Labs, & Users**
  Kuma Sumathipala, American Wood Council
  Steve Quarles, Insurance Institute for Business and Home Safety

10:50 am **Break**

11:00 am **Current Research Initiatives**

Mark Dietenberger, US Forest Service
Woody Stratton, US Fire Administration
Alex Maranghides & Nelson Bryner, National Institute of Standards and Technology

12:00 pm **Lunch**

1:10 pm **Charge for Breakout Sessions and Instructions ~ Anand Raghunathan, Energetics Incorporated**

1:20 pm **Move to Concurrent Breakout Sessions: •Smokey •Blaze •Sparky**

1:30 pm **BREAKOUT SESSION I**

Focus: 1) Shortcomings of current WUI fire mitigation
2) Ignition prevention/limiting fire spread

Session agenda:

- **Stage-setting discussions**
- **Facilitated brainstorming on current limitations and development areas**

2:50 pm **Break**

3:05 pm **BREAKOUT SESSION II**

Focus: Discussion on developing of new codes, materials, designs, technologies, and response to improve WUI communities' fire resistance

Session agenda:

- **Facilitated brainstorming of development areas**
- **Prioritization of ideas for plenary report out**

4:10 pm **Break**

4:30 pm **PLENARY SESSION** – Room 1107

Breakout Session Day 1 Group Reports: •Smokey •Blaze •Sparky

Q&A

5:00 pm **Day 1 Closing Remarks ~** Nelson Bryner, National Institute of Standards and Technology

5:10 pm **Day 1 Adjourns**

Thursday, August 16, 2012

8:10 am **DAY 2 OPENING PLENARY SESSION** – Room 1107 ~ Nelson Bryner, National Institute of Standards and Technology

8:15 am **GROUP PRIORITIZATION OF RESEARCH NEEDS**

Instructions for Plenary Prioritization ~ Anand Raghunathan, Energetics Incorporated

8:50 am **Return to Original Breakout Sessions for Small Group Work: •Smokey •Blaze •Sparky**

9:00 am **BREAKOUT SESSION III**

Focus: Expound selected development priorities identified at the start of Day 2

Session agenda:

- **Small group work**

10:15 am **Break**

10:35 am **CLOSING PLENARY SESSION** – Room 1107

Breakout Session Day 2 Group Reports: •Smokey •Blaze •Sparky

Q&A

11:15 am **Closing Remarks ~** Nelson Bryner, National Institute of Standards and Technology

11:30 am -12:00 pm **Tours of National Institute of Standards and Technology Atomic Clock** (Optional)

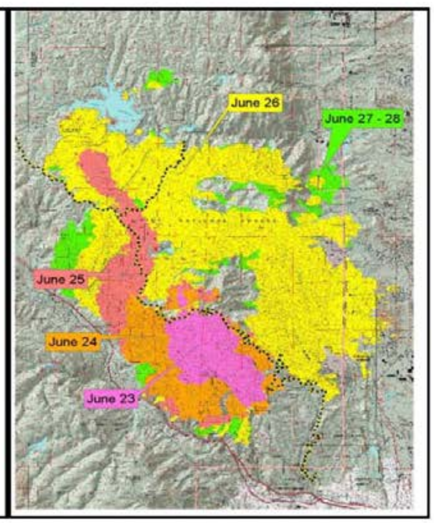
Appendix E: Overview Briefings

I. BRETT LACEY, FIRE MARSHAL, COLORADO SPRINGS – WALDO CANYON FIRE

8/21/2012

Waldo Canyon Fire

- Pre-Disaster fire behavior
- Management Objectives
- Evacuation Decision Points
- Tactics employed
- Tactical Objective

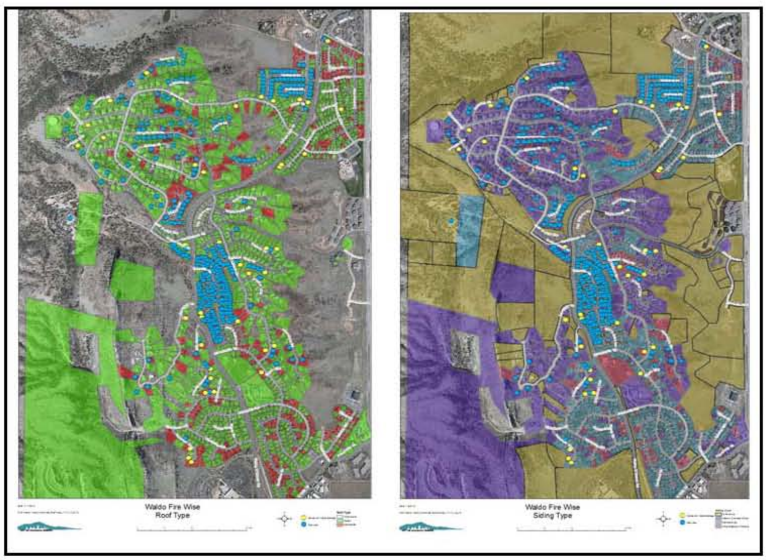


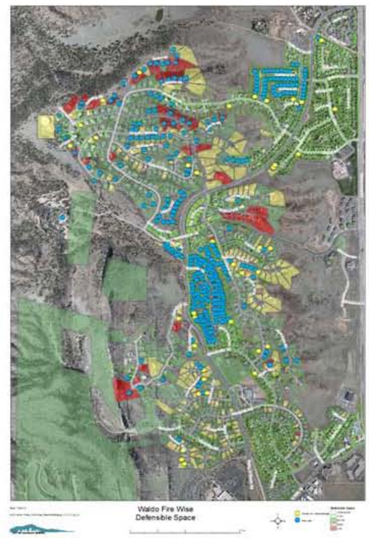
1

Waldo Canyon Wildfire

June 26, 2012

- Difficult decisions
- Initial findings:
  - Totals
    - Destroyed 345
    - Damaged 47
      - Total 392
  - Wildfire impact on boundary
  - Spotting/Branding
    - ✓Cedar Fencing
  - Exposures
  - Conflagration

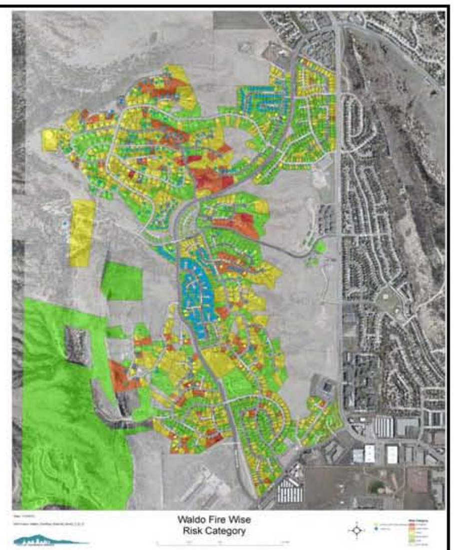




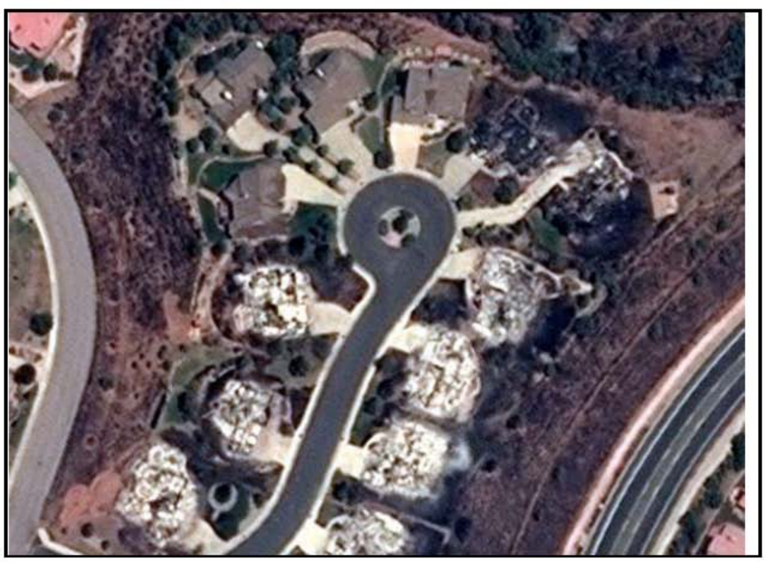
Known Factors

- •Fuel
- •Weather
- •Topography

- •Home Ignition Zone
  - •Combustible Const.
    - •72% (Roof or Siding)
  - •Conflagration Area
    - ✓99.5%
  - •WUI
    - ✓27%
  - •WUI vs. Conflagration
    - ✓53% vs. 47%

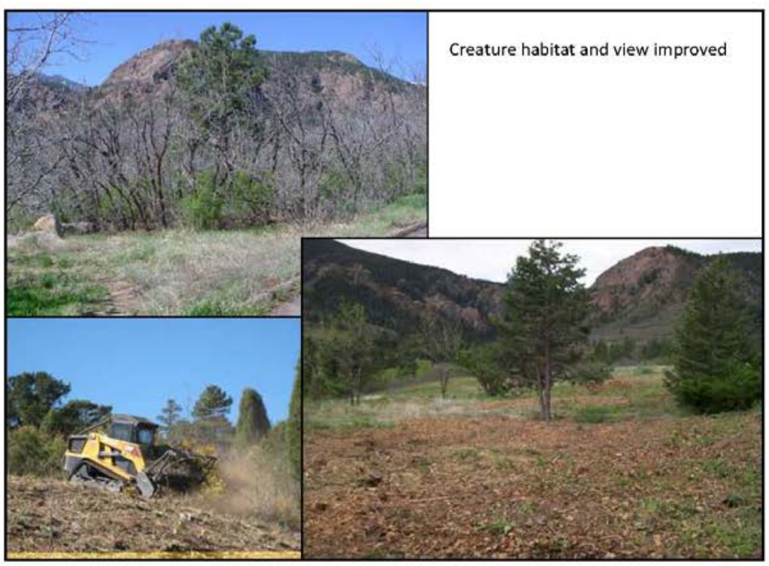



Incident Information System



7


NCC Mixed conifer "Before"
Mitigation is not clear-cutting
Neighborhood Chipping
Fuels Management
On-Sites
NCC Shaded Fuel Break in mixed conifer


Creature habitat and view improved

Objective is to change fire behavior

Mason Gulch Fire
July, 2005
Fremont County, CO

Fire Behavior – Untreated Gambel oak and Ponderosa pine
High intensity crown fire, 100% stand mortality

Mason Gulch Fire
Fremont County, CO
July, 2005

Fire Behavior – Treated Area
Gambel oak, Ponderosa Pine
Low intensity, surface fire

Mason Gulch Fire
July, 2005
Fremont County, CO

Treated area, Post-burn
Scorching, Less than 25% stand mortality


Cedar Heights Mitigation


Cedar Heights Mitigation

Things we want to avoid!

