Fire Research Group

TOWARDS CONTROLLING WILDFIRES BY HARMONIZING ENGINEERING TECHNOLOGY AND ENVIRONMENTAL APPROACHES

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GOALS OF THIS GROUP

Consistent with the university's mission to serve the best interest of the State, we are a COE-SSL-LBNL working group that is working toward the development and implementation of more effective solutions for uncontrolled wildfires. It is our belief that by engaging a broad range of talent across the UCB-SSL-LBNL, we can innovate new approaches to address this challenge for the State of California, the nation and the world. The objective is

- **To harness modern technology and engineering science**
- **To develop long-term planning strategies and near-term solutions**
- **To develop on-demand rapid solutions for firefighting in real time**

OBJECTIVES:INCORPORATION OF MODERN ENGINEERING TECHNOLOGY INVOLVING

1. Environmental Management: remote sensing, mapping, policy, etc.
2. Telecommunications and data assimilation
3. Combustion: pyrology, toxicology, fire retardant design, etc.
4. Large Equipment: water and human transport, etc
5. Fire-fighter (carry-on) equipment: cameras, gas sensors, etc
6. UAVs, UGVs, robotics, etc.
7. Real-time modeling, simulation and on-demand prediction
8. Health issues and epidemiology
9. Post disaster cleanup, detoxification and remediation Environmental Management: remote sensing, mapping, policy, etc.

Current Members…

- Tim Ball tim@fireballit.com, Sebastien Biraud <scbiraud@lbl.gov>
- PhilColella pcolella@lbl.gov, Wayne Lee Delker <wdelker@berkeley.edu>,
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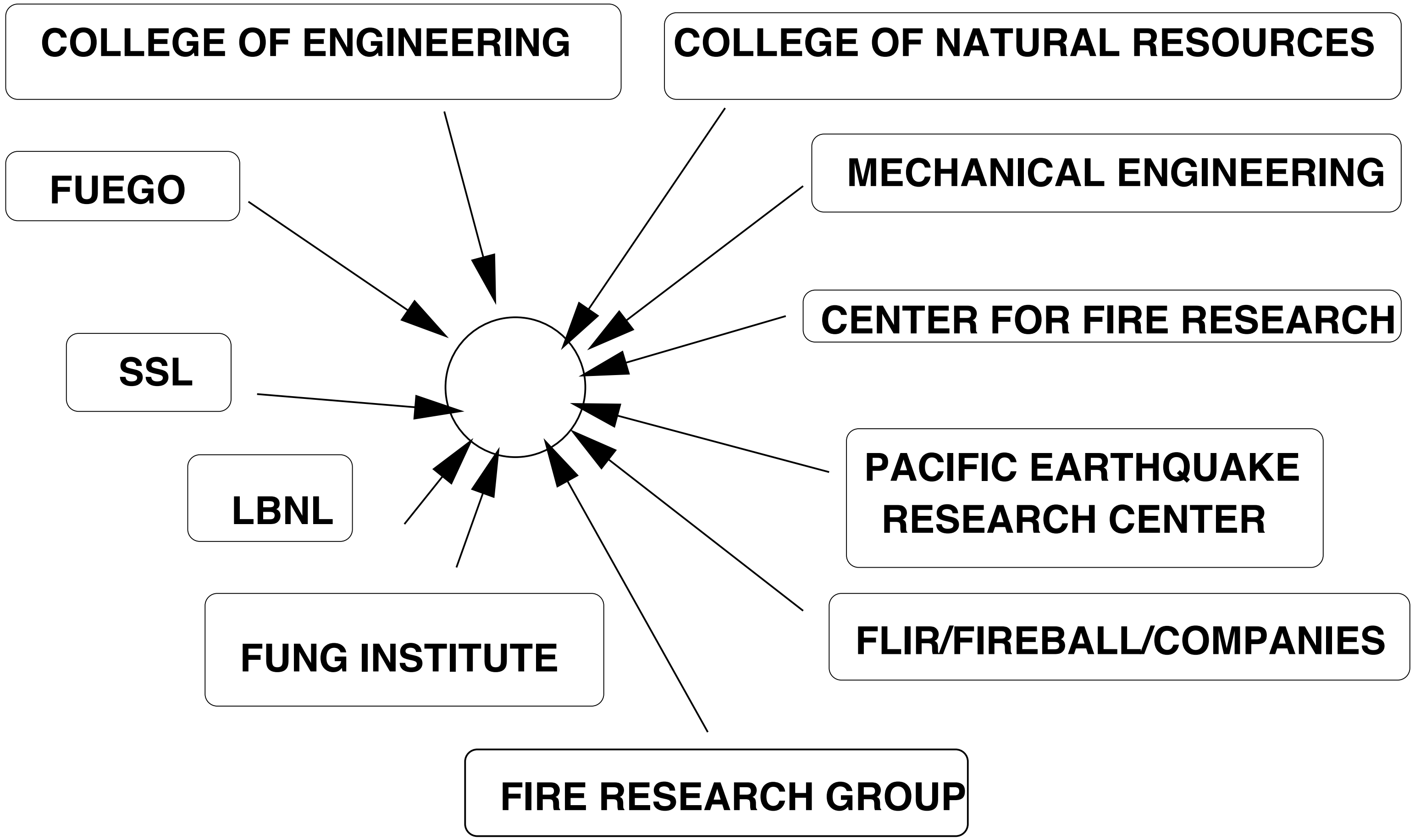
- Tarek Zohdi <zohdi@berkeley.edu>, Daniel Feldman <drfeldman@lbl.gov>

LINKS OF INTEREST RELATED TO THIS GROUP

- **College of Engineering: https://engineering.berkeley.edu**
- **Department of Mechanical Engineering: Mechanical Engineering**
- **FUEGO: http://fuego.ssl.berkeley.edu/team/**
- **Space Sciences Laboratory: http://www.ssl.berkeley.edu/**
- **PEER: https://peer.berkeley.edu,**
- **FLIR: https://www.flir.com**
- **Fung Institute: https://funginstitute.berkeley.edu/**
- **College of Natural Resources: https://nature.berkeley.edu**
- **Center for Fire Research: https://ucanr.edu/sites/cfro/**
- **CA Forestry:http://bofdata.fire.ca.gov/about_the_board/board_member_bios/**

THE STRUCTURE



Objectives of this meeting

1. A brief round introductions
2. Determine the genuinely interested parties
3. Coordinate information aggregation, gathering
4. Open discussion: Campus Signature Initiatives, Calfire, Private Philanthropy in Silicon Valley, Corporate Outreach, State Outreach, DHS, etc

What does UCB offer?

