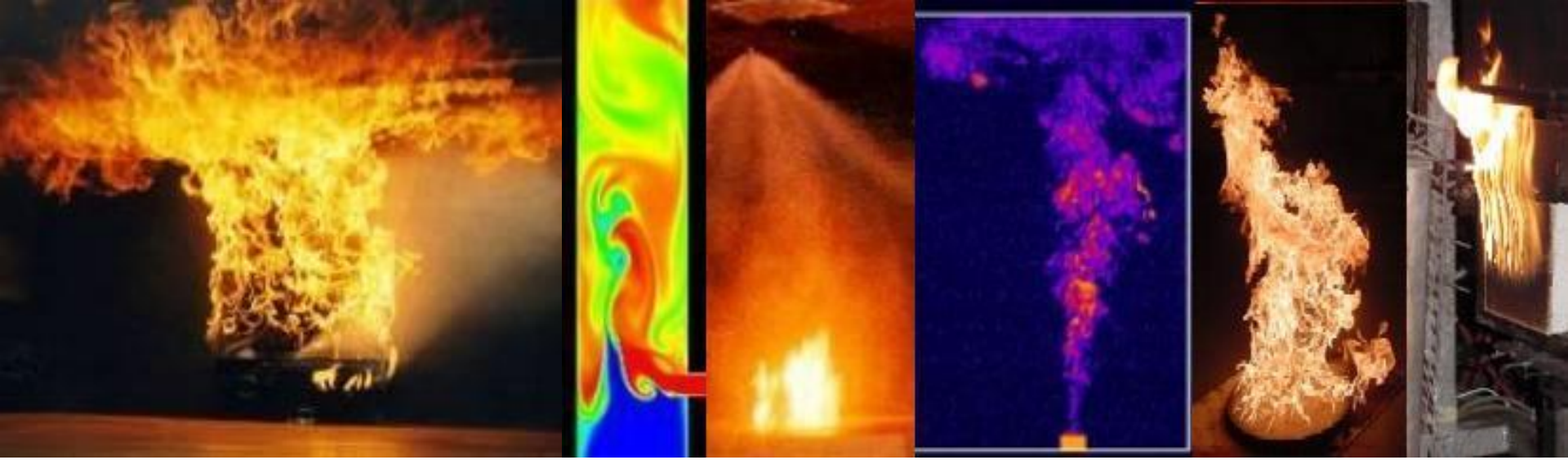


Research Overview

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

http://www.fpe.umd.edu

February 2018

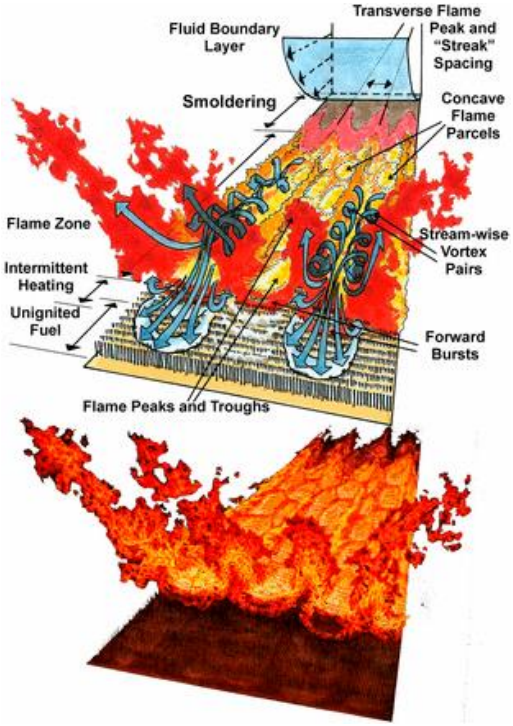
Full-Time Faculty

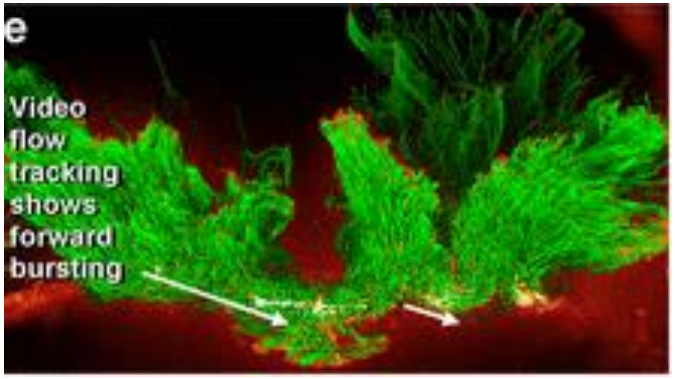
Faculty	Research Areas
M. di Marzo	suppression, detection
M. Gollner	wildfires, flammability, sustainability
K. E. Isman	suppression systems
A.W. Marshall	fire flows, combustion, suppression
J. A. Milke	structures, detection, egress
S. I. Stoliarov	pyrolysis, flammability, fire growth
P. B. Sunderland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



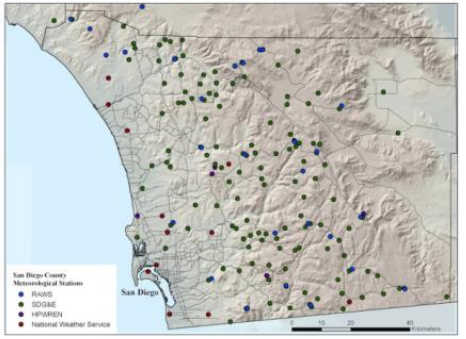


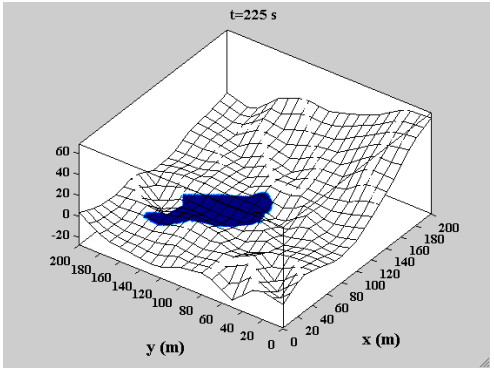
Proc. Natl. Acad. Sci. USA. 112(32) 9833–9838, 2015

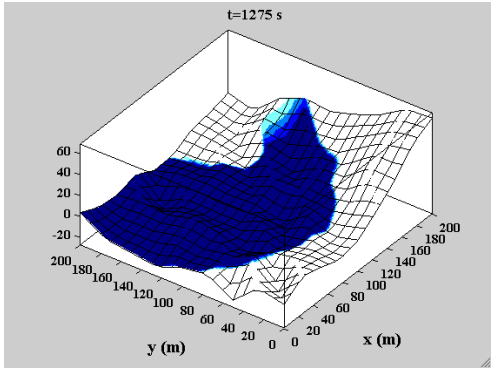
Wildland Fires

WIFIRE – Real Time Wildfire Predictions

- *Faculty*: M. Gollner, A. Trouvé
- *Ph.D. Students:* C. Zhang
- *Title*: Real-time wildland fire modeling
- *Sponsor:* National Science Foundation
- *Collaborators*: UC San Diego
- *Objective*: NSF-funded Development of a cyberinfrastructure for real-time wildfire monitoring and prediction







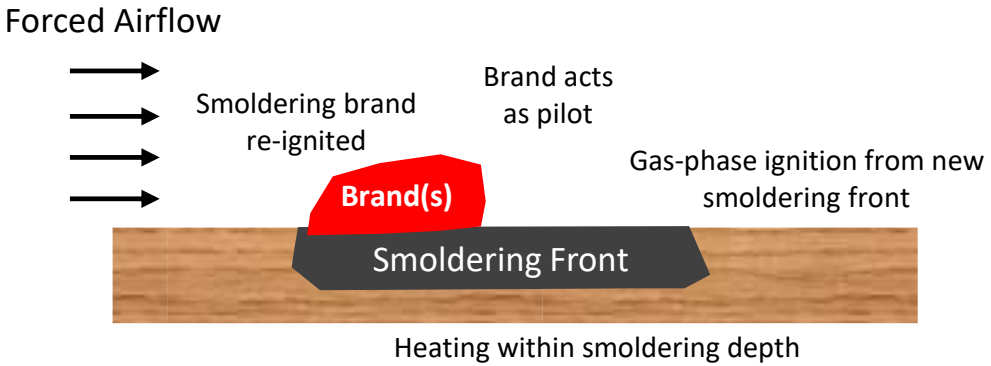
Example of a test simulation performed with FIREFLY showing the time evolution of the burnt area (in blue) on a complex terrain. (a) t = 225 s; (b) t = 1275 s (Trouve)

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

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.

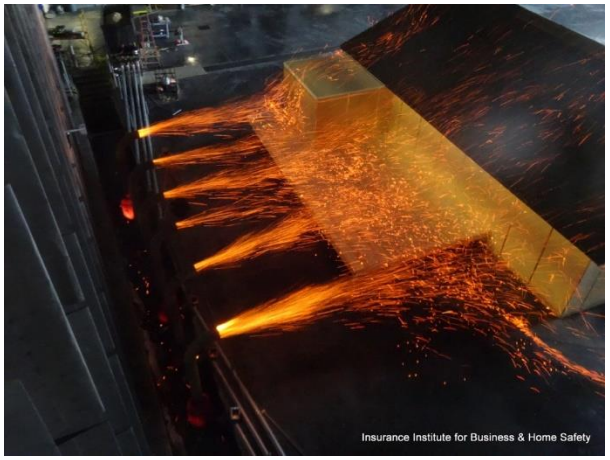
Flaming ignition of a Redwood decking assembly due to firebrand accumulation (Manzello and Suzuki, 2014).