Code Requirements for Urbanites

- **Class A Roof Covering 2003 (55K changed)**
- **Exterior Walls Non Combustible (Fire Resistive)**
  - Cementitious Hardboard
  - Stucco
  - Soffits fire resistive
- **Solid Core Doors**
- **Double pane glazing**
- **1/8 inch attic screens**

Takeaways from Colorado Springs:

May not work for you!!!

- Wildfire Mitigation Program!!!
- Lots of time
- Lots of effort
- Lots of information
- Lots of communication
- Never give up!
- Honest, Trust and Collaboration
- Patience
- Must find common ground and shared beliefs
- Provide assistance (Gumby not Code Nazi)

13

II. Hylton Haynes, National Fire Protection Association

NFPA and the WUI

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

What is the National Fire Protection Association?

- The National Fire Protection Association (NFPA) founded 115 years ago
- Nonprofit life safety codes and standards organization
- 70,000+ members worldwide
- 300+ consensus codes and standards documents
- Fire Protection Research Foundation
- Fire prevention advocacy and outreach

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

Background

- Wildfire safety standards date back to the 1920s
- Modern involvement in "the WUI" came 25 years ago
- Partner with:

on WUI Fire Protection since 1986

Fire Protection and Prevention for
Summer Homes in Forested Areas

Prepared by the Forest Committee
of the National Fire Protection Association
Adopted 1935

Price: Ten Cents

National Fire Protection Association
International
60 Batterymarch Street
Boston, Mass., U.S.A.

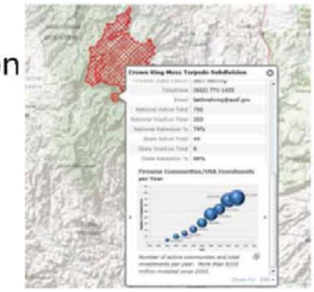
Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

THE
FIRE PROTECTION
RESEARCH FOUNDATION

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

FPRF: Role

- Plan, manage and communicate research in support of the NFPA mission
- Independent charitable organization
  - Formed by NFPA in 1982
  - Intended to provide data to support the needs of NFPA codes & standards
  - Research funds come primarily from:
    - Private and public sector consortia
    - Grants and government sources (e.g. DHS S&T, DOD, FEMA AFG, NIOSH, NIST, NSF, etc)
    - Multiple other sources (including NFPA)



Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

FPRF: How

I. Benchmarking – state of the art symposia

II. Agenda Setting – research planning in emerging areas

III. Research Programs –

- Research projects to meet the needs of NFPA Committees and others
- Projects range from small literature search type studies to major fire testing programs

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

Research Process (for FPRF Projects)

1) Research Projects Initiation:
   - Need for research identified by technical committee, organizations/associations, manufacturers, end user groups, other affected interests
2) Core Planning Meeting:
   - Outline goals, scope, tasks, schedule
   - Develop preliminary work plan
   - Determine likely funding sources and secure sponsors

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

Research Process (for FPRF Projects)

3) Project Technical Panels:
   - Code enforcers, code writers, subject matter experts, principal sponsors, NFPA staff liaisons
   - Determines technical details of the project, oversees and provides guidance to contractor
4) Research Performed:
   - Primary Contractor selected
   - Sponsors receive early access to program results
5) Research Reports Published:
   - Final reports published and made available to all

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

Research Process (for "Advisory Service" Projects)

1) Project Technical Panels:
   - Code enforcers, code writers, subject matter experts, principal sponsors, NFPA staff liaisons
   - Determines technical details of the project, oversees and provides guidance to contractor
2) Research Performed:
   - Other organization obtains funding and leads project
   - FPRF in supporting role
3) Research Reports Published:
   - Final reports published and made available to all

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

Project Participants... Who are they?

Funding (Sponsors): *Where does it come from?*

- Manufacturers, trade associations, NFPA, federal agencies, research organizations, nowhere, etc...

Contractors: *Who Does the Work?*

- Consultants, research organizations, test labs, universities, NFPA Fire Analysis, volunteers

Advisory Oversight: *Project Technical Panel*

- Typically small (6 to 15)
- Meet at important stages of project (start/end/other)

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Project Characteristics and Ideas

- Characteristics of Foundation Projects: (collaboration, cost sharing, independence, pipeline to implementation, communications network)
- Project Ideas:
  - TC struggling with an issue, via staff liaison
  - Industry wants to introduce new technology into standard; needs data
  - Two opposing views on an issue and data needed
  - Data presented is not trusted by committee
  - Emerging technical issue – e.g. alternative energy
  - TC establishes ongoing research planning activity

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Benefits

- Independence
- Collaboration
- Cost sharing
- Credibility
- Pipeline to implementation
- Communications network

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

Past WUI research efforts have included:

- NFPA *Firewise ArcView* Lessons Learned Research Project, 2006.
- Development of a Framework for Statistical Analysis of Factors Contributing to Structure Ignition in the WUI (NIST/NFPA combined proposal: 2009-NIST-ARRA-MSE-Research-01).
- Analysis of Pathways and Exposure Conditions for Structure Ignition in the WUI (NIST/NFPA combined proposal: 2009-NIST-ARRA-MSE-Research-01).
- Addressing Community Wildfire Risk: A Review and Assessment of Regulatory and Planning Tools, 2011.

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Current WUI research efforts:

- An assessment 3 different county WUI codes and comparative analysis of potential regulatory opportunities that are available given current knowledge and understanding. (due end of 2012).

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Possible future NFPA efforts/ideas:

- Wildland Fire Data Reporting Initiative
- Economic impact of WUI fire on agricultural and tourism industries.
- Fire Department wildland/urban interface response needs assessment.
- Efficacy of prescribed burning in reducing wildland fire risk to adjoining interface/mix communities.
- What fuel types are more likely to contain embers? What embers are most likely to stay hot enough to burn structures in front of the flame front?
- Community Wildfire Risk DSS technology opportunities, adoption barriers, utility and efficacy.
- Physics-based WUI fire modeling initiatives.

Hylton Haynes, CF | NIST Workshop on WUI Fire Research Needs 08/15-16

Hylton Haynes – hhaynes@nfpa.org
Casey Grant – cgrant@nfpa.org

www.firewise.org | www.nfpa.org

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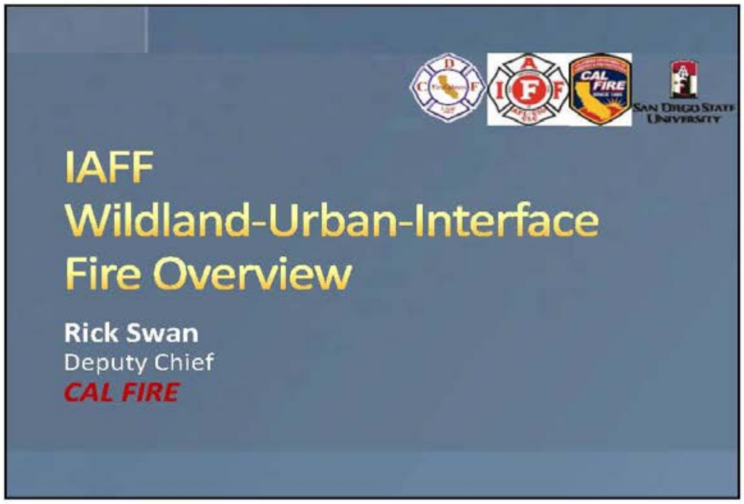
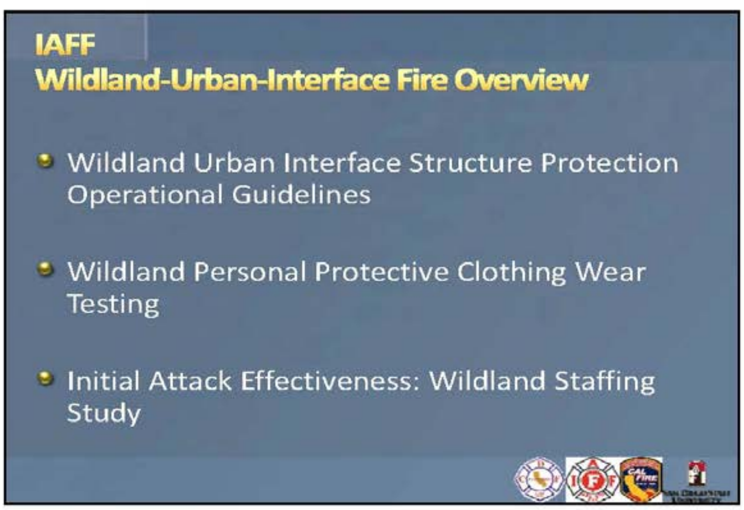
III. Rick Swan, California Department of Forestry, International Association of Fire Fighters