- Remote sensing, mapping, etc.
- Wireless communication, sensor technologies, data analytics, etc.
- Computer vision, infrared technologies, optics, etc.
- Experiments: combustion, toxicology, etc.
- Ground to air technologies, UAV’s, UGV’s, Robotics, etc.
- ***Real time*** modeling and rapid *re*-simulation
- **Signature Initiative: Env. Change, Sustainability and Justice**

ADVANCES IN EQUIPMENT: https://www.flir.com

- https://www.mesfire.com
- https://www.thefirestore.com/store/category.aspx/categoryId/516/Fire-Department-Detectors/
- https://www.flir.com/instruments/firefighting/
- https://www.flir.com/browse/public-safety/firefighting-cameras/
- https://www.flir.com/products/flir-kf6/

Wildfire modeling:https://en.wikipedia.org/wiki/Wildfire_modeling

- Objective: Speed and direction of spreading
- Utilize fuel models-types of materials
- Ascertain ecological effects that result (smoke, etc.)
- Incorporate environmental factors: relative humidity, precipitation…
- Classes of models: **Empirical, Semi-empirical, and Physically based**

Empirical and semi-empirical models

- **Empirical models: semi-empirical fire spread equations, as in those published by the USDA Forest Service, Forestry Canada, Australasian fuel complexes have been developed for quick estimation of fundamental parameters of interest such as fire spread rate, flame length, and fireline intensity of surface fires at a point for specific fuel complexes, assuming a representative point-location wind and terrain slope.**
- **Semi-empirical models: Two-dimensional fire growth models such as FARSITE and Prometheus, the Canadian wildland fire growth model designed to work in Canadian fuel complexes, have been developed that apply such semi-empirical relationships.**

Physically Based Models

Physically based models and coupling with the atmosphere: simplified physically based two-dimensional fire spread models based upon conservation laws that use radiation as the dominant heat transfer mechanism and convection, which represents the effect of wind and slope, lead to reaction-diffusion systems of partial differential equations. More complex physical models join computational fluid dynamics models with a wildland fire component and allow the fire to feed back upon the atmosphere. These models include NCAR's Coupled Atmosphere-Wildland Fire-Environment (CAWFE) model developed in 2005, WRF-Fireat NCAR and which combines the Weather Research and Forecasting model with a spread model by the level set method, University of Utah's Coupled Atmosphere-Wildland Fire Large Eddy Simulation developed in 2009, Los Alamos National Laboratory's FIRETEC developed in, the WUI (Wildland Urban Interface) Fire Dynamics Simulator (WFDS) developed in 2007,and, to some degree, the two-dimensional model FIRESTAR. These tools have different emphases and have been applied to better understand the fundamental aspects of fire behavior, such as fuel inhomogeneities on fire behavior,feedbacks between the fire and the atmospheric environment as the basis for the universal fire shape,and are beginning to be applied to wildland urban interface house-to-house fire spread at the community-scale.

Data Assimilation Models

Data assimilation periodically adjusts the model state to incorporate new data using statistical methods. Because fire is highly nonlinear and irreversible, data assimilation for fire models poses special challenges, and standard methods, such as the ensemble Kalman filter (EnKF) do not work well. Statistical variability of corrections and especially large corrections may result in nonphysical states, which tend to be preceded or accompanied by large spatial gradients. In order to ease this problem, the regularized EnKF penalizes large changes of spatial gradients in the Bayesian update in EnKF. The regularization technique has a stabilizing effect on the simulations in the ensemble but it does not improve much the ability of the EnKF to track the data: The posterior ensemble is made out of linear combinations of the prior ensemble, and if a reasonably close location and shape of the fire cannot be found between the linear combinations, the data assimilation is simply out of luck, and the ensemble cannot approach the data. From that point on, the ensemble evolves essentially without regard to the data. This is called filter divergence. So, there is clearly a need to adjust the simulation state by a position change rather than an additive correction only. The *morphing EnKF* combines the ideas of data assimilation with image registration and morphing to provide both additive and position correction in a natural manner, and can be used to change a model state reliably in response to data.

Archival Software

- **ASCOS (Analysis of Smoke Control Systems)** is a program for steady air flow analysis of smoke control systems.
- **ASET-B (Available Safe Egress Time - BASIC)** is a program for calculating the temperature and position of the hot smoke layer in a single room with closed doors and windows.
- **ASMET (Atria Smoke Management Engineering Tools)** consists of a set of equations and a zone fire model for analysis of smoke management systems for large spaces such as atria, shopping malls, arcades, sports arenas, exhibition halls and airplane hangers.
- **BREAK1 (Berkeley Algorithm for Breaking Window Glass in a Compartment Fire)** is a program which calculates the temperature history of a glass window exposed to user described fire conditions.
- **CCFM (Consolidated Compartment Fire Model version VENTS)** is a two-layer zone-type compartment fire model computer code. It simulates conditions due to user-specified fires in a multi-room, multi-level facility.
- **DETACT-QS and DETACT-T2** DETACT-QS (DETector ACTuation - Quasi Steady) is a program for calculating the actuation time of thermal devices below unconfined ceilings.
- **ELVAC (Elevator Evacuation)** is an interactive computer program that estimates the time required to evacuate people from a building with the use of elevators and stairs.
- **FIRDEMND** simulates the suppression of post flashover charring and non-charring solid-fuel fires in compartments using water sprays from portable hose-nozzle equipment used by the fire departments.
- **FIRST (FIRe Simulation Technique)** is the direct descendant of the HARVARD V program developed by Howard Emmons and Henri Mitler.
- **FPETool** (Software and Documentation) is a set of engineering equations useful in estimating potential fire hazard and the response of the space and fire protection systems to the developing hazard.
- **GetGo** - GetGo transfers results (temperatures, deflections and strains) between a structural model that uses beams and shells, and a thermal model that uses solid (brick) elements.
- **LAVENT** is a program developed to simulate the environment and the response of sprinkler links in compartment fires with draft curtains and fusible link operated ceiling vents.

