NIST Technical Note 1662

Proceedings of the 2009 Workshop on Innovative Fire Protection

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NIST National Institute of Standards and Technology • U.S. Department of Commerce

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Executive Summary

To address the U.S. fire problem, the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) is developing a roadmap to identify gaps in knowledge and measurement science that impede development of critical enabling technologies. The roadmap will be used in planning how to best use limited resources to reduce fire losses, provide a basis for BFRL strategic planning, and provide a shared vision. Stakeholder perspective on the fire problem is considered a critical part of the Roadmap development process. This report documents the proceedings of a stakeholder workshop on the national fire problem.

The Innovative Fire Protection Workshop was held at the National Institute of Standards and Technology (NIST) on June 4 and 5, 2009. The 70 participants represented a broad range of stakeholder perspectives, including various non-profit, academic, industry, and government organizations with an interest in fire safety. This report documents the Workshop results, which provided valuable suggestions on how best to reduce fire losses in the United States.

The Workshop was broken into 3 plenary and 9 group breakout sessions. During the breakout sessions, the participants met in five Groups ("Breakout Groups") to discuss various aspects of the national fire problem including fire prevention, fire protection, fire service, wildland-urban interface fires, and global cross-cutting issues. This charge of the last group was to focus on areas of overlap and areas that might be overlooked by the other groups. Each of the Breakout Groups was composed of about 10 to 15 participants. The Groups were asked to identify technologies that could reduce fire losses and improve life safety, identify metrics to evaluate the potential of the various technologies, and identify the technical and non-technical barriers that hinder application of the technologies. The Groups were also asked to identify any gaps in measurement science that prevent successful implementation of the technologies.

Through this process, more than 200 technologies were identified as potentially important in reducing the national fire problem. The Groups also identified dozens of barriers, both technical and non-technical in nature, and measurement science needs that they felt were preventing successful implementation of enabling technologies. After establishing metrics, the Groups selected a set of the technologies for detailed evaluation, rating the potential of the technologies to have an impact on the fire problem. The results of the group discussions are documented as part of this report. A series of tables summarize the group discussions and provide the basis for understanding a broad range of stakeholder perspectives on potential technological solutions to the U.S. fire problem. Highlights from the workshop are summarized in the Tables below. Table E1 presents representative and selected enabling technologies identified by each of the Breakout Groups. Table E2 presents the measurements science needed to enable selected high-impact long-reach technologies and overcome key barriers as identified by each of the Breakout Groups.

More detailed information on the discussions of the Breakout Groups on technologies and measurement science needs are presented in the report.

The full list of approximately 200 technologies identified by the Breakout Groups were further evaluated by NIST using two metrics, namely the likelihood of realization of a technology and its potential impact. This process is seen as a first step in using the information from this workshop to benefit the NIST Roadmap. The results showed that while a large fraction of the technologies identified in the workshop are likely to be realized or may have significant impact, only about 20 % of the technologies have both of these attributes. This information will be valuable as alternate paths to achieve NIST's innovative fire protection goal.

This document, in addition to other input, will be used as a reference to inform the development of NIST's technology-centric Roadmap on Innovative Fire Protection and guide NIST in pursuing a portfolio of programs that are focused on providing the measurement science needed to enable innovative fire protection. It can also be used by both the public and private sectors to guide policy, research and development, and other decision-making relevant to this important area of national interest.

Table E1. Representative Enabling Technologies Identified for Innovative Fire Protection

Area	**Fire Prevention**	**Fire Protection**	**Fire Service**	**WUI Fires**	**Global Fire Issues**
Enabling Technologies	• Advanced fire resistant materials • National open flame test for upholstered furniture • Next generation smart sensor network • Integrated path lighting for flooring • Positive pressure ventilation for low rise • Sensors to detect pre-ignition conditions • Sensor activated suppression-homes & vehicles	• Appliance suppression • Improved Smoke Detectors • Improved suppression technology • Structural fire performance • Robotic firefighting • Responder communication technology • Mass Notification technology • Reliable sprinklers • Low-cost sprinklers • Installed air supply	• Health screening/risk ID tools • Improved communication equipment • Virtual environment trainer & data • Fire fighter tracker/ locator • Fire fighter research clearing house • Next generation fire fighter respiratory protection • Enhance suppression dynamics • Sustainable suppression agents • Enhanced fire fighter protection clothing	• Fire Weather Model • Firebrand Prevention technology • Firebrand Model • WUI Risk Model • Benefit-Cost Assessment Model • Messaging Tool	• Home fire suppress-ion retrofit kit • Barrier materials for very low combustibility furnishings • Automatic fire detection and power-off feature for anything with an automatic control • Life-cycle analysis of fire protection systems and features of products • Multi-hazard techniques for cost-effective fire protection solutions • Next-generation fire alarm • Fire-safe, energy-efficient appliances • Reliable firefighter locator/tracker/navig ation system • Firefighter black box

Table E2. Representative Measurement Science Needs to Enable High-Impact Long-Reach Technologies and Overcome Key Barriers for Innovative Fire Protection

Area	High-Impact Long-Reach Technology	Measurement Science Need
Fire Prevention	Testing and classification system for material flammability	• Measure and characterize smoke toxicity and develop metrics • Measure physical effects of heat release: spalling, melting, etc. • Measure heat of gasification (to classify fire performance) • Develop models to understand scaling and predict performance • Gauge repeatability and reliability (Accuracy) • Measure heat of gasification (to classify fire performance)
Fire Protection	Suppression systems for open flame, cooking, and heating appliances	• Test method for agent effectiveness • Characterization of toxicity of suppressant when added to fire • Characterize types of fire • Human factors: measure – what will prompt an owner to repair the system • Measurement of aging characteristics of suppressant • Determine the most appropriate sensor • Discrimination between desired and undesired heat sources
Fire Service	Health screening/risk ID tools for firefighters	• Identify risk factors for disease • Quantitative medical factors and conditions • Establish consensus testing protocol • Characterize fireground conditions, interior attack, overhaul • Determine impact of conditions on fire fighter health
WUI Fires	Legislative mandate to retrofit of pre-existing houses to address WUI fires	• Determination of relative effectiveness of technology options • WUI definition independent of fire risk • Relative effectiveness of alternative incentives • Economics - quantification of benefit-cost, etc. • Fire model measurements to identify most needed areas • Global benchmarking to understand test standards
Global Fire Issues	Home fire suppression retrofit kit	• Design fires, test method, performance criteria, agent properties • How to achieve reliable installation by amateurs • Guidance for storage of or access to extinguishing agent • Approval test • Minimize the amount of agent used

Acronyms

AFST: BFRL's Advanced Fire Service Technologies Program

APR: air-purifying respirator

ASTM: ASTM International

BFRL: Building and Fire Research Laboratory

CO_2: Carbon Dioxide

EHS: environmental health and safety

ESLI: end of service-life indicator

FF: firefighter

FR: fire retardant

GIS: global information system

GPS: global positioning system

HRR: heat release rate

HVAC: Heating, ventilation, and air conditioning system

LCA: life-cycle analysis

LIDAR: light detection and ranging technology

NFPA: National Fire Protection Association

NIST: National Institute of Standards and Technology

PBDE: Polybrominated diphenyl ethers

PPE: personal protective equipment

RRFSB: BFRL's Reduced Risk of Fire Hazard in Buildings Program

SCBA: self-contained breathing apparatus

SRM: standard reference material

SIP: structural insulated panel

TV: television

VID: video

WUI: wildland-urban interface

WUI Program: BFRL's Reduced Risk of Fire Spread in the Wildland-Urban Interface Program

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Proceedings of the Workshop on Innovative Fire Protection

1. Introduction

The Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) is developing a roadmap to identify gaps in knowledge and measurement science that hinder development of critical enabling technologies that could reduce fires costs and losses in the U.S. The roadmap will enable the best use of limited resources to address the U.S. fire problem, provide a basis for BFRL strategic planning, and provide a shared vision for communication with those who will use BFRL output to improve fire safety.

Stakeholder perspective on the fire problem is a critical part of the Roadmap development process. To capture their thinking, the Innovative Fire Protection Roadmap Workshop was held at NIST on June 4 and 5, 2009. The participants represented a broad range of perspectives and numerous stakeholder groups. The information gained from the Workshop will be used to help shape the NIST Roadmap on Innovative Fire Protection.

1.1 Objectives for the Workshop

The U.S. fire problem can be defined in terms of life safety and societal costs. At the highest level, NIST is approaching the problem in three component programs: Reduced Risk of Fire Hazard in Buildings, Advanced Fire Service Technologies, and Reduced Risk of Fire Spread in the Wildland-Urban Interface (WUI). The Workshop was designed for the participants to:

- Rethink ways to reduce fire losses and improve cost-effective fire protection,
- Identify innovative strategies and critical technologies that best address the fire problem, and
- Identify measurement science needed to enable high-impact technologies.

The participants, who are listed in Appendix 1, were encouraged to think broadly. Although a primary purpose of the Workshop was to identify emerging technologies that might significantly impact aspects of the fire problem, participants were encouraged to think about both technological and non-technological approaches.

A premium was placed on obtaining a large number of ideas and a variety of perspectives for evaluating their potential impact. The Workshop specifically did not include a ranking of the ideas because (a) this requires significant additional analysis, (b) the ideas from the participants were not assured of being a complete set, and (c) participation in the Workshop was not balanced among the many stakeholder groups. The Workshop agenda is given in Appendix 2.

1.2 NIST's Roadmap on Innovative Fire Protection

To address the U.S. fire problem, NIST is working on a roadmap to identify gaps in knowledge and measurement science that hinder the development of critical enabling technologies. The Roadmap will help identify critical staff, equipment needs, and financial resources necessary for a successful attack on the U.S. fire problem. The intent of the Roadmap is to organize evolutionary and revolutionary thinking on technological solutions to significant elements of the fire problem.

The Roadmap is technology-centric and is focused on the following questions:

1. What technologies are needed to attack the national fire problem?
2. For the top technologies, what needs to be done, by when, and by whom, to achieve the strategic goal?
3. What technical and non-technical barriers might limit the success of these technologies?
4. What measurement science needs stand in the way of achieving the goal?
5. What are the metrics to ensure that progress is being achieved?

From the answers to these questions, including incorporation of input from NIST staff and stakeholders, a set of strategic research priorities are being developed.

1.2.1 Background Materials

A set of handouts was sent to workshop participants. This provided background material on NIST's perspective on the national fire problem. The materials are provided in Appendix 3 and are composed of a series of brief summaries on the national fire problem. The handouts also include a draft statement of the BFRL vision as to how to address the fire problem, a description of BFRL Program goals, and draft approaches to BFRL's programmatic goals.

1.2.2 Defining Roadmap Components

A roadmap is a document that starts with a goal and traces the technological paths that lead from the current state of knowledge to that goal. In this case, the paths are centered on the principal NIST contribution, namely, measurement science (which is defined below). A roadmap typically indicates the potential contribution of each path to meeting the goal, enabling sorting of (but not rigidly determining) the best chances for success. It is anticipated that the roadmap will need to evolve as technical progress continues and as the external world changes. Stakeholder perspective on the fire problem is a critical part of the Roadmap development process.

With a focus on the NIST Roadmap, an effort was made to develop a common language among workshop participants to enable effective communication. A number of common terms associated with specific components of the NIST Roadmap were defined as follows:

***Goal*:** Overarching strategic target to be impacted by BFRL's research activities.

***Problem*:** An identified contributor to the national fire problem. Examples include ignition sources (i.e., candles, cooking appliances, etc.) or inadequate egress facilities (i.e., too few exits, stairs too narrow, etc.).

***Approach*:** A generic class of mitigation strategies to address a specific problem. Examples include <u>suppression</u> of an unwanted fire or <u>controlling</u> fire-generated smoke so that it doesn't affect building occupants.

***Technology*:** A specific tool used to address a problem. For example, nuisance-free smoke detectors would likely lead to reduced residential fire fatalities and injuries as building occupants would be less likely to disable the alarms.

***Measurement Science*:** Use of the scientific method to acquire knowledge based on quantitative observation of physical phenomena.[1] In the context of the NIST Fire Protection Roadmap, measurement science is applied to address specific research gaps that hinder a technology from being developed or implemented. For example, a standard for construction materials that resist ignition from a wildfire requires understanding of the ignition mechanisms and a reproducible way of generating firebrands.

Barrier: To achieve the goal of reducing fire losses and enhancing innovation in fire safety, certain technical and non-technical barriers. The application of measurement science is a means to overcome a technical barrier. Other methods will be needed to overcome non-technical barriers.

1.3 Conduct of the Workshop

The workshop was broken into 12 sessions – three plenary sessions and 9 group sessions, as highlighted in the agenda provided in Appendix 2 of this document. The Introductory Session

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[1] Measurement science includes:

- development of performance metrics, measurement methods, protocols, predictive tools, reference materials, data, and artifacts;
- conduct of intercomparison studies and calibrations;
- quantitative evaluation of technologies, systems, and practices; and
- development and dissemination of technical guidelines and bases for standards, codes, and practices, often via testbeds, consortia or partnerships with the private sector.

and Sessions VI and XI included all participants, while the other sessions were held in five smaller breakout groups, each composed of about 10 to 15 participants. The breakout groups were assigned to address various aspects of the national fire problem and included groups on Fire Prevention, Fire Protection, Fire Service Technologies, Wildland-Urban Interface (WUI) Fires, and Global or Cross-Cutting Group with the assignment of considering all fire safety related issues, with an emphasis on issues not necessarily covered by the other groups or topics at the boundaries of the other groups. In total, 67 people attended the Workshop and all participants were assigned to one of the five breakout groups. The full list of workshop participants is included in Appendix 1. The participants represented a broad range of stakeholder perspectives, representing various non-profit, academic, industry and government organizations with an interest in fire safety.

Before the meeting, participants were asked to identify three technologies (existing or emerging) that they felt should be considered as a way to reduce the national fire problem. The ideas could apply to one or more of the areas identified above and may be conceptual or specific. These ideas were compiled and provided to jump start the discussions for each of the breakout groups during Session III of the workshop. That information is documented as part of the workshop results.

- INTRODUCTORY SESSION

The introductory session explained the purpose of the workshop, what to expect over the course of the workshop, and the context of the workshop in terms of NIST roadmapping activities. The introduction to the workshop, presented by Anthony Hamins of NIST, covered the vision, mission and overall goals of the NIST Fire Research Program. A brief overview of the NIST Fire Protection Roadmap was presented, including its three-components: Reduced Risk of Fire Spread in Buildings, Advanced Fire Service Technologies, and Reduced Risk of Fire Spread in the Wildland-Urban Interface (WUI) and their objectives. In addition, the purpose and the components of the roadmap were presented. The presentation concluded by outlining the objectives of the workshop and how the workshop is a critical part of the roadmap development process. Next, two stage-setting lectures were presented as part of the introductory session. The presentation slides are given in Appendix 4.
John Hall of the National Fire Protection Association (NFPA) presented an overview of the U.S. fire problem. Dr. Hall characterized the problem in terms of lives lost, injuries suffered, and the total societal costs of fires. In addition to discussing accomplishments that would reduce the current values of these metrics (e.g., by less fire-prone cigarettes, fire detectors, low heat release rate mattresses), Dr. Hall stressed that attention must be paid to potentially large new additions to the fire problem arising from societal changes (e.g., losses at the wildland-urban interface) and avoiding regression due to possible limitations on current fire protection technologies (e.g., banning of Polybrominated diphenyl ethers (PBDE), a fire retardant additive).

Sarah Slaughter of the Massachusetts Institute of Technology (MIT) presented the second plenary lecture. Prof. Slaughter's lecture presented a framework for the application of technological innovation to large societal problems, including some successful examples of the mitigation of problems analogous to fire losses. Her presentation discussed innovation in terms of evolutionary and revolutionary technologies that could be brought to bear on the U.S. fire problem.

- SESSION I. Vision For the Future and Goals

The first participant-active session examined the NIST Vision and Goals. Participants in each of the Breakout Groups were asked to think beyond short-term incremental changes and focus on what could be possible with advanced/emerging technologies. The objective of this session was to provide feedback on NIST's vision and goal statements and to answer:

  - What radical changes do we want to achieve?
  - What targets do we want to strive for?

The results of the discussion on the NIST vision and goals in each of the five breakout groups are included in Section 2 of this report.

- SESSION II. Approaches

Each of the Breakout Groups was asked to identify ten approaches to reduce the overall U.S. fire problem and then discuss each in turn. Each breakout group created a list of approaches and associated technologies that the Group felt might provide solutions to specific fire problems. This list formed the basis for later discussion.

- SESSION III. Brainstorming Technologies

Each of the Breakout Groups was asked to create an unlimited list of technologies that might contribute to the approaches that the Group members identified during Session II and which might provide a solution to specific aspects of the national fire problem. Each of the suggested technologies was grouped under one of the approaches.

This list formed the basis for later discussion. Brainstorming ground rules required that participants present only one idea at a time, in one minute or less per idea. Participants were encouraged to consider existing and emerging technologies in other fields that might be applied to address the fire problem.

- SESSION IV. Technology Metrics and Attributes

Each Breakout Group was asked to develop a list of about 5 metrics to assess the potential contribution of a technology to reducing the fire problem (e.g., cost, likelihood of success, market readiness) and to develop attributes for the metrics. The attributes are complementary to the metrics, often defining a quantitative way to characterize the metrics.

- SESSION V. Short List of Technologies

Referring to their results from Session III, each Breakout Group was asked to identify 10 to 12 technologies, including some for each approach that appeared likely to have an impact on the fire problem. This was accomplished through an election-like process in which each group participant was given 2 orange stickers and 6 blue stickers and asked to identify the technologies that he/she considered to be game-changing and/or generally important, respectively. They were not required to use all of their stickers or to prioritize their choices. This information was used to narrow the focus of the discussion to a manageable number of technologies for further discussion.

- SESSION VI. Appraisal of Technologies

The metrics developed in Session IV were applied, along with the corresponding attributes, to characterize the potential contribution of each of the short-listed technologies to reducing the fire problem. A tabular format was used to highlight the relationship of the technologies, the metrics, and the attributes. The results of the Breakout Group deliberations are summarized in Tables 3.3, 4.2, 5.2, 6.2, and 7.2 in Sections 3-7 of this report, respectively.

- SESSION VII. Presentation of Day 1 Results

All participants gathered in a plenary session for the last session of Day 1 to hear brief presentations by each of the Breakout Groups on their results. The presentations addressed the following questions:

  - What were the most important results?
  - What were successes/difficulties of the process?

The presentation content was based on a template that was provided to each of the Breakout Groups. Audience questions during this session mainly addressed clarification of the presentations.

- SESSION VIII. Review of Results

Day 2 of the Workshop began with each of the Breakout Groups reconsidering their results from Day 1. Each of the groups discussed, revised, and modified the technologies, metrics, and attributes, as desired.

- SESSION IX. Barriers

Each of the Breakout Groups identified the technical and non-technical barriers to the implementation and effectiveness of each of their short-listed technologies.

- SESSION X. Measurement Science Needs

Each of the Breakout Groups identified the measurement science needs required to overcome the barriers, which had been identified in Session IX. The Breakout Groups also worked to identify the stakeholders who need to participate in defining these challenges.

- SESSION XI. Presentation of Results

During this plenary session, each of the Breakout Groups presented approximately five technologies for more detailed discussion, each of which being characterized by at least one of the following criteria:

1. High impact/long reach
2. Short-term delivery
3. Long-term delivery
4. Multiple measurement science research needs
5. Non-technical barrier

Use of these categories facilitated selection of a wide range of technology options and provided helpful examples, representing the broad range of challenges and benefits that must be considered in prioritizing research. This process highlighted a number of technologies and provided a model for analyzing the full set of technologies.

Summaries of these presentations are documented in Sections 3 to 7 below. A general discussion followed in which the participants expressed their observations and identified patterns in the measurement science needs. For instance, some technologies fit more than one Approach. As each of the technologies was discussed in turn, a number of measurement science needs emerged that were broadly relevant. These are discussed in Section 8 of this report. Appendix 5 provides the completed template slides, which were presented by the Breakout Group Chairs during the Day 1 and Day 2 summary presentations.

No information generated during the workshop was purposefully omitted from this report, although the information may have been reorganized in an attempt to clearly communicate the key ideas. While the exact words and the format may be different, the intent was not to change the content. This does not mean that further analysis would not lead to different results.

The next section of this report provides feedback on the vision and goals of BFRL's Fire Protection activities. Sections 3 through 7 document the results of the discussions of the Fire Prevention, Fire Protection, Fire Service, WUI Fire, and Global Fire Reduction Breakout Groups, respectively. Each Section is broken into two main parts. The first part identifies viable approaches and technologies. The second part addresses appraisal of the technologies. The metrics and attributes used for evaluation of the technologies are identified, and then applied to examine selected technologies. A series of tables in each section abridge the results of the discussions. Section 8 provides a summary of the workshop findings as well as a final evaluation of the technologies identified during the Breakout Sessions.

2. Results of Discussion on NIST Vision and Goals

Each of the five Breakout Groups was asked to provide feedback on NIST's vision and goal statements, which were presented in draft form to promote discussion:

NIST Vision

Unwanted fires shall be removed as a limitation to life safety, technical innovation, and economic prosperity in the United States.

Near-term Program Goals

The goal of BFRL's Innovative Fire Protection Strategy is to develop and demonstrate, by 2013, the measurement science needed to achieve a 25 % reduction in the impact of fire on structures, their occupants, and the fire service. The measurement science to achieve this goal is organized into three Programs:

- The Reduced Risk of Fire Hazard in Buildings (RRFSB) Program is focused on increasing the safety of building occupants and the fire performance of structures. The objective is to provide the measurement science needed to reduce preventable fire losses by 25 %.
- The Advanced Fire Service Technologies (AFST) Program is focused on increasing the safety and effectiveness of fire fighters by 25 %. The emphasis is on improvement of fire fighting operations by enabling effective use of existing and new technologies and tactics.
- The Reduced Risk of Fire Spread in the Wildland-Urban Interface (WUI) Program is focused on reducing by 25 % the fraction of houses that are ignited due to exposure to outdoor fires, with an emphasis on WUI fires. Within 10 years, improved risk assessment and risk mitigation tools will be developed and provided to communities, homeowners, and fire officials for implementation.

Feedback from the Fire Prevention, Fire Protection, Fire Service, WUI Fire, and Global Fire Reduction Breakout Groups, respectively, is given below.

2.1 Input from the Fire Prevention Group

- Vision
  - The group had no suggested changes regarding the NIST vision statement.
- Goal
  - There was extensive discussion of the RRFSB goal, including the goal and the focus of the "Prevention" group. To some, fire prevention meant preventing ignition while others believed preventing rapid fire spread should also be

included. The group decided both were equally important to reducing residential fire losses. A few examples provided by the group were materials with lower ignition susceptibility, lower heat release rate, and/or the potential to self extinguish. Section 3 of this report contains more information on the specific focus of the Prevention group, such as what was deemed to be in and out of its scope.

- The meaning of the target date should be clarified. It took some discussion before the full Group recognized that the objective was to develop the measurement science by 2013, and that others (regulators, product manufacturers, etc.) would use this to reduce fire losses by 25 % in later years.
- Given that the reduction in the fire problem would occur after 2013, it was not clear how BFRL would evaluate their progress between now and 2013.
- The goal should also include "understanding" and perhaps should be used in replacement of "increasing" as in "*understanding the safety of building occupants and the fire performance of structures*.
- The group suggested either to remove or to define "preventable" fires. The definition should be specific enough to establish targeted approaches and metrics, such as a 20 % reduction of open flame ignited upholstered furniture fire by 2013.
- The goal based on these suggestions is "to understand the fire performance of structures and increase the safety of building occupants with the objective to provide the measurement science needed for a 25 % reduction in preventable fire losses by 2013."
- The group expressed a concern that the fire science community does not fully understand the current fire problem. There was a specific mention of the impact of changing supply (raw material, polymer type, and manufacturer), impact of importing overseas "counterfeited" products, impact of new "green" building materials, impact of building design and materials changes, etc. on fire losses, ignition propensity, and fire spread, etc. Due to this lack of understanding, the existing tests and regulations, as well as those in the pipeline, may not accurately reflect real world fire performance. There was also a concern that the technologies and training we are providing fire fighters may not be appropriate for the current fire environment. Though these comments were not directly related to the goal, they indicated that there are several factors simultaneously in play that are impacting fire losses and while BFRL may be making significant measurement science advances, their impact may be lessened by not fully understanding all the factors, stakeholders, etc.

2.2 Input from the Fire Protection Group

- Vision
  - The group rewrote the vision statement to read: "BFRL's long term vision is to significantly reduce or minimize unwanted fire through technological innovation, to enhance life safety and economic prosperity in the US."
  - The group also noted that it may be desirable to incorporate the concept of sustainability, but did not have any specific suggestions.
- Goal
  - The group made a number of suggested changes to the RRFSB Goal including adding "emergency responders" to "building occupants," replacing "structures" with "buildings and contents," and removing the word "preventable" because there was no consensus on what fires are preventable or unpreventable.
  - There was substantial discussion about the economic impact of fires and the desire to reduce the cost of fire losses as well as the cost of fire protection systems, but these concepts were not integrated by the group into the goal statement in a specific way.

2.3 Input from the Fire Service Group

- Vision
  - The Group felt that the NIST vision as presented is not achievable. The term "removed" is absolute, unrealistic, and incredibly broad. A shorter vision is better. It is suggested that the impact of fire be reduced or minimized while promoting or enhancing life safety and economic prosperity. The Group had trouble with the idea that "technical innovation" could be impacted by unwanted fire as stated in the draft vision statement.
  - The mission statement or goal should be more specific and include technology. Should we consider other things besides technology that change behavior and also work to reduce the impact of fire?
  - Suggested vision revision: "Reduce the impact of unwanted fire on life safety and economic prosperity."
- Goal
  - Want to be able to show progress over time for the goal.
  - Fire fighting goal: 25 % reduction from what level? We don't now have a number from which to start. How would we pick a baseline? Should we add a soft word like "significant" or "substantial" reduction? Are we referring to

deaths, injuries, cost, and/or effectiveness? Need to be specific about what we are measuring.

  - NIST is pushing the measurement science banner. Might want to add 2009 as the baseline in the goal. If it is measurement science, we need real numbers.
  - *America Burning* clearly states goals; can we say something like that? The number of fires is declining, but fire deaths are holding steady, which means that deaths per fire are increasing. Compared to other countries, we are much higher in the absolute numbers of deaths. Cardiac arrest is the cause of most fire service deaths.
  - Today's fire fighters are doing more than fighting fires. The statistics are for all calls, not just fire calls. Is there a problem, or is the current level as good as it gets?
  - What about the rest of the goal statement? Safety and effectiveness is different from improving technology, so should we make them two different goals?
  - Are there activities that NIST cannot be involved in that should/should not be in the goal statement? We should discuss the things that NIST can't affect, and consider that NIST may still be able to enable work in areas that are best left to others. How do we measure the impact?

2.4 Input from the WUI Fire Group

- Vision
  - The group had no suggested changes regarding the NIST vision statement.
- Goal
  - The goal introduced was "a 25 % reduction in the number of houses impacted by WUI fires." The group quickly decided that this was too narrowly focused on houses and structures, and rather should provide for a reduction in WUI fire fatalities and injuries.
  - The group felt that the geographic extent of the vision—interface communities—may ignore potential successes brought about by also examining the wildland fire problem, since WUI fire typically begin as wildland fires.
  - Some discussion questioned whether 25 % was too lofty a goal, unless retrofit-based technologies were developed, given the number of pre-existing houses already within the WUI.

2.5 Input from the Global Fire Reduction Group

- Vision
  - Some thought that the verbiage was “hard to wrap your head around."
  - Structure is similar to the NFPA mission (“…reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education.”), with three key parts: (1) we are focusing on unwanted fires, (2) we want to remove limitations to reducing unwanted fires, and (3) the reduction in unwanted fires will promote life safety, technical innovation and economic prosperity.
  - NFPA focuses on “reducing impact” while NIST appears focused on “removing limitations” through measurement science. The phrase “removing limitations,” though perhaps not as strong conceptually, may be more broadly applicable than “reducing impact.”
  - Should the environmental impact of fire be worked into the vision statement? The impact might include not only the direct effect of unwanted fires (emissions, erosion) but also the effect of chemical agents used in fire retardants. It was noted that these effects, along with the scope of “life safety,” already mentioned, may be encompassed by a phrase like “quality of life.” "Quality of life" may be too broad a phrase.
- Goal
  - Is the goal to achieve the 25 % reduction? Or is the goal to develop the measurement science needed to achieve the reduction? Is the value of 25 % significant in some way or is it completely arbitrary? The number “25 %” seems to have value in that it is a reasonable target that can be considered “high” impact and can generate “momentum” toward achieving the goal. As a historical precedent, in its early years the U.S. Fire Administration successfully achieved its stated goal of 50 % reduction within a generation.
  - Consider that the goal should be to develop the measurement science [needed to *design, refine, assess,* and *evaluate* the innovations] needed to achieve the 25 % reduction.
  - The NIST goal is similar to the goals of other federal agencies, such as NIOSH and the U.S. Fire Administration, and that these agencies should work together whenever possible to achieve their goals. Simply put, the fire problem is much too large for NIST to solve on its own, and teamwork will play an integral role in any successful fire protection strategy.

- Some within the group were of the opinion that the U.S. has actually already "solved" the fire problem; i.e., the magnitude of the life loss, was now quite small. In looking at the problem from all sides, we should also understand the economic *benefits* of fires (e.g., new housing construction, keeping fire fighters employed). If the fire problem is not solved, when can we say that it is? What is the acceptable measure? In fact, the fire death rate has been successfully managed over the last 100 years with an order of magnitude reduction in lives lost. Most of the perceived problem can be better managed between the insurance industry and homeowners themselves. What really needs to be done is to measure the economic impact of fire; and if we truly want innovation, we need to get outside the framework we have been living in for the last 100 years.

  It was conceded that perhaps viewing fire as a solved or well-managed problem would get away from the charter of the group, part of which was to help refine NIST's current goal statement. But this view brought to light the need to look at fire from a *multi-hazard* standpoint. For example, 40 years ago, foam plastic insulation was introduced as a means to address the then-critical energy problem, and this *increased* the fire problem. To avoid similar mistakes in the future, it is important that fire is considered part of a multi-hazard dynamic system. It was suggested that the impact should be measured first, and then the results should be used to manage the fire problem.

2.6 Summary of Discussion

Consistent with NIST's experience in developing its draft Vision and Goal statements, there were a rich variety of ideas and suggestions provided during the Breakout Group discussions. Many of the comments were quite perceptive and highlight the challenges in arriving at a succinct and clear statement of vision and goals. As NIST refines these ideas, the thinking captured during the Breakout Sessions will serve as a useful reference.