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.

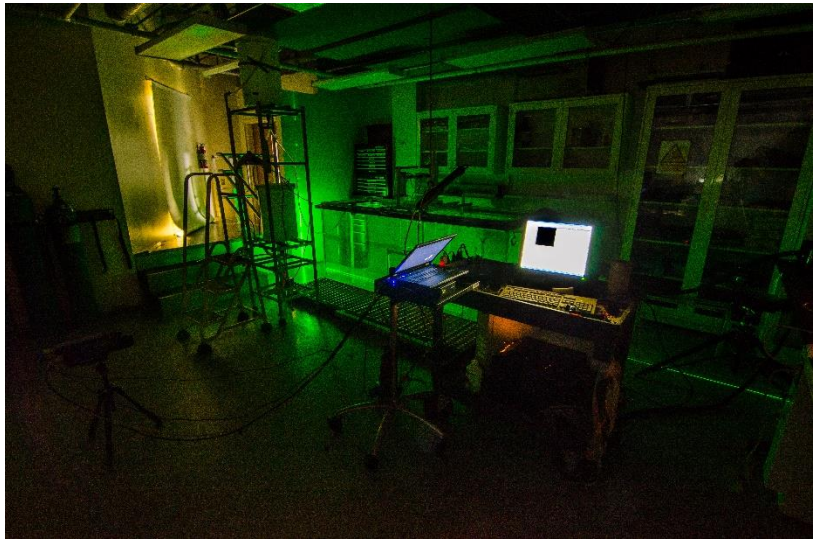
Generation of Firebrands

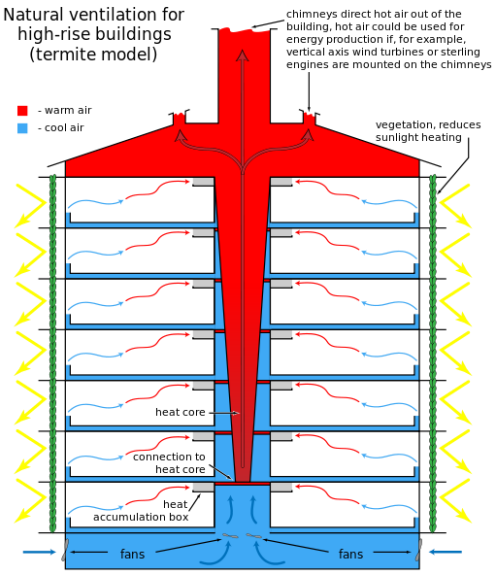
- *Faculty*: M.J. Gollner
- *Title*: Fire Ember Production from Wildland and Structural Fuels
- *Sponsors*: Joint Fire Science Program (USFS)
- *Objective*: (1) Understand how firebrands are generated by vegetation using simple laboratory experiments and scaling. (2) Perform large-scale experiments at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



Fire Safety in Green Buildings

- *Faculty*: M.J. Gollner, A.W. Marshall
- *Ph.D. Students:* P. Maisto
- *Title*: Characterizing smoke transport in naturally-ventilated green buildings
- *Sponsors*: Department of Homeland Security, Fire Grant
- *Collaborators:* B. Meacham
- *Objective*: Apply PLIF, PIV, and other non-intrusive diagnostics to model smoke transport in green buildings. Focusing on double-skinned facades and sloped ceilings.





Fire Safety in Commercial Spaceports

- *Faculty*: M.J. Gollner
- *B.S. Students:* S. Lattner, E. Griffith, A. Fitzpatrick
- *Title*: Literature Review on Fire Safety in Spaceports
- *Sponsors*: NFPA Fire Protection Research Foundation
- *Objective*: Perform a literature review of fire safety hazards present in spaceports, review recent incidents, understand the current hazards, and document gaps in current safety standards.

RESEARCH FOUNDATION

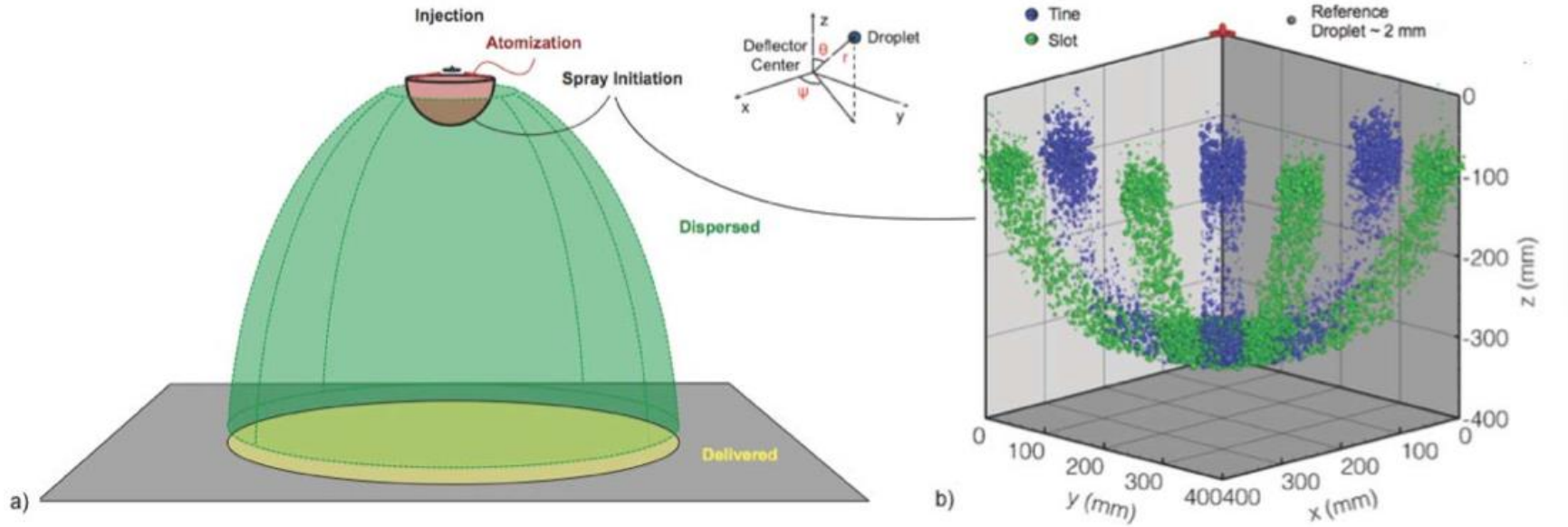
RESEARCH FOR THE NFPA MISSION

Risk Analysis in WUI Communities

- *Faculty*: M.J. Gollner
- *M.S. Students:* Samiyah Mustafa
- *Title*: A framework for risk analysis in wildland-urban interface communities
- *Objective*: Apply current tools for hazard analysis in disasters to a new, multi-hazard analysis focused on fire risk to homes and communities in wildland-urban interface fires. A key is incorporating the combined influence of embers, wildfire flames, and interactions between homes into the risk framework.

