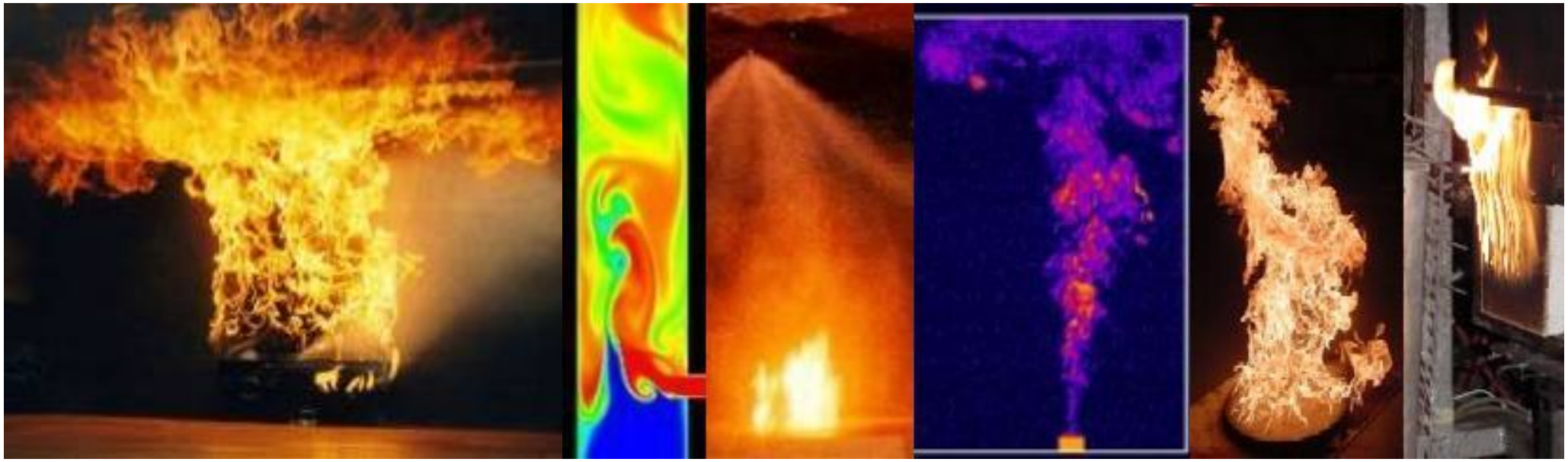


Research Overview

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

http://www.fpe.umd.edu

September 2019

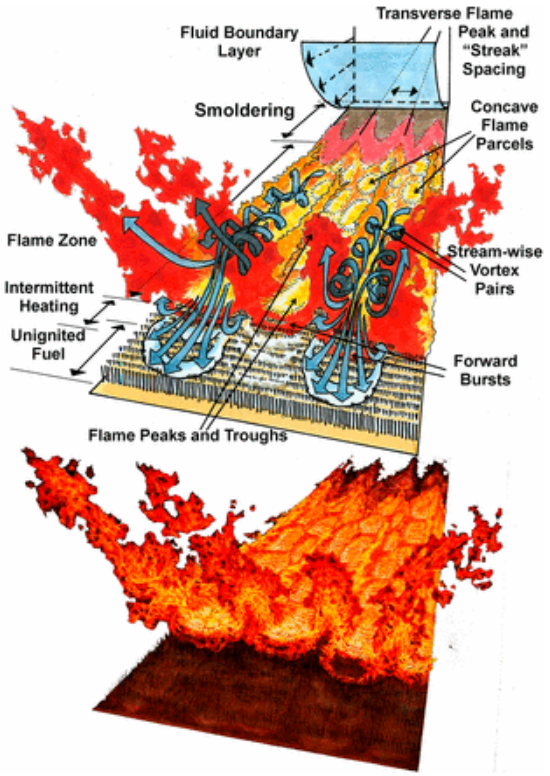
Full-Time Faculty

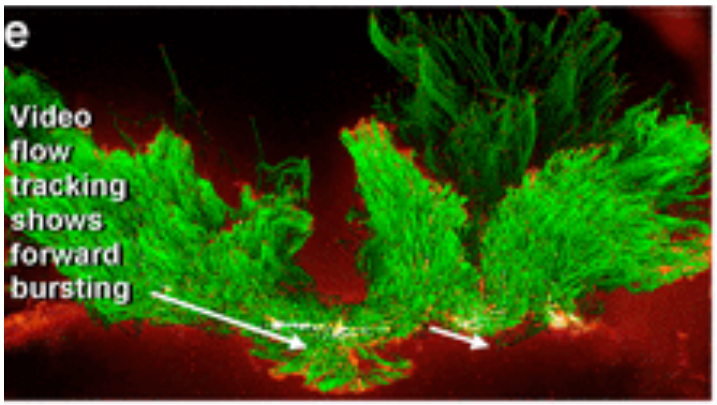
Faculty	Research Areas
M. di Marzo	suppression, detection
M. Gollner	wildfires, flammability, sustainability
K.E. Isman	suppression systems
A.W. Marshall	fire flows, combustion, suppression
J.A. Milke	structures, detection, egress
S.I. Stoliarov	pyrolysis, flammability, fire growth
P.B. Sunderland	fire dynamics, diagnostics, refrigerant fires
A. Trouvé	turbulent combustion, fire modeling

Wildland Fires

Flame Attachment and Fire Spread

- *Faculty*: M. Gollner, A. Trouvé
- *M.S. Students:* Lana Benny, Evan Sluder
- *Ph.D. Students*: Xingyu Ren
- *Title*: Buoyant instabilities in inclined fires
- *Sponsor:* USFS RMRS Decision Support Center
- *Collaborators*: M. Finney, S. McCallister (USFS)
- *Objectives*: Determine the mechanisms responsible for wildland fire spread. Current work on adding grid-generated turbulence, understanding flame attachment and intermittent heating on fuels.



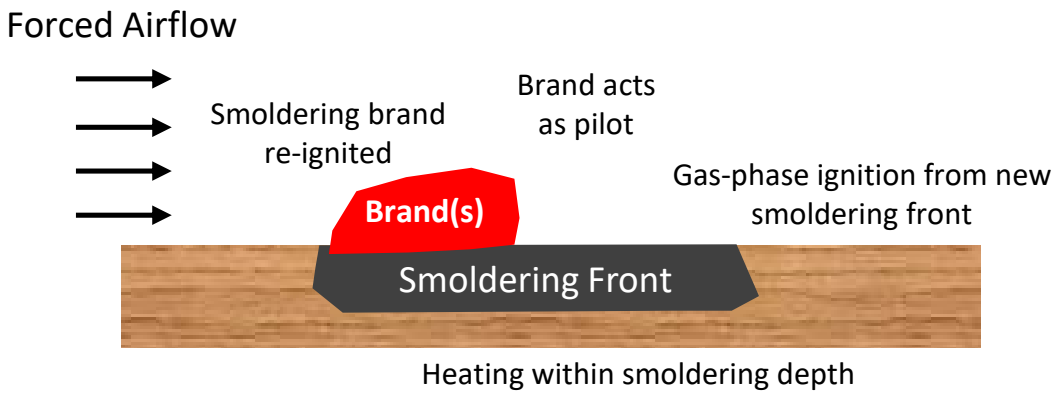


Proc. Natl. Acad. Sci. USA. 112(32) 9833–9838, 2015

Ignition by Firebrands

- *Faculty*: M.J. Gollner
- *Students:* H. Salehizadeh (M.S.), R. Hakes (Ph.D.), A. Davis (B.S.), E. Griffith (B.S.)
- *Title*: Understanding Ignition Susceptibility of Wildland Urban Interface (WUI) Fuels to Firebrand Attack
- *Sponsors*: NIST EL Fire Grant Program
- *Objective*: Understand ignition by firebrands of wood, plastic and composite assemblies attached to structures, such as decks, fences, porches, etc.

