

Ablation Activities in the NASA Entry Systems Modeling Project (ESM)

Justin Haskins,[1] Aaron Brandis ,[1] Monica Hughes,[2] Tom West[2]

[1]NASA Ames Research Center

[2]NASA Langley Research Center

Ablation Workshop 2023 | November 7th, 2023

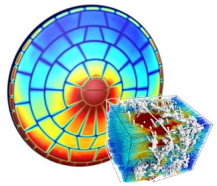
Entry Systems Modeling (ESM)

Technology Capability Product: cross-cutting tools and technologies for modeling entry systems that improve performance, reduce mission risk, and enable new system capabilities across the Solar System

Technical Capability: consists of *five technical capability areas* & *one special topic*

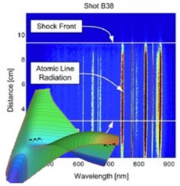
Technical Capability Areas

TPS Materials Modeling



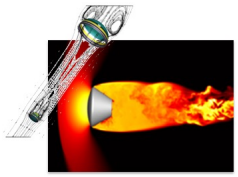
multiscale models of TPS material reliability and performance

Shock Layer Kinetics & Radiation



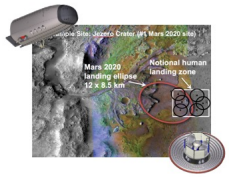
high-temperature gas physics of entry systems from quantum to engineering scales

Aerosciences



parachute dynamics, vehicle dynamics & stability, turbulent heating, advanced numerical methods

Guidance, Navigation & Control



end-to-end simulation capability for multiple mission EDL concepts of operation

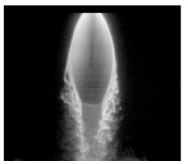
Ground Test Validation



ground testing to support uncertainty quantification – unique facilities and diagnostics

Special Topic

Hypersonic Wake Flows



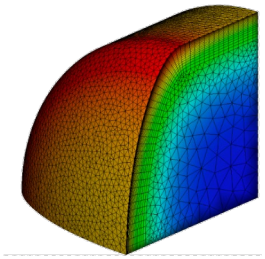
simulation and experimental interrogation of unsteady wake flows

AW 2023

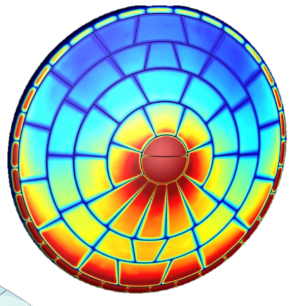
TPS Modeling Research & Development

Developing design tools and validated performance models for all ablative TPS leveraged for NASA spaceflight projects

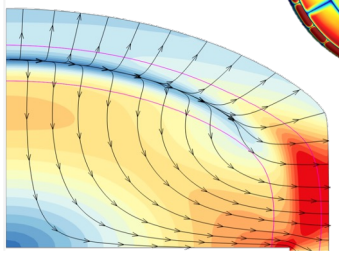
Material Response Capabilities



Icarus

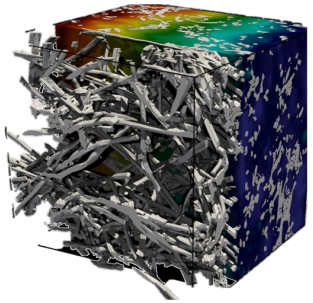


PATO



Coupled Tools

Multiscale Material Models

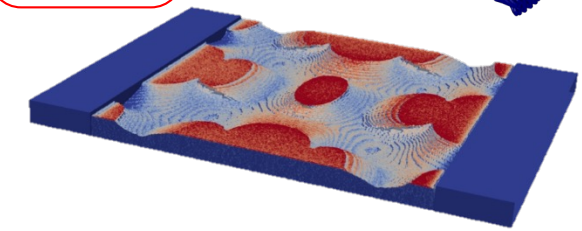


PuMA



LAMMPS/ HYDRA

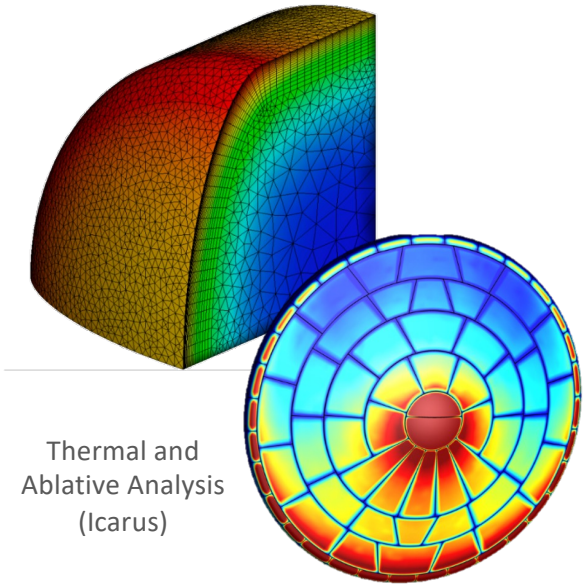
SPARTA



Material Response Capabilities

Mission Design Tools

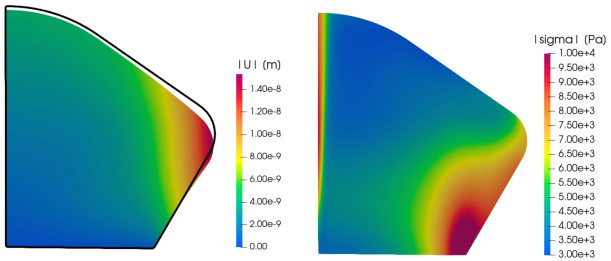
Improving reliability of multi-D material response for TPS sizing



