EL Program: Fire Risk Reduction in Buildings

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Strategic Goal: Measurement Science and Standards for Disaster- Resilient Buildings, Infrastructure, and Communities

Summary: The total cost of fire in the United States in 2008, as defined by NFPA, is estimated at $310 B, or roughly 2 % of U.S. gross domestic product. Structure fires and fire protection account for $170 B. To reduce the U.S. fire burden, the Fire Risk Reduction in Buildings program focuses on the development and application of measurement science and standards directly on the two largest components of the structure fire problem: a reduction in the cost of installed fire protection through performance-based design ($63 B) and a reduction in residential fire losses ($31 B), which includes deaths, injuries, and property loss, through science-based prevention and mitigation.

DESCRIPTION

Objective: To develop and deploy advances in measurement science to increase the safety of building occupants and the performance of structures and their contents by enabling innovative, cost-effective fire protection technologies by 2016.

What is the problem? The total cost of fire in the United States in 2009, as estimated by NFPA, is $331 B, or roughly 2.3% of U.S. gross domestic product.[1] An analysis of the total social cost of fire in buildings in the U.S. was documented in the Strategic Roadmap for Fire Risk Reduction in Buildings and Communities[2]. Of the total cost, structure fires and fire protection account for nearly $185 B.[3] Fire protection costs ($63 B) are the single largest component of the structure fire problem and are typically estimated from 2% of construction costs overall in the developed countries up to 12% of construction costs for non-residential buildings in the U.S.[4] The second largest component of the structure fire problem is $35 B in direct fire losses (property loss and civilian injuries and deaths). Structure fire losses are dominated by residential fires, totaling $30.7 B in 2009 (85% of all fire deaths, 77% of all fire injuries, and 72% of all structure fire property loss).[5] This program is focused on reducing the total social cost of the two largest components of the U.S. fire burden, namely fire protection costs through advanced building design and residential fire losses through improved materials and sensing.

Why is it hard to solve? Fire protection is multi-disciplinary. The degree of complexity of interacting fire processes involving complex chemistry, radiative and convective heat transfer, differing combustion modes, fluid dynamics, structural dynamics, and human behavior preclude the use of existing approaches and tests that address only one of these disciplines. The lack of knowledge about interacting fire processes inhibits accurate simulation of fire spread, growth, detection, suppression and egress for a typical building fire. Special emphasis is placed on gaps between disciplines that are roadblocks to meaningful progress.[6] The Program is composed of 10 projects, addressing key measurement science challenges. For fire modeling, state of the art sub-models are needed to describe complex fire-related phenomena such as turbulent flow, combustion, radiative heat transfer for length and time-scales that vary many orders of magnitude. For fire protection in buildings, methodologies are needed to account for uncertainties in the estimate of safety margins for fire performance and to demonstrate that proposed innovations are technically feasible, safe, and economically viable. Challenges in structure-fire measurements include extremely harsh thermal environments, measurement

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[1] Hall, J. The Total Cost of Fire in the United States. National Fire Protection Association, Quincy, MA. Feb 2012.
[2] Hamins et al., Reducing the Risk of Fire in Buildings and Communities: A Strategic Roadmap to Prioritize and Guide Research, NIST SP 1130, April 2012
[3] This value is determined by starting with the total cost and subtracting the cost of career fire departments, the cost of volunteer fire departments, and the cost of firefighter injuries and deaths.
[4] "World Fire Statistics," Geneva Association Information Newsletter, No. 21, October 2005; John R. Hall, Jr., Total Cost of Fire in the U.S., National Fire Protection Association, Fire Analysis and Research Division, March 2010.
[5] Karter, M. *Fire Loss in the United States During 2009.* National Fire Protection Association, Quincy, MA. August 2010.
[6] including pyrolysis and flame spread on heterogeneous building materials, sub-lethal toxicity of fire products, human behavior in fire environments, including egress and ingress in emergency situations, temperature-induced failure of structural elements and load redistribution in fire-weakened structures, innovative training methods for firefighters and code officials.

interference, scaling issues, and turbulent, time-evolving flow fields. Furthermore, developing the measurement science tools to enable industry to accurately evaluate the sustainability of fire safe products, including both gas-phase retardants (such as halogenated compounds such as bromine), as well as those based on nano-materials, is primarily impeded by the lack of data available on their sustainability, i.e., the data are not available on their environmental health and safety, manufacturability, ageing and recyclability. The challenge of coupling the difficult fire problem to the equally complex sustainability analysis is considerable.