3. Fire Prevention Group Results

The results of the discussions of the Fire Prevention Group are presented below. The Group identified 12 approaches to reducing the U.S. fire problem as it pertains to fire prevention, discussing each in turn. Section 3.1 gives a list of the approaches and the technologies that the Group identified, which might provide solutions to specific fire problems. Section 3.2 gives a set of metrics that was developed and then used as a tool to identify technologies that may have special importance within the context of this workshop.

3.1 Approaches and Technologies

The group discussed several approaches that should result in *a* 25 % reduction in fire losses (*please refer to Section 2.1 for* the discussion of the *Fire Prevention group's* goal*). The group initially identified* 11 approaches*, but after further discussion realized many of these* were rephrasing of the same *idea. Therefore, these 11* approaches *were reorganized into the five listed* below*:*

1. Prevent Ignition – Human Behavior (passive)
2. Prevent Ignition – Source (passive)
3. Prevent Ignition – Reaction (passive)
4. Reduce Impact of ignition (active)
5. Improve Egress Time

To delineate the outputs of this group from others in this workshop, the Fire Prevention group decided to focus primarily on Passive rather than Active technologies.

- Active fire protection technologies *respond to a fire*. These technologies detect the characteristics of a fire (elevated temperature and CO, smoke, etc.) and/or respond to a fire with the purpose of reducing/controlling fire spread and/or suppressing the fire, such as sprinklers and fire fighting tactics.
- Passive fire protection technologies *prevent ignition*. These technologies include low ignition propensity materials, and detectors that identify conditions are appropriate for ignition then either shutdown the system to isolate the energies (to prevent ignition) and/or alert residents/emergency responders of the detected ignition hazard.

During these discussions the group did not specify sensor technologies, but emphasized that developing such technologies were important and, therefore, decided sensors were within the scope of the Fire Prevention group. Also within scope of the Fire Prevention group was all material flammability technologies, such as material aging and fire retardants, regardless if the technology was intended to reduce ignition propensity or reduce fire spread.

The group developed an initial list of 43 technologies, and then reduced the number of technologies to 24 as some technologies were actually a measurement science, a rephrasing of another technology, or were better combined into a single technology (see Table 3.1). In some cases, a brief discussion ensued after a technology was proposed, which focused on the potential impact of the technology. The numbers refer to the technologies listed in Table 3.1. The potential impacts of many of the technologies were thought to be as follows:

A. This technology will significantly reduce fire losses – Technologies: 7 - 9, 12 - 14, 18
B. This technology is immediately ready – Technology: 2
C. Stopping a fire from even starting will save civilian and fire fighter lives more than any other technology – Technologies: 3, 6, 7, 9
D. To develop the next generation of fire safe materials and products, improved small scale testing is needed – Technologies: 12, 21 - 23

None of these potential impacts (A-D) were mentioned for 11 of the technologies (1, 4-5, 10-11, 15-17, 19-20, and 24). Technology 9 was mentioned with two potential impacts. This does not mean that these potential impacts do not apply to these 11 technologies or only 9 has more than one potential impact, but rather this only communicates what the group said during the brainstorming of technologies.

Below is a summary of the group's discussions on the Fire Prevention approaches and technologies. The technologies listed below and in Table 3.1 that are in *italics* were selected by the team for further evaluation as discussed in Section 3.2.1.

- **Prevent Ignition – Human Behavior**

This approach reduces fire losses by preventing human behavior based ignitions. The examples given were housekeeping, such as trash or clutter, which could result in large fuels loads at or near a potential ignition source, or a group of people with high incidence of both smoking and drinking, which are behaviors strongly associated with ignition. While there has and continues to be a heavy focus on education, it was suggested that outside of the United States, incentive programs that reward people for using fire safe behaviors, such as replacing batteries in smoke alarms, and/or penalizing programs for practicing non-fire safe behavior worked well and should be considered. This behavior based approach could also include educating people to help them accurately select products with a better alignment between an application and a product's fire safety performance. For example, using space heaters appropriately designed for the occupant space (residential versus commercial, etc.) and removing clutter from around the space heater.

Brainstormed technologies

- *Testing & classification to align performance with end-use applications - help with material selection* [2]
- Create a NIST Fire 101 education document

- **Prevent Ignition – Source**

This approach reduces fire losses by better understanding and characterizing existing and new ignition sources and developing sensors to detect pre-ignition conditions. An example discussed by the group was to understand the potential arcing hazard in electrical units that could create a spark or thermal induced ignition. With a better understanding of this ignition hazard, a sensor could be developed that would detect when conditions in an electrical unit are suitable for the creation of an ignition source. Detection of such a condition could trigger the unit to shutdown and cut off electricity to the potential ignition source and/or activate an alarm warning the occupants or first responders of the potential hazard.

Brainstormed technologies

- *Characterization of pre-ignition conditions (existing, new, and near term technologies)*
- *Sensors to detect pre-ignition conditions*
- Smart grid ignition hazards

- **Prevent Ignition – Reaction**

This approach reduces fire losses by reducing the propensity of materials to ignite and result in fire spread. This is a material focused approach that includes new flame retardants, high fire resistant materials, and understanding how processing and aging impact fire performance. Passive technologies to reduce the consequence of ignition were determined to also be in scope for this approach. For example, reduced fire spread by incorporation of an ignition delay additive as compared to activating a sprinkler (active technology).

Brainstormed technologies

- *Advanced Fire Resistant Materials* (lower toxicity, inorganic composites with thermoplastic processability and/or low heat release rate, HRR)
- Protective integrated coatings
- Fire retardants (FR) that incorporate into polymer upon use to reduce environmental health and safety (EHS) concerns
- *Material aging and reliability metrics*

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[2] Italicized technologies are evaluated in Table 3.3.

- EHS friendly flame retardants

- **Reduce Impact of Ignition**

This approach reduces the fire losses by preventing or reducing the rate of fire spread through the use of fire controlling or suppression technologies and developing standardized measurements and metrics (tools, methods, materials, and data) to accurately evaluate material fire performance. Unlike, Preventing Ignition – Source, this approach is focused on hardware and methods development rather than materials. However, standard reference materials (SRMs) were included in this approach because the purpose of an SRM is to develop a consistent reference product for a more reproducible test and not to evaluate new material technologies.

Brainstormed technologies

- Heat seeking water gun (sensor activated or deployable)
- *Reverse microwave gun to remove heat*
- *Sensor activated suppression for homes and/or vehicles*
- FR suppression through Heating, Ventilation, and Air Conditioning (HVAC)
- Auto detect of failure points in fire protection system
- SRMs for tests to increase repeatability and accuracy
- *Improved Measurement and Metrics for Tests, standard reference materials (SRMs) and Ignition Sources*
- *Open flame test for upholstered furniture*
- Develop small/bench scale tests that correlate/predict large scale/regulation test performance
- Develop an understanding of how component versus composite, small versus large scale, and geometry changes impact fire testing
- Develop an understanding of how fluctuations in component composition, geometry, and manufacturing processes impact testing performance

- **Improve/Increase Egress Time**

This approach reduces fire losses through the use of early detection alarm networks or escape assistance hardware. This approach focused primarily on next generation smoke/fire alarm technologies; however, this group only focused on the sensors needed to activate the alarm and not on the alarm performance or response of civilians and fire fighters to the alarm. The role of sensor technologies will depend on the fire timeline. In the Prevent Ignition- Source approach, the role of sensors is to detect pre-ignition conditions, whereas in the Improve Egress Time approach their role is to detect post-ignition conditions.

Brainstormed technologies

- *Positive Pressure Ventilation for low rise buildings*
- *Next generation smart sensor network (early post-ignition detection with no nuisance alarms, works well with elderly and children)*
- Improved kitchen alarms
- *Floor integrated emergency lights*

General Comments made by the group

- BFRL and the fire community must stay current, addressing the measurement science needs for cutting edge technologies. Some examples provided are as follows:
    - Utilization of new technologies or existing technologies but used in a different capacity may have unexpected fire performance concerns, such as using Bamboo, etc. in building construction.
    - What are the potential electrical fires stemming from plugging in electric cars in the garage?
- Fires are behaving differently as changes occur for materials, fuel loading and distribution, building structures, etc. The concern expressed was that the fire community's current understanding of materials and products may not accurately represent reality. It was suggested that perhaps there should be an evaluation of the relevance and accuracy of regulations to new technologies. Fire fighting tactics and technologies may also need to be considered in this regard.
- When developing technologies there should be a "check-box" to ensure that it is well aligned with behavior. For example, continuous expensive and expert maintenance of a home suppression system is unreasonable if the system is targeted for lower income dwellings.

The 24 brainstormed technologies in this section are listed in Table 3.1. Of these, the 12 technologies listed below were selected by the group for further evaluation (see Table 3.3). The 12 technologies could be grouped into 4 main categories as follows:

Fire Control or Suppression

- Reverse microwave gun
- Improved measurements & metrics for tests, SRMs, and ignition sources
- Integrated path lighting for flooring
- Positive pressure ventilation for low rise

Detection

- Sensors to detect pre-ignition conditions
- Sensor activated suppression-homes & vehicles

- Next generation smart sensor network (early post-ignition detection & no nuisance alarms)
- Characterization of pre-ignition sources

Materials

- Material aging and reliability metrics
- Advanced fire resistant materials

Testing Tools and Methodology

- National open flame test for upholstered furniture
- Testing and Classification system for material flammability

Table 3.1. Technologies partitioned by Fire Prevention Approaches and Fire Prevention Technology Classifications. In the next section, attributes and metrics were applied to technologies in italics.

Technology Classification	Approach				
	Prevent Ignition			Reduce Impact of Ignition	Improve Egress Time
	Behavior	Source	Reaction		
Fire Control or Suppression				1. Heat seeking water gun (sensor activated or deployable)	*2. Positive Pressure Ventilation for low rises*
				3. Reverse microwave gun to remove heat	
				4. Sensor activated suppression-homes & /or vehicles	
				5. FR suppression thru HVAC	
				6. Auto detect of failure points in fire protection system	
Pre/Post-Ignition Detectors		*7. Characterization of pre-ignition conditions (existing, new, and near term technologies)*			8. *Next generation smart sensor network (early post-ignition detection & no nuisance alarms*)

Pre/Post-Ignition Detectors (continued)		***9. Sensors to detect pre-ignition conditions***			
		10. Smart grid ignition hazards			**11. Improved kitchen alarms**
Materials	***12. Testing & classification to align performance with end-use applications***		**13.** ***Advanced Fire Resistant Materials (lower toxicity, inorganic composites with thermo-plastic process-ability, low HRR*****)**	**14. SRMs for tests to increase repeatability and accuracy**	
			15. Protective integrated coatings		
			16. FR that incorporate into polymer upon use to reduce EHS		
			17. Material aging and reliability metrics		
			18. EHS friendly Flame retardants		

Testing Tools and Methodology				***19. Improved Measurement and Metrics for Tests, SRMs and Ignition Sources***	
				20. Open flame test for upholstered furniture	
				21. Develop small/bench scale tests that correlate/predict large scale/regulation test performance	
				22. Understanding how small vs. large scale, component versus composite, & geometry changes impact fire testing	
				23. Understanding how fluctuations in component composition, geometry, & manufacturing impact testing performance	
Other	**24. NIST Fire 101 education document**				***25. Floor integrated emergency lights***

3.2 Appraisal of Selected Technologies

3.2.1 Metrics

The group was asked to develop a list of metrics and associated attributes, which were then applied to the technologies listed in Section 3.1. Due to time constraints, the group applied the metrics to 12 of the top 24 technologies listed in Section 3.1 (see Table 3.3). The intent of this exercise was not to create a hierarchical list of the technologies, but to use the metrics to better understand the characteristics of the technologies.

The Breakout Group made two assumptions when defining the attributes. One assumption was that the technology would meet the performance requirements targeted. The other assumption was that the attribute would be directly connected with the ability of the technology to achieve a 25 % reduction in residential fire losses. The following metrics were determined:

- Impact
- Technical Development
- Sustainability
- Political acceptance

A discussion of the meaning of each of the metrics is presented in Table 3.2. The evaluation of the technologies using these attributes and metrics is provided in Table 3.3. The technologies in italics in Table 3.3 were further evaluated for barriers to implementation in section 3.2.2.

Table 3.2 Metrics and Attribute for Evaluating Technologies

No	Metric	Meaning	Attribute
3.1	Impact	The probability that the technology would result in a 25 % reduction in residential fire losses (lives, injuries, property loss).	Low (< 33 %) Medium (33 % - 66 %) High (>66 %)
3.2	Technical Development	The probability that someone can technically develop this technology to result in a 25 % reduction in residential fire losses. This includes technical readiness, and reasonable development costs if the innovation is revolutionary or incremental.	Low (< 33 %) Medium (33 % - 66 %) High (>66 %)
3.3	Sustainability	The sustainability impact, determined by life cycle analysis (LCA) that results in a 25 % reduction in residential fire losses. This includes "cradle to grave" measure of environmental health & safety factors, service life & cost to use the technology. LCAs can be used to compare 2 technologies; therefore the attributes reflect the LCA output as a function of switching to an alternate technology.	**P**=Positive (More Sustainability) NZ=Net-Zero (Neutral; no change) **N= N**egative (Less Sustainability)
3.4	Political Acceptance	The willingness of the stakeholders to support this technology that results in a 25 % reduction in residential fire losses. The stakeholders could include government, manufacturers, consumers, and regulators.	S=Supported (by majority or >50% of stakeholders) C=Compromise (stakeholders willing to support technology but compromise necessary) NS=Not Supported (by majority or >50 % of stakeholders)

Table 3.3 Evaluation of Selected Technologies. The first 5 technologies were evaluated further in Section 3.2.2

No.	Technology	Attributes of Metrics: 1.Impact	2. Technical Development	3. Sustainability	4. Political Acceptance	5. High Impact / Long Reach
3.1	*Testing and Classification system for material flammability*	H*	M*	NZ *	C*	Yes
3.2	*Material aging and reliability metrics*	M	H	P	S	N
3.3	*Advanced fire resistant materials*	H	L	NP	C	Y
3.4	*Improved measurements & metrics for tests, SRMs, and ignition sources*	H	M	P	S	N
3.5	*National open flame test for upholstered furniture*	H	H	NZ	NS	N
3.6	Characterization of pre-ignition sources	M	M	NP	C	N
3.7	Reverse microwave gun	H	L	P	S	Y
3.8	Next generation smart sensor network	H	M	P	S	No
3.9	Integrated path lighting for flooring	M	H	NZ	S	Y
3.10	Positive pressure ventilation for low rise	H	H	NZ	C	Y
3.11	Sensors to detect pre-ignition conditions	H	L	P	C	N
3.12	Sensor activated suppression-homes & vehicles	H	H	P	S	N

* The attributes are defined in the right hand column of Table 3.2.

3.2.2 Detailed Examination of Selected Technologies

The group selected five potentially high-impact technologies from Table 3.3 for further evaluation and more detailed discussion following the categories defined in Section 1.3 of this report (for Session XI).[3] The group then identified barriers to the development and implementation of each of these technologies and subsequently identified measurement needs to aid in their development and implementation. The group's assumption was that the remaining technologies will contain one or more of the classifications and therefore should have similar barriers and measurement science needs. Finally, the group reorganized the measurement need under the barriers they seemed best focused on addressing.

The barriers were classified as either non-technical or technical. Many of the barriers were cross cutting; so were many of the measurement science needs. The group did not connect the measurement science needs directly to the barriers. Tables 3.4 and 3.5 summarize the results of the deliberations of the group on the barriers and measurement science needs for key technologies.

[3] The technologies were selected so that there was one in each of the five following categories: 1. High impact/long reach, 2. Short-term delivery, 3. Long-term delivery, 4. Multiple measurement science needs, 5. Non-technical barrier. These categories facilitated selection of a range of technology options and were examples, representing the broad range of challenges and benefits that must be considered in prioritizing research. This process highlighted a number of technologies and provided a model for analyzing the full set of technologies.

Table 3.4 Barriers Associated with Select Technologies

	HIGH IMPACT & LONG REACH	SHORT TERM	LONG TERM	MULTIPLE MEASURE-MENT SCIENCE NEEDS	NON-TECHNICAL BARRIERS
Technologies →	Testing and Classification system for material flammability	Material aging and reliability metrics	Advanced fire resistant materials	Improved measurements & metrics for tests, SRMs, ignition sources	National open flame test for upholstered furniture
Non-Technical Barriers					
Manufactures' consensus – resistance to change may void product	**X**	**X**			**X**
Investment Legacy – support from stakeholders	**X**			**X**	**X**
Consensus on fire performance criteria and/or details of standard	**X**	**X**			**X**
Stakeholders trusting lab data is aligned with real world		**X**			
High capital investment – new manufacturing plant			**X**		
Environmental Health, & Safety impact (reality and perceived)			**X**		**X**
Counterfeiting: non-U.S. companies generate low performing products			**X**		
Long stock turnover – replacement time of non-compliant products					**X**
Technical Barriers					
Component vs final product (variation in composition, geometry, etc.)	**X**	**X**		**X**	**X**
Test scaling (correlation of bench with full scale testing)	**X**	**X**		**X**	**X**
Defining the repeatability and accuracy of tests	**X**	**X**		**X**	**X**
Aligning aging conditions to reality		**X**			
Bridge between fire science and materials (modeling)			**X**	**X**	
Lack of scientific and manufacturing knowledge			**X**		
Tests depend on standard materials which may not exist				**X**	
Unknown ignition propensity		**X**	**X**	**X**	

Table 3.5 Measurement Science Needs for Select Technologies

	HIGH IMPACT & LONG REACH	**SHORT TERM**	**LONG TERM**	**MULTIPLE MEASURE-MENT SCIENCE NEEDS**	**NON-TECHNICAL BARRIERS**
Technologies →	Testing and Classification system for material flammability	Material aging and reliability metrics	Advanced fire resistant materials	Improved measurements & metrics for tests, SRMs, ignition sources	National open flame test for upholstered furniture
Measurement Science					
Measure and characterize smoke toxicity and develop metrics	**X**	**X**			**X**
Measure physical effects of heat release: spalling, melting, etc.	**X**	**X**			
Measure heat of gasification (to classify fire performance)	**X**	**X**			
Develop models to understand scaling and predict performance	**X**	**X**	**X**	**X**	**X**
Gauge repeatability and reliability (Accuracy)	**X**	**X**	**X**	**X**	**X**
Measure/understand physical/chemical aging as related to fire performance		**X**			
Identify degradation products		**X**			
Transition aging to tools to a cost favorable tool for general use		**X**			
Develop and review (by an external party) EHS impact data			**X**		**X**
Develop a system to review EHS risk			**X**		**X**
Develop a small scale tool to predict large heat and smoke release			**X**		
Measure and define arc signature – product dependence				**X**	
Measure temperature & heat flux histories of non-electrical sources				**X**	
Measure heat of gasification (to classify fire performance)	**X**	**X**			

4. Fire Protection Group

The results of the discussions of the Fire Protection Group are presented below. The Group identified many approaches to reducing the U.S. fire problem as it pertains to fire protection, discussing each in turn. Section 4.1 gives a list of the approaches and the technologies that the Group identified, which might provide solutions to specific fire problems. Section 4.2 gives a set of metrics that was developed and then used as a tool to identify technologies that may have special importance within the context of this workshop. This process, along with the identified technologies (in italics in Section 4.1) is discussed in greater detail in Section 4.2.

4.1 Approaches and Technologies

The discussion of approaches focused primarily on the organizational framework used, with the group finally settling on the two categories identified in NFPA 550 (Guide to the Fire Safety Concepts Tree): Manage the Fire and Manage the Exposed (people and property).

- Manage the Fire

  The following approaches were identified:

  - Fire Suppression

    This approach had not been explicitly identified in advance, but its selection as an important approach was uncontroversial.

  - Manage the Combustion Products

    Managing the products was considered important because this contributes to the protection of the occupants.

  - Prevent Ignition of Second Item

    Preventing ignition of a second item was considered important because this essentially halts the fire spread.

  - Detection

    Detection was considered important because this allows the notification of both the occupants and the emergency responders, as well as the activation of any automatic suppression systems.

  - Compartmentalization.

    Compartmentalization was considered important because this is another way to reduce the fire spread and protect the occupants.

  - Emergency Management (including Education)

    This approach was considered important because it can improve the effectiveness of emergency responders via pre-planning.

- Manage the Exposed

  The following approaches were identified:

  - Egress Design

    This approach was considered important because good design can limit the exposure of occupants to fire.
  - Occupant Response

    This approach was considered important because even the best design will not function unless used as intended.
  - Emergency Response

    This approach was considered important because it improves the effectiveness of emergency responders.
  - Property Protection

    This approach was considered important because technologies such as automatic fire suppression and compartmentalization can limit the exposure to fire and reduce the rate of fire spread.
  - Emergency Management

    This approach was considered important because it can improve the effectiveness of emergency responders during an incident.
  - Fire induced Collapse

    This approach was considered important because understanding and predicting collapse is a key to protecting both occupants and emergency responders.

The discussion on technologies was more structured, with each participant asked in turn to suggest a technology, returning to each participant several times. After all the ideas were exhausted, the group collected some related technologies into broader categories.

- Fire Suppression

  - *Improved suppression technology*[4]

    This includes installed compressed air foam systems, fire extinguishing systems, refined water mist systems, manual sprinkler controls for emergency responders, improved sprinkler performance, and an improved understanding of the interaction of a water droplet and a burning item.

  - *Improved sprinkler reliability*

    This involves automatic detection of non-functioning sprinklers, possibly reported to emergency responders so the fault can be addressed, as well as maintenance-free and self-diagnostic systems.

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[4] Italicized technologies are considered further in Table 4.2.

- *Installed air supply for firefighter and occupant protection*

This technology would provide compressed air to firefighters (either as an airline or to refill self-contained breathing apparatus, SCBA cylinders) and could also be used by occupants in a designated place of refuge, much like oxygen masks in aircraft.

- *Robotic firefighting apparatus*

This technology was initially envisioned as an engine- or truck-mounted semiautonomous or remote control vehicle much like a bomb-disposal robot, but for suppression and rescue in high-challenge fire environments. However, as discussion progressed, the idea developed for an autonomous residential device, analogous to currently-available robotic vacuum cleaners, that could both detect and suppress (or extinguish) small fires before they could grow spread significantly.

- *Integral suppression system for heat-generating and open-flame appliances*

Recognizing that a large number of fires are the result of accidental ignition on appliances like stoves, the group considered the possibility of requiring the incorporation of some kind of detection and suppression system.

- Technology to protect against wind-driven fire

This technology was envisioned to use sensing of wind speed and direction to activate preemptive automatic suppression, to reduce or prevent blowtorching and wind-driven fire spread in structures.

- Temperature sensors to measure progress of fire

This technology envisions using a network of temperature sensors within a structure to determine a fire's location and behavior, information that can then be relayed to emergency responders.

- Embedded sensors and smart building technologies, tied to the fire department

This technology focuses on the link of building sensors explicitly to the fire department so that they have real-time information about the building status. This includes applications for detection, suppression, predicting collapse, and emergency management.

- Environmentally acceptable total flooding gaseous & foam agents

This technology is essentially a replacement for halon extinguishing systems, specifically designed to have little adverse environmental or health impact.

- Reduction of sprinkler cost

This technology was aimed primarily at making sprinkler retrofit easier and less costly.

- Detection
    - *Refinement of existing smoke detectors*

    This includes nuisance-free detection and an improved understanding of smoke detector placement.

    - Detection of electrical discharge

    This technology would detect sparks and/or unintentional grounding of energized wires, potentially mitigating an otherwise difficult to detect source of fires

    - Wireless technology to assist firefighters to identify location of incident

    This technology would involve some kind of geographical database and links to a building information system so that emergency responders would have information on the building (floor plans, installed fire protection, etc.) while en route to the emergency.

    - Faster / earlier detection

    This technology would provide occupants more time to escape and/or alert the fire department earlier such that the fire would be less advanced at the time of their arrival. It was noted that faster detection may be mutually exclusive with nuisance-free detection.

    - Heat detectors

    Already used in commercial installations, heat detectors for residential applications could be an alternative approach to reducing nuisance alarms.

- Manage Combustion Products
    - Predict the burning rate of a single object

    This involves developing the principles, equations, and necessary inputs so that the burning rate of any individual object (e.g. a chair) can be predicted with confidence. This analysis can then be extended to all objects involved in a fire, so that the growth and progression of a hypothetical fire could be determined, and appropriate design remediation could be undertaken.

    - Automatic ventilation (residential)

    This technology involves a response to heat and smoke that would create an exterior opening for ventilation, for example having the upper sash of a double hung window suspended by a fusible link.

- Prevent Ignition of a second item
    - Fire resistant furnishings

This includes controlling the flammability of stuffed furniture, fire-safe cushion materials, and a mercaptan-like additive to furniture (such as cushions) which would alert occupants by odor that the item was on fire.

  - Study ignition

  This technology involves developing an understanding of how a second item ignites, which is potentially different from the direct application of an ignition source to the first item.

- Compartmentalization
  - Cheaper/faster ASTM E119-style test for barrier performance

  This technology is a new test method that can allow more innovation in construction methods in that more approaches could be tested without the requirement that the element or assembly pass on the first test.

  - Require home heating equipment (air and water), a frequent source of ignition, to be isolated by 1-hour construction. This technology is a code change that would decrease the risk of fires due to home heating equipment.
- Emergency management
  - Refined Geographic Information System (GIS)

  This technology involves developing a database containing a community-wide hazard/vulnerability analysis, especially for residential occupancies.

- Egress design
  - Egress monitor system

  This technology would enable emergency responders to determine the travel patterns of exiting building occupants, particularly to reduce counter flow problems.

  - Regulate or license egress analysis and tools

  The absence of any professional licensing for egress design is a barrier to gaining Authority Having Jurisdiction (AHJ) approval for performance-based design.

  - Efficacy of current egress width factors

  This information would inform future code updates.

  - Directional signage for responders

  This technology could be active or passive. In the active version the signage would only activate with the alarm system, and could for example guide firefighters to the fire.

- Occupant response
    - *Enhanced communication technology to occupants*

    This includes non-RF communication (such as a directed audible Long Range Acoustic Device, LRAD), reliable and cost effective mass communication for evacuation and relocation management, and the ability to “push” emergency communications to handheld and portable electronic devices without pre-registration.

    - Human behavior models

    This technology is still in its infancy and has yet to produce a fully validated model.

    - Evacuation devices for the disabled

    This technology would aid people with disabilities in an evacuation, for example, a device to help people in wheelchairs navigate stairs.

- Emergency response
    - *Enhanced communication technologies for responders*

    This includes better radio communication, databases of building information (floor plans etc) for emergency responders, and technology to limit unnecessary emergency response.

    - Elevators for evacuation and emergency responders

    This is primarily a code change.

    - Technology for rescue access

    This is primarily concerned with the ability of first responders to cut through walls, particularly when faced with new construction systems like structural insulated panels (SIPs).

    - Technology to locate people within structures

    This technology would allow emergency responders to locate people within structures; which could allow victims to be rescues, or could show that parts of the structure are unoccupied and do not require search and rescue operations.

- Property
    - Smoke cleanup

    This technology would improve the cleanup of a building after a fire, returning it to service more quickly and reducing cost.

- Emergency management
    - Maintenance of emergency procedures

This is primarily a code change requiring evacuation drills and performance assessment; and or making participation mandatory (enforced by fines for non-compliance) and/or requiring buildings above a certain size to perform full evacuation drills annually.

  - Standardized fire warden training

Better and more consistent training for fire wardens would improve building evacuations.

  - Generate lessons learned

A more formalized system for documenting lessons learned after unusually large emergencies would improve communication of these lessons to others and could be used to modify standard procedures to reduce large emergencies in the future.

  - Involve residents and occupants in procedure design

By involving residents and occupants in the design process, they will be more inclined to follow proper procedure because they would have a better understanding of the thought process behind the design.

  - Integrate life safety procedure with security practice and routine use

Life safety and security are often at odds—this can be alleviated by designing them together.

- Understanding fire-induced collapse
  - Develop real fire scenarios other than isolated compartments

Compartmented structures are only a fraction of all occupancies. Many residences and offices have "open" floor plans.

  - Improve passive insulation

Better insulation on structural members would extend the time they can sustain fire exposure before losing design strength.

  - Understanding system performance

This technology would seek to determine the performance of an entire system as opposed to individual materials and assemblies.

  - *Understanding fire resistance under real conditions*

Protection and determination of the performance of structural connections, including lightweight structural elements such as trusses and engineered lumber, and development of the ability to predict collapse in real time.

Ten of the technologies identified in this section were selected for further analysis. There were four major groupings of these technologies, which are found in Table 4.2 and also listed here:

1. Fire Protection Equipment (non-suppression related)
    a. Improved smoke detectors
    b. Installed air supply for firefighter and occupant protection
2. Suppression Technologies
    a. Sprinklers with higher reliability
    b. Sprinklers with reduced cost
    c. Robotic firefighting
    d. Improved suppression technology
    e. Appliance suppression technologies
3. Structural fire performance
    a. Technologies that enhance the performance of lightweight structural elements including trusses and engineered lumber, and tools to predict collapse in real time.
4. Communications
    a. Enhanced communication technology for emergency responders
    b. Enhanced communication technology for building occupants (Mass Notification)

In terms of the framework provided by NFPA 550, technologies in #1 and 4 above relate to managing the exposed, while technologies in #2 and 3 relate to managing the fire. Both approaches need to be considered in achieving BFRL's vision discussed in Section 2 above.

4.2 Appraisal of Selected Technologies

4.2.1 Metrics

The group brainstormed possible metrics, and then revised the list so that similar metrics were consolidated as seen in Table 4.1. Note that for the metric "applicability and reach," in addition to grading this metric, the group decided to identify whether the technology would have any secondary benefits outside of its primary application and potentially outside of fire altogether.

Impact on response time refers to how well the technology produces a faster response to the fire. For example with sprinklers or detectors this would involve faster activation of the device, whereas for building occupants, more effective communication would remove them from danger more quickly. Determining whether the technology addresses the problem was an attempt to measure impact, i.e. would it lead to a reduction in fire losses. Applicability and reach are the perpendicular metrics to impact, in that a high-impact solution that only applies to buildings over 100 stories would have a much narrower reach than one that applies to all single family homes. The determination of likelihood of success was an assessment of both the technical challenges and the group's sense of whether the solution would be embraced or rejected by the target stakeholders. Installation and lifecycle cost were generally intended to reflect the cost of a single item or installation and was intended to include maintenance costs; however in the case of structural fire performance the cost reflects the cost of developing the understanding rather than the cost of an installed system.

Table 4.1 Metrics and Attribute for Evaluating Technologies

No	Metric	Meaning	Attribute
4.1	Impact on response time	Ability of technology to reduce the amount of time it takes for a building occupant to become aware of a fire	High, medium, none
4.2	Addresses the problem	Directly addresses an aspect of the fire problem	High, medium, low
4.3	Applicability and reach	Applicability to an aspect of the fire problem and penetration of implementation	Broad or narrow, plus secondary benefits
4.4	Success	Likelihood of success	High, medium, low
4.5	Installation and lifecycle cost	Life cycle analysis (LCA) considers "cradle to grave" measures of environmental health & safety factors, service life & cost to use the technology	$ to $$$$ ($5 to $5000)
4.6	Impact on understanding of fire	Developing an understanding of fire phenomena that enables the development of technologies to address the problem	High, medium, low

Table 4.2. Evaluation of Selected Technologies. The first 5 technologies were evaluated further in Section 4.2.2.