9/4/2012





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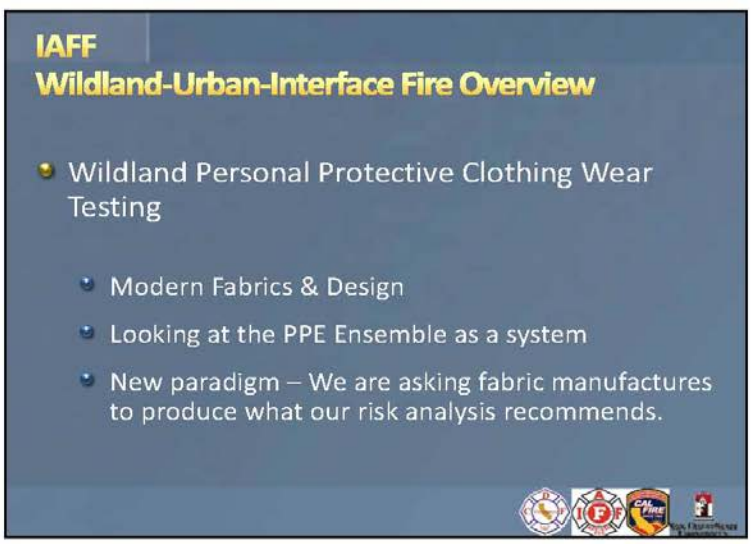
IAFF
Wildland-Urban-Interface Fire Overview
Wildland Urban Interface Structure Protection Operational Guidelines
Common Terminology
Standard Operational Principles
Guidelines
Risk Management Process
Checklists


IAFF
Wildland-Urban-Interface Fire Overview
Wildland Personal Protective Clothing Wear Testing
Modern Fabrics & Design
Looking at the PPE Ensemble as a system
New paradigm – We are asking fabric manufactures to produce what our risk analysis recommends.


IAFF
Wildland-Urban-Interface Fire Overview
Initial Attack Effectiveness Study
Wildland Firefighter Staffing
Resources and Equipment
Firefighter Health and Safety
Community Wildfire Protection Planning
Districts v. Regional Planning
Interoperability and Communication
Prioritization and Management
Online Resources
SAN DIEGO STATE UNIVERSITY

3

IV. Kuma Sumathipala, American Wood Council

1

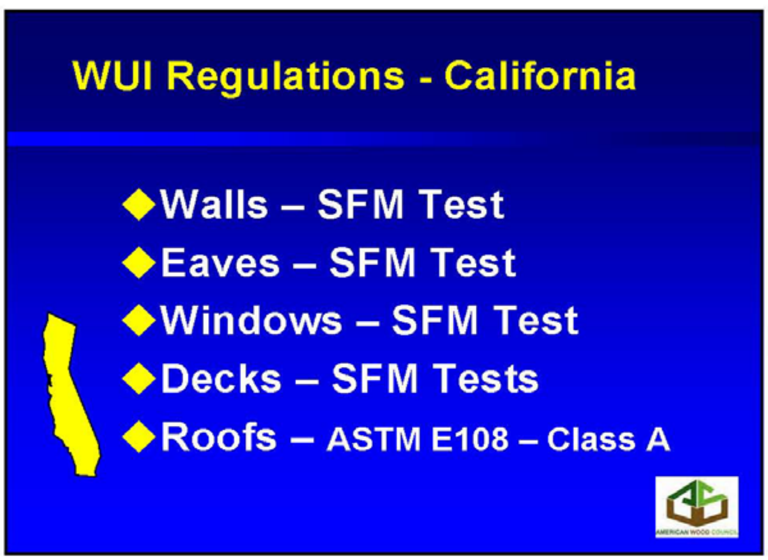

Building Survival in
Urban Wildland Interface Fires
Systems approach:
Terrain
Vegetation
Type, Proximity, Quality
Building perimeter - fuel
Building Regulation


Inhospitable Terrain

2

3


WUI Mitigation Strategies
◆Perimeter fuel clearance
◆Building regulation
●California


WUI Regulations - California
◆Walls – SFM Test
◆Eaves – SFM Test
◆Windows – SFM Test
◆Decks – SFM Tests
◆Roofs – ASTM E108 – Class A

4

WUI Regulations-California Compliant Wood Siding

Log Cabin 2x8	Pond Pine or better
Shiplap 1x6	Pond Pine or better
Tongue & Groove	Pond Pine or better
Rabbeted Bevel	Cedar /Redwood
Board and Batten 1x8 and 5/4x4 bats	Cedar/Redwood

WUI Regulations-California Compliant Wood Decking

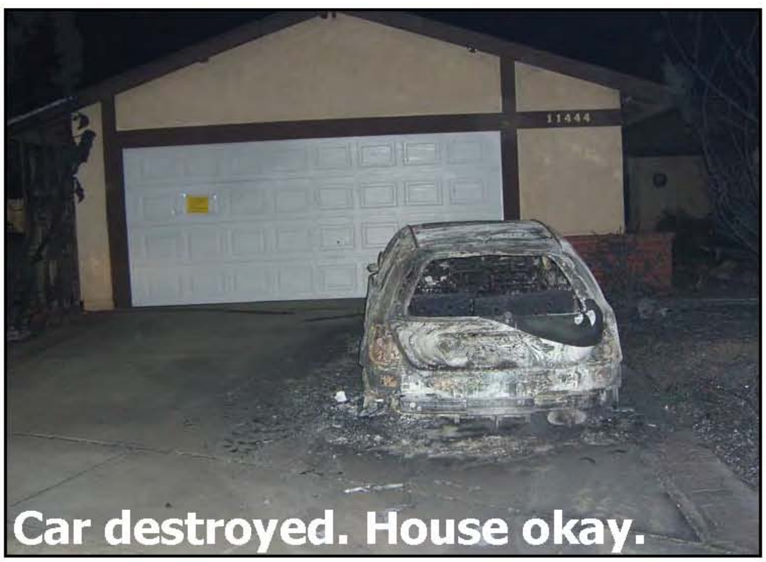
- Cedar
- Redwood

WUI Regulations-California Compliant Wood Roof Covering

- Non fire retardant treated wood shingles do not comply

6

WUI Destruction
An *Act-of-God?*



7

8


Mitigate WUI Property Losses
◆Wood industry offer to work with NIST to find strategies

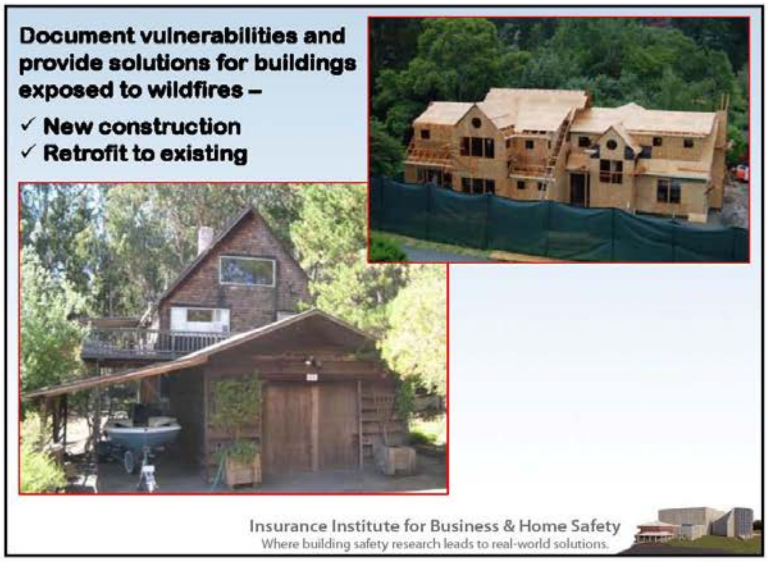

American Wood Council
The End

9

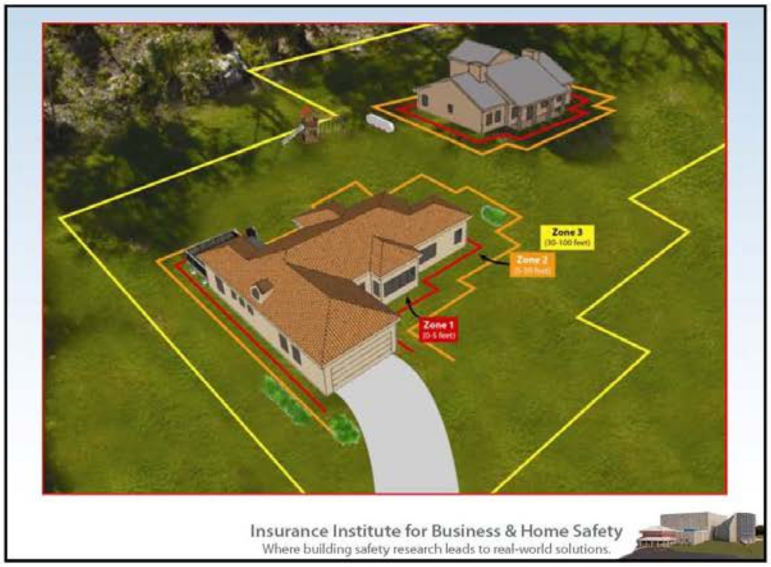
V. Steve Quarles, Insurance Institute for Business and Home Safety

8/21/2012

1


Document vulnerabilities and provide solutions for buildings exposed to wildfires –
✓ New construction
✓ Retrofit to existing
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Protecting your home from wildfire – you must consider building materials / components *and* near-home vegetation
Vegetation
Home
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Zone 3
Zone 1
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Ember / Firebrand
Flame Contact
Radiant
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.