How is it solved today, and by whom? Many parts of the national fire problem remain unresolved and innovation is limited due to gaps in measurement science. For fire safety design in constructed facilities, many fire protection professionals and building designers still follow the traditional prescriptive-based approach. While recent fire safety innovations such as improved mattresses and reduced ignition propensity cigarettes will continue to lower fire losses, a performance-based approach will provide flexibility for cost-effective fire safety design to achieve an acceptable level of fire protection. This will enable U.S. building and fire protection industries to compete effectively in the global marketplace as more and more countries are transitioning from prescriptive-based fire safety to a performance-based approach.

Fire research is conducted in commercial laboratories (Factory Mutual Global, Southwest Research Institute), US government laboratories (Sandia, NRL, FAA), and around the world (NRC-Canada, BRE, BRI, SP, SKLFS). However, most groups focus on their mission, which is some subset of the issues, e.g., the flammability performance, passing new regulations, material cost, halogen/environmental, or nanotechnology aspects only. In Europe, the PREDFIRE NNANO program focuses on non-halogenated nanoclay flame retardants, but not on the development of better bench scale flammability tests or sustainability.[7] This program is only open to European industry and therefore puts US industry at a competitive disadvantage, especially with respect to dealing with European regulations mandating steps towards sustainability (e.g. REACH, RoHS, WEEE).[8] A concerted program on developing sustainable flame retardants has been called for by VECAP participants and sought by polymer companies and fire retardant manufactures.[9].[10] Elimination of halogenated fire retardants (whether voluntarily by industry or through regulations due to EH&S impacts) will have a negative

7 PREDFIRE NANO- Predicting Fire Behavior of Nanocomposites from Intrinsic Properties, http://www.engj.ulst.ac.uk/predfire/project.php

8 European Union, "Registration, Evaluation, Authorization and Restriction of Chemicals" (REACH), EC Reg. No 1907/2006 (2006), "Restriction of Hazardous Substances Directive (RoHS), Dir. 2002/95/EC (2003), "Waste Electrical and Electronic Equipment Directive" (WEEE) Dir. 2002/96/EC (2003).

9 Polybrominated diphenyl ethers (PBDEs) and Hexabromocyclododecane (HBCD) are very widely used fire retardants, and are both the subject of future regulations. The European Union has adopted the Restriction of Hazardous Substances Directive (RoHS) (and the related Waste Electrical and Electronic Equipment Directive (WEEE)), under which PBDEs are currently banned; similarly, HBCD is proposed to be banned under a pending RoHS revision. Walmart and Washington State have recently banned products with PBDE. A global ban on HBCD is currently being considered under the framework of the Stockholm Convention on Persistent Organic Pollutants (an international environmental treaty, to which the US is a signatory).

10 www.vecap.info, and S. Landry, R.B. Dawson, The Regulatory Landscape for Flame Retardants, proceedings of the 2009 BCC flame retardants conference.

effect on fire safety unless alternatives are developed; hence, new approaches are being sought by industry[11].

Why NIST? This program directly fits in EL's mission[12] and vision[13] and is consistent with the National Institute of Standards and Technology Act, which directs NIST to conduct basic and applied fire research into the behavior of fires in buildings and design concepts for providing increased fire safety.[14] This work is directly aligned with EL's strategic priority goal on Measurement Science for Disaster-Resilient Buildings, Infrastructure, and Communities and leverages EL's core competency on *Fire protection and fire dynamics within buildings and communities*. NIST is uniquely qualified to lead this effort, having the technical expertise, infrastructure, and experimental facilities to address key topics in fire protection measurement science. Individual companies do not have the resources to develop the facilities and expertise needed to be successful. The responsibility for ensuring that these tools are accurate and maintained will, by necessity, fall largely on governmental fire research organizations.

