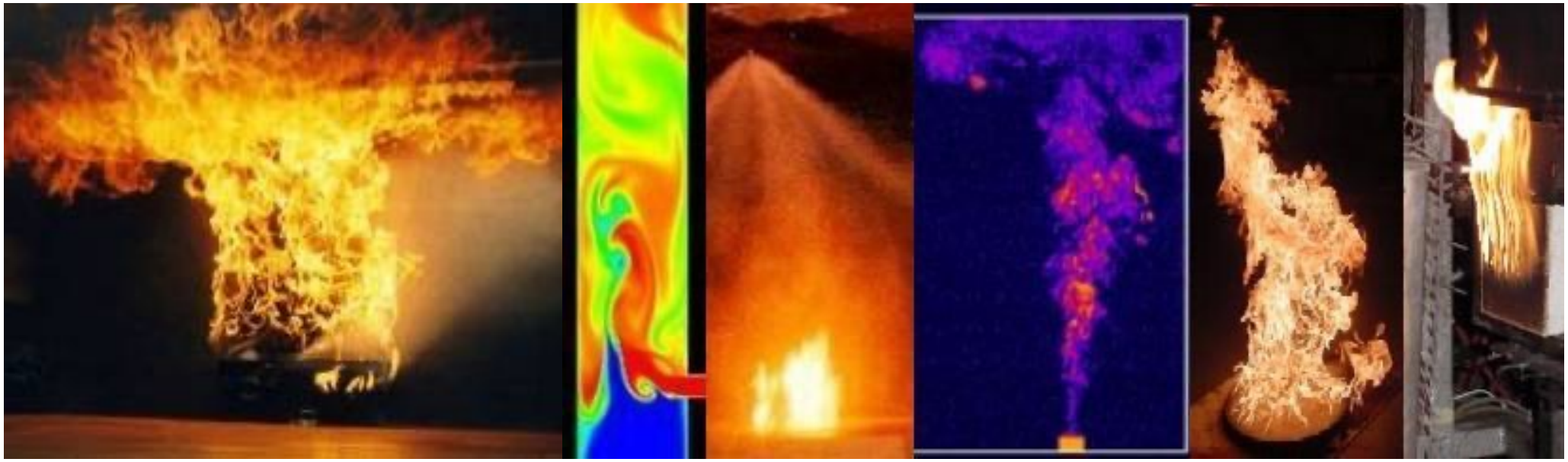


Research Overview

Department of Fire Protection Engineering
University of Maryland
College Park, MD 20742, USA

http://www.fpe.umd.edu

November 2026

Full-Time Faculty

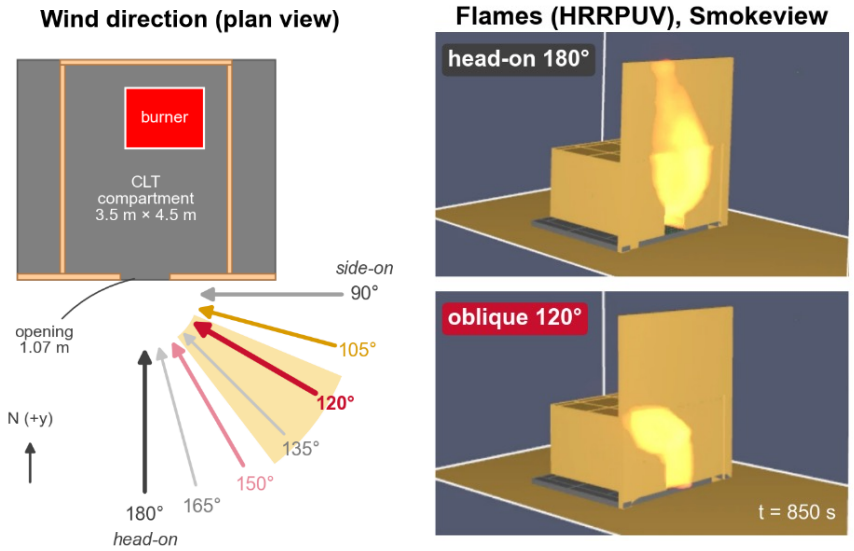
Faculty	Expertise/Research Areas
R. Hrybyk	life safety analysis, performance-based design
W.E. Koffel	suppression/detection systems, egress, codes & standards
S. Ni	structures, fire forensics, mass timber
F. Raffan-Montoya	flammability, toxicity, wildfires, robotic applications
S.I. Stoliarov	pyrolysis, flammability, flame spread, battery fires
P.B. Sunderland	firebrands, pyrometry, cool flames, microgravity
A. Tohidi	CFD, fire/wildfire modeling, AI
A. Trouvé	CFD, fire/wildfire modeling



Fire Safety in Mass Timber Buildings

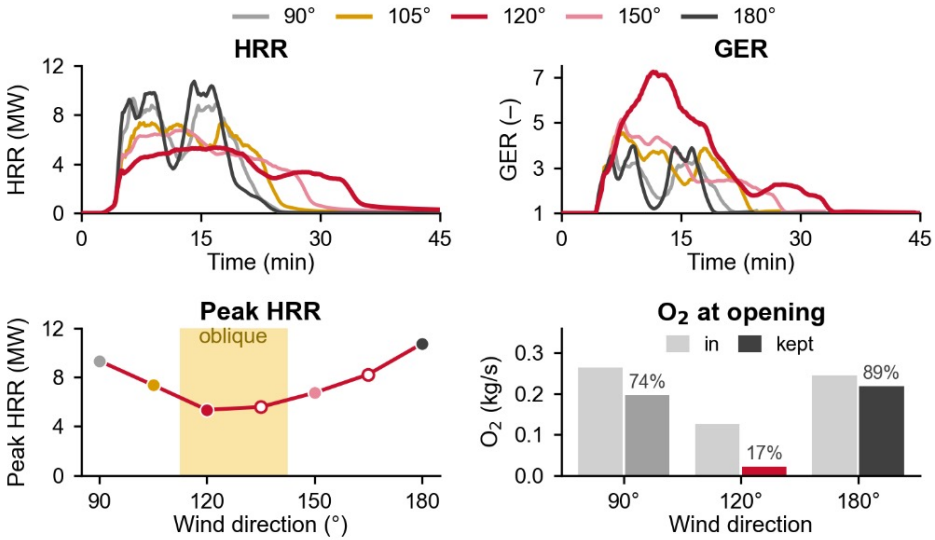
- *Faculty*: S. Ni
- *Student*: Z. Wei
- *Collaborators*: FPE Department at WPI
- *Title*: "Understanding the Impact of Wind on Fire Dynamics in Mass-Timber Compartment"
- *Sponsor*: Grand Challenge Grant at UMD
- *Objective*: Understanding the impact of wind on fire dynamics in mass-timber compartments.

FDS MODEL



At 120˚, the external flame is bent sideways at the opening instead of climbing the façade

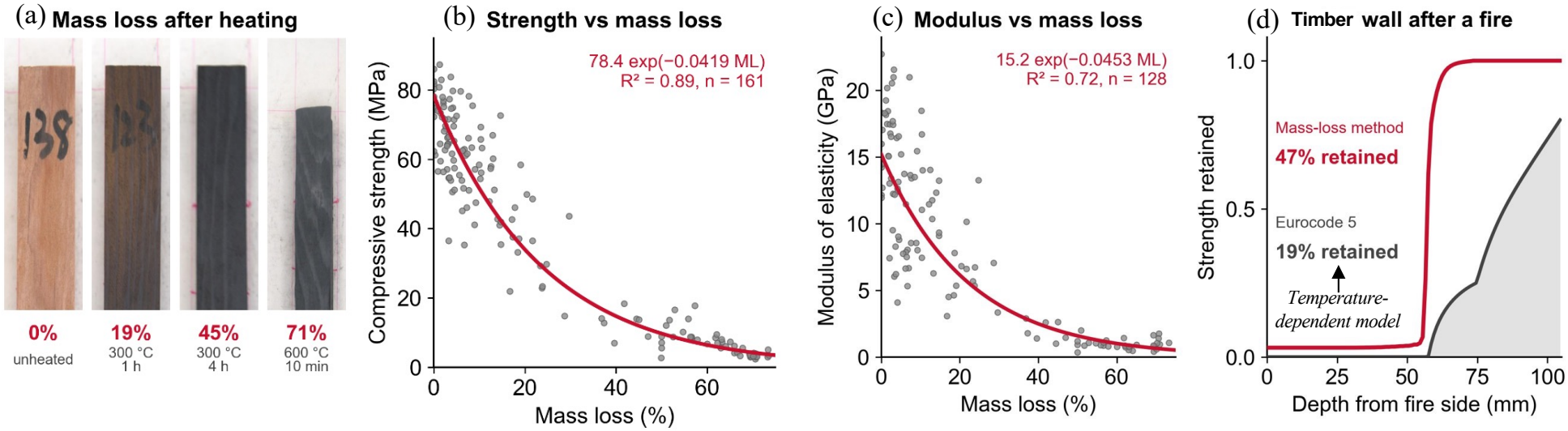
FDS RESULTS: 4 m/s WIND, PROPANE BURNER, EXPOSED CLT



At 120˚, the peak HRR falls from 10.7 MW (head-on) to 5.4 MW; the two HRR peaks vanish between 105˚ and 150˚.

Residual Strength of Fire-Exposed Wood

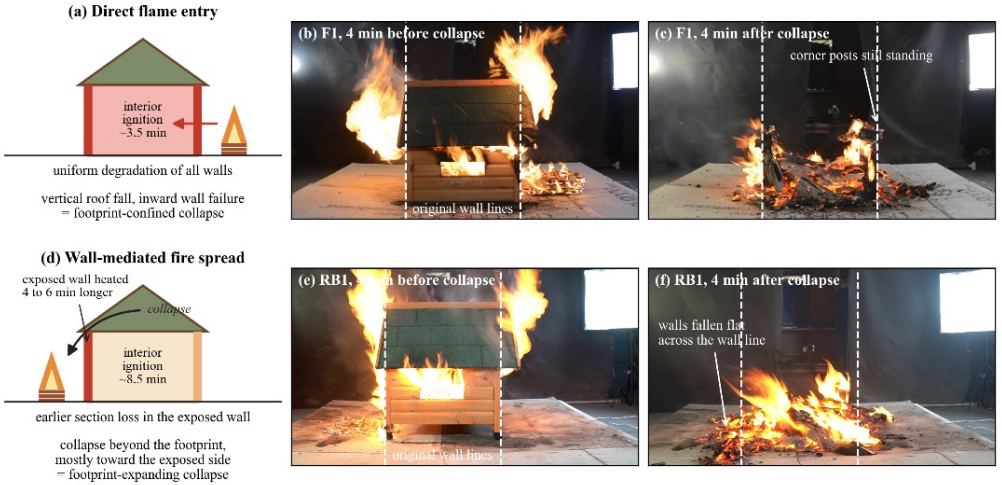
- *Faculty*: S. Ni and S. Stoliarov
- *Students*: H. Qi (postdoc), Z. Wei, M.B. Mannan
- *Title*: "Evaluating Residual Strength of Fire-Exposed Wood through a Mass-Loss-Based Characterization of Pyrolysis"
- *Sponsor*: UMD
- *Objective*: Predict the residual strength and stiffness of fire-exposed wood from pyrolysis mass loss rather than from temperature.