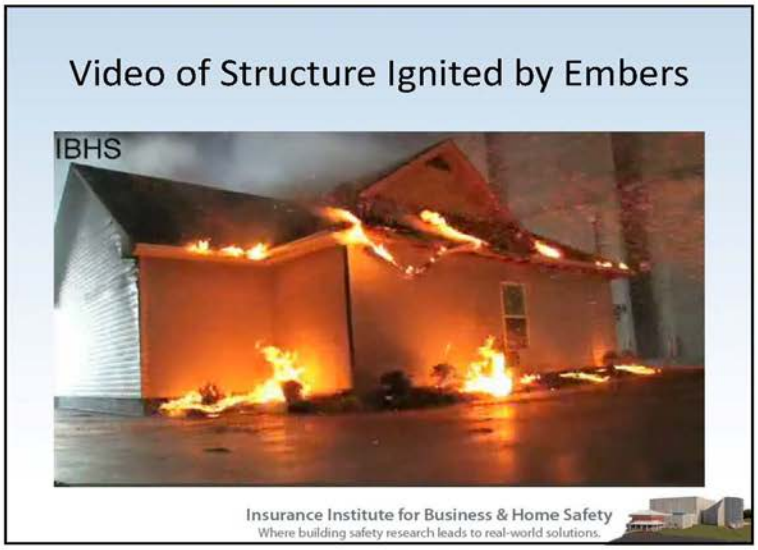

5 ember generators with 3 outlets per generator. Generators and associated fan systems located below grade.
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.

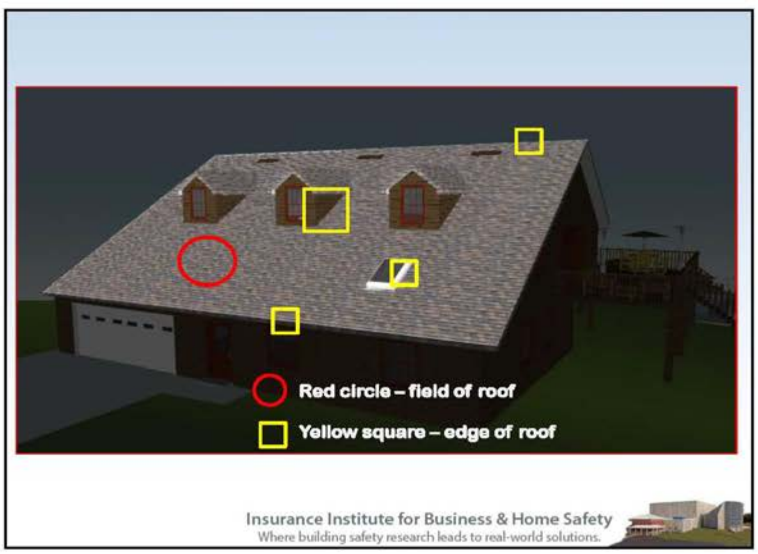

Raw material –
✓ Large chunk bark
✓ Medium bark mulch
✓ Wood dowels
~ 90 kg (200 lbs) material in five generators
Ignition of raw material with propane gas burner. Currently a batch process.
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.

4

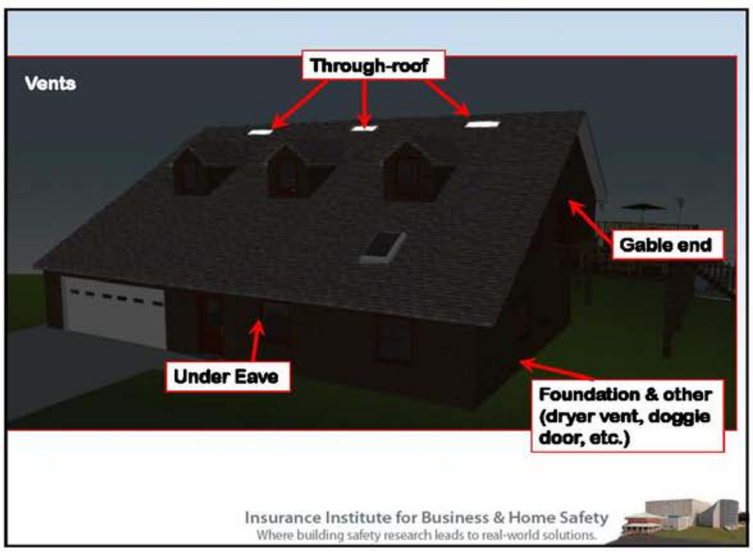

✓105 ~5.5 ft diameter fans
✓145 ft W x 145 ft L x 70 ft H test chamber
✓60 ft W x 30 ft H wind inlet
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Test building located on a turn table.
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Video of Structure Ignited by Embers
IBHS
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Red circle – field of roof
Yellow square – edge of roof
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Standard roof test
Edge of Roof
Vulnerability
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Vents
Through-roof
Gable end
Under Eave
Foundation & other
(dryer vent, doggie
door, etc.)
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.

Planned research in the large test chamber and fire lab

1) Large test chamber – ember exposure

Ember penetration through vent and accumulation on and round building as a function of wind speed and building orientation.

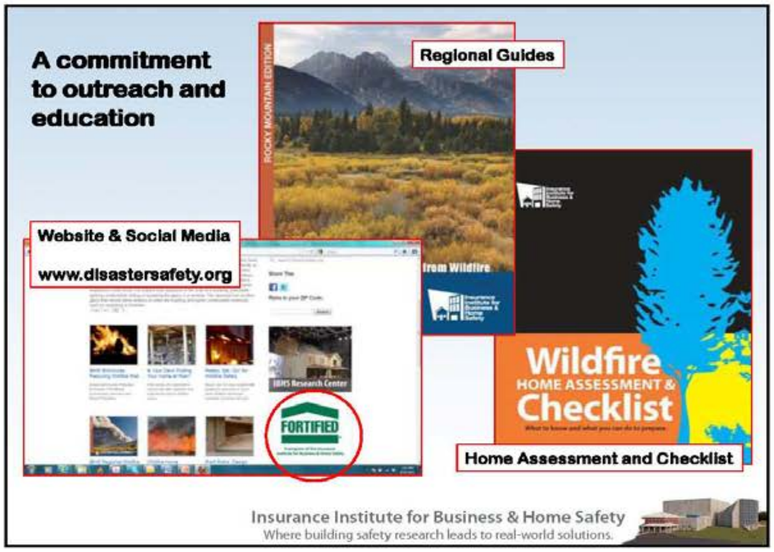
2) Fire lab – direct flame contact and radiant heat exposures [component and assembly]

Roof covering (assembly)

Skylights & windows

Siding (assembly)

Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


A commitment to outreach and education
Regional Guides
ROCKY MOUNTAIN EDITION
Website & Social Media
www.disastersafety.org
from Wildfire
FORTIFIED
IBHS Research Center
Wildfire
HOME ASSESSMENT &
Checklist
Home Assessment and Checklist
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.


Thanks for your attention!
Steve Quarles
squarles@ibhs.org
Office: (803) 789-4209
Cell: (813) 404-4942
http://www.disastersafety.org
http://www.eXtension.org/surving_wildfire
Insurance Institute for Business & Home Safety
Where building safety research leads to real-world solutions.

VI. Mark Dietenberger, US Forest Service

9/7/2012

Wildland-Urban Interface Research at the Forest Products Laboratory: Past, Present, And Future

By
Mark A. Dietenberger, Ph.D.
Research General Engineer
Durability and Wood Protection Research

FPL

Forest Products Laboratory

- U.S. Department of Agriculture, Forest Service
- Emphasis Areas:
  - Advanced Structures
  - Advanced Composites
  - Forest Biorefinery
  - Nano technology
  - Woody Biomass Utilization

Centennial Research Facility viewed from main building

FPL

1

Forest Products Laboratory

- 172 permanent staff
  - including 52 scientists.
- Web site:
- www.fpl.fs.fed.us

- **Seven Research Work Units:**
  - Economics & Statistics
  - Engineering Properties of Wood, Wood-based Materials & Structures
  - **Durability & Wood Protection**
  - Engineered Composites Sciences
  - Institute for Microbial & Biochemical Technology
  - Performance Enhanced Biopolymers
  - Fiber & Chemical Sciences

FPL

FPL FIRE RESEARCH TEAM

- Part of **Durability and Wood Protection Research** RWU
  - **Carol Clausen,** Project Leader
- Staff
  - **Dr. R. H. White**, Scientist
  - **Dr. M. A. Dietenberger**, Scientist
  - **C.R. Boardman**, Engineer (20%)
  - **Comazel Caldwell**, Technician
  - **Anne Fuller**, Technician
  - **Keith Bourne**, Student trainee
- Brochure "Durability and Wood Protection: Fire Research for Safe and Durable Wood Structures Laboratory" available on FPL web site.

FPL

Predating "Wildland Urban Interface"

FPL

1950s Conclusions Still Applicable

"1. Investigations of the ignition temperature of wood, while informative have not yielded result that can be used for predicting the actual performance of wood under fire conditions, nor in evaluating the significance of fire retardant treatments and coatings.

2. Fire spread is the characteristic of wood that is most affected by fire-retardant treatments and coatings. Size, form, density, moisture content, and arrangement of members are factors that have an important affect on the fire-spread characteristic of wood.

