Research Overview

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

http://www.fpe.umd.edu

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## Full-Time Faculty

<table>
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<tr>
<th>Faculty</th>
<th>Research Areas</th>
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<tbody>
<tr>
<td>M. di Marzo</td>
<td>suppression, detection</td>
</tr>
<tr>
<td>M. Gollner</td>
<td>wildfires, flammability, structures</td>
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<tr>
<td>A.W. Marshall</td>
<td>fire flows, combustion, suppression</td>
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<tr>
<td>J.A. Milke</td>
<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>soot, fire dynamics, diagnostics</td>
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<tr>
<td>A. Trouvé</td>
<td>turbulent combustion, fire modeling</td>
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</table>
Battery-Free Flashover Alarm for Firefighters

- **FPE Faculty**: di Marzo, Baz, Quintiere, Sunderland
- **M.S. Students**: K. Buda-Ortins, K. Hamburger
- **Title**: Optimization and Implementation of Thermoacoustic Flashover Detector
- **Sponsor**: Department of Homeland Security
- **Objectives**: Design a thermoacoustic resonator for use as an early-warning flashover alarm in firefighters’ helmets.

![Thermoacoustic Resonator](image)

**Time-Temperature Plot of Resonator Components During Operation**

- **T2-hot**
- **delta_T**
- **T1-cold**
- **Sound starts**
- **Power reduced to 19 W**
- **Power increased to 31 W**
- **Power increased to 62 W**
- **Sound resumes**
- **Sound stops**
Faculty: M. Gollner, A. Trouve
Ph.D. Student: W. Tang
Title: Inclination Effects on Flame Spread
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)
Faculty: M. Gollner
M.S. Student: D. Gorham
B.S. Student: R. Hakes
Title: Buoyant instabilities influencing fire spread
Sponsor: US Forest Service
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.
Faculty: M. Gollner

M.S. Students: Z. Zhao, C. Miller

Title: Discrete Fuel Effects on Flammability and Flame Spread

Sponsor: Minta Martin Foundation, Bryan Chair

Objective: Model flame spread through discrete fuels such as wooden dowels and dispersed PMMA in order to model wildland fuels and spread through wire trays
Faculty: M. Gollner
M.S. Students: B. Hall
Title: Fuel Loading in Aluminum Ferries
Sponsor: US Coast Guard
Objective: Determine appropriate fuel loads for aluminum ferries by performing luggage surveys, FDS modeling and egress analysis to determine whether structural fire insulation coating may be necessary (in contrast to current Coast Guard standards)
Hybrid Water Mist Literature Review

- **Faculty:** Gollner
- **B.S. Students:** P. Raia
- **Title:** Hybrid Water Mist Literature Review
- **Sponsors:** NFPA Fire Protection Research Foundation
- **Objective:** Review work on hybrid water mist (combined water and inert gas suppression systems) and present recommendations for code adaptations or a new standard.
Faculty: Gollner, 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 (WPI)
Objective: Apply PLIF, PIV, and other non-intrusive diagnostics to model smoke transport in green buildings. The addition of wind on smoke dispersion will enhance the benefit to firefighters from the project.
Faculty: Marshall, Trouvé, Sunderland, Baum
Ph.D. Students: Zheng, Viltfayeau, 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).
**Faculty:** Marshall, Quintiere  
**Ph.D. Students:** Kahrmann  
**M.S. Students:** Layton  
**Title:** Characterizing Buoyancy Induced Dispersion via Scale Modeling  
**Sponsors:** NIJ

**Objective:** Apply PLIF, PIV, and other non-intrusive diagnostics for use in dispersion studies. Current focus is salt-water dispersion experiments (used for: applied studies of smoke transport and detector response; plume dispersion studies; CFD model validation).

**Dispersion measurements; impinging plume (above); centerline unconfined plume (right)**
Faculty: Marshall, Quintiere

Collaborators: Sheppard (ATF)

Title: Scale Modeling of Static Fires in a Complex Geometry for Forensic Fire Applications

Sponsor: NIJ

Objective: Apply Froude scaling to various fuels to develop a methodology for fire investigators.