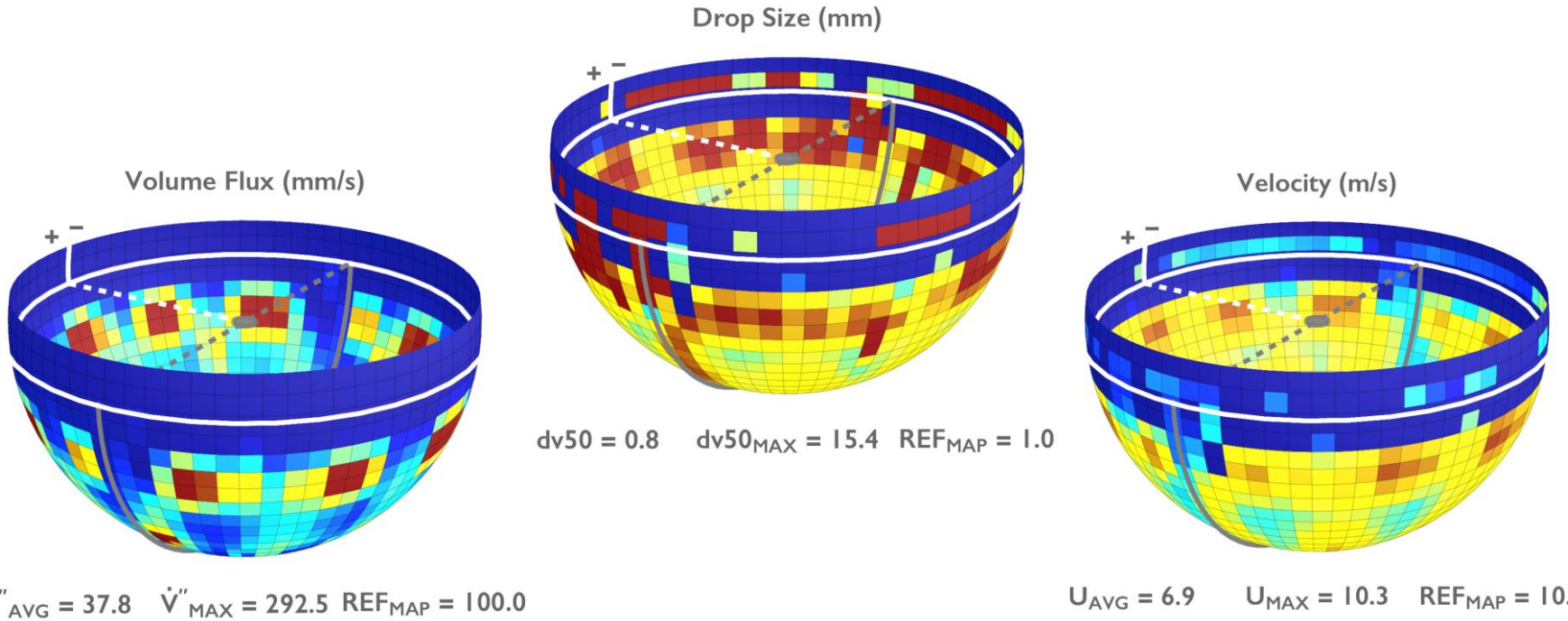
Spray Suppression

- *Faculty*: Marshall, Trouvé, Sunderland, Baum
- *Ph.D. Students:* Zheng, Vilfayeau, White, Myers, Jordan, Link
- *Title*: Quantifying Fire-Spray Interactions
- *Sponsors*: NSF MRI, NSF GOALI, FM Global, UTRC
- *Objective*: Characterization and Model development for fire suppression spray interactions with fire plumes (kinematic), flame sheets (cooling and dilution), and flame radiation (scattering and absorption).



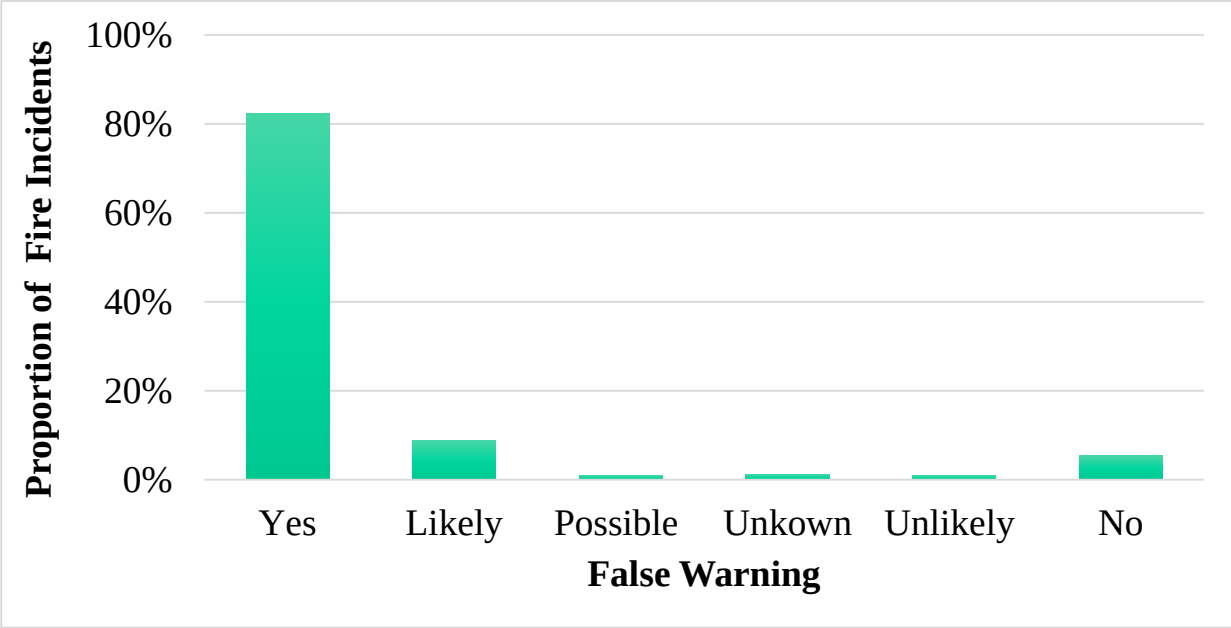
Spray Characterization

- *Faculty:* Marshall
- *Ph.D. Students:* S. Jordan
- *Collaborators:* Custom Spray Solutions (CSS)
- Title: Spatially-resolved Spray Scanning System (4S)
- *Sponsor:* NSF MRI
- *Objective:* Develop next-generation spray characterization technology to support advanced suppression analysis.



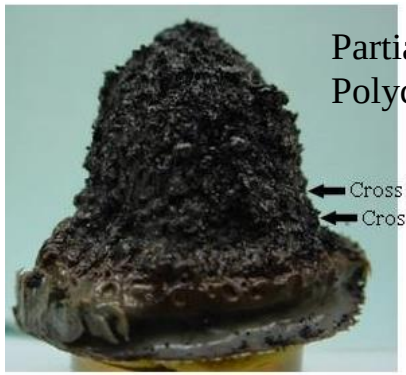
Fire Detection in Aircraft

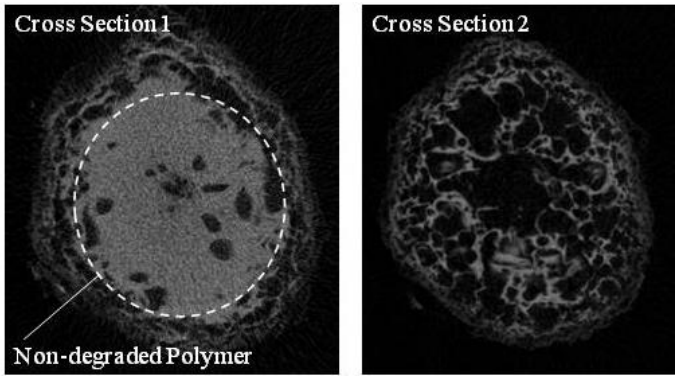
- *Faculty*: J.A. Milke
- *Student:* I. Lemberos and N. Schraffenberger
- *Title*: “Improvements in Aircraft Fire Detection”
- *Sponsor*: FAA
- *Objective*: provide an initial study into potential fire detection improvements for passenger and cargo compartments and hidden spaces on aircraft. Improvements are sought to provide prompt detection given the contemporary fuel loads and arrangements of cargo while ignoring nuisance sources.

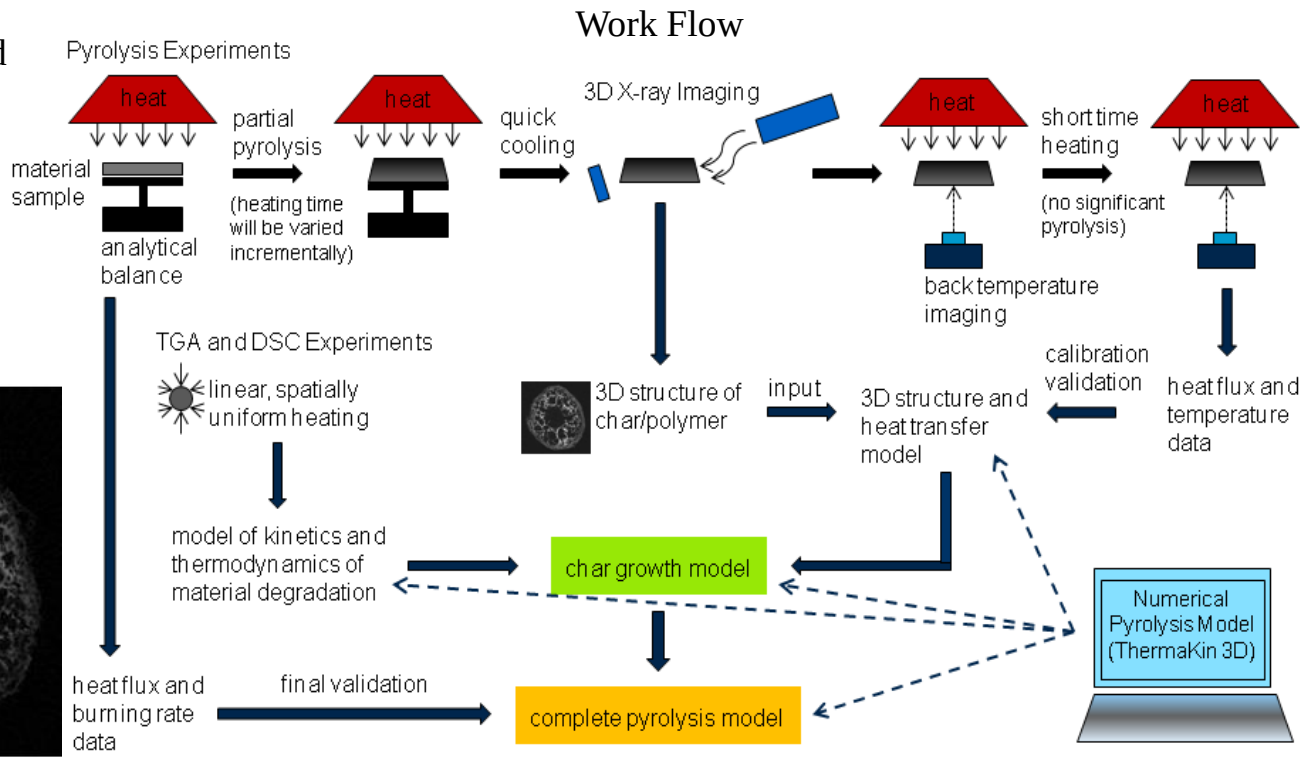


Understanding Flammability of Charring Polymers

- *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.