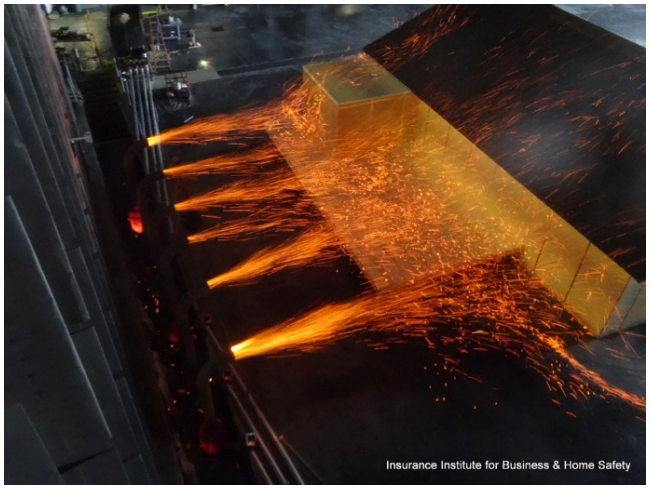
Flaming ignition of a Redwood decking assembly due to firebrand accumulation (Manzello and Suzuki, 2014).



Different possibilities for the ignition process conceived as a result of a single brand or pile of smoldering embers placed on a wooden substrate. The possible locations for ignition will be determined by experiments and then incorporated into analyses.

Generation of Firebrands

- *Faculty*: M.J. Gollner
- *Title*: Fire Ember Production from Wildland and Structural Fuels
- *Sponsors*: Joint Fire Science Program (USFS)
- *Objective*: (1) Understand how firebrands are generated by vegetation using simple laboratory experiments and scaling. (2) Perform large-scale experiments at IBHS to characterize firebrand generation.



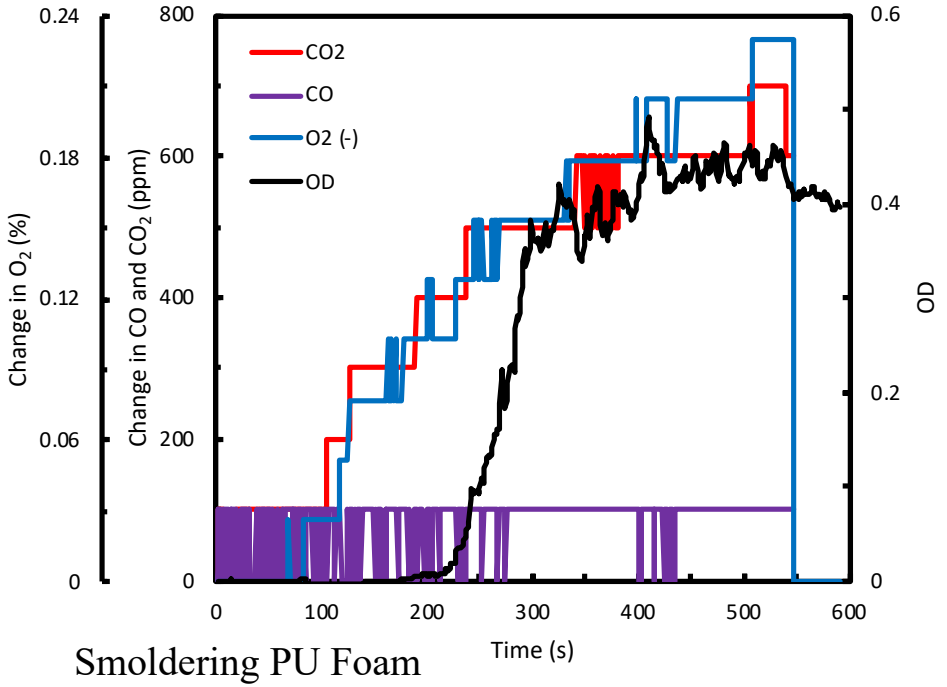
UNC CHARLOTTE

Insurance Institute for Business & Home Safety®

JOINT FIRE SCIENCE PROGRAM

Fire Detection in Aircraft

- *Faculty*: J.A. Milke
- *Students:* S. Chin and J. Wood
- *Title*: "Improvements in Aircraft Fire Detection"
- *Sponsor*: FAA
- *Objective*: assess the ability of state-of-the-art detection technologies to provide rapid detection while ignoring nuisance sources for cargo compartments in aircraft. Particular attention is given to the response of gas sensors and dual wavelength detectors located inside unit load devices and along the ceiling of the cargo compartment.

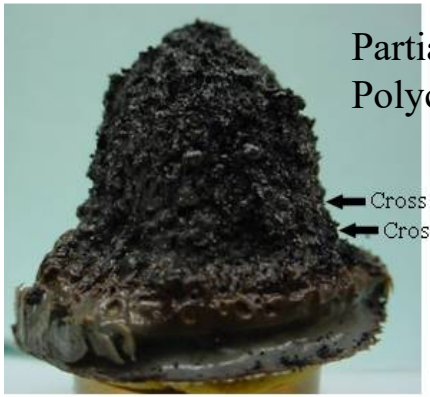


Smoldering PU Foam

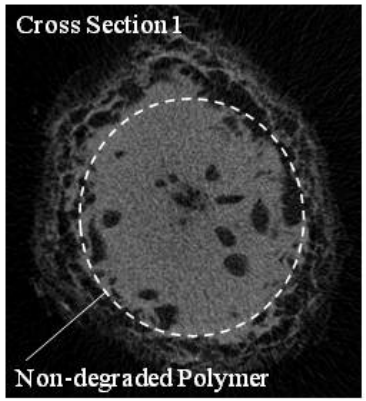
Pyrolysis and Oxidation

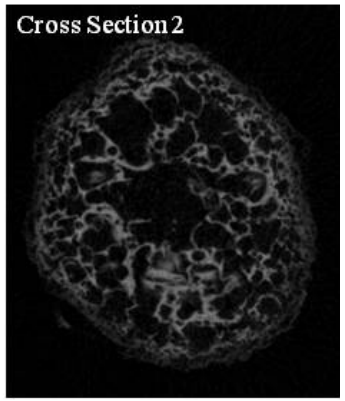
Understanding Flammability of Charring Polymers