Presented at 2009 ESSCI Conference.

\[ Q^* = \frac{\dot{Q}}{\rho_c c_p T_c \sqrt{g \ell^{5/2}}} \]
Heat Transfer

Near Wall Mixing and Heat Transfer

- **Faculty:** Marshall, Trouvé
- **Ph.D. Students:** Voegele, Raffan
- **Collaborator:** Cadou (UMD)
- **Title:** Detailed Experiments and Model Development for Thrust Chamber Film Cooling
- **Sponsor:** NASA Marshall
- **Objective:** Characterize the detailed mixing and transport processes near film cooled surfaces to support near-wall CFD model development.

Film cooling effectiveness and near wall diagnostics
**Faculty:** J.A. Milke  
**Student:** R. Zevotek  
**Title:** “Analysis of Data from Cooktop Fire Experiments”  
**Sponsor:** UL  
**Objective:** Development of precursor signatures that can be distinguished from those associated with normal cooking and are capable of predicting an impending fire to provide adequate warning to homeowners in order to intervene.

### Precursors to Cooking Related Fires

**Figure:**

- **Graph 1:** 3D Scatter plot showing ionization signal (Serial Data) vs. obscuration (%/m) vs. temperature (Deg. C).
- **Graph 2:** Bar graph illustrating smoke obscuration per meter above stove with different stages indicated: Flame, Photo/CO, Photo/Ion, and Ion.
Hazard Analysis

Hazards of PV Panels

- **Faculty:** J.A. Milke
- **Students:** R. F. Wills
- **Title:** “Commercial Roof-Mounted Photovoltaic System Installation Best Practices Review and All Hazard Assessment”
- **Sponsor:** Fire Protection Research Foundation
- **Objective:** conduct a review of best practices for installation and an all-hazard assessment of photovoltaic panels installed on roofs.

![Image of fire and solar panels]
Faculty: J.A. Milke
Student: R. Hanson
Title: “Assessment of Fire Risk in US Residences”
Sponsor: State Farm
Objective: The research project will provide a holistic review of the previous activities in the area and synthesize those results to develop a tool to assess the relative risks due to fire in U.S. residences. Initially, the risk assessment will address the fire risk in one- and two-family dwellings.

Project just initiated, no results to report
Pyrolysis and Oxidation

Parameterization of Burning Models for Polymers

- **Faculty:** Stoliarov
- **Students:** J. Li (Ph.D. candidate), M. McKinnon (Ph.D. candidate)
- **Sponsor:** NIST
- **Objective:** To develop a systematic methodology for the measurement and validation of kinetic, thermodynamic and heat transport properties of polymeric solids.

![Simultaneous Thermogravimetry - Differential Scanning Calorimetry (TGA-DSC)](image1)

![Gram-Scale Pyrolysis Calorimetry](image2)

![Cone-Based Gasification Device](image3)
Small Scale Vertical Flame Spread on Polymers

- **Faculty:** Stoliarov
- **Students:** I. Leventon (Ph.D. candidate), K. Korver (M.S. candidate)
- **Sponsor:** FAA
- **Objective:** To develop an empirical model that generates a detailed flame-to-surface heat flux profile for a given mass loss rate and couple this model with a newly developed 2D pyrolysis solver to predict early stages of flame spread on polymeric surfaces.
**Ignition and Flame Spread**

**Efficiency of Gas-Phase Flame Retardants**

- **Faculty:** Stoliarov
- **Students:** F. Raffan (Post-doc), X. Ding, C. Frances (M.S. candidates)
- **Sponsor:** BASF, FAA
- **Objective:** To develop experimental techniques for the measurement of impact of gas-phase-active flame retardant additives on ignitability and burning intensity of solid materials using mg-sized samples.