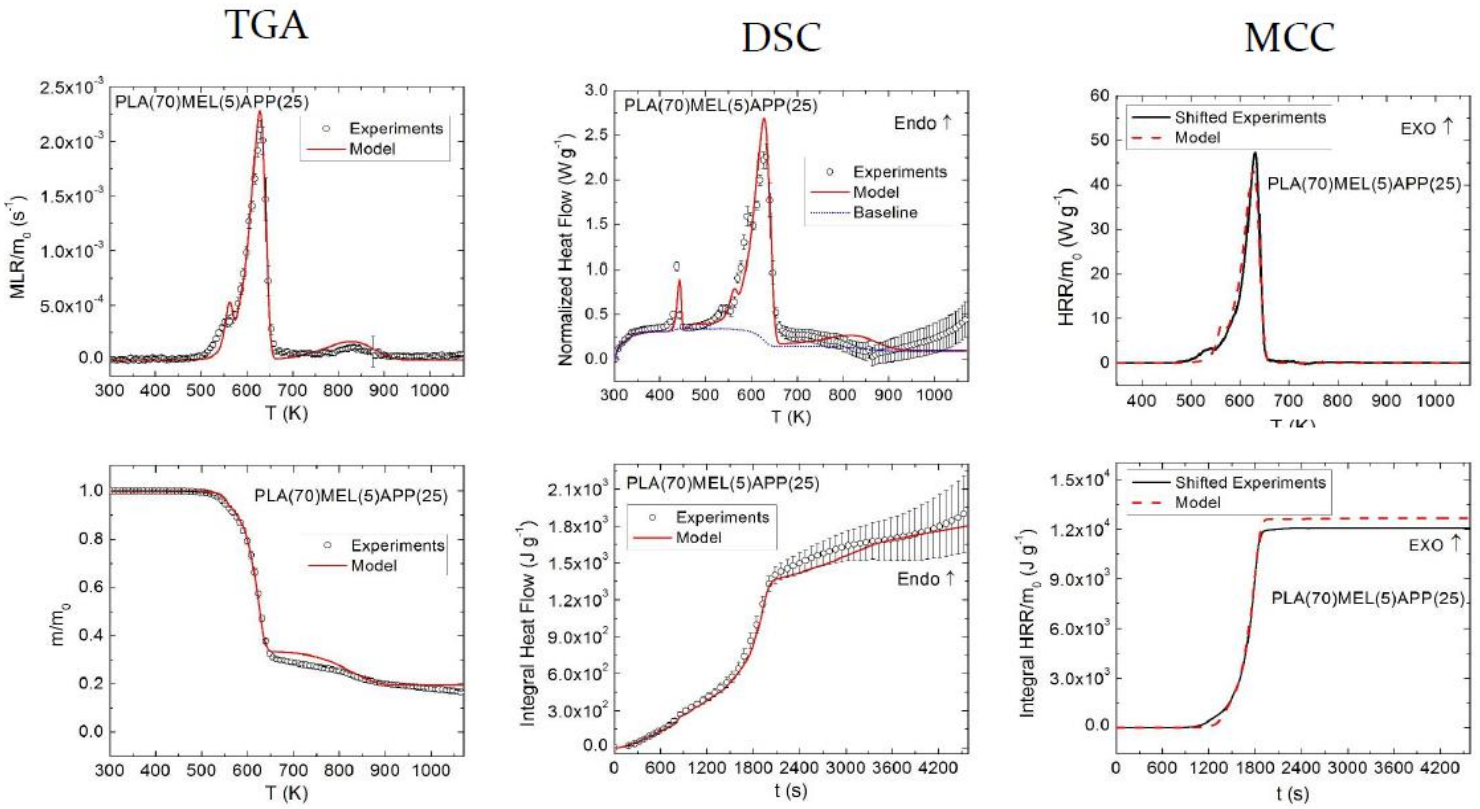




Modeling Impact of Condensed-phase Active Flame Retardants

- *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

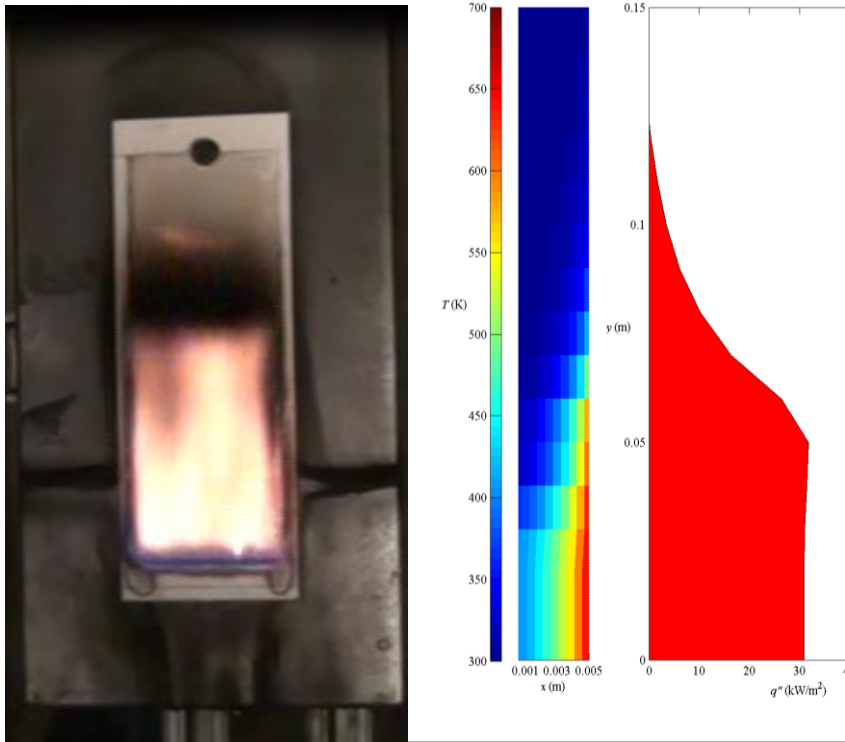


Prediction of Material Performance in Standard Flammability Tests

- *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

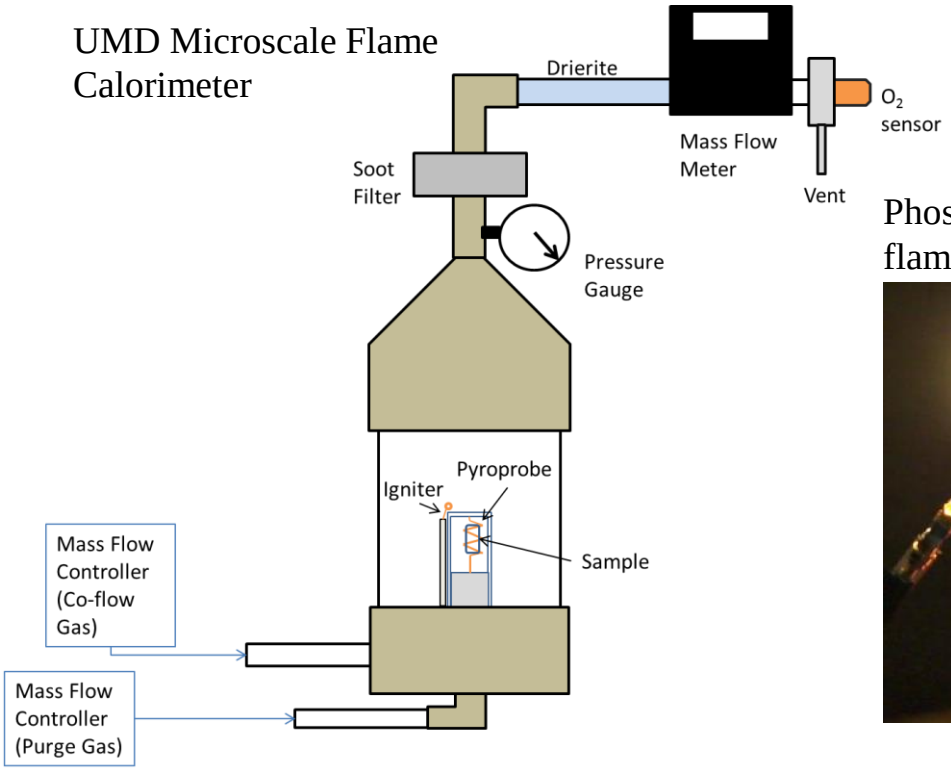
Flame Spread Experiment versus Model Prediction



