Research Overview

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

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Faculty: M. Gollner, A. Trouvé
Ph.D. Students: W. Tang and C. Miller
Title: Buoyant instabilities influencing fire spread
Sponsor: USFS RMRS Decision Support Center, NSF CAREER award
Collaborators: M. Finney, S. McCallister (USFS), K. Saito (Kentucky)
Objective: Determine the mechanisms responsible for wildland fire spread (new instabilities discovered) and characterize the process in a simple manner for operational firefighting.

Wildland Fires
Fundamental Wildland Fire Spread Research

Faculty: M. Gollner, A. Trouvé
Ph.D. Students: W. Tang, 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) $t = 225 \text{ s}$; (b) $t = 1275 \text{ s}$ (Trouve)
Faculty: M.J. Gollner
M.S. Students: R. Hakes
B.S. Students: M. Weston-Dawkes
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.

Forced Airflow

- Smoldering brand re-ignited
- Brand acts as pilot
- Gas-phase ignition from new smoldering front

Smoldering Front

Heating within smoldering depth

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.
Wildland Fires

Generation of Firebrands

- **Faculty:** M.J. Gollner
- **M.S. Students:** S. Caton, N. May
- **Title:** Fire Ember Production from Wildland and Structural Fuels
- **Sponsors:** NIST Pathways Program, 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.
Faculty: M.J. Gollner, E. Oran
Postdoc: Huahua Zhao
M.S. Students: Sriram Hariharan, Yu Hu
Title: The Blue Whirl
Sponsors: NSF EAGER
Objective: Further understand the formation and transition between different modes of fire whirls and understand how to utilize their enhanced combustion efficiency. Submitting manuscript for Annual Review of Fluid Mechanics.
**Faculty:** M.J. Gollner, E. Ellicott (Geography)

**Ph.D. Students:** C. Miller (FPE), K. Lasko (Geography), Nate May (FPE)

**Title:** A bottom-up approach to characterize crop residue burning practices and the associated air pollution emissions variation

**Sponsors:** UMD Council on the Environment

**Objective:** Understand emissions variation due to residue burning practice differences. Ongoing studies on wildfire emissions and remote sensing calibration will complement this effort.

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**Figure 1:** Satellite Aerosol Optical Depth (AOD) and Ultraviolet Aerosol Index (UVAI) are measures of air pollution. High UVAI is often associated with biomass burning as seen in the RRD during burning season. The graph shows average values for the RRD region with UVAI and AOD peaks during harvest time in March followed by small peaks during harvest in July-Aug, and Oct – Nov.
Faculty: M.J. Gollner, A.W. Marshall
Ph.D. Students: P. Maisto, Cui Wuquan
Title: Characterizing smoke transport in naturally-ventilated green buildings
Sponsors: Department of Homeland Security, Fire Grant
Collaborators: B. Meacham (WPI)
Objective: Apply PLIF, PIV, and other non-intrusive diagnostics to model smoke transport in green buildings. Focusing on double-skinned facades and sloped ceilings.
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).
Smart Fire Fighting

Cyber-Physical Systems and Decision Support

- **Faculty**: Marshall
- **M.S. Students**: R. Wills
- **Title**: Modern Infrastructure and Emergency Response - Challenges and Opportunities
- **Sponsor**: SFPE Chief Burns Memorial Grant
- **Objective**: Develop a cyber-physical system test-bed to develop smart fire fighting decision support technology.
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.
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.
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.
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
**Faculty:** Stoliarov, Marshall

**Students:** A. Said (Ph.D. candidate), C. Lee (B.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.
Suppression

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](image1.png)

![Sound Pressure Profile at Resonator Opening](image2.png)

![Flame Response](image3.png)
Refrigerant Flammability

ASTM E-681 Enhancements

- **FPE Faculty**: Sunderland
- **Ph.D. Student**: D. Kim
- **M.S. Students**: A. Klieger, J. Reymann
- **Title**: 1717-TRP, Accuracy and Reproducibility of ASTM E681
- **Sponsor**: ASHRAE
- **Objectives**: Develop an E-681 apparatus. Use this to test A2L refrigerant flammability limits. Improve the accuracy of this test standard.