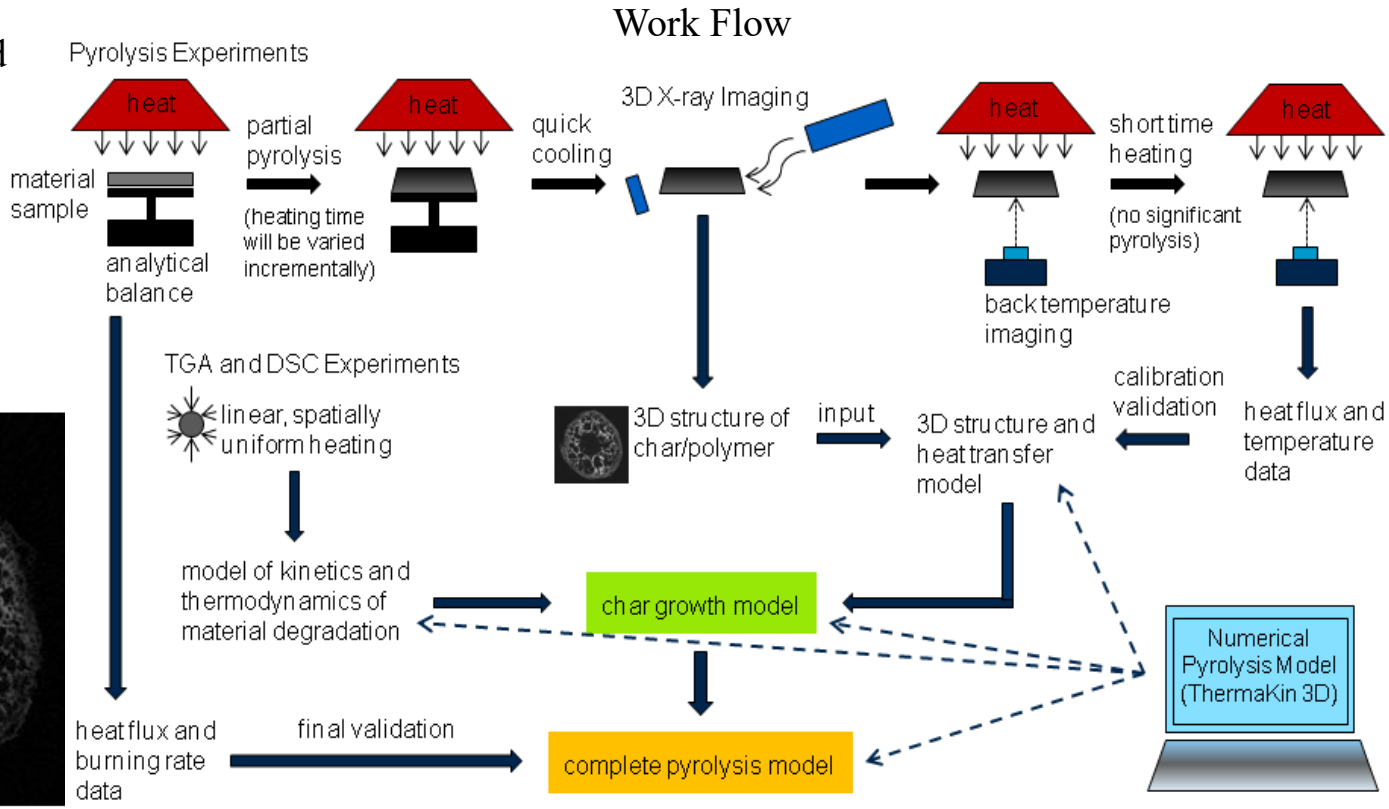
- *Faculty:* Stoliarov
- *Students:* J. Swann (Ph.D. candidate), Y. Ding (Ph.D. candidate)
- *Sponsor:* NSF CAREER
- *Objective:* To develop quantitative understanding of char growth dynamics and its relations to the thermal decomposition chemistry and heat transfer in a wide range of polymeric systems including a new generation of biodegradable materials.



Partially Pyrolyzed Polycarbonate



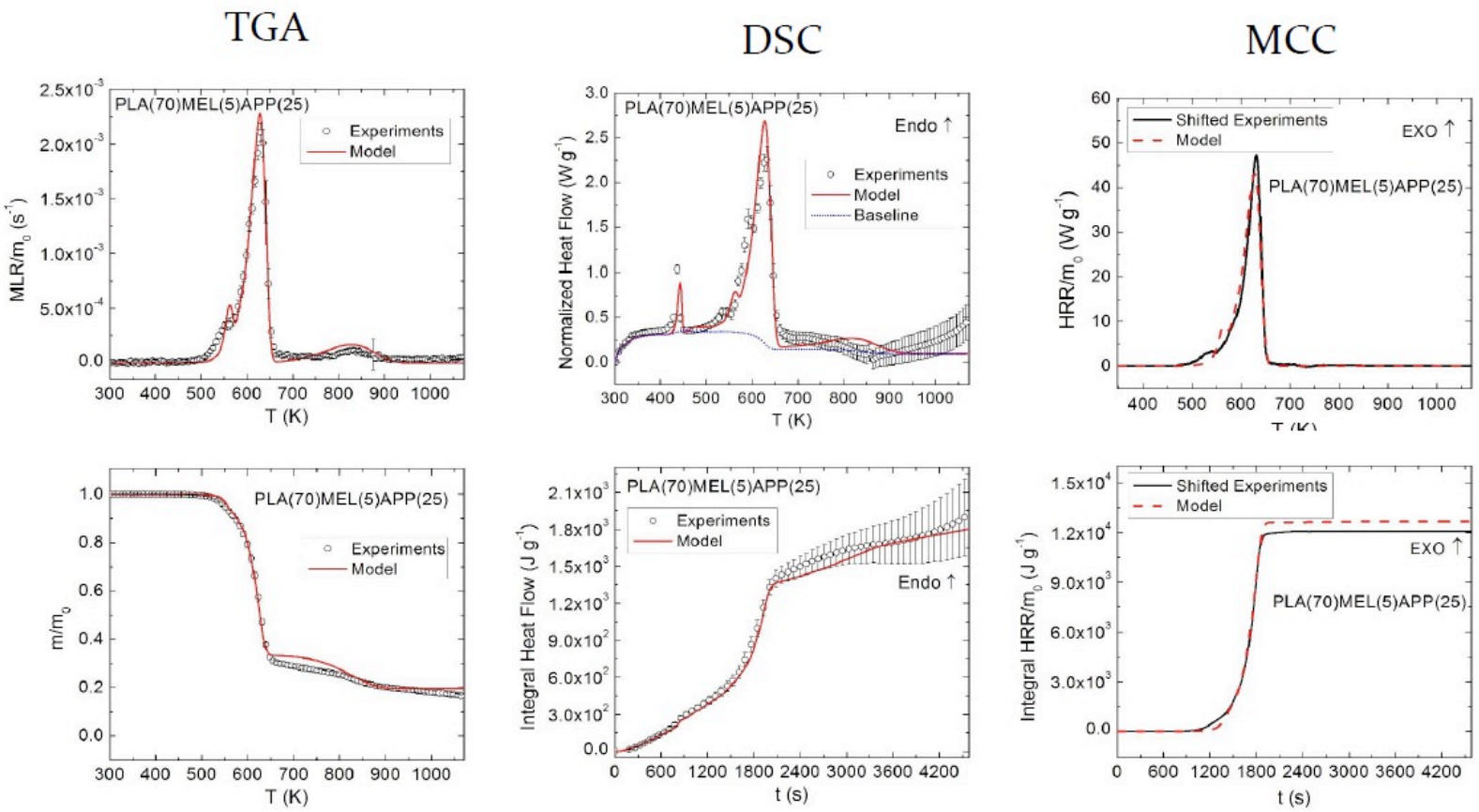




Modeling Impact of Condensed-phase Active Flame Retardants

- *Faculty:* Stoliarov
- *Students:* Y. Ding (Ph.D. candidate), C. McCoy (Ph.D. candidate)
- *Sponsor:* BASF
- *Objective:* To develop a systematic approach to quantification of the impact of condensed-phase active flame retardants on the rate on pyrolysis and flame spread.

Prediction of mg-scale experiments for a material containing multiple flame retardants

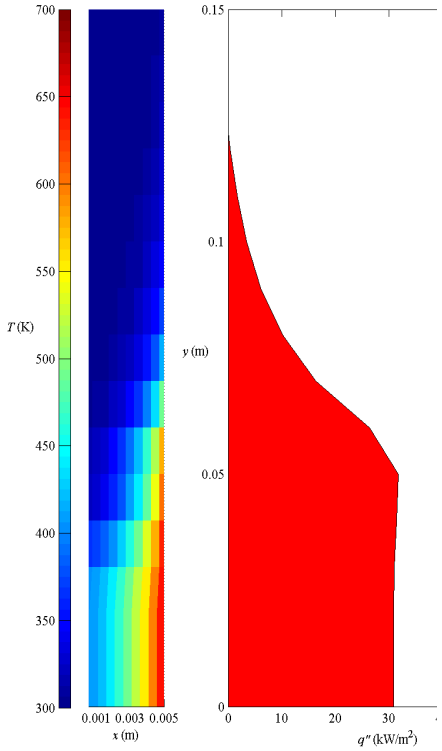


Prediction of Material Performance in Standard Flammability Tests

- *Faculty:* Stoliarov
- *Students:* J. Tilles (M.S. candidate), C. McCoy (Ph.D. candidate)
- *Sponsor:* FAA
- *Objective:* To develop a computational tool for prediction of fire growth in a range of standard flammability testing scenarios, including cone calorimetry, UL-94 and single burning item test, from material properties.

