Reducing the Risk of Fire in Buildings and Communities

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ABSTRACT

Fire costs and losses are a significant life safety and economic burden on society comprising about two percent of the United States gross domestic product. This paper presents the results of a roadmap developed by the National Institute of Standards and Technology (NIST) in response to the U.S. fire problem and proposes ways to best reduce fire losses and costs in buildings and communities. In an effort to address the most pressing fire problems, attention is directed towards the burden of fire on communities, structures and their occupants, the fire service, and the economy in three key areas: Reducing fire risk in buildings, Advancing fire service technologies, and Reducing fire risk in wildland-urban interface (WUI) communities. The roadmap sets targets for new measurement capabilities that underpin innovation in fire-risk-reducing technologies and best practices. These advanced capabilities are required to overcome technical hurdles that stand in the way of nascent or current technologies with the potential to deliver a wide range of fire safety benefits. The roadmap stresses the measurement science needed to enable the most promising technologies that will reduce the preventable burden of fire in the three focus areas. The breadth of key technology issues ranges from reliable nuisance-free fire detection, improvements in the fire-safety design and construction of buildings and communities, to better firefighting equipment and tactics, to more effective approaches to preventing and responding to "wildland-urban interface" fires, which is a rapidly growing problem in the U.S. and many other countries. The roadmap sets short, medium and long-term goals for accomplishing the overall objective of reducing the U.S. fire burden and emphasizes the importance of science-based standards, regulatory codes, engineering tools, and best practices.

KEYWORDS: Fire safety, roadmap, strategic planning

THE U.S. FIRE PROBLEM

Life safety associated with fire has been improving in the U.S. over the last three decades as seen in Figure 1 and Tables 1 and 2 with data provided by the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS) as analyzed by the National Fire Protection Association (NFPA). [1] The decrease is even more significant if the rising U.S. population is considered. [2] On the other hand, the number of civilian deaths and injuries normalized by the number of reported fires has essentially remained flat, while the number of firefighter injuries and fatalities has significantly increased on a per fire basis (see Table 2). Furthermore, the cost of fire protection has increased, and new and potentially costly threats to fire safety are emerging. Consequently, now is an appropriate time to address this continuing problem and consider how best to achieve consistent and significant reductions in overall fire losses and costs.

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

In 2008, the U.S. experienced about 1.5 million reported fires, 3320 civilian fatalities, 16 700 civilian injuries, 105 firefighter fatalities, and 79 700 firefighter injuries. [1] For 2008, the *Total Fire Burden*, that is the sum of all costs and losses associated with fire, was estimated to be about $314 billion (in 2008 dollars) [3] or 2.2 % of the gross domestic product. Costs and losses can be broken into: fires in structures ($185 billion), wildland-urban interface (WUI) fires ($14 billion), vehicle fires ($6 billion), and fire service costs ($109 billion). Due to uncertainty, the actual 2008 *Total Fire Burden* is estimated to range from $230 billion to $460 billion. [3] While some costs are not preventable, to ensure the current level of life safety, a significant fraction could be reduced by implementation of advances in technology and knowledge. The National Institute of Standards and Technology's (NIST) long-term vision is that *unwanted fire be removed as a limitation to life safety, technical innovation, and economic prosperity in the United States.* To systematically address the national fire problem, complementary efforts in education, engineering solutions, and code enforcement are all important, but are not addressed here. This paper presents a summary of a technology-focused roadmap developed by the NIST based on input from the fire protection community, stakeholders, and government staff, as a response to the U.S. fire problem. [3]