Fire modeling programs from NIST

- https://www.nist.gov/engineering-laboratory/fire-modeling-programs
- FDS (Fire Dynamics Simulator) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires.
- CFAST (Consolidated Model of Fire and Smoke Transport) is a two-zone fire model used to calculate the evolving distribution of smoke, fire gases and temperature throughout compartments of a building during a fire.
- There is no shortage of simulation codes.
- **Limitations: real-time accuracy and simultaneous practical use remains elusive.**

UCB (Zohdi): FIRE AUTOMATION SIMULATION TOOL (F. A. S. T)
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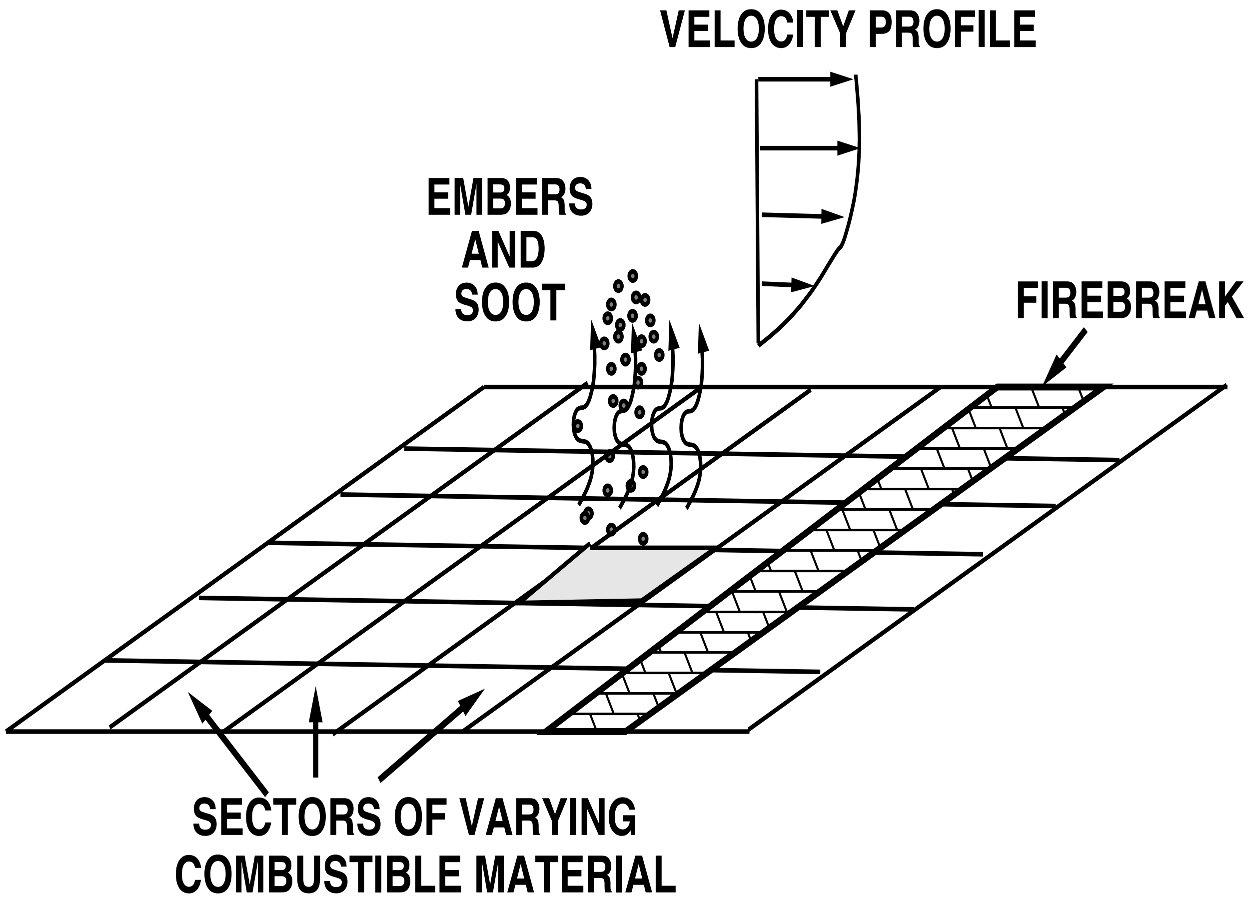
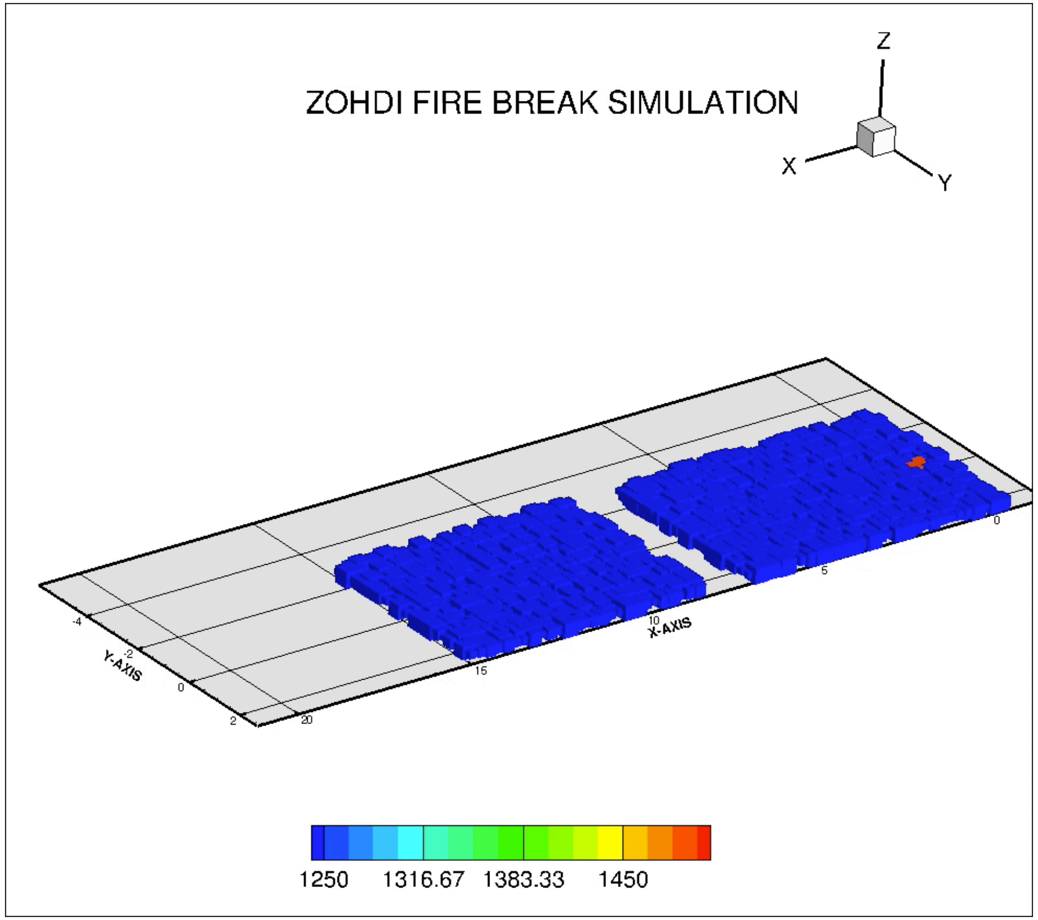
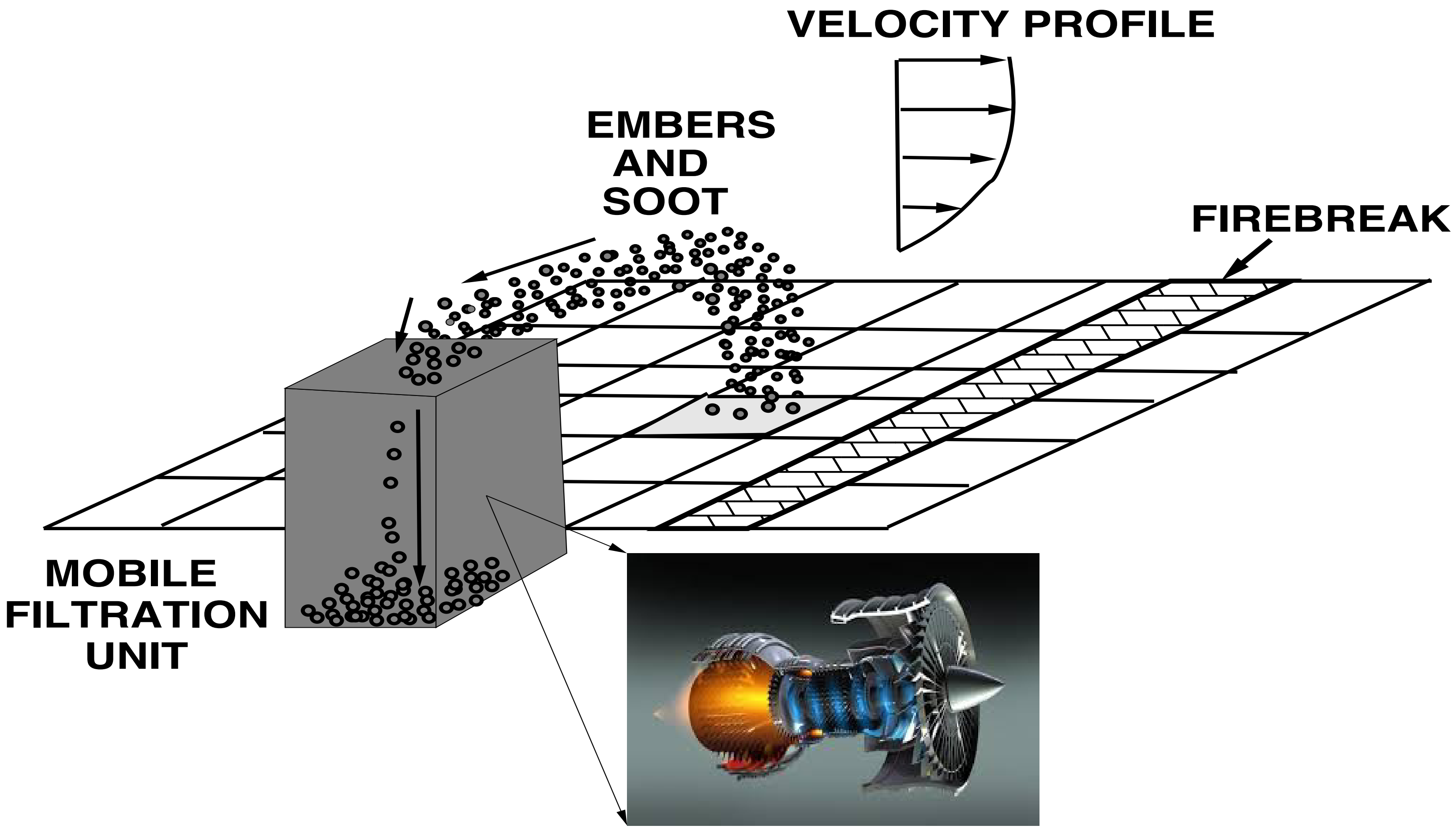