No.	Technology	Attributes of Metrics					
		1. Impact on Response Time	2. Addresses the problem	3. Applicability and reach (secondary?) [A]	4. Chance of success	5. Cost [B]	6. Impact on understanding of fire
4.1	Appliance suppression	High	High	Broad (none)	High	$$$	Low
4.2	Improved Smoke Detectors	Medium	Medium	Broad (possible)	High	$$	Medium
4.3	Improved suppression technology	Medium	High	Broad (yes)	Medium	$$$$	Medium
4.4	Structural fire performance	NA	High	Broad (yes)	Medium	$$$$ for research	High
4.5	Robotic firefighting	High	High	Broad (yes)	High	$$$$	Medium
4.6	Responder communication	High	High	Broad (yes)	High	$$$$	None
4.7	Mass Notification	High	Low; high in a catastrophe	Broad (yes)	High	$$$$	None
4.8	Sprinkler reliability	High	Low	Broad (none)	High	$$	None
4.9	Sprinkler cost	High	High	Broad (none)	Low	$$	Medium
4.10	Installed air supply	High	Medium	Broad (yes)	High	$$$	none

A. secondary benefits beyond the primary application.
B. includes installation and lifecycle costs.

4.2.2 Detailed Examination of Selected Technologies

The group selected five potentially high-impact technologies from Table 4.2 for further evaluation and more detailed discussion following the categories defined in Section 1.3 of this report (for Session XI).[5] The group then identified barriers to the development and implementation of each of these technologies, then went back and identified measurement needs to aid their development and implementation. Finally, the group reorganized the measurement science needs for the barriers that they seemed best focused on addressing. The results of the discussion are summarized in Table 4.3.

The remaining five technologies (#6 to #10) from Table 4.2 were also evaluated for barriers, but were not categorized by type of impact. In these cases, the group specifically differentiated between technical and non-technical barriers.

- **Responder Communications**

  Non-technical barriers include:
  - Reluctance to share data / interconnect networks
  - Distrust of accuracy of information

  Technical barriers include:
  - Information technology requirements
  - Radio frequency transmission in challenging environments
  - Processing / reducing data flood in real time

- **Mass Notification**

  Non-technical barriers include:
  - Privacy (personal / organizational)
  - Nuisance aspects / behavior
  - Assurance of accuracy
  - Multi-jurisdiction conflicts

  Technical barriers include:
  - No guidance on message design
  - Information technology integration over multiple formats / systems

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[5] The technologies were selected so that there was one in each of the five following categories: 1. High impact/long reach, 2. Short-term delivery, 3. Long-term delivery, 4. Multiple measurement science needs, 5. Non-technical barrier. These categories facilitated selection of a range of technology options and were examples, representing the broad range of challenges and benefits that must be considered in prioritizing research. This process highlighted a number of technologies and provided a model for analyzing the full set of technologies.

- **Sprinkler Reliability**

Non-technical barriers: primarily regulation

- Increased cost / complexity

- **Reduced Cost of Sprinkler Systems**

Non-technical barriers include:

- Inertia of NFPA 13 interferes with development of new technology

Technical barriers include:

- Insufficient understanding of suppression

- **Water and Air Supply**

Non-technical barriers include:

- Perception of potential users / trust in system
- Reluctance of building owner / cost

Technical barriers include:

- Human factors
- Long term viability of system without maintenance

Table 4.3 Barriers and Measurement Science Needs for Selected Technologies

No.	Technology/Category	Barriers to Broad Implementation	Measurement Science Needs
4.1	**Suppression Systems for Open Flame, Cooking, and Heating Appliances** (High Impact and Long Reach)	o Uncertainty in agent selection	o Test method for agent effectiveness o Characterization of toxicity of suppressant when added to fire o Characterize types of fire
		o Need for recharging and maintenance	o Human factors measure – what will prompt owner to repair the system
		o Danger to person near suppressed fire (toxicity of resulting gases, splashing of hot oil)	
		o Stability of agent over time	o Measurement of aging characteristics of suppressant
		o Increased cost and complexity of adding the suppression systems	
		o Miscellaneous problems	o Determine the most appropriate sensor o Discrimination between desired and undesired heat sources
4.2	**Improved Nuisance-Free Smoke Detectors (**short-term impact)	o Time/cost for manufacturer	o New performance standard for smoke alarms
		o Discriminating between cooking and unwanted fire	o Characterize aerosol signature of nuisance fires

No.	Technology/Category	Barriers to Broad Implementation	Measurement Science Needs
4.2	**Improved Nuisance-Free Smoke Detectors (**near-term impact) (continued)	o People disable smoke alarms	o Measure most effective way to communicate diagnostic information
		o Lack of knowledge for residential multi-criteria detectors	o Measure performance of multi-sensor networks
4.3	**Improved Suppression Technology** (long-term impact)	o Insufficient Science / fundamental understanding (interaction of water and fire /burning objects, flame spread over burning objects, etc. Other agents….)	o Characterize effect of water (individual droplets) on heat release rate o Measure characteristics of spray (droplet size mass velocity) o Measure spray interaction with fire plume o Measure agent effectiveness
		o Suppressants delivery systems require too much piping	
		o Unique suppression requirements of special hazards (i.e. lithium batteries)	

No.	Technology/Category	Barriers to Broad Implementation	Measurement Science Needs
4.4	**Understanding and Predicting Structural Fire Performance** (multiple needs)	o Lack of understanding of response of structural systems to fire	o Measure structural response to fire (experiments with loaded systems and subsystems) o Develop tools to predict structural response
		o Inability to predict fire	o Develop tools to predict fire
		o Issues of different scales o Inability to predict material response to fire	o Measure heat release of individual items o Measure heat transfer in building materials
		o Lack of training in design profession	
		o Public and firefighter perception o Trust and confidence o Sensing and detection o Tolerance to terrain, fire conditions	o Assess trust and perception o Performance standard o Determine training requirements
4.5	**Robotic Fire Fighting** **(**non-technical barriers)	o	

5. Fire Service Group

The Fire Service Group identified ten approaches to reducing the U.S. fire problem as it pertains to the fire service and then discussed each in turn. The results of the discussions are presented below. Section 5.1 gives a list of the approaches and the technologies that the Group identified, which might provide solutions to specific fire problems. Section 5.2 gives a set of metrics that was developed and then used as a tool to identify technologies that may have special importance within the context of this workshop. This process, along with the identified technologies (in italics in Section 5.1) is discussed in greater detail in Section 5.2.

5.1 Approaches and Technologies

An overall Group concern was that some of the approaches were very broad and appeared to be in a higher-level category than others. Also, many of the technologies apply to more than one approach. The Group spent some time discussing other ways to organize the approaches so that the technologies don't overlap, i.e., divide the approaches into categories that work within the fire service hierarchy: by usefulness to the fire fighter, crew, team, and Incident Commander; or by its relevance to the burning structure versus the firefighter. It was decided that technologies having multiple applications would be labeled with letters (a-j) that indicate each approach to which it was applied. Therefore, each approach below is followed by a letter in parenthesis for the purpose of identification.

- **Anticipate Fire Growth (a)**
  - Clarification was needed regarding this topic. Anticipating fire growth was defined as "getting information about the burning environment for the Incident Commander to decide how to attack the fire".
    - Another title for this approach was suggested: Anticipating Building Response"
  - Brainstormed technologies
    - Technologies to evaluate and/or monitor the stability of buildings exposed to fire ground conditions
    - Turbulent combustion dynamics (a,c)
- **Improve Communication (b)**
  - This is a very broad approach
  - Similar to situational awareness. How much information does the fire fighter have of the big picture?
  - Brainstormed technologies

        - *Improve communications equipment* [6]
            - *durable, reliable, easy to use systems*
            - *better verbal radio communication*
        - Respirator radios that give clear voice communication
        - Ad hoc self-healing networks (b,e,f)
        - Multiple person hierarchy communication

- **Improve/Develop Fire Suppression (c)**
    - Brainstormed technologies
        - Class A and compressed air foam effectiveness
        - *Enhanced understanding of suppression dynamics for modeling*
        - Robotic fire fighting technology
            - with suppression
            - for search and rescue
        - *Sustainable suppression (materials, etc...)*
            - *Ecologically sensitive post-fire decontamination*
        - Water attack optimization
            - Stream, fog, fine mist
- **Investigation/Reconstruction (d)**
    - Brainstormed technologies
        - Improved reconstruction tools for investigations (a, d)
            - Pre-fire building condition
        - Fire modeling tool for post-fire analysis
            - At local level
            - Evaluation of tactics
            - Lessons learned
            - Fire behavior and effect of suppression tools
- **Improve Situational Awareness (e)**
    - This is a very broad approach, would it be better to divide it into separate categories, e.g., inside versus outside the structure?
        - Tracking fire fighters is beneficial to the incident commander, not as beneficial to the fire fighter. Thermal imaging is beneficial to the fire fighter, but not as useful to the incident commander.

[6] Italicized technologies are considered further in Table 5.2.

        - May be best to look at this approach using individual, crew, task, and command levels.
    - Part of physiological/occupational health and safety is covered under situational awareness.
    - Brainstormed technologies
        - *Technologies to track fire fighter movement inside structures*
            - *Smart building 3-d fire fighter locators*
        - Residential fire detectors to convey fire characterization to fire departments (a, e)
        - Anticipate building response (a, e)
        - Use of sensor technology to improve awareness
            - Individual level
            - Crew level
            - Task level
            - Command level
        - Probabilistic fire spread model using real-time sensor input to project fire spread (a, e)
        - Response routes on apparatus
            - Traffic patterns
        - Control technology to couple sensor input with communication and control in buildings
            - Maybe artificial intelligence too
        - VID (video technology) and other fire detection technology to look at fire and response

- **Fire Fighter Health (f)**
    - Where is "physiological/occupational health and safety"? Integrated into each approach or stand alone? Part of this is covered under situational awareness.
    - Brainstormed technologies
        - Core body temperature measurement sensor (e, f)
            - Heat stress
            - Strain
            - Rehabilitation
        - *Screening test for fire fighter risk factors for heart attack or sudden cardiac death*

        - Fire fighter physical condition alarm
            - Before
            - During
            - After

- **Improve/Develop Tactics (g)**
    - Never rule out running to exit a burning building as a tactical option
    - Brainstormed technologies
        - Fire apparatus equipment organization to reduce injury (g, i)
        - Lightweight construction tactics
        - Labels or design logo to identify lightweight construction/conversion (e,g)
- **Improve Use of Resources (h)**
    - Brainstormed technologies
        - Fire station location analysis tool
        - Resource coverage tool or model
        - Apparatus fuel
- **Firefighter Training and Education (i)**
    - Brainstormed technologies
        - Training and education for injury prevention (f, i)
        - *Enhanced virtual environment for training and data collection*
            - *Training with fire simulator to improve or understand current tactics (interactive)*
            - *Computer-based training programs*
            - *Modeling and simulation labs for recruits*
        - Virtual reality of buildings for future potential incident familiarity (a,e,g,i)
        - Effective communication of needs to Congress for funding
        - *Clearing house to review, coordinate and combine the multiple Federal agency's research and development activities*

- **Improve/Develop Personal Protective Equipment (PPE) (j)**
    - Brainstormed technologies
        - *Revolutionary heat resistant materials/integrated clothing technologies for fire fighters*
        - Enhanced thermal protection, heat stress, use, durability of fire fighter PPE

- Slim self-contained breathing apparatus (SCBA) profile to allow quick egress
- Real time personal exposure monitoring devices (a, e, j)
  - Inhalation, dermal exposures
  - Used for fire suppression and overhaul
- End of Service Life Indicator (ESLI) for fire fighter PPE service life
- Lightweight gear that changes color due to heat effects
- *Next generation fire fighter respiratory protective equipment*
  - *Combinations*
    - *All-in-one SCBA, radio, thermal detector pack*
    - *Integrated thermal imaging with heads up display in SCBA face piece, crew-to-crew communication, radio, wireless (e, j)*
  - *SCBA*
  - *Closed circuit*
  - *Air-Purifying Respirator (APR)*
- Safety ice cells/kiosks
- High temperature respirator face pieces
- Passive/reactive cooling PPE
- Body-worn gas sensor (e, f, j)

- **Summary**

Nine of the technologies identified in this section were selected for further analysis. There were four major groupings of these technologies, which are presented below and also in Table 5.2:

1. Fire fighter Health and Safety Equipment
   a. Next generation fire fighter respiratory protection
   b. Enhance fire fighter protection clothing
   c. Health screening/risk ID tools
2. Situational Awareness
   a. Improved communication equipment
   b. Fire fighter tracker/locator
3. Fire fighter Information
4. Fire Fighting Effectiveness
   a. Fire fighter research clearing house
   b. Sustainable suppression (agents)

5.2 Appraisal of Selected Technologies

5.2.1 Metrics

The Fire Service Group identified six metrics to characterize the potential contribution of a technology to reducing the fire problem, as well as attributes for each metric (see Table 5.1). The nine technologies that were identified as potentially game-changing or generally important were then evaluated in terms of the metrics identified in Table 5.1. The results are seen in Table 5.2.

Table 5.1 Metrics and Attributes for Evaluating Technologies

No.	Metric	Meaning	Attributes		
			Low (L)	**Medium (M)**	**High (H)**
5.1	Ease of Technical Development	Feasibility of completing technical development; high ease means the technology is very feasible.	Easy; technology is very feasible	Somewhat difficult	Difficult
5.2	Multiple Stakeholder Benefits	Probability of impacting multiple stakeholder groups	< 10 %	10 % - 50 %	> 50 %
5.3	Market Readiness/ Timing	Time to commercial marketability	< 2 years	2 – 5 years	> 5 years
5.4	Likelihood of Implementation	Includes initial cost and other barriers	Unlikely	Likely	Very unlikely
5.5	Overall Economic Benefit	Relative economic benefit	$	$$	$$$
5.6	Impact on Fire Problem	Relative impact	Low	Medium	High

Table 5.2 Evaluation of Selected Technologies. The first 5 technologies were evaluated further in Section 5.2.2.

No.	Technology	Attributes of Metrics					
		1. Ease of technological development	2. Multiple stakeholder benefits	3. Market readiness/ timing	4. Likelihood of implementation	5. Overall economic benefit	6. Impact on fire problem
5.1	Health screening/risk ID tools	High	High	< 2 yrs	Very Likely	$$$	High
5.2	Improved communication equipment	Med	Med	< 2 yrs	Likely	$	High
5.3	Virtual environment trainer & data	High	Med	2 – 5 yrs	Very Likely	$$	High
5.4	Fire fighter tracker/locator	Med	High	2 – 5 yrs	Very Likely	$$	High
5.5	Fire fighter research clearing house	High	Med	2 – 5 yrs	Unlikely	$$$	High
5.6	Next generation fire fighter respiratory protection	Med	Med	2 – 5 yrs	Very Likely	$$	High
5.7	Enhance suppression dynamics	High	High	2 – 5 yrs	Very Likely	$$$	High
5.8	Sustainable suppression (agents)	Med	Med	2 – 5 yrs	Likely	$$	Med
5.9	Enhance fire fighter protection clothing	Med	High	2 – 5 yrs	Likely	$	Med

5.2.2 Detailed Examination of Selected Technologies

Of the nine technologies appraised in Section 5.2.1, the group selected five potentially high-impact technologies for further evaluation and more detailed discussion following the categories defined in Section 1.3 of this report (for Session XI).[7] The discussion of the five technologies is summarized in Table 5.3. Below are lists of technical and non-technical barriers for each of the five important technologies. Measurement science needs are also listed with each technology. As each of the technologies was discussed in turn, a few measurement science needs emerged that were broadly applicable. It was further noted that the measurement science needs generally fell into one of four basic categories, dubbed "the elements of performance-based assessment," which relate to: (1) identifying the goal, (2) identifying the challenge, (3) setting the rules for estimating performance, and (4) developing candidate designs for the technology. In the context of the workshop, these are the four types of measurement science that are needed in order to develop tools and technologies.

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[7] The technologies were selected so that there was one in each of the five following categories: 1. High impact/long reach, 2. Short-term delivery, 3. Long-term delivery, 4. Multiple measurement science needs, 5. Non-technical barrier. These categories facilitated selection of a range of technology options and were examples, representing the broad range of challenges and benefits that must be considered in prioritizing research. This process highlighted a number of technologies and provided a model for analyzing the full set of technologies.

Table 5.3 Barriers and Measurement Science Needs for Select Technologies.

	Technology/Category	Barriers to Broad Implementation: Non-Technical	Barriers to Broad Implementation: Technical	Measurement Science Needs
Game-changing technology	Health Screening/ Risk ID Tools	o Economics, health care costs o Public policy (local, state, federal) o Lifestyle	o Unknown medical factors o Approved testing practices o Exposure conditions, evaluation of impacts	o Identify risk factors for disease o Quantitative medical factors and conditions o Establish consensus testing protocol o Characterize fireground conditions, interior attack, overhaul o Determine impact of conditions on fire fighter health
Short term technology	Improve Communication Equipment	o Retrofit costs o Certification requirements o Public policy (local, state, federal)	• Signal attenuation by structure • FCC limitations • Systems integration • Power supplies • Voice recognition & audibility	• Effect of structural materials and configuration on signals • Signal strength • Regulations • Compatibility with other systems • Standardized information displays • Integration into face piece • Weight and performance • Human factor measurements and metrics

	Technology/Category	Barriers to Broad Implementation		Measurement Science Needs
		Non-Technical	Technical	
Long term technology	Fire Fighter Tracking/ Locator Technology	o System costs o Certification requirements o Public policy (local, state, federal)	• Signal attenuation by structure • FCC limitations • Systems integration • Power supplies • Capability to track/locate multiple assets • Access to floor plans	• Effect of structural materials and configuration on signals • Signal strength • Regulations • Compatibility with other systems • Standardized information displays • Weight and performance • Accuracy of system performance • Reliability of system performance • Development of floor plan model software
Multiple stakeholder technology	Enhanced Virtual Fire Environment Tool for Training and Data	o Consensus on performance metrics o Systems cost	• Understanding fire and suppression mechanisms • Ease of operation • Incorporation of non-sight sensing data • Data and validation	• Detailed suppression dynamics and fire physics • Model development and validation • Standardized operation and display of information • Multi-user dynamics • Development of interactive "virtual reality environment" to simulate fire experience • Experimental data (fire, suppression, victim tenability, fire fighter safety, structural integrity • Incorporation of data into model

	Technology/Category	Barriers to Broad Implementation		Measurement Science Needs
		Non-Technical	**Technical**	
Technology with non-technical barrier	Clearinghouse/Review for Coordination and Planning of Fire Problem Research	o Political will o Coordination of funding o Coordination of research agendas and dissemination of findings o Key players: congress, entire alphabet of federal and other organizations, associations, unions, societies, academia)	o Standardized information center accessible to all	o Information asset management system

6. Wildland-Urban Interface Fire Group

The results of the discussions of the Wildland-Urban Interface (WUI) Fire Group are presented below. The Group identified and discussed numerous approaches to reducing the U.S. WUI fire problem. Section 6.1 gives a list of the approaches and the technologies that the Group identified, which might provide solutions to specific fire problems. Section 6.2 gives a set of metrics that was developed and then used as a tool to identify technologies that may have special importance within the context of this workshop.

6.1 Approaches and Technologies

The Group identified eight approaches to reducing fatalities and property losses. While the focus was on WUI communities, it was recognized that fire spread in the wildlands often brings the fire to the community. As a result, the group felt it was imperative to include wildland fire spread within the framework of vegetative fuel management. The following is a list of the approaches and the technologies that the Group members identified and associated with each approach and that might provide solutions to specific fire problems. The technologies in italics are considered further in Section 6.2.

- **Vegetative fuel management**
    - *Model coupling interactions between fire and atmosphere*
    - Light Detection and Ranging (LiDAR) fuel mapping
    - Predictive physics-based models for outdoor fire spread—including wildland, urban & WUI fires
    - Spray coatings to reduce flammability of vegetation
- **Community planning construction, codes, and standards**
    - *Firebrand intrusion prevention technologies (intumescent materials and fenstration protection)*
    - Surface applied coatings/treatments: predictable service life with exterior weathering
    - Uniform flame resistant roofing technologies (roof attic vents, roof coverings, roof sheathing)
    - Prediction tool for wind patterns at a local level
    - Design/installation standard attic sprinkler
    - Instrumentation to capture firebrands to quantify exposure
    - New test method for exterior finish materials for WUI fire exposure

    - Affordable, widely available test facilities for building products
    - Ignition resistant building materials (siding) for fire prevention
    - Durable topically applied materials for attic and under-floor ignition resistance

- **Defensible space (buildings and parcel), ignition resistance**
    - Simple comprehensive decision tool for wildlands (species and equipment selection, spacing in wildland near structures)
    - Employable fire prevention "house tent" or other treatment
    - IR technology for detection/activation of home prevention devices (shutters, vent closures)
    - Low flammability vegetation (for homes)
    - Tables of vegetation firebrand production
    - Weathering (accelerated) procedures to predict long-term performance of topical treatments
    - Airborne imaging to high light wildland encroachment near building
    - *Quantify firebrand quantities, transport, characteristics as a function of wind and ignition potential*

- **Influencing home and community actions (before and after fire incident)**
    - Systems approach coupling flame spread prediction and evacuations
    - *Legislative mandate/incentive to retrofit existing homes*
    - Design home landscape that help protect home
    - *Benefit-cost assessment tools/models for retrofit technologies and systems approaches to retrofit*
    - Single fire modeling tools to better use available building materials
    - In depth case studies of fire moving through communities for communication with homeowners
    - *Message development tool—sociological/*education; deliver to *homeowner to influence behavior*
    - Opt-out voluntary compliance homeowner standards

- **Fire detection, suppression, control, and containment**
    - Forward looking hot spotting tools to predict burning brand or ember transport
    - Longer-run forecasting to better predict fire season severities (effective pre-positioning of fire suppression resources)
    - High resolution satellite and detection and tracking of new/existing fires (in real time)
    - Exterior sprinklers for fire prevention
    - Time-dependent Geographic Information System (GIS) for observation of fire behavior
    - Guideline for prevention of structure to structure fire spread
    - Cheap robotic firefighter for home deployment
- **After action review—learning assessment and improvement**
    - Special reporting for fire investigation of WUI fires (reporting mechanism)
    - Standardized characterization for building and surrounding
    - *Technology to help document and analyze WUI fires (3D visualization tools—the Secret Service uses test flights to map sightlines for upcoming presidential trips)*
    - Improved scientific basis for wildland portion of NFPA 92
    - Fire investigation team rapid response (deterring near-term incendiary fires maybe accidental fires)
    - Firefighting actions training during WUI events
    - Develop database of fire behavior (temporal and spatial) for evaluation of fire models
    - Storm debris flow models (after WUI fire)
    - Rapid deployment monitoring systems
- **Problem Definition (i.e., a better understanding of the WUI problem).**
    - Tools to better predict dry lightning
    - Standardized methodology to evaluate performance of risk assessment tools
    - Potential to simulate fire spread processes across multiple scales
    - *WUI risk model for suppression that includes market and non-market values*

- **Summary**

Eight of the technologies identified in this section were selected for further analysis and represented ideas from almost all seven of the major groupings presented above. The technologies were extremely varied in their nature. They are presented below and evaluated further in Table 6.2:

  - *Legislative mandate/incentive to retrofit existing homes*
  - *Model coupling interactions between fire and atmosphere*
  - *Firebrand intrusion prevention technologies (intumescent materials and fenstration protection)*
  - *Quantify firebrand quantities, transport, characteristics as a function of wind and ignition potential*
  - *WUI risk model for suppression that includes market and non-market values*
  - *Benefit-cost assessment tools/models for retrofit technologies and systems approaches to retrofit*
  - *Technology to help document and analyze WUI fires (3D visualization tools—the Secret Service uses test flights to map sightlines for upcoming presidential trips)*
  - *Message development tool—sociological/*education; deliver to *homeowner to influence behavior*

6.2 Appraisal of Selected Technologies

6.2.1 Metrics

The Group identified six metrics to characterize the potential contribution of a technology to reducing the WUI fire problem, as well as attributes for each (Table 6.1). These were then applied to the eight technologies that received the most votes (see Section 6.1 and Table 6.2). The following issues are noted regarding the process of assigning attributes:

- The attributes “high,” “medium,” and “low” were simply relative measures that had no additional definition.
- The attribute “positive” meant that any unintended consequence was beneficial to society (on net).
- The attribute “neutral” meant that any unintended consequence was neither beneficial nor costly to society (on net).
- The attribute “negative” meant any unintended consequence was costly (on net).

Table 6.1 Metrics and Attributes for Evaluating Technologies

No.	Metric	Meaning	Attribute
6.1	Effectiveness	The ability to reduce the impact of WUI fires	high, medium, low, unknown
6.2	Benefit-Cost Ratio	The relative benefit versus cost performance	high, medium, low, unknown
6.3	Marketability	Public perception of the usefulness of the technology and its aesthetics	high, medium, low, unknown
6.4	Feasibility	Whether the technology can be developed, and if so, in a timely manner	high, medium, low, unknown
6.5	Collateral Impact	Existence of any unintended consequences (e.g., political, social, environmental) from use of the technology	positive, neutral, negative
6.6	Implementability	User group perception and acceptable of the technology	high, medium, low, unknown

6.2.2 Detailed Examination of Selected Technologies

Of the eight technologies appraised in Section 6.2.1, three potentially high-impact technologies were selected for further evaluation and more detailed discussion following the categories defined in Section 1.3 of this report (for Session XI).[8] The results of the discussions on the three technologies are summarized in Table 6.3, including identification of barriers to implementation and measurement science needs.

[8] The technologies were selected so that there was one in each of the five following categories: 1. High impact/long reach, 2. Short-term delivery, 3. Long-term delivery, 4. Multiple measurement science needs, 5. Non-technical barrier. These categories facilitated selection of a range of technology options and were examples, representing the broad range of challenges and benefits that must be considered in prioritizing research. This process highlighted a number of technologies and provided a model for analyzing the full set of technologies.

Table 6.2 Evaluation of Selected Technologies. The first 3 technologies were evaluated further in Section 6.2.2.

		Attributes of Metrics					
No.	**Technology**	**1. Effectiveness**	**2. B-C Ratio**	**3. Marketability**	**4. Feasibility**	**5. Collateral Impact**	**6. Implementability**
6.1	Legislative Mandate	High	Medium	Medium	Low	Negative	Medium
6.2	Fire/Weather Model	High	Medium	N/A	Medium	Positive	Medium
6.3	Firebrand Prevention	High	High	High	High	Neutral	High
6.4	Firebrand Model	High-Medium	High-Medium	N/A	High	Positive	Medium
6.5	WUI Risk Model	High	High-Medium	Low	Medium	Negative	Medium
6.6	Benefit-Cost Assessment Model	High	High	High	High	Positive	Medium
6.7	Document WUI Fires	High	High	Medium	Medium	Positive	High
6.8	Messaging Tool	High	High	Medium	Medium	Positive	High

Table 6.3 Barriers and Measurement Science Needs for Select Technologies.

No.	Technology/Category	Barriers to Broad Implementation	Measurement Science Needs
6.1	Legislative mandate to retrofit pre-existing houses (Home run & non-technical barriers)	o Complexities of structures, products, and conditions and their influence o Insufficient data o Uniform test standards	o Determination of relative effectiveness of technology options o WUI definition independent of fire risk o Relative effectiveness of alternative incentives o Economics - quantification of benefit-cost, etc. o Fire model measurements to identify most needed areas o Global benchmarking to understand test standards
6.2	Fire model coupling weather, smoke, and fire-behavior (Long Term & multiple measurement science needs)	o Insufficient data o Research complexities/difficulties of understanding physical interactions o Cost to develop o Integrating roles of different agencies	o Deployable instrumentation for field data collection o Model validation o Material property measurements o Flame propagation for vegetation o Improved computing efficiency and optimization algorithms o Performance metrics

No.	Technology/Category	Barriers to Broad Implementation	Measurement Science Needs
6.3	Ember intrusion prevention (Near-term)	o Variability of the phenomenon and physical factors o Uniform test standards o Complexities of structures, products, and condition and their influences	o Large variety of basic data of phenomenon o Basic or fundamental science data needs o Ember characteristics and generations/source of embers o Home and material ignition characteristics o Physics of heat and mass transfer

7. Global Fire Protection Group

7.1 Approaches and Technologies

The Group identified ten approaches to reducing the overall U.S. fire problem and then discussed each in turn. The following list of the approaches, the essence of the discussion associated with each approach, and the technologies that the Group members identified with each approach that might provide solutions to specific fire problems. The technologies in italics are developed further in Section 7.2.

- **"Real-time" Data Collection and Analysis**
    - Statistic information regarding the U.S. fire experience, provided with minimal time lag, to support quality decisions regarding, e.g., resource allocation, equipment purchases. For example, investigations of the infrequent WUI fires take years to complete, and the fire scenes change rapidly as the community rebuilds.
        - Data need to be a good representation of the true distributions.
        - Collection tools need to be sufficiently facile that data of sufficient detail and accuracy to address specific fire issues are collected.
        - "Conditional" aspects of the data need to be well understood.
        - Local law enforcement is well ahead of the fire service in data analysis.
    - Information regarding an active fire provided to incident commanders to enable high quality decisions regarding emergency responder tactics.
    - Brainstormed technologies
        - Mobile fire data collection capabilities
        - Zoning fire protection systems; e.g., additional devices such as flow switches to better locate a fire, opposed to one per floor
        - Fire data collection that includes affective measures [behavioral response]
        - Automated data collection system
            - hand held
            - narrative to text to data algorithm
- **Analysis Tools for Decision Making**
    - Methodology to evaluate efficiently an idea and its potential to impact the fire problem, in order to make quality decisions on the allocation of scarce resources.
    - Enable early examination of potential innovations by identifying the relevant fire problems(s) and quickly estimating whether the idea can make a big difference.

