Title and Research Team

Project Title: Investigating the Thermochemical Response of Avcoat TPS from First Principles for Comparison with EFT-1 Data

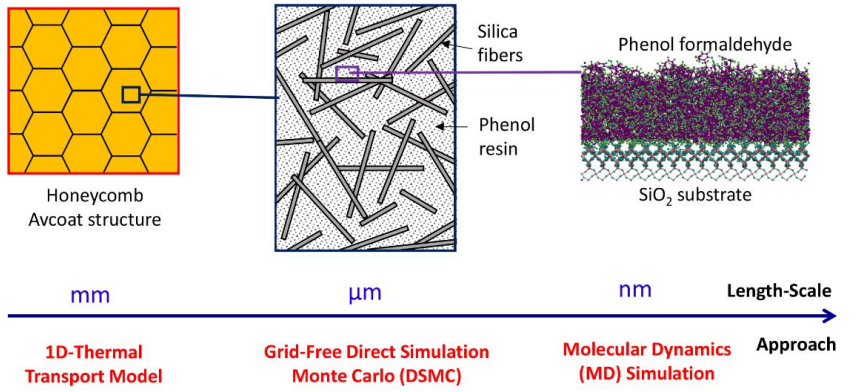
Solicitation: SpaceTech-REDDI-2015 Early Stage Innovations
Topic 6 Atmospheric Entry Modeling Development Using Orion EFT-1 Flight Data

PI: Deborah A. Levin
Co-I: Huck Beng Chew

Institute: Department of Aerospace Engineering
University of Illinois at Urbana-Champaign

Research Objectives

- Develop high fidelity and multi-scale thermal response models of the Avcoat TPS from first principles.
- Validate the predicted structural response against measured in-depth temperature and calorimeter data from EFT-1 and any available radiometer data.



Multi-scale framework to model the thermal response of Avcoat TPS from first principles, bridging chemical reactions at the atomic scale to structural-thermal response for validation with EFT-1 data.

- High-fidelity porous TPS modeling is notoriously difficult, and current models (FIAT, STAB, CHAR) rely on continuum consideration of both the flow and the material response.
- Innovation is in incorporating non-continuum gas-dynamic and gas-surface chemistry with bottom-up physics-based models.
- Improved thermal response predictions, validated with EFT-1 data, expected to raise TRL level from 2 to 4.

Approach

- Proposed TPS response model to be based on kinetic particle simulations of both gas transport and chemistry at multi-scales.
- At the atomistic-scale, MD simulations will characterize the ablation chemistry and fiber/resin recession rates.
- At the meso-scale, grid-free DSMC method, informed by MD, will account for both homogeneous and heterogeneous chemistry, and true 3D microstructure of the TPS material.
- Results from MD and DSMC model will be used to calibrate the parameters of a 1D Thermal Transport model for comparison with EFT-1 data at the macroscopic-scale.

Potential Impact

- The programmatic tolerances for atmospheric re-entry are stringent, and require accurate predictive models beyond 1960s era FIAT, STAB, CHAR.
- Proposed research will contribute to understanding and developing high-fidelity predictive tools for TPS regression and fracture, accounting for ablation chemistry and true, time-dependent microstructure of the TPS.
- While focusing on Avcoat, the fundamental modeling framework can be applied to a variety of potential TPS materials, allowing NASA the ultimate flexibility and confidence to choose the required type and minimum quantity of TPS material.