LARGE-SCALE FILTRATION

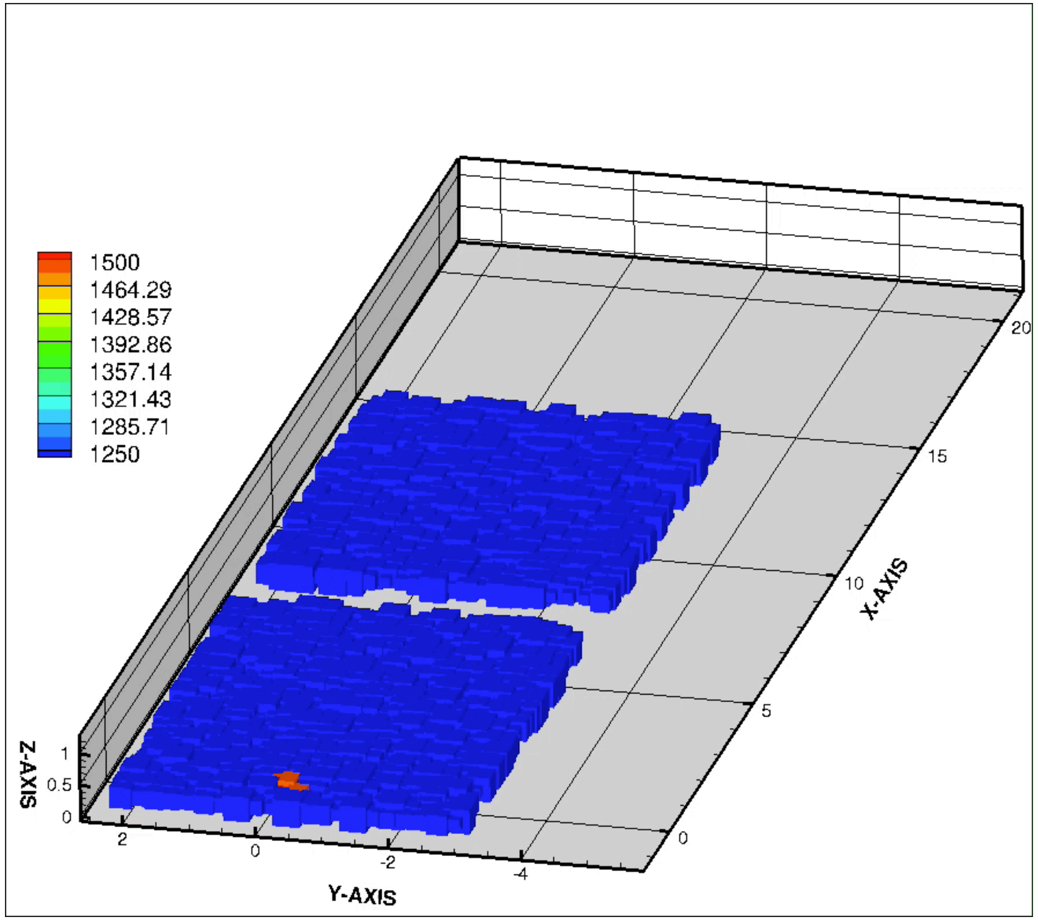


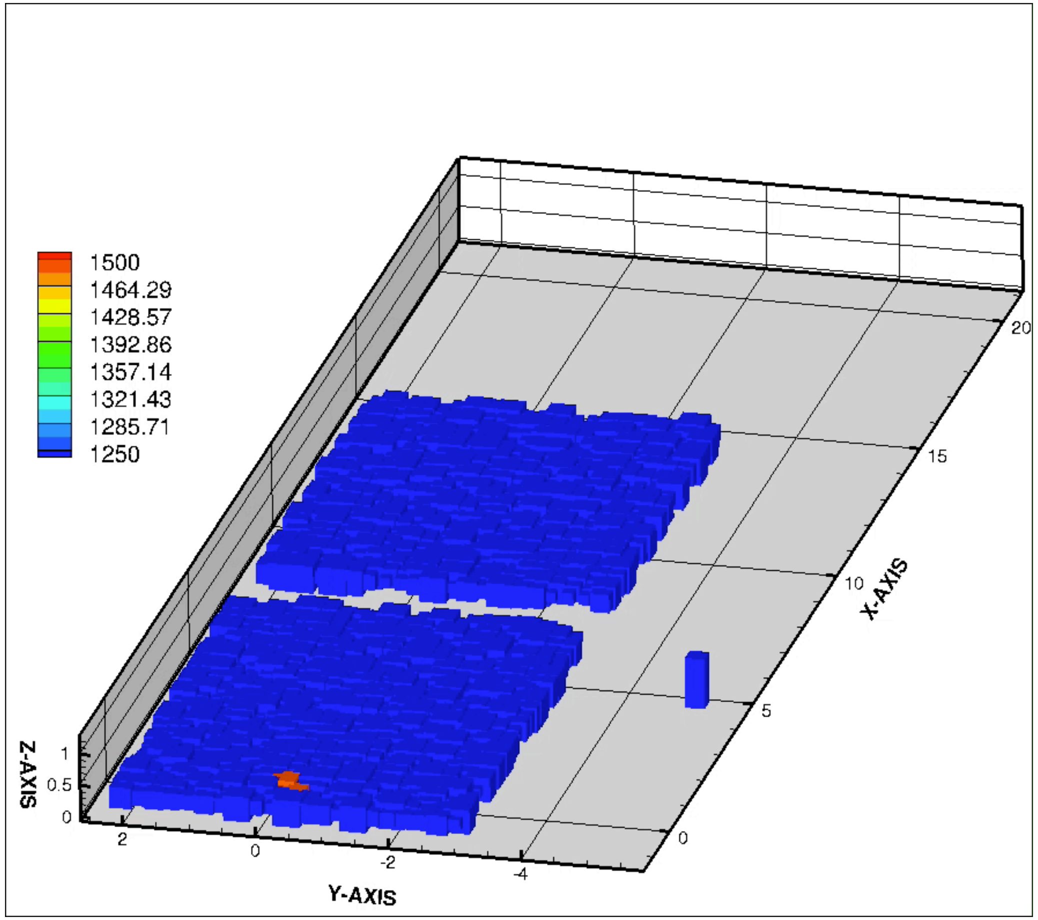
MOBILE LARGE-SCALE AIR-FILTRATION

MADNESS(?)