- Includes broad range of possible impacts, e.g., clearing trees away from house would lower the fire risk but increase the cost of cooling.
- Brainstormed technologies
  - *Multi-hazard analysis techniques for cost effective fire protection solutions*
  - Innovation potential analysis tool
    - scenario-based tool to predict impact
    - linked to data-based frequency and severity parameters
  - Improved and accessible data for fire models for engineering, education, analysis
  - <u>True</u> cost/benefit analysis for potential solutions
    - considers more than just the fire aspects
    - benefits may be well outside usual fire safety considerations
  - 3D software for reviewing building plans
    - evaluates building for early detection/analysis
    - prevention and preplan tool
  - *Life-cycle analysis of fire protection systems and features of products*

- **Engineering for Fire Safety and Prevention**
  - Development of new flame retardant chemicals
  - Enhanced electrical safety
  - Control of heat and fuel sources
  - Analytical tools, such as finite element analysis and computational fluid dynamics
  - Brainstormed technologies
    - *Home fire suppression retrofit kit; e.g., a non-plumbed system that does not require installed piping*
    - Comprehensive integrated fire models derived from fire test results
    - Improved understanding of fire characteristics for the wall/floor/ceiling system
    - Thermal barriers for foam plastic insulation
    - Finite-element analysis and computational fluid dynamics fire models
    - CO detector, in lieu of photoelectric smoke alarms
    - Multi-sensor residential fire detector
      - custom message
      - connect to fire department
      - alert occupants
    - Simple, reliable on/off sprinkler

        - Sensor technology for building stability
        - Building health sensors for fire incidents
            - motion detectors
            - security
            - air handling systems based on CO_2
        - *Fire-safe, energy-efficient appliances, especially for cooking*
        - *Automatic fire detection and power-off feature for anything with an automatic control*
        - Fire-safe alternative fuel vehicles

- **Fire Safety and Prevention Education and Training**
    - Includes school children, older individuals, and emergency responders.
    - Education managed at the municipal level, with uneven resources, such as a fire safety house that all second graders are required to visit.
    - Lack of a Federal mandate
    - Brainstormed technologies
        - Web technology – mass education
        - Live burns
            - demonstrate speed and damage of fire spread
        - Digital TV channel dedicated to fire news, education, events
            - street, neighborhood, city, state, national
            - interrupt other local TV and radio channels in emergencies
- **Life-cycle Analysis of Aging Materials and Equipment**
    - All fire prevention strategies are based on materials properties and test results from new products which are properly constructed.
    - Fire properties can change with age.
    - Need to acknowledge the need for understanding the aging and deterioration characteristics of combustibles.
    - Brainstormed technologies
        - Development and application of product-relevant aging/weathering protocols
        - *Barrier materials to achieve very low combustibility furnishings*
- **Advocacy: Building Coalitions to Effect Technology Implementation**
    - Overcome barriers to acceptance of technologies

- Build commitments among groups with dissimilar goals, e.g., commercial organizations (profits and dividends) and public safety advocates (fire loss reduction).
- No brainstormed technologies

- **Community Development for Containment of Large-scale Fires**
  - Political and social issues
  - Strategies at the product level, the individual level, the building level, and the community-wide level
  - Brainstormed technologies
    - Exposure protection
      - sprinklers, foam, novel methods
    - Natural interface protection
      - earthquake, flood, wildfire
    - Evaluate acceptable level of risk to community and to individual dwelling
- **Wildland-urban Interface (WUI)**
  - A sub class of the community development Approach
  - Brainstormed technologies
    - Construction practices for improved structural resistance to ignition and fire propagation
    - WUI heat source strategy: a systematic review of heat source patterns and a portfolio of strategies to reduce heat source threats by type of heat source
      - equipment that will not generate sparks
      - safe setup for camp fires
    - Application heat release calorimetry for evaluation of structure exteriors
    - Community evacuation tools to evaluate risk
    - WUI automatic detection and response
      - satellite monitoring
      - fire starts and related conditions
      - tied to response plans parametrically tied to conditions
- **Firefighter Health and Safety**
  - Brainstormed technologies
    - *Fire fighter (FF) black box*
      - Sensor and communication hardware that records and transmits data on the environment, and firefighter bio-indicators and position

            - FF voice communicators
                - in self-contained breathing apparatus
                - tracking
            - *Reliable firefighter locator/tracking/navigation system to get them out of harm's way*
            - Technology to locate building occupants and help manage egress (possibly tied to cell phones)
            - Risk-based firefighter timeline
                - data and communication to firefighters on the scene
                - include differences in risk to firefighters posed by different home constructions, depending on time to response
                - conditional strategies for firefighter safety, depending on initiation of event
            - Sensor in self-contained breathing apparatus that measures bio-indicators (heart rate, etc.) and translates these into minutes left of breathing air

- **Technology Transfer**
    - Use of existing technologies from other fields to address the fire problem.
    - Brainstormed technologies
        - *Next generation fire alarm technology*
        - Geographic Information System mapping
        - Multi-detection units in all structures
        - Radio frequency waves for fire suppression along with wireless detection
        - Smoke alarm "black box" for use in fire investigations

- **Summary**

  Nine of the technologies identified in this section (in italics) were selected for further analysis. They represent ideas from 5 of the 10 major categories considered here including:

    - Firefighter Health and Safety
    - Life-cycle Analysis of Aging Materials and Equipment
    - Engineering for Fire Safety and Prevention
    - Analysis Tools for Decision Making
    - Technology Transfer

  The technologies are presented below and evaluated further in Table 7.2:

    - Home fire suppression retrofit kit
    - Barrier materials for very low combustibility furnishings

- Automatic fire detection and power-off feature for anything with an automatic control
- Life-cycle analysis of fire protection systems and features of products
- Multi-hazard techniques for cost-effective fire protection solutions
- Next-generation fire alarm technology
- Fire-safe, energy-efficient appliances
- Reliable firefighter locator/tracker/navigation system
- Firefighter black box

7.2 Appraisal of Selected Technologies

7.2.1 Metrics

The Group identified 10 metrics to characterize the potential contribution of a technology to reducing the fire problem, as well as attributes for each (Table 7.1). These were then applied to the nine technologies that were thought to merit further consideration (Table 7.2). The process of assigning attributes in this Breakout Group considered the following issues:

- Tools which will be used to evaluate technologies were treated separately from the technologies themselves.
- It may be necessary to develop more detailed tools before metrics for some technologies can be properly evaluated.
- In some cases, attributes were a precondition for the existence or acceptance of the technology. For example, the reliability of an auto off device must be high if the device is to be accepted by the consumer.

Table 7.1 Metrics and Attributes for Evaluating Technologies

No.	Metric	Meaning	Attributes		
			Low (L)	Medium (M)	High (H)
7.1	Size of target problem	Loss and cost potentially affected by an innovation	$1M to $5 M	$10M to $100 M	$1 B
7.2	Impact	Percentage of the problem size	< 10 %	10 % to 50 %	> 50 %
7.3	Cost to end user	Perceived affordability	Discretionary (can buy on an impulse)	Somewhat difficult (need a credit card)	Practically unaffordable (needs a mortgage)
7.4	Ease of use	Ease for the user, once the technology is in place	Expert	Medium	Elementary
7.5	Ease of implementation	Ease for the installer	Expert	Medium	Elementary
7.6	Acceptability to customer	Non-cost acceptability factors, e.g. aesthetics, perception of necessity or reliability	Not	---	Acceptable
7.7	Reliability	Probability of failure	30 %	60 %	90 %
7.8	Speed to market	Reflection of position in the developmental cycle and potential technology transfer issues	> 5 years	1 year to 5 years	< 1 year
7.9	Speed to universal adoption	Time to percolate throughout the society once it is ready for the market. (L) picks up innovations installed in buildings, (M) picks up slow-turnover furnishings, e.g., mattresses and upholstered furniture, and (H) picks up cigarettes, lighters, etc.	50 years	10 years	2 years
7.10	Criticality for decision-making (for tools only)	Important of an analysis tool; e.g., if expert judgment would suffice, then the tool is not critical (L); specialized, sophisticated tools that are the only way to solve a problem are (H); easy-to-use tools for decisions requiring more than just a judgment call are (M).	Expert judgment sufficient	Simple tool needed	Unique

Table 7.2 Evaluation of Selected Technologies. The first 5 technologies were evaluated further in Section 7.2.2.

No.	Technology	Attributes of Metrics									
		1. Size	2. Impact	3. Cost	4. Ease of use	5. Ease of implementation	6. Acceptability	7. Reliability	8. Speed to	9. Speed to universal	10. Criticality
7.1	Home fire suppression retrofit kit	H	H	M	H	M	Y	M	M	L	
7.2	Barrier materials for very low combustibility furnishings [A]	H	H	M	H	H	Y	M	L	M	
7.3	Automatic fire detection and power-off feature for anything with an automatic control [B]	H	M	M	H	H	Y	H	M	M	
7.4	Life-cycle analysis of fire protection systems and features of products	H	L	L	L to H	H	Y	L to M	M	M	L
7.5	Multi-hazard techniques for cost-effective fire protection solutions	H	L	L	L to H	H	Y	M	M	M	L
7.6	Next-generation fire alarm	H	M	M	H	H	Y	M	M	M	
7.7	Fire-safe, energy-efficient appliances [C]	H	M	M	H	H	Y	H	M	M	
7.8	Reliable firefighter locator/tracker/navigation system [D]	M	M	M	H	H	Y	M	M	M	
7.9	Firefighter black box [E]	M	L	M	M	M	Y?	M	M	M	

A. Barrier materials: Size is H, based on application to upholstered furniture alone. The impact is H, looking at the impact of similar technology for mattresses. The impact for cars may be M.
B. Auto off: Size is H because of the large number of devices this would affect; ranges alone would suffice to make this problem large. Cost is M due to the cost of accurate sensors.
C. Safe appliances: The group questioned whether this technology would be encompassed by Technology #3 (Auto off). This technology also deals with energy efficiency and attempts to make a fire less likely to begin with. The attributes were agreed to be identical.

D. Firefighter locator: There was a great deal of discussion about the differences in the necessary technologies for firefighter location versus firefighter communication. The former requires that a signal (GPS from a satellite, for example) penetrate the building. The latter requires coherent voice communication from the firefighter to someone outside the building. Though a carrier frequency that can penetrate buildings may be needed in both technologies, there may be additional technologies required for voice communication. Size was determined as M, based on this technology affecting one-third of firefighter deaths, which equate to $0.5 B. Many companies market such devices, but none of them work. Thus, reliability should be a key factor in a successful innovation. However, given the severity of the firefighting environment, high reliability is not a guarantee, and so the group settled on M. Firefighter black box: There was some discussion about what technologies currently exist to record the data of the firefighting environment.

E. This technology was envisioned as a possible precursor to the firefighter locator technology. Ease of use was originally thought to be H (no intervention by the firefighter, someday integrated into the self-contained breathing apparatus). However, given issues related to maintenance and calibration, the group decided to estimate the ease of use as M to be conservative. Acceptability may be questionable (Y?), due to fears that the firefighter may be questioned about the data.

7.2.2 Detailed Examination of Selected Technologies

Of the nine technologies appraised in Section 7.2.1, five potentially high-impact technologies were selected for further evaluation and more detailed discussion following the categories defined in Section 1.3 of this report (for Session XI).[9] The results of the discussions on the technologies are summarized in Table 7.3, including identification of barriers to implementation and measurement science needs.

As each of the technologies was discussed in turn, a few measurement science needs emerged that were broadly applicable. In today's world, developing an understanding of the environmental and health impacts and multi-hazard impacts of an innovation is critical and can be a "show stopper" if not considered early in the development cycle. Further, a benchmark impact study for the current technologies is usually needed so that we can place the performance of a new technology in perspective.

Although discussed sporadically, it was generally acknowledged that liability concerns for manufacturers may play a big part in bringing a new technology to market. Any measurement science solutions that address liability concerns may therefore improve impact and speed to market.

7.2.3 Examination of All Technologies

The technologies listed in Section 7.1 and Table 7.2 were reconsidered, applying the metrics developed above and shown in Table 7.1. The results are shown in Table 7.3 below.

[9] The technologies were selected so that there was one in each of the five following categories: 1. High impact/long reach, 2. Short-term delivery, 3. Long-term delivery, 4. Multiple measurement science needs, 5. Non-technical barrier. These categories facilitated selection of a range of technology options and were examples, representing the broad range of challenges and benefits that must be considered in prioritizing research. This process highlighted a number of technologies and provided a model for analyzing the full set of technologies.

Table 7.3 Barriers and Measurement Science Needs for Selected Technologies

No.	Technology/Category	Barriers to Broad Implementation: Non-Technical	Barriers to Broad Implementation: Technical	Measurement Science Needs
7.1	Home fire suppression retrofit kit (High-impact/long reach)	o Myths to be dispelled o Insufficient user knowledge for installation o Resistance to change o Liability concerns o Resistance from traditional sprinkler providers (competition) o Lack of precedent for an installed, unplumbed system	• Lack of system goal • Lack of design fires • Lack of performance criteria • Lack of a test method • Lack of effectiveness data for non-water-based agents • Poor understanding of dispersion characteristics • Design concept that can be made effective, reliable, and inexpensive	o Design fires, test method, performance criteria, agent properties o How to achieve reliable installation by amateurs o Guidance for storage of or access to extinguishing agent o Approval test o Minimize the amount of agent used
7.2	Barrier materials for very low combustibility furnishings (Short-term delivery) Note: Barrier materials will likely be developed separately from those who incorporate the materials into their products.	o Resistance from manufacturers o Resistance from consumers (comfort, aesthetics) o Resistance to need o Overcome liability concerns	• Lack of hazard analysis to determine performance criteria (combustibility and ignition resistance) • Need for guidance on integration of barrier material into furniture product • Unknown durability of product • Lack of a test method • Need environmental or health impacts from materials	• Large-scale test method for the hazard analysis phenomena • Small-scale test that captures the full-scale performance • Quantify the design challenge (design fires) • Accelerated aging and durability analysis • Benchmark for environmental impact • Effects of the barrier-product integration

No.	Technology/Category	Barriers to Broad Implementation		Measurement Science Needs
		Non-Technical	Technical	
7.3	Automatic fire detection and power-off feature for anything with an automatic control (Long-term delivery)	o Consumer resistance due to false positives or features o Lack of product education o Concern over aesthetics o Manufacturer resistance o Liability exposure o Preferences for alternative approaches to the problem o Redundancy with GFCI	• Vulnerability to overriding safety features • Lack of test standards • Increased power demand • Difficulty of reset • Difficulty in sensing the threat early and reliably • Lack of standards relating detection logic and thresholds on the state of the system • Integration with other fire sensing devices	• Understanding of malfunctions of devices that lead to fire • Identification of conditions to be detected • Failure mode analysis: identify scales of detection and thresholds for action • Quantification of false positive and false negative problem and refined failure mode analysis • Prediction of pending faults • Test standard or procedure • Assessment of vulnerability to tamper resistance • Identification and engineering of solutions to systems integration issues (e.g. power, data transmission, avoiding false positives elsewhere in the system)
7.4	Life-cycle analysis of fire protection systems and features of products (Multiple measurement science	o Resistance from system advocates based on cost and complexity o Resistance from manufacturers	• Environmental conditions (any degree of insensitivity to critical factors) • Practical means of	• Develop data and means to access other people's data • User interface for model (flexible, customizable) • Test protocol for aging

No.	Technology/Category	Barriers to Broad Implementation		Measurement Science Needs
		Non-Technical	Technical	
7.4	needs)	o Consumer resistance to replacing fire protection systems o Reliability of data o Lack of certification of users o Liability for those who use the tools to give advice o Environmental concerns (e.g., burden to landfills from discarded detectors)	accessing the needed data • Common framework for data archiving; usability of interface • Accelerated aging tests	devices, components for model validation • Standard for the approach • Develop model architecture (being explicit about what is and is not included; develop for diverse applications to determine impacts accurately)
7.5	Multi-hazard techniques for cost-effective fire protection solutions (Non-technical barrier)	o Acceptance of a true cost/benefit with respect to life loss o Reliability of data o All barriers from Life-cycle o Lack of agreement on relative weighting on different scales: lives, environment, no clear path to a consensus o Acceptable risk philosophy o Resistance from traditional fire safety advocates o High uncertainty of best available tools (a tech barrier)	• Access to needed input data • Lack of data architecture (GPS) • Need to establish boundaries, uncertainty ("intended use" confidence level) • Lack of a documented standardized approach	• Data and access to data • User interface for model (flexible, customizable) • Test protocol for model validation • Standard for the approach • Model architecture (diverse applications to determine impact)

8. Summary and Conclusions

This document represents the proceedings from the June 2009 NIST Workshop on Innovative Fire Protection. The deliberations documented in these proceedings represent a snapshot in time from a specific group of stakeholders who generously volunteered their time to attend the Workshop, and share their thoughts on elements of the national fire problem. Information exchanges, such as this Workshop, are central to obtaining the best thinking from a range of perspectives. They comprise an important step in the development of a strategy to address the national fire problem.

This Workshop provided many creative suggestions on how best to address the fire problem. Over 200 technologies were identified and are documented in Sections 3.1, 4.1, 5.1, 6.1, and 7.1 of this report. Most of the ideas represent extensions of current technologies, which would incrementally improve their effectiveness. Others represent new technologies that are not now commercially available. Some of the latter were conceptual in nature, while others are in the prototype stage or are being actively developed and tested.

The Workshop was broken into 3 plenary and 9 group breakout sessions. During the breakout sessions, the participants met in five Groups ("Breakout Groups") to discuss various aspects of the national fire problem. All five Breakout Groups addressed a part of the fire problem that would benefit from specialized discussion and expertise, and was justified by the size or trend of the fire problem it targeted:

- Breakout Groups 1 and 2 were concerned with fire prevention and fire protection – reducing the frequency and severity of fire. At the beginning of the workshop, Hall (see presentation in Appendix 4 of this report) described the costs of the different parts of the fire problem and identified civilian deaths and economic loss as two of the three largest components. Fire prevention and fire protection are the two strategies available to reduce these losses.
- Breakout Group 3 was the fire service group. Hall's presentation identified firefighter injuries as the third of the three largest cost components of the U.S. fire problem.
- Breakout Group 4 was the wildland/urban interface fire group; this problem has been one of the few parts of the large-loss fire problem that has been rapidly growing. The research issues are unlike those in structural fire safety.
- Breakout Group 5 was the global group, charged with considering areas of overlap and areas that might be overlooked by the other groups.

The Groups were asked to identify technologies that could reduce fire losses and improve life safety, identify metrics to evaluate the potential of the various technologies, and identify the technical and non-technical barriers that hinder application of the technologies. The Groups were also asked to identify gaps in measurement science that prevent successful implementation of the technologies.

8.1 Metrics

The Breakout Groups identified systems of metrics to evaluate the potential of the various technologies. There were commonalities in these results as summarized in Table 8.1 below, which is derived from Tables 3.3, 4.2, 5.2, 6.2, and 7.2. The first column in Table 8.1 assembles the metrics into seven general categories associated with:

- The problem being addressed
- Impact of a technology
- Societal issues
- Technical development
- Technology adoption
- Costs
- Special considerations

The first category (metric 1) denoted as the "problem being addressed" focused on the size of the problem. The second category (metric 2) denoted as "impact of a technology" focused on the potential effect of a technology to resolve a specific problem. The third category (metric 3) denoted as "societal issues" referred to political acceptance, and stakeholder and collateral benefits associated with a technology. The fourth category (metric 4) denoted as "technical development" is self-explanatory. The fifth category (metric 5) denoted as "technology adoption" involved many issues, including ease of implementation, speed to market, and marketability. The sixth category (metric 6) denoted as "costs" was related to sustainability and economic issues. The seventh category (metric 7) denoted as "special considerations" included effect on the occupant response time or better understanding of fire phenomena.

Consideration of the seven types of metrics can be reduced to two fundamental considerations: (a) How quickly and with what likelihood will the research successfully produce the identified technology? (b) If the technology is successfully developed, what will be the net results of having it available? Metric 4, technology development, provides the primary measurement of (a). And most of the examples cited under metric 7, special considerations, are strategic precursors of what is needed before a technology can be developed including the ease or difficulty of producing the technology. The primary measure of the net impact of the technology if it is developed can be related to the size of the target problem (metric 1) times the degree of reduction in problem size likely to result from the technology (metric 2) times the breadth of use of the technology (metric 5) as compared to a net measure of cost (metric 6). Most of the examples cited under the remaining metric type (3), societal issues, refer to other effects of the technology (e.g., environmental benefits or costs[10]).

[10] **T**he environmental, health and safety impacts of a technology can be a "show stopper" if not considered early in the development cycle. Liability concerns for manufacturers may play a big role in bringing a new technology to

The second column in Table 8.1 lists the Breakout Group (by section number in this report) that developed the metric, and the metric number listed in Tables 3.2, 4.1, 5.1, 6.1, and 7.1. The third column lists the metric and the fourth column describes the meaning of the metric. Examination of the entries in Table 8.1 show that there is overlap among the categories and some metrics could fit under more than one category.

Table 8.1 Summary of Breakout Group Results on Metrics for Evaluating Technologies

Topic	No.*	Metric Designation	Meaning
Problem	4.2	Addresses problem	Directly addresses aspect of fire problem
	7.1	Size of target problem	Loss and cost potentially affected by an innovation
	7.2	Impact	Percentage of the problem size
Impact	3.1	Impact	Probability that a technology would result in a 25 % reduction in residential fire losses (lives, injuries, property losses).
	4.3	Applicability and reach	Applicability to an aspect of the fire problem and penetration of implementation
	5.6	Impact	Relative impact
	4.4	Success	Likelihood of success
	6.1	Effectiveness	The ability to reduce the impact of fires
Societal Issues	3.4	Political Acceptance	Willingness of the stakeholders (government, manufacturers, consumers, and regulators) to support a technology
	5.2	Multiple Stakeholder Benefits	Probability of impacting multiple stakeholder groups
	6.5	Collateral Impact	Existence of any unintended consequences (e.g., political, social, environmental) from use of the technology
Technical Development	3.2	Technical Development	Probability that technology can be technically developed and reduce residential losses 25 % at reasonable development.
	5.1	Ease of Technical Development	Feasibility of completing technical development; high ease means the technology is very feasible.
	6.4	Feasibility	Whether the technology can be developed, and if so, in a timely manner
	7.7	Reliability	Probability of failure
	7.8	Speed to market	developmental cycle and potential technology transfer issues

market. Measurement science solutions that address liability concerns may therefore improve impact and speed to market.

Topic	No.*	Metric Designation	Meaning
Adoption Issues	5.3	Market readiness/timing	Time to commercial marketability
	5.4	Likelihood of implementation	Includes initial cost and other barriers
	6.3	Marketability	Public perception of technology usefulness and its aesthetics
	6.6	Implementability	User group perception and acceptable of the technology
	7.4	Ease of use	Ease for the user, once the technology is in place
	7.5	Ease of implementation	Ease for the installer
	7.6	Acceptability to customer	Non-cost acceptability factors, e.g. aesthetics, perception of necessity or reliability
	7.9	Speed to universal adoption	Time to percolate throughout the society once it is ready for the market
Cost Issues	3.3	Sustainability	The sustainability impact determined by life cycle analysis (LCA) that results in a 25 % reduction in residential fire losses
	4.5	Installation/ lifecycle cost	life cycle analysis (LCA) considers EHS, service life, cost
	5.5	Overall economics	Economic benefit
	6.2	Benefit-Cost ratio	The relative benefit versus cost performance
	7.3	Cost to end user	Perceived affordability
Special Considerations	4.1	Impact on response time	Ability of technology to reduce the amount of time it takes for a building occupant to become aware of a fire
	4.6	Impact on understanding of fire	Developing an understanding of fire phenomena that enables the development of technologies to address the problem
	7.10	Criticality for decision-making (for tools only)	Importance of an analysis tool; e.g., if expert judgment would suffice, then the tool is not critical

* The No. in column two of this table refers to the metric number listed in Tables 3.2, 4.1, 5.1, 6.1, and 7.1.

The attributes associated with each of the metrics are not shown in Table 8.1, but are given in Tables 3.3, 4.2, 5.2, 6.2, and 7.2 in Sections 3 – 7. They were almost universally assigned to a three-tier ranking scheme, typically listed as high, medium and low, although more specific attributes were also used. The definitions of the attributes varied from group to group and are given in detail in Tables 3.3, 4.2, 5.2, 6.2, and 7.2.

8.2 Barriers

The metrics in Table 8.1 associated with technical development and adoption issues, as well as the political acceptance component of societal issues, describe degrees of success in providing technological solutions. A detailed examination of these metrics naturally focuses on the identification of barriers to completion of the process, and the Breakout Groups were asked to devote some time to barrier identification.

The Breakout Groups identified dozens of technical and non-technical barriers that might hinder successful implementation of the technologies to address the national fire problem. The barriers are technology specific and information on the barriers is found in each of the respective Breakout Group sections. A set of barriers for a select number of technologies are summarized in Tables 3.4, 4.3, 5.3, 6.3, and 7.3. Some of the barriers were explicitly connected to the metrics listed in Table 8.1 by the Breakout Groups. Information on the possible technical and non-technical barriers provides insight on the types of collaborations and partnerships that may be needed to pursue the implementation of a particular technology.

Within the Technical Development process, there is a type of barrier that is especially appropriate for NIST to address, given NIST's mission, role, and core competences, namely, gaps in measurement science. For a number of select technologies, the Breakout Groups identified the measurement science gaps that need to be bridged to overcome barriers for successful implementation of fire protection technologies (see Tables 3.4, 4.3, 5.3, 6.3, and 7.3). This information provides a range of views on how NIST could best contribute to address the national fire problem. The intimate relationship between measurement science needs and technical barriers was noted during the discussion, and it was observed that measurement science needs could be defined with relative ease by placing the words "Development of measurement science to overcome…" in front of each of the technical barriers.

8.3 Likelihood of Technological Realization and Impact

As noted earlier, the seven types of metrics discussed in Section 8.1 and shown in Table 8.1 can be reduced to two primary keys to success: "likelihood of realization" and "impact" of a technology. Speed of success and background trends also come into play in prioritizing technologies. Is a technology that is likely to be realized expected to become available in the short term or in the long term? Is the breadth of usage of a potentially high-impact technology likely to grow rapidly or slowly? Is the targeted problem growing or shrinking in size?

Both keys to success are strongly affected by success and speed of completion of technology development and technology adoption; and these processes are subject to both technological and non-technological barriers. Table 8.2 provides the results of a NIST staff evaluation of the likelihood of realization and the impact of the approximately 200 technologies identified in

Sections 3-7, with only technological barriers considered in the evaluation. Significant non-technical barriers, such as societal acceptance, breadth and speed of adoption, and cost, were set aside for more detailed consideration by those who better understand market forces and who are better positioned to create and implement strategies to overcome these barriers. The idea was to avoid filtering out potentially high-impact technologies based on a limited understanding of the barriers.

This evaluation is seen as an additional step in using the output from the workshop to benefit NIST strategic planning. While a large fraction of the technologies identified in the workshop are likely to be realized or may have significant impact, only about 20% of the technologies have both of these keys to success. This group should be carefully considered as prime technology candidates to address the national fire problem.

Table 8.2 The Likelihood of Technological Realization (R) and Significant Impact (I) for Technologies and Measurement Science in Each Breakout Session.

