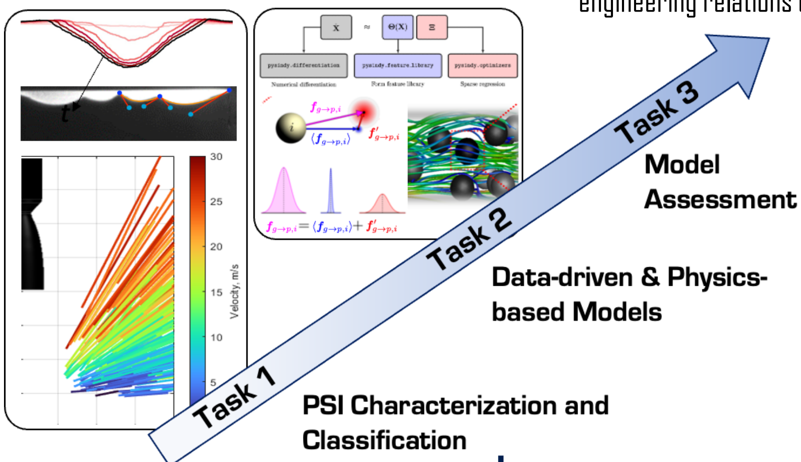
Integrating Data-Driven and Physics-Based Models for Plume-Surface Interaction Predictions

PI: **Laura Villafañe**,
Co-I **Fabien Evrard**, University of Illinois at Urbana-Champaign
Co-I **Jesse Capecelatro**, University of Michigan

ILLINOIS
Aerospace Engineering
COLLEGE OF ENGINEERING

MICHIGAN ENGINEERING
UNIVERSITY OF MICHIGAN



Approach

Multi-stage approach that builds from large volume of video and other diagnostic data to erosion and ejecta physics products

- **Automated characterization** and **classification** of PSI phenomena through a multi-fidelity data analysis approach via machine learning aided image segmentation, k-means clustering and particle velocimetry and tracking algorithms
- Machine learning using **symbolic regression** and **genetic programing** to automate **model discovery** and derive empirical relations for cratering and ejecta and to complement **physics-based erosion models**
- Quantify **parametric uncertainty** and **validate** proposed models against historical and other modern PSI data

Research Objectives

Goal: Bring to the PSI community an **improved understanding of crater formation, surface erosion, and resulting ejecta**, and how they relate to **thruster, ambient and granular surface properties**

Key Innovations:

- Efficiently reduce large volumes of experimental data into taxonomy of observable behaviors
- Provide a unified framework for representing crater profiles based on their geometrical features
- Utilize symbolic regression and genetic programming to extract closed-form engineering relations of PSI phenomenology

Comparison to SOA: No empirical/numerical models can accurately predict plume surface interactions. Building on experimental NASA datasets this project will identify leading parameters and formulate empirical relations and models that represent the physics of PSI

Start TRL 1-2: basic principles with formulated concepts.
End TRL 3: engineering models and datasets ready for application

Potential Impact

- Data products in the form of QoIs with uncertainty provides **validation of future higher-fidelity computational models**
- Identification of key physical mechanisms and leading parameters across a broad range of PSI conditions enables **vehicle design and descent strategies that mitigate risks**
- The data reduction and model discovery approaches used for this highly parametric multi-physics problem could be applied to other datasets posing similar challenges. **Closed-form** and **interpretable models** for **multiparametric data** are sought across disciplines