What is the new technical idea? There are two primary thrusts in the FRRIB program: reduce the cost of fire protection in buildings by enabling performance-based design (PBD) and reduce residential fire losses through improved fire-sensing and reduced flammability of key building contents. Within the PBD thrust, there are several new ideas. First, use of predictive fire models for performance-based design depends on demonstrated accuracy and robustness of the models combined with targeted development based on user needs. Recent progress in verification and validation (V&V) standards has enabled V&V for both FDS and CFAST to be conducted in a consistent manner. Additionally, new algorithms will improve the accuracy of the predictions.[15] The egress project will capture novel movement and human behavior data to establish the likely distribution of life safety outcomes for structure fires. The ability to predict fire growth and spread, the combustion products and their effect on occupants, and the movement / behavior of the occupants is critical to realizing the potential of PBD. Finally, new measurement capabilities for predicting the response of multi-story structural frames to fire and other imposed loads will be developed in the National Fire Research Laboratory (NFRL), which will enable more cost-effective structural installations.

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[11] Comments by industrial participants at a recent workshop *NIST Workshop on Gas-Phase Fire Retardants*.

12 EL's mission is "to promote U.S. innovation and industrial competitiveness in areas of critical national priority by anticipating and meeting the: - measurement science and - standards needs for technology-intensive manufacturing, construction, and cyber-physical systems in ways that enhance economic prosperity and improve the quality of life."

13 EL's vision is "to be the source for: - creating critical solution-enabling measurement science, and - critical technical contributions underpinning emerging standards, codes, and regulations that are used by the U.S. manufacturing, construction, and infrastructure industries to strengthen leadership in domestic and international markets."

[14] National Institute of Standards and Technology Act, 15 U.S.C.271. As updated with America COMPETES Act of 2007, the NIST Organic Act incorporated Fire Research as Section 16 (15U.S.C278f, previously The Fire Prevention and Control Act of 1974). Section 16 (a) (1) (E) includes "the behavior of fire involving all types of buildings……and all other types of fires, including forest fires, brush fires…" (G) includes "design concepts for providing increased fire safety consistent with habitability, comfort, and human impact in buildings…."

[15] Implementation of novel algorithms such as Immersed Boundary Method (IBM) will improve and expand the predictive capability of current fire models using sub-models that better describe critical physical and chemical processes in fires and can be validated using advanced fire measurement techniques.

The strategy to reduce residential fire losses through improved material flammability is pursuing several new technical ideas. First, the foam project will evaluate novel nanoparticle fire retardant-filled Layer-by-Layer (nanoFR/LbL) coatings as a technology to reduce the fire hazard of polyurethane foam in order to reduce the heat release rate (HRR) of foam by 30%. Closely aligned, the furniture flammability project will develop a technically sound furniture design tool based on characterized physical and combustion properties of the furniture components that will be used by furniture manufacturers to produce residential upholstered furniture (RUF) with improved flammability behavior.[16] The design tool would enable RUF manufacturers to identify the materials and configurations necessary to produce RUF with desired levels of fire performance. The smoke alarm project will characterize very early combustion signatures using multi-angle scattering methods (which can be orders of magnitude more sensitive than traditional sensing methods) combined with new knowledge about particle characteristics of various sources and on-board sensor analytics. These signatures will be differentiated from nuisance sources and novel real-time analytical methods will achieve both a reduction in sensing time and a reduction in nuisance alarms. Finally, the advanced fire retardant project will leverage new insights about the critical gas-phase kinetic mechanisms which inhibit flames to improve the validity of small scale test methods for ignition resistance of commodity polymers with improved effectiveness and environmental health and safety (EH&S) performance of the product fire retardants.

Why can we succeed now? NIST is uniquely positioned to reduce the burden of structure fires in the United States. The Program is focused on improving standards and codes, and is staffed with world-class experts capable of producing significant advances in measurement science to reduce the risk of fire hazard in buildings. Recent technological advances such as highly accurate analytical instruments, and fine and sub-grid modeling of fire physics and chemistry have provided opportunities to improve and advance current fire metrology and fire models. Stakeholders and customers are demanding tools and knowledge that will enable performance-based design (e.g., fire modeling, data and knowledge on evacuation), economic-based decision making, and fire safety engineering, facilitating the rapid transfer of research results into practice.

EL has extensive expertise in real-scale flammability, validated bench scale flammability measurements, life cycle assessment (LCA), nanotechnology, materials decomposition modeling and novel flame retardant approaches; the combination of these expertise will produce the necessary tools for industry to develop sustainable fire safe products, innovate and compete in the markets where new domestic and foreign regulations mandate both performance and sustainability.[17]

What is the research plan? There are two primary thrusts in the FRRIB Program: to reduce the cost of fire protection in buildings by enabling performance-based design (PBD) and to

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[16] Much like the existing mattress standard, a hazard analysis will guide the development of an upholstered furniture standard or regulation which will ensure that compliant products produce significantly better outcomes in residential fire events.