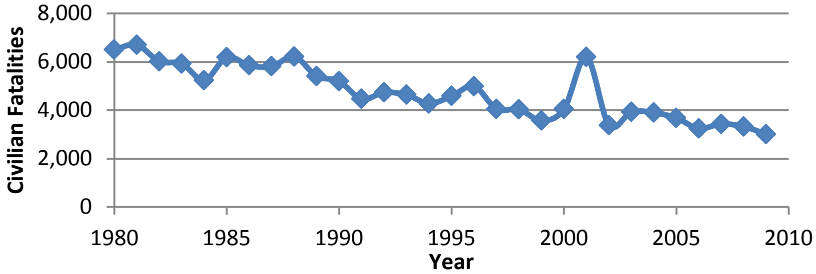

Figure 1. Civilian fire deaths. [1]

Table 1. U.S. Fire Losses from 1980 to 2008. [1]

Year	Reported Fires	Civilian Deaths	Civilian Injuries	Firefighter Deaths	Firefighter Injuries	Core Cost ($ B 2008 dollars)
1980	3,000,000	6,505	30,200	138	98,070	$74 B
1990	2,250,000	5,195	28,600	108	100,300	$86 B
2000	1,750,000	4,045	22,350	103	84,550	$102 B
2008	1,451,500	3,320	16,710	105	79,700	$138 B

Table 2. Normalized U.S. Fire Losses from 1980 to 2008.

Year	Reported Fires per Capita	Civilian Deaths per 1000 Fires	Civilian Injuries per 1000 Fires	Firefighter Deaths per 1000 Fires	Firefighter Injuries per 1000 Fires	Per Capita Core Cost (2008 dollars)
1980	0.0132	2.2	10	0.046	33	$330
1990	0.0090	2.3	13	0.048	45	$340
2000	0.0062	2.3	13	0.059	48	$360
2008	0.0048	2.3	12	0.072	55	$450

CHANGING FIRE SAFETY LANDSCAPE

The fire safety landscape is complex, dynamic and influenced by societal, technological and environmental changes, which can either support or inhibit progress. New problems arise and old problems may reappear. Current gaps in understanding limit the ability to create new fire safety technologies, to devise efficient ways to make fire safer products without sacrificing other functional requirements, and to demonstrate that proposed innovations are technically feasible, safe, and economically viable. [4] Advances in computing, materials, and sensors enable new capabilities, and technologies offers new opportunities, but cannot itself eliminate the burden of fire as aspects of the problem are related to cultural, educational, and societal issues. Changing demographics and an aging population can affect fire safety as risks vary by age group, race, region, and community size; higher fire death rates are seen in states with a large percentage of people who possess one or more of the following characteristics: poor, smoker, less formal education, or living in a rural area. [5] Financial constraints on localities place limits on fire service resources. An aging infrastructure requires new approaches to preserving fire performance while restoring functionality and ensuring resilience. Sustainability, climate change, and environmental and human health considerations can also influence fire safety. Changing building designs and practices present new fire protection challenges and opportunities. Legislation and model code changes are important and represent a unique fire safety opportunity. Professional inertia, exemplified by the current U.S. system of often archaic and prescriptive fire standards and codes, stifles innovation of fire safety systems, technologies, and building design. As the fire safety landscape continues to change, the best ways to address fire problems need to evolve through planning and collaboration among the broad fire protection community. [6,7,8] A national strategy is needed.

REDUCING THE FIRE BURDEN

The strategy to reduce the risk of fire in buildings and communities emphasizes outputs and outcomes that advance existing and emerging technologies, which address significant and preventable portions of societal fire burden. A series of complementary approaches are needed to solve various parts of the fire problem, as no single solution will completely work. To achieve technological solutions, a series of research hurdles must be overcome. A timeline for the research priorities is given in Ref. [3]. A true measure of success will only be clear over the next generation as data on the national fire burden becomes available, through traceable third-party fire statistics such as the National Fire Protection Association's (NFPA) *Annual Summary of the U.S. Fire Problem*, including a net decrease in fire-related civilian injuries and fatalities, fire-fighter injuries and fatalities, direct and indirect fire property losses, and fire protection costs. The NIST roadmap [3] builds on the work of other organizations that have performed similar planning exercises and proposed various strategies to attack parts of the U.S. fire burden. The research to enable the strategy is organized into three focus areas:

- Reduced Fire Risk in Buildings
- Advanced Fire Service Technologies
- Reduced Fire Risk in Wildland-Urban Interface (WUI) Communities

Strategic Focus Area: Reduced Fire Risk in Buildings

The burden of building fires in 2008 was characterized by about 500 000 reported fires, 2900 civilian fatalities, 15 000 civilian injuries, \$14 B in direct property loss, \$63 B in fire protection in constructed facilities, and \$74 B in fire protection costs for equipment and standards. *The objective of this focus area is to increase the safety of building occupants and the performance of structures and their contents by enabling innovative, cost-effective engineered fire protection* *technologies*. While there are other viable frameworks, the NFPA Guide to the Fire Safety Concepts Tree [9] is a useful basis for deriving strategies to evaluate how fire protection objectives can be best achieved. It involves effective strategies for preventing and managing a fire, and addressing issues for those exposed to a fire. Cost-effectiveness and life safety as well as commercial and residential buildings are considered. Systematic consideration of how to intervene in the fire timeline is a key part of the analysis - i.e., addressing the incident before and during fire occurrence. To reduce the preventable burden of fire in buildings, several approaches are considered:

- Engineered Fire Protection,
- Safety of Building Occupants,
- Advanced Flammability Performance of Materials and Products,
- Next Generation Reliable Detection of Incipient Fires, and
- Performance-based Design.

Engineered fire protection systems utilize three primary means to reduce the threat of fire: containing the fire, suppressing the fire, and controlling the heat and smoke. These features are more frequently deployed in commercial and high-value structures, than in residential construction. Automatic sprinklers have demonstrably reduced losses in residential fires. [10] While the International Residential Code (IRC) was recently modified to require a residential sprinkler system for new one and two-family dwellings, [11] widespread adoption has not been achieved and retrofit in existing homes is costly and impractical. Therefore, novel methods to suppress a fire during its initial phase could have significant impact. These methods may be targeted to specific products (cooking fire suppression, for example, in the form of a non-plumbed suppression system) or may be systematic, such as robotic fire suppression that can detect and actively move through a residence to deliver a suppressant.

Hall indicates that one-fourth of fire victims perish during evacuation, which suggests that as many as 700 people could be saved by egress improvements. [12] However, design changes in single-family residences (with the possible exception of requiring a second means of escape from basements and upper stories) would not address the root causes [13] of residential life loss. Further, improvements in signage, markings, stair width, and emergency lighting would not likely save many lives in residences where occupants tend to be familiar with the egress routes and occupant crowding during escape is not the issue. Residential fire fatalities would be better addressed by reducing the number of fires and the resulting fire growth and spread, and by advances in detection to provide very early and reliable warning. In non-single family residential buildings, improvements in egress signage, markings, and lighting as well as use of elevators would be useful to consider. A key technology for enhanced egress is an elevator that can be used by occupants to escape during a fire. This would be especially valuable for people with conditions that make egress difficult, a group estimated as 6 % of the occupants of the World Trade Center towers. Advanced egress design could also mitigate the growing costs of fire protection features in building construction, which are now approximately $10 B annually.

