Research Overview

Department of Fire Protection Engineering
University of Maryland
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http://www.fpe.umd.edu

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<td>M. di Marzo</td>
<td>suppression, detection</td>
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<td>M. Gollner</td>
<td>wildfires, flammability, sustainability</td>
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<td>K.E. Isman</td>
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<td>A.W. Marshall</td>
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<td>structures, detection, egress</td>
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<td>S.I. Stoliarov</td>
<td>pyrolysis, flammability, fire growth</td>
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<td>P.B. Sunderland</td>
<td>fire dynamics, diagnostics, refrigerant fires</td>
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<td>A. Trouvé</td>
<td>turbulent combustion, fire modeling</td>
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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.

**Wildland Fires**

**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.

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

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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.
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.
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.
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.

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**Partially Pyrolyzed Polycarbonate**

- Cross Section 1
- Cross Section 2
- Non-degraded Polymer

**Pyrolysis Experiments**
- Heat
- Partial pyrolysis
- Heating time will be varied incrementally
- Analytical balance
- Material sample

**TGA and DSC Experiments**
- Linear, spatially uniform heating
- Model of kinetics and thermodynamics of material degradation
- Heat flux and burning rate data

**Work Flow**

- Heat
- Quick cooling
- 3D x-ray imaging
- Back temperature imaging
- Calibration validation
- Heat flux and temperature data

**3D structure and heat transfer model input**

**Complete pyrolysis model**

**Numerical Pyrolysis Model (Thermakin 3D)**
**Pyrolysis and Oxidation**

**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.
Ignition and Flame Spread

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.

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**

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

**Phosphorus-induced flame extinction**
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

(a) (b) (c) (d) (e) (f) (g) (h) (i)
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.

**Suppression**

Experimental Setup

Sound Pressure Profile at Resonator Opening

Flame Response
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
Microgravity Fire Dynamics

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
Microgravity Fire Dynamics

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
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).
- **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.
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


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.


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. Roguame, 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)

Wildfire Spread

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.