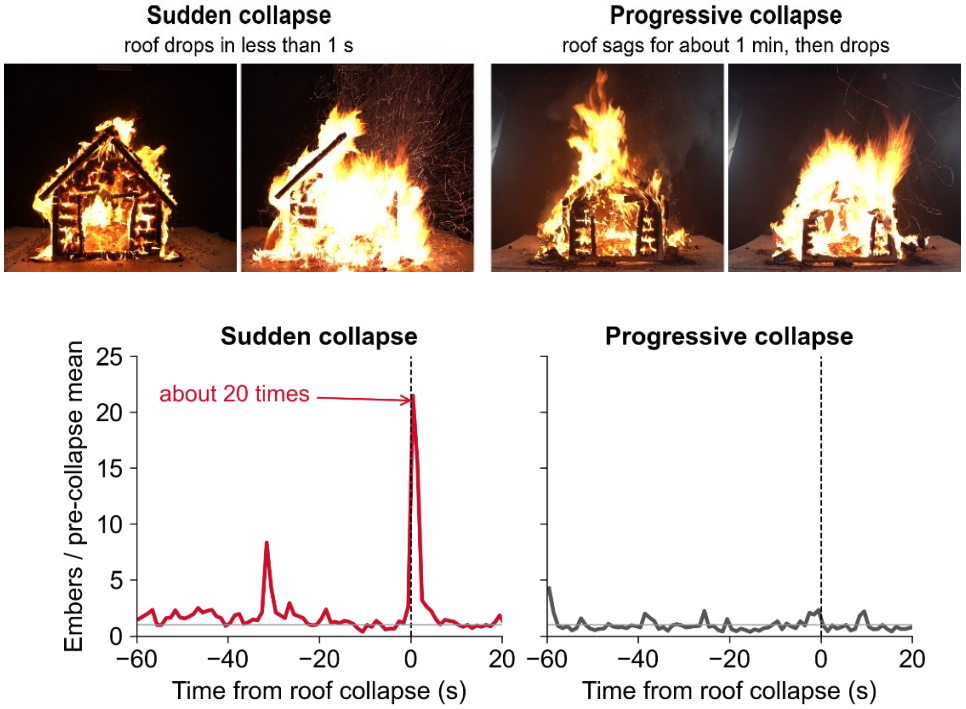
(a) Douglas-fir specimens heated at 200 to 600 ˚C for 5 min to 4 h; (b) compressive strength falls on one exponential curve of pyrolysis mass loss, whatever the temperature and duration; (c) Stiffness follows the same law (left); (d) In a compartment fire, the mass-loss method retains 47% of the capacity of a CLT wall; the temperature-based Eurocode 5 method retains 19% (right)

Fire-Induced Structural Collapse

- *Faculty*: S. Ni
- *Students*: N. Lei, H. Qi (postdoc), K. Mohan Kumar, T. Rawool
- *Title*: "CAREER: Understanding and Modeling Collapse-induced Fire Dynamics at Multiple Scales"
- *Sponsor*: National Science Foundation (CAREER)
- *Objective*: Understand and model how the collapse of burning timber structures changes fire dynamics and promotes structure-to-structure fire spread.



The exterior-to-interior ignition pathway governs the collapse pattern and where the burning debris lands (13 reduced-scale tests)



The roof drops within 1 s (top) and the embers leaving the structure rise to about 20 times the pre-collapse level (bottom)

WUI Fire Resilience

- *FPE Faculty:* S. Ni, S. Stoliarov and A. Trouvé
- *Student*: Z. Wei
- *Collaborators*: IBHS and UL
- *Title*: Enhancing WUI Fire Assessment through Comprehensive Data and High-Fidelity Simulation
- *Sponsor*: National Science Foundation
- *Objective*: Evaluate high-resolution CFD models for simulating fire spread on and between individual structures.

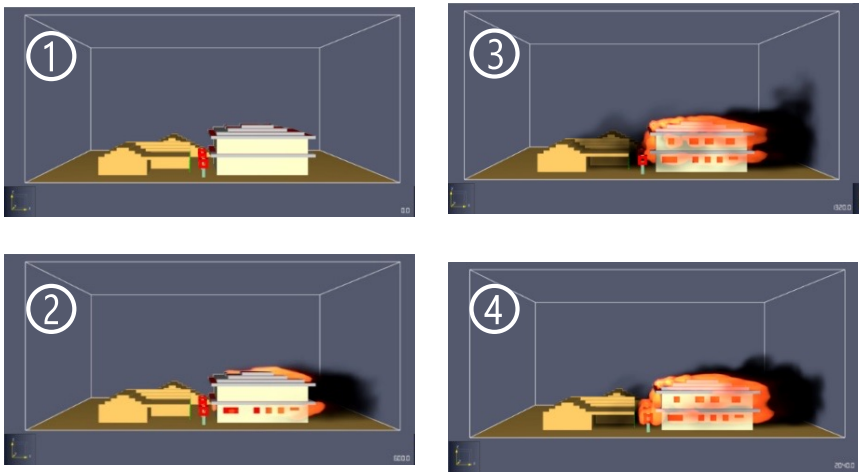
DATA RECONSTRUCTION



Representative Nahale Place scenario: 1267 source, 1259 target, 1253 undamaged



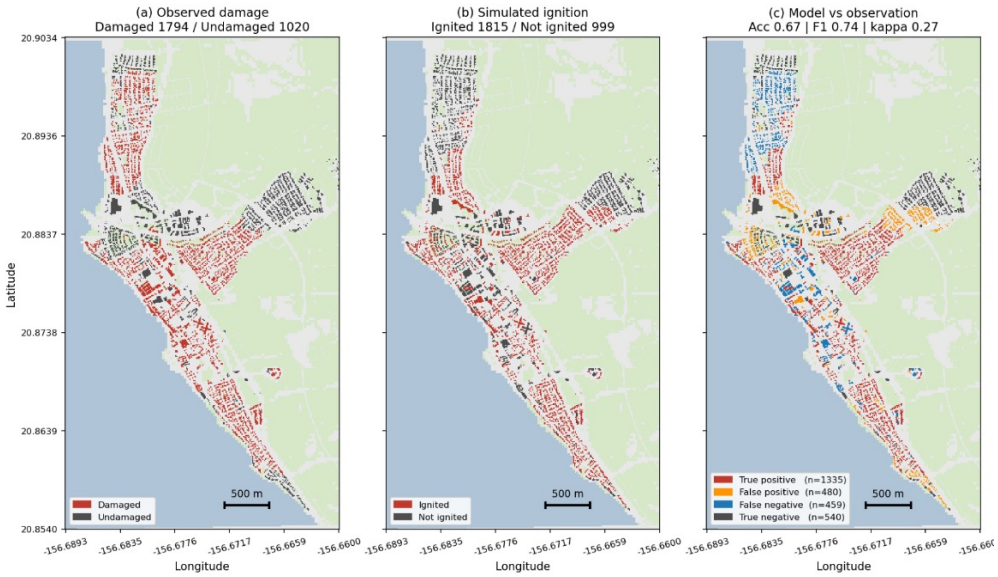
HIGH-RESOLUTION CFD RESULTS



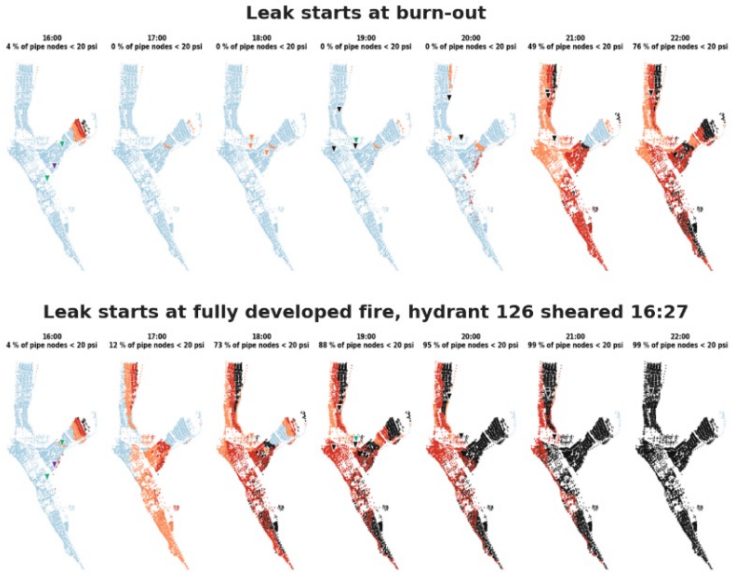
FDS reproduced the observed progression at 0, 1000, 1781, and 2000 s

Coupled Wildfire and Water System Modeling

- *Faculty*: S. Ni
- *Student*: Y. Ding (postdoc)
- *Collaborators: X. Fan (CEE Department at UMD)*
- *Title*: "Coupled Wildfire, Water Infrastructure and Firefighting Modeling for Wildland-Urban Interface Communities"
- *Sponsor*: National Science Foundation and UMD
- *Objective*: Coupled Modeling of Wildfire Spread, Firefighting Operations and Water System Performance



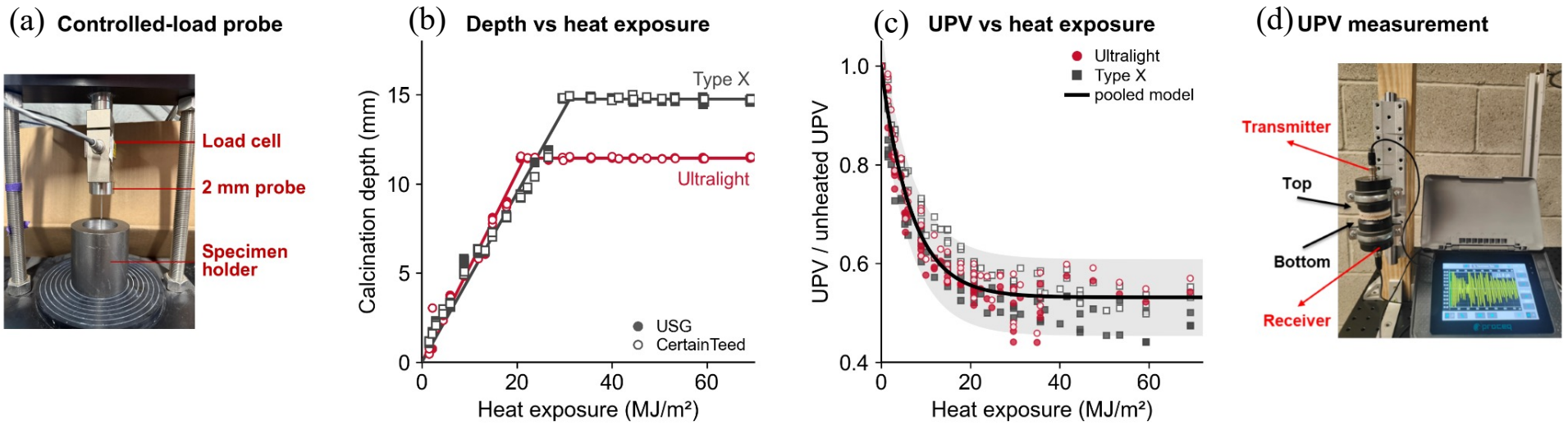
Lahaina, 8 August 2023, is the testbed: 1,815 structures ignited against 1,794 observed, perimeter IoU 0.78, damage F1 0.74



When a burned building starts to leak decides the outcome: at burn-out, 76% of pipe nodes fall below 20 psi by 22:00; from flashover, 99% by 21:00

Fire Damage Quantification in Drywall

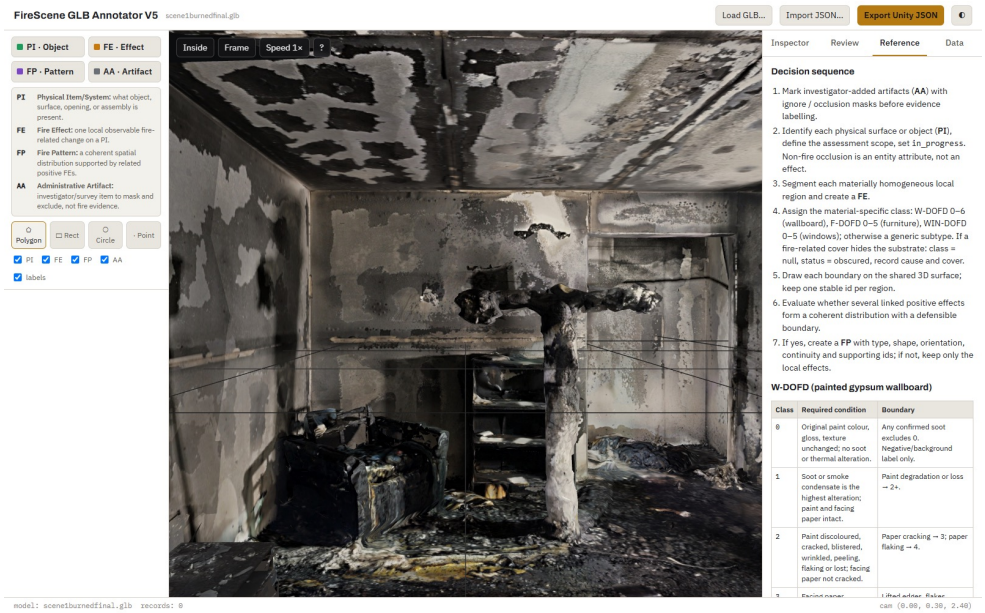
- *Faculty*: S. Ni and S. Stoliarov
- *Students*: M.B. Mannan, N. Lei
- *Collaborators*: A. Sharma, K. Opert (Jensen Hughes) and J. Hodges (UL FSRI)
- *Title*: "Improving Fire Pattern Analysis Using Non-Invasive Sensor Technologies"
- Sponsor: National Institute of Justice
- *Objective*: Develop quantitative tools that measure the degree of fire damage in gypsum drywall and convert it into heat exposure for fire investigation.