Effectiveness of Gas-Phase Flame Retardants

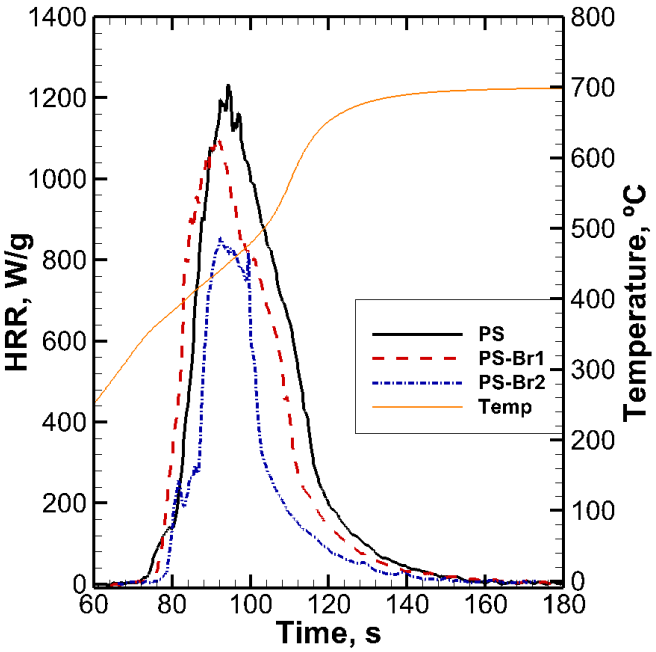
- *Faculty:* Stoliarov
- *Students:* F. Raffan (Post-doc) , A. Kushner (B.S. candidate)
- *Sponsor:* ICL-IP
- *Objective:* To develop an experimental method for the measurement of effect of gas-phase-active flame retardant additives on ignitability and burning intensity of solid materials using mg-sized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

UMD Microscale Flame Calorimeter



Phosphorus-induced flame extinction

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

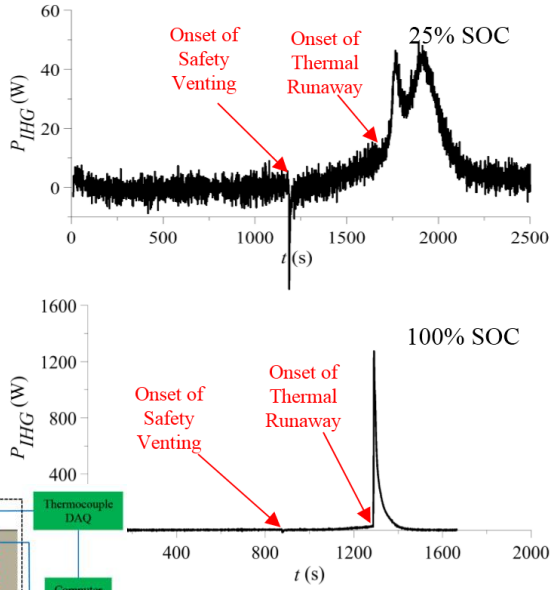


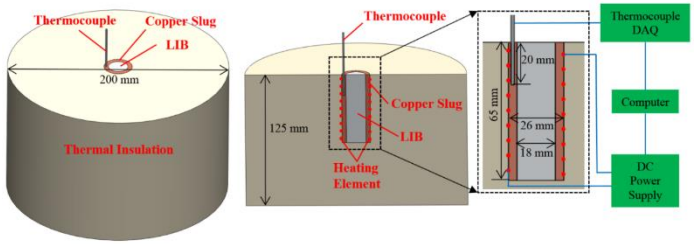
Applied Studies

Fire Safety of High Capacity Electrical Energy Storage Systems

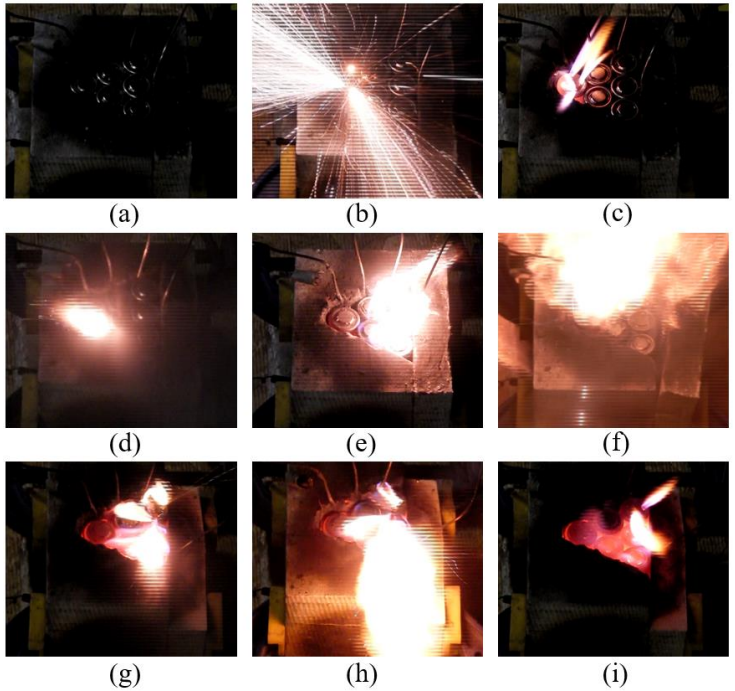
- *Faculty*: Stoliarov, Marshall
- *Students:* A. Said (Ph.D. candidate), C. Lee (M.S. candidate)
- *Sponsor:* Carrier Center of Excellence
- *Objective:* To conduct an investigation of the processes that drive cascading failure of lithium ion battery packs and examine a spectrum of detection and suppression 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





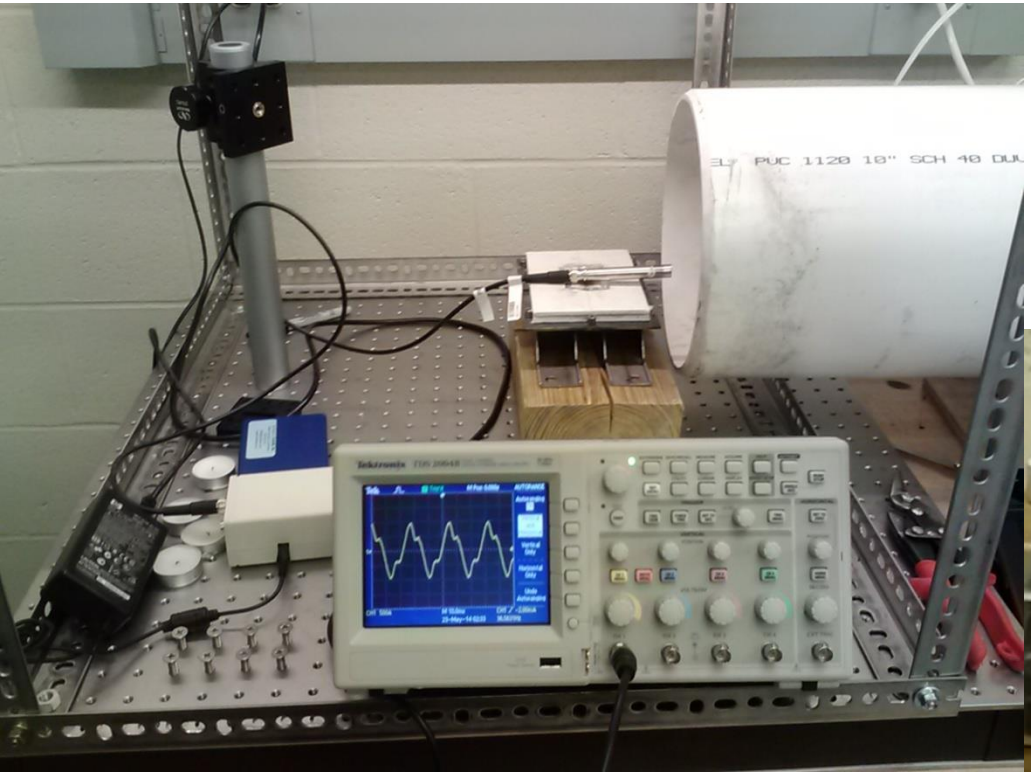
Cascading Failure of a Lithium Ion Cell Array



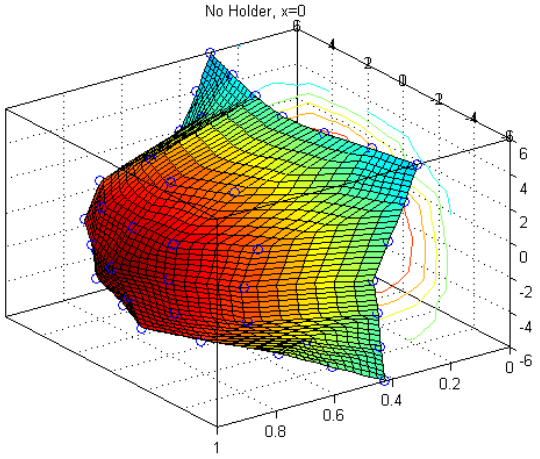
Flame Suppression with Low Frequency Sound

