Research Needs for the Fire Safety Engineering Profession

SFPE
Engineering A Fire Safe World

Tool, Applications, & Methods

Threads	Data	Innovative Technology /Materials	Design Tools	Risk /Probabilistic Approaches
Human Behavior	○	○	○	○
Building Fires	○	○	○	○
Resilience/Sustainability	○	○	○	○
Fire Service	○	○	○	○
Fire Dynamics	○	○	○	○
Fire Safety Systems	○	○	○	○
Forensics/Investigations	○	○	○	○
Wildland/WUI Fires	○	○	○	○
Non-Building Fires	○	○	○	○

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September 26, 2017

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

	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 & 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 o Preventative and predictive maintenance o Human impact on ITM reliability o Reliability of water supplies o 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 o Rate, severity o Fire as a secondary impact	• **Smart firefighting** o **IoT integration** o **Mechanical augmentation** o **Fire department communication with BIM** o **Firefighter tracking and location** • Automated, quantifiable exposure monitoring • Firefighting PPE and tools o Firefighting and fire apparatus cameras for investigation/debrief	• **Model fire department response leading to better models of** o **Reverse evacuation** o **Egress / ingress** o **Duration of water for FP systems** o **Structural collapse** o **Firefighter response recreation & training aids** • Compare / contrast tactics internationally to. determine impact of firefighting / construction differences on fire growth / severity	• **Evolving building technology and fire suppression tactics (i.e. effect of smoke / heat ventilation during firefighting tactics**) • Fire fighter injuries o Effect of understaffed apparatus on individual personnel o Fire ground safety o 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
	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:** o **Pyrolysis of complex materials** o **Extinction & reignition** o **Sprinkler suppression** o **Underventilated combustion** o **Glass breakage** o **Human consequences** o **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
		  o Suppression of unique and emerging hazards
		  o System design criteria
		  o 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
			  o Automated
			  o High challenge
			• Reliability of detection/ alarm/communication
			  o False positives
			  o Failure on demand
			  o Failure modes due to extreme environments
				• **Corrosion protection design best practices**
				• Guidelines on suppression effectiveness at various heights
				• FP System design
				  o Atrium protection and modeling
				  o Smoke control systems
				  o Passive FP system design and test methods
					• **Adequacy of passive fire resistive construction**
					• Evaluation of
					  o Smoke control systems impact on reduction of risk of losses
					  o Adequacy of passive fire resistive construction
					  o Effectiveness of fire stop installation by multiple trades versus certified technicians
					  o Life quality indices to assess FP performance
					• Reliability of
					  o Water supplies
					  o Suppression systems failure modes, aging and complex systems
					• Relationship between safety, security and routine operations
					• Matching reliability of installed systems with risk assessment

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

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.

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