(a) Load-controlled probe tests show that ultralight board needs about half the NFPA 921 probe pressure; (b) at a matched pressure, calcination depth tracks heat exposure; (c) Ultrasonic pulse velocity (UPV) drops with heat exposure along one curve for four products; (d) UPV setup

3D Fire Scene Analysis, Visualization, and VR Training

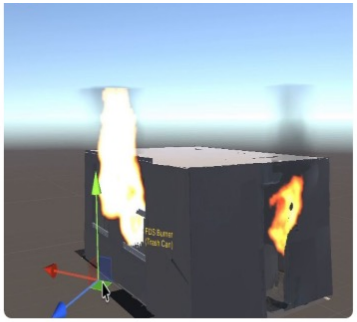
- *Faculty*: S. Ni and S. Stoliarov
- *Student*: K. Mohan Kumar, Z. Wei
- *Title*: Collaborative Research: Multimodal Immersive Training to Develop Expertise in Spatial-Temporal Reasoning for Fire Investigations
- *Sponsor*: National Science Foundation
- *Collaborators*: R. Go (UMD), S. Li (Lehigh), S. Li (UF)
- *Objectives*: Create a multimodal embodied training platform that advances fire investigation training through adaptive deliberate practice and learning analytics.



FireScene GLB Annotator: full-room view with Reference tab



Registered Matterport post-fire scene



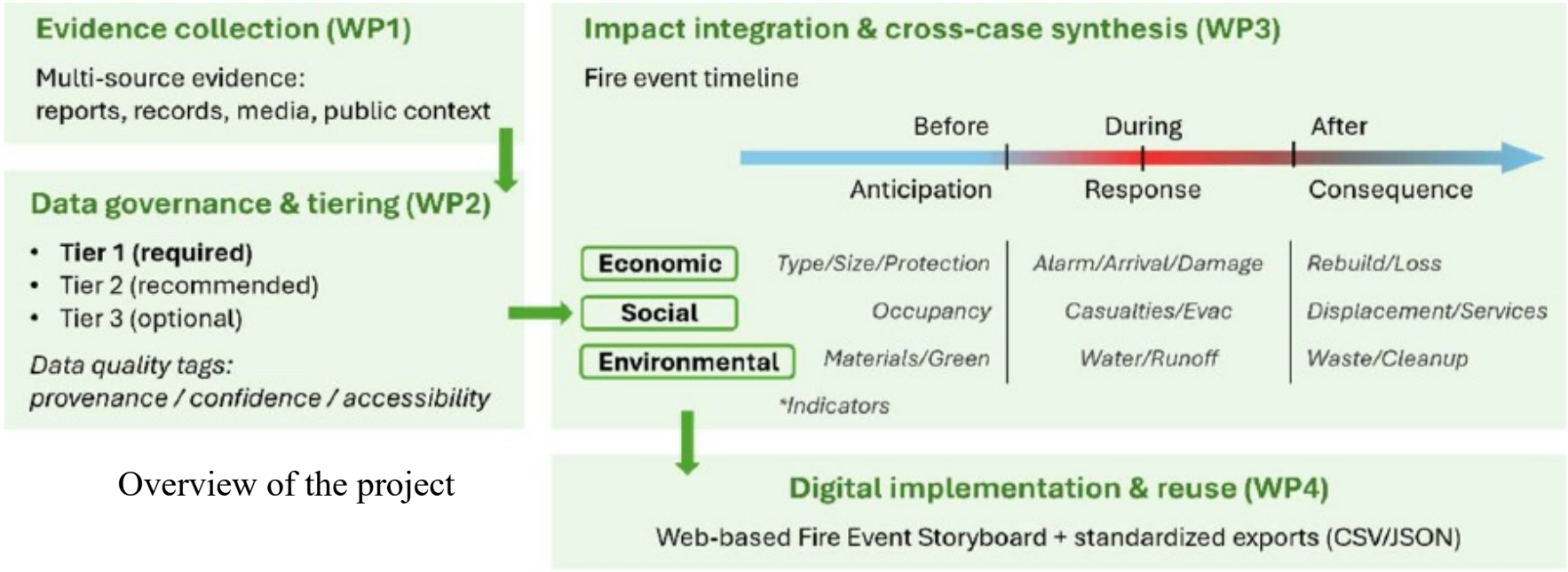
FDS volumetric rendering



Interactive Unity playback

Evidence-to-Impact Fire Event Learning

- *Faculty*: S. Ni
- *Students*: Y. Ding (postdoc)
- *Title*: Evidence-to-Impact Fire Event Learning for Resilience and Sustainability: Tiered Evidence, Impact Mapping, and Storyboard-Based Knowledge Translation
- *Sponsor*: SFPE Foundation
- *Collaborators*: Z. Nan (TU Delft), N. Flores Quiroz (Stellenbosch)
- *Objectives*: Develop a source-traceable framework that links fire-event evidence to economic, social, and environmental impacts.



Overview of the project

Milligram-scale Flame Calorimetry

- *Faculty*: F. Raffan-Montoya and S. Stoliarov
- *Students*: Thomas Roche (Ph.D.) and Connor Kragh (M.S.)
- *Title*: Development of a methodology for the evaluation of fire retardancy of fabrics using the Milligram-scale Flame Calorimeter
- *Sponsor:* U.S. Army DEVCOM Soldier Center
- Collaborators: R. Nagarajan (Umass-Lowell), A.B. Morgan (University of Dayton Research Institute)
- *Objectives*: Characterize flammability parameters and thermal response of fabrics using milligram-sized samples and compare data to bench scale tests (vertical flame spread, mannequin test)

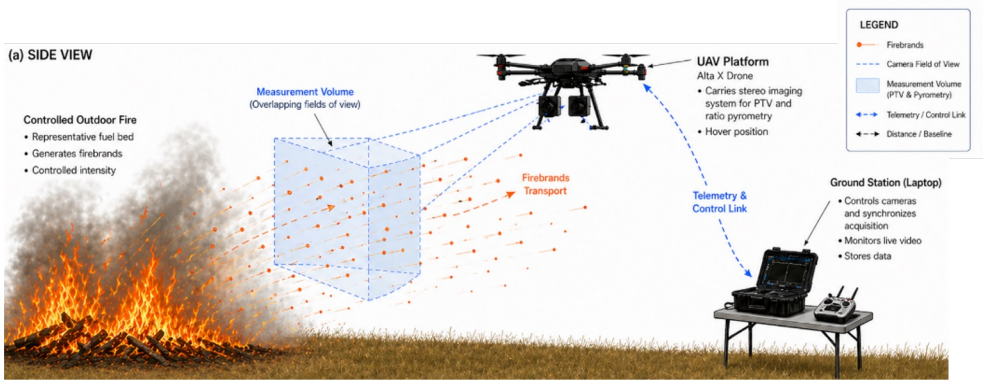




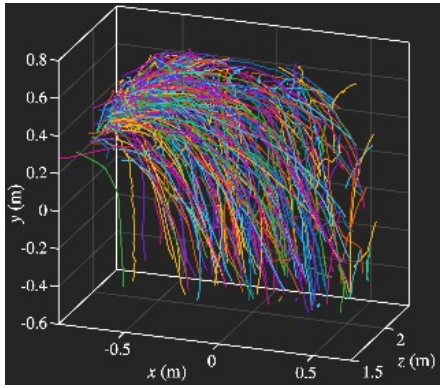


Wildfire Monitoring and Characterization: Firebrands

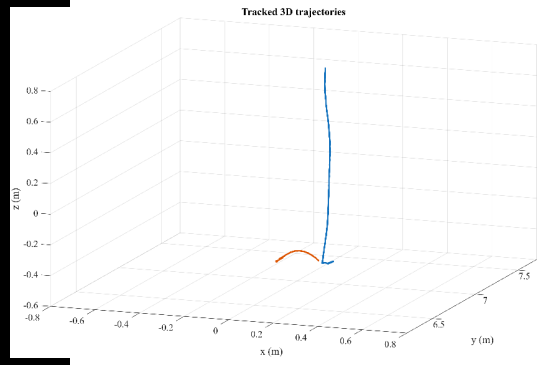
- *Faculty*: F. Raffan-Montoya
- *Student:* Adetola Koiki (Ph.D.)
- *Title*: High-Resolution Observations of Wildfires and Wildland-Urban-Interface Fires Through State-of-the-Art UAVs and Fire Imaging Technologies
- *Sponsor:* UMD
- *Objectives*: Characterize ember trajectories and fluxes with camera system onboard UAV.