- *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



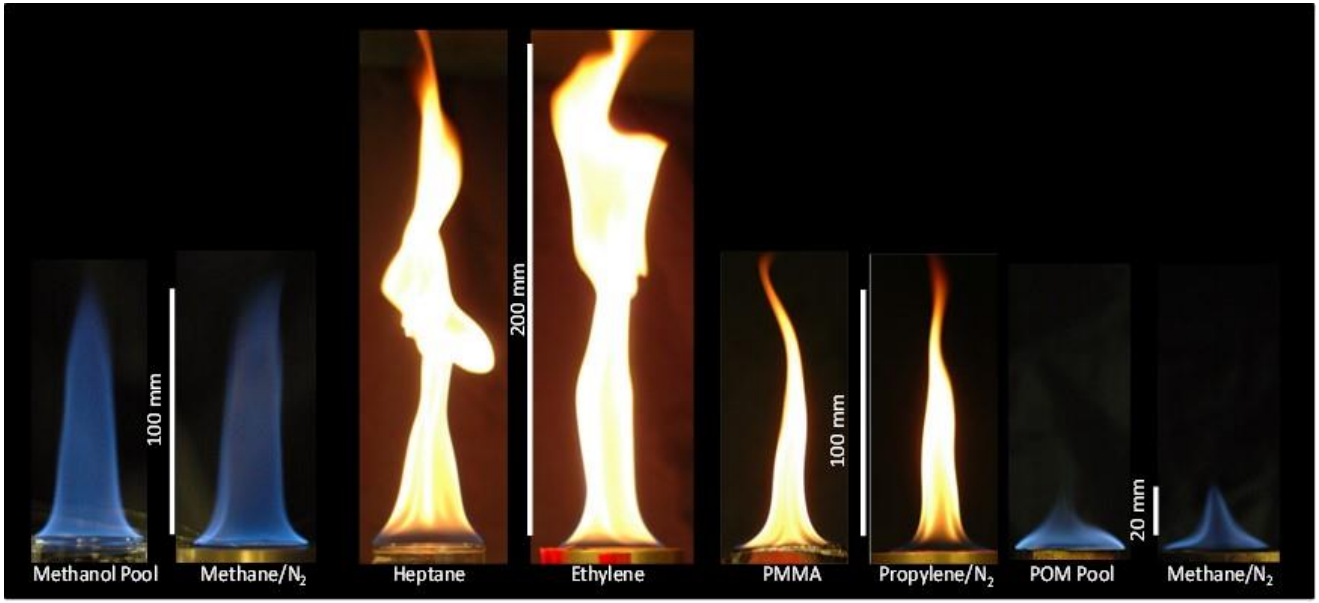
Sound Pressure Profile at Resonator Opening



Flame Response

Burning Rate Emulator

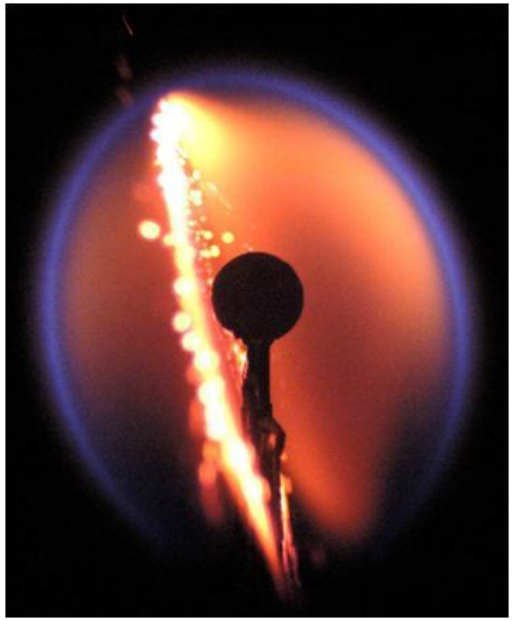
- *FPE Faculty:* Quintiere, Sunderland
- *Ph.D. Student*: Akshit Markan
- *Collaborator*: J. deRis
- *Title*: Experimental Investigation of Emulated Burning Rate at Various Gravity Levels
- *Sponsor*: NASA Glenn
- *Objectives*: Use gases to emulate condensed fuel burning in microgravity. Heat flux gages are embedded in the burner face. Flight tests will occur on ISS.

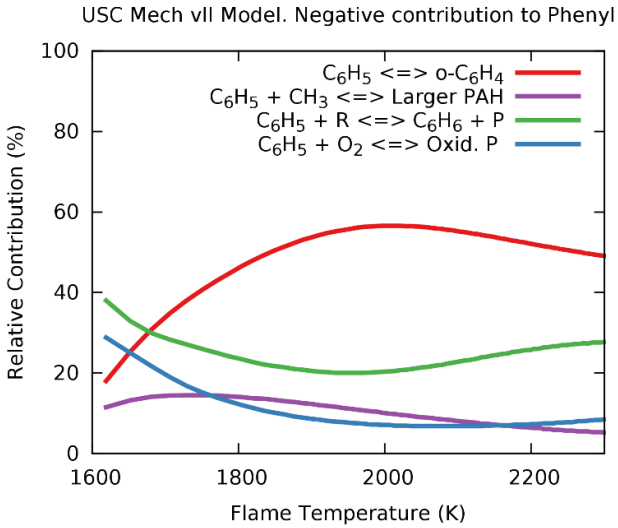


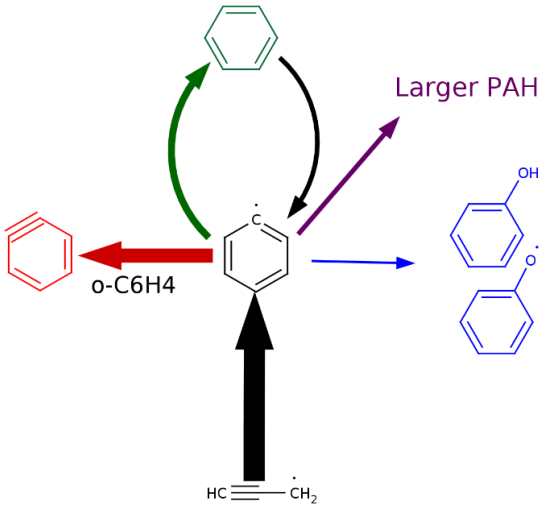
BRE emulations in normal gravity

Flame Design

- *FPE Faculty*: Sunderland
- *Ph.D. Student:* 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 to identify the effects of dilution on soot formation and flame extinction. Flight tests will occur on ISS.







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

Spherical Cool Diffusion Flames

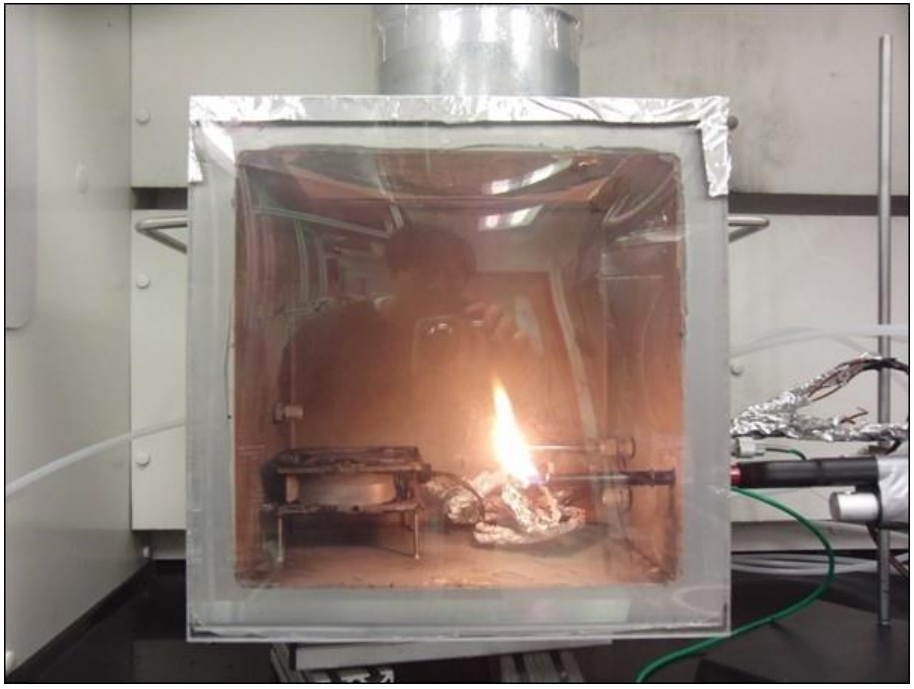
- *FPE Faculty*: Sunderland
- *Ph.D. Student:* Han Ju Lee
- *Collaborators*: R.L. Axelbaum, F.A. Williams
- *Title:* Spherical Cool Diffusion Flames Burning Gaseous Fuels
- *Sponsor*: NSF
- *Objectives*: Observe cool diffusion flames in microgravity aboard the International Space Station. Use porous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