Standard Flammability Tests

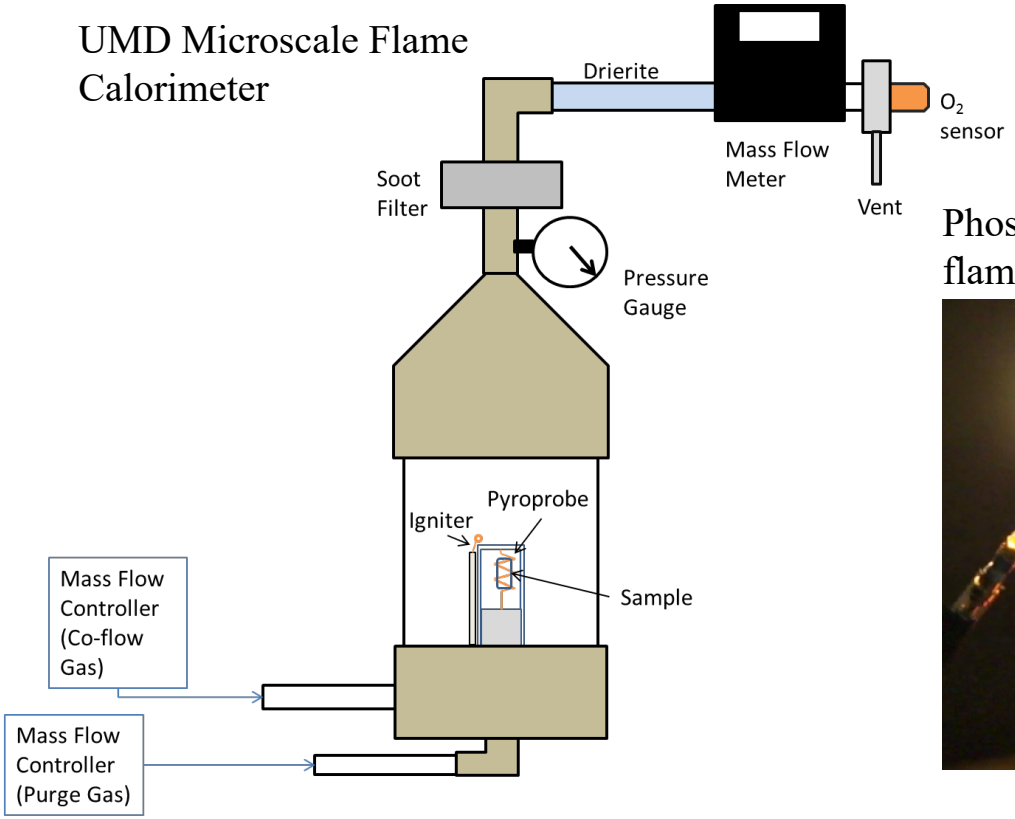
Flame Spread Experiment versus Model Prediction



Effectiveness of Gas-Phase Flame Retardants

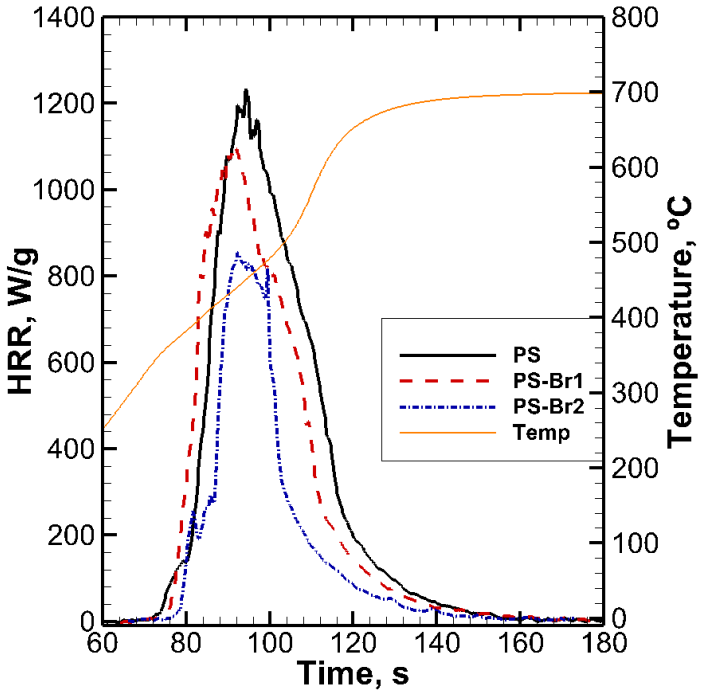
- *Faculty:* Stoliarov
- *Students:* F. Raffan (Post-doc) , A. Kushner (B.S. candidate)
- *Sponsor:* ICL-IP
- *Objective:* To develop an experimental method for the measurement of effect of gas-phase-active flame retardant additives on ignitability and burning intensity of solid materials using mg-sized samples.

UMD Microscale Flame Calorimeter



Phosphorus-induced flame extinction

Polystyrene (PS) and brominated polystyrene (PS-Br) heat release rate (HRR) histories

