Research Needs for the Fire Safety Engineering Profession

Note: Items highlighted in **RED** are identified as the highest priority for each thread. Items highlighted in **BOLD** are identified as the highest priority for each cell.

TOOLS, APPLICATIONS, AND METHODS

THREADS

	Data	Innovative Technology/ Materials	Design Tools	Risk/Probabilistic Approaches
Human Behavior	**Demographics** ▶ **Vulnerable populations** ▶ **Anthropometry** ▶ **Cultural differences**	**Smart egress systems** ▶ **Cameras** ▶ **Cell phones** ▶ **Exit usage** ▶ **Other**	**Design egress scenarios**	**Residential buildings**
	Basis for numbers in codes	LED strobes	Behavior based models ▶ Cultural ▶ Pre-evacuation time ▶ Actions other than evacuating	Large populations
	Response to notification	Occupant evacuation elevators	Combined fire and evacuation models	Community level
				High-challenge environments
				Quantify level of “life safety” in a building
				Effects of fire ▶ Visibility ▶ Gases
				Impact of public education on fire risk
Building Fires	**Combustibility of external cladding systems**	**Building information modeling**	**Standardization of design fires and analysis approaches**	**High-rise building design**
	Fire loads for structural fire engineering	Smart buildings	Best practices for retrofitting existing buildings to achieve equivalent level of safety	Risk-informed PBD
	Material testing data (new materials)	Big data		Single family homes
	Effectiveness of existing/new fire safety solutions	Improved test methods		Risk assessment/management systems
	Quantification of building code performance criteria			Structural FP performance

TOOLS, APPLICATIONS, AND METHODS

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Resilience/Sustainability	**Environmental impact of fire and fire suppression activities** Cost of fire events Cost/benefit of different types and multiple levels of FP measures Environmental impact of fire testing Quantification of structural fire resilience Flame retardant toxicity	**Assess fire hazard of new sustainable building materials/ practices** Identify/quantify sustainability benefits of smoke control systems and natural ventilation Evaluate fire hazards of new sustainable energy technologies Evaluate fire hazards of flammable refrigerants Life expectancy of installed fire protection systems Determine appropriate suppression systems for new technologies	**Development of design tools/ best practices for fire safety engineering for resilient systems/buildings** Analysis of impact of climate change on fire safety Cost-effective and resilient FP practices for developing countries Post-fire seismic behavior Identification of critical fire protection aspects for disaster reliability	**Development of risk-based analysis to compare hazards of fire to long-term health impacts of fire mitigation measures** Risk- and reliability-based methods for ITM of fire protection systems ▶ Preventative and predictive maintenance ▶ Human impact on ITM reliability ▶ Reliability of water supplies ▶ Reliability of installed equipment
Fire Service	**Exposure tracking from incidents** Data-driven fire inspection scheduling Improved injury, holistic fatality data collection and economic analysis Impact of WUI on fire service Naturally occurring events ▶ Rate, severity ▶ Fire as a secondary impact	**Smart firefighting** ▶ **IoT integration** ▶ **Mechanical augmentation** ▶ **Fire department communication with BIM** ▶ **Firefighter tracking and location** Automated, quantifiable exposure monitoring Firefighting PPE and tools ▶ Firefighting and fire apparatus cameras for investigation/ debrief	**Model fire department response leading to better models of** ▶ **Reverse evacuation** ▶ **Egress/ingress** ▶ **Duration of water for FP systems** ▶ **Structural collapse** ▶ **Firefighter response recreation and training aids** Compare/contrast tactics internationally to determine impact of firefighting/construction differences on fire growth/severity	**Evolving building technology and fire suppression tactics (effect of smoke/heat ventilation)** Firefighter injuries ▶ Effect of understaffed apparatus on individual personnel ▶ Fire ground safety ▶ Long-term exposures on individual personnel Effect of firefighting interventions on occupant risk New vehicle technology and fire suppression tactics Lessons learned to reduce risks in developing countries Tactics and training for emerging technologies