Thermal and Ablative Analysis (Icarus)

High-Fidelity Models

Assessing influence of additional physics on performance and design



Pyro-gas Flow and Stress Analysis (PATO)

Codes

Icarus

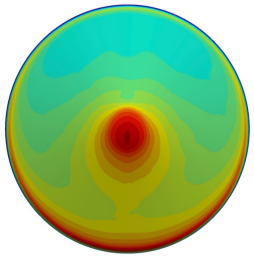


PATO

PATO Porous Material Analysis
NASA ARC

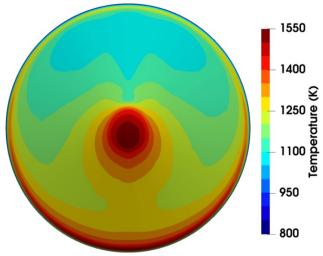
Coupled Tools

Streamlining multi-D material response by coupling to CFD codes

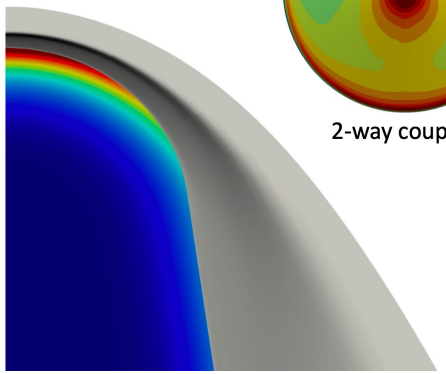


1-way coupling

Impact of Coupling on Surface Temperature (Icarus-US3D, PATO-DPLR)



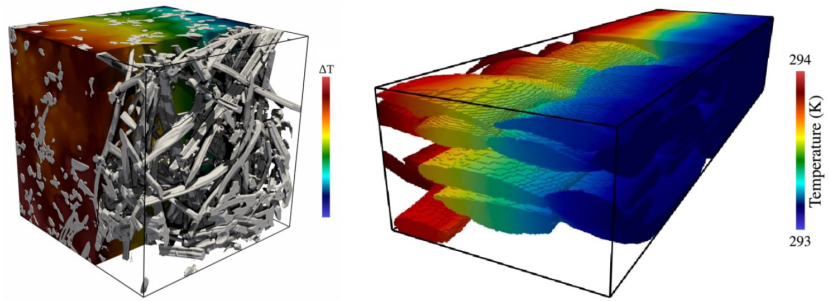
2-way coupling



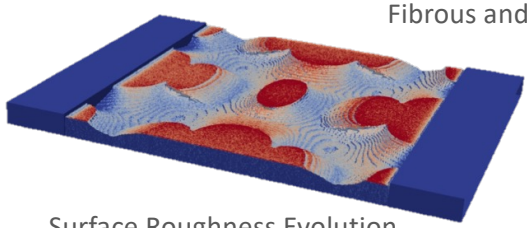
Multiscale Material Models

Microscale Property Models

Evaluating influence of structure on properties and variability



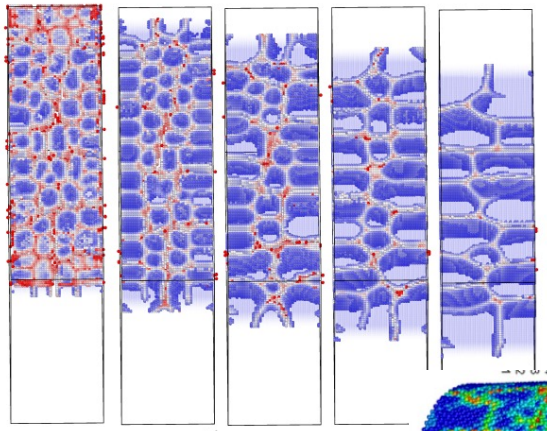
Micro-CT based thermal/mechanical properties of Fibrous and Woven TPS (Finite Volume/PuMA)



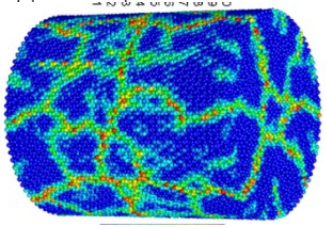
Surface Roughness Evolution and Stress (DSMC/SPARTA)