Approach	Fire Prevention Group	R	I
Prevent Ignition – Behavior	Testing & classification to align performance with applications		X
	NIST Fire 101 education reports	X	
Prevent Ignition – Source	Characterization of pre-ignition conditions (existing, new, and near term technologies)		
	Sensors to detect pre-ignition conditions		X
	Identification and mitigation of Smart Grid ignition hazards		
Prevent Ignition – Reaction	Advanced Fire Resistant Materials: low toxicity, inorganic composites with thermo-plastic processability, low HRR		X
	Protective integrated coatings		
	FR that incorporate into polymer upon use for improved EHS		
	Material aging and reliability metrics	X	
	EHS friendly flame retardants		X
Reduced Impact of Ignition	Heat seeking water gun (sensor activated or deployable)		
	Reverse microwave gun to remove heat		X
	Sensor activated suppression for homes & vehicles	X	X
	FR suppression thru HVAC		
	Auto detect of failure points in fire protection system		
	SRMs for tests to increase repeatability and accuracy		
	Improved Measurement and Metrics for Tests, SRMs and Ignition Sources		X
	Open flame test for upholstered furniture	X	X
	Develop small/bench scale tests that correlate/predict large scale/regulation test performance		
	Understanding small vs. large scale, component versus composite, & geometry changes impact fire testing		
	Understanding how fluctuations in component composition, geometry, & manufacturing impact testing performance		
Improve Egress Time	Positive Pressure Ventilation for low rises	X	X
	Next generation smart sensor network (early post-ignition detection & no nuisance alarms)		X
	Improved kitchen alarms		X
	Floor integrated emergency lights	X	

Table 8.2 (cont.) Likelihood of Technological Realization (R) & Significant Impact (I) for Technologies and Measurement Science

Approach	Fire Protection Group	R	I
Fire Suppression	Improved suppression technologies • compressed air foam systems • fire extinguishing systems • refined water mist systems • manual sprinkler controls for emergency responders • improved sprinkler performance • improved understanding of the interaction of water droplets and burning items	X	
	Improved sprinkler reliability including, maintenance-free and self-diagnostic sprinkler system	X	X
	Installed air supply for firefighters (either as an air hose or to refill SCBA cylinders) and occupant protection (in a designated place of refuge, much like oxygen masks in aircraft).	X	
	Robotic firefighting apparatus, possibly engine- or truck-mounted semiautonomous or remote control vehicle for suppression and rescue in high-challenge fire environments or an autonomous residential device that could both detect and suppress small fires.		X
	Integral suppression system for heat-generating and open-flame appliances such as stoves.	X	X
	Technology to protect against wind-driven fire using sensing of wind speed & direction to activate preemptive suppression	X	
	Temperature sensors to measure/relay fire behavior/location for emergency responders	X	
	Embedded sensors and smart building technologies, tied to the fire department for detection, suppression, predicting collapse, and emergency management.	X	X
	Environmentally acceptable total flooding gaseous & foam agents as a replacement for halon extinguishing systems		X
	Reduction of sprinkler cost to make retrofit less costly	X	X
Detection	Refinement of existing smoke detectors for nuisance-free detection and improved understanding of detector placement.	X	X
	Detection of electrical discharge, sparks, and/or unintentional grounding of energized wires	X	X

Approach	Fire Protection Group	R	I
	Wireless technology to provide information to firefighters on the building (floor plans, installed fire protection, etc.) while en route	X	
	Faster / earlier detection	X	X
	Improved heat detectors	X	
Manage Combustion Products	Predict the burning rate of any single object from principles, equations, and necessary inputs.		X
	Automatic ventilation (residential) as a response to heat and smoke, for example, a window suspended by a fusible link.	X	X
Prevent Ignition of second item	Fire resistant furnishings including control of flammability and a mercaptan-like chemical added to furniture (cushions?) to alert occupants by odor that the item was on fire.		
	Study ignition and understand how a second item ignites		X
Compartmentalization	Cheaper/faster E119-type test method for barrier performance	X	X
	Require a code change so that home heating equipment (air and water) would be isolated by 1-hour construction	X	X
Emergency management	Refined GIS systems that has a database containing a community-wide hazard/vulnerability analysis		
Egress design	Egress monitor system to monitor travel patterns of exiting building occupants and reduce counterflow problems.		
	Regulate or license egress analysis (the absence of any professional licensing for egress design is a barrier to gaining AHJ approval for performance-based design).	X	X
	Efficacy of current egress width factors for code updates.	X	
	Directional signage: active (activated with the alarm system to guide firefighters to the fire) or a passive system.	X	X
Occupant response	Enhanced communication to occupants for reliable and cost effective communication for evacuation and relocation management, and the ability to "push" emergency communications to handheld and portable electronic devices without pre-registration,	X	X
	Human behavior models with validation		X
	Evacuation assistance devices for the disabled; for example a device to help people in wheelchairs navigate stairs.	X	X

Approach	Fire Protection Group	R	I
Emergency response	Enhanced communication for responders including better radio communication, databases of building information (floor plans etc) for emergency responders, and technology to limit unnecessary emergency response.	X	X
	Elevators for evacuation and emergency responders. This is primarily a code change.	X	X
	Technology for rescue access allowing first responders to cut through walls, even in new construction systems like structural insulated panels (SIPs).	X	X
	Technology to locate people within burning structures or could show that parts of the structure are unoccupied and do not require search and rescue operations.		X
Property	Inexpensive and fast smoke cleanup technology to return a building fire scene to service		
Emergency management	Maintenance of emergency procedures: a code change requiring mandatory annual evacuation drills/performance assessment for all buildings (or those above a certain size)		
	Standardized fire warden training to improve evacuations.		
	Generate lessons learned for documenting lessons learned after unusually large emergencies	X	X
	Involve residents and occupants in procedure design		
	Integrate life safety procedure with security practice and routine use (by designing them together)		
Understanding fire-induced collapse	Develop understanding for spaces other than isolated rooms; residences & offices often have open floor plans.		X
	Improve passive insulation		
	Understanding system performance (as opposed to individual materials and assemblies).		
	Understand fire resistance under real conditions • Performance of structural connections • Performance of lightweight structural elements including trusses and engineered lumber • Ability to predict collapse in real time		X

Table 8.2 (cont.) Likelihood of Technological Realization (R) & Significant Impact (I) for Technologies and Measurement Science

Approach	Fire Service Group	R	I
Anticipate Fire Growth	Technologies to evaluate and/or monitor the stability of buildings exposed to fireground conditions		X
	Turbulent combustion dynamics		
Communication	Improve communications equipment:, durable, reliable, easy to use systems, better verbal radio communication	X	X
	Respirator radios that give clear voice communication		
	Ad hoc self-healing networks		
	Multiple person hierarchy communication		
Suppression	Class A and compressed air foam effectiveness	X	
	Enhanced understanding of suppression dynamics for modeling	X	X
	Robotic fire fighting technology, with suppression, for search and rescue		X
	Sustainable suppression (materials, etc...), Ecologically sensitive post-fire decontamination	X	
	Water attack optimization, stream, fog, fine mist	X	
Investigation & reconstruction	Improved reconstruction tools for investigations, pre-fire building construction		
	Fire modeling tool for post-fire analysis		
	Smoke alarm “black box” for use in fire investigations, at local level, evaluation of tactics, lessons learned, fire behavior and effect of suppression tools	X	X
Situational Awareness	Technologies to track fire fighter movement inside structures, smart building 3-d fire fighter locators	X	X
	Simple, reliable, on/off sprinkler	X	
	Residential fire detectors to convey fire characterization to fire departments	X	
	Anticipate building response	X	
	Use of sensor technology to improve awareness, individual level, crew level, task level, command level		
	Probabilistic fire spread model using real-time sensor input to project fire spread		X
	Response routes on apparatus, traffic patterns	X	
	Control technology to couple sensor input with communication and control in buildings, maybe artificial intelligence too	X	
	VID and other fire detection technology to look at fire and responses		

Approach	Fire Service Group	R	I
Fire Fighter Health	Core body temperature measurement sensor, heat stress, strain, rehabilitation	X	
	Screening test for fire fighter risk factors for heart attack or sudden cardiac death	X	X
	Advanced voice communicators	X	
	Fire fighter physical condition alarm, before, during, after	X	
Firefighting Tactics	Fire apparatus equipment organization to reduce injury	X	
	Lightweight construction tactics	X	
	Labels or design logo to identify lightweight construction/conversion	X	
Improve Use of Resources	Fire station location analysis tool	X	
	Resource coverage tool or model	X	
	Apparatus fuel	X	
Training & Education	Training and education for injury prevention	X	
	Enhanced virtual environment for training and data collection, training with fire simulator to improve or understand current tactics (interactive), computer-based training programs, modeling and simulation labs for recruits	X	X
	Virtual reality of buildings for future potential incident familiarity		
	Effective communication of needs to Congress for funding		X
	Clearing house to review, coordinate and combine the multiple Federal agency's research and development activities		X
PPE	Revolutionary heat resistant materials/integrated clothing technologies for fire fighters		X
	Enhanced thermal protection, heat stress, use, durability of fire fighter PPE		
	Slim SCBA profile to allow quick egress	X	
	Real time personal exposure monitoring devices, inhalation, dermal exposure, used for fire suppression and overhaul	X	
	ESLI for fire fighter PPE service life	X	
	Lightweight gear that changes color due to heat effects	X	
	Next generation fire fighter respiratory protective equipment, all in one SCBA, radio, thermal detector pack, integrated thermal imaging with heads up display in SCBA face piece, crew to crew communication, radio, wireless, SCBA, closed circuit, APR	X	X
	Safety ice cells/kiosks	X	
	High temperature respirator face pieces	X	
	Passive/reactive cooling	X	
	Body-worn gas sensor	X	

Table 8.2 (cont.) Likelihood of Technological Realization (R) & Significant Impact (I) for Technologies and Technologies

Approach	WUI Group	R	I
Vegetative fuel management	Modeling coupling interactions between fire & atmosphere		X
	Predictive models for outdoor fire spread - including wildland, urban & WUI fires		X
	Spray coatings to reduce flammability of vegetation		X
Community planning construction, codes & standards	Firebrand intrusion prevention technologies (intumescent materials and fenestration protection)	X	X
	Surface applied coatings/treatments: predictable service life with exterior weathering		X
	Uniform flame resistant roofing technologies (roof attic vents, roof coverings, sheathing)	X	X
	Design/installation standard attic sprinkler	X	X
	Instrumentation to capture firebrands to quantify exposure	X	X
	Affordable, widely available test facilities for building products		X
	Ignition resistant building materials (siding) for fire prevention	X	X
Defensible space (buildings and parcel), ignition resistance	Simple comprehensive decision tool for wildland species & equipment selection; spacing in wildland near structures		X
	Employable fire prevention "house tent" or other treatment		X
	IR technology for detection/activation of home prevention devices (shutters, vent closures)	X	?[11]
	Low flammability vegetation (for homes)		X
	Tables of vegetation firebrand production	X	X
	Weathering (accelerated) procedures to predict long-term performance of topical treatments		X
	Airborne imaging of wildland encroachment near building	X	?
	Quantify firebrand quantities, transport, characteristics as a function of wind and ignition potential	X	X
Influencing home and community actions	Systems approach coupling flame spread prediction & evacuations		X
	Technical basis for legislative mandate/incentive to retrofit existing homes	?	X

[11] A question mark (?) indicates that extensive further analysis is necessary to fully assess the technology.

Approach	WUI Group	R	I
Influencing home and community actions (cont.)	Design home landscape that help protect home		X
	Benefit-cost assessment tools/models for retrofit technologies and systems approaches to retrofit	X	X
	Single fire modeling tools to better use available building materials		X
	In depth case studies of fire moving through communities for communication with homeowners	X	X
	Message development tool—sociological/education; deliver to homeowner to influence behavior		X
	Opt-out voluntary compliance homeowner standards		?
Fire detection, suppression, control, and containment	Forward looking hot spotting prediction tools		?
	Longer-run forecasting to better predict fire season severities (effective pre-positioning of fire suppression resources)		X
	High resolution satellite and detection and tracking of new/existing fires (in real time)	X	X
	Exterior sprinklers for fire prevention	X	X
	Time-dependent GIS for observation of fire behavior		X
	Guideline for prevention of structure to structure fire spread	X	X
	Cheap robotic firefighter for home deployment		X
	Tools to better predict dry lightning		X
	WUI risk model for suppression	X	X
After action review—learning assessment and improvement	Special reporting for fire investigation for WUI fires (reporting mechanism)	X	
	Standardized characterization for building and surrounding	X	
	Technology to help document and analyze WUI fires (3D visualization tools—the Secret Service uses test flights to map sightlines for upcoming presidential trips)		X
	Fire investigation team rapid response	X	X
	Firefighting actions training during WUI events		X
	Develop database of fire behavior (temporal and spatial) for evaluation of fire models		X
	Rapid deployment monitoring systems		X

Table 8.2 (cont.) Likelihood of Technological Realization (R) & Significant Impact (I) for Technologies and Measurement Science

Approach	Global Fire Protection Group	R	I
Decision-making tools	Real-time fire incidence data collection (hand-held, with voice), compilation, analysis (especially of patterns), and dissemination. Availability of results to incident commanders.		X
	Methodology to quantify the fire loss and cost impact of a technology – both prospective and retrospective	X	X
	Comprehensive life cycle cost/effectiveness analysis method for fire protection systems and products, including non-fire aspects	X	
	Comprehensive integrated fire models	X	X
	Improved and accessible data for fire models for engineering, education, analysis	X	X
Reduced ignition probability	Fire-safe, energy-efficient electrical devices, with automatic detection and power-off feature		X
Less flammable products	New flame retardant chemicals	X	X
	Barrier materials to achieve very low combustibility furnishings	X	X
	Thermal barriers for foam plastic insulation	X	
	Knowledge-based, accelerated protocols for assessing the aging and deterioration characteristics of combustibles	X	?
	Fire-safe alternative fuel vehicles		X
	Improved understanding of fire characteristics for the wall/floor/ceiling system	X	
Fire detection	Multi-sensor residential fire detector, with custom message and connection to fire department	X	X
	Building health sensors for fire incidents, including fire location, motion detectors, security, and air handling systems		X
	Smoke alarm "black box" for use in fire investigations	X	
Fire suppression	Home fire suppression retrofit kit; e.g., a non-plumbed system that does not require installed piping		X
	Simple, reliable on/off sprinkler		X
Advanced emergency response	Fire fighter black box that records and transmits data on environment and firefighter bio-indicators (minutes of breathing air remaining) and position		X
	Effective information for improved awareness and response training for school children and adults		?

Approach	Global Fire Protection Group	R	I
Advanced emergency response	Advanced voice communicators	X	
	Technology to locate building occupants and help manage egress (possibly tied to cell phones)	X	
	Real-time information to firefighters on the scene, indicating differences in risk posed by different home constructions (depending on time to response) and presenting conditional strategies for firefighter safety.		?
WUI	Construction practices for improved structural resistance to ignition and fire propagation		X
	WUI heat source strategy: a systematic review of heat source patterns and a portfolio of strategies to reduce heat source threats by type of heat source, e.g., equipment that will not generate sparks	X	?
	Construction practices for improved structural resistance to ignition and fire propagation	X	
	Satellite detection and response monitoring of fire starts and related conditions, tied to response plans and environmental/fire conditions		X
	Heat release calorimetry for evaluation of structure exteriors	X	X
	Exposure protection (sprinklers, foam, novel methods)		X
	Community evacuation tools to evaluate risk		X
Education and training	Materials for web technology for mass education	X	
	Live burns to demonstrate the speed of and damage from fire spread	X	X
	Digital TV channel dedicated to fire (and other hazard?) news, education, events, that would interrupt other local TV and radio channels in emergencies		?
	Build commitments among groups with dissimilar goals, e.g., commercial organizations to overcome barriers to acceptance of technologies		X

8.4 Breakout Group Recommendations for Most Favored Approaches

Each of the Breakout Groups was asked to select a most highly recommended technology, using the metrics (see Section 8.1) as a primary basis of their selection. The participants were also asked to apply the metrics to evaluate a select set of technologies that fit into one of the following categories:

1. Magnitude of impact (including breadth of adoption, magnitude of impact, and problem size, aiming for high impact).
2. Short-term delivery (i.e., short time to technological development completion), aiming for quick impact
3. Long-term delivery (i.e., long time to technological development completion), aiming for highest cumulative impact over time
4. Multiple measurement-science needs (i.e., major barriers especially well suited to leadership by NIST and other science-based organizations)
5. Non-technical barrier (i.e., major barriers especially well suited to leadership by those other than NIST)

The Breakout Groups ended up taking two rather different approaches to identifying the most recommended technology. Some of the Groups decided to highlight a technical or non-technical barrier rather than a technology in this evaluation. The results are summarized in Tables 3.5, 4.3, 5.3, 6.3, and 7.3. The results illustrate multiple pathways for establishing a national fire protection strategy. Technologies characterized by items 1 and 2 in this list would be attractive candidates for inclusion in the development of the NIST Roadmap, whereas technologies characterized by items 3 - 5 might require significantly more effort to realize.

A comprehensive evaluation of the place of a technology on the NIST Roadmap will necessitate consideration of a carefully selected spectrum of metrics. In that regard, Table 8.1 is a useful point of departure. The results are summarized in the language of the Breakout Groups in Tables 3.5, 4.3, 5.3, 6.3, and 7.3. Shown below are the selected technologies from each Breakout Group (see Sections 3-7), described first in the language used by the Breakout Group and then paraphrased in terms intended to fit better with the types of metrics and processes discussed in this Section:

1. Testing and classification system for material flammability. (Conduct measurement-science research to develop a testing and classification system to direct design and selection of new materials technologies based on material flammability).
2. Suppression systems for open flame, cooking, and heating appliances. (Conduct measurement-science research to modify suppression technologies to a form suited for protection of open flame, cooking, and heating appliances).

3. Health screening/risk identification tools for firefighters. (Conduct measurement-science research to develop a screening and risk identification tool in order to direct design and selection of technologies and strategies to improve firefighter health and safety).
4. Legislative mandate to retrofit pre-existing houses to address WUI fires. (Conduct measurement-science research to provide test methods for design guidance of new and retrofit applications for wildland/urban interface structural fire protection).
5. Home fire suppression retrofit kit. (Conduct measurement-science research to modify home fire suppression technologies into a form suited for retrofit of existing homes).

The fourth Breakout Group included the idea of a legislative mandate as a part of the strategy for rapid widespread adoption of key technologies, once developed. The two recommendations of modification for retrofit presumably are concerned about the higher costs normally associated with retrofit. The research would presumably seek design changes that would reduce those costs or strike a balance between impact and cost.

Table 8.3 provides an overview of the measurement-science needs identified by the Breakout Groups for their respective most favored technological initiatives. See Tables 3.5, 4.3, 5.3, 6.3, and 7.3, as well as associated text in those chapters, for additional details.

As the U.S. fire problem evolves, strategies to address the fire problem will also need to evolve in order to continuously and effectively address new threats to fire safety and to take advantage of recent advances in science and technology. Through candid discussion among partners in the fire safety community, this workshop and these proceedings identify many key technologies that may be useful in addressing the national fire problem and form a basis for a measurement science blueprint for realizing the vision of fire safety in the United States.

Table 8.3 Measurement Science Needs to Enable High-Impact Long-Reach Technologies and Overcome Key Barriers

No.	Technology	Measurement Science Need
3.1	Testing and classification system for material flammability	o Measure and characterize smoke toxicity and develop metrics o Measure physical effects of heat release: spalling, melting, etc. o Measure heat of gasification (to classify fire performance) o Develop models to understand scaling and predict performance o Gauge repeatability and reliability (Accuracy) o Measure heat of gasification (to classify fire performance)
4.1	Suppression systems for open flame, cooking, and heating appliances	o Test method for agent effectiveness o Characterization of toxicity of suppressant when added to fire o Characterize types of fire o Human factors: measure – what will prompt an owner to repair the system o Measurement of aging characteristics of suppressant o Determine the most appropriate sensor o Discrimination between desired and undesired heat sources
5.1	Health screening/risk ID tools for firefighters	o Identify risk factors for disease o Quantitative medical factors and conditions o Establish consensus testing protocol o Characterize fireground conditions, interior attack, overhaul o Determine impact of conditions on fire fighter health
6.1	Legislative mandate to retrofit of pre-existing houses to address WUI fires	o Determination of relative effectiveness of technology options o WUI definition independent of fire risk o Relative effectiveness of alternative incentives o Economics - quantification of benefit-cost, etc. o Fire model measurements to identify most needed areas o Global benchmarking to understand test standards
7.1	Home fire suppression retrofit kit	o Design fires, test method, performance criteria, agent properties o How to achieve reliable installation by amateurs o Guidance for storage of or access to extinguishing agent o Approval test o Minimize the amount of agent used

Acknowledgements

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Steering Committee and Key External Experts:

John Hall	Plenary Speaker
Sarah Slaughter	Plenary Speaker
Mike Hilbruner	Chair: WUI Breakout Group
Susan Landry	Chair: Building Fire Prevention Breakout Group
John Mueller	Chair: Global/Cross-Cutting Breakout Group
Dan O'Connor	Chair: Building Fire Protection Breakout Group
Bruce Varner	Chair: Firefighter Breakout Group
Carl Galioto	Chair: Closing Session, Day 1
Tom Chapin	Chair: Closing session, Day 2
Carl Baldassarra	Planning
Clas Jacobson	Planning
Pravin Gandhi	Planning
Franco Tamanini	Planning

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Jay McElroy	Audio recording

Facilitators (Energetics Inc.)

Matt Antes	Building Fire Prevention Breakout Group
Chris Clark	Firefighter Breakout Group
Melissa Eichner	Global/Cross-Cutting Breakout Group
Fred Hansen	WUI Breakout Group
Joan Pellegrino	Building Fire Protection Breakout Group

Appendix 1 Workshop Attendee List

	Name	Affiliation	Group Assignment
	Anthony Hamins	NIST	Workshop Chair
1	Dawn Castillo	National Institute of Occupational Safety and Health	Global/Cross-Cutting
2	Christian Dubay	National Fire Protection Association	Global/Cross-Cutting
3	Dick Gann	NIST	Global/Cross-Cutting
4	John Hall	National Fire Protection Association	Global/Cross-Cutting
5	Dan Madrzykowski	NIST	Global/Cross-Cutting
6	Randy McDermott	NIST	Global/Cross-Cutting
7	Fred Mowrer	University of Maryland	Global/Cross-Cutting
8	John Mueller	NY Office of Fire Prevention and Control	Global/Cross-Cutting
9	Kevin Roche	Phoenix Fire Department	Global/Cross-Cutting
10	Sarah Slaughter	Massachusetts Institute of Technology	Global/Cross-Cutting
11	Howard Stacy	Western Fire Center	Global/Cross-Cutting
12	Victoria Valentine	National Fire Sprinkler Assoc	Global/Cross-Cutting
13	John Woulfe	International Association of Fire Chiefs	Global/Cross-Cutting
14	Woody Stratton	US Fire Administration	Global/Cross-Cutting
15	Robert Neale	US Fire Administration	Global/Cross-Cutting
16	Francine Amon	NIST	Fire Fighting
17	Brian Berchtold	Naval Sea Systems Command	Fire Fighting
18	Janice Bradley	International Safety Equipment Association	Fire Fighting
19	Nelson Bryner	NIST	Fire Fighting
20	Peter Darley	Fire and Emergency Manufacturers & Service Assoc	Fire Fighting
21	Stan Gibson	Coos Bay Fire Department	Fire Fighting

	Name	Affiliation	Group Assignment
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23	**Doug Hinkle**	**Montgomery County Fire Department**	**Fire Fighting**
24	**Brian Meacham**	**Worcester Polytechnic Institute**	**Fire Fighting**
25	**Paul Neal**	**Montgomery County Fire Department**	**Fire Fighting**
26	**Mark Salley**	**Nuclear Regulatory Commission**	**Fire Fighting**
27	**Ron Sheinson**	**Naval Research Laboratory**	**Fire Fighting**
28	**Bruce Varner**	**Santa Rosa Fire Department**	**Fire Fighting**
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30	**Roger Barker**	**North Carolina State University**	**Building (Prevention)**
31	**Tom Chapin**	**Underwriter's Laboratory**	**Building (Prevention)**
32	**Fred Clarke**	**Consultant**	**Building (Prevention)**
29	**Rick Davis**	**NIST**	**Building (Prevention)**
30	**Jeff Gilman**	**NIST**	**Building (Prevention)**
31	**Randall Griffin**	**Department of Homeland Security**	**Building (Prevention)**
32	**Rich Lyon**	**Federal Aviation Administration**	**Building (Prevention)**
33	**Susan Landry**	**Albermarle**	**Building (Prevention)**
34	**Larry McKenna**	**US Fire Administration**	**Building (Prevention)**
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37	**Mike Stevens**	**Ashland**	**Building (Prevention)**
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39	**Jason Averill**	**NIST**	**Building (Protection)**
40	**John deRis**	**FM Global**	**Building (Protection)**

	Name	Affiliation	Group Assignment
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44	**Steve Gwynne**	**Hughes Associates**	**Building (Protection)**
45	**Jeff Hull**	**DC Fire Department**	**Building (Protection)**
46	**Nathan Marsh**	**NIST**	**Building (Protection)**
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49	**Dan O'Connor**	**Schirmer Engineering**	**Building (Protection)**
50	**Bill Troup**	**US Fire Administration**	**Building (Protection)**
51	**Joe Urbas**	**University of North Carolina, Charlotte**	**Building (Protection)**
52	**Yicheng Wang**	**NIST**	**Building (Protection)**
53	**Roger Ayotte**	**Solutia**	**WUI**
54	**Dave Butry**	**NIST**	**WUI**
55	**Ali Fattah**	**San Diego City**	**WUI**
56	**Mike Hilbruner**	**US Forest Service**	**WUI**
57	**Morgan Hurley**	**Society of Fire Protection Engineers**	**WUI**
58	**Sam Manzello**	**NIST**	**WUI**
59	**Alex Maranghides**	**NIST**	**WUI**
60	**Ruddy Mell**	**NIST**	**WUI**
61	**Jeff Prestemon**	**US Forest Service**	**WUI**
62	**Steve Quarles**	**University of California, Berkeley**	**WUI**
63	**Tim Reinhold**	**Institute for Business and Home Safety**	**WUI**
64	**Peter Roohr**	**National Oceanic & Atmospheric Admin.**	**WUI**

	Name	Affiliation	Group Assignment
65	**Dave Sheppard**	**Bureau of Alcohol, Tobacco, Firearms, & Explosives**	**WUI**
66	**David Weise**	**US Forest Service**	**WUI**
67	**Greg Daniels**	**O'Hagin's Inc.**	**WUI**

Appendix 2 Workshop Agenda

Time Frame	Description of Activity	Main Outcomes
Day 1		
8:30 – 9:00 am	Registration (Bldg 101/Lecture Room A)	
9:00 – 9:15 am Employee Lounge	• Welcome – Anthony Hamins, NIST • Objectives for the Workshop • NIST's Roadmap on Innovative Fire Protection Introduction to Breakout Groups, including names of Group chairs, Co-chairs, members and facilitators • Handouts - 1 page summaries of fire problems - NIST Vision, Program goals, and NIST draft approaches to Program goals • Definition of "measurement science"	• Understand purpose of workshop and what to expect over next two days • Context of NIST activities
9:15 – 10:15 am Employee Lounge	• Stage-setting Presentations (25 min each, 5 min Q&A) - The U.S. Fire Problem (John Hall, NFPA) - Opportunities for Innovation in Fire Protection (Sara Slaughter, MIT)	• Overview of the current fire situation • How new, emerging technologies have impacted other areas and could impact fire losses • Role of technology
10:15 – 10:30 am Breakout Rooms	Break <u>Breakout Groups</u> Fire Fighting (Orange): Lecture Room E WUI (Green): Lecture Room F	• Move to Breakout Groups

Time Frame	Description of Activity	Main Outcomes
Day 1		
	Building Fire Prevention (Red): Lecture Room A Building Fire Protection (Blue): Lecture Room B Cross-Cutting (Yellow): NIST Lunch Club	
10:30 –12:00 pm Breakout Rooms How shall we attack the fire problem? Brainstorming Rules: One idea at a time, one minute per idea, reserve judgment until later, be forward-thinking, hitch-hiking allowed.	I. VISION FOR THE FUTURE and GOALS (30 min): Participants examine NIST Vision and Goals, thinking beyond short-term incremental changes, and considering what could be possible with advanced/emerging technologies. • What radical changes do we want to achieve? • What targets do we want to strive for? II. APPROACHES (30 min): Brainstorm (add to or modify) the draft approaches (research, development, education, training or other actions) to solving the important fire problems in the topic area. Organize ideas considering vision defined earlier. III. BRAINSTORM TECHNOLOGIES (30 min): Begin to list existing (not yet applied to fire) and potential technologies that could reduce the fire problems being addressed by this Group.	• Scope and ground rules for brainstorming • Potentially revised vision and goal statements • Revised list of approaches • Start list of technologies that might contribute to each approach
12:00 – 12:50 pm	Lunch (sit according to Breakout Groups in Cafeteria)	• Continue discussion

Time Frame	Description of Activity	Main Outcomes
Day 1		
12:50 – 2:15 pm Identify Key Technologies and Metrics to Evaluate their Value	III (Continued). BRAINSTORM TECHNOLOGIES (30 min): Add to the list, grouping the technologies under the Approaches. IV. TECHNOLOGY METRICS AND ATTRIBUTES (40 min): Develop a list of about 5 metrics to assess the potential contribution of a technology to reduce the fire problem (e.g., cost, likelihood of success, market readiness); develop attributes for the metrics (e.g., high, medium, low). V. PICK SHORT LIST OF TECHNOLOGIES (15 min): Identify 10 to 12 technologies, including some for each approach, that are likely to have some impact on the fire problem. (Note: No technologies will be "lost.")	• A list of technologies that attack the Group's fire problem area, grouped in Approaches • A set of criteria for estimating the impact of the technologies • Short list of technologies for closer examination
2:15 – 2:30 pm	Break	
2:30 – 3:45 pm	VI. APPLY METRICS (75 min): Apply the metrics and their attributes to each technology; develop a tabular means for presenting the results; adjust the technologies, the metrics, and the attributes as needed.	• Charts of appraised technologies
3:45 – 4:00 pm Employee Lounge	Reassemble for Plenary Session (15 min): Session Chairs prepare the results for presentation using template with assistance from note-takers.	• Prepare summary of discussion
4:00 – 5:00 pm Summary and Adjourn for Day	VII. PLENARY SESSION (60 min): Brief presentations of technologies and attributes. Questions for clarification only.	• What were the most important results? • What were successes/difficulties of the process? • Prepare for next day • Presentations based on template

Time Frame	Description of Activity	Main Outcomes
Day 1		
Time Frame	**Description of Activity**	**Main Outcomes**
Day 2		
8:30 – 9:00 am Breakout Rooms	VIII. REVIEW RESULTS (30 min) Breakout Groups discuss/revise/modify technologies, metrics, and attributes, as desired.	• Reconsider and add to Day 1 results
9:00 –10:00 am Barriers to Impact	IX. BARRIERS (60 min): Identify technical and non-technical barriers to the implementation and effectiveness of each of the 10 to 12 technologies (e.g., cost, technology gaps, knowledge gaps, etc.); identify barriers common to multiple technologies.	• List of barriers to be overcome for each selected technology to have impact on the fire problem
10:00 – 11:45 am Identify Key Measurement Needs	X. MEASUREMENT SCIENCE NEEDS (105 min including a short break): Identify measurement science needs to overcome barriers; identify stakeholders who need to participate in defining these challenges.	• Set of measurement science needs for 10-12 technologies
11:45 – 12:30 pm	Lunch (sit according to Breakout Groups in Rear of Cafeteria) (45 min): Session Chairs prepare the results for presentation with assistance from note-takers.	• Continue discussion • Presentation based on template
12:30 – 2:45 pm Employee Lounge Summary Presentations	XI. PLENARY SESSION (75 min): Presentations of technologies, barriers, and measurement science needs. Questions for clarification only. (60 min): General discussion, observations, and identification of patterns in measurement science needs.	• Set of measurement science needs for all technologies analyzed with sufficient details to extend analysis to additional technologies • Presentation of four technology examples
2:45 – 3:00 pm	Next Steps and Adjourn	

Appendix 3 Workshop Handouts

The materials provided on the following pages provide a series of brief summaries on the national fire problem. The handouts also include draft statements of BFRL's vision, strategic goal on innovative fire protection, and draft approaches to attain the programmatic goals.

BFRL/NIST's Innovative Fire Protection Roadmap

Workshop
June 4-5, 2009

Overview of the U.S. Fire Problem

The data suggest organizing the total core cost of fire into three main components:

*** Cost associated with fires that initiate in structures,**

*** Cost associated with fires that initiate in wildlands and spread into a community, and**

*** Cost associated with fighting fires**

The total impact of fire on society is associated with civilian and fire fighter life loss and injuries, and the total economic cost of fire. The *total cost of fire* is a combination of the direct losses caused by fire and the economic costs expended to prevent additional losses. The economics of fire protection has several components, including the costs of insurance, capital fire protection systems and equipment, life-cycle and opportunity costs, firefighting readiness, fire-safe product development, and the interruption of business.

In the U.S., the declines in the numbers of reported fires, fire deaths, and fire injuries have slowed considerably (left figure below), though the U.S. population has increased during this period. In a quarter century, civilian injuries and fatalities have been roughly halved, while firefighter injuries and fatalities have each been reduced by about one-third. Most civilian deaths and injuries (about 84 % and 79 %, respectively) have occurred in residential structure fires.

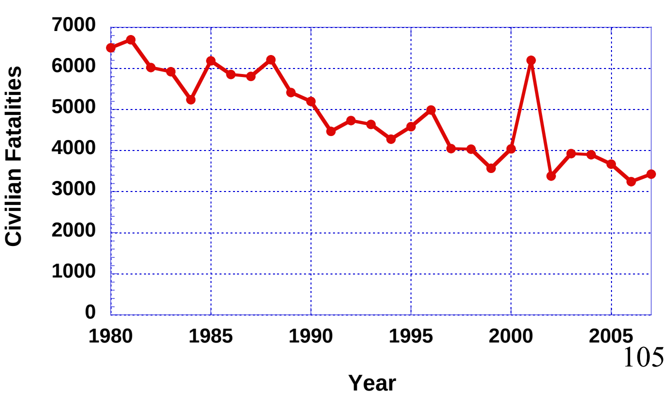
Recently, the number and severity of wildland-urban interface (WUI) fires has increased and is expected to continue to substantially increase. In 2006, about half of the reported fires were classified as natural vegetation fires with relatively low life loss. Most of the cost is in direct property loss, and the costs of insurance, fire protection, lost tourism and sales, fuel treatments, and suppression. The majority of these costs accrued due to the fire threats to communities at the wildland-urban interface (WUI).