[17] For example, the U.S. EPA's Toxic Substances Control Act (TSCA), the EU Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), the EU Restriction of Hazardous Substance Directive (RoHS), and the EC Waste Electrical and Electronic Equipment Directive (WEEE).

reduce residential fire losses through early and reliable warning and reduced flammability of key building contents. Within the PBD thrust, the research plan is to enable the next generation of PBD through accurate simulation of the hazard of a fire to building occupants and the performance of the structure. This will require four highly coupled projects. First, predictive fire modeling will simulate the growth and spread of fire. Critical tasks include extending the FDS V&V parameter space, implementing novel algorithms,[15] enabling direct CAD import for building geometry, and improving the computational efficiency of SmokeView.[18] Second, the movement and behavior of building occupants must be characterized. The egress project will publish a database of stairwell movement characteristics for tall buildings and simulate occupant behaviors during a fire, utilizing a novel theoretical framework. Third, based on the results of the FY12 toxicity project, the egress project will consider the generation and transport of toxic combustion products as part of an egress hazard analysis. Finally, after fully commissioning the NFRL, NIST will develop partnerships and coalitions with the construction industry and research community to develop innovative measurement science capabilities which support characterization of the performance of a multi-story structural frame responding to fire and other loads. Each project contributes to realizing the full potential of PBD.

The research plan for the residential fire loss thrust will primarily address a reduction in the flammability (ignition and HRR) of residential soft furnishings and enable early warning of unwanted fires. To mitigate the largest fuel source in homes (residential upholstered furniture, RUF), three highly coupled projects will create a design tool and develop the measurement science for condensed/gas phase technologies for furniture construction. This will enable flexible and cost-effective design alternatives for manufacturers, while significantly reducing the hazard of RUF. First, the foam project will identify the micro- and macrostructure architecture of the nanoFRs and the LbL coatings that can be used to control foam flammability, developing and evaluating candidate tools to measure released nanoFR and separate tools to stress foam under conditions simulating end-use conditions. The furniture flammability project will conduct small- and meso-scale measurements of RUF to establish the technical basis for a RUF design tool which will produce RUF with substantially reduced fire hazard. Third, the advanced fire retardant project will establish the fundamental principles and modes of action of gas-phase fire retardants, as well as the appropriate standard test methods to quantify gas-phase FR effectiveness. In addition, the smoke alarm project will characterize very early combustion signatures using a novel multi-angle multi-wavelength light scattering measurement device. These signatures will be differentiated from nuisance sources, and novel real-time signal processing will achieve a reduction in sensing time and a reduction in nuisance alarms. Together, these four projects will produce the measurement science to enable a significant reduction in residential fire losses.

How will teamwork be ensured? This program is part of the Measurement Science and Standards for Disaster- Resilient Buildings, Infrastructure, and Communities Goal and is coordinated with the other programs (including Fire Risk Reduction in Communities Program and the Structural Performance under Multi-Hazards Program and is derived from strategies

[18] SmokeView will implement methods for running in parallel and in the background to enable efficient visualization of massive cases.

outlined in the NIST Fire Research Division Roadmap.[19] There is synergy across programs and their contributions are required to achieve the strategic goal. The Program involves staff from all units in the Fire Research Division as well as staff in the EL Applied Economics Office, and the Materials and Construction Research Division. Interaction among team members is ensured by informal and formal sharing of project information in individual meetings and group gatherings such as the Fire Research seminars.

What is the impact if successful? Measurement science in the PBD thrust (collectively) will enable more efficient fire safety design of buildings, which may exceed $7B annually.[20] It is anticipated that more than 20 individual codes, standards, and regulations will be created or improved by this thrust.[21] Each project emphasizes outputs, outcomes, impacts aligned with the program objectives. Predictive fire modeling will continue to support a user group of roughly 10,000 professionals, establish and implement consensus V&V methods, and enable performance assessment of complex buildings. The egress project will develop a draft V&V consensus standard (ASTM), enable rapid evacuation of high-rise buildings through implementation of occupant-use elevators, and establish a technical foundation for stair movement through a comprehensive database of occupant movement. In addition to world-class large-scale HRR measurements, the NFRL will change the practice of performance based design for structural and fire engineering by enabling multi-load analysis of building systems to include fire.