Damage Models

Informing material and condition dependent failure modes of TPS



Cracking models of porous TPS materials (HYDRA)



Codes

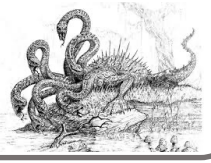
PuMA



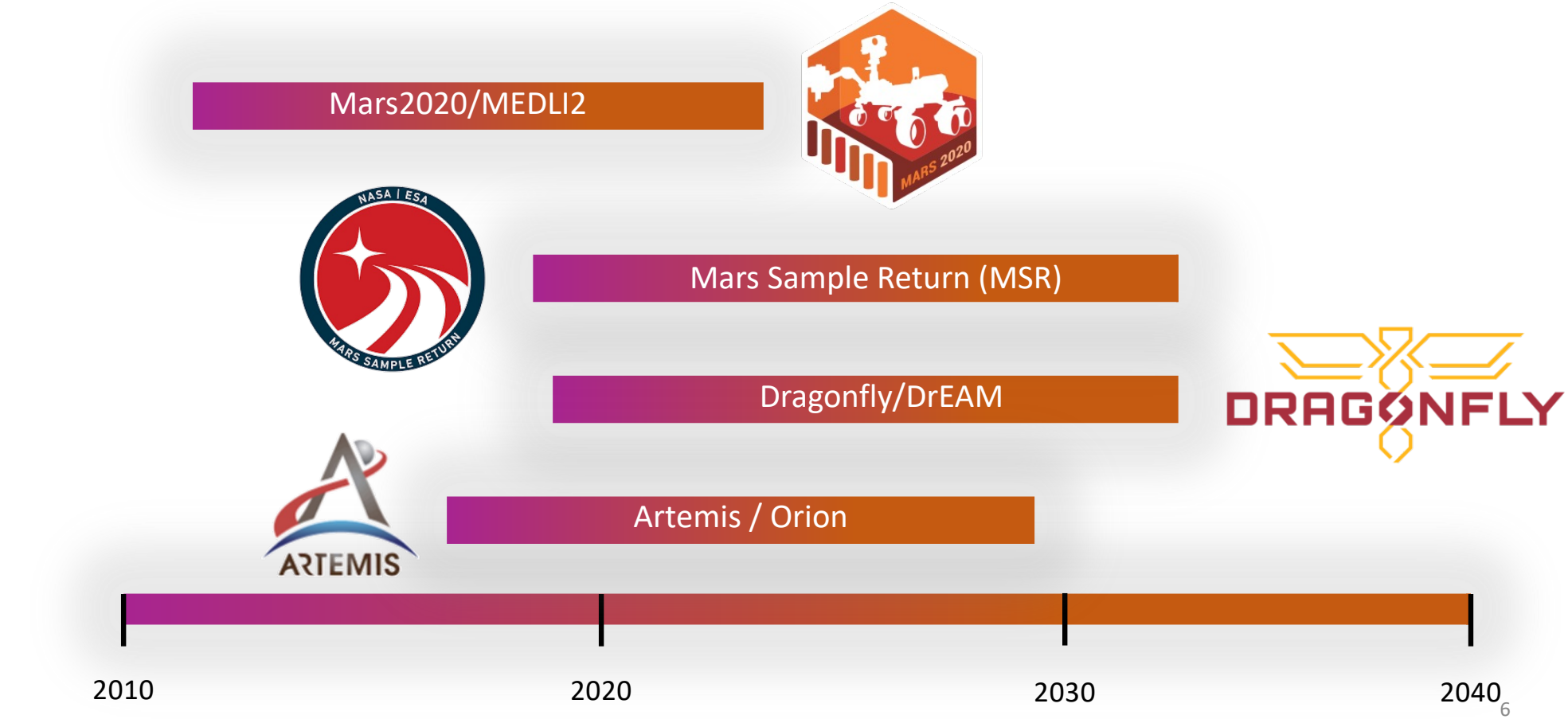
SPARTA



HYDRA



Spaceflight Project Timelines

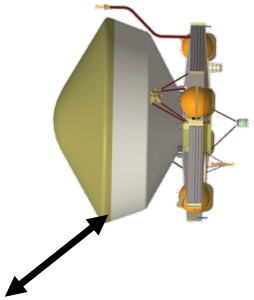


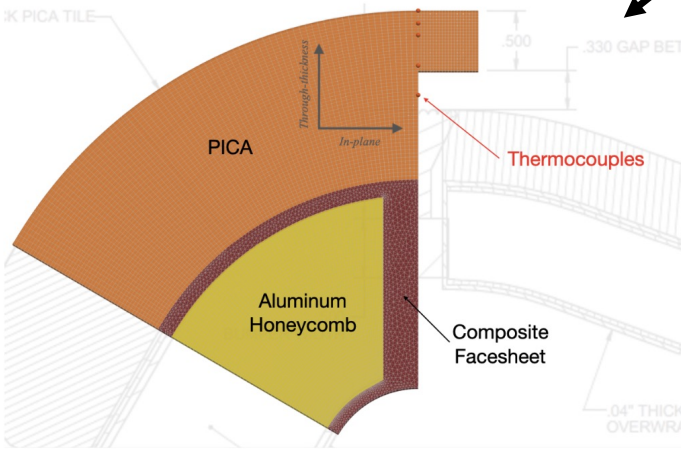
AW 2023

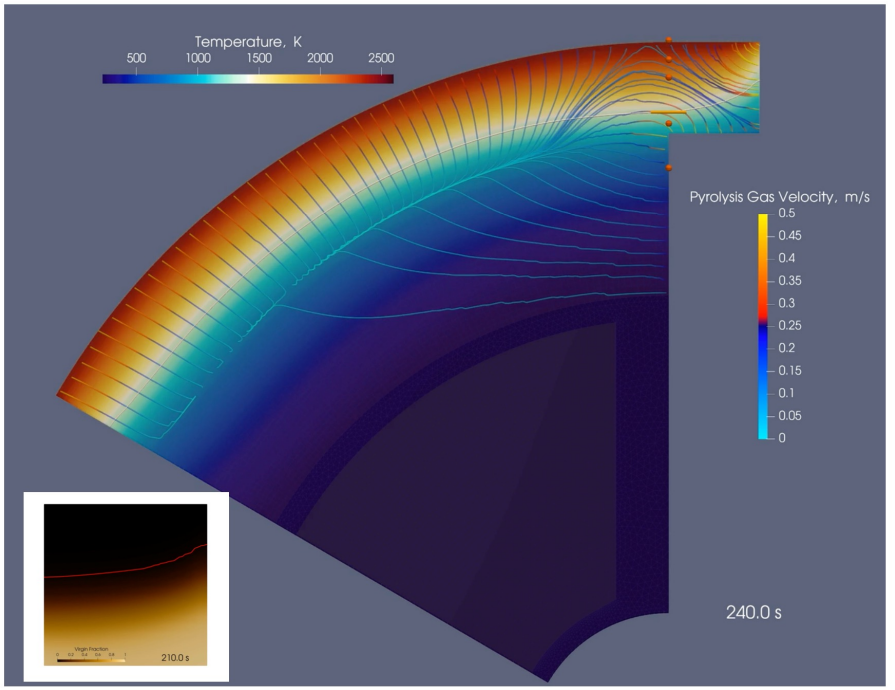
Dragonfly
Multidimensional Analysis