3. Resistance of wood to destruction by fire, such as rate of penetration of fire and maintenance of structural properties under standard time-temperature conditions, is affected by its physical properties and structural details. Resistance to charring is not greatly increased by fire-retardant treatments, perhaps at most by some 10 to 20 percent.

4. Good performance of wood construction under fire conditions is obtained by taking advantage of the self-insulating qualities of wood, by employing good structural details, and by using fire-retardant treatments and coatings where circumstances warrant."

(From Fire Research and Results at the Forest Products Laboratory / 1. R. Truax / FPL Report No. 1999 (September 1954)

FPL

Fire research continues because of...

- introducing new wood products,
- introducing new treatment technologies,
- updating test methods,
- bettering fire prediction analysis and models, and
- developing and updating of building codes

FPL

Recent Fire Research Highlights

- Updated "*Fire Safety of Wood Construction*" chapter for 2010 *Wood Handbook*
- Models for predicting E84 FSI from cone calorimeter data
- Data for additional fire resistance provided by adding gypsum board to individual structural wood members
- Assisted National Frame Building Association with preliminary FPL fire testing leading to their successful 3 hours rated post-frame wall assembly test at UL
- ASTM E2768 –"*Test method for extended duration surface burning characteristics of building materials (30-minute tunnel test)*"
- Chapter "*Fire damage in wood framed structures*" for "Inspection, Testing, and Monitoring of Buildings and Bridges" to be published soon by National Council of Structural Engineers Association.
- Several cone calorimeter studies on wood composites and wood-plastic composites, including FRT samples.
- Cone calorimeter database accessible via www.fpl.fs.fed.us

FPL

Wildland-Urban Interface FPL Research Topics

- Wood shingles
- Exterior sidings
- Native and ornamental single vegetation
- Forest litter or wood shaving beddings
- Decks and other exterior wood structures
- Railroad trestle bridges
- Home assessment

FPL

Wildland-Urban Interface Test Methods at FPL

- Accelerated weathering
- Cone calorimeter
- Mass loss calorimeter with sensible HRR
- FPL-modified Schlyter panel test with HRR
- 0.3 kW to 3 MW HRR hood facility
- Roof test with fire brands and fan wind
- Lateral ignition flame travel test
- E648 Radiant Panel

FPL

Wood Shingles, Sidings, and Decks

- Fire-retardant treatments
- Accelerated weathering prior to fire tests
- Long-term outdoor weathering
- Combined preservative and fire-retardant treatments
- Cone calorimeter for initial evaluation
- Modified Schlyter test with HRR
- Roof test can be used when warranted

FPL

Cone Calorimeter

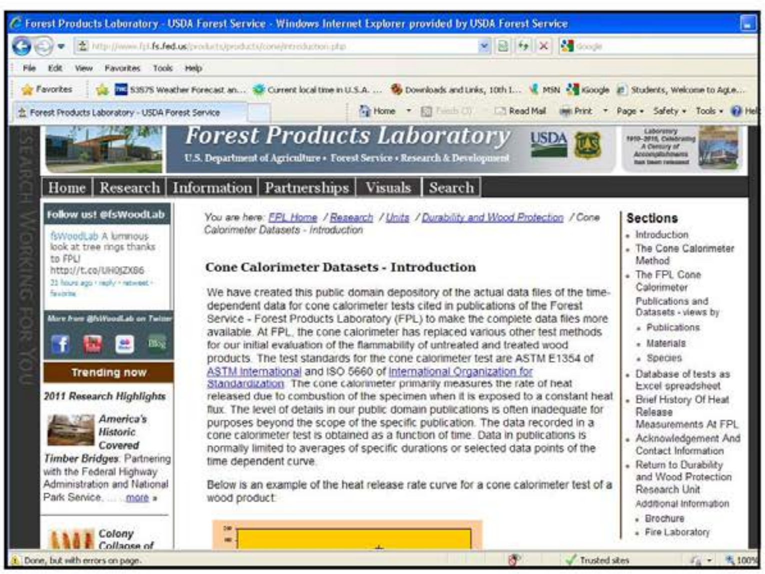
- Obtained by FPL in 1995.
- Uses oxygen consumption to measure the RHR.
- Widely used for R&D of building products.
- Upgraded recently

FPL

FPL Cone Calorimeter Data Depository

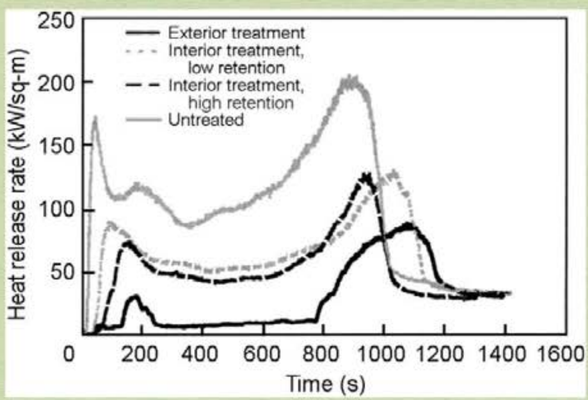
- Objective of this AWC funded project is to make available on the internet the actual data files for FPL cone calorimeter (ASTM E1354) tests *conducted on building products* and *cited in FPL publications.*
- The web pages are directly accessible from the FPL homepage.
- Plans to update the depository with more recent publications in 2012.

FPL



7

Southern pine sawn lumber

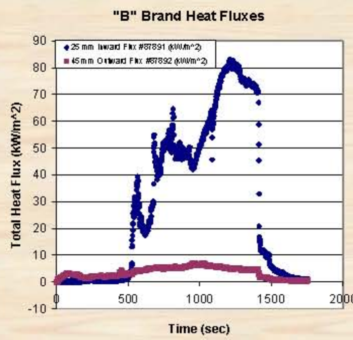


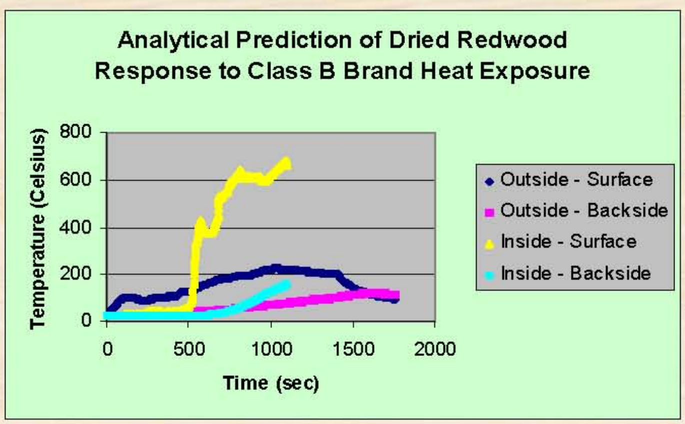
"B" Brand Cone Test - Fire Spread

- Two Fluxmeters
- Erratic fire spread
- Measure mass loss & heat release
- Flame height varies with HRR, not with object height
- Conical flame shape

"B" Brand Cone Test - Heat Flux

- At 45 mm away – only 6.7 kW/m^2 peak – no damage
- At 25 mm inward – Fluxes easily ignite combustibles
- Time duration of about 15 minutes





"B" Brand Cone Test – Heat Flux

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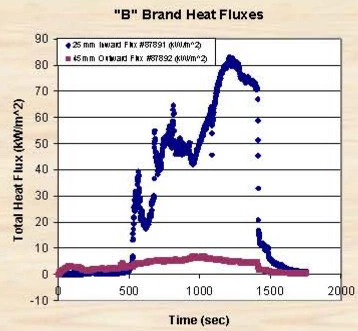
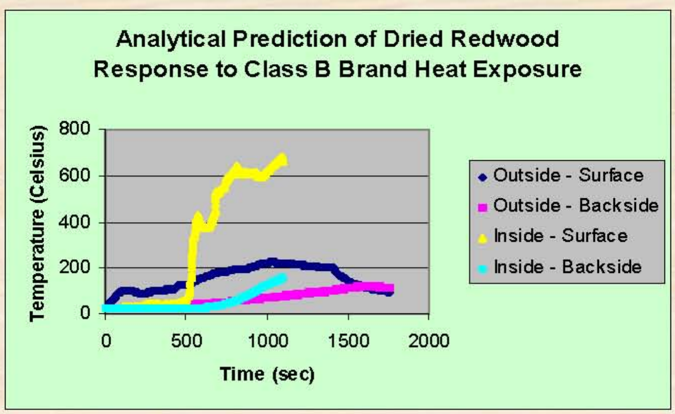
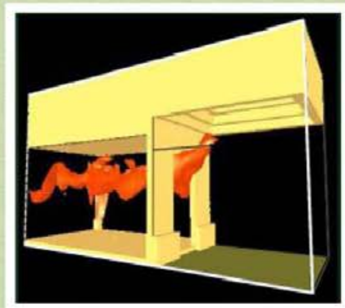




Upgraded Cone Calorimetry to Derive Thermophysical Properties for FDS

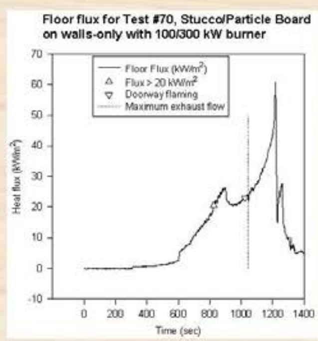
- Ignition temperatures
- Thermal diffusivity
- Thermal conductivity
- MLS and HRR model
- Gases, soot, and emissions model