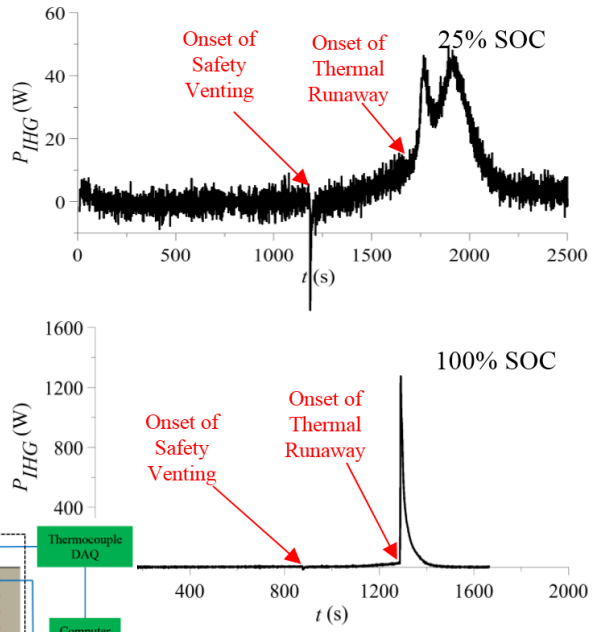


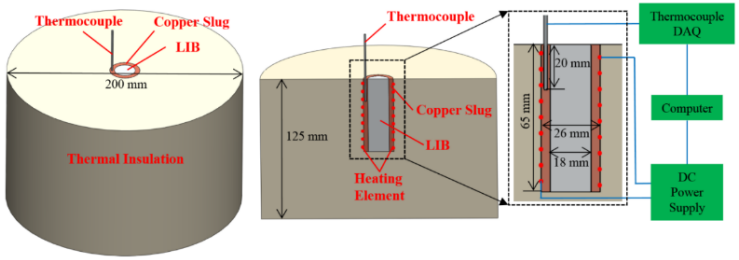
Applied Studies

Fire Safety of High Capacity Electrical Energy Storage Systems

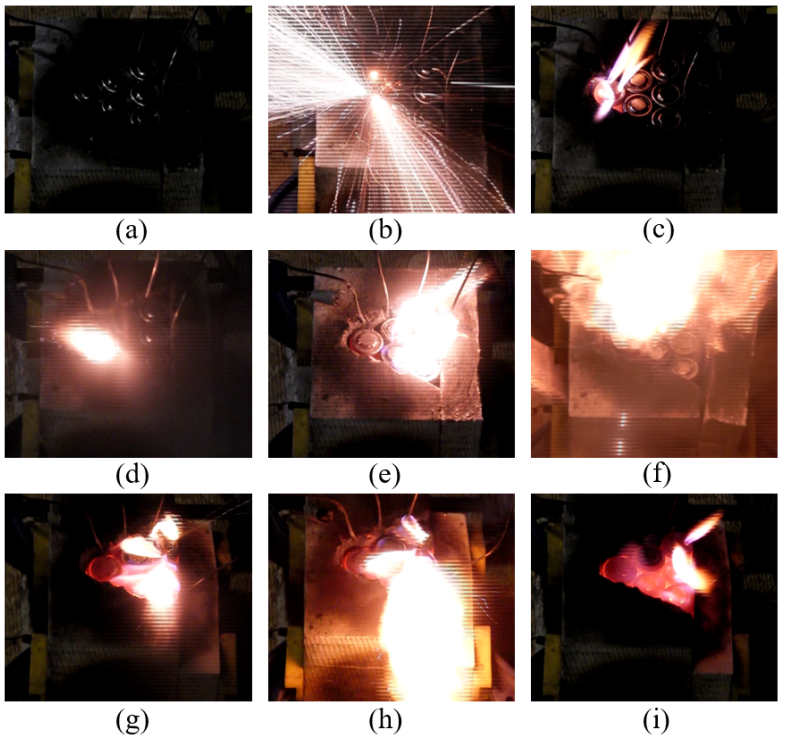
- *Faculty*: Stoliarov, Marshall
- *Students:* A. Said (Ph.D. candidate), C. Lee (M.S. candidate)
- *Sponsor:* Carrier Center of Excellence
- *Objective:* To conduct an investigation of the processes that drive cascading failure of lithium ion battery packs and examine a spectrum of detection and suppression methodologies with the goal of identifying the most effective and cost-efficient approach to lithium ion battery fire mitigation.

Heat generation by the processes inside a lithium ion cell during its thermal failure measured in the Copper Slug Battery Calorimeter





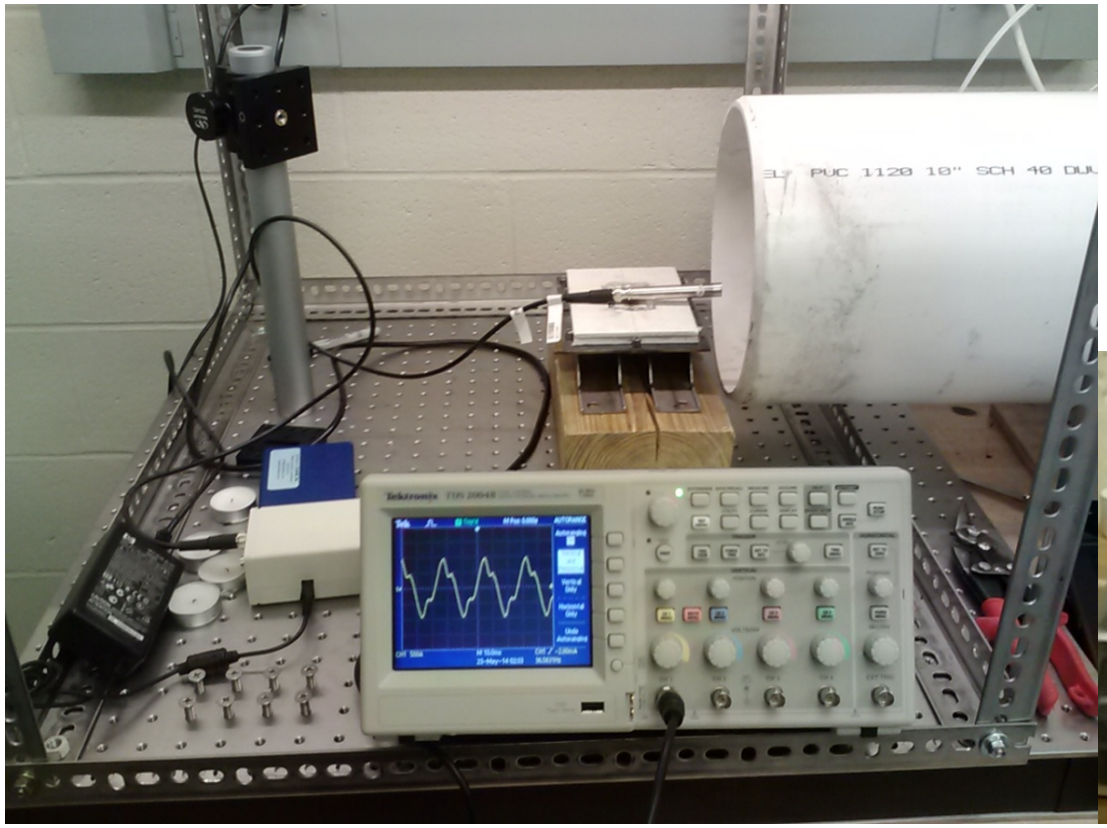
Cascading Failure of a Lithium Ion Cell Array



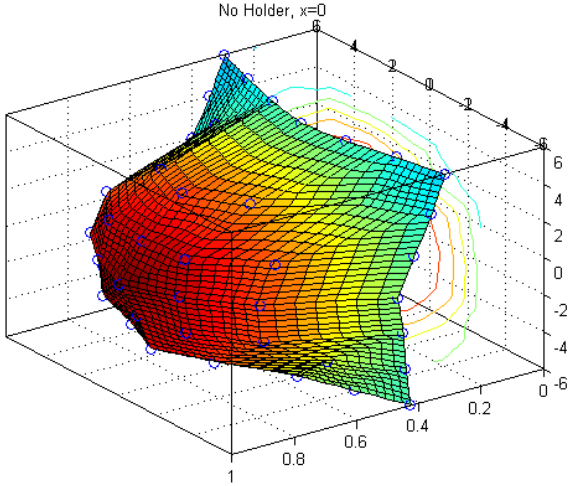
Flame Suppression with Low Frequency Sound

- *Faculty*: Stoliarov
- *Students:* A. Friedman (M.S. candidate), P. Denis (B.S. candidate)
- *Sponsor:* ARL
- *Objective:* To examine feasibility of using a low frequency and high amplitude sound waves for suppression of localized aircraft fires.

Experimental Setup



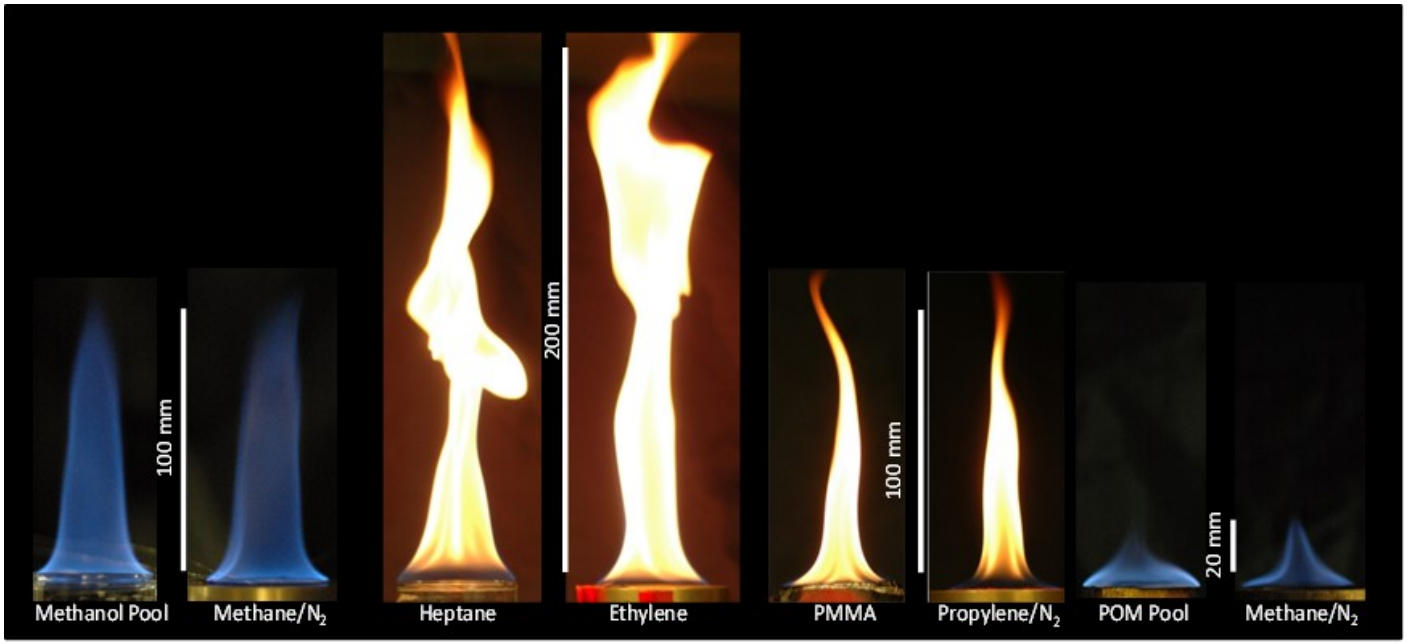
Sound Pressure Profile at Resonator Opening



