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FORUM Position Paper[1] The Growing Global Wildland Urban Interface (WUI) Fire Dilemma: Priority Needs for Research

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Introduction

Fires at the wildland urban interface (WUI) have been growing in frequency and intensity on over the past 15 years. The WUI fire problem is global: 2007 brought devastating wildland fires to Greece where 70 people perished. France, Portugal, Spain, Italy, and Greece experienced 43,000 wildfires in 2010 alone. Chile, Argentina and Brazil have all saw major wildland fire losses, and Australia has suffered the greatest loss from a wildland fire incident in 2009 which claimed 1000 structures and 170 people in the state of Victoria. In 2016, Fort McMurray, Canada, the WUI fire displaced more than 80,000 people for a month, destroyed more than 2000 structures, and shut down almost a quarter of Canada's oil production, with an estimated total cost near $9 billion. In 2017, fires in Portugal resulted in the deaths of more than 120 people and multiple WUI fires destroyed more than 5,000 structures and resulted in more than 40 deaths in California.

In the United States alone, an average of 75,000 wildland fires consume a total of 2.8 million hectares of forest land on average each year. Roughly, 2–3% of these fires spread into adjacent urban areas, resulting in an average loss of approximately 3000 homes. As Table 1 illustrates, seven of the fifteen largest U.S. fire loss incidents in this period were WUI fires, with an average property value dollar loss of $1.4 billion. Concurrently, the U.S. WUI areas continue to grow; at least 46 million structures are located in these areas comprising over 70,000 communities and affecting 120 million people.

Over the past 60 years, the global fire safety science community has developed a deep body of knowledge on fire dynamics within urban building structures. As opposed to traditional building fires, there exists no validated models to predict fire spread and structure ignition in WUI fires. Due to great strides in traditional building fire research, for lack of better term, *fire in the box*, the fire safety science community now has zone models, and most recently computational fluid dynamics (CFD) models, such as the Fire Dynamics Simulator (FDS),

[1]The International FORUM of Fire Research Directors (FORUM) was formed in 1991 with a goal to reduce the burden of fire (including the loss of life and property, and effects of fire on the environment and heritage) through international cooperation on fire research. This paper was prepared by the listed authors and the members of the FORUM support its conclusions.

an international collaborative effort led by the National Institute of Standards and Technology (NIST) and VTT, or FM Global's (FM) FireFOAM, that have been instrumental to understand fire growth within buildings.

In the case of FDS, many hours have been put in to validate the model against experimental results. While challenging, this is much simpler than trying to validate models that must be able to resolve physical processes over the disparate range of scales needed for WUI fires, from kilometers to resolve fire spread, down to centimeters to capture individual firebrand ignitions. Due to the range of complex scales, research into WUI fires, and how to potentially mitigate losses from such fires, is far behind other areas in the field of fire safety science. This is due to the fact that the WUI fire problem is unique in its complexity, involving the interaction of topography, weather, vegetation and structures and thus there are many gaps in our scientific understanding of the problem and potential effective mitigation.

The International FORUM of Fire Research Directors recognizes the growing nature of the WUI fire problem and the need to extend fire safety science research resources and fundamentals to this new challenge. This position paper highlights the current state of the art and the need for future developments in research, standardization, and dissemination related to the WUI fire problem. The paper is organized to address the key hazards and mitigation strategies for WUI fires with a holistic approach delineated into four major focus areas.

Research Needs

Hardening by Design: More Ignition Resistant Communities

Designing structures to be more resistant to ignition in WUI fires, known as hardening, is an accepted approach to lessen structure and community losses. Currently there are international standards and codes that attempt to harden structures to WUI fires exposures. These approaches were developed using the best methods at the time of their implementation, albeit in a time when WUI fire science was in the early stages of development. As WUI fire science has begun to advance further, it has become apparent that the current codes and standards are not adequate to address the range of WUI exposures. Current standards and codes are largely focused on radiant heat and flame contact exposure, while recent research has found that firebrands, or embers, are responsible for most of the structure ignitions. It should be of no surprise that the current standards and codes to harden structure are not adequate since the fire safety science research community has only begun to focus resources on WUI fires. Recent international workshops that have collected a global perspective on the state of the art in WUI fire research, show that the exposure threats to structures in WUI fires, such as firebrands, are not measured or quantified [1–2]. Again, in the case of traditional building fire research, based on decades of tests on compartment fires, essential quantification has been undertaken, starting with the pioneering work of Kawagoe [3]. WUI fires have started to receive major focus, as evidenced by the most recent Emmons Lecture at the 12th International Symposium on Fire Safety Science, the leading conference in fire safety science [4].

In order to design more ignition resistant structures, the following research is needed:

Improved understanding of how WUI fires spread and ignite structures in communities

- Better understanding of burned/unburned structure patterns
- Standardized data collection strategies
- Fundamental understanding of firebrand ignition mechanisms

Better quantification of WUI fire exposures

- Understanding and quantification of WUI fire exposures
- Understanding the exposure that a wildfire presents to a community in conjunction with wildland fire behavior research
- Quantification of firebrand exposure from wildland and community sources
- Improve the understanding of firebrand mechanisms
- Translation of research results into mitigation strategies such as the development of representative standard test methods indicative of the exposures, of new materials, designs, and technologies, of scientifically proven retrofitting strategies for existing communities
- Incorporation of research results into codes and standards through better communications and interchange between the WUI standards and codes community and fire safety science research community.