FPL

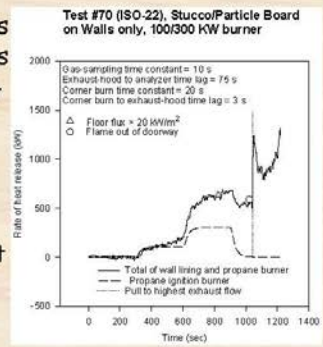
Stucco/OSB Room-Corner Test - Heat Flux

- At the floor center, the irradiance of 20 kw/m^2 is reached at 8 minutes after burner ignites to indicate flashover
- As wall becomes involved, the heated and cracked stucco volatizes the OSB to contribute to the fire



Stucco/OSB Room-Corner Test - HRR

- After only 3 min the wall ignites and upward flame spread ensues
- Burner increasing to 300 kW at 5 min ignites more wall areas
- Flame out of doorway in 12 min even after burner shutdown at the 10 min duration
- Stucco can thus protect against firebrands but not against direct vegetation flames



Native and ornamental plants

- A number of cooperative studies examined the use of cone calorimeter to determine relative flammability of different vegetation.
- In 2010, an overview article on testing of individual plants was published in International Journal of Wildland Fire.
- Christmas trees of varying dryness were tested under the HRR hood

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Accelerated weathering of FRT Wood Products

- ASTM D2898 Method A – Rain test
  - 1,152 hrs of 0.30 L/min/m^2 water
- ASTM D2898 Method B – FPL Chamber
  - 336 hrs of 12.2 L/min/m^2 water
  - UV sunlamps
- ICBO AC 107 / D2898 Method C
  - 1,008 hrs of 12.2 L/min/m^2 water
  - UV sunlamps

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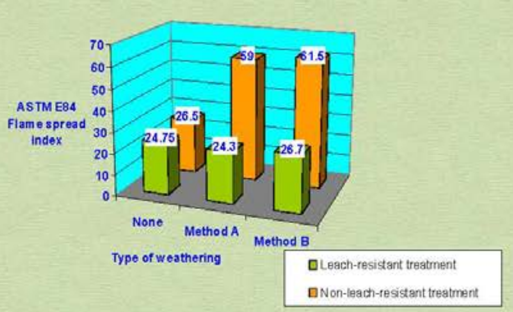
Alternative Weathering Procedures



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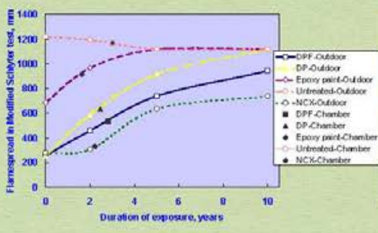
Outdoor Weathering Results (with Modified Schlyter Fire Test) from LeVan and Holmes, FPL Paper 474



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Railroad Trestle Bridges

- Problem of hot-metal ignition of railroad bridges
- Fire performance of creosote-treated wood
- Performance of FRT coatings as a solution
- Accelerated weathering
- Cooperative research with railroad utility

FPL

Initial Fire Performance Tests - Metal ignition, and MLS Calorimeter

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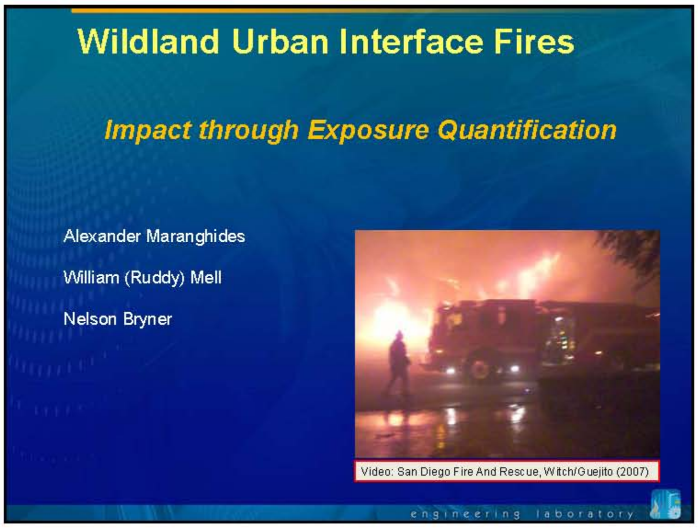
Continuing FPL WUI Research

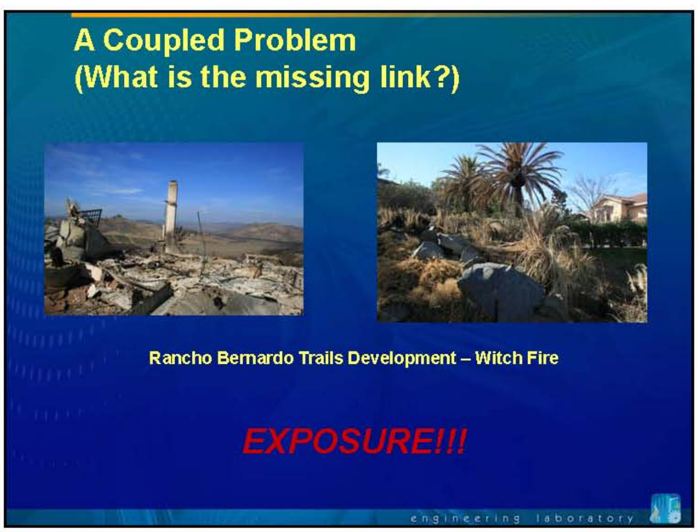
- Upgrading fire tests for WUI application
- Continuing work on thermophysical properties for performance based codes
- Using new technology to impart fire retardancy and resist wood rot
- Continuing work on accelerated and natural weathering on exterior products
- Extending fire expertise to vegetative fires

FPL

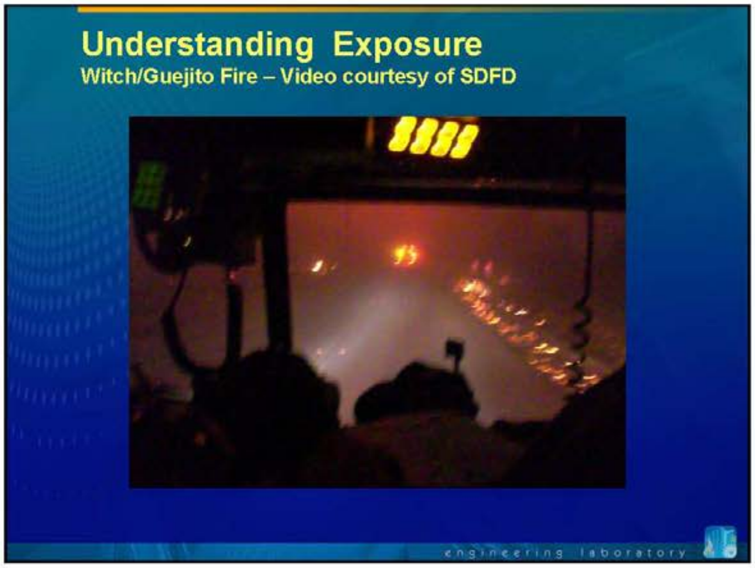

Questions ?
Thank You !
See web site
http://www.fpl.fs.fed.us for
additional publications

VII. Alex Maranghides & Nelson Bryner, National Institute of Standards and Technology





1


Understanding Exposure
Witch/Guejito Fire – Video courtesy of SDFD
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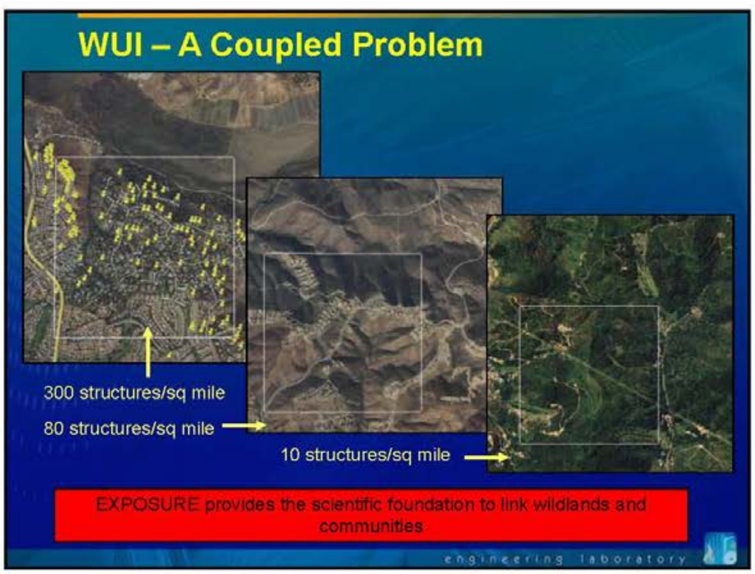
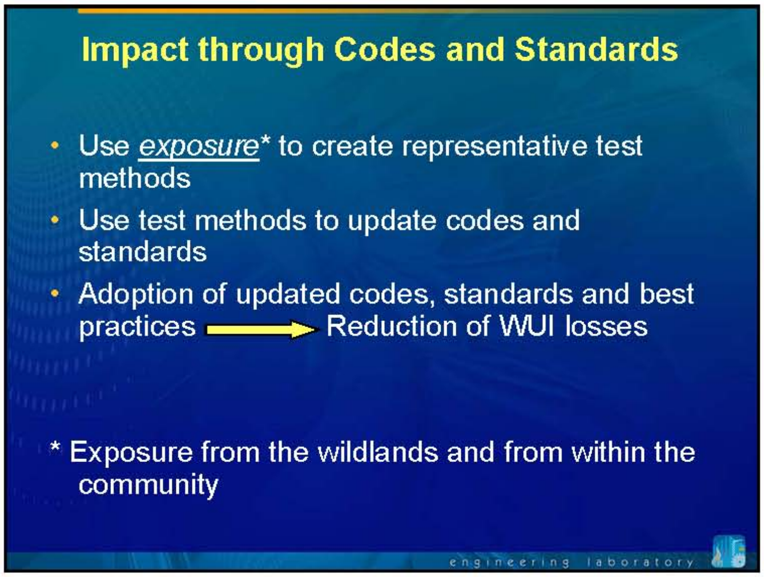
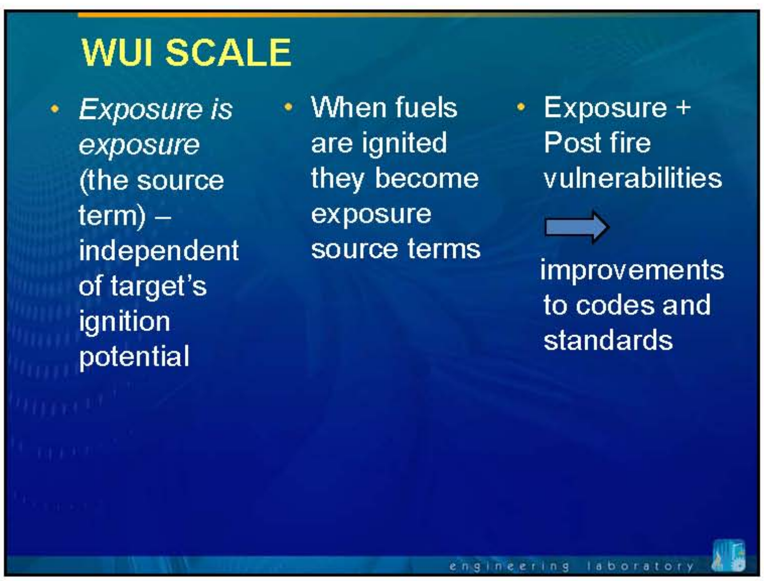