Ideally, the fire problem would be solved through prevention, accomplished by eliminating ignition sources or by making "targets" resistant to thermal threats. Most building fire losses are due to just a few types of ignition sources and first items ignited. [14] Smoking materials stand out as the leading ignition source, accounting for about one in four of the fire deaths and 10 % of the injuries. [15] Two of every five reported home structure fires started with cooking equipment accounting for 15 % of the civilian fire deaths, and 37 % of the injuries. [14] In 2006, electrical distribution or lighting equipment was identified as a significant fraction of the first item ignited in residential fires, accounting for about 120 000 fires, 860 civilian deaths and more than $2.3 B in property loss. A majority of the electrical fires were the result of wiring, cord and plug failures. In 2006, fires involving soft furnishings led to about 30 % of the deaths, 17 % of the injuries, and 11 % of the property damage. Yet, the role of soft furnishings is probably significantly underestimated. [7] Unlike other items such as building materials or wire and cable, a change in the fire performance of soft furnishings could have widespread impact in less than 20 years due to its expected life cycle. Beyond soft furnishings, thermoplastic polymers (curtains, wiring cable insulation, carpeting and electronic appliance housings) appear to play a large role in the first item ignited in over 29 000 fires per year, resulting in 280 deaths and over 1100 injuries. In addition, thermoplastic-based fabrics used in upholstered furniture and bedding are a significant contributor to annual fire losses. Consequently, a number of emerging or future ignition fire prevention technologies need consideration including the next generation of low-ignition propensity cigarettes, self-regulating cook-tops, advanced materials and coatings to prevent ignition of furnishings and construction products, and the next generation of self-monitoring space heaters. Better information on fire losses is needed as about half the losses are associated with unknown ignition sources.

A recent analysis of U.S. fire statistics by NFPA showed that about 22 % of civilian deaths occurred in homes with smoke alarms present, but that failed to operate, and 43 % of civilian deaths occurred in homes with no smoke alarms. [16] It is estimated about 1000 additional lives could be saved annually in the U.S. if all homes had working smoke detectors. [17] About half the homes without working alarms had units installed that did not properly operate due to missing or discharged batteries or intentional power source interruption. [18] Unreliable detection that leads to false alarms due to nuisance sources is thought to be a contributing issue. A quicker detector response to a range of fires with reduced nuisance alarms may be a key component to reducing fire fatalities. Early and reliable alarming has been shown to improve survivability and reduce property loss. Analysis by Hall indicates that roughly half of the fatalities and two-thirds of the injuries could be prevented if the time to incapacitating exposures was sufficiently lengthened, if alarms were successful in waking sleeping victims, and if victims in close proximity to a fire were able to escape; sufficient extra time alone would likely reduce about one-quarter of the fatalities and injuries. [19] A new generation of highly sensitive and reliable (false alarm free) alarms is needed and would have significant benefit. Another benefit of nuisance-free fire detection is that fully reliable detection is needed to allow direct transmission of alarm information from a residence to a local fire department. The resulting reduction in fire department response time would improve chances of survival for victims unable to escape a fire without assistance.

Most fire safety requirements currently are prescriptive, rather than performance-based, inflating construction costs by more than 0.5 % of the $1.2 trillion U.S. annual construction and building costs. [20,21] A suite of validated engineering tools (deterministic and stochastic methods) with quantified uncertainty are needed to perform risk analysis and advance performance based design, including tools to better predict fire spread and growth on real materials, the effectiveness of active fire protection systems, the relationship between building design and people movement, and the effect of fire effluent on people movement and behavior. At the same time, bench-scale tests are needed to predict the impact of material and geometry changes of interior furnishings on fire growth. Design tools are also needed to assure full building burn-out without collapse, to predict building fire resistance performance from small-scale tests, and to enable the use of innovative materials and designs. Standard test methods are needed to evaluate fire resistance of structural components, connections, assemblies, and systems at elevated temperatures for improved fire resistance design and retrofit of buildings. NIST's National Fire Research Laboratory scheduled to open in 2013 will provide advanced capabilities to test the performance of real-scale structures under realistic fire and structural loading, enabling the next generation of performance-based standards for fire resistance design of structures.

Research is needed to enable and improve emerging technologies that have a significant potential to reduce the risk of fire hazards in buildings, including next generation detectors (early, fully reliable, nuisance resistant, self-diagnose malfunctions), automatic fire department notification, fire barrier materials for soft furnishings, ignition resistant upholstery fabrics, second-generation low ignition propensity cigarettes, self-regulating cooking units, next generation self-monitoring space heaters, non-plumbed and robotic fire suppression systems, next generation sustainable fire retardants, advanced materials, and advanced predictive tools.