WUI Firefighting

WUI firefighters have a challenging dilemma: they need to have incident command, tactics, training, and equipment to combat conventional wildland fires AND a different set of strategies to address structure fire exposures. These often have different objectives which come together at the WUI. Here are some fundamental research needs to inform safe and effective WUI firefighting:

Preplanning, tactics and incident command strategies

- Recognizing that the range of size and hazard presented by WUI fires is much larger than conventional structure fires, development of risk assessment strategies to inform resource allocation, tactics, and strategies
- Assessment of conventional structural firefighting tactics and their relevance to structures at the WUI, incorporating knowledge of unique WUI structural fire exposures
- Recognizing that time scale for WUI ignition and fire spread is on the order of minutes to hours, not the days to weeks for some wildland events
- Global review of WUI firefighting tactics and strategies documenting damage assessment and its relationship to tactical strategies

Firefighting equipment and technologies and firefighter personal protective equipment (PPE)

- Development and assessment of the performance of wildland firefighting technologies (e.g. shelter-in-place, respirator, and turnout gear technologies) with reference to their application to the WUI environment
- Exploration of the efficacy of water additives and gels through the development and application of standardized assessment methods
- Exploration of firefighter exposures unique to the WUI environment (thermal, event duration, air quality, etc.) and development of performance criteria and technological solutions for PPE
- Development of performance criteria/limitations for firefighting equipment (transport, hose, etc.) unique to WUI firefighting environments
- Study of water supply requirements for WUI firefighting with particular reference to the multi-structure implications of a WUI event

Communications and Data Collection

- Enhancement of firefighter safety through situational awareness in the WUI through the development of applied SMART technologies and data systems (UAVs) to include weather data, and other relevant global data sets
- Include WUI fires/firefighting in fire statistics in a proper way, at a global level

Evacuation, Emergency Management, Public/Technical Education

Emergency management is another unique aspect of the WUI fire problem and mitigation strategies. Recent major WUI fires have illustrated the challenges associated with event management in the highly variable and unpredictable WUI fire environment. Research needs in this topic fall in three categories:

- Incident pre-planning, emergency management, recognizing that the range of size and hazard presented by WUI fires is much larger than conventional structure fires, there is a need to develop risk assessment and management strategies which are a function of these parameters
- Notification/communication and evacuation protocols such as the utilization of human behavior research to develop effective and evidence-based emergency communication strategies for communities in the WUI, of standardized protocols for emergency communication and a better understanding of the likelihood of residents responding to notification and adopting the desired response
- Public education and awareness, including the utilization of human behavior research to develop effective education and awareness programs for the public living, working, and visiting WUI communities

Environmental Issues from WUI Fires

Environmental issues related to both suppressing WUI fires, as well the exposure to products of combustion from WUI fires need to be addressed. Research needs in this topic may be delineated as:

- Consequences to residents as well as fire responders from WUI fire and smoke exposures (acute, sub-acute, and long-term effects)
- WUI fires can generate significant amounts of greenhouse gases which exasperate climate change
- WUI fires release inhalable particulates that compromise the respiratory health of exposed population
- Run off during and post fires contaminate water quality
- Cascading damage can result from WUI fires including mudslides in subsequent years
- Loss of endangered species habitat threatens vulnerable species
- Degradation of ecosystem predisposes areas to insect and pathogen attack and accommodates invasive species
- Extinguishing agents, such as foams, and their long-term health effects

Conclusions

The growing nature of the WUI fire problem and the need to extend fire safety science research resources to this challenge have been presented as four major research needs: (1) Hardening by Design: More Ignition Resistant Communities, (2) WUI Firefighting, (3) Evacuation, Emergency Management, Public/Technical Education, and (4) Environmental Issues from WUI Fires. The WUI fire problem is challenging and it is hoped the research needs delineated here will provide critical guidance to tackle this emerging area within the field of fire safety science.

Reference

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Table 1.

Largest U.S. Fire Loss Incidents. WUI fires are underlined (NFPA).

Incident	Date	Adjusted Loss (2012 dollars)
1. World Trade Center, New York	2001	$43 billion
2. Earthquake and Fire, San Francisco	1906	$8.9 billion
3. Great Chicago Fire	1871	$3.2 billion
4. Oakland Hills Fire, CA	1991	$2.5 billion
5. So. California Firestorm, San Diego County	2007	$2.0 billion
6. Great Boston Fire, Boston	1872	$1.4 billion
7. Polyolefin Plant, Pasadena, TX	1989	$1.4 billion
8. Cerro Grande Wildland Fire, Los Alamos	2000	$1.3 billion
9. Wildland fire Cedar, Julian, CA	2003	$1.3 billion
10. Baltimore conflagration, Baltimore, MD	1904	$1.3 billion
11. “Old” Wildland Fire, San Bernadino, CA	2003	$1.2 billion
12. Los Angeles Civil Disturbance	1992	$0.9 billion
13. PowerPlant, Dearborn, MI	2000	$0.9 billion
14. Southern California Wildfires	2008	$0.9 billion
15. Laguna Beach Wildland Fire, CA	1993	$0.8 billion