**Modified Microscale Combustion Calorimetry (MCC)**

**Microscale Flaming Combustion Calorimetry**
**Applied Studies**

**Arc Formation in a Heated Electric Cable**

- **Faculty**: Stoliarov
- **Students**: R. Fisher (M.S. candidate)
- **Sponsor**: ATF
- **Objective**: To understand and quantify the process of degradation leading to arc formation in energized residential electric cables subjected to external heating and/or electrical overload.

![Graph of Time to Arc Dependence on Heat Flux]
Applied Studies

Fire-Induced Failure of Lithium Ion Batteries

- **Faculty**: Stoliarov, Sunderland, Milke
- **Students**: X. Liu (Ph.D. candidate)
- **Sponsor**: Ford Motor
- **Objective**: To analyze hazards associated with the exposure of lithium ion batteries to fire conditions. To develop an engineering model of battery ignition and subsequent heat release dynamics.

18650 Li-Ion Battery Subjected to a Non-Premixed Propane Flame

Flammable gas venting.  
Battery core ejection.
Emissions

Soot Oxidation

- **FPE Faculty**: Sunderland
- **Students**: P.M. Anderson, J. Castillo, H. Guo
- **Title**: Soot Oxidation in Hydrocarbon-Free Flames
- **Sponsor**: NSF
- **Objectives**: Measure soot volume fraction, temperature, velocity, and morphology, species concentrations, and soot oxidation kinetics.

![Graph showing soot flux and oxidation rate over z (mm)]

- Soot flux and oxidation rate
- Ternary flame system
FPE Faculty: Quintiere, Sunderland

Students: M.J. Bustamante, K.T. Dotson, M. Kim, Y. Zhang

Title: Experimental Investigation of Emulated Burning Rate at Various Gravity Levels

Sponsor: NASA Glenn

Objectives: Use gases to emulate condensed fuel burning by matching heat of gasification, surface temperature, and heat of combustion.
FPE Faculty: Sunderland
Postdoc: V.R. Lecoustre
Title: Flame Design: A Novel Approach to Clean Efficient Diffusion Flames
Sponsor: NASA Glenn
Objectives: Study microgravity spherical flames to identify the effects of fuel and oxidizer dilution on soot formation and flame extinction.

Predicted H₂/air temperature and flame radius versus scalar dissipation rate for normal and inverse flames.
Flammability of R32 Refrigerant

- **FPE Faculty**: Sunderland
- **Collaborators**: A. Mosleh, R. Radermacher
- **Postdoc**: V. Lecoustre
- **Student**: A. Boussouf
- **Title**: Flammability and Risk Assessment of R32 Refrigerant
- **Sponsor**: Daikin Industries
- **Objectives**: Assess the fire risks of R32 leaks using experiments, CFD simulations, and risk analysis.

R32 jet burns only with external flame present  
FDS predictions of R32 jet
Faculty: A. Trouvé – Post-doc: V. Lecoustre – PhD students: S. Vilfayeau, J. White

Title: “Modeling of Under-Ventilated Fires and Fire Suppression”

Sponsors: NSF (OCI, PetaApps Program), FM Global (GOALI)

Collaborators: N. Ren, 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 flame stretch, thermal losses, air vitiation and fuel vitiation)

2013 Results: Formulation of new CFD combustion model using a Damköhler-number-based flame extinction criterion. Implementation into FireFOAM and preliminary evaluation in under-ventilated compartment and canonical slot burner configurations.