E-681 apparatus (left), and R-32 flame (right).
Refrigerant Flammability

Ignition of Refrigerants

- **FPE Faculty**: Sunderland
- **Ph.D. Student**: D. Kim
- **M.S. Students**: A. Klieger, 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).
FPE Faculty: Sunderland
Ph.D. Student: P.M. Anderson
Title: Soot Oxidation in Hydrocarbon-Free Flames
Sponsor: NSF
Objectives: Use a novel flame system to develop improved correlations of soot oxidation kinetics.

Optimized soot oxidation rate model (left) and ternary flame system (right).
**FPE Faculty:** Sunderland

**Ph.D. Student:** Z. Wang

**Collaborators:** R.L. Axelbaum, D.L. Urban, B.H. Chao

**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
Microgravity Fire Dynamics

Burning Rate Emulator

- **FPE Faculty:** Quintiere, Sunderland
- **Collaborator:** J. deRis
- **Ph.D. Student:** A. Markan
- **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


FPE Faculty: Sunderland
B.S. Student: S. Chin
Collaborator: G. Jomaas
Title: Forces on Firefighting Nozzles and Hoses
Objectives: Solve conservation of fluid momentum for firefighting nozzles and hoses. Develop improved expressions for nozzle reaction and hose tension and compare these with experiments.

Control volume for firefighting nozzle (left) and predicted reactions (right).
Faculty: A. Trouvé – MS student: H. Li; PhD student: S. Verma; Post-doc: A. Marchand

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 biennial workshops sponsored by IAFSS.

2016 Results: Perform a series of well-resolved large eddy simulations of laboratory-scale turbulent fires

Faculty: A. Trouvé – PhD student: S. Verma
Title: “Modeling of Under-Ventilated Fires and Fire Suppression”
Sponsors: NSF, FM Global
Collaborators: N. Ren, K. Meredith, Y. Wang (FM Global); A.W. Marshall, P.B. Sunderland (UMD)
Objective: Develop a CFD model to describe flame extinction under fire conditions (including effects of mixing times, air/fuel vitiation, evaporative cooling by water spray)
2016 Results: Evaluation of the flame extinction model in a canonical slot burner configuration with controlled co-flow (nitrogen dilution or water mist loading)
Thermal Radiation

Flame Radiation Properties in Fires

- **Faculty**: A. Trouvé – **Post-doc**: A. Marchand
- **Title**: “Modeling of Emission and Transport of Thermal Radiation in Fires”
- **Sponsors**: NSF, FM Global
- **Collaborators**: A. Gupta, K. Meredith, Y. Wang (FM Global)
- **Objective**: Evaluate the performance of spectrally-averaged (gray) and spectrally-resolved (wide-band, narrow-band) models to describe gas/soot radiant emissions in fires. Evaluate performance of wide-band and narrow-band models to describe thermal radiation transport through water sprays.

RadCal simulations of radiation transport across a one-dimensional column of gas
Faculty: A. Trouvé – PhD student: S. Verma

Title: “Large Eddy Simulation (LES) of Flame Spread in Wildfires”

Sponsor: USDA Forest Service

Collaborators: M. Finney (Forest Service); M.J. Gollner (UMD)

Objective: Perform detailed numerical simulations of the dynamics of wildfire flames; identify origin of organized vortical structures; evaluate relative weight of convective/radiative heat transfer; provide companion computational tool to UMD experimental program (Gollner)

2016 Results: Simulations of thermal boundary layers and boundary layer flames subjected to representative unstable buoyancy-driven effects (FireFOAM)

Simulation of Rayleigh-Taylor instability in thermal boundary layers
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).

2016 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.