AIR FLOW FOR A JET=10^3 KG/S=$1.7\text{x}10^7$ FT^3/MIN=EVACUATE 17 MEDIUM SIZED BUILDINGS A MINUTE

WITHOUT AND WITH MOBILE FILTRATION https://cmmrl.berkeley.edu/77-2/





MANUFACTURING SAFETY: SPATIO-TEMPORAL FOOTPRINTS OF INCANDESCENT EJECTA

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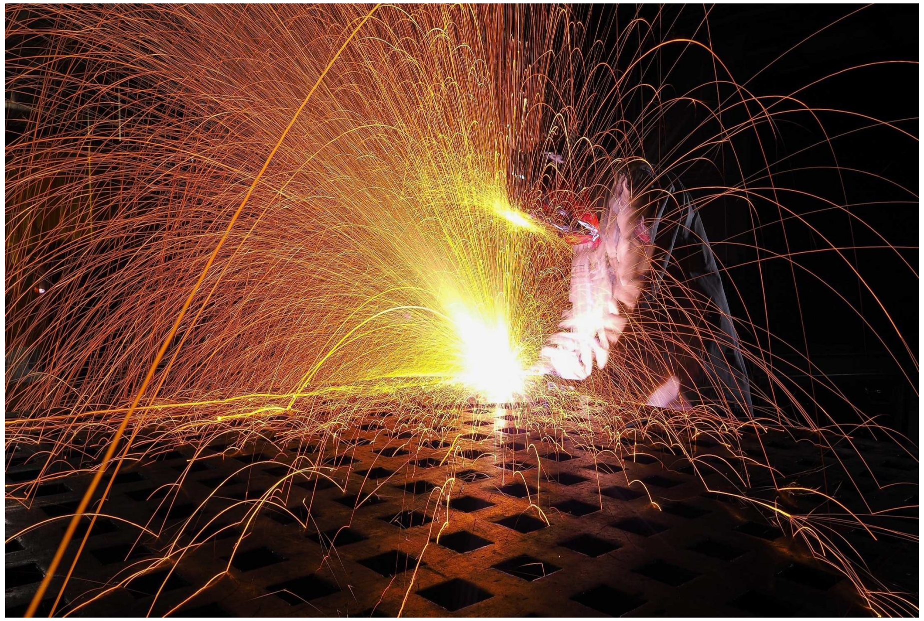

EXPLOSION MODELING AND SIMULATION

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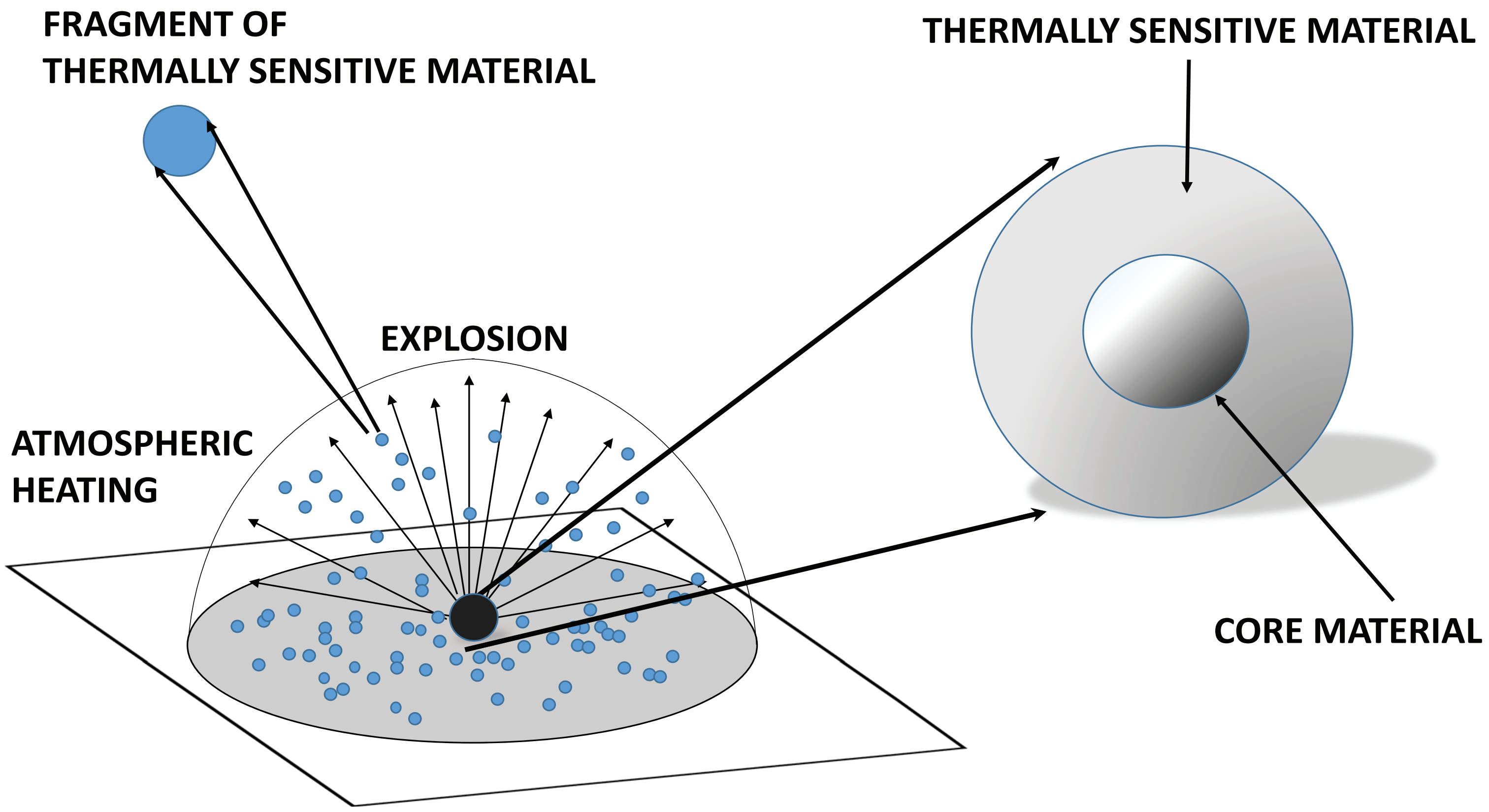