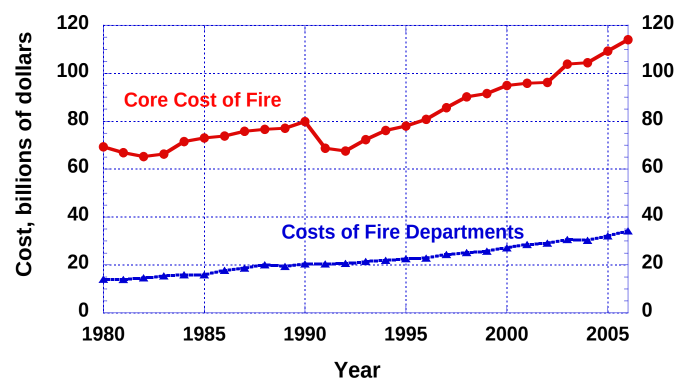
Meanwhile, the economic burden of fire has been growing. Over the last 25 years, property damage due to fire, the cost of fire protection in construction, and the cost of career fire departments have increased in absolute terms about 35%, 87%, and 145%, respectively, after adjustment for inflation.

During 2006, the *core cost of fire* totaled approximately $117 B (right figure below). Significant contributors to the 2006 *core cost of fire* (in 2006 dollars), as defined by NFPA, include:

- The cost of career fire departments ($34 B)
- Building costs for fire protection in constructed facilities ($49 B)
- The net costs of insurance coverage ($20 B)
- Property loss – reported and unreported, direct and indirect ($14 B)

The *total social cost of fire* adds the social cost of deaths and injuries due to fire (estimated as $41 B in 2006 using formulas developed by the U.S. Consumer Product Safety Commission), $119 billion in estimated labor cost of volunteer firefighting, $49 billion in the cost of standards for equipment and buildings, and about $7 B in costs associated with wildland fires (fuel treatment, suppression, and post-fire business interruption). For 2006, the *total social cost of fire is estimated* as being over $320 billion or nearly 4 % of GDP, detracting significantly from the optimal use of the nation's resources and economic health. A closer look at the components of this burden is warranted in order to provide a basis for setting goals for improvement.





A Vision Statement

BFRL's View of the Road Ahead

DEFINING ROADMAP COMPONENTS

Goal:
Overarching strategic target to be impacted by BFRL's research activities.

Problem:
An identified contributor to the national fire problem. Examples include ignition sources (i.e., candles, cooking appliances, etc.) or inadequate egress facilities (i.e., too few exits, stairs too narrow, etc.).

Approach:
A generic class of mitigation strategy to address a specific problem. Examples include suppression of an unwanted fire and keeping fire-generated smoke from building occupants.

Technology:
A specific solution to a problem. For example, nuisance-free smoke detectors would likely lead to reduced residential fire fatalities and injuries as building occupants would be less likely to disable the alarms.

Measurement Science:
Use of the scientific method to acquire knowledge based on quantitative observation of physical phenomena. In the context of the NIST Fire Protection Roadmap, measurement science is applied to address specific research gaps that hinder a technology from being developed or implemented. For example, a standard for construction materials that resist ignition from a wildfire requires understanding of the ignition mechanisms and a reproducible way of generating firebrands.

Overall, the decline in the rate of reduction in fire deaths and injuries and the increasing cost of fire to the U.S. emphasizes the need for a new goal, a new set of objectives, and the bringing of new technology to bear. Accordingly, this roadmap is being developed to sharpen the focus on the most productive fire safety activities. Since the fire losses from systemic causes are potentially preventable, technology and measurement science can play a key role in improving fire protection and enhancing public safety. The premise underlying BFRL's Innovative Fire Protection Goal is that measurement science, in concert with other activities such as public education, training, and larger societal considerations, will play a pivotal role:

- saving people's lives from fires,
- helping firefighters do their jobs better and more safely,
- helping save people's homes from structural fires and wildfires,
- promoting U.S. exports by furthering sound international fire safety standards, and
- advancing U.S. commerce by developing, and bringing to market, fire safe products and the capability to design facilities whose fire protection is performance-based.

The goal of BFRL's Innovative Fire Protection Strategy is to develop and demonstrate, by 2013, the measurement science needed to achieve a 25 % reduction in the impact of fire on structures, their occupants, and the fire service. The measurement science to achieve this goal is organized into three Programs:

The Reduced Risk of Fire Spread in Buildings Program is focused on increasing the safety of building occupants and the fire performance of structures. The objective is to provide the measurement science needed to reduce preventable fire losses by 25 %.

The Advanced Fire Service Technologies Program is focused on increasing the safety and effectiveness of fire fighters by 25 %. The emphasis is on improvement of fire fighting operations by enabling effective use of existing and new technologies and tactics.

The Wildland-urban Interface (WUI) Program is focused on reducing by 25 % the fraction of houses that are ignited due to exposure to outdoor fires, with an emphasis on WUI fires. Within 10 years, improved risk assessment and risk mitigation tools will be developed and provided to communities, homeowners, and fire officials for implementation.

"BFRL's long-term vision is that unwanted fire be removed as a limitation to life safety, technical innovation, and economic prosperity in the U.S."

The focus of the Innovative Fire Protection goal is on activities that are likely to have a major impact on fire losses. Selection of paths to the goal will consider the potential for:

- cost and loss reduction of the nation's fire problem,
- existence and emergence of beneficial techniques and technologies that can be enabled by measurement science, and
- barriers to the implementation of the technology, including market readiness, which may involve cost and non-financial barriers.

It is recognized that, while BFRL/NIST plays a unique role in furthering fire protection and public safety, that this is a supporting role. BFRL does not promulgate building codes or product standards, does not do compliance testing, or even promote the use of such products in the marketplace. The role of BFRL/NIST is to conduct measurement science. In this manner, BFRL seeks to work with the greater fire community to enable a fire-safe future.

Global Fire Reduction Breakout Group

Workshop
June 4-5, 2009

Over the years, technical ingenuity has led to new and diverse approaches to reducing the U.S. fire problem, such as residential smoke detectors, reduced ignition propensity cigarettes, viscosity reducing additives for hose streams, new plastics for turnout gear, and phosphorescent exit markings. In each case, an advance in measurement science was needed to enable the contribution of the new technology.

BFRL's long-term vision is that unwanted fire be removed as a limitation to life safety, technical innovation, and economic prosperity in the U.S.

Innovative Fire Protection Strategies

The United States spends over $100 billion annually to contain fire losses at the levels indicated in the table below. Typically, these costs, which are rising steadily, are applied to such approaches as:

- Preventing unwanted ignitions
- Controlling the intensity and spread of fire
- Improving the promptness and accuracy of detection;
- Mitigating the potential for harm from the combustion products
- Providing safe and effective automatic fire control and emergency response
- Conveying information to occupants and emergency responders
- Preventing fire-induced structural failure
- Improving emergency management
- Assuring adequacy of the egress capacity relative to demand.

Perhaps there are ways to contain fire losses at the current level using fewer resources; perhaps there are new approaches that might provide increased fire safety at the current cost. Almost certainly, there are technologies that could increase fire safety at additional cost.

The role of this Breakout Group is to think broadly and for the long term about the U.S. fire problem as a whole:

- What is "enough" fire safety and how will we know when we have it?
- Are there potential changes in how we might approach notable reductions of the costs and the remaining fire losses?
- The world is creating new technologies and advancing existing technologies at a dizzying pace. Which of these might be brought to bear on the U.S fire problem?
- What metrics should we use in characterizing a potential fire safety technology?
- Are there institutional barriers to the implementation of innovative fire protection approaches and technologies that we should be starting to re-shape?
- What fire measurement science can stimulate fire technology development and break down barriers to implementation?

Approximate United States Fire Losses in 2007 (NFPA, 2008)

	Structures	Outdoor	Vehicles	Responders
Reported Fires	0.5 M	0.8 M	0.3 M	1.6 M
Deaths	3000	45	400	100
Injuries	15,000	700	2,000	100,000
Property Loss	$11 B	$1 B	$1 B	---

Recent data trends:

Stable or slightly downward
Increasing moderately
Increasing sharply

Fire Prevention Breakout Group

Workshop
June 4-5, 2009

Over the years, technical ingenuity has led to new and diverse approaches to reducing the U.S. fire problem by fire prevention, such as reduced ignition propensity cigarettes, flame retardants for thermoplastics, child-proof lighters, and tip-over shutoffs for space heaters. In each case, an advance in measurement science was needed to enable the contribution of the new technology to improve fire prevention.

BFRL's long-term vision is that unwanted fire be removed as a limitation to life safety, technical innovation, and economic prosperity in the U.S.

Innovative Fire Prevention Strategies

In 2006, there were more than 3200 fire fatalities and over 16,000 injuries. The cost associated with prevention of structural fires in terms of fire protection equipment and regulatory compliance rose to $100 B annually. Ideally, the fire problem could be solved through fire prevention, since it obviates the need to respond and mitigate the impact of fire. To prevent ignition one needs to address relatively few ignition sources and first items ignited. Of the leading ignition sources (see table below), cigarettes stand out, accounting for approximately one-fourth of the fire deaths and one-tenth of the injuries. Flaming ignitions ("open flame" and "cooking" in the table) account for one-third of the deaths and half of the injuries, suggesting a high impact for improving the flame retardancy of the first items ignited. The first items ignited are can be broken into a few major groupings. Soft furnishings (upholstered furniture and beds) were the first items ignited in fires and they led to one-third of the deaths, one-sixth of the injuries, and one-ninth of the property damage. Thermoplastics (carpet, wall coverings, curtains, appliances and electrical wiring) also account for a major fraction of the deaths, injuries and property losses.

The role of this Breakout Group is to consider approaches, technologies, and metrics of success for enabling the prevention of ignition and flame spread of fire in structures. The group will explore the following questions:

- What are the preventable parts of the fire problem? What additional issues must be considered in parallel with the fire problem?
- What are the new approaches for reducing fire losses associated with kitchen fires, cigarettes and furnishings?
- What new materials or designs could be used to attack the fire problem?
- What metrics should we use in characterizing a potential fire prevention technology?
- Are there barriers to the implementation of fire prevention approaches and technologies that should be considered?
- What measurement science is required to break down barriers to implementation?

Leading Ignition Sources (NFPA, 2008)

	Smoking Materials	Open Flame	Electrical Distribution/Lighting	Cooking
Reported Fires	13 k	26 k	21 k	150 k
Deaths	700	400	400	500
Injuries	1,200	2,100	800	4,700
Property Loss	$0.4 B	$0.7 B	$0.7 B	$0.8 B

Recent data trends:

Stable or slightly downward
Increasing moderately
Increasing sharply

BFRL

Fire Protection Breakout Group

Workshop
June 4-5, 2009

Innovative Fire Protection Strategies

In 2006, about 34 % (530,000) of the reported fires in the U.S. were in structures. These fires occurred in commercial buildings and assorted residences. Associated with these fires were almost 2,500 civilian fatalities and 14,000 injuries, with over 90 % of the life loss occurring in residences. While life loss in non-residential construction was relatively small, the cost of fire protection in non-residential structures was about twice as large as that of residential structures.

BFRL's long-term vision is that unwanted fire be removed as a limitation to life safety, technical innovation, and economic prosperity in the U.S.

The U.S. spends more than $100 billion annually to pay for property loss associated with building fires and to prevent future losses through the costs of building fire protection, code compliance and standards. There are many fire protection challenges - fire detection is an important example. About 43 % of civilian deaths occurred in homes with no working smoke alarms. It is estimated that if every home had working smoke alarms, U.S. residential fire deaths could drop by 36 %.

The goal of the Reduced Risk of Fire Spread in Buildings Program is to provide the measurement science to enable a decrease of 25 % in preventable fire losses. While there are other viable approaches, consideration of the fire timeline and the *margin of safety* for building occupants is a useful framework for deriving strategies to achieve a reduction in the impact of fire on life safety and costs. The *margin of safety* is defined as the difference between the available and required safe escape time for an individual occupant to travel to a safe refuge.

The figure below shows several possible approaches for increasing the margin of safety. Increases in the margin of safety could be achieved by:

1. Preventing unwanted ignitions at the source and/or nearby items (covered by the Fire Prevention Breakout Group);
2. Decreasing fire hazard by controlling the growth and spread of fire;
3. Improving detection, including sensitivity, reliability, and early recognition of fire;
4. Mitigating the potential for harm from the combustion products; and
5. Preventing fire-induced structural failure.

Alternatively, an increased margin of safety could be achieved by decreasing RSET by:

6. Improving management of an emergency, including the ability to deliver evacuation information to occupants and responders in a timely manner, and
7. Assuring adequacy of the egress capacity relative to demand.

Fire Fighting Breakout Group

Workshop
June 4-5, 2009

In 2006, fire fighters responded to more than 1.6 million fires with an associated $62 billion in total core cost of fire fighting. While the number of fire fighting injuries has decreased over the last 30 years, there are still more than 80,000 fire fighter injuries and about 100 fatalities annually. While the majority of the injuries and fatalities occur in existing residential structures, significant numbers occur in commercial structures.

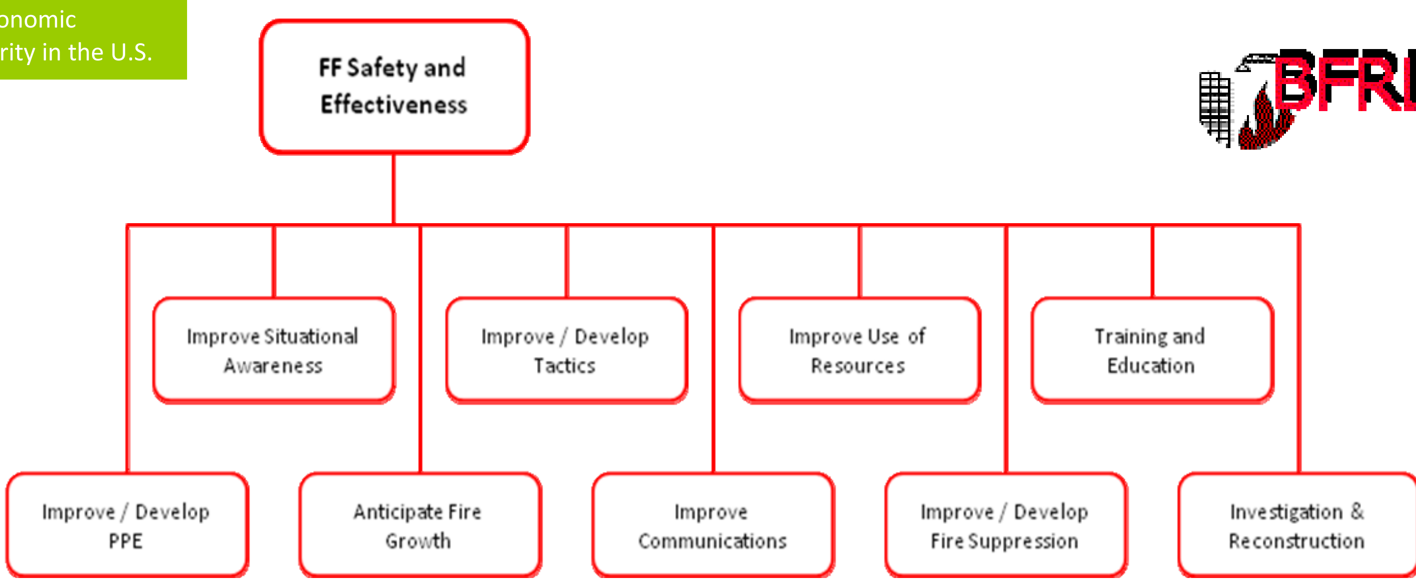
BFRL's long-term vision is that unwanted fire be removed as a limitation to life safety, technical innovation, and economic prosperity in the U.S.

Strategies for Fire Service Safety and Effectiveness

NIST's Advanced Fire Service Technologies Program has a goal of 25 % reduction in the impact of fire on the fire service by focusing on improving the safety and effectiveness of fire fighters. The program places an emphasis on improved fire fighting by enabling effective use of existing and new technologies and tactics. While the Advanced Fire Service Technologies Program is primarily focused on increasing the safety and effectiveness of fire fighters, there is a beneficial collateral effect on building occupant safety and property loss, when fire fighters can size-up, search, rescue, and suppress fires more efficiently. The problems facing the fire service are considered here in terms of firefighter safety. Improving a firefighter's effectiveness will also improve some aspects of safety, due to decreased exertion and exposure to harmful conditions. Injuries and fatalities are grouped by type of duty such as responding to or returning from alarm, causes of injury including caught/trapped, and nature of injury such as burns or cardiac death.

A hierarchy of approaches provides a suitable framework to addresses the safety and effectiveness of the fire service. Each of the high level approaches can be further divided into specific emerging and existing technologies. The specific approaches are seen in the graphic at the bottom of the page. The role of this Breakout Group is to focus on firefighting technologies, considering the most efficient way to quickly achieve improvements by addressing questions such as:

- What emerging and existing technologies could be used to improve fire service operations?
- How will those technologies be tested?
- What types of operations need immediate attention and improvement?
- What will the next generation of personal protective equipment (PPE) look like? How will it functionally differ from the current generations of PPE?
- How can technology optimize training and education?



Wildland-Urban Interface Fires Breakout Group

Workshop
June 4-5, 2009

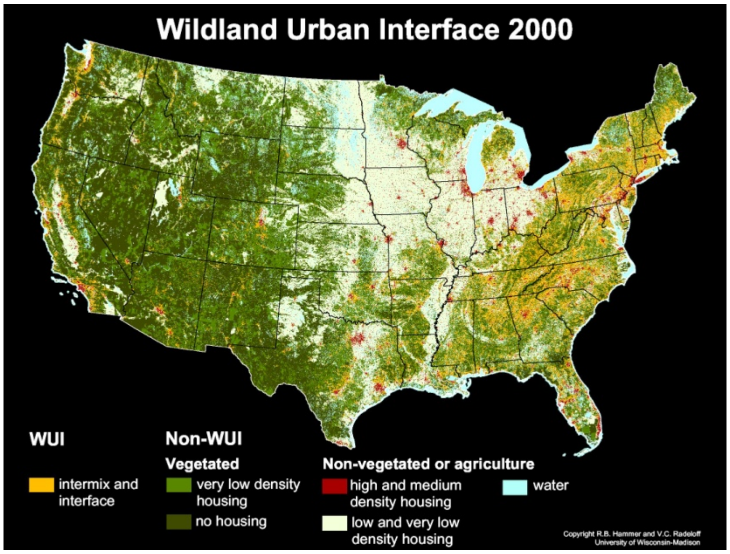


Figure A. http://silvis.forest.wisc.edu/library/WUILibrary.asp

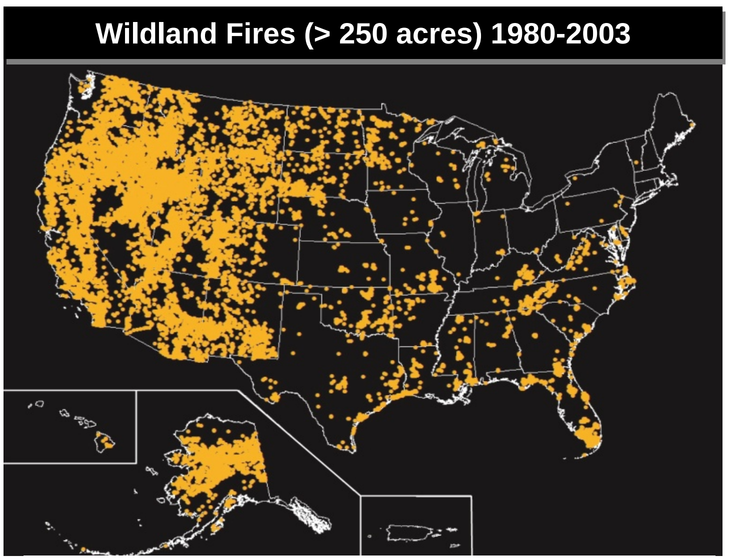


Figure B. USGS

The wildland-urban Interface (WUI), where homes and wildland vegetation are in proximity or intermixed, exists throughout the U.S. (denoted by orange in Figure A). Fires in the WUI predominantly begin as wildland fires.

Of the 10 largest fire loss events in the U.S. within the last 100 years, six have been WUI fires. Consistent with Figure B, all six have been in the western U.S., with five of the six in California.

The WUI fire problem is growing. For example, the frequency of large wildland fires and damaging WUI fires is increasing - leading to rising suppression costs (Figure C) and rising structure losses (Figure D).

The objective of this session is to identify approaches and supporting technologies to best reduce the impact of WUI fires. Approaches may include:

- Wildland fuel treatments
- Community planning, construction and maintenance
- Building codes and standards
- Wildland fire suppression and control
- Improved Ignition resistance of homes
- Structure fire suppression

BFRL's long-term vision is that unwanted fire be removed as a limitation to life safety, technical innovation, and economic prosperity in the U.S.

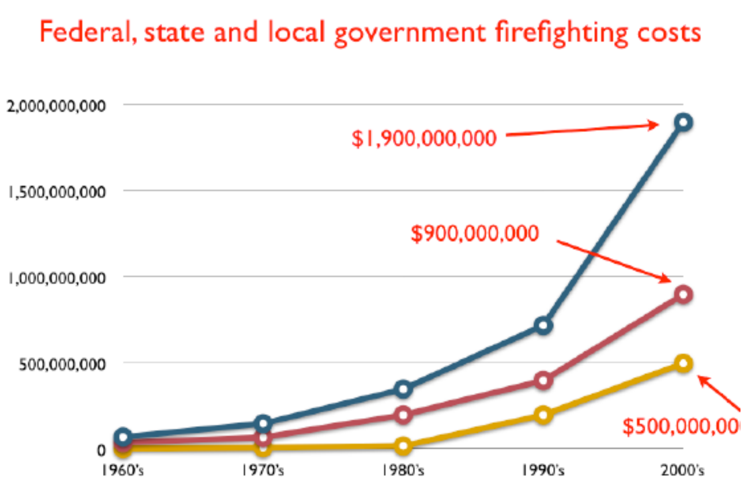


Figure C. Blue Ribbon Panel on WUI Fires, 2008

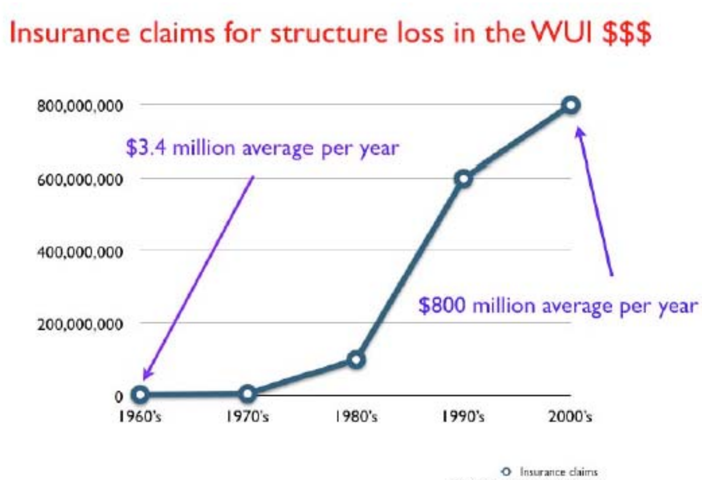


Figure D. Blue Ribbon Panel on WUI Fires, 2008

Appendix 4 Keynote Presentations

- "The U.S. Fire Problem" by John Hall (NFPA)
- "Opportunities for Innovation in Fire Protection" by Sara Slaughter (MIT)

U.S. Fire Problem

Setting Research Priorities by the Size of the Problem

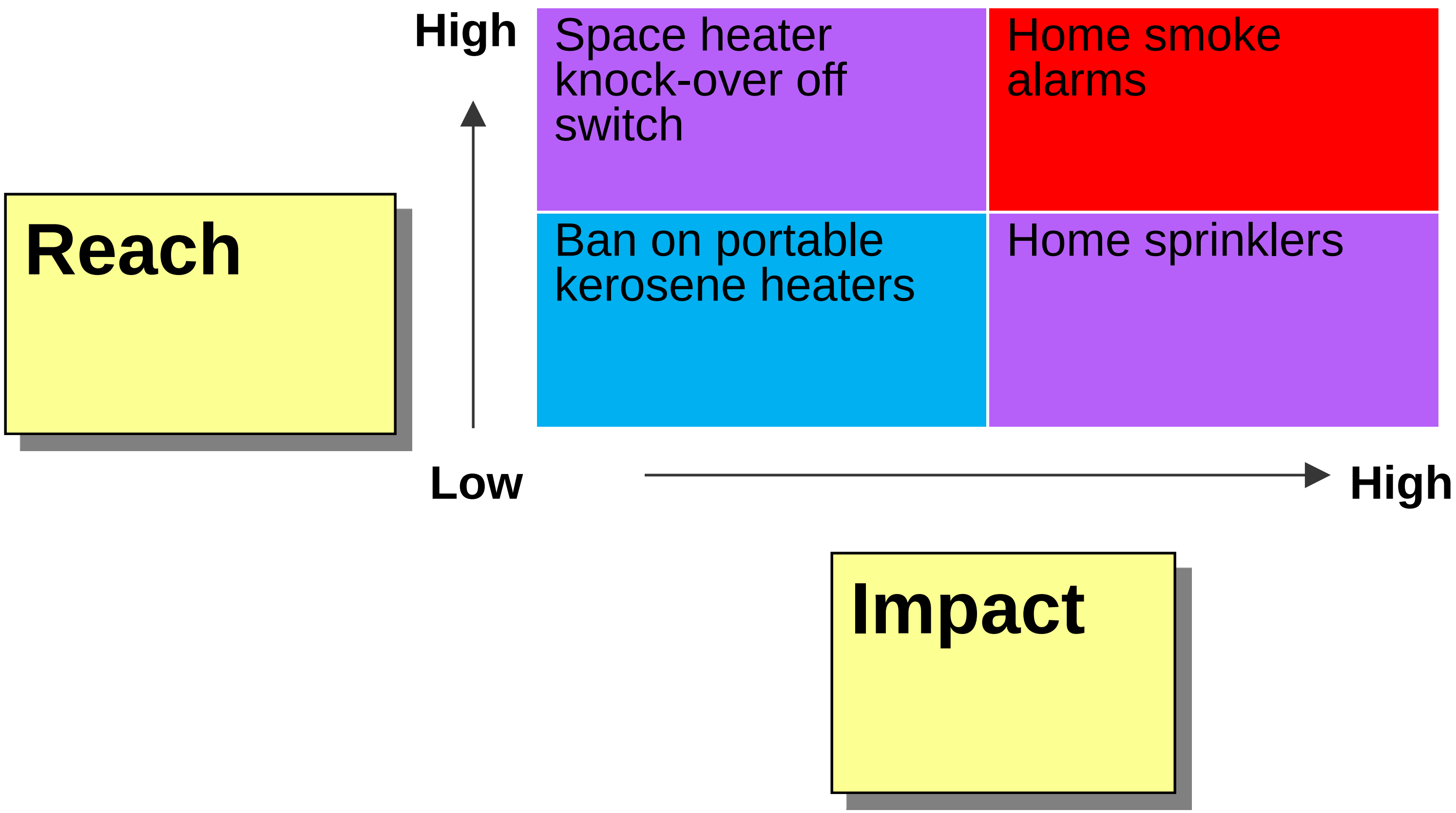
NIST Fire Program Planning Exercise

Dr. John R. Hall, Jr.
National Fire Protection Association
June 2009

What drives the benefits of fire safety research?

- Problem size: How much loss are we experiencing? Where are the trends going?
- Impact: How much reduction in loss can we achieve if our research is successful? How effective is the strategy or technology we are trying to develop, refine or prove?
- Reach: How broadly and how quickly will the new strategy or technology be put into use? What is the normal replacement cycle for such products? Is it affordable and attractive?