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Fire Dynamics	**Material properties** Fire dynamics of large compartments Test data archiving Model stewardship Toxicity data Sprinkler data	**Standardized/accepted approach for developing material properties** Retardant behavior Massively parallel computing Mesoscale Extreme ambient conditions	**Practical models for:** ▶ **Pyrolysis of complex materials** ▶ **Extinction and reignition** ▶ **Sprinkler suppression** ▶ **Underventilated combustion** ▶ **Glass breakage** ▶ **Human consequences** ▶ **Deflagrations/detonations** Realism in test standards	**Ignition frequencies** Probabilistic distributions of heat-release rate curves Fire spread models Fire frequencies
Fire Safety Systems	**Impact of ITM requirements on system reliability** FP systems performance data Evaluation of new and existing active FP systems efficacy ▶ Suppression of unique and emerging hazards ▶ System design criteria ▶ Smoke control system Evaluation of passive FP systems efficacy Evaluation of durability of FP systems Gaseous fire suppression systems applied to high air flow environments	**Integrated FP systems and building connectivity** Efficacy of detection, alarm, communication systems Protection of storage ▶ Automated ▶ High challenge Reliability of detection/alarm/ communication ▶ False positives ▶ Failure on demand ▶ Failure modes due to extreme environments	**Corrosion protection design best practices** Guidelines on suppression effectiveness at various heights FP System design ▶ Atrium protection and modeling ▶ Smoke control systems ▶ Passive FP system design and test methods	**Adequacy of passive fire resistive construction** Evaluation of ▶ Smoke control systems impact on reduction of risk of losses ▶ Adequacy of passive fire resistive construction ▶ Effectiveness of fire stop installation by multiple trades versus certified technicians ▶ Life quality indices to assess FP performance Reliability of ▶ Water supplies ▶ Suppression systems failure modes, aging, and complex systems Relationship between safety, security, and routine operations Matching reliability of installed systems with risk assessment

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Forensics/Investigations	**Persistence of burn patterns under different compartment fire conditions** Building material properties as inputs for fire models Fire effects on building electrical systems/components Evaluation of incident heat-flux profiles from non-standard fuels Damage resulting from heat radiation and blast waves on buildings, industrial assets, etc. Digital recordings of distributed control systems and programmable logic controllers Digital data collection (black boxes) Status and data related to availability of FP measures during event	**Improved tools for obtaining building dimensions and fire sizes from photographs and video** Use of cloud-based home/ consumer devices to pinpoint fire origin Linking of 3D scanning technology with computer fire models Overview of large scenes from drones Data mining to identify chemical process deviations Methods to preserve evidence Tools to extract data from digital sources	**Improved software to create multiple-source dynamic event timelines** Tools to evaluate impact of ventilation on compartment fires Simulation tools to recreate process conditions in chemical plants Advanced calculation methods to evaluate hypothesis Tools to estimate damage effects Virtual reality/augmented reality to describe and test scenarios	**Improved guidance for quantifying measurement and calculation uncertainty** Repeatability of fire test measurements Root cause analysis methods and tools Causes and causal mechanism analysis Human error assessment methods and tools
Wildland/WUI Fires	**Impact of firebrands** Fire hazard identification and quantification Ignition of WUI materials Fire behavior and fire spread Emissions and health effects Fire ecology and long-term effect Data to support WUI codes and standards	**Building fire protection in WUI** Wildland/WUI fire damage mitigation Warning and notification Remote sensing and communications	**Design against exterior building fires** Wildland/WUI fire modeling Firebrand ignition prevention Fire behavior prediction tools Resilience design tools Landscape planning tools	**Risk assessment of WUI structures** Risk of combustible fuels in WUI/wildland Assessment of risk, effectiveness, and economics

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Non-Building Fires	**Data for hazard identification/ reliability/severity/frequency (industrial)**	**Energy Storage** ▶ **Containment for new products/damaged products** ▶ **Higher reliability manufacturing/more resilient product design** ▶ **Safer energy storage chemistries** ▶ **New inspection techniques** ▶ **Self-monitoring of equipment** ▶ **Safe transportation**	**Product safety standards**	**Improved identification of high-risk industrial facilities**
	Alternative energy generation	Improvements to petrochemical equipment safety	Installation Standards ▶ ESS ▶ Oil/gas drilling	Improvement of risk management practices at chemical facilities
	PV installation fire spread	Tunnel fire suppression	CFD fire models (tunnels/ underground, tank fires	
	Petrochemical fire incident frequency		Design considering first responders (ESS, vehicles, tunnels)	
	Causes of vehicle fires		Heat transfer models for energy storage cell design	
			Tunnel evacuation/fire models	
			Models for use in siting and design of tank farms	
			Tunnel design fires	

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LIST OF ACRONYMS

BIM – Building Information Modeling
CFD – Computational Fluid Dynamics
ESS – Emergency Storage System
FP – Fire Protection
IoT – Internet of Things
ITM – Inspection, Testing and Maintenance
LED – Light Emitting Diode
PBD – Performance-Based Design
PPE – Personal Protective Equipment
PV – Photovoltaic
WUI – Wildland Urban Interface