Faculty: A. Trouvé – Post-doc: V. Lecoustre

Title: “Petascale Computing, Visualization, and Science Discovery of Turbulent Sooting Flames”

Sponsor: NSF (OCI, PetaApps Program)

Collaborators: H.G. Im (U. MI), D. Haworth (Pennstate U.), T. Lu (U. Connecticut), R. Sankaran (Oak Ridge Ntl. Lab.), K.-L. Ma (U.C. Davis)

Objective: Develop a massively-parallel, high-fidelity, direct numerical simulation (DNS) solver to simulate soot-flame-radiation interactions in turbulent combustion


Boundary Layer Combustion

- **Faculty:** A. Trouvé – PhD students: L. Bravo, A. Voegele – **MS student:** B. Trettel
- **Title:** “Numerical Modeling of Non-Premixed Flame-Wall Interactions in Turbulent Boundary Layer Flows”
- **Sponsor:** NSF (ENG/CBET)
- **Collaborator:** U. Piomelli (Queens U., Canada)
- **Objective:** Develop a high-fidelity, parallel, large eddy simulation (LES) solver for boundary layer combustion
- **2013 Results:** Simulations of momentum-driven and buoyancy-driven wall flames

**LES of turbulent wall diffusion flame**
Faculty: A. Trouvé – PhD students: A. Ojofeitimi, S. Vilfayeau

Title: “CFD Modeling of Vertical Turbulent Wall Fires”

Sponsor: FM Global

Collaborators: N. Ren, Y. Wang (FM Global)

Objective: Develop a CFD model to describe wall flame heat transfer. Participate in development of FireFOAM, an advanced CFD fire modeling software based on OpenFOAM and developed by FM Global (http://code.google.com/p/firefoam-dev/).

2013 Results: Validation study in a simplified vertical wall flame configuration with a prescribed fuel mass flow rate (using an experimental database previously developed at FM Global). Extension of previous work to different flow rates and different fuels

Publication: in preparation
Faculty: A. Trouvé – PhD student: Z. Ghorbani

Title: “Parameter Estimation Techniques for Pyrolysis Modeling”

Collaborators: R. Webster (Bechtel), M. Lázaro (U. Cantabria, Spain)

Objective: Develop CFD models to describe the formation of flammable vapors from pyrolysis of solid fuel sources.

2013 Results: Evaluation of current methodologies for pyrolysis modeling. Extension of previous work to case of oscillatory radiant heat flux.

Publication: Fire Safety J. (2013)

1D simulations of PVC mass loss rate in cone calorimeter test

Simulations (FDS) of vertical flame spread along PVC wall
Faculty: A. Trouvé – MS student: C. Pongratz
Title: “Methods to Increase Maximum Velocity of Makeup Air for Atrium Smoke Control - CFD Study”
Sponsor: ASHRAE
Collaborator: J.A. Milke (UMD)
Objective: Evaluate the effects of velocity and location of make-up air flow used in atrium smoke control systems. Develop a technical basis for a possible change in maximum make-air flow velocity recommended in current codes and guidelines relevant to the design of fire smoke control systems for atrium configurations (e.g., NFPA 92).
2013 Results: Perform a series of FDS simulations to evaluate effects of high make-up air velocity (greater than 1 m/s) on smoke layer depth and fire spread propensity.
Faculty: A. Trouvé – PhD student: M. Rochoux (France)

Title: “Data-driven simulation of wildfire propagation”

Sponsors: ANR-COSINUS-IDEA (France), NSF (OCI), UMD/ConE

Collaborators: S. Ricci, B. Cuenot (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 wildfire dynamics. Evaluate data assimilation methodologies (as used in weather forecasting).

2013 Results: Development of a prototype data-driven wildfire model based on an Ensemble Kalman Filter (EnKF) algorithm. Comparison between parameter estimation and state estimation approaches. Extension from flat to complex terrain.

Faculty: A. Trouvé – MS student: S. Verma

Title: “Validation of Supersonic Film Cooling Numerical Simulations Using Detailed Measurements and Novel Diagnostics”

Sponsor: NASA

Collaborator: C. Cadou (UMD)

Objective: Evaluate performance of LOCI-CHEM (RANS solver developed by NASA) in a canonical supersonic film cooling configuration (studied experimentally at UMD). Evaluate benefits of LES approach using OpenFOAM.

2013 Results: Preliminary comparisons of LOCI-CHEM results with experimental data. Perform a series of OpenFOAM simulations to evaluate ability to simulate shock waves.