Flame Response

Burning Rate Emulator

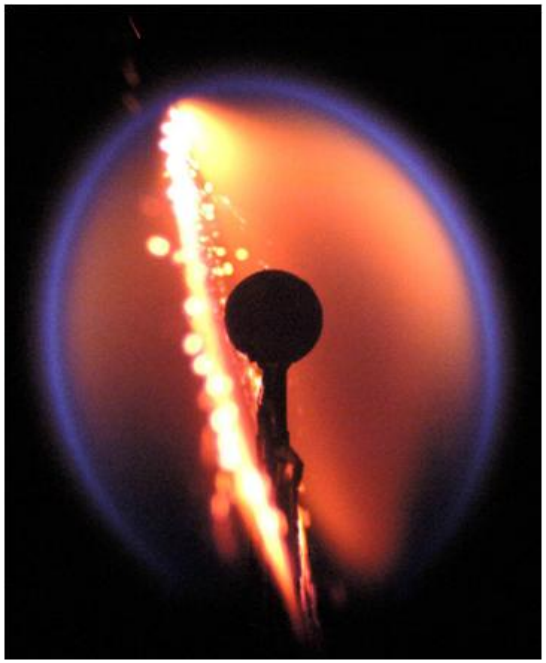
- *FPE Faculty:* Quintiere, Sunderland, Baum
- *Ph.D. Students*: Parham Dehghani, Akshit Markan,
- *M.S. Student*: Eric Auth
- *Collaborator*: J. deRis
- *Title*: Experimental Investigation of Emulated Burning Rate at Various Gravity Levels
- *Sponsor*: NASA Glenn
- *Objectives*: Use gases to emulate condensed fuel burning in microgravity aboard the ISS. Heat flux gages are embedded in the burner face.

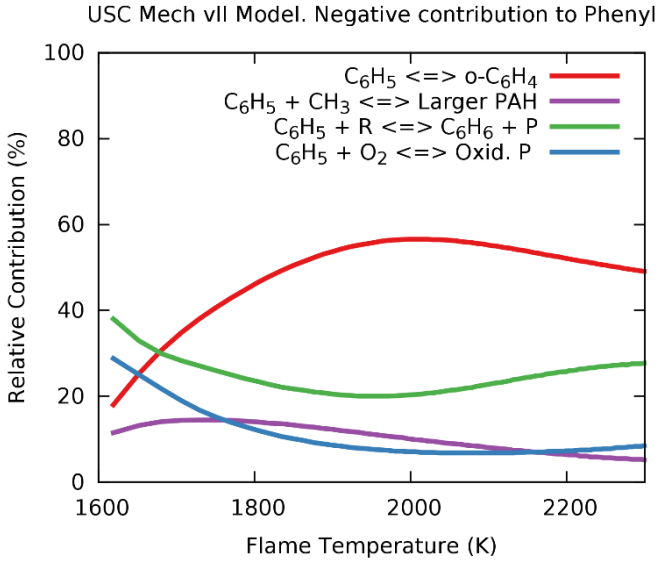


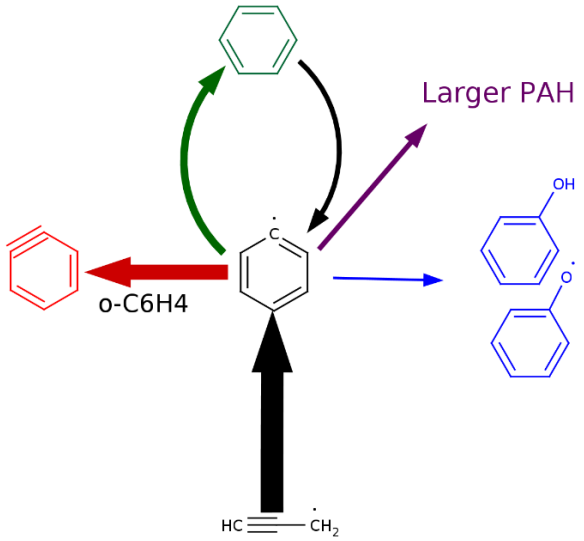
BRE emulations in normal gravity

Flame Design

- *FPE Faculty*: Sunderland
- *Ph.D. Students:* Kendyl Waddell, Zhengyang Wang
- *Collaborators*: R.L. Axelbaum, D.L. Urban
- *Title*: Flame Design: A Novel Approach to Clean Efficient Diffusion Flames
- *Sponsor*: NASA Glenn
- *Objectives*: Study microgravity spherical flames aboard the ISS to identify the effects of dilution on soot formation and flame extinction.







Identification of PAH main pathways in premixed flames with varying flame temperature

Spherical Cool Diffusion Flames

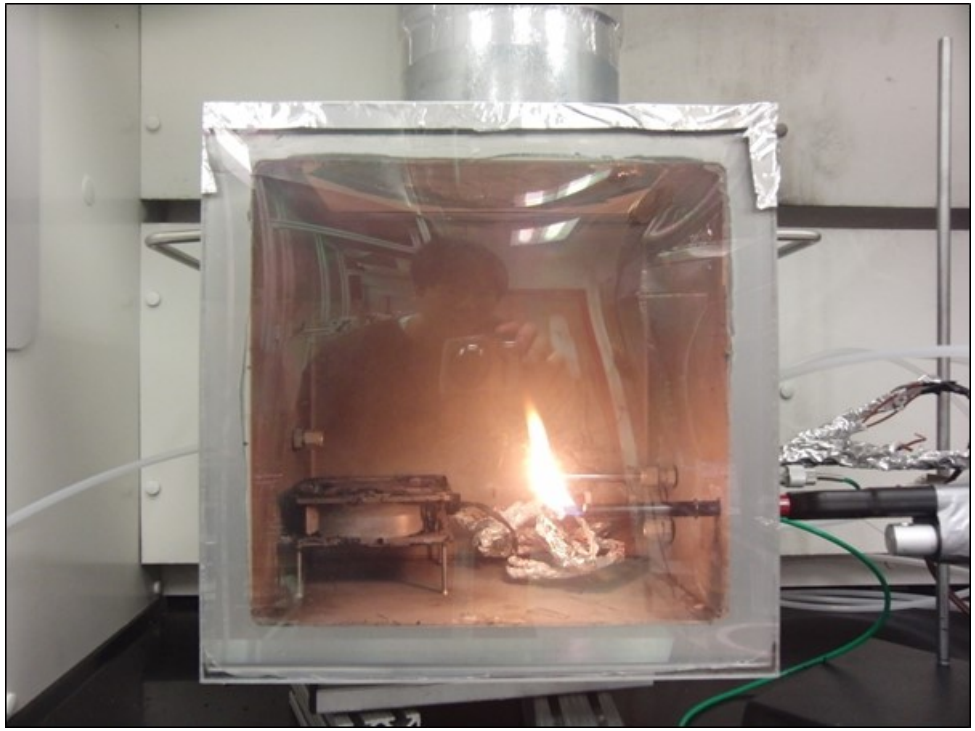
- *FPE Faculty*: Sunderland
- *Ph.D. Student:* Han Ju Lee
- *Collaborators*: R.L. Axelbaum, F.A. Williams
- *Title:* Spherical Cool Diffusion Flames Burning Gaseous Fuels
- *Sponsor*: NSF
- *Objectives*: Observe cool diffusion flames in microgravity aboard the ISS. Use porous spherical burners fed with propane, *n*-butane, and DME. Model the flames with high-fidelity simulations.