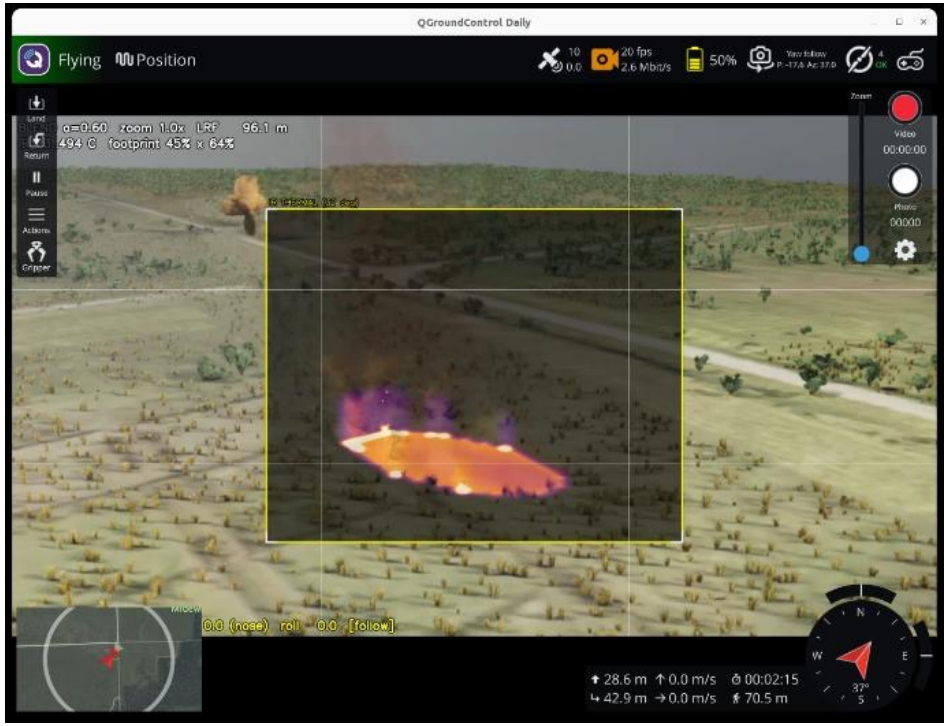




Wildfire Monitoring and Characterization: Fireline Tracking

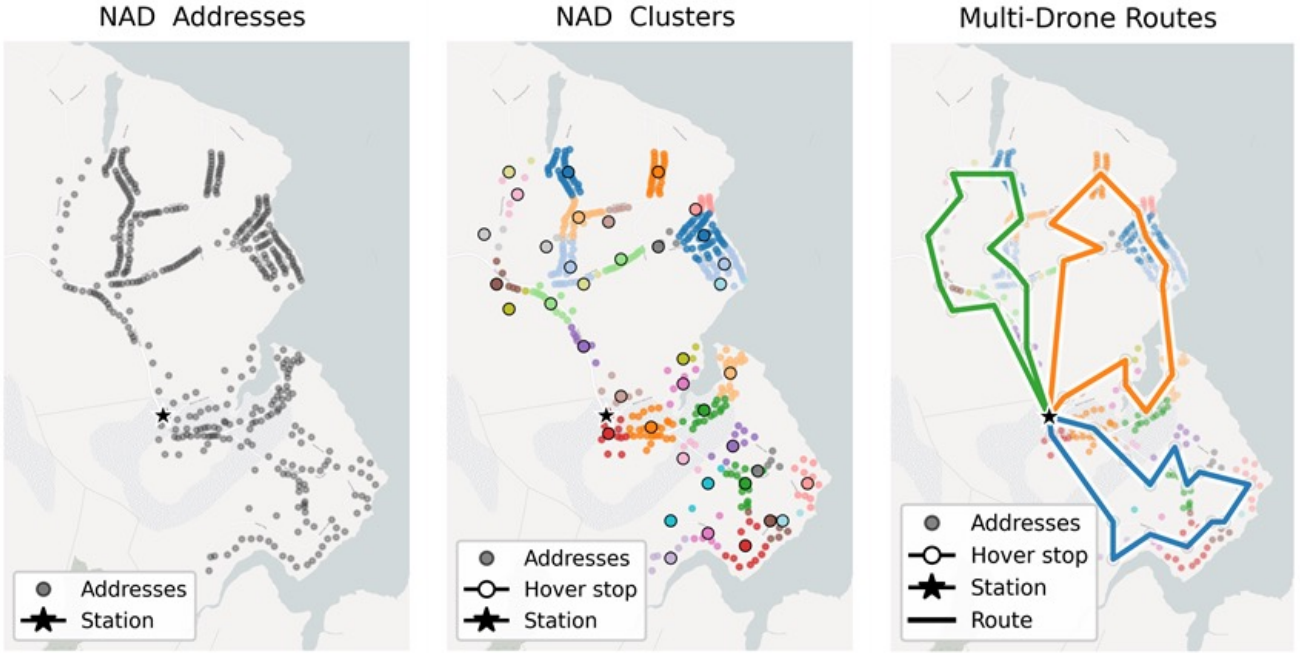
- *Faculty*: F. Raffan-Montoya
- *Student:* Andres Rivas-Bolivar (Ph.D.)
- *Title*: High-Resolution Observations of Wildfires and Wildland-Urban-Interface Fires Through State-of-the-Art UAVs and Fire Imaging Technologies
- *Sponsor:* UMD
- *Objectives*: Autonomously monitor wildfire location, perimeter, size. Fusion of wildfire and robotics simulations for a variety of applications.





Wildfire Monitoring : Autonomous Evacuation Notification

- *Faculty*: F. Raffan-Montoya
- *Student:* Andres Rivas-Bolivar (Ph.D.)
- *Title*: High-Resolution Observations of Wildfires and Wildland-Urban-Interface Fires Through State-of-the-Art UAVs and Fire Imaging Technologies
- *Sponsor:* UMD
- *Objectives*: Autonomously notify sparsely populated areas using national/local address databases and loudspeaker-equipped UAVs. Routes are optimized to notify all addresses within a given radius in the shortest possible time.

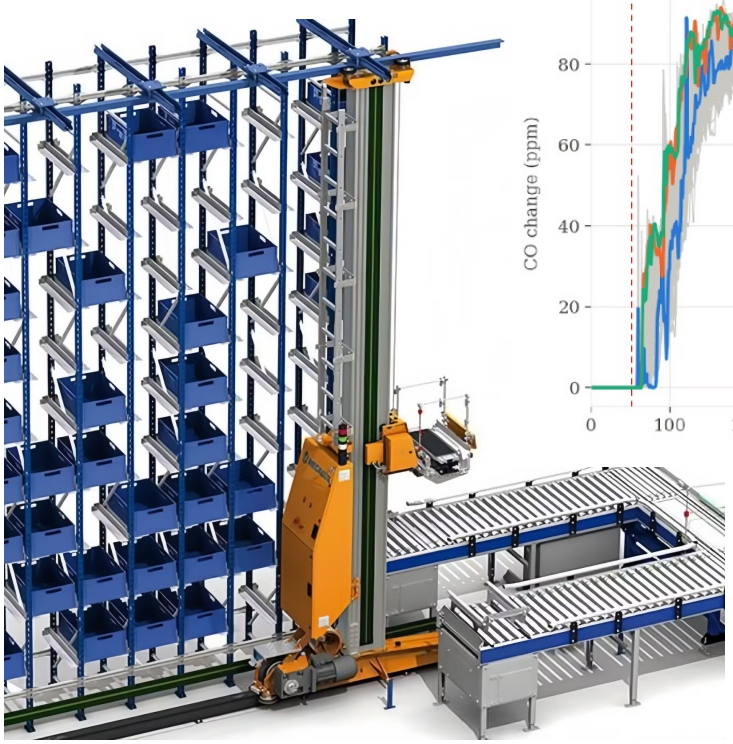


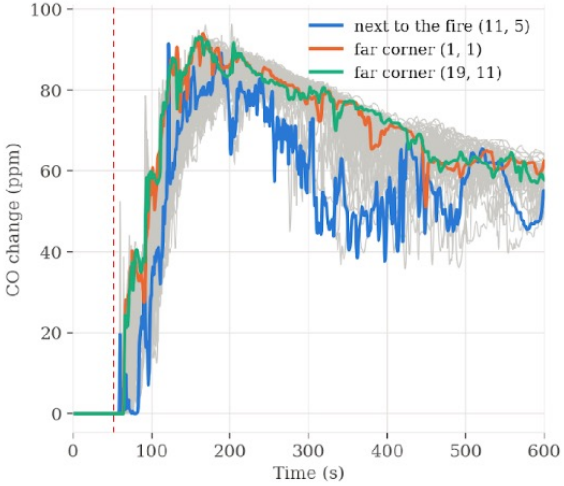
Routing Model

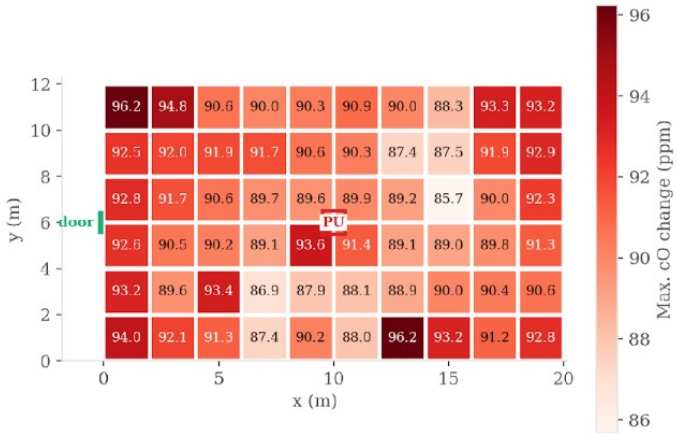
- Constant-velocity holonomic UAV model, no wind coupling
- 3-drone scenario (~2 km radius): 9.986 ms planning time

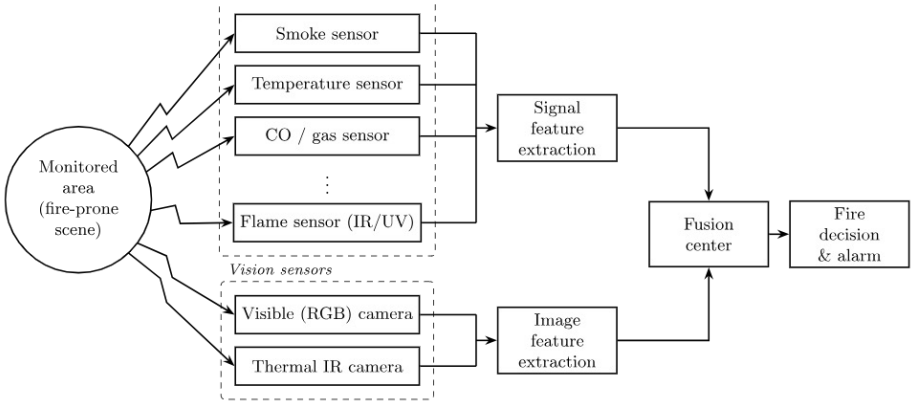
Early Detection of ASRS Warehouse Fires

- *Faculty:* F. Raffan-Montoya, A. Tohidi
- *Student:* Samuel Yepez-Romero (M.S.)
- *Sponsor*: FM Fellowship
- *Objectives*: Simulate fires in ASRS warehouse geometries and couple them with sensor simulations to identify critical sensor spacing and data fusion approaches for early fire detection.



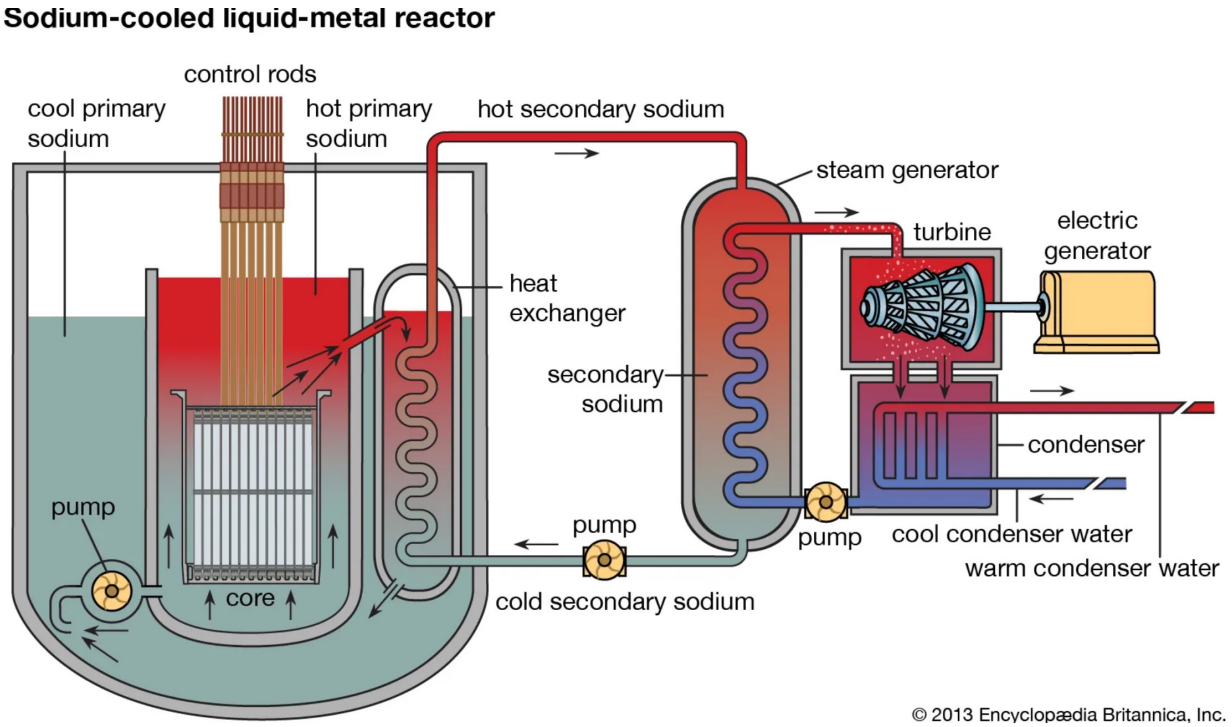






Sodium Fire Safety in Nuclear Power Plants

- *Faculty:* F. Raffan-Montoya, P. Sunderland
- *B.S. Students*: J. Chung, B. Columbus, D. Hernandez, A. Jean, M. Kim, A. Risso, M. Wilt, N. Wasserman
- *Sponsors*: Bechtel Corp. and UMD VIPS program
- *Objectives*: Study the fire hazards of liquid sodium systems. Identify and perform experiments and detailed simulations.