EXPERIMENTAL VALDIDATION SEQUENCE AT ABERDEEN https://cmmrl.berkeley.edu/77-2/

SPATIO-TEMPORAL FOOTPRINTS OF INCANDESCENT EJECTA

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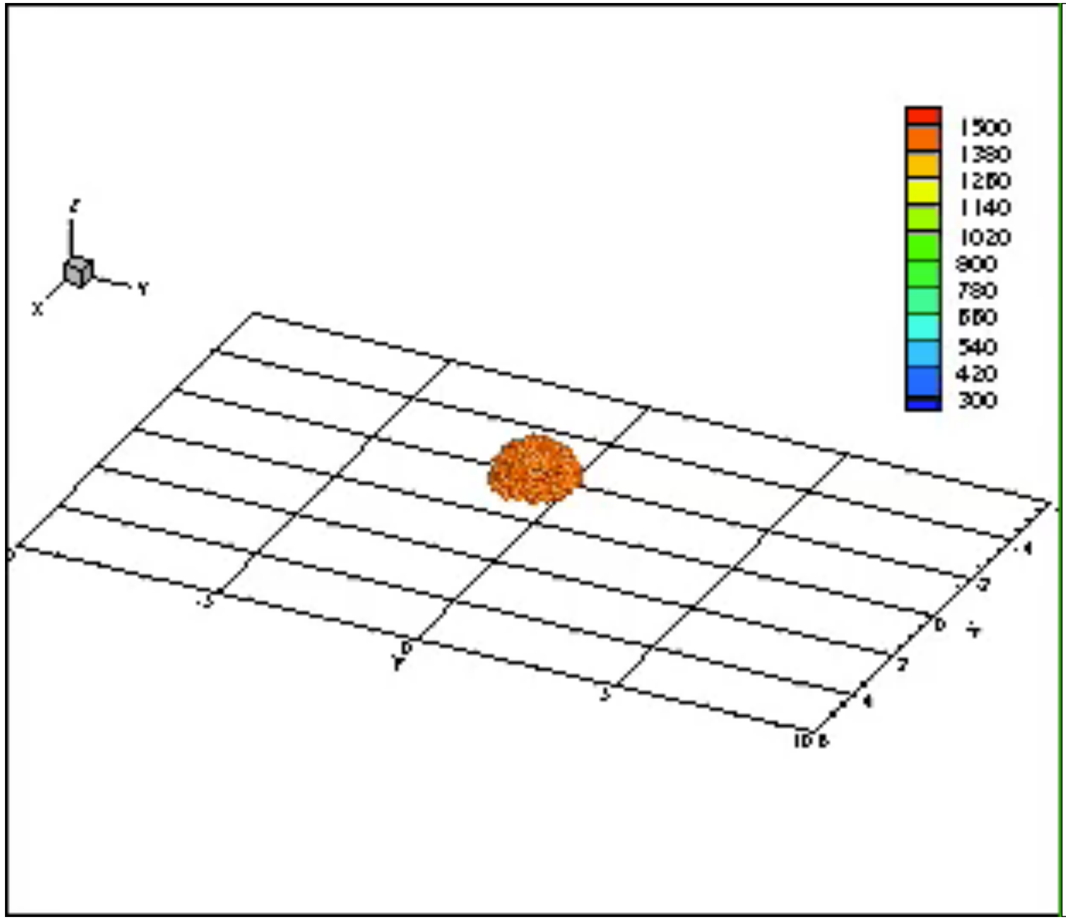