PICA ”tooth” design being traded for Dragonfly heatshield to provide protection of main seal – performance assessment requires multi-D capability (Icarus)





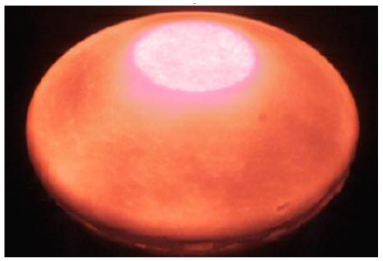


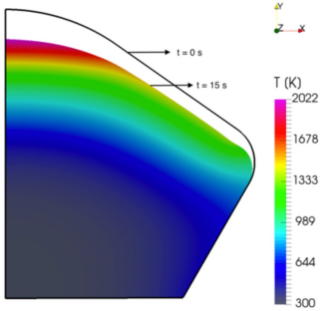
POCs: Stern and Schultz

Mars2020/MEDLI2
Nusil Coating Modeling

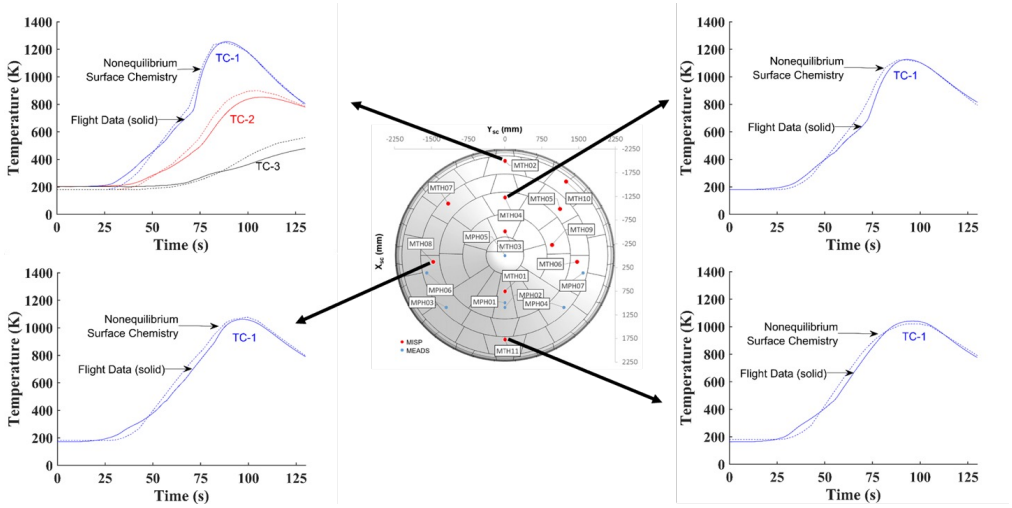
Characterization of NuSil coating on PICA in arc jet test conditions – geared to develop better models for recession of MSL and Mars2020 (PATO)