Measurement science in the residential fire loss thrust will enable a major reduction in residential fire losses. First, estimates suggest that early and accurate fire sensing can achieve a 50% reduction in residential fire deaths and injuries.[22] Further reductions will be enabled through sharp reductions in the flammability of foam and the hazard of upholstered furniture (a major component of residential fire load).

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19 Hamins, et al. Reducing the Risk of Fire in Buildings and Communities: A Strategic Roadmap to Guide and Prioritize Research, NIST Special Publication 1130, April 2012..

20 The Australian Building Code Boards estimated that PBD can achieve a 0.5% reduction in the total construction cost, which translates to roughly $7B in the United States, annually, according to recent national construction data.

21 Codes and standards organizations include but are not limited to ASTM, International Code Council (ICC), International Organization for Standards (ISO), National Fire Protection Association (NFPA), and Underwriter's Laboratory (UL). Regulators include the Consumer Product Safety Commission (CPSC) and the Nuclear Regulatory Commission (NRC).

22 While the penetration of smoke alarms has approached 96% of households, it is estimated that only 77% have at least one working smoke alarm (Ahrens, 2009). An increase in the prevalence of working smoke alarms should proportionally reduce the risk of dying in home fires. According to U.S. fire statistics, between 2003 and 2006, of the 380,000 annual average home fires reported, smoke alarms were present in 69% of those fires. By increasing the percentage of homes that have at least one smoke alarm working to 100%, an estimated 650 lives per year would be saved. The main reason given for non-functioning smoke alarms is disabling due to nuisance alarms, thus addressing nuisance alarms has been a strategic priority. In roughly half of the home structure fires with fatalities, smoke alarms operated or did not operate but were otherwise functioning (Ahrens 2009). About 40 percent of victims were escaping, attempting fire control, or attempting rescue when fatally injured, thus quicker fire detection could make the critical difference in these circumstances. With an annual average of 2,850 home fire deaths, an additional 730 lives per year would theoretically be saved if the number of lives lost from fatal fires that go undetected or are detected too late for escape or rescue is reduced by one third by quicker fire detection. Thus, the combination of early warning fire detection and nuisance resistance in residential smoke alarms could cut the fire death rate in half.

What is the standards strategy? The program has a significant focus on delivering technical findings to improve codes, standards, and practices associated with reducing the risk of fire in buildings. Recent NIST technical contributions include the 2006 and 2009 International Building Code and the 2009 NFPA Life Safety Code (improvements to egress markings, high-rise evacuation, and stairwell integrity are adopted in all 50 states), ISO (toxicity measurement and calculation methods and cigarette testing protocols are now the worldwide standard of practice in toxicity calculations and reduced-ignition cigarette testing), and UL 0217 standard on nuisance-resistant smoke alarms (the majority of residential smoke alarms are certified using the UL 0217-2011 standard). The CFAST and FDS models have transformed performance based design of fire protection in buildings and have been used to support codes and standards development worldwide.[23] Changes to fire safety engineering practices include the Society of Fire Protection Engineers (SFPE) "Engineering Guide to Substantiating a Fire Model for a Given Application" and the US Nuclear Regulatory Commission (NRC) publication "Fire Model Verification and Validation Study (NUREG-1824, 2007)," which stipulates how fire models are to be used in nuclear power plant applications.

The standards strategy for the Program focuses on two technical thrust areas: reduction of residential fire losses and enabling performance-based design (PBD). Standards development needs for reducing residential fire losses include: a) improved test method for evaluating reduced-ignition cigarettes (FY 13), b) standard for enabling early detection and reliability of smoke alarms (FY15), and c) standard for reduced flammability of upholstered furniture (FY16). Standards development needs for enabling performance-based design include: a) standards for verification and validation of computation fire and egress models (FY13), b) standards to improve building evacuation (FY14), and c) standards to improve structural design under fire conditions (FY 16).

Researchers in the Program conduct measurement science focused on areas that need new or improved codes and standards, which are aligned with programmatic objectives, available resources, and staff expertise. At the highest level of involvement, the staff convene and lead

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[23] Building Codes:

- The ICC International Performance Code is dependent upon the existence of validated fire models
- The ICC International Building Code recently considered code change proposals whose sole technical justification was the results of FDS simulations (e.g., Boeing Co. simulated large (10 MW) fires in large volume aircraft assembly structures).

