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# Overview of Ablation Research at Sandia National Laboratories

12<sup>th</sup> Ablation Workshop

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Distinguished R&D Chemical Engineer  
Engineering Sciences Center

November 9, 2022

Contributions from: Nicholas Anderson, Marco Arienti, Kenneth Armijo, Patrick Blonigan, Katya Casper, Lincoln Collins, Peter Creveling, Paul Delgado, Martin Di Stefano, Jeff Engerer, Travis Fisher, Collin Foster (UIUC), Mitchell Gosma (UIUC), Mike Hansen, Bernadette Hernandez-Sanchez, Ryan Hess, Sarah Kieweg, Kyle Lynch, Erin Mussoni, Kevin Potter, John Tencer, Nekoda van de Werken, Zach Wilson, Justin Wagner, Ross Wagnild

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