Strategic Focus Area: Advanced Fire Service Technologies

In recent history, firefighter safety has been characterized by about 100 on-duty deaths and more than 80 000 injuries annually. These numbers are affected not only by the quality and condition of firefighters, their training, their equipment, and fireground procedures, but also by the number and nature of the fires attended. The annual cost of maintaining fire departments is about $40 B, not counting the larger value of volunteer labor. The majority of firefighter (and civilian) injuries and fatalities occur in residential buildings. The majority of on-duty firefighter deaths are associated with heart attack, stress and over-exertion. [22,23] A significant number of firefighter fatalities are associated with those caught or trapped and unable to escape a fire, as well as exposure to heat, smoke, and toxic gases. More than half of the injuries occur on the fire ground with about 10 % during training. Significant strains, sprains, and muscular pain were the most frequently reported injury category; wounds also constitute a significant fraction of the injuries. [22,23] To reduce the preventable fire burden associated with the fire service, several areas need improvement, including:

- Equipment,
- Tactics,
- Training and Education,
- Strategic Resource Allocation, and
- Situational Awareness.

The objective of this focus area is to increase the effectiveness and safety of firefighters by enabling the development of improved science-based tactics, tools, and equipment. Enhanced personal protective equipment (PPE) and electronic equipment is needed to provide adequate protection from the extreme firefighting environments. Advances in operational equipment that is user-friendly, lightweight, thermally durable, and robust (e.g., apparatus, nozzles, hoses, pumps, ladders, extraction equipment, robotics, cooling stations) require methods to evaluate their effectiveness. A new generation of robust smart firefighting equipment for extreme environments combining sensors, computational resources, and communication would enhance fireground operations (e.g., monitors that predict imminent building collapse; sensors that alert of impending fire conditions). The embedded intelligence and linked technologies would support improvements in functionality, heat resistance, size, and weight of firefighting equipment. Robotics could be useful for high-risk operations such as rescue.

In the U.S., firefighting tactics often rely on tradition and experience; there are no national standard operating procedures (SOPs) for firefighting. While there have been significant changes in construction (building size, design, glazing, materials) and interior furnishings (thermo-plastics), firefighting tactics have not kept pace. Research and implementation of science-based tactics are needed to inform fireground operations and advanced decision aids are needed to guide incident decision making. Emerging cyber-physical systems combining existing and new sensors with computers to identify occupants, fire location, and direct suppression resources would enable a new paradigm of smart firefighting.

Improvements in firefighter training along with community education programs are needed to prepare the fire service and the community for emergency events. There is no national standardized firefighter curriculum in the United States. The development of such a curriculum with associated training would increase operational effectiveness and reduce the risk of injury. This includes a heavy emphasis on fire dynamics and physics-based (not “theatrical”) training.

Appropriate resources are needed to respond to emergency events. The economic return from investment into firefighting resources is poorly understood and inadequately tracked. Cost effective resource planning requires detailed information on costs versus benefits including the number and location of fire stations, number, type, and location of fire apparatus, firefighter staffing levels, and pre-planned alarm assignments. Resource allocation must also address community infrastructure such as hydrants and building inspections.

Situational awareness is a key to safety and effectiveness of firefighters including the layout of a structure, firefighter and building occupant locations, building contents (chemicals or other unusual hazards), access points, water availability, adjacent structures, and suppression options. Emerging cyber-physical technologies that enable real-time tracking and analysis of fire location and conditions, fire ground operations, and information on the status and location of all emergency responders and changing egress routes are critically needed. Standard test methods are needed to ensure that tracking is of acceptable accuracy and reliability in extreme environments. Improving communication is also of critical importance. Currently, firefighters have problems communicating with each other and the Incident Commander. Communication systems must be compatible and the command structure adequate to affect timely and coordinated actions. Sensors and controls for fire detection, suppression, and tactical decision-aids could be integrated into design of new buildings, worn by a firefighter, or for robots sent into a fire to monitor the environment.