Standards

- NFPA 72 (Smoke Alarms) includes PBD modeling as a component to determine detector spacing for automatic detection systems
- NFPA 130 (Passenger Rail and Tunnel Safety) requires validated fire model calculations as part of the design of tunnel ventilation.
- NFPA 802 (Fire Protection Practice for Nuclear Reactors) requires validated fire models for design calculations.
- The (NFPA) Fire Protection Research Foundation has recently highlighted the use of FDS in six major studies that it has sponsored with industry including, Smoke Detector Performance for Ceilings with Deep Beam Pockets, Siting Requirements for Hydrogen Supplies, Modeling of Fire Spread in Roadway Tunnels, Smoke Detection of Incipient Fires, Smoke Detector Spacing for Sloped Ceilings, and Smoke Detector Spacing for Corridors with Deep Beams. All of these studies were motivated by technical issues originating with the above NFPA standards.
- ASTM E1355 and ISO (ISO/TC 92/SC 4) have published guidance documents on evaluating the performance of fire models. CFAST and FDS development and V&V supports these international standards.

committees. Current examples include ISO (chair, secretary, and task leaders), ASME (task group leadership), and UL (task group leadership). Additionally, researchers are full voting members on key committees (three NFPA committees, ICC Means of Egress, five ASTM committees, one ASCE[24] committee, and 15 ISO committees and working groups). Finally, researchers often make invited technical presentations to committees or hearings in order to communicate results of NIST research.

Additionally, the Program will work with regulatory agencies on critical research, including collaborations with the NRC on fire modeling[25] and with the CPSC on mattress flammability, cigarette ignition, and smoke alarm/sprinkler effectiveness. Fully aligned sponsored research from regulatory agencies will accelerate the time frame typical for realization of impact.

How will knowledge transfer be achieved? Knowledge and results from the program will be disseminated to customers and stakeholders through archival publications, reports and data on the web, reports to sponsors, presentations at technical conferences, downloadable software, the participation in workshops, standards, codes, and technical committee meetings, scientific engagement through the NIST post-doctoral and guest researcher programs, and strategic planning/roadmapping involving a broad range of stakeholders.

MAJOR ACCOMPLISHMENTS

Outcomes: The FRRIB Program is advancing the underlying basis of performance-based engineering. The fire modeling project continues to support the practice of fire protection engineering and roughly 10,000 registered users through the publication of validated, numerically efficient fire models (FDS, CFAST, and SmokeView). Recent outcomes include ASTM and ISO V&V standard development[26] and engineering design guides.[27] The utility of FDS in performance based design has been demonstrated in many highly visible applications including the Columbus Hilton (consultant saved client over $3,700 k in smoke control expenses using FDS analysis), Ohio University's Scripps College (consultant saved client over $800 k using FDS analysis), the Air and Space Museum's Dulles extension, as well as a number of historically sensitive applications such the newly refurbished Treasury Building and the Library of Congress. Through use of FDS, architects are able to minimize disruption of the original architectural design without sacrificing fire protection safety.

The egress project has published complete datasets for five building evacuations on NIST website with hundreds of registered users in October 2010.[28] Video-based observations of 14 unique fire drill evacuations have been completed with data published for five of these. While

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[24] American Society of Civil Engineers (ASCE)

[25] US Nuclear Regulatory Commission (NRC) published a seven-volume Fire Model Verification and Validation Study (NUREG-1824, 2007).

[26] ASTM E1355 and ISO (ISO/TC 92/SC 4) have published guidance documents on evaluating the performance of fire models. CFAST and FDS development and V&V supports these international standards.

[27] The Society of Fire Protection Engineers (SFPE) published its Engineering Guide to Substantiating a Fire Model for a Given Application. McGrattan was on the committee that wrote the report, and many lessons learned from CFAST and FDS development were incorporated.