Combustion Integrated Rack, spaceflightsystems.grc.nasa.gov

Ignition of Refrigerants

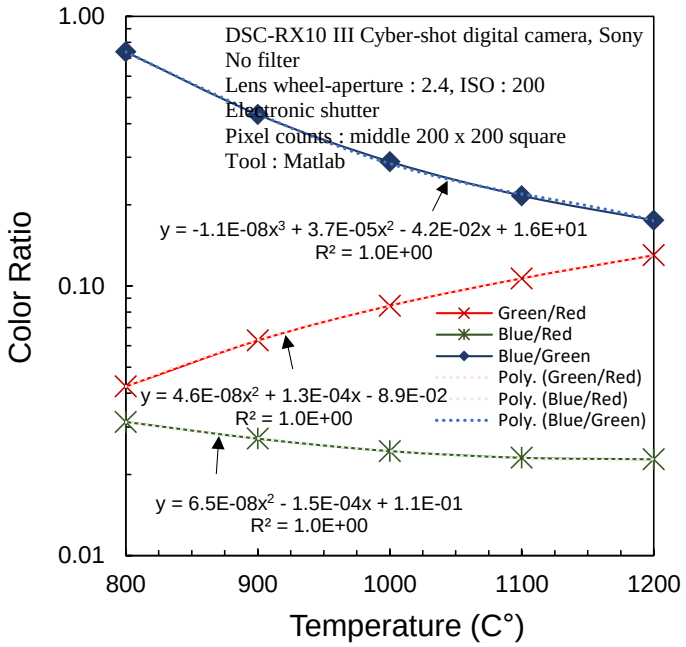
- *FPE Faculty*: Sunderland
- *Ph.D. Student:* D. Kim
- *M.S. Students:* A. Klieger, P. Lomax, C. McCoy, J. Reymann
- *Title*: Investigation of Energy Produced by Potential Ignition Sources in Residential Application
- *Sponsor*: AHRI
- *Objectives*: Identify and characterize residential ignition sources. Measure their ability to ignite refrigerant mixtures.

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

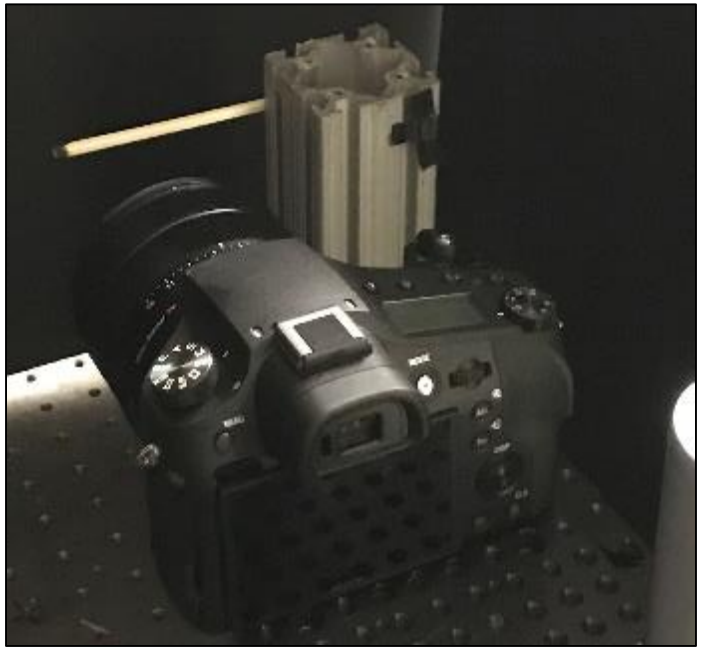


Firebrand Pyrometry

- *FPE Faculty*: Sunderland
- *Ph.D. Student:* Dennis Kim
- *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.



Blackbody calibration (left) and Sony RX10 camera with burning dowel (right).

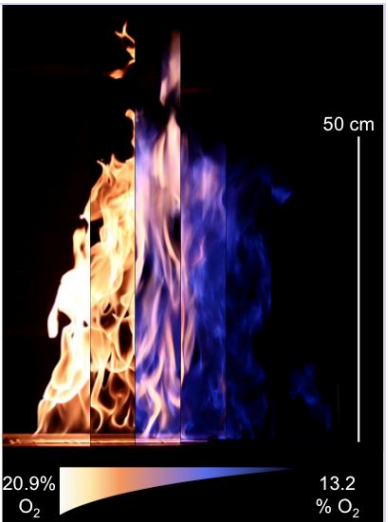


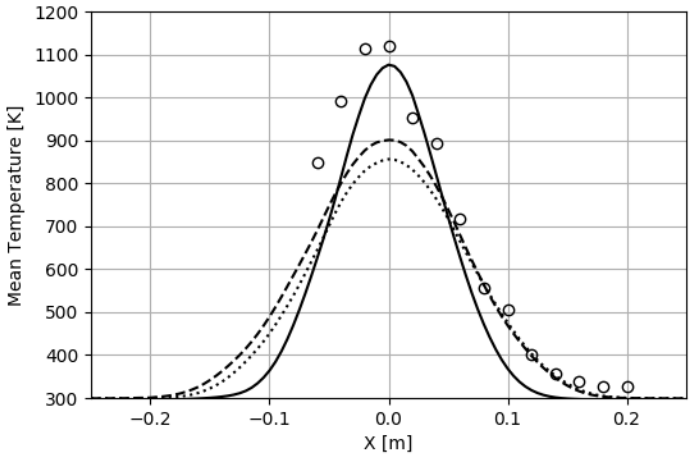
The MaCFP Working Group

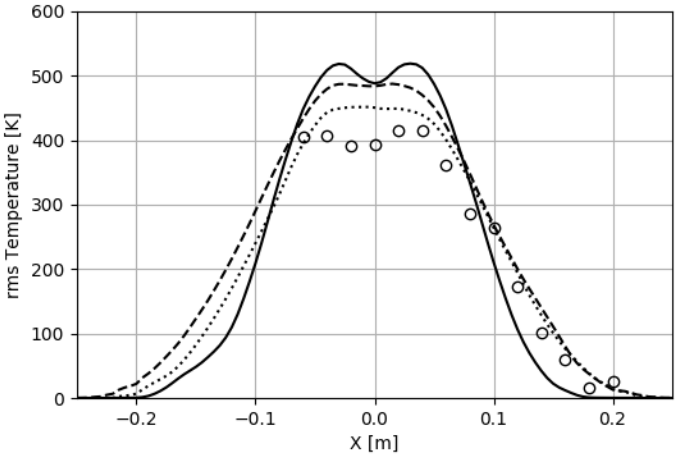
- *Faculty*: A. Trouvé – *MS students*: S. Vargas-Cordóba, S. Wu; *PhD student*: S. Verma; *Post-doc*: A. Marchand
- *Title*: "Towards a Collaborative Research Infrastructure for Fundamental Studies of Turbulent Fire Phenomena"
- *Sponsor*: NSF
- *Collaborators*: the IAFSS Working Group on **M**easurement **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 biennial workshops sponsored by IAFSS.
- *2017 Results*: Evaluation of performance of current fire models in a series of well-resolved large eddy simulations of laboratory-scale turbulent fires. Organization of the first MaCFP Workshop (June 2017, Lund).
- *Publications*: *Fire Safety J.* **90**:72-85 (2017); *Fire Safety J.* **86**:16–31 (2016); *Combust. Flame*, **169**:194-208 (2016)

Flame Extinction in Fires

- *Faculty*: A. Trouvé – *Post-doc*: A. Marchand; *PhD students*: M. Le, S. Verma, R. Xu
- *Title*: "Modeling of Under-Ventilated Fires and Fire Suppression"
- *Sponsors*: NSF, FM Global
- *Collaborators*: N. Ren, K. Meredith, Y. Wang (FM Global);); T. Rogaume, F. Richard, J. Luche (Poitiers, France); A.W. Marshall, P.B. Sunderland (UMD)
- *Objective*: Develop CFD models to describe flame extinction under fire conditions (including effects of mixing times, air/fuel vitiation, evaporative cooling by water spray)
- *2017 Results*: Development of a new flamelet combustion model that accounts for detailed chemistry (CFD solver: FireFOAM)
- *Publications*: *Fire Safety. J.* **91**:705-713 (2017); *Proc. Combust. Inst.* **36**:3287–3295 (2017); *Fire Safety J.* **86**:16–31 (2016)