Combustion Integrated Rack,
spaceflightsystems.grc.nasa.gov

Mildly-Flammable Refrigerants

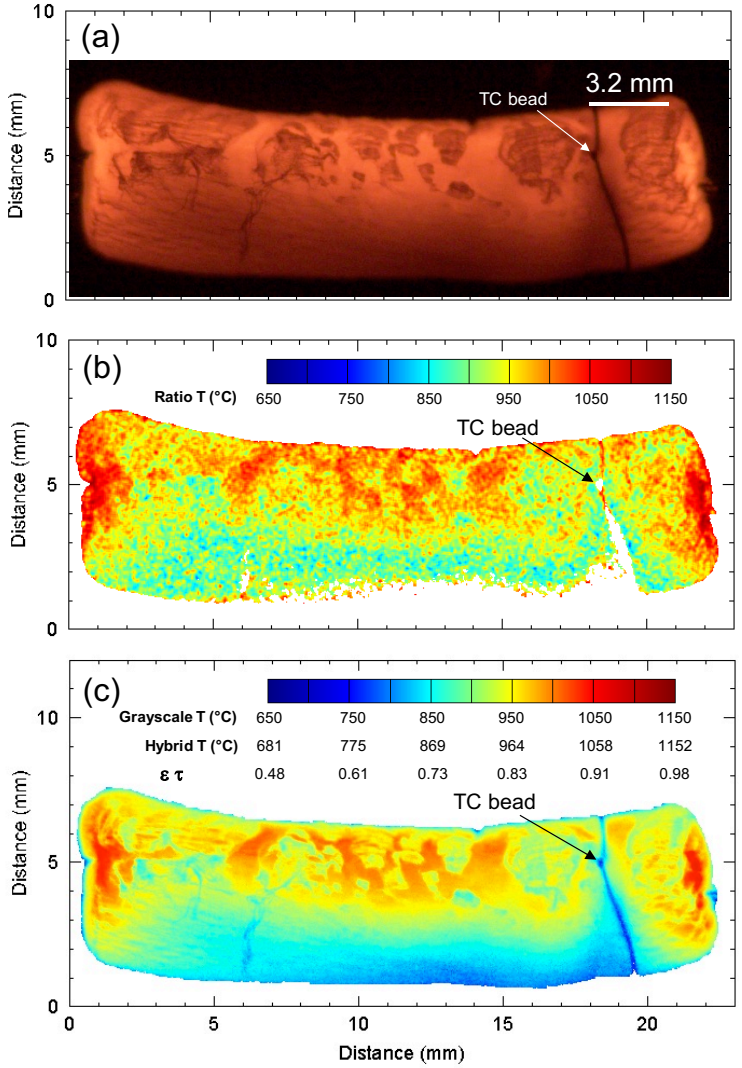
- *FPE Faculty*: Sunderland
- *Ph.D. Student:* Dennis Kim
- *M.S. Student:* Garrett Wack
- *Sponsor*: Carrier Corp.
- *Objectives*: Identify and characterize the potential fire hazards of mildly-flammable refrigerants.

R-32 autoignition by a hot plate at 764 °C (left) and 27 L test enclosure (right).



Firebrand Pyrometry

- *FPE Faculty*: Sunderland
- *Ph.D. Student:* Dennis Kim
- *M.S. Student:* Kyle Decker
- *Title:* Temperature Measurements of Airborne Firebrands
- *Sponsor*: NIST
- *Objectives*: Develop a firebrand pyrometer with an inexpensive digital camera. Characterize the temperatures of diverse airborne firebrands.



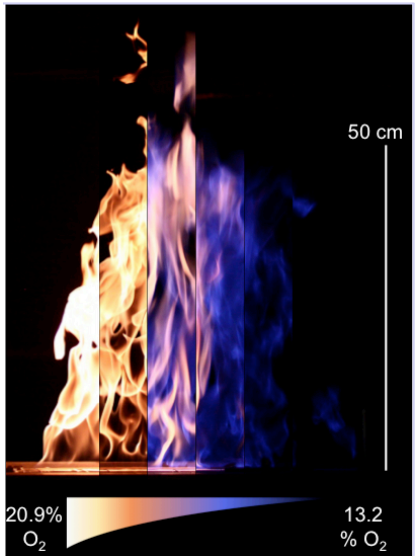
(a) Color image (1200 × 432 pixels) of a smoldering ember.
(b) Color contour plot of ratio pyrometry temperatures.
(c) Color contour plot of: grayscale pyrometry temperatures, hybrid pyrometry temperatures, and visible emissivity times ash transmittance.

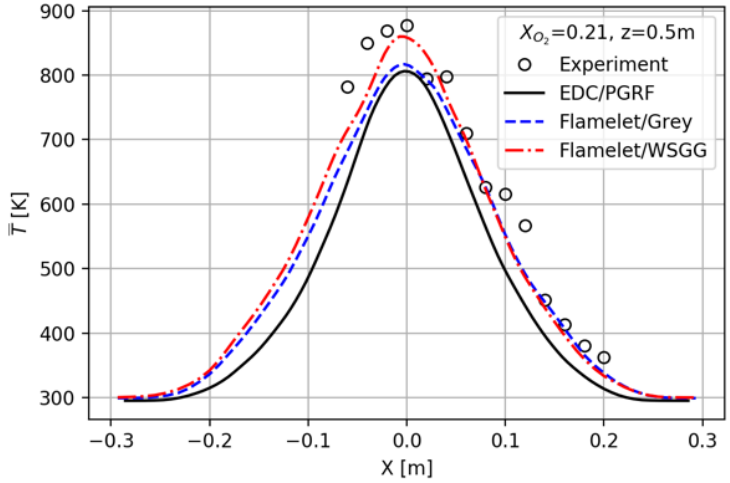
The MaCFP Working Group

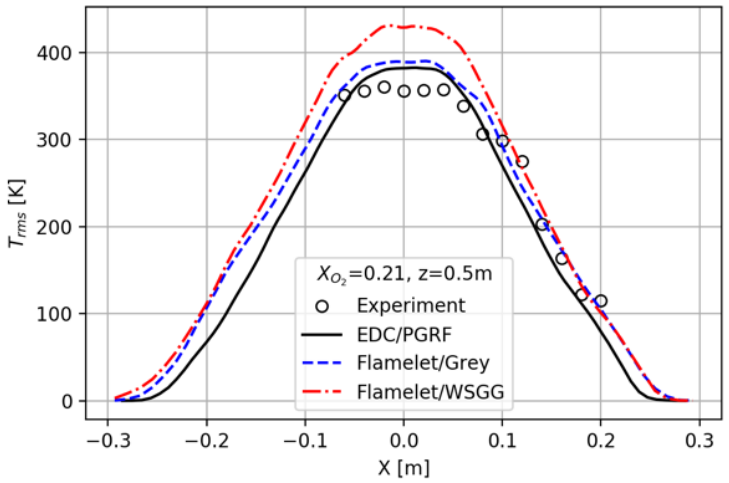
- *Faculty*: A. Trouvé – *MS student*: S. Wu; *PhD student*: R. Xu
- *Title*: "Towards a Collaborative Research Infrastructure for Fundamental Studies of Turbulent Fire Phenomena"
- *Sponsor*: NSF
- *Collaborators*: the IAFSS Working Group on **M**easurement **a**nd **C**omputation of **F**ire **P**henomena (the MaCFP Working Group, http://www.iafss.org/macfp)
- *Objective*: Build a collaborative framework between computational and experimental fire researchers around the topic of the experimental validation of computer-based fire models. Organize a new series of workshops sponsored by IAFSS.
- *2018-19 Results*: Evaluation of performance of current fire models in a series of well-resolved large eddy simulations of laboratory-scale turbulent fires. Publication of the Proceedings of the first MaCFP Workshop (June 2017, Lund, Sweden). Planning of the second MaCFP Workshop (April 2020, Waterloo, Canada).
- *Publication*: *Fire Safety J.* **101**:1-17 (2018)