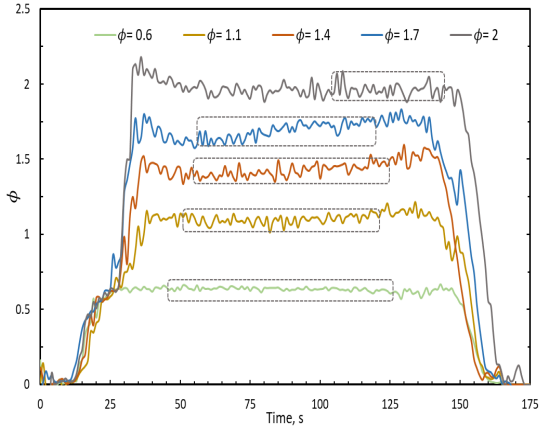


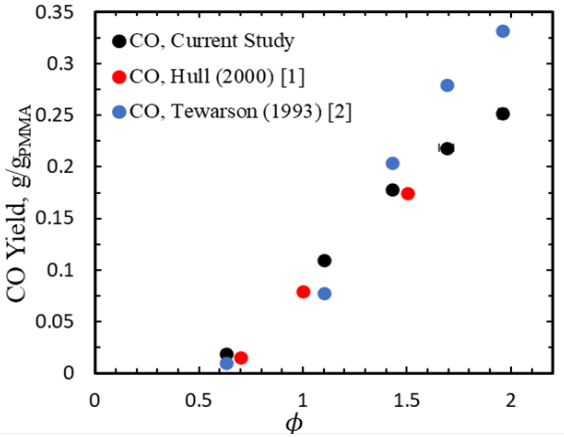
Fire Toxicity

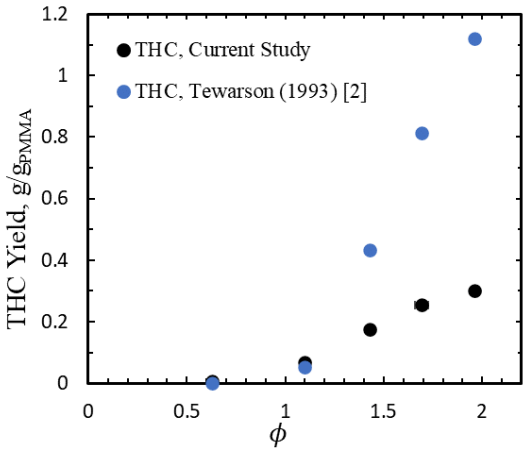
Characterization of Fire Effluent Composition

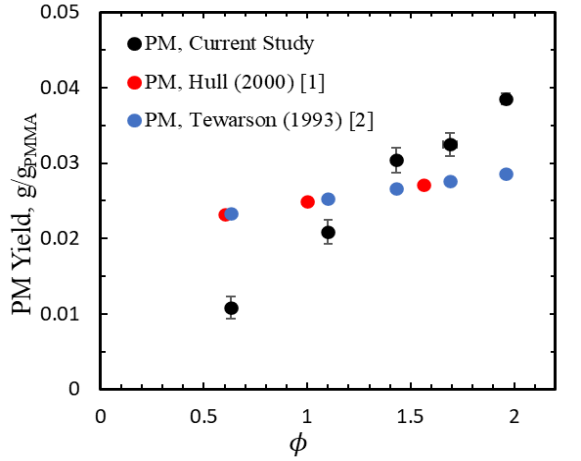
- *Faculty:* S. Stoliarov and F. Raffan-Montoya
- *Student:* F. Beygi (Ph.D.)
- *Sponsor:* FAA and FM Global
- *Objective:* To develop an advanced version of the Fire Propagation Apparatus that enables controlled equivalence ratio fire experiments including time resolved measurements of O_2, CO, CO_2, soot, HCN, HCl, HBr, and total hydrocarbons (THC)





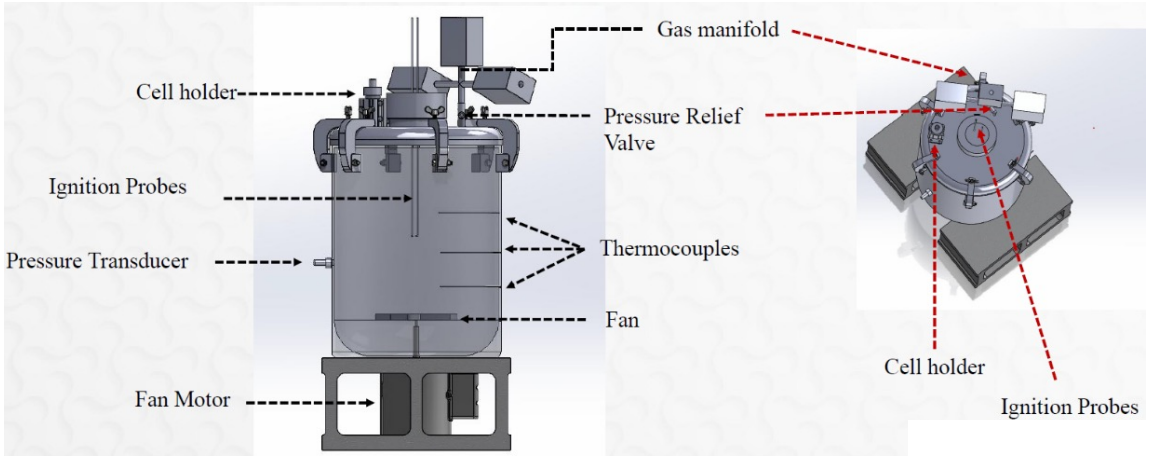


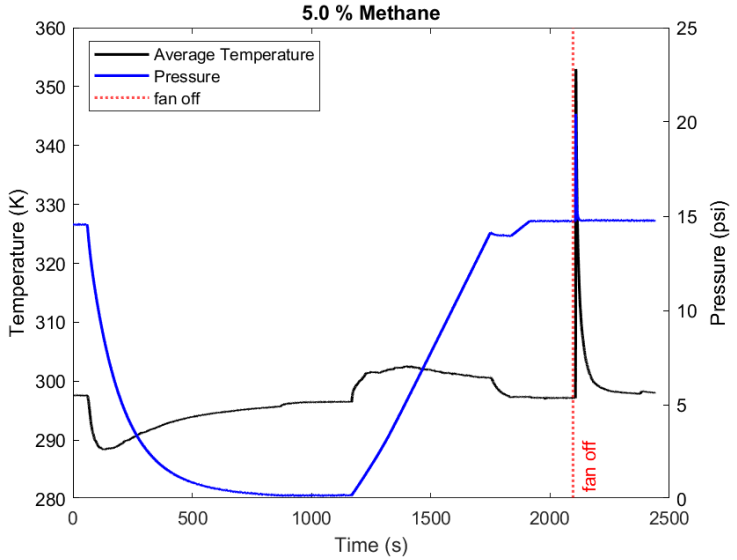




Flammability of Lithium-ion Battery Ejecta

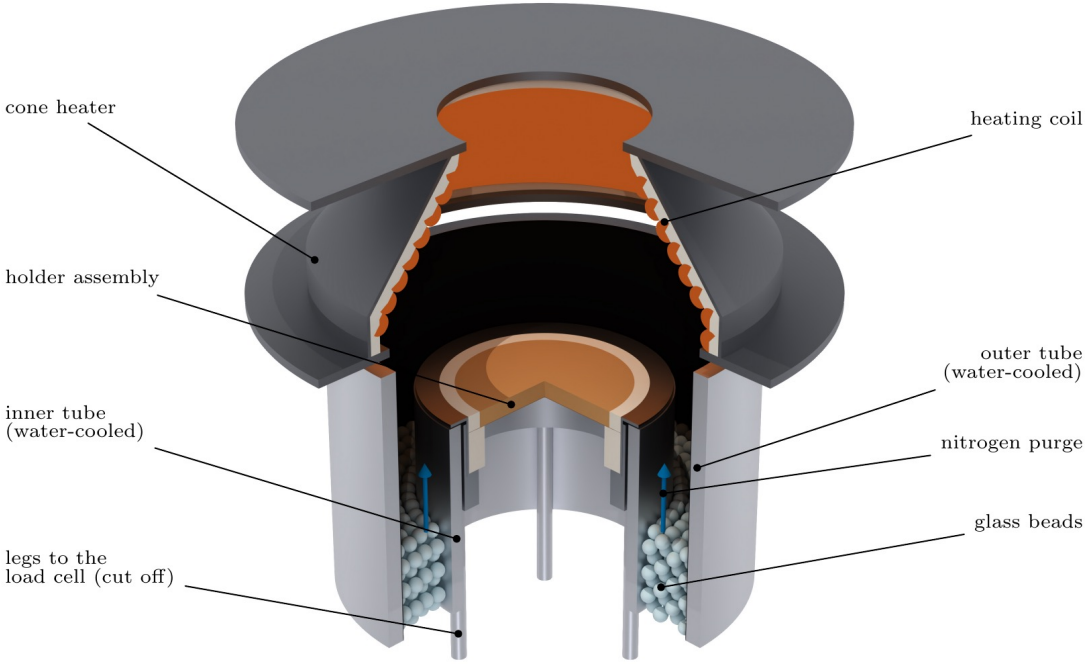
- *Faculty:* S. Stoliarov
- *Student:* J. Schwartz (Ph.D.)
- *Sponsor:* ONR
- *Objective:* To develop a method for the measurement of the lower flammability limit for gases and aerosols ejected from a lithium-ion cell undergoing a thermal runaway





Flaming and Smoldering Combustion of Wood

- *Faculty:* S. Stoliarov
- *Student:* G. Bellamy (Ph.D.)
- *Sponsor:* UL Research Institutes
- *Objective:* To measure how Douglas fir and red oak decompose and release heat in nitrogen and air, at milligram and bench scales, and develop a unified pyrolysis model that predicts both flaming and smoldering combustion of wood



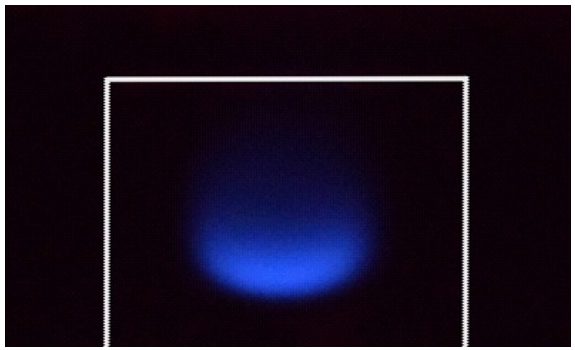
Controlled Atmosphere Pyrolysis Apparatus II:
bench-scale tests on 70 mm wood discs in nitrogen and air



Red oak smoldering in air at 35 kW/m^2

Cool Pool Diffusion Flames

- *Faculty*: P. Sunderland
- *Ph.D. Student:* S. Roy
- *M.S. Students:* S. Pimple, Y. Zheng
- *B.S. Students:* E. Ho, A. Lyons, N. Mertz
- *Sponsor*: National Science Foundation
- *Objectives*: Observe cool diffusion flames supported by pools of diverse liquid and solid fuels and perform detailed measurements and modeling.



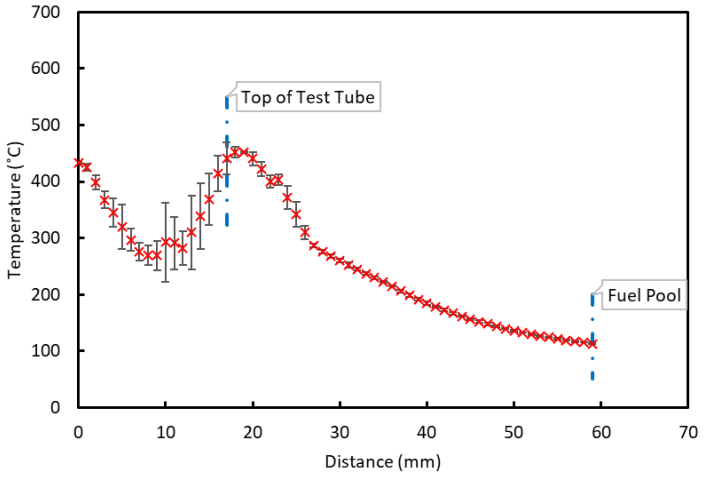
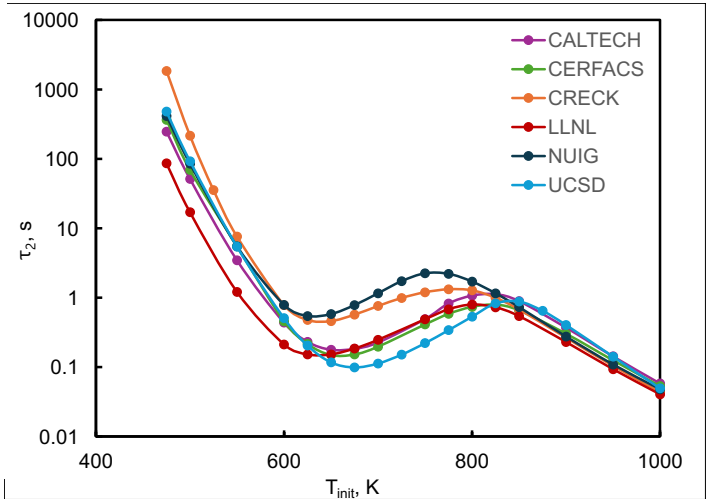


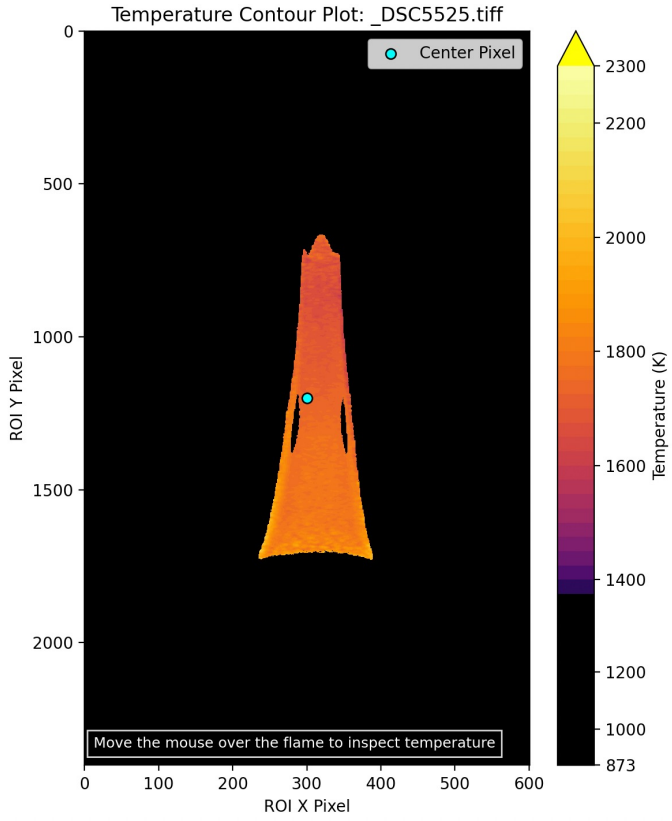
Image of n-heptane cool pool diffusion flame with the test tube shown in white (left), and measured temperatures (center).