Research is needed to enable and improve physics-based virtual training tools, biometric monitors and guidelines for use, environmental sensors linked to exposure warning systems, health screening tests for health risk factors, resource guidelines and risk analysis tools for crew sizes and station location, use of building sensors for fire control, real-time modeling, wireless information for IC decisions, structural collapse monitors to track building integrity and warn firefighters, body worn sensors (biometrics and fire environment monitors), flashover predictors that track conditions and alarm, personnel locator and tracking systems, advanced/integrated self-contained breathing apparatus (SCBA) that include a personal alert safety system (PASS), communication, heads-up display, improved lightweight, durable, and robust equipment, smart firefighting equipment combining sensors, processors, and/or communication, robotics for high-risk fire operations, passive/active cooling turnout gear, physics-based tactical decision aids, and smart tactical decision tools based on fireground sensor data and computation.

Strategic Focus Area: Reduced Fire Risk in Wildland-Urban Interface Communities

The wildland-urban interface (WUI) encompasses housing and other structures that are either collocated or abut wildland vegetation and forest. WUI communities are especially susceptible to destruction from wildland fires. In the U.S. over the last 100 years, 6 of the top 10 fire losses occurred in WUI areas. [2] More than 45 million homes in 75 000 communities are at risk of WUI fires with an average of 3000 structures destroyed annually over the last decade. The burden of WUI fires is estimated as about $14 B annually and rapidly growing with significant suppression and wildland fuel treatment costs. Recent increases in costs, area burned, and fire occurrences in WUI communities imply an intensification of the WUI fire problem. The traditional approach to mitigating WUI fires has been to control or suppress a wildland fire as quickly as possible. The 3% of wildland fires that are not quickly suppressed threaten communities. These typically involve extreme fire behavior such as high winds, prolonged dry conditions, and accumulated fuels. Using principles of ignition and fire spread in the WUI, standards development organizations such as the NFPA, the International Code Council (ICC), and ASTM International have developed building codes and standards for WUI communities. However, the range of actual exposures has not been fully characterized, resulting in a very limited coupling between the potential exposure that a structure might experience and the performance requirements in building codes and standards. While WUI communities have a limited number of design requirements, most are not performance based or realistic. Reducing the likelihood of structure ignition is needed to reduce the WUI fire problem. [24]

The objective of this focus area is to mitigate WUI fires and increase the fire performance of structures and communities by enabling development of innovative engineered fire protection technologies, fire resistant designs, standard test methods, and risk assessment tools for use by architects, builders, community decision-makers, homeowners, and fire officials. Advanced fire mitigation technologies for WUI building elements and materials, structures, parcels, communities, and surroundings are emphasized through:

- Prevention of Fire in WUI Buildings and Communities,
- Fire Protection Engineering in the WUI,
- Response for Improved Firefighter Safety and Effectiveness and People Evacuation, and
- Recovery Guidelines for WUI communities.

Prevention efforts are needed on fire resistant materials and vegetation (fuels management), stakeholder education and compliance, and engineered fire resistant design. Hardening WUI structures and communities requires realistic test methods, better understanding of ignition phenomena particularly for embers, and research on ignition resistant construction materials and design. A new exposure scale is needed that quantifies the intensity of expected fire and ember exposure (for various fuel types, terrain, and weather) applicable to WUI communities, which provides a basis for performance-based building code and land-use.

Engineering fire resistant design for building components, structures and communities is the focus of mitigation that begins with improving risk assessment tools and using engineered fire protection to mitigate or limit the impact of a WUI fire. Lessons learned for interior fire protection need to be reconsidered for outdoor WUI fire protection in buildings and communities.

WUI fires differ from structural fires; they are more complex and require different suppression equipment and operating procedures. Because existing standards are directed to either wildland or structural firefighting scenarios, WUI-specific standard equipment and operating procedure standards need to be developed to effectively fight fires in the WUI. Improved guidelines and standards are needed for unified command and cooperative tactics to improve attack effectiveness as well as equipment to protect responders.