WUI – A Coupled Problem
300 structures/sq mile
80 structures/sq mile
10 structures/sq mile
EXPOSURE provides the scientific foundation to link wildlands and communities
engineering laboratory

2


Impact through Codes and Standards
• Use exposure* to create representative test methods
• Use test methods to update codes and standards
• Adoption of updated codes, standards and best practices → Reduction of WUI losses
* Exposure from the wildlands and from within the community
engineering laboratory


WUI SCALE
• Exposure is exposure (the source term) – independent of target's ignition potential
• When fuels are ignited they become exposure source terms
• Exposure + Post fire vulnerabilities → improvements to codes and standards
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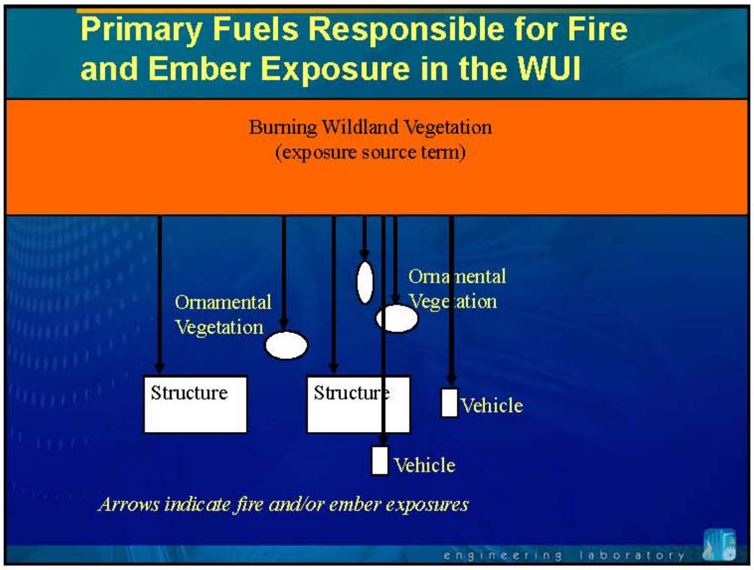
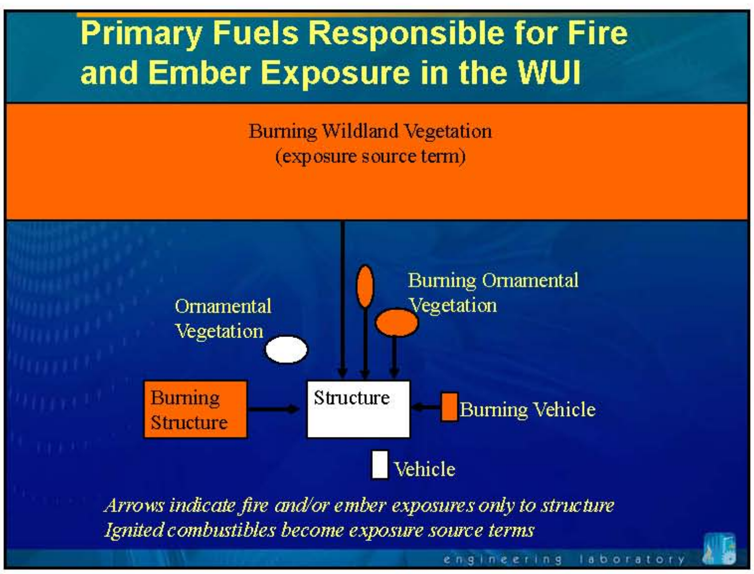
3



Primary Fuels Responsible for Fire and Ember Exposure in the WUI
Burning Wildland Vegetation
(exposure source term)
Ornamental Vegetation
Ornamental Vegetation
Structure
Structure
Vehicle
Vehicle
Arrows indicate fire and/or ember exposures
engineering laboratory



Primary Fuels Responsible for Fire and Ember Exposure in the WUI
Burning Wildland Vegetation
(exposure source term)
Ornamental Vegetation
Burning Ornamental Vegetation
Burning Structure
Structure
Burning Vehicle
Vehicle
Arrows indicate fire and/or ember exposures only to structure
Ignited combustibles become exposure source terms
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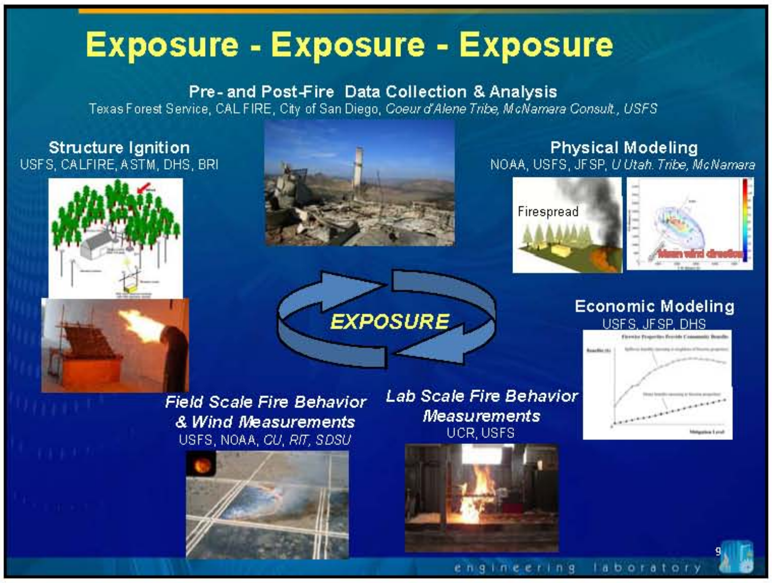
4



Building Element Response to Ember and Fire Exposure

Building Elements	Potential Ignition Vulnerability	
	Embers	Direct Fire Assault
Metal Frame Closed Window	No	Yes[1]
Untreated Wooden Deck	Yes	Yes
Attic Insulation	Yes[2]	No

[1] Window may crack under direct flame exposure
[2] Combustible insulation may ignite from embers away from attic vents

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5

Quantifying Exposure
Fire and Embers

Source Terms: all fuels, Wildland *and* WUI

Fire: kW/m^2 (peak*)

Embers**: gr/m^2-sec

* In order to simplify the scale, peak values are used – instead of integrated fluxes.