Coupled Combustion-Radiation Effects in Fires

- *Faculty*: A. Trouvé – *PhD students*: M. Le, R. Xu
- *Title*: "CFD Modeling of Flame Suppression and Radiant Emissions in Fires"
- *Sponsors*: NSF, FM Global
- *Collaborators*: Y. Wang (FM Global); T. Rogaume, F. Richard, J. Luche (Poitiers, France)
- *Objective*: Develop advanced models to describe finite rate combustion chemistry effects and thermal radiation emissions in large eddy simulations of fires. Apply the models to well-characterized laboratory-scale turbulent fires.
- *2018-19 Results*: Development and evaluation of a new coupled combustion-radiation model based on the flamelet modeling approach (CFD solver: FireFOAM)
- *Publications*: *Fire Safety J., submitted for publication*; *Fire Safety J.* **106**:105-113 (2019)



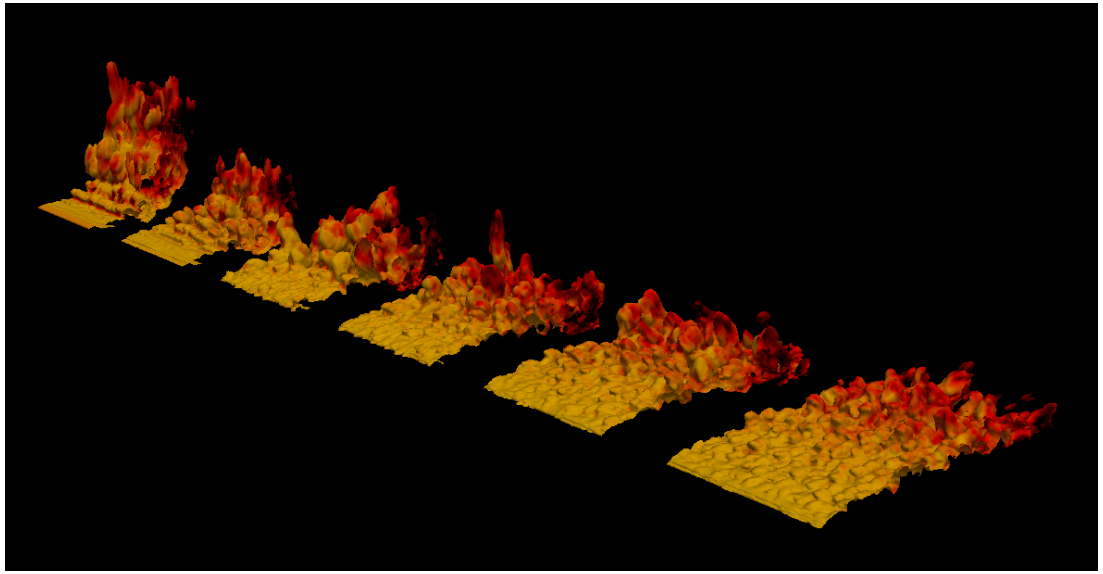




FireFOAM simulations of UMD turbulent line burner

Flame Structure in Wildfires

- *Faculty*: A. Trouvé – *PhD student*: M. Ahmed
- *Title:* "Large Eddy Simulation of Flame Spread in Wildland Fires"
- *Sponsor*: USDA Forest Service
- *Collaborators*: M. Finney, T. Grumstrup (Forest Service); M.J. Gollner (UMD)
- *Objective*: Perform detailed numerical simulations of the dynamics of wildland fire flames in simple wind- and slope-driven configurations; provide companion computational tool to UMD experimental program (Gollner)
- *2018-19 Results*: Simulations of line fires in cross-wind and in sloped terrain (CFD solver: FireFOAM). Analysis of simulation results in order to differentiate between attached *vs* lifted flame regime.
- *Publications*: *Fire Safety J., submitted for publication*

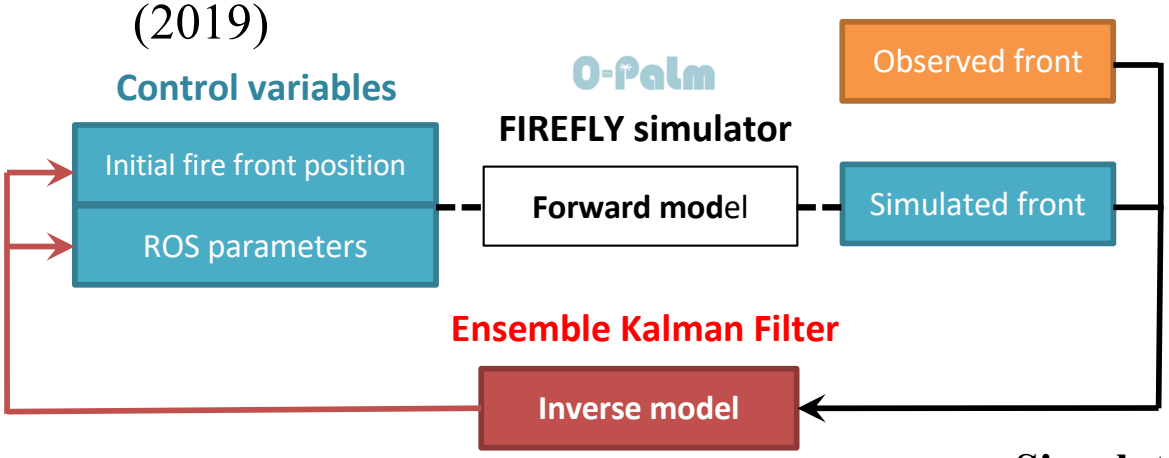


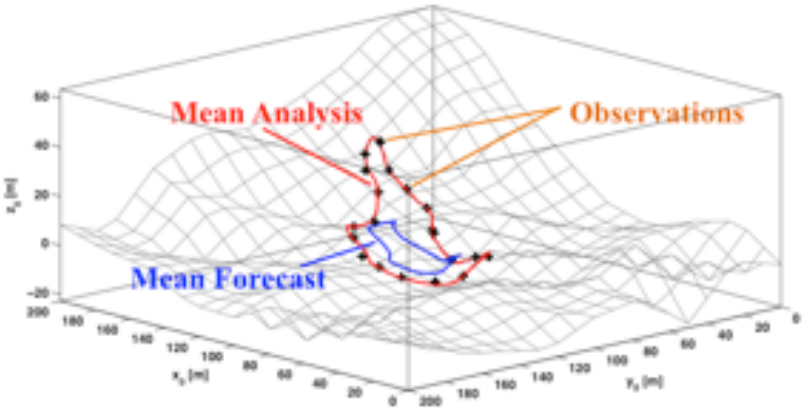
Series of FireFOAM simulations of line fire exposed to cross-wind with variable wind velocity

Wildfire Spread

Data Assimilation

- *Faculty*: A. Trouvé – *PhD student*: C. Zhang
- *Title:* "Data-Driven Wildland Fire Spread Modeling"
- *Sponsor*: NSF
- *Collaborators*: M. Rochoux (CERFACS, France); E. Ellicott, K. Ide, M.J. Gollner (UMD)
- *Objective*: Demonstrate the feasibility of coupling fire sensor technology with fire modeling software for improved predictions of wildland fire dynamics. Evaluate data assimilation methodologies (as used in weather forecasting applications).
- *2018 Results*: Evaluation of prototype data-driven wildfire model, called FIREFLY, in prescribed fire experiments (FireFlux, RxCADRE). Development of an improved formulation for dual parameter/state estimation.
- *Publications*: *Fire Safety J.* **105**:286-299 (2019); *Proc. Combust. Inst.* **37**:4201-4209 (2019)





Simulation of wildfire propagation (regional scale)