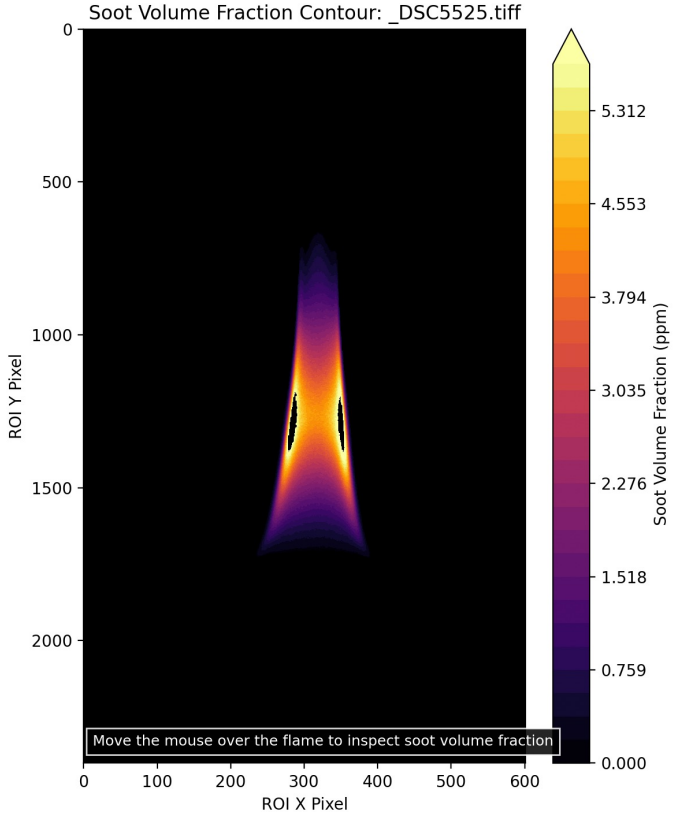


Cantera simulations of *n*-heptane negative-temperature coefficient behavior.

Camera-Based Fire Radiation Measurements

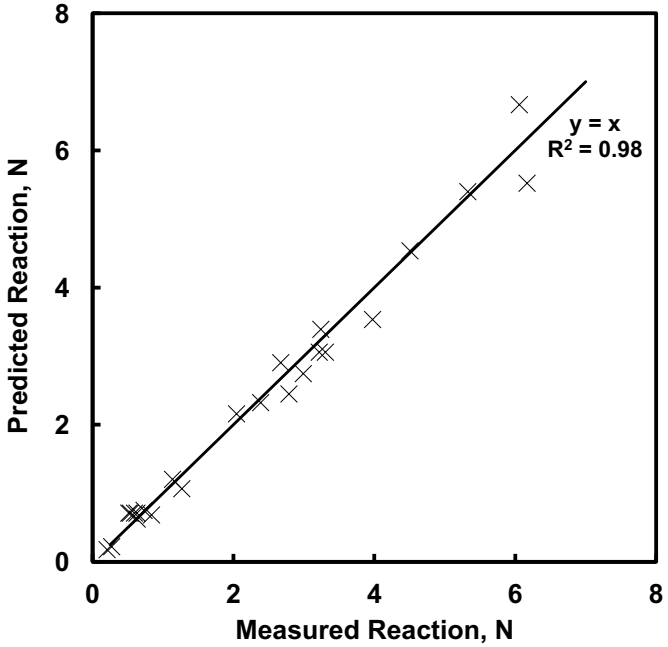
- *Faculty:* P. Sunderland
- *M.S. Student*: E. Bridges
- *Sponsor*: John L. Bryan Chair Endowed Graduate Research Assistantship
- *Objectives*: Perform color ratio pyrometry in flames and embers. Identify flaming and smoldering regions. Measure the line-of-sight temperatures, soot concentrations, and heat fluxes. Measure the radiative heat fluxes from biomass fires.

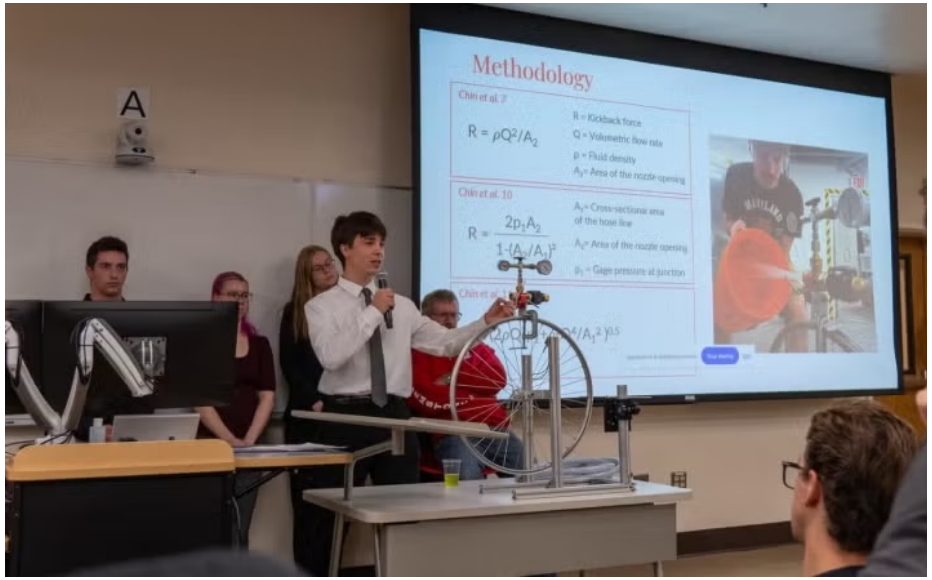


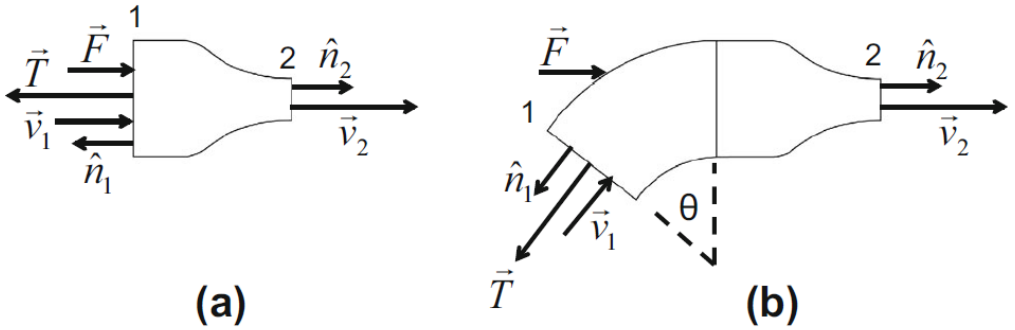


Firefighting Nozzle Reaction Forces

- *Faculty:* P. Sunderland
- *B.S. Students*: H. Coale, L. Duncan, E. Kim, A. Moulton, E. Mourlas, K. Paparrizos, R. Pusinsky, E. Safra, S. Schweitzer
- *Sponsor*: Gemstone Honors Program
- *Objectives*: Measure and analyze firefighting nozzle reactions for various nozzle sizes and flow rates.

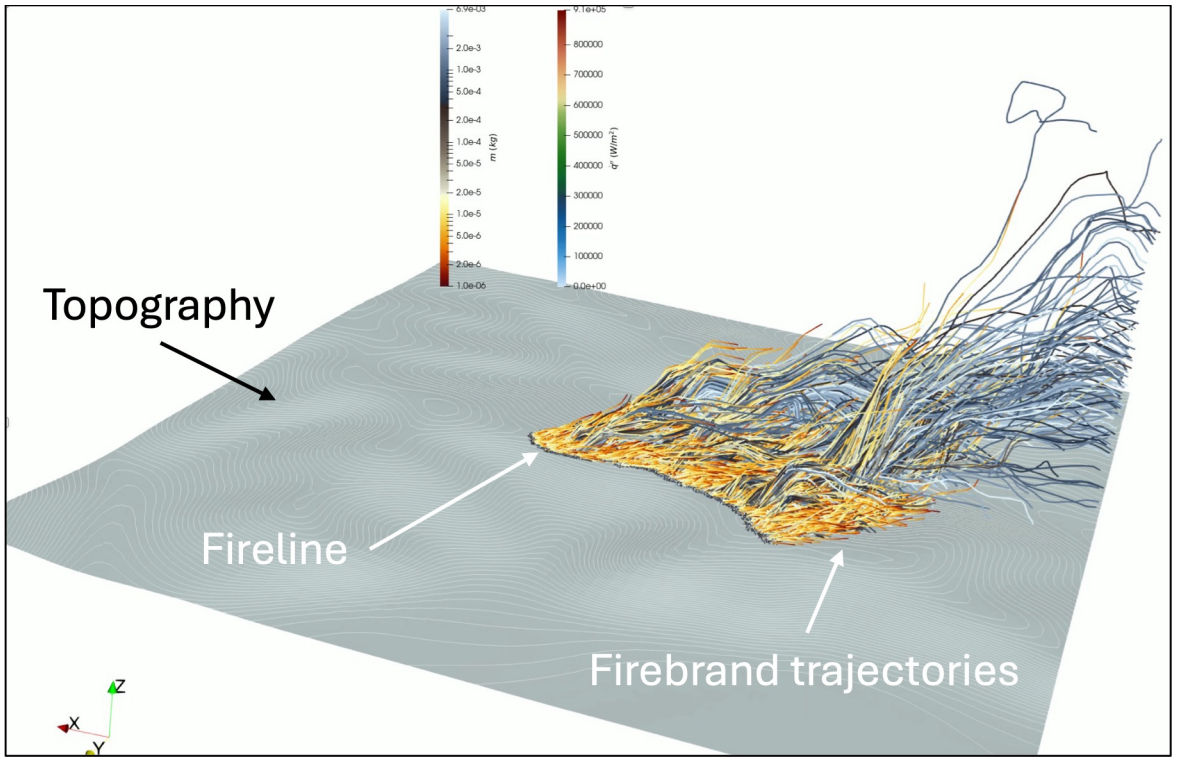






Firebrand Transport

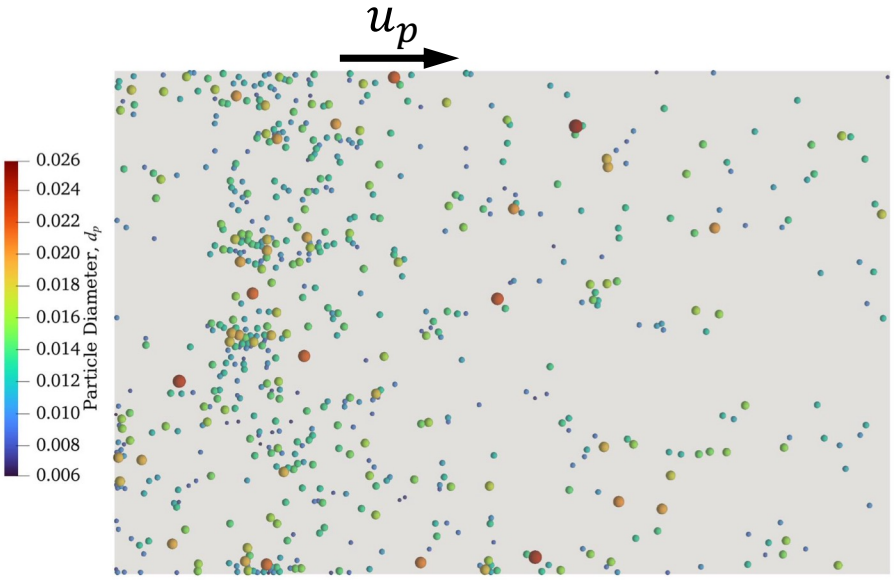
- *Faculty*: A. Tohidi
- *Title:* "A Deterministic Model for Firebrand Transport at the Landscape Scales"
- *Sponsor*: NSF-IUCRC Wildfire Interdisciplinary Research Center.
- *Collaborators: Adam Kochanski (SJSU)*
- *Objective*: Development of a highly scalable deterministic firebrand transport model to understand the effects of fire and boundary layer dynamics on firebrand transport at landscape scales. We developed a parallel code in-house and coupled it with WRF-SFIRE and FDS.