** All embers do not exhibit the same characteristics and pose the same ignition potential

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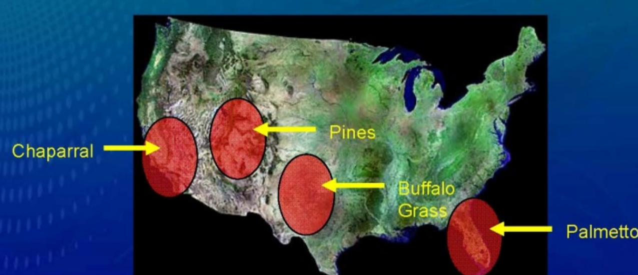
Wildland Fuels in High-Risk WUI Areas



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Wildland Fuels Complexity
Fuel Types and Characteristics

- Grasses - Homogeneous
- Shrubs - Homogeneous
  - Heterogeneous
- Trees (canopy) - Heterogeneous
  - Multilayered

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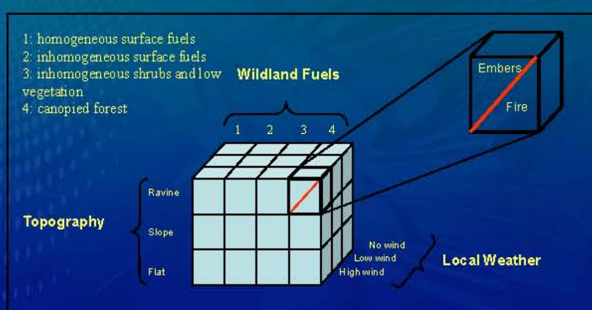
Capturing Exposure from Wildland Fuels*



* Similar approach is used for addressing threat from community fuels

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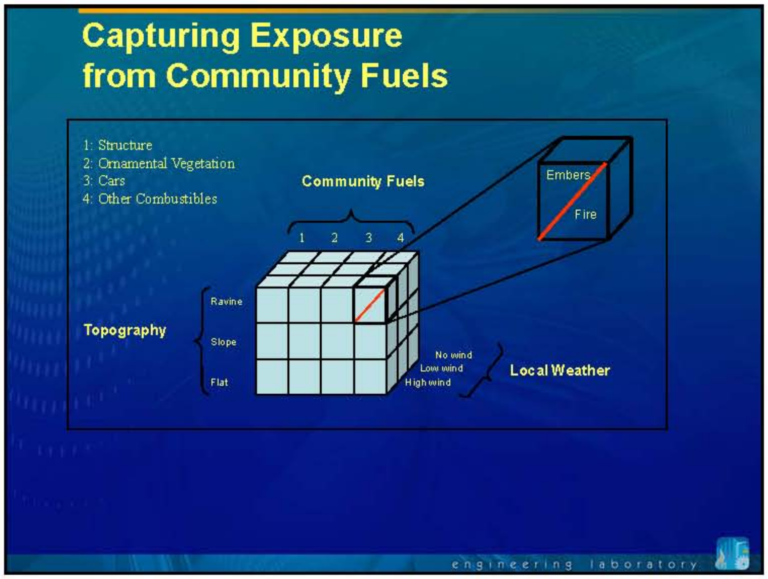
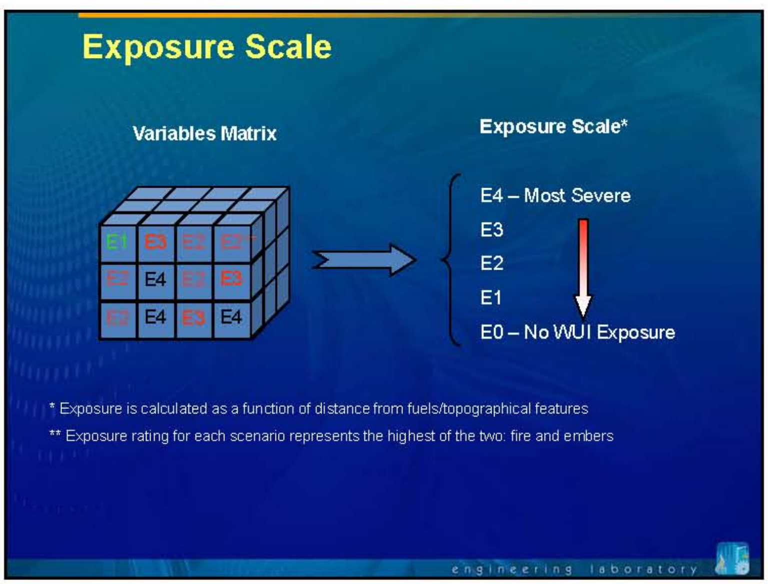

Capturing Exposure
from Community Fuels
1: Structure
2: Ornamental Vegetation
3: Cars
4: Other Combustibles
Community Fuels
1 2 3 4
Embers
Fire
Topography
Ravine
Slope
Flat
No wind
Low wind
High wind
Local Weather
engineering laboratory


Exposure Scale
Variables Matrix
Exposure Scale*
E4 – Most Severe
E3
E2
E1
E0 – No WUI Exposure
* Exposure is calculated as a function of distance from fuels/topographical features
** Exposure rating for each scenario represents the highest of the two: fire and embers
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8

Reducing Loses
*Coupling Exposure to Construction**

Exposure Scale		Building Construction Scale
E4 - Most Severe		
E3	↔	E3 – Most Resistive
E2	↔	E2
E1	↔	E1
E0 – No WUI Exposure	↔	E0 – Unrestricted** Construction

* Building and landscaping – construction and maintenance

** Unrestricted only with respect to WUI exposure

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Representative E-Zone Fuel, Terrain and/or Local Weather Characteristics

E-Zone	Ember Exposure	Fuel	Terrain	Local weather
E1	no ember exposure	light fuels- wet environment	flat terrain	- low or moderate humidity - light winds
E2	minimal ember exposure	light fuel loading	moderate slope	- low humidity - intermediate winds
E3	significant ember exposure	intermediate fuel loading	moderate slope	- low humidity - strong winds
E4	extensive ember exposure	- dry flash[1] fuels - high fuel loading	- steep slope - chimneys	- low humidity - strong winds

[1] **Flash Fuels:** Fuels such as grass, leaves, draped pine needles, fern, tree moss and some kinds of slash, that ignite readily and are consumed rapidly when dry. Also called fine fuels. Source: Glossary of Wildland Fire Terminology, National Wildfire Coordinating Group, PMS 205, October 2006

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9

A New Community Design Using the WUI Hazard Scale

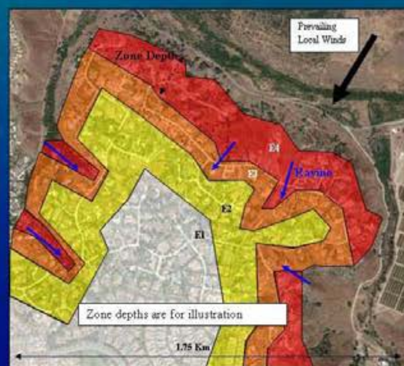

Illustration of Wildland Ember Exposure on Community

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Model Validation / Verification

- Fuels (type, moisture)
- Coupling of fire-weather
- Topography (terrain)
- Weather (wind)

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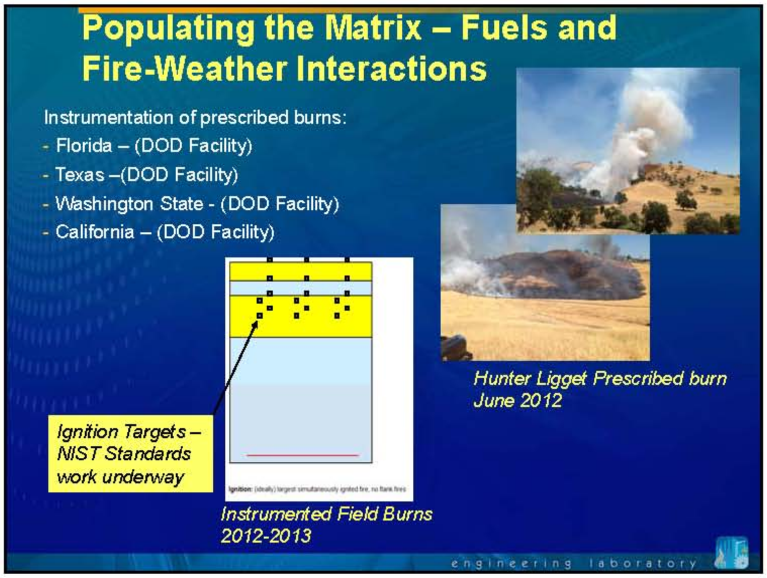
10


Populating the Matrix – Fuels and Fire-Weather Interactions
Instrumentation of prescribed burns:
- Florida – (DOD Facility)
- Texas –(DOD Facility)
- Washington State - (DOD Facility)
- California – (DOD Facility)
Ignition Targets – NIST Standards work underway
Instrumented Field Burns 2012-2013
Hunter Ligget Prescribed burn June 2012
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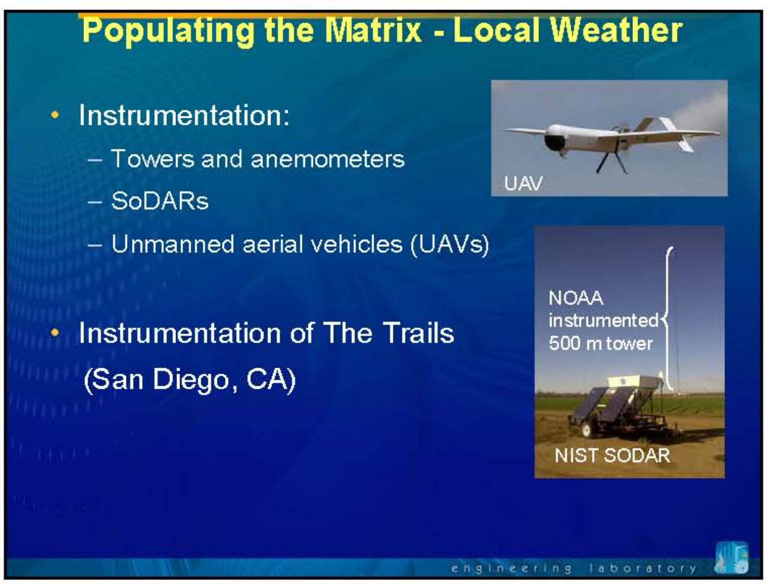
Populating the Matrix - Local Weather
• Instrumentation:
– Towers and anemometers
– SoDARs
– Unmanned aerial vehicles (UAVs)
• Instrumentation of The Trails (San Diego, CA)
UAV
NOAA instrumented 500 m tower
NIST SODAR
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Summary

1. Wildland and WUI fire problems are growing
2. Lack of scientific knowledge necessary to generate high impact solutions
3. NIST/USFS have jointly developed an exposure centric technical approach that is generating quantifiable impact.

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Thank You

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12

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