Recovery and rebuilding communities needs to incorporate advanced ignition-resistant materials, improved methods of construction, and enhanced fire-resistant designs. The limited exposure information currently available does not address the full range of realistic WUI exposures and offers little context for the design and construction of ignition-resistant landscapes and buildings.

Improved fire performance of structures and communities in the WUI must include ignition-resistant materials and construction, engineered fire-resistant design, passive and active fire protection, risk assessment tools, implementable codes, stakeholder education and compliance, and firefighter safety and effectiveness.

RESEARCH ENABLED IMPACT

The process of achieving fire safety progress requires three stages of organizational commitment, which includes (i) developing a technical basis to initiate or support a particular fire safety improvement and translating this into usable code or standard format; (ii) Performing additional research to address issues arising during standardization technology development, and code implementation phases; and (iii) following implementation of the standards and code provisions, identifying external changes that have the potential to negate the safety gains. These activities occur over many years and can require various amounts of resources and follow-up. Real-world impact may take decades to discern. In the short term, contributions to reduce fire losses can be evaluated based on a broad list of outcomes, including the development or improvement of best-practices, standard operating procedures, or specifications, technologies, standard reference materials, manufacturing processes, patents, and research publications or software that is used. Domestic and international standards and codes development is an especially effective means to translate research outputs into tangible and long-lasting impacts on the national fire problem. To reduce the costs of and losses from unwanted fires, the scientific basis for technically sound codes and standards are needed through domestic fire safety standards and code provisions, International standards, which help ensure that international products meet specific safety requirements, and regulatory rulemaking by key states and other Federal agencies. In the U.S., key states, such as California, Texas, and others have significant influence in regulatory rulemaking conducted by other states. Long term, a tangible and objective marker of success is observable improvement in the national fire statistics including reduced civilian and firefighter fatalities and injuries, improved cost-effectiveness of building fire protection systems, and reduced property loss and other core costs. [3]

Fundamental and applied fire research over the last few decades has facilitated a safer world. Some of the work has revolutionized fire safety. To continue to reduce the burden of fire on society, exploration of new scientific and engineering approaches, measurement methods, and technologies are needed. While research has a distinct function in furthering fire protection and public safety, it is a supporting role. Research does not promulgate building codes or establish product standards, does not encompass compliance testing, does not include testing or manufacturing fire protection products, and does not provide public and professional education, or promote the use of fire protection products and technologies in the marketplace. Research does enable the technical basis for these functions, which are critical endeavors of the greater fire protection community. There are many players in the fire protection community. Due to the size and nature of the fire problem, the best hope of achieving lasting impact is through collaboration with organizations involved with fire protection, including those in the fire safety, business, industrial, public and professional education, academic, government (code and enforcement officials, emergency responders, regulators), product testing, certification, and standards and model code development communities. The entire community of fire safety organizations needs to work together, if the vision of a fire-safe future is to be realized.

The NIST roadmap [3] was developed to provide a shared vision for communication, bring the limited available resources to bear on the U.S. fire burden in a focused manner for enhanced effectiveness, provide a basis for strategic planning, and identify gaps in knowledge that hinder the development of critical enabling technologies. History has shown that the field of fire safety has demanded and spawned technological advances. Tens of thousands of lives have been prolonged because of such classic inventions as the automatic sprinkler, the rollable fire hose, and the smoke detector. Today, the cultural and technological environment in which fire safety is provided is experiencing change as never before. New products, materials, technologies, advances in computing, advanced information analysis and availability, and environmental constraints are driving new concepts for preventing and mitigating fires as prevalent approaches are strained. This changing landscape requires constant observation and re-assessment of the most critical research needs. By necessity, this roadmap will need to evolve as technical progress continues, as new problems emerge, and as the world of fire safety progress changes. This document ought to be periodically reviewed to ensure that it is current.

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