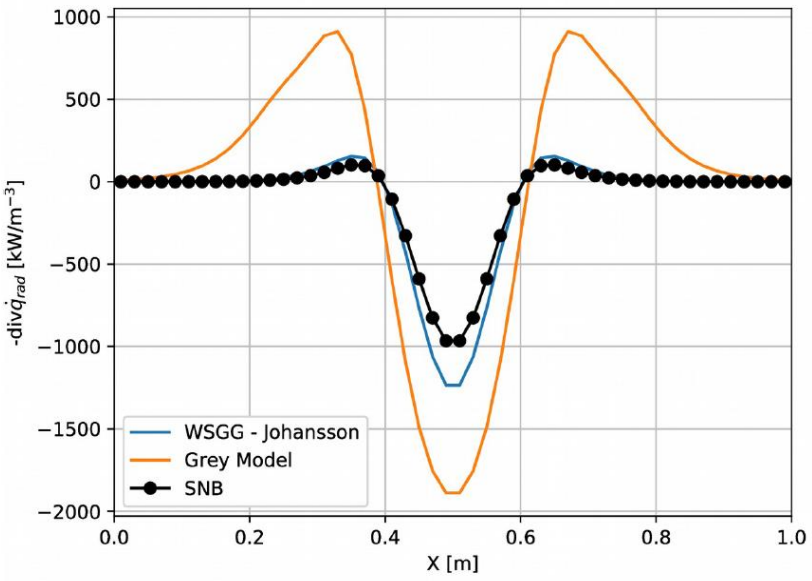


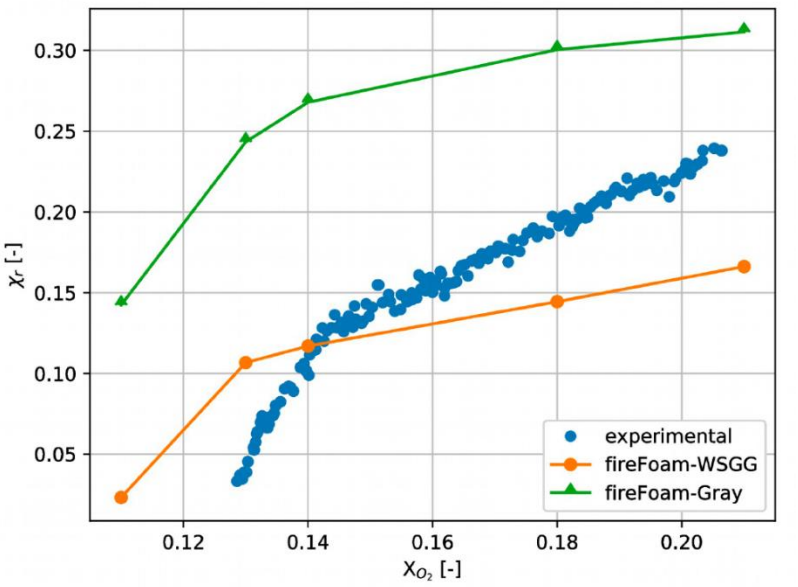


FireFOAM simulations of UMD turbulent line burner

Flame Radiation Properties in Fires

- *Faculty*: A. Trouvé – *Post-doc*: A. Marchand; *PhD students*: M. Le, S. Verma, R. Xu
- *Title*: "Modeling of Thermal Radiation in Fires"
- *Sponsors*: NSF, FM Global
- *Collaborators*: K. Meredith, Y. Wang (FM Global); T. Rogaume, F. Richard, J. Luche (Poitiers, France); A. Collin, P. Boulet (Nancy, France)
- *Objective*: Develop spectrally-averaged (gray) and spectrally-resolved (WSGG, SNB) models to describe gas/soot radiant emissions in fires (CFD solver: FireFOAM)
- *2017 Results*: Coupling of gas radiation models (gray and WSGG) with new flamelet combustion model in order to treat turbulence-radiation interactions (TRI)

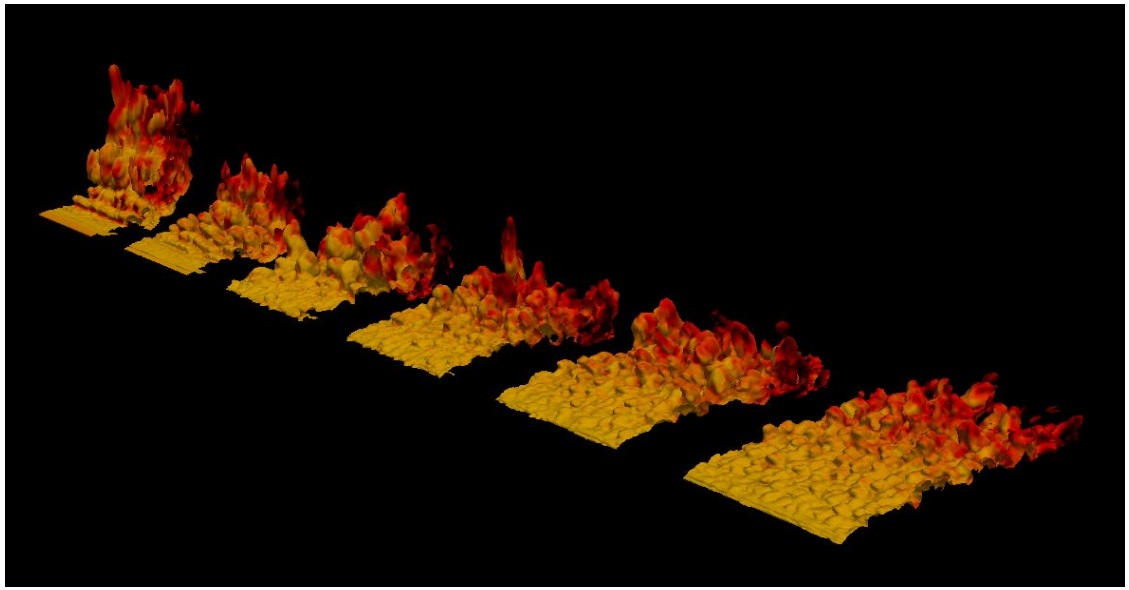




Comparison of gray and WSGG radiation models: (Left) 1D column of gas; (Right) turbulent line fire

Flame Structure in Wildfires

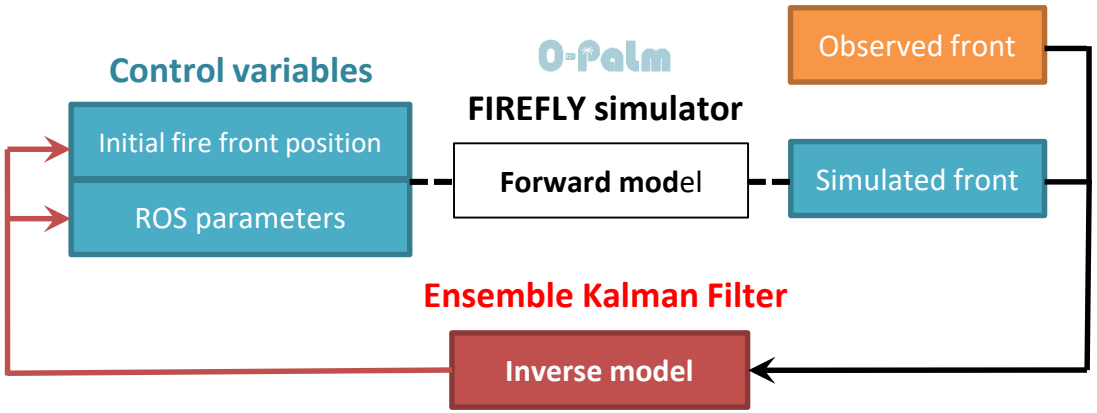
- *Faculty*: A. Trouvé – *PhD student*: S. Verma
- *Title:* "Large Eddy Simulation of Flame Spread in Wildfires"
- *Sponsor*: USDA Forest Service
- *Collaborators*: M. Finney, T. Grumstrup (Forest Service); M.J. Gollner (UMD)
- *Objective*: Perform detailed numerical simulations of the dynamics of wildland fire flames; identify origin of organized vortical structures; evaluate relative weight of convective/radiative heat transfer; provide companion computational tool to UMD experimental program (Gollner)
- *2017 Results*: Simulations of line fires in cross-wind and line fires in sloped terrain (CFD solver: FireFOAM). Analysis of simulation results in order to differentiate between attached *vs* lifted flame regime

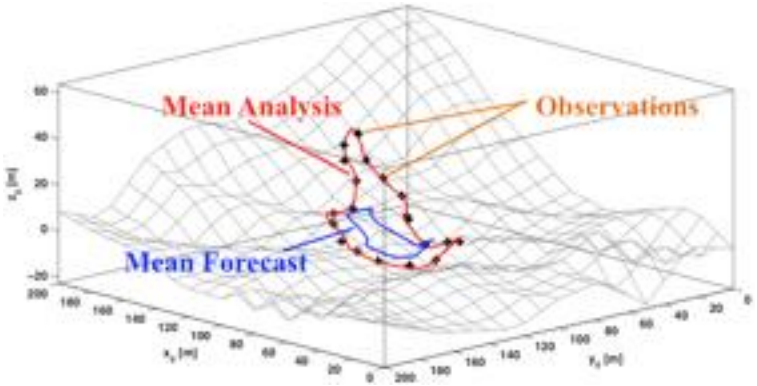


Series of FireFOAM simulations of line fire exposed to cross-wind with variable wind velocity

Data Assimilation

- *Faculty*: A. Trouvé – *PhD student*: C. Zhang
- *Title:* "Data-Driven Wildland Fire Spread Modeling"
- *Sponsor*: NSF (OCI)
- *Collaborators*: M. Rochoux (CERFACS, France); I. Altintas, J. Block, R. de Callafon (UCSD); 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).
- *2017 Results*: Evaluation of prototype data-driven wildfire model, called FIREFLY, in prescribed fire experiments (FireFlux, RxCADRE) and past wildfires (Rim fire, 2013, CA). Development of an improved formulation for dual parameter/state estimation.
- *Publications*: *Fire Safety J.* **91**:758-767 (2017); *Fire Technol*. **52**:1779-1797 (2016)





Simulation of wildfire propagation (regional scale)