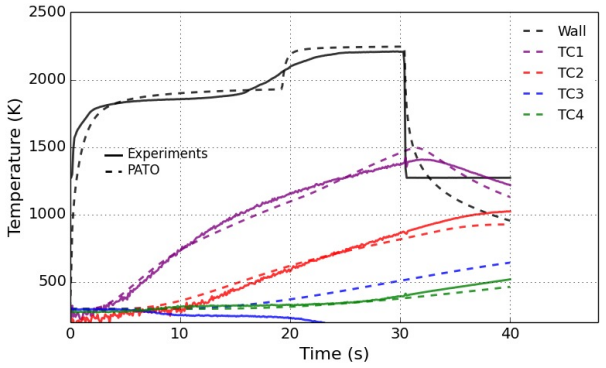
Model of Arc Jet Tests





Model of Flight Conditions

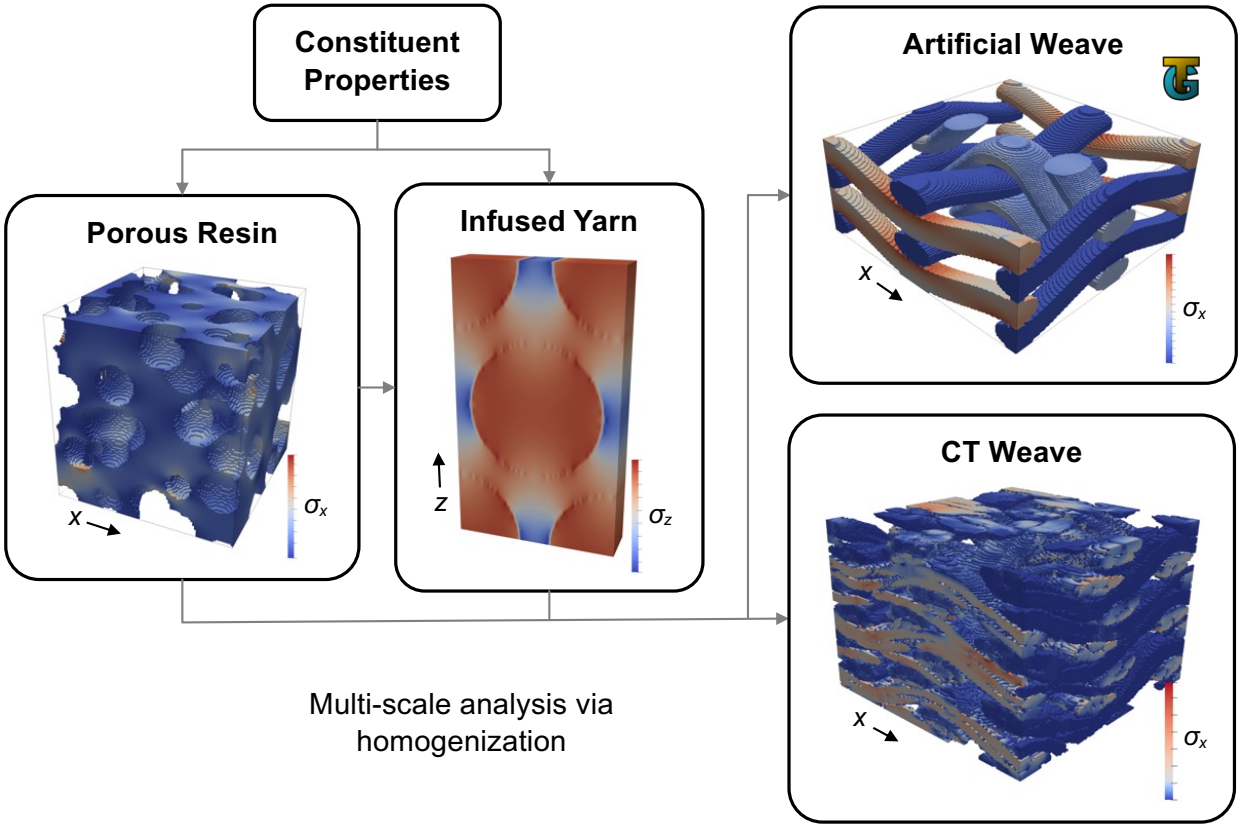




POCs: West, Meurisse, Bessire, and Panerai

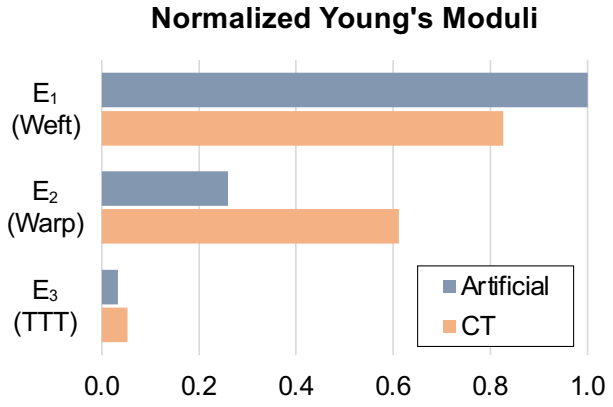
Mars Sample Return – Earth Entry System

Woven TPS Mechanical Properties



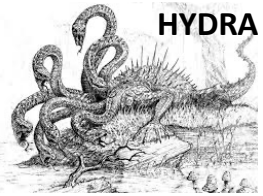