Displaying the Keys to Fire Safety Improvement



The U.S. Fire Problem – 2007

- 1,557,500 (↓) reported fires [7.2 million unreported home fires]
- 3,430 (↓) civilian deaths in reported fires (plus estimated 200 deaths in unreported fires) [~$18 B]
- 102 (→) on-duty firefighter deaths [~$1/2 B]
- 17,675 (↓) reported civilian injuries in reported fires (plus 130,000 injuries in unreported home fires, equal to 1,600 of comparable severity) [~$5 B]
- 80,100 (↓) on-duty firefighter injuries [~$20 B]

The U.S. Fire Problem – 2007

- $14.6 billion (↑) in direct property damage in reported fires. [2007 was an anomaly; recent trend has generally been →]
- Plus estimated $2.7 billion in direct damage in unreported fires and indirect loss (e.g., business interruption, business closings)

The U.S. Fire Problem – 2007 Home Structure Fires

- 399,000 (→) reported fires (26%)
- 2,865 (↓) civilian deaths in reported fires (84%)
- 13,600 (↓) civilian injuries in reported fires (77%)
- $7.4 billion (↑) in direct property damage in reported fires (50%) and $1.1 billion (41%) in indirect loss and direct damage in unreported fires
- Not counting the California Fire Storm ($1.8 B), where most dollar damage was damage to homes

The U.S. Fire Problem – 2007
Non-Home Structure Fires

- 131,500 (↓) reported fires (8%)
- 135 (↓) civilian deaths in reported fires (4%)
- 1,750 (↓) civilian injuries in reported fires (10%)
- $3.2 billion (→) in direct property damage in reported fires (22%) and $1.6 billion (59%) in indirect loss and damage in unreported fires

The U.S. Fire Problem – 2007
Vehicle Fires

- 256,000 (↓) reported fires (16%)
- 385 (↓) civilian deaths in reported fires (11%)
- 1,675 (↓) civilian injuries in reported fires (9%)
- $1.4 billion (↓) in direct property damage in reported fires (10%)

The U.S. Fire Problem–2003-06
Fires by Type of Vehicle

- Passenger road vehicles (cars): 85% (↑) of vehicle fires, 77% (↑) of deaths, 76% (↑) of injuries, 58% (↓) of damages [shares are up but numbers are down]

- Freight road vehicles (trucks): 8% (↓) of vehicle fires, 14% (↓) of deaths, 11% (↓) of injuries, 18% (→) of damages

- Construction, industrial, and agricultural vehicles (forklifts, tractors, balers, lawn mowers): 4% (↑) of vehicle fires, 1% (↓) of deaths, 4% (↓) of injuries, 14% (↑) of damages

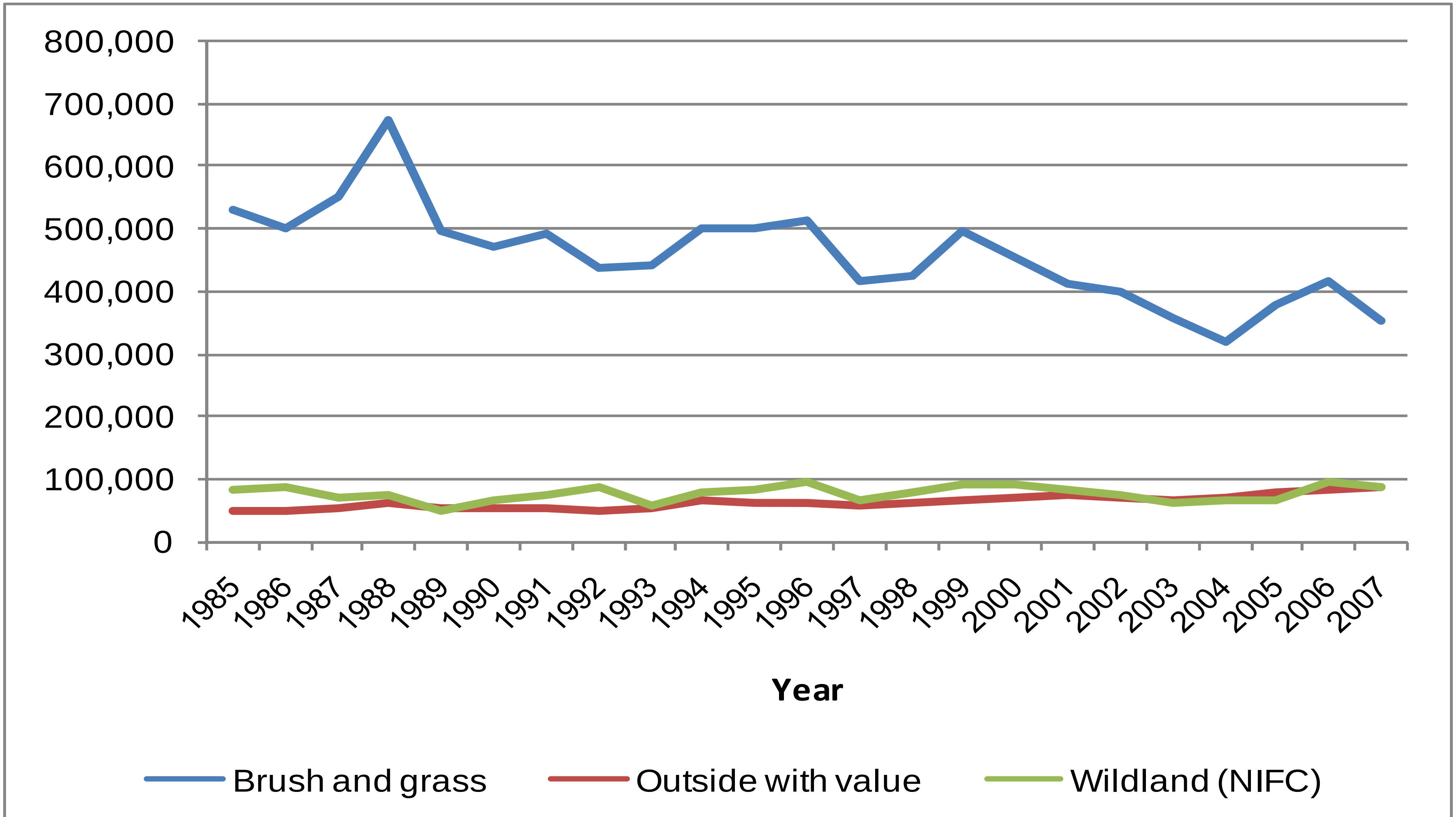
The U.S. Fire Problem–2003-06
Fires by Type of Vehicle

- Water craft (boats): 1% of vehicle fires, 1% of deaths, 6% (→) of injuries, 3% (↓) of damages
- Rail vehicles (trains): 0% of vehicle fires, 0% of deaths, 0% of injuries, 2% (→) of damages
- Aircraft: 0% of vehicle fires, 6% (↓) of deaths, 1% of injuries, 4% (→) of damages
- Unclassified vehicles: 2% (↓) of vehicle fires, 1% of deaths, 1% of injuries, 1% of damages

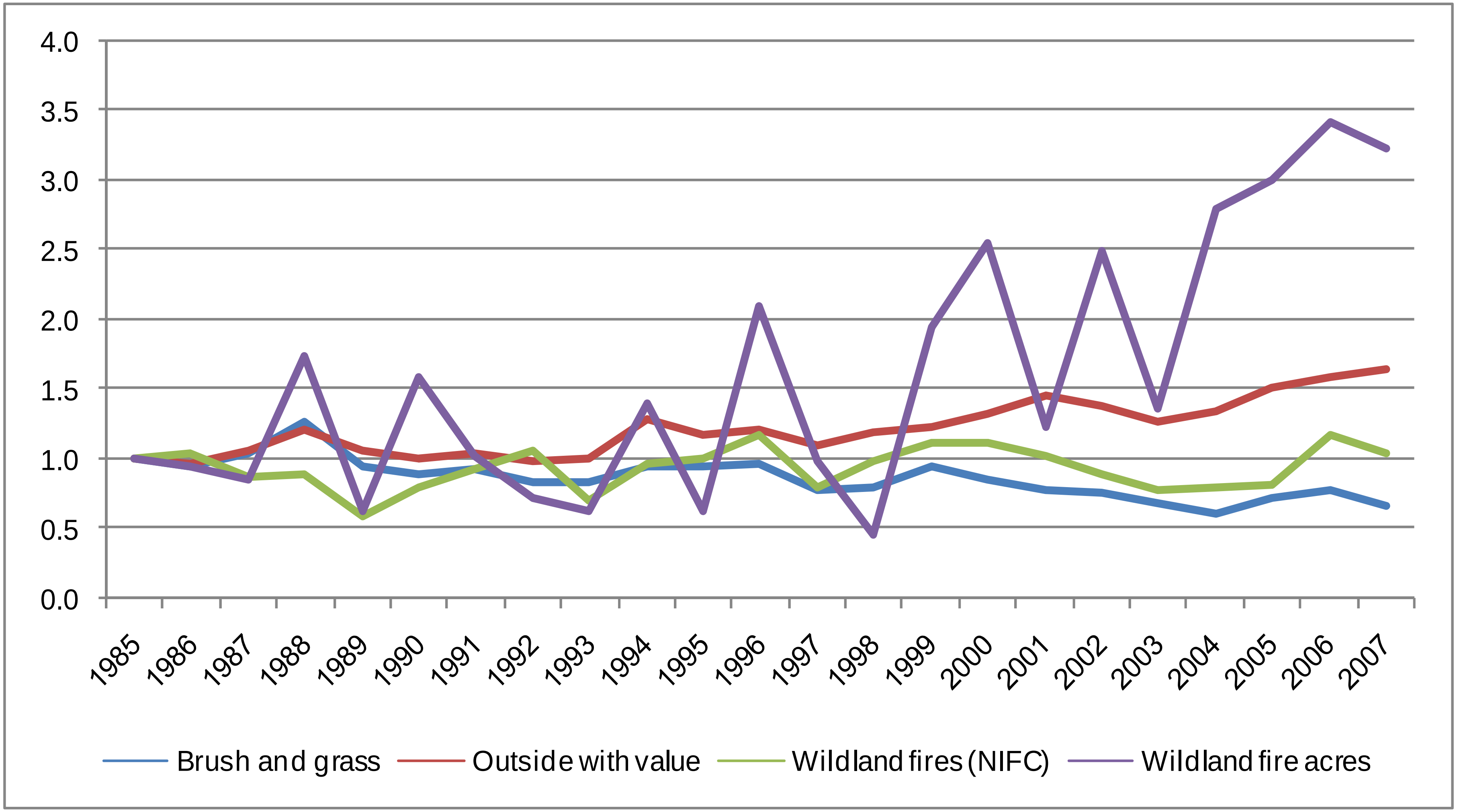
The U.S. Fire Problem – 2007 Vegetation Fires

- 355,000-440,000 (↓) reported fires (23-28%)
- Up to 45 civilian deaths in reported fires (1%) [category includes outside trash fires and unclassified fires]
- Up to 650 civilian injuries in reported fires (4%)
- $2.5 billion in direct property damage in reported fires (17%) [including $1.8 billion in California Fire Storm of 2007, which makes 2007 an unusually high year]

The U.S. Fire Problem – Vegetation Fire Trends



The U.S. Fire Problem – Vegetation Fire Trend Indexes



The U.S. Fire Problem – Historic Vegetation Fires

- Of the 30 costliest fires and explosions in U.S. history, 6 occurred in 1918 or before, 4 occurred in 1919-1985, and 20 occurred in 1986 or later
- 9 of 20 are wildfires
- #4 is Oakland fire of 1991
- #5 is California Fire Storm of 2007
- We have averaged a history-class wildfire every two years since 1990.

The U.S. Fire Problem – 03-06
Firefighter Fireground Injuries

- Split about 3-to-1 minor vs. moderate or severe
- Leading primary apparent symptom is sprain or strain (27% overall, 25% minor, 34% moderate or severe)
- Thermal burn, scald, other burn, or smoke inhalation (18% overall, 19% minor, 14% moderate or severe)
- Thermal burn only (11% overall, 11% minor, 9% moderate or severe)

The U.S. Fire Problem – 03-07 Firefighter Deaths and Injuries

- At the fireground: 32% of deaths (↓), 50% of injuries (↓)
- On site at non-fire emergency: 7% of deaths (→), 17% of injuries (↑)
- During response or return: 30% of deaths (↓), 6% of injuries (→)
- Training: 11% of deaths (↑), 9% of injuries (→)
- Other: 19% of deaths (↑), 17% of injuries (↑)

The U.S. Fire Problem – 03-06
Firefighter Fireground Injuries

- Injured part of body: Arm or hand (20%), leg or foot (20%), trunk (15%), head (14%), neck or shoulder (12%), internal (8%), multiple parts (8%)

- Injured part of body for burns: Head (36%), arm or hand (29%), neck or shoulder (18%), leg or foot (9%), multiple parts (4%), trunk (3%), internal (0%)

- Activity when injured: Extinguishment (52%), overhaul or salvage (16%), ventilation or forced entry (10%), moving things (9%), access (3%), EMS or rescue (3%), operating apparatus (2%)

Home Smoke Alarms

- Target the entire home fire death problem (2,500 to 3,000 deaths a year)
- Smoke alarm usage: > 95%
- Smoke alarm presence when reported fires occur: ~70%
- Operating smoke alarms reduce rate of deaths per 100 fires by about half

Non-Home
Fire Detection and Alarm

- Non-home structures have a small number of total fire deaths
- In this context, “problem size” is deaths in large multiple-death fires
- Also can be evaluated for its contribution to ASET/RSET design and performance
- Properties with high levels of fire detection/alarm usage include health care, non-home residential, educational, correctional, offices

Home Fire Sprinklers

- Target the entire non-home fire problem (2,500 to 3,000 deaths a year; $5 to $6 billion a year)
- Usage in one- and two-family dwellings: 2%
  Usage in apartments: 11%
- Presence when reported fires occur in one- and two family dwellings: 1%
  Presence when fires occur in apartments: 12-16%
- Reduction in deaths per 100 fires (wet pipe): 80%
- Reduction in damages per fire (wet pipe): 71%

Non-Home Fire Sprinklers

- Target the entire non-home fire problem (~100 deaths a year; $3 to $4 billion a year)
- With so few deaths, "problem size" for deaths refers more to deaths in large multiple-death fires
- No incidents of 3+ deaths in a fully sprinklered building with operating sprinklers *except* for firefighting personnel or explosions/flash fires
- Properties with high levels of fire sprinkler usage include health care, non-home residential, eating or drinking, manufacturing, high-rise offices

Type of Construction – Fire Resistance, Compartmentation

- Type of construction has not been recorded in national fire incident databases since 1999
- Prior to 1999, type of construction was highly correlated with percentage of fires having extent of flame damage beyond room of origin
- This is taken as an indicator of the likelihood of flashover
- However, few fires – even large fires – become large by involving construction materials. Containment is due more to correlated features.

Type of Construction – Fire Resistance, Compartmentation

- What part of fire problem is targeted by a strategy of heightened fire resistance?
- Losses that result from early loss of structural integrity but would *not* result from full building involvement in fire without loss of structural integrity.
- Building may be uninhabitable in both cases.
- There may be no significant damage to neighboring buildings in both cases.

Heating equipment

- Average 2003-06 in homes, 620 civilian fire deaths
- 1,610 civilian injuries
- $945 million in direct property damage
- Average 2003-06 in non-home structures, 40 civilian fire deaths
- 240 civilian injuries (excluding confined fires)
- $323 million in damages (excluding confined fires)

Cigarettes and other lighted tobacco products

- Average 2003-06 in homes, 710 civilian fire deaths – and 1 in 4 is not the smoker
- 1,270 civilian injuries in reported fires
- $431 million in direct property damage
- In 2006 everywhere but homes, 70 civilian fire deaths
- 310 civilian injuries in reported fires
- $122 million in direct property damage

Cooking equipment

- Average 2003-06 in homes, 500 civilian fire deaths
- 4,660 civilian injuries in reported fires
- $756 million in direct property damage
- Average 2003-06 in non-home structures, 10 civilian fire deaths
- 230 civilian injuries in reported fires
- $197 million in direct property damage

Upholstered furniture

- Average 2003-06 in homes, 590 civilian fire deaths
- 900 civilian injuries in reported fires
- $416 million in direct property damage
- Average 2003-06 in non-home structures, 30 civilian fire deaths
- 70 civilian injuries in reported fires
- $45 million in direct property damage

Intentional fires (arson)

- Average 2003-06 in homes, 320 civilian fire deaths
- 870 civilian injuries in reported fires
- $542 million in direct property damage
- Average 2003-06 in everything but homes, 120 civilian fire deaths
- 640 civilian injuries in reported fires
- $534 million in direct property damage

Electrical distribution and lighting equipment

- Average 2003-06 in homes, 370 civilian fire deaths
- 840 civilian injuries in reported fires
- $737 million in direct property damage
- Average 2003-06 in non-home structures, 20 civilian fire deaths
- 150 civilian injuries in reported fires
- $355 million in direct property damage

Mattresses and bedding

- Average 2003-06 in homes, 380 civilian fire deaths
- 1,400 civilian injuries in reported fires
- $371 million in direct property damage
- Average 2003-06 in non-home structures, 60 civilian fire deaths
- 160 civilian injuries in reported fires
- $47 million in direct property damage

Room linings – interior wall, ceiling and floor coverings

- Average 2003-06 in homes, 260 civilian fire deaths
- 690 civilian injuries in reported fires
- $523 million in direct property damage
- Average 2003-06 in non-home structures, 20 civilian fire deaths
- 80 civilian injuries in reported fires
- $206 million in direct property damage

Flammable or combustible liquid or gas

- Average 2003-06 in homes, 230 civilian fire deaths
- 1,160 civilian injuries in reported fires
- $308 million in direct property damage
- Average 2003-06 in non-home structures, 40 civilian fire deaths
- 420 civilian injuries in reported fires
- $269 million in direct property damage

Clothing

- Average 2003-06 in homes, 160 civilian fire deaths
- 510 civilian injuries in reported fires
- $159 million in direct property damage
- Average 2003-06 in non-home structures, 10 civilian fire deaths
- 80 civilian injuries in reported fires
- $27 million in direct property damage

Other causes

- Candles
- Playing with fire [matches and lighters]
- Structural members and framing

Summary

- In total cost terms, the largest parts are
  - Civilian deaths
  - Property damage
  - Firefighter injuries

Summary

- In shares of deaths, the leading property uses are
  - Homes
  - Passenger road vehicles

Summary

- In shares of deaths, the leading property uses are
  - Homes
  - Passenger road vehicles
- In shares of deadliest incidents, add:
  - Office buildings (terrorist attacks)
  - Aircraft post-crash fires
  - Nightclubs

Summary

- In shares of damages, the leading property uses are
  - Homes
  - Non-home structures

Summary

- In shares of damages, the leading property uses are
  - Homes
  - Non-home structures
- In shares of costliest incidents, add:
  - Wildland fires
  - Industrial plants and warehouses
  - City fires/conflagrations

Summary

- Nearly all the leading parts of the fire problem are amenable to technological strategies
- Always look to homes first
- For firefighter deaths and injuries, look at more than fireground incidents
- For wildfire incidents, look at more than fire spread and firefighting

Opportunities for Innovation in Fire Protection

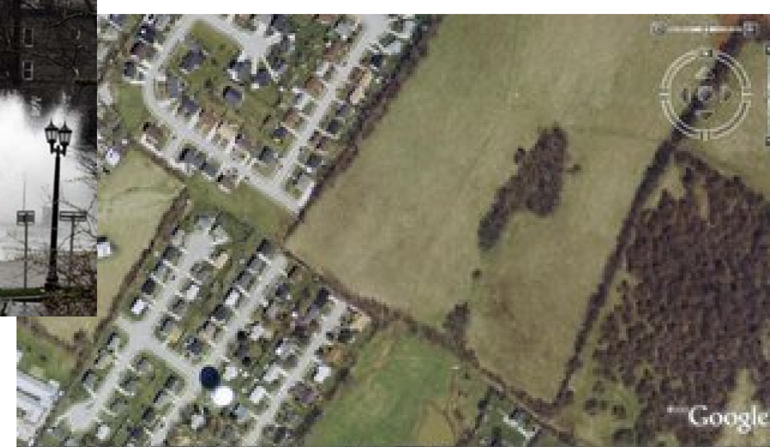
Innovative Fire Protection Roadmap Workshop
NIST Building and Fire Research Lab

Prof. Sarah Slaughter
MIT Sloan School of Management

June 4, 2009

Challenges

- **Changing Demographics**
- **Economic Constraints**
- **Aging Infrastructure and Built Environment**
- **Frequency and Magnitude of Natural and Man-Made Disasters**



Opportunities

- **Re-Investment in Infrastructure and the Built Environment**
  - EISA, Energy Policy Act, EOs
  - Recovery Act
  - FY09 Federal Budget
- **Focus on Sustainability**
- **Focus on Disaster Resiliency and Life Safety**
- **Rapid RD&D in Related Fields**

Sustainable Critical Infrastructure Systems: A Framework For Meeting 21st Century Imperatives

NAS Press Report Outcomes:

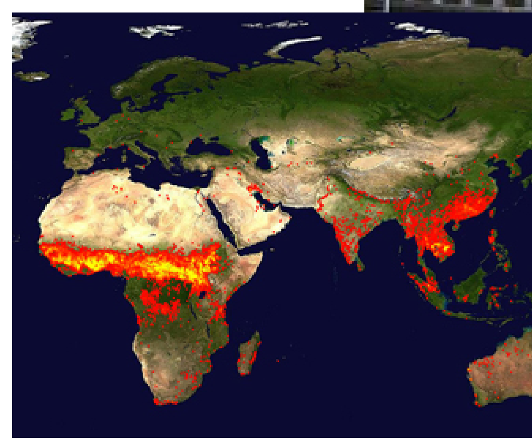
- **Establish a Broad and Compelling Vision**
- **Focus on**
  - National Priorities Coordinated by Region
  - Essential Infrastructure Services
  - Interdependencies of Systems
  - Collaborative Systems-based Approaches
- **Establish Robust Performance Measures**

Fire Protection – Integral to Sustainable Critical Systems

- **Survivability – Ability to continue to operate during a disaster**
  - **Active Survivability**: Continues to function during and after disaster to care for vulnerable populations with full capacity of critical services.
  - **Passive Survivability**: Provides refuge with critical life-support conditions without services
- **Resiliency – Ability to rapidly re-establish critical functions after a disaster**
  - ➔ Effective Fire Protection Depends Upon Existing Infrastructure Systems
  - ➔ Can Use Active and Passive Systems

Fire Protection Priorities

- **Protect lives**
  - Occupants
  - Fire fighters
- **Prevent fire ignition and spread**
  - Buildings
  - Communities
  - Natural systems
- **Reduce property loss**

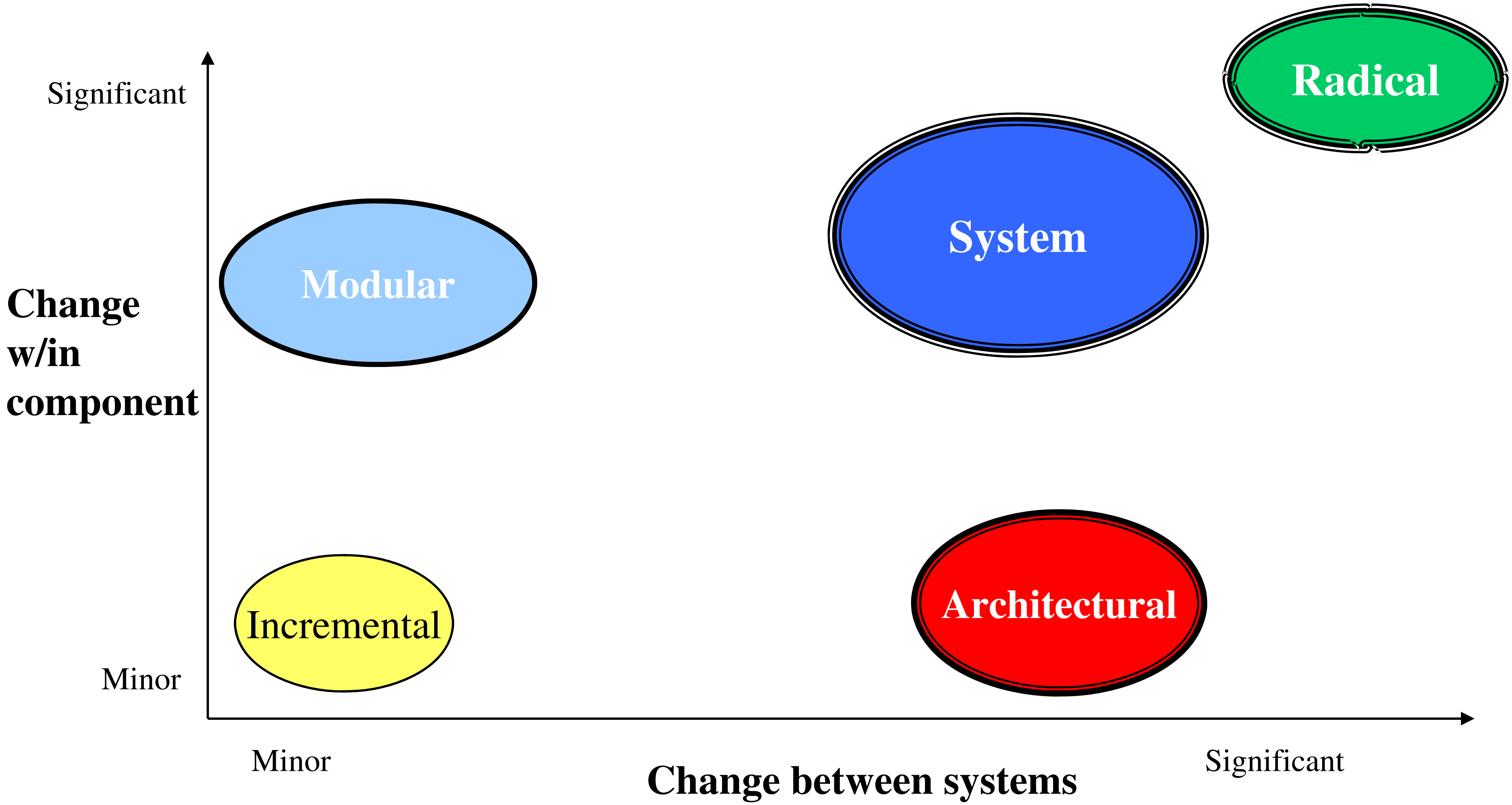


NASA Rapid Response System Global Fire Map

Innovations in Fire Protection

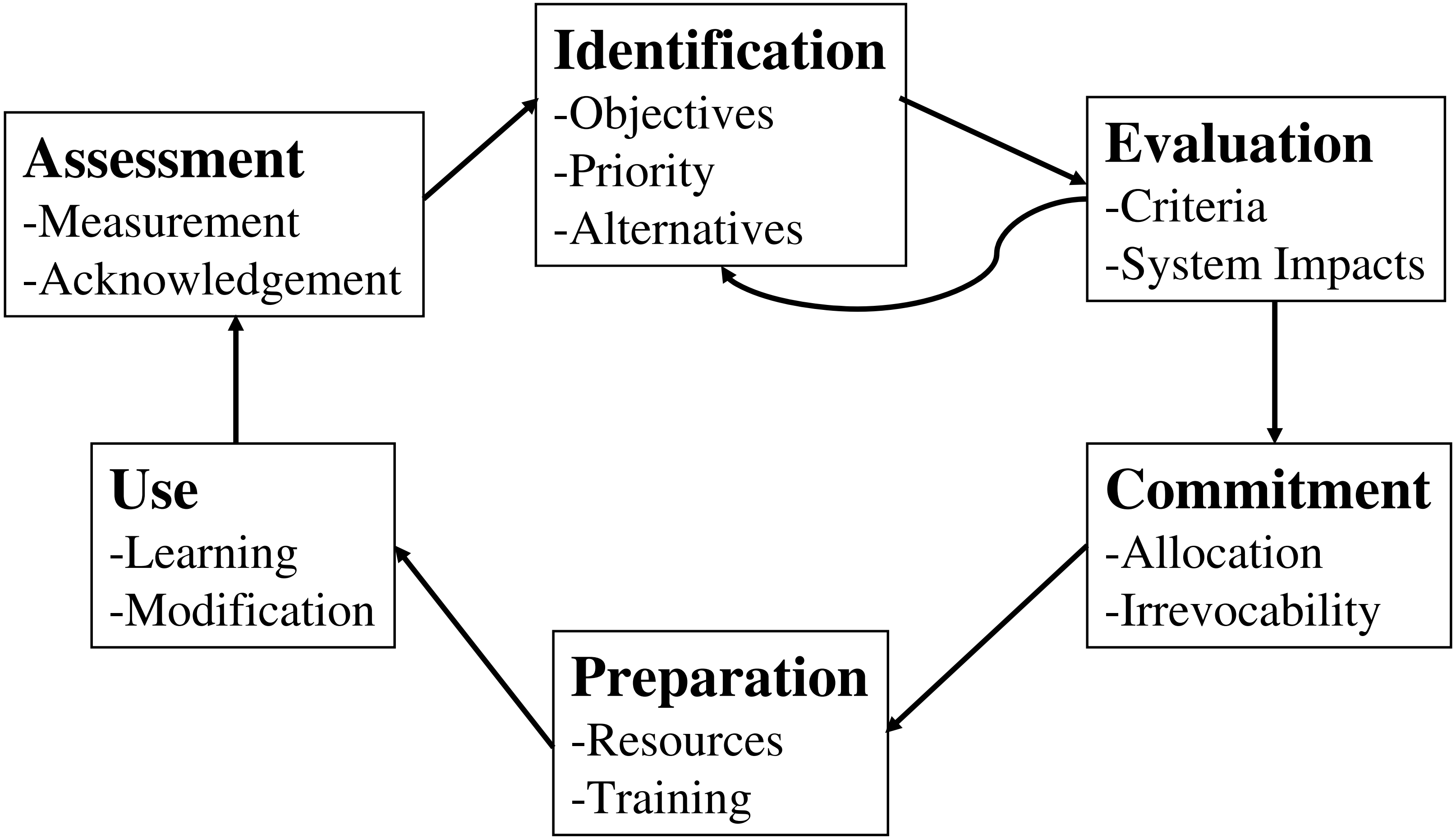
- **"Innovation":**
  - Actual use of a nontrivial change and improvement in a process, product, or system,
  - which is novel to the institution developing the change.
- **Key Issues:**
  - Effectiveness
  - Robustness
  - Availability
  - Ease of Deployment

Types of Innovations



Source: Slaughter, "Models of construction innovation," *Journal of Construction Engineering and Management,* 1998.

Implementation of Innovations



Source: Slaughter, "Implementation of construction innovation," *Building Research & Information, 2000*.

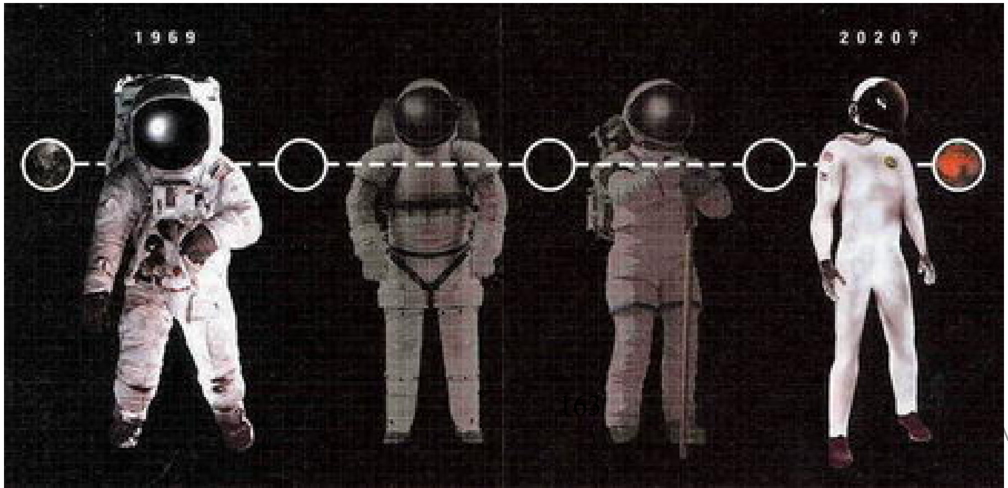
Implementation by Type of Innovation - Incremental

- **Rapid evaluation,**
- **Allocation of available resources,**
- **Rapid preparation,**
- **Direct use**
- **Immediate assessment**
  - Example: Cold Weather/Protective Gloves with special grip

Cold Water Scuba Gloves

Implementation by Type of Innovation (cont'd) - Modular

- **Evaluation by experts,**
- **Commitment from community,**
- **Preparation through specific acquisition and training,**
- **Direct use,**
- **Assessment re. performance**
  - Example: New fire fighting suit



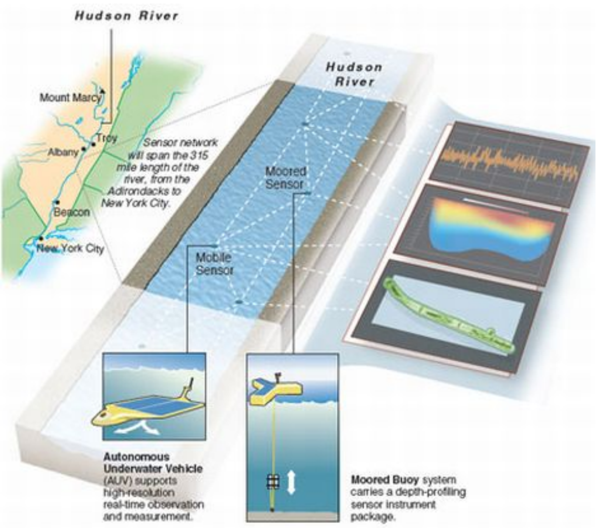
MIT Man Vehicle Lab

Implementation by Type of Innovation (cont'd) - Architectural

- **Evaluation for system impacts,**
- **Commitment and preparation by all effected parties,**
- **Use with in-practice learning and modification,**
- **Assessment re. performance**
  - Example: Cementitious foam for insulation and fire prevention

http://www.airkrete.com/

Implementation by Type of Innovation (cont'd) - System



IBM Hudson River monitoring

- **Early evaluation, commitment and preparation among all parties with access to special resources and training,**
- **Use with constant learning and modification,**
- **Assessment re. new performance attributes.**
  - Example: "Smart Building" real-time monitoring

Implementation by Type of Innovation (cont'd) - Radical

- **Evaluation with scientific expertise on new paradigm,**
- **Commitment across community,**
- **Preparation with extensive new resources and training,**
- **Use by multiple organizations with modifications,**
- **Assessment re. new functions and performance.**
  - Example: Remote controlled "robotic" fire fighting units

iRobot Packbot 510

Successful Innovations

- **Super-Ordinate Goals**
  - Formal recognition of a higher performance level
  - Achievement of a strategic objective
- **Team Relationship**
  - Strong among team members (innovation source and implementers)
  - Extensive internal competence
  - Strong involvement throughout

Source: Slaughter and Cate, "Critical actions by clients for effective development and implementation of construction innovations," in Brandon and Lu (eds), Clients Driving Innovation, 2008.