[28] http://www.nist.gov/el/fire_research/egress.cfm and Kuligowski, E. D. and Peacock, R. D., "Building Occupant Egress Data," NIST Report of Test FR 4024

the research portion of the toxicity project is complete, follow-up standards work will continue to support the standards process including shepherding the standards documents through ISO and looking for opportunities for domestic standards engagement on this topic.**Error! Bookmark not defined.**

The Program has significantly advanced measurement science which will enable a substantial reduction in residential fire losses. First, the nanoparticle foam project has developed several new measurement capabilities, including the ability to use carbon nanotubes and nanofibers in the LbL process,[29] a foam smoldering assessment device and protocol that quantifies smoldering performance,[30] and developed a UV-VIS spectroscopy method to quantify carbon nanotubes at concentrations an order of magnitude lower than any previously reported method.[31] The pyrolysis project developed and validated a new measurement method to capture the broad-band IR absorption of polymers subjected to radiant heating, so that this parameter can be accurately used in pyrolysis modeling. Additionally, the project published a database of broadband IR absorbance and reflectance measurements of typical commodity polymers which is now actively used by researchers in numerical pyrolysis model development. The advanced detection project recently led the development of an improved nuisance source standard for smoke alarms (UL 0217).

Recognition of EL: The program staff have a leadership role in developing measurement science for innovative fire protection, which is internationally recognized. For example, FDS/Smokeview and CFAST are considered premier fire models worldwide.[32,33,34,35] Recognition of EL can be documented through honors bestowed on staff for their program-related research activities,[36,37,38] participation on editorial boards,[39,40] research steering committees,[41] as keynote speakers,[42] leadership in the organization of international

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[29] Three-dimensional LBL use of nanotubes and nanofibers opens a new field of FR options for foam, textiles, and hard plastics.
[30] This could replace the less sensitive and qualitative BS-5852 standard test.
[31] Once validated this could replace the qualitative SEM method currently used by OSHA for assessing workplace nanoparticle concentrations.
[32] FDS and CFAST were recently accepted by US NRC for use in nuclear power plants that have adopted NFPA 805, the performance-based fire code for light water reactors.
[33] The SFPE conducts semi-annual training courses in the use of Smokeview, CFAST and FDS.
[34] FDS/Smokeview Version 5.5 was released in Feb. 2010 with about 5,000 downloads.
[35] The (NFPA) Fire Protection Research Foundation has recently highlighted the use of FDS in 6 major studies.
[36] McGrattan was awarded the 2007 Interflam Trophy at the 11th International Fire Science and Engineering Conference in London for his "key contribution to the development of NIST FDS, and to his sustained leadership in the application of computational fluid dynamics models in fire protection engineering practice."
[37] Gann was recognized in 2007 by the International Forum of Fire Research directors with the Sjolin Award for contributions to advance the state of the art in fire safety engineering practice of extraordinary significance. The FDS Team including McGrattan, Forney, and McDermott were awarded the 2012 Sjolin Award.
[38] McGrattan, "Modeling Fire Using Computational Fluid Dynamics (CFD)," SFPE Handbook of Fire Protection Engineering, 4th ed., National Fire Protection Association, Quincy, MA, 2009.
[39] Cleary serves as Associate Editor of the Fire Protection Engineering Journal since 2008.
[40] Gann serves on the editorial boards of the journals Fire Technology and Fire and Materials.
[41] Averill, Cleary, and McGrattan have recently been technical consultants to NFPA Research Foundation.
[42] Pitts presented a plenary lecture at the 2009 Mediterranean Combustion Institute Meeting.

conferences,[43,44,45,46] and leadership positions in international fire safety organizations.[47] EL research on flammability was recognized as one of the top five NIST National Nanotechnology Initiative (NNI) accomplishments for the President's Council of Advisors on Science and Technology (PCAST) presentation of their review of the NNI to the President in March 2012. National Nanotechnology Coordination Office (NNCO) is developing a video of the programs results. The U.S. House of Representatives Committee on Energy and Commerce requested the assistance of the EL staff in gathering information on flame retardants important to the reauthorization of the regulatory authority for the EPA known as the Toxic Substance Control Act (TSCA) and continue to serve on EPA committees.[48]

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[43] Hamins was the technical program chair of the 2008 International Association of Fire Safety Science (IAFSS) Symposium and Chair of the 2011 IAFSS Symposium.
[44] Averill was the co-chair of the 2010 International Conference on Pedestrian and Evacuation Dynamics.
[45] Cleary was the co-chair of the 14th International Conference on Automatic Fire Detection, AUBE'09.
[46] Averill was on the steering committee of the 2008 Human Behavior Conference.
[47] Hamins serves as Vice-President of the International Association of Fire Safety Science (2008-2014).
[48] Davis attends monthly meeting as a part of steering committees to consider banning and identify replacement of fire retardants (e.g., DecaBromo FR and HexaBromo FR) and shares the information with Linteris.