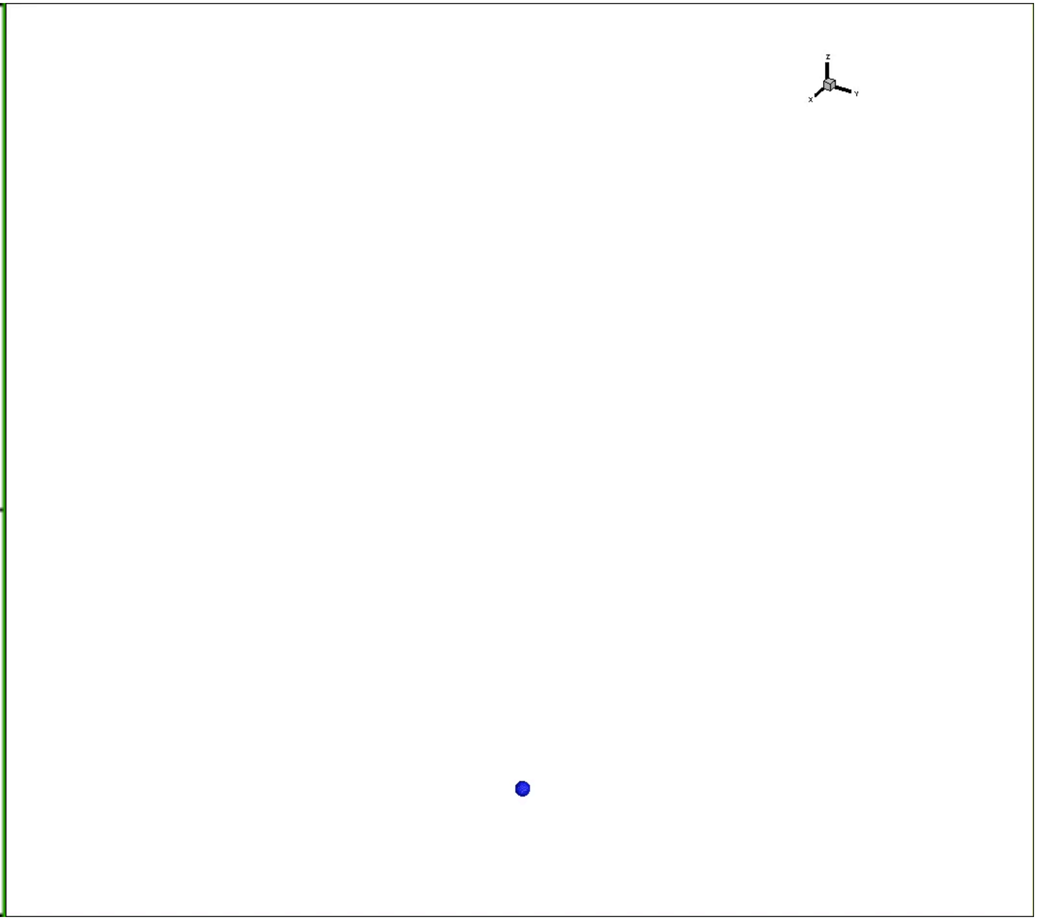

OBSCURANTS
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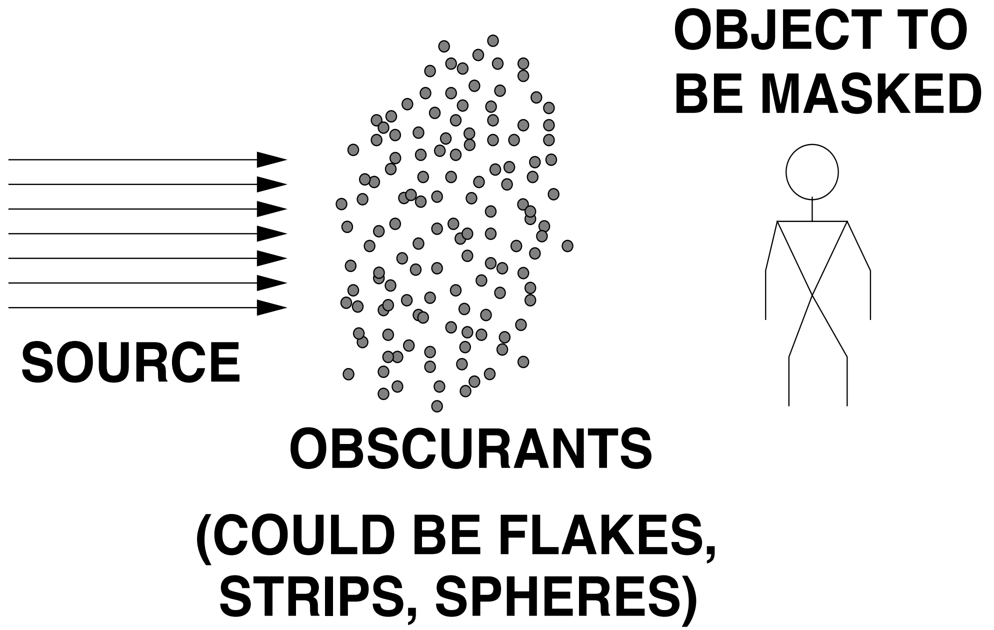

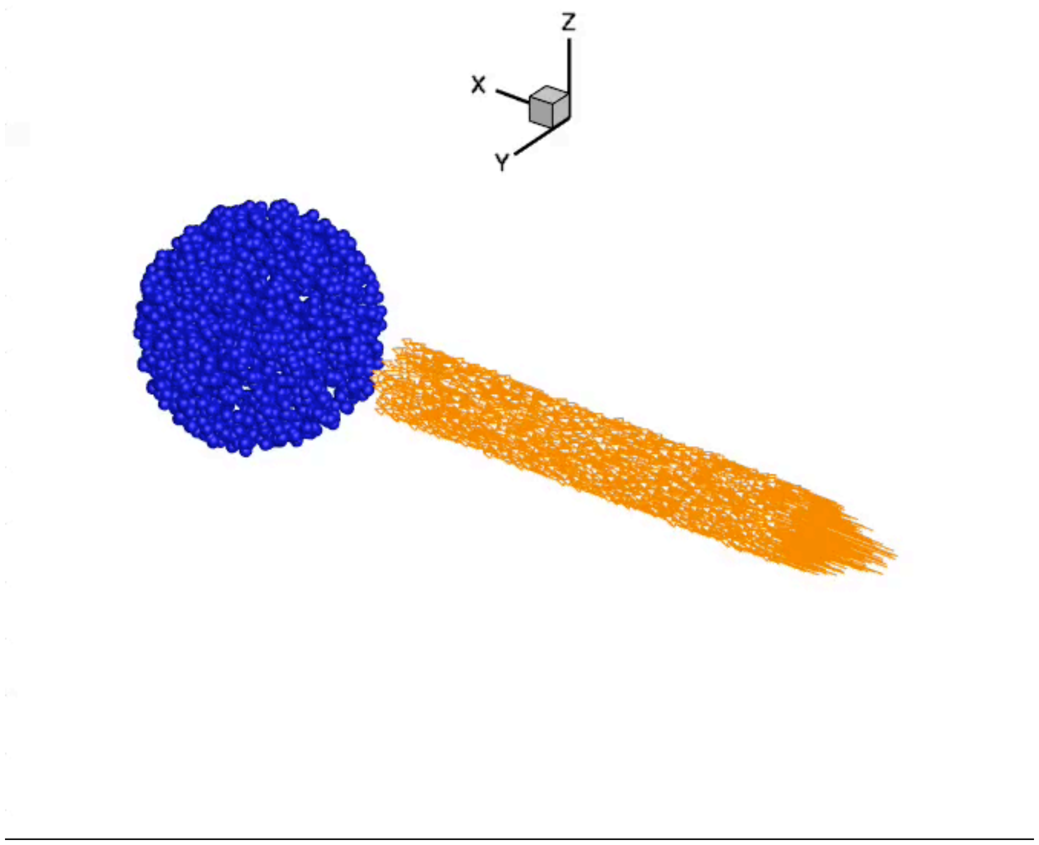

UAV PATH PLANNING

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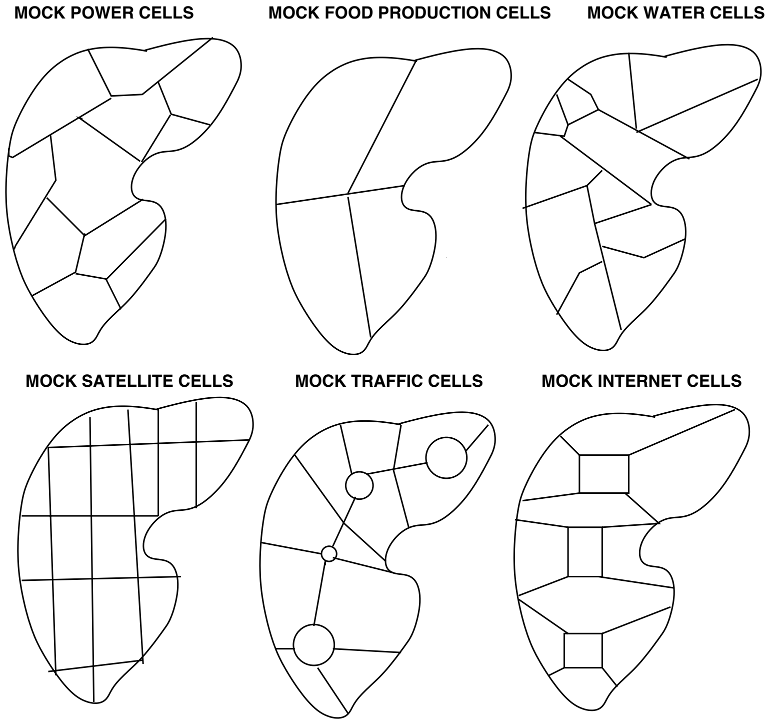

EXAMPLES

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