MITSloan MANAGEMENT

Implications for Fire Protection Innovations

- **Innovations can emerge from many different sources**
  - Professionals in the field
  - Materials and equipment suppliers
  - Other fields
- **Time required for development, testing, and diffusion will differ by innovation type**

➔ Many Strategies Can Be Pursued Simultaneously – Critical to Ensure Wide Scanning for Promising Approaches

Appendix 5 Breakout Group Reports to Plenary Session

- **Day 1 Reports**
- **Day 2 Reports**

Innovative Fire Protection Roadmap Workshop (Fire Prevention Breakout Group)

Facilitated Session Results

Day 1: June 4, 2009

Approaches: (Breakout Session)

- **Prevent Ignition – Behavior**
- **Prevent Ignition – Source**
- **Prevent Ignition – Reaction**
- **Reduce Consequence of Ignition (Active)**
- **Improve Egress**

Technologies: (Breakout Session)

- **Prevent Ignition – Behavior**
  - Testing and Classification system for material flammability
- **Prevent Ignition – Source**
  - Characterization of Ignition Sources
- **Prevent Ignition – Reaction**
  - Material Aging and Reliability Studies
  - Next Generation Hybrid Materials
- **Reduce Consequence of Ignition**
  - Reverse Microwave Gun to Remove Heat
- **Improve Egress**
  - Next Generation Smart Sensor Network

Metrics/Attributes: (Breakout Session)

- **Metrics**
  1. **Performance and Impact (Deaths, injuries, Property Loss)**
  2. **Degree of Sustainability (LCA, Cost of Use)**
  3. **Political Acceptance**
  4. **Technical Development (Cost to Development, Market Readiness, Likelihood of Success)**

- **Attribute**
  - **Metrics 1-3: High, Medium, Low**
  - **Metric 4: Easy, Medium, Hard**

	Testing and Classification system for material flammability	Next Generation Smart Sensor Network	Material Aging and Reliability Studies	Next Generation Hybrid Materials	Characterization of Ignition Sources	Reverse Microwave to Remove Heat
1. Performance and Impact	High	High	Medium	High	Medium	High
2. Degree of Sustainability	Medium	High	High	Low	Medium	High
3. Political Acceptance	Medium	8/2/1	High	Medium	Medium	High
4. Technical Development (easy-hard)	Medium	Medium	Easy	Hard	Medium	Hard

Metrics 1-3: High, Medium, Low
Metric 4: Easy, Medium, Hard

Innovative Fire Protection Roadmap Workshop (Fire Protection Breakout Group)

Facilitated Session Results

Day 1: June 4, 2009

Approaches: (Building Fire Protection)

- **Detection**
- **Suppression**
- **Manage Combustion Products**
- **Emergency Management**
- **Egress Design**
- **Human Response**
- **Property**
- **Prevent or Warn of Collapse**

Technologies: (Breakout Session)

- **Detection**
  - Nuisance-free
  - Placement
- **Occupant Response**
  - Mass Notification Tech
  - Training
- **Suppression**
  - Sprinkler Reliable
  - Sprinkler Cost
  - Performance
- **Emergency Response**
  - Radio Comm
  - Sensors in Buildings
  - Limiting Unnecesary Response

Metrics/Attributes: (Breakout Session)

- **Impact on Time (low med high)**
- **Impact on Fire Problem (low med high)**
- **Applicability and Reach +secondary benefits? (low med high + yes/no)**
- **Probability of Success (low med high)**
- **Upfront and Lifecycle Cost ($ $$ $$$ $$$$)**
- **Improves Understanding of Fire (low med high)**

	Smoke Detectors	Responder Communication	Mass Notification	Prediction of Structural Perfromance	Sprinkler Reliability	Sprinkler Cost	Robotic Firefighting
Impact on Time	Mod	High	High	NA	High	High	High
Impact on Fire Problem	Med	High	Low* (H for catast	High	Low	High	High
Applicability and Reach (2ndary benefits)	Broad (maybe)	Broad (yes)	Broad (yes)	Broad (yes)	Broad (no)	Broad (no)	Broad (yes)
Probability of Success	High	High	Med	Med	High	Low	High
Upfront and Lifecycle Cost	$$	$$$$	$ to $$$$	$$$$	$$	$$	$$$$
Impact on Understanding of Fire	Med	None	None	High	None	Med	Med

Innovative Fire Protection Roadmap Workshop (Fire Service Breakout Group)

Facilitated Session Results

Day 1: June 4, 2009

Approaches: (Fire Service Breakout)

- **Anticipate Fire Growth**
- **Improve Communication**
- **Improve/Develop Fire Suppression**
- **Investigation/Reconstruction**
- **Improve Situational Awareness**
- **Health**
- **Improve/Develop Tactics**
- **Improve Use of Resources**
- **Training & Education**
- **Improve/Develop PPE**

Metrics/Attributes: (Fire Service Breakout)

- **Technical Risk** (low, med, high)
- **Crosses Multiple Disciplines** (good, better, best)
- **Market Readiness/Timing** (<2, 2 – 5, >5)
- **Likelihood** (unlikely, likely, very likely)
- **Cost Reduction** ($, $$, $$$)
- **Impact on Fire Problem** (low, med, high)

Fire Service Breakout

	Improve Comm. equip	Virtual Env. Train & data	FF tracker locator	IntegrateTIC in HUD in SCBA & next gen respir.	Enhance thermal protection /heat stress	Enhance suppression dynamics	Res. clearing house	Sustainable suppression (materials)	Health Screening
Tech Risk	med	low	med	low	med	low	low	med	low
Cross Multiple Discipline	better	better	best	better	good	better	best	best	best
Market Readiness/Timing	<2	2 - 5	2 - 5	2 - 5	>5	2 - 5	2 - 5	2 - 5	<2
Likelihood of Success (implementation)	likely	Very likely	Very likely	Very likely	unlikely	Very likely	unlikely	likely	Very likely
Cost Reduction (econ benefit)	$	$$	SS	$$	$	$$$	$$$	$$	$$$
Impact on Fire Problem	high	high	high	high	low	high	high	med	high

Innovative Fire Protection Roadmap Workshop (WUI Breakout Session)

Facilitated Session Results

Day 1: June 4, 2009

Approaches: (WUI Breakout Session)

- **Vegetative fuel treatment**
- **Community planning, construction codes and standards**
- **Defensible spaces/ignition resistance of building and parcels**
- **Influencing homeowner and community actions (before, during, after fire)**
- **Fire detection, suppression, control, containment**
- **After action review-learning assessment improvement**
- **Improving problem definition**
- **Systemic integration and linking of approaches**

Technologies: (WUI Breakout Session)

- WUI risk model that includes market and non-market economics
- Benefit-cost assessment tools/models for retrofit technologies and systems approaches to retrofit
- Quantify ember quantities, transport, characteristics as function of wind and ignition potential
- Legislative mandate/incentive to retrofit existing homes
- Modeling of coupling of fire and atmosphere, and smoke transter
- Technology to help document and analyze WUI fires
- Ember intrusion prevention technology
- Message development tool—sociological/ marketing, etc. education. deliver to homeowner to influence behavior

Metrics/Attributes: (WUI Session)

- **Effectiveness**
- **Benefit-Cost**
- **Marketability**
- **Feasibility (likelihood of success)**
- **Collateral impact (externalities)**

Examples:

- **Market Readiness** (short term, medium term, long term)
- **Lives Saved** (few, some, many)
- **Cost** (low, medium, high)

	WUI Risk Model include mkt & non-mkt economics	Benefit-Cost Assessment Tool for retrofit tech	Quantify ember quantities, transport characteristics vs. wind and ignition potential	Legislative Mandate/Incentive to Retrofit existing homes	Modeling coupllng weather and fire & smoke at fire scale	Technology to help document and analyze WUI fires	Ember Intrusion prevention technologies	Message Deployment Tool
Effectiveness								
Benefit-Cost								
Marketability								
Feasibility								
Collateral Impact								

Innovative Fire Protection Roadmap Workshop (Global/Cross-Cutting Session)

Facilitated Session Results

Day 1: June 4, 2009

Vision and Goal

- NIST Vision: BFRL's long term vision is that unwanted fire be removed as a limitation to life safety, technical innovation, and economic proserity in the U.S.
- NIST Goal: The goal of BFRL's Innovative Fire Protection Strategy is to develop and demonstrate, by 2013, the measurement science needed to achieve a 25% reduction in the impact of the fire on structures, their, occupants, and the fire science.

Approaches: (Global/CC Session)

- **Real time data collection and analysis**
- **Analysis tools, e.g. FEM, CFD**
- **Engineering fire safety**
- **Education**
- **Life-cycle analysis, aging materials and equipment**

Observations/Comments

Approaches: (Global/CC Session)

- **Advocacy: building coalitions to affect technologies**
- **Data collection, including jurisdictional differences**
- **Rapid prototyping**
- **Community development for large-scale fire containment**

Observations/Comments

	Retofit Kit	Smoke alarm Tech.	Auto on/off	Fire safe appliances	Barrier Materials for VERY low comb	FF locator GPS/com	FF black box	Tools
size	H	H	H	H	H	M	M	
Impact	H	M	M	M	H	M	L	
cost	M	M	M	M	M	M	M	
Ease of use	Elem.	H	Elem. H	Elem. H	H	H	M	
Ease of implementation	Mod.	H	H	H	H	H	M	
acceptability	yes	Yes	yes	Yes	Yes	Yes	Yes ??	
Reliability	Mod.	M	H	H	H	M	M	
Speed to market	Mod 1-5 yrs	M	M	M	L	M	M	
Speed to univ. adopt	L	M 10 yrs	M	M	M	M	M	

Building Fire Prevention Breakout Group

Technologies, Barriers and Measurement Science

1. **Testing and Classification System for Material Flammability – HOME RUN**
2. Next Generation Smart Sensor Network
3. **Material Aging and Reliability Metrics – NEAR TERM**
4. **Advance Fire Resistance Material – LONG TERM**
5. Characterization of Ignition Sources
6. Reverse Microwave to Remove Heat
7. **Improve Measurements and Metrics for Tests , SRMs, and Ignition Sources – MULTIPLE MS NEEDS**
8. Integrated Path Lighting for Flooring
9. Positive Pressure Ventilation for Low Rise
10. Improved Sensors (in Building Construction) for Early Detection
11. **National Open Flame Upholstered Furniture Fire Standard – NON-TECHNICAL BARRIERS**
12. Automatic Extinguishers for Vehicles

Fire prevention filtering used for selecting Technologies

HOME RUN TECHNOLOGY

Testing and Classification System for Material Flammability

- Non-technical Barriers
  - Manufacturer’s consensus: resistant to change because it may void their product
  - Investment Legacy –buy-in from those invested – resistance to change (EU fire standards)
  - Flammability criteria consensus
- Technical Barriers
  - Component vs. Final product (composition, geometry and manufacturing variability)
  - Test Scaling (bench vs. real-world)
  - Define repeatability and accuracy
- Measurement Science
  - Measure and characterize smoke toxicity and develop criteria
  - Measure physical effects on HRR (spalling, melting, deforming, etc.)
  - Measure heat of gasification
  - Develop models to understand scaling and predict performance
  - Gauge Repeatability and Reliability (accuracy)

NEAR TERM TECHNOLOGY

Material Aging and Reliability Metrics

- Non-technical
  - Trusting lab data correlates with real world
  - Manufacturer's consensus: resistant to change because it may void their product
  - Flammability criteria consensus
- Technical
  - Component vs. Final product (composition, geometry and manufacturing variability)
  - Test Scaling (bench vs. real-world)
  - Define repeatability and accuracy
  - Align aging conditions to reality
  - Evaluate new technology solutions
- Measurement Science
  - Measure and characterize smoke toxicity and develop criteria
  - Measure physical effects on HRR (spalling, melting, deforms, etc.)
  - Measure heat of gasification
  - Develop models to understand scaling and predict performance
  - Measure and understand physical and chemical aging in relation to fire performance
  - Identify degradation products
  - Transition aging tools into new cost favorable tools
  - Develop data package to influence standard
  - Gauge Repeatability and Reliability (accuracy)

LONG TERM TECHNOLOGY

Advance Fire Resistance Material

- Non-technical
  - Cost – new manufacturing plant, etc.
  - EHS – reality and perceived
  - Counterfeiting – nonUS company copies your product, but has lower performance
- Technical
  - Bridge between fire science and materials (models)
  - Lack of scientific and manufacturing information
- Measurement Science
  - Develop models to understand scaling and predict performance
  - Develop and review EHS impact data
  - System to review EHS risk
  - Small scale tool to measure and predict (large scale) heat and smoke release
  - Gauge Repeatability and Reliability (accuracy)

MULTIPLE MEASURMENT SCIENCE NEEDS TECHNOLOGY

Improve Measurements and Metrics for Tests , Standard Research Materials, and Ignition Sources

- Non-technical
  - Getting consensus of details of standard
- Technical
  - Define repeatability and accuracy
  - Test dependent standard materials
  - Unknown ignition propensity of new/changing technologies
  - Bridge between fire science and materials (models)
- Measurement Science
  - Develop models to understand scaling and predict performance
  - Gauge Repeatability and Reliability (accuracy)
  - Measurement of arc signatures – product dependence
  - Measure temperature and heat flux profile histories from non-electrical sources

NON-TECHNICAL BARRIER TECHNOLOGY

National Open Flame UF Fire Standard

- Non-Technical
  - Manufacturer's consensus: resistant to change because it may void their product
  - Investment Legacy –buy-in from those invested – resistance to change (EU fire standards)
  - Flammability criteria consensus
  - Stock turnover
  - EHS
- Technical
  - Component vs. Final product (composition, geometry and manufacturing variability)
  - Test Scaling (bench vs. real-world)
  - Define repeatability and accuracy
- Measurement Science
  - Measure and characterize smoke toxicity and develop criteria
  - Generate and review toxicology data and environment impact
  - System to review risk
  - Develop models to understand scaling and predict performance
  - Gauge Repeatability and Reliability (accuracy)
- Stakeholders
  - Entire supply chain – Consumers – Gov't – Testing Labs - Regulators

Building Fire Protection Group

Technologies, Barriers and Measurement Science

- Smoke Detectors
- Responder Communication
- Mass Notification
- Prediction of Structural Performance (design and realtime)
- Sprinkler Reliability
- Sprinkler Cost
- Robotic Firefighting
- Improved Suppression Technology (includes sprinklers)
- Suppression Systems for Open Flame, Cooking, Heating Appliances
- Installed Air Supply in Buildings

Technology 1

- Suppression Systems for Open Flame, Cooking, Heating Appliances
  - Home Run
  - Increased Cost / Complexity
  - Uncertainty in Agent Choice
    - Characterize toxicity of suppressed fire (interaction with agent)
    - Characterize type of fire
    - Test method for Agent Effectiveness
  - Recharging and Maintenance
    - Human Factors, most effective way to get owner to repair system
  - Danger to person near suppressed fire (toxicity, splashing)
  - Stability of Agent Over Time
    - Measurement of aging characteristics
  - Miscellaneous Problems
    - Problem with sensors? Best method of detection?
    - Discrimination between desired and undesired heat sources (bananas foster?)

Technology 2

- Improved Smoke Detectors (Nuisance-Free)
  - Near Term
  - Time/cost for manufacturer
    - New performance standard for smoke alarms
  - Lack of Knowledge for Residential Multi-criteria Detectors
    - Characterize aerosol signature of nuisance fires
    - Measure performance of multi-sensor networks
  - Discriminating between cooking and unwanted fire
    - Characterize aerosol signature of nuisance fires
  - People disable smoke alarms
    - Measure why
    - Measure most effective way to communicate diagnostic information

Technology 3

- Improved Suppression Technology
  - Long Term
  - Cost / Prescriptive Standards, Conflicts Between Manufacturers
  - Insufficient Science / Fundamental Understanding (Interaction of water and fire / burning objects, flame spread over burning objects, etc. Other agents….)
    - Characterize effect of water (individual droplets) on heat release rate
    - Measure characteristics of spray (droplet size mass velocity)
    - Measure spray interaction with fire plume
    - Measure effectiveness of extinguishing agents
  - Suppressants delivery systems require too much piping
  - Unique suppression requirements of special hazards (i.e. lithium batteries)

Technology 4

- Predict Structural Collapse and Performance of Lightweight Construction
  - Multiple Measurement Science Needs
  - Resistance to Regulation / Awareness (affordable housing issues)
  - Lack of Understanding of Response of Structural Systems to Fire
    - Measure structural response to fire (experiments with loaded systems and subsystems)
    - Develop tools to predict structural response
  - Inability to Predict Fire
    - Develop tools to predict fire
    - Measure heat release of individual items
    - Measure heat transfer in building materials
  - Inability to Predict Material Response to Fire
  - Lack of Training in Design Profession
  - Issues of Different Scales

Technology 5

- Robotic Firefighting
  - Non-technical Barrier
  - Public and Firefighter Perception (Threat to Jobs)
  - Trust and Confidence
    - Assess trust and perception
    - Performance standard
    - Determine training requirements
  - Sensing and detection
  - Tolerance to terrain, fire conditions

Other technologies

- Responder Communications
- Mass Notification
- Sprinkler Reliability

Technology 6

- Responder Communications
  - Reluctance to Share Data / Interconnect Networks
  - Distrust of accuracy of information
  - IT requirements
  - RF Transmission in Challenging Environments
  - Processing / Reducing Data Flood in Real Time

Technology 7

- Mass Notification
  - Privacy (personal / organizational)
  - Nuisance Aspects / Behavior
  - Assurance of Accuracy
  - Multi-jurisdiction Conflicts

  - No Guidance on Message Design
  - IT Integration Over Multiple Formats / Systems

Technology 8

- Reduced Cost of Sprinkler Systems
  - Inertia of NFPA 13 interferes with development of new technology
  - Insufficient Understanding of Suppression

Technology 9

- Installed Air Supply
  - Perception of Potential Users / Trust in System
  - Reluctance of Building Owner / Cost

  - Human Factors
  - Long Term Viability of System w/o Maintenance

Technology 10

- Sprinkler Reliability
  - Non-Technical Barriers, Primarily Regulation
  - Increased Cost / Complexity

Fire Service Breakout Group

Technologies, Barriers and Measurement Science

- Improve Communication Equipment
- Virtual Environment Training & Data
- FF Tracker Locator
- Next generation FF respiratory protection
- Enhance FF Protection Clothing
- Enhance Suppression Dynamics
- FF Research Clearing House
- Sustainable Suppression (agents)
- Health Screening/Risk ID Tools

Game Changing Technology

- **Health Screening/Risk ID Tools**
  - Barrier: Unknown medical factors
    - Identify risk factors for disease
    - Quantitative medical factors and conditions
  - Barrier: Approved testing practices
    - Establish consensus testing protocol
  - Barrier: Exposure conditions, evaluation of impacts
    - Characterizing fireground conditions, interior attack, overhaul
    - Determine impact of conditions on firefighter health
  - Barrier: Economics, health care costs (non-technical)
  - Barrier: Public policy (non-technical)
  - Barrier: Lifestyle (non-technical)

Long Term Technology

- **FF Locator System**
  - **Barrier: Signal attenuation by structure**
    - Measure effect of structural materials and configuration on signals
  - **Barrier: FCC limitations**
    - Signal strength
    - Regulations
  - **Barrier: Systems integration**
    - Compatibility with other systems
    - Standardized information display
  - **Barrier: Power supplies**
    - Weight and performance
  - **Barrier: Capability to locate/track multiple assets**
    - Accuracy of system performance
    - Reliability of system performance
  - **Barrier: Access to floor plans**
    - Development of floor plan model software
  - Barrier: Systems costs (non-technical)
  - Barrier: Certification requirements (non-technical)
  - Barrier: Public policy (fed, state, local, non-technical)

Near Term Technology

- **Improve Communication Equipment**
  - Barrier: Signal attenuation by structure
    - Measure effect of structural materials and configuration on signals
  - Barrier: FCC limitations
    - Signal strength
    - Regulations
  - Barrier: Systems integration
    - Compatibility with other systems
    - Standardized information display
    - Integration into facepiece
  - Barrier: Power supplies
    - Weight and performance
  - Barrier: Voice recognition/audibility
    - Human factor measurements and metrics
  - Barrier: Retrofit costs (non-technical)
  - Barrier: Certification requirements (non-technical)
  - Barrier: Public policy (fed, state, local, non-technical)

Technology w/ Multiple Measurement Sciences

- **Enhanced Virtual Fire Environment Tool for Training and Data***
  - Barrier: Understanding fire and suppression mechanisms
    - Detailed suppression dynamics and fire physics
    - Model development and validation
  - Barrier: Ease of operation
    - Standardized operation and display of information
    - Multi-user dynamics
  - Barrier: Incorporate non-sight sensing data
    - Development of interactive "virtual reality environment" to simulate fire experience
  - Barrier: Data and validation
    - Experimental data
      - Fire, suppression, victim tenability, FF safety, structural integrity
    - Incorporation into modeling
  - Barrier: Consensus on performance metrics (non-technical)
  - Barrier: Systems cost (non-technical)

*** this can be used to better understand combustion/suppression for modeling and simulation**

Technology w/ Non-Technical Barrier

- **Clearing House/Review for Coordination & Planning of Fire Problem Research**
  - Barrier: Political will (non-technical)
    - Congress
    - Federal Gov't: DHS et al
    - Entire Alphabet Organizations
    - Other: Organizations/Associations/Societies/Unions
  - Barrier: Coordination of funding (non-technical)
    - Federal Gov't: DHS et al
    - Entire Alphabet Organizations
    - Other: Organizations/Associations/Societies/Unions
    - Academia
  - Barrier: Coordination of research agendas and dissemination of findings (non-technical)
    - Federal Gov't: DHS et al
    - Entire Alphabet Organizations
    - Other: Organizations/Associations/Societies/Unions
    - Academia

Fire Service Breakout

Metric	Description of Attribute
Ease of Technical Development	(high-easy, med, low-difficult) High ease means the technology is very feasible.
Multiple Stakeholder Benefits	(low, med, high) Probability of impacting multiple groups
Market Readiness/Timing	(<2, 2 – 5, >5)
Likelihood of Implementation	(unlikely, likely, very likely) Includes initial cost and other barriers
Overall Economic Benefit	($, $$, $$$)
Impact on Fire Problem	(low, med, high)

WUI Group

Technologies, Barriers and Measurement Science

Technologies:

- WUI risk model that includes market and non-market economics
- Benefit-cost assessment tools/models for retrofit technologies and systems approaches to retrofit
- Quantify ember quantities, transport, characteristics as function of wind and ignition potential
- Legislative mandate/incentive to retrofit existing homes
- Modeling of coupling of fire and atmosphere, and smoke transfer
- Technology to help document and analyze WUI fires
- Ember intrusion prevention technology
- Message development tool—sociological/ marketing, etc. education. deliver to homeowner to influence behavior

Technology 1

- **Legislative mandate to retrofit pre-existing homes**: (1) A “home run” that if successful would make a substantial impact on the overall fire problem; (2) An important technology that has non-technical barriers (i.e., social, political, and environment impacts/concerns)
  - Complexities of structures, products, and conditions and their influence
    - Relative effectiveness of technology options to be mandated
    - WUI definition independent of fire risk
  - Insufficient data
    - Relative effectiveness of alternative incentives
    - Funding—quantification of benefit-cost, etc.
  - Uniform test standards
    - Fire model measurements to identify most needed areas
    - Benchmarking globally can help understanding test standards

Technology 2

- **Fire modeling coupling weather, smoke, and fire-behavior**: (1) An important technology that can be implemented in the *long-term*; (2) An important technology that has *multiple* measurement science needs
  – Insufficient data
    - Deployable instrumentation for field data collection
    - Model validation
    - Material property measurements
  – Research complexities/difficulties of understanding physical interactions
    - Flame propagation for vegetation
    - Improved computing efficiency and algorithms optimizations
  – Cost to develop
    - Integrating different agencies
    - Performance metrics

Technology 3

- **Ember intrusion prevention**: An important technology that can be implemented in the *near-term*
  - Variability of the phenomenon and physical factors
    - Large verity of basic data of phenomenon
    - Basic/fundamental science data needs
  - Uniform test standards
    - Ember characteristics and generation/source of embers
    - Home and material ignition characteristics
  - Complexities of structures, products, and condition and their influences
    - Physics of heat and mass transfer

Global/Cross-Cutting Group

Technologies, Barriers and Measurement Science

- Home fire suppression retrofit kit (home run)
- Barrier materials to achieve VERY low combustible furnishings (near term)
- Problem detection and auto shut off for appliances (long term)
- Life-cycle analysis for fire protection systems (multiple measurement science)
- Multi-impact analysis for fire protection approaches (nontechnical barrier)

Metrics/Attributes: (Global/CC Session)

- **Targeted problem size** (L $1-5 Mil, M $10-100 Mil, H $1 Bil)
- **Impact** (L 10%, M 10-50 %, H greater than 50%)
- **Cost to end user** (L discretionary, M difficult, H unaffordable)
- **Ease of use** (L expert, M moderate, H elementary)
- **Ease of implementation** (L professional, M moderate, H elementary)
- **Acceptability to customer** (no, yes)
- **Reliability** (L 30%, M 60%, H 90%)
- **Speed to market** (L > 5 years, M 1-5 years, H < 1 year)
- **Speed to universal adoption** (L 50 years, M 10 years, H 2 years)
- **Criticality of decisions for tools** (L expert judgment sufficient, M lesser tool, H unique)

- Technology: Home fire suppression retrofit kit (homerun)
  - Non technical barriers
    - Myths
    - Education
    - Insufficient user knowledge for installation
    - Resistance to change
    - Overcome liability concerns
    - Resistance from traditional sprinkler providers, competition
  - Technical barriers
    - What is the goal (life safety)?
    - Acceptable level of performance (criteria)?
    - Knowledge of dispersion characteristics
    - Would non- water-based agents be effective?
    - What type of fires are we targeting?
    - Lack of a design concept that can be made effective, reliable and inexpensive

- **Technology: Home fire suppression retrofit kit (homerun)**
  - **Measurement Science Needs**
    - **Performance-based layout**
      - **Setting goal and metric**
      - **Set the challenge**
      - **Set the rules for estimating performance**
      - **Develop candidate designs**
    - **Storage or access to extinguishing agent (plumbed or not)**
    - **Procedure for reliable installation by amateurs**
    - **Assessing fire tests**
    - **Development of approval test**
    - **Minimization of quantity of agent**
    - **Benchmark against residential sprinklers**

- Technology: Barrier materials to achieve VERY low combustible furnishings (near term)
  - Non-tech barriers
    - Acceptance by manufacturers
    - Aesthetics for consumers
    - Resistance to need
  - Tech barriers
    - Acceptable level of combustibility
    - Integration of barrier into furniture product
    - Durability of product (continued function to stop fires)
    - Lack of test method
    - Ignition resistance (what level)
    - Environmental or health impacts from materials that are developed or used

- **Technology: Barrier materials to achieve VERY low combustible furnishings (residential and vehicles) (near term)**
  - **Measurement Science Needs**
    - **Hazard analysis to determine level of performance needed**
    - **Accelerated aging and durability analysis**
    - **Small scale test that captures real scale performance for whatever the hazard analysis dictates**
    - **Benchmark for environmental impacts of what we do now**
    - **Estimate performance for materials**
    - **Address manufacturing issues of integration of barriers into product**

- Technology: Problem detection and auto shut off for appliances (long term)
  - Non-tech barriers
    - Consumer resistance based on false positives
    - Lack of product education
    - Aesthetics
    - Manufacturer resistance
    - Liability exposure
    - Consumer resistance to feature
    - Preference for alternative approaches to the problem (e.g. AFCI)
  - Tech barriers
    - Vulnerability to overriding safety features
    - Development of test standards
    - Ease of reset
    - Detection logic and action thresholds
    - Integration with other fire sensing devices

- **Technology: Problem detection and auto shut off for appliances (long term)**
  - **Measurement science needs**
    - **Failure mode analysis; identification of thresholds for action and scales**
    - **Quantify false positives and negatives**
    - **System integration impacts: power, data transmission, avoid false positives**
    - **Assessment of vulnerability to tampering**
    - **Test standard or procedure**

- **Technology: Life-cycle analysis for fire protection systems (multiple measurement science)**
  - **NT barriers**
    - Resistance from system advocates based on cost and complexity
    - Trusting reliability of data
    - Consumer resistance in replacing fire protection systems
    - Lack of certification of users
    - Liability for those who use the tools to give advice to others
    - Confidence in the long-term data
    - Resistance from manufacturers
    - Environmental concerns; add burden to landfills if detectors must be thrown away
  - **Tech barriers**
    - Environmental conditions (any degree of insensitivity to critical factors)
    - Practical means of accessing the needed data
    - Common framework for data archiving; usability of interface
    - Accelerated aging tests

- **Technology: Life-cycle analysis for fire protection systems (multiple measurement science)**
  - **Measurement Science Needs**
    - **User interface: flexible, customized**
    - **Develop data and access to other's data**
    - **Test protocol for aging**
    - **Test protocol for model validation**
    - **Develop model architecture; explicit about applications**
    - **Standard for the modeling approach**

- **Technology: Multi-impact analysis for fire protection approaches (nontechnical barrier)**
  - **NT barriers**
    - **Acceptance of a true cost/benefit with respect to life loss**
    - **Reliability of data**
    - **All barriers from Life-cycle can be absorbed here**
    - **Lack of agreement on relative weighting on different scales: lives, environment, no clear path to a consensus**
    - **Concept of acceptable risk**
    - **Resistance from traditional fire safety advocates**
    - **High uncertainty of best available tools (could also be considered a tech barrier)**
  - **Tech barriers**
    - **Access to needed data**
    - **Data architecture (GPS)**
    - **Establish boundaries (intended use confidence level)**
    - **Documented standardized approach**

- **Technology: Multi-impact analysis for fire protection approaches (nontechnical barrier)**
  - **Measurement Science Needs**
    - **Access to input data**
    - **Development of model architecture; diverse applications to determine impacts**
    - **Validation protocol**
    - **User interface**
    - **Standardization of the modeling approach**