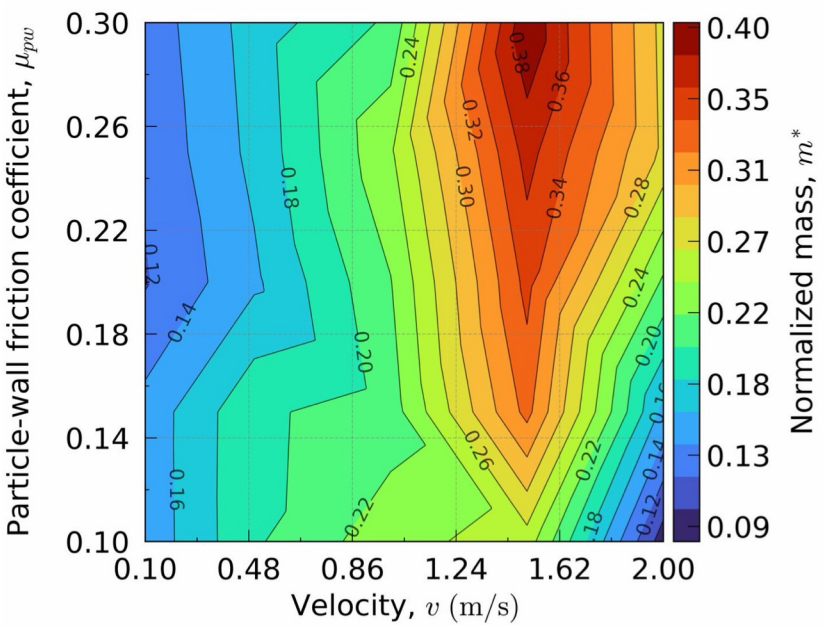
Trajectories of polydisperse polyhedron and non-polyhedron firebrands at large-scales. Millions of trajectories are resolved per time-stamp and color-coded with instantaneous particle mass. Fire line is color-coded with heat flux.

Firebrand Assemblage and Heat Transfer

- *Faculty*: A. Tohidi
- *Title:* "Understanding Assemblage Patterns and Settlement Dynamics of Firebrands"
- *Sponsor*: National Science Foundation (NSF)
- *Objective*: Understanding the effects of physical properties of firebrand particles on their assemblage patterns over surface fuels. Developed a model and conducted a set of parametric studies to identify the most influential parameters on post-landing dynamics.



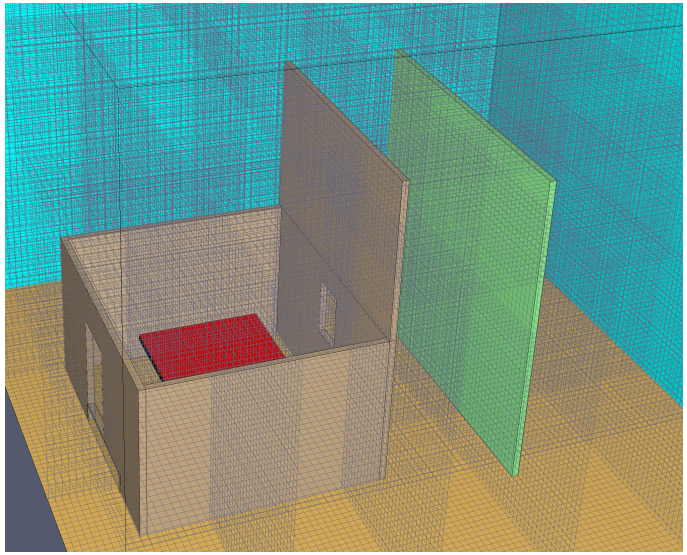
Sample firebrand assemblage pattern using the discrete element method (DEM) in MFiX.



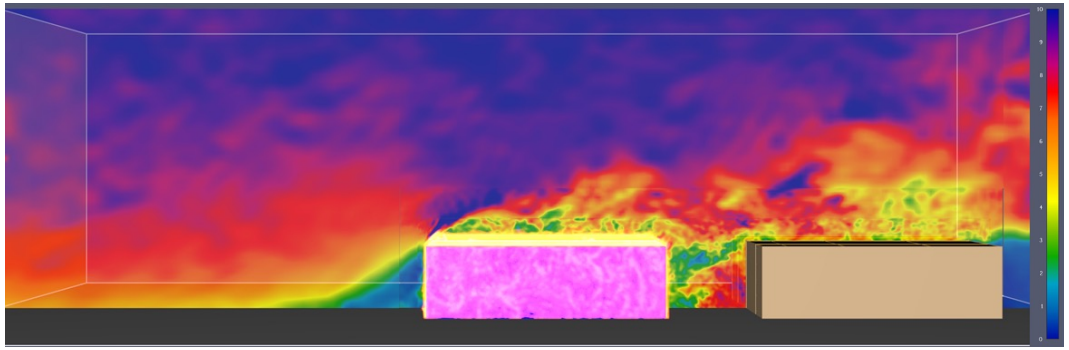
Resolved normalized mass of settled firebrands over surface fuel as a function of particle velocity and particle-wall friction coefficient.

Structure-to-Structure (StS) Fire Spread Modeling

- *Faculty*: A. Tohidi
- *Title:* "Advancing Wildland-Urban-Interface (WUI) Fire Risk Modeling Using 3D Physics-Based High-Resolution Simulations"
- *Sponsor*: California Department of Forestry and Fire protection (CAL FIRE)
- *Collaborators: Arnaud Trouve (UMD)*
- *Objective*: To advance StS modeling by enhancing the FDS modeling capabilities. The framework will enable 3D physics-based and high-resolution parametric simulations of WUI fires, accounting for the complex interactions of terrain, community layout, vegetation, wind, and ember exposure.



Domain of validation studies



A sample of parametric simulations of StS.

Digital-twin for WUI Thermal Exposure

- *Faculty*: A. Tohidi
- *Title:* "An Explainable Digital-Twin Framework for Estimating the Thermal Exposure of Structures in Wildland Urban Interface Fires"
- *Sponsor: Insurance Institute for Business and Home Safety (IBHS)*
- *Objective*: To develop a data-driven and explainable machine-learning pipeline for estimating the thermal exposure of structures during Wildland Urban Interface (WUI) fires.

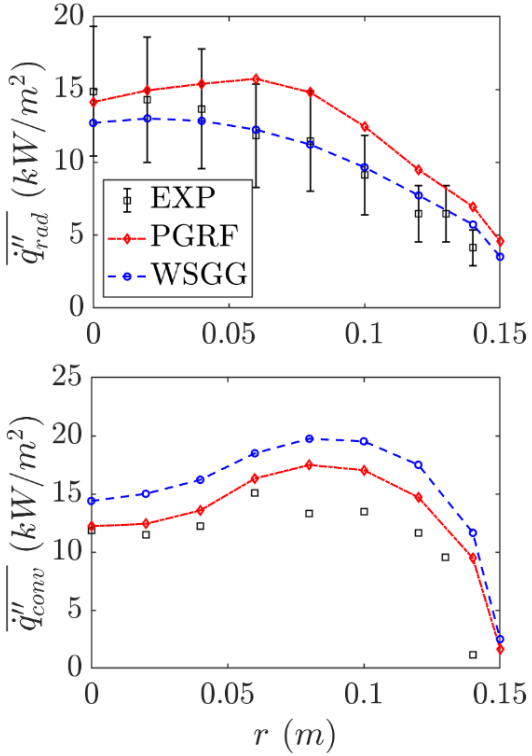


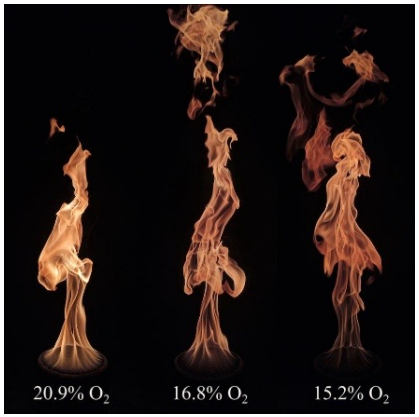
Image excerpted from Hedayati et al. (2026) [1].

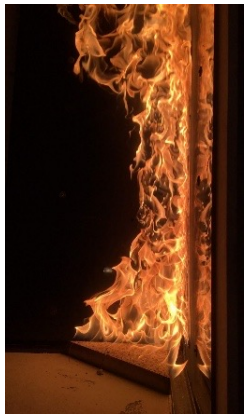
[1] Hedayati, F. et al. Wind-Driven Building-to-Building Fire Spread: Experimental Results and Probabilistic Modeling. Fire Technol ***62****, 32 (2026).*

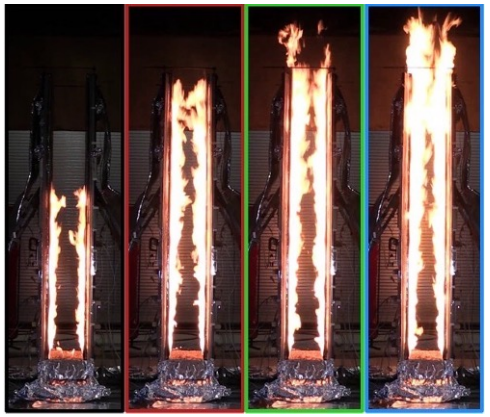
The MaCFP Working Group

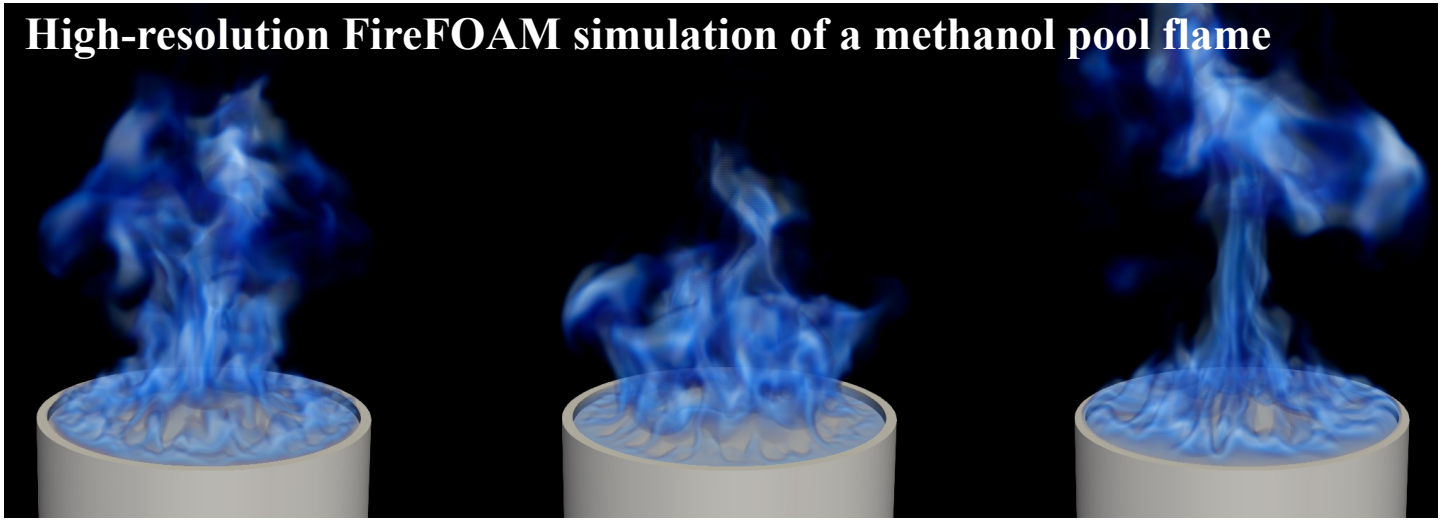
- *Faculty*: A. Trouvé
- *Collaborators*: the IAFSS Working Group on Measurement and Computation of Fire Phenomena (the MaCFP Working Group, http://www.iafss.org/macfp)
- *Objective*: Build a collaborative framework (through a series of workshops) around the topic of the experimental validation of computer-based fire models.





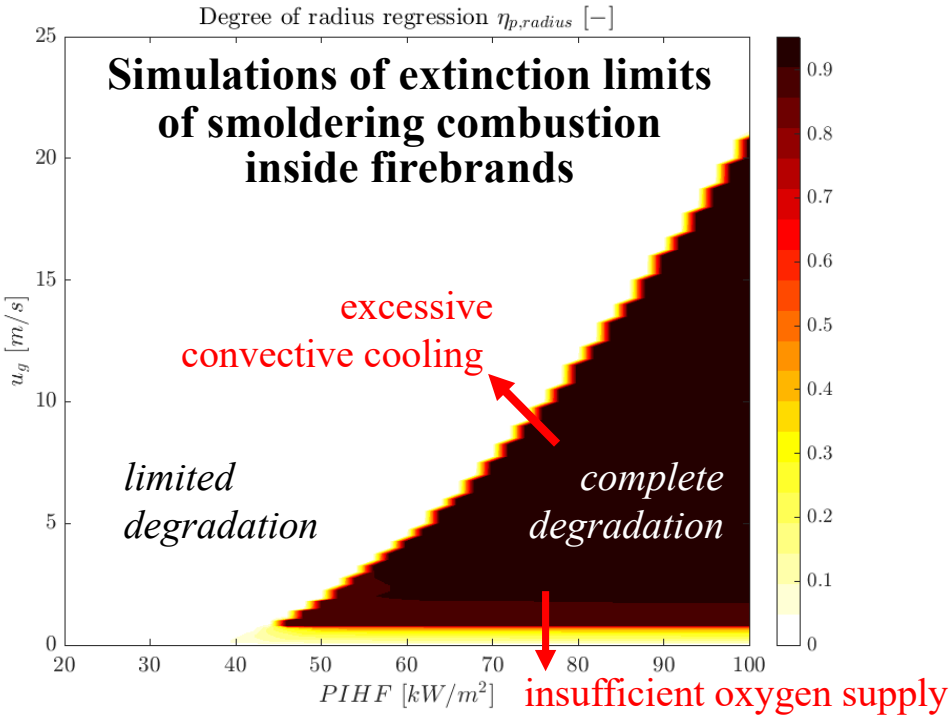


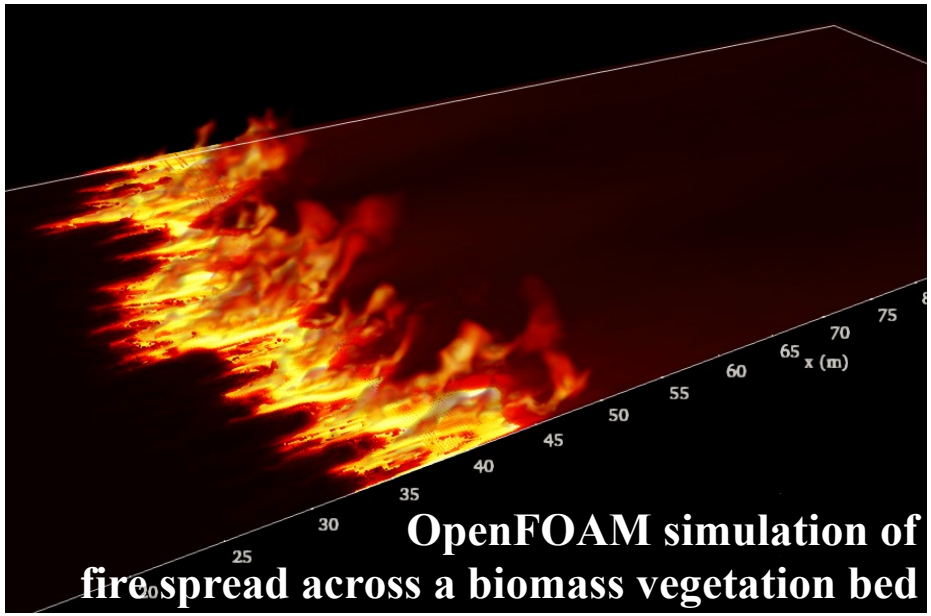




Flame-Scale Modeling of Wildland Fire Spread

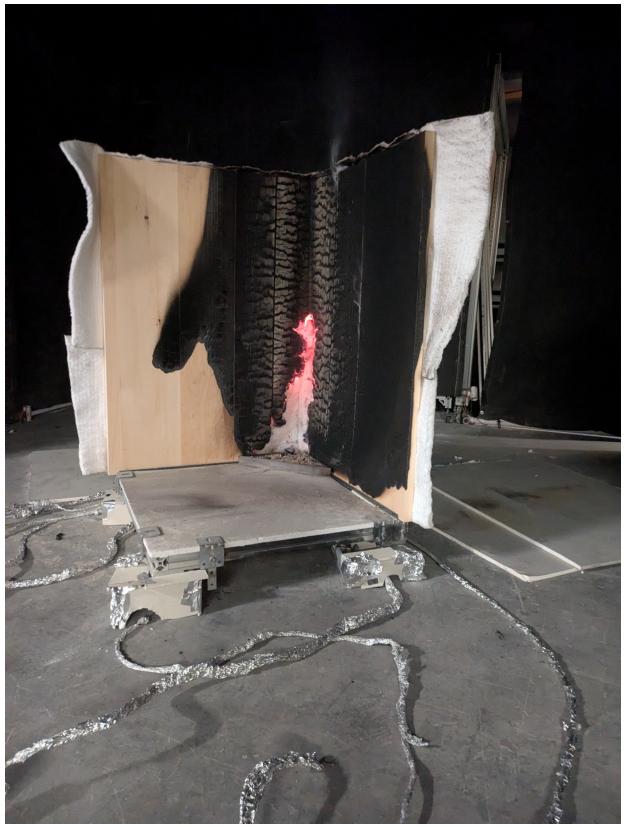
- *Faculty*: A. Trouvé – *Postdoc*: L. Li; *PhD student*: H. Al-Bulqini; *MS student*: B. Zhan
- *Title:* "Modeling of flaming and smoldering combustion in firebrands and in biomass vegetation beds"
- *Sponsor*: UL Fire Safety Research Institute
- *Objective*: Develop a state-of-the-art computational modeling capability that simulates wildland fire behavior at vegetation and flame scales. Perform detailed simulations of wildland fire behavior with a high-resolution description of flame spread, heat release and fuel consumption. (Solvers: OpenFOAM; FDS.)



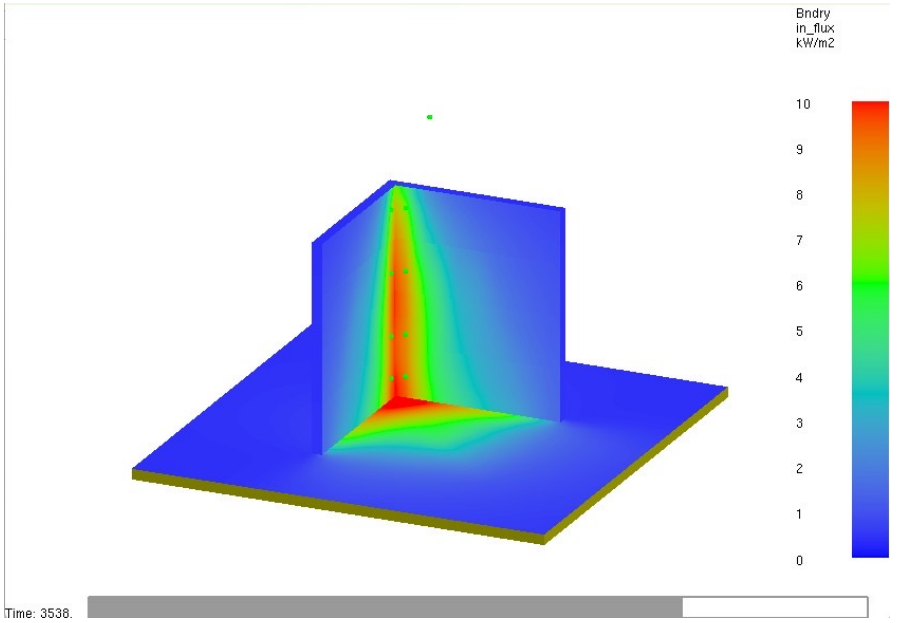


Modeling of Smoldering Combustion

- *Faculty*: A. Trouvé, S. Ni – *PhD student*: Z. Hussain
- *Title:* "Modeling of self-sustained smoldering in mass timber compartment fires"
- *Sponsor*: Code Consultants, Inc. (CCI)
- *Objective*: Develop a submodel that simulates smoldering combustion in scenarios relevant to fire safety in mass timber buildings. (Solver: FDS.)



Corner wall fire experiment leading to sustained smoldering combustion at the corner location



FDS simulation of the corner wall fire experiment

Flame-Scale Modeling of WUI Fire Spread

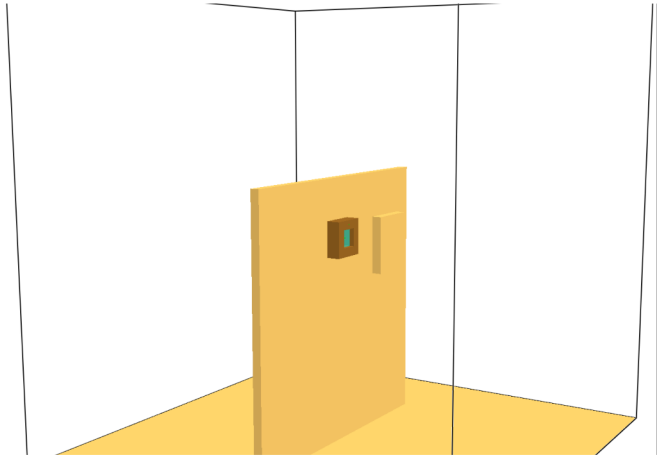
- *Faculty*: A. Trouvé, A. Tohidi – *MS student*: R. Vacek
- *Title:* "Modeling of window failure in structure-to-structure fire spread"
- *Sponsor*: UL Fire Safety Research Institute
- *Collaborator*: D. Chaudhari (UL FSRI)
- *Objective*: Develop a submodel that simulates window failure (glass or frame) in scenarios relevant to wildland-urban-interface (WUI) fires and urban fires. (Solver: FDS.)



R.L. Schrader, S. Ni, N.W. Dow, J.M. Willi, M.J. DiDomizio, G.P. Horn (2025) Fire Technol. 61, 2361-2387.



J.M. Willi, D.J. Gorham, G.P. Horn (2025) Fire Technol. 61, 1613-1645.



FDS representation of Schrader's experiment

Regional-Scale Modeling of Wildland/WUI Fire Spread

- *Faculty*: A. Trouvé – *PhD student*: M. Giorgi
- *Title:* "Preventing the next Disaster at the Wildland-Urban Interface: Development of a validated end-to-end WUI modeling system to optimize mitigation"
- *Sponsor*: Gordon and Betty Moore Foundation
- *Collaborators*: M. Gollner (UCB), C. Lautenberger (CloudFire Inc.)
- *Objective*: Extend modeling capabilities of current landscape-scale wildland fire spread models to the case of wildland/WUI fire spread due to firebrands (Solver: ELMFIRE, developed by CloudFire Inc.)