Multi-scale analysis via homogenization

Analysis of mechanical properties of woven TPS material for MSR-EES using micro-CT data (PATO)

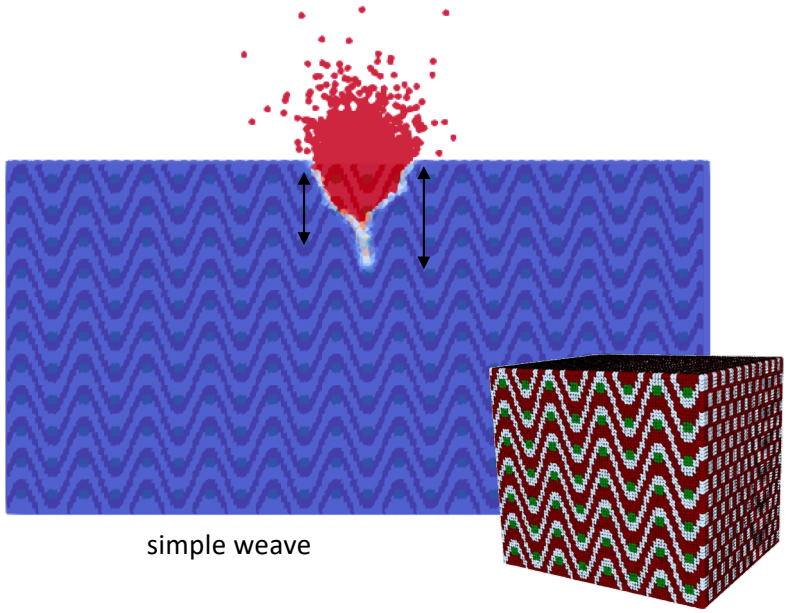


POCs: Fraile Izquierdo and Semeraro

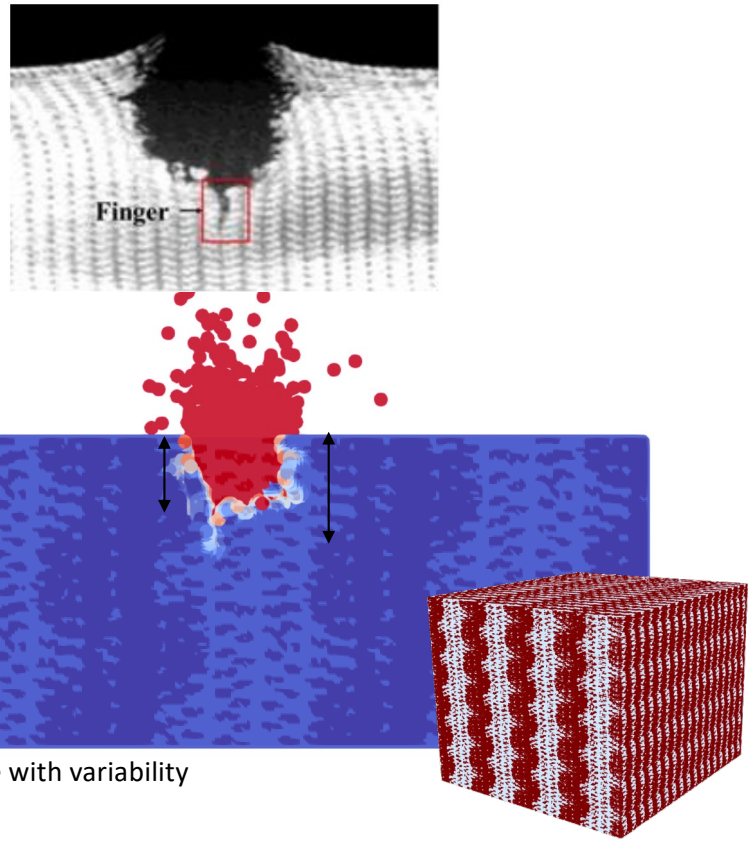
Mars Sample Return – Earth Entry System
Micrometeoroid/Orbital Debris Impact and Damage Propagation



HYDRA employed to study mechanical-mediated failure of weaves and the damage and propagation resulting from ballistic testing impacts



simple weave



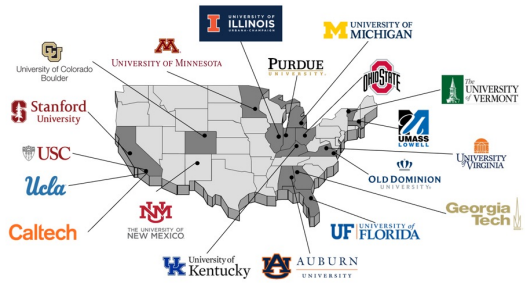
weave with variability

POCs: Abbott, Santos, Haskins

Collaborations & Partnerships

Academic Institutions

21+ ESM, EPSCoR, ESI, ECF, and STRI Grantee Institutions
25 NSTGRO at Various Institutions



NASA Spaceflight and Technology Projects

Orion
Mars2020
Mars Sample Return – Earth Entry System (MSR-EES)
Mars Sample Return – Sample Retrieval Lander (MSR-SRL)
Dragonfly
DaVinci
STMD technology projects: MEDLI2, LOFTID, DrEAM, and others

OGA

- **Air Force Office of Scientific Research**
- **Office of Naval Research**
- **Missile Defense Agency**
- **Sandia National Labs**
- **Lawrence Berkeley National Lab**
- **Lawrence Livermore National Lab**
- **Oak Ridge National Lab**

NASA ECI

- **EPIC (parachute instrumentation)**
- **Aerocapture Ice Giants**

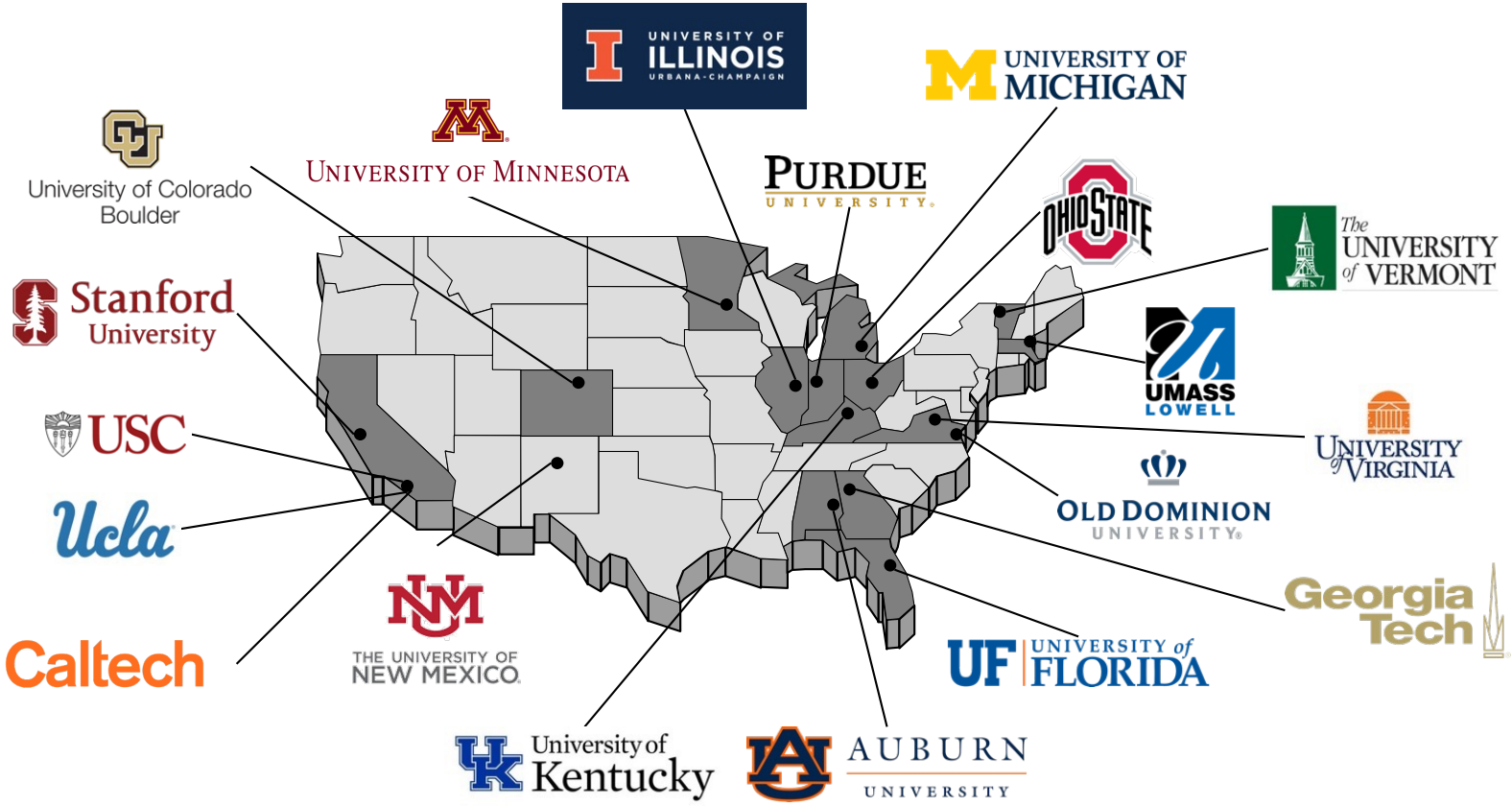
International

- **German Aerospace Center**
- **Ecole CentraleSupelec**
- **Von Karman Institute**
- **University of Queensland**
- *Oxford University*
- **Instituto Superior Tecnico**
- **European Space Agency**
- **JAXA (partnered with Orion)**

SBIR/STTR

- **Corvid Technologies**
- **ATA**
- **CFDRC**
- **M4**
- **Metrolaser**

Academic Partnerships*



*Non-NSTGRO Institutions

University Partnership Highlights

NASA Space Technology Research Institute (STRI)



Advanced Computational Center for Entry Systems Simulation (ACCESS)

Five-year institute dedicated to advancing the computational state-of-the-art of entry systems simulations. Four main thrusts investigated by a consortium of universities led by CU Boulder (Boyd)

NASA Unsolicited Proposal

ESM fields and funds unsolicited proposal submitted through NSPIRES.

NASA Center-Specific Summer Internship Programs

ARC regularly hosts 20-40 summer interns focused on entry systems

NASA Space Technology Graduate Research Opportunity (NSTGRO)

10+ current students at Stanford, UIUC, CUB, UK, and UMN with focuses ranging from dust erosion to influence micrometeoroid impact on ablative response

Early Career Faculty (ECF) / Early Stage Innovations (ESI)

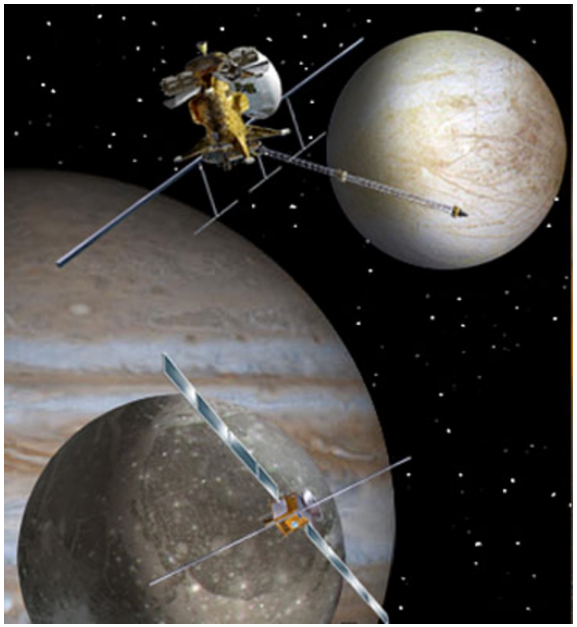
- Enhanced Diagnostics for Characterizing Entry Aerothermal Environments in High-enthalpy Impulse Facilities (Purdue, UCLA and University of Virginia)
- Modeling Shock Layer Radiation and Chemical Kinetics for Planetary Entry (Montana State University and University of Illinois Urbana Champaign)

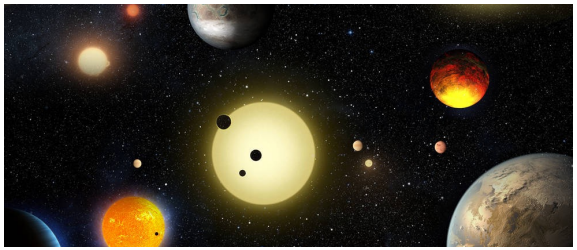
NASA Established Program to Stimulate Competitive Research (EPSCoR)

Kentucky EPSCoRs have been awarded on topics ranging from better characterizing TPS radiation response to design, manufacture, and entry testing of probes (KRUPS/KREPE)

Collaborative Opportunity Thoughts

- Modern Workshop Test Cases
  - Traditional cases focused on increasing fidelity of material model
  - Prime case for future test cases could include coupling to flow and radiation solvers
- Open Experimental Datasets
  - ESM generates a significant quantity of experimental data (arc jet and similar testing)
  - Possibility of creating an open database of arc jet testing results and basic conditions (may be some restrictions)





Acknowledgements

Teams and Modeling Efforts

Entry Systems Modeling (ESM) Leadership
ESM/Icarus Team
ESM/Predictive Material Modeling Team
ESM/Certification by Analysis Team
JSC Ablation Modeling Team
ARC Ablation Subject Matter Experts
ARC Experimentalists

NASA ARC/JSC Contributors

Michael Wright
Michael Barnhardt
Aaron Brandis
Eric Stern
Joseph Schulz
Georgios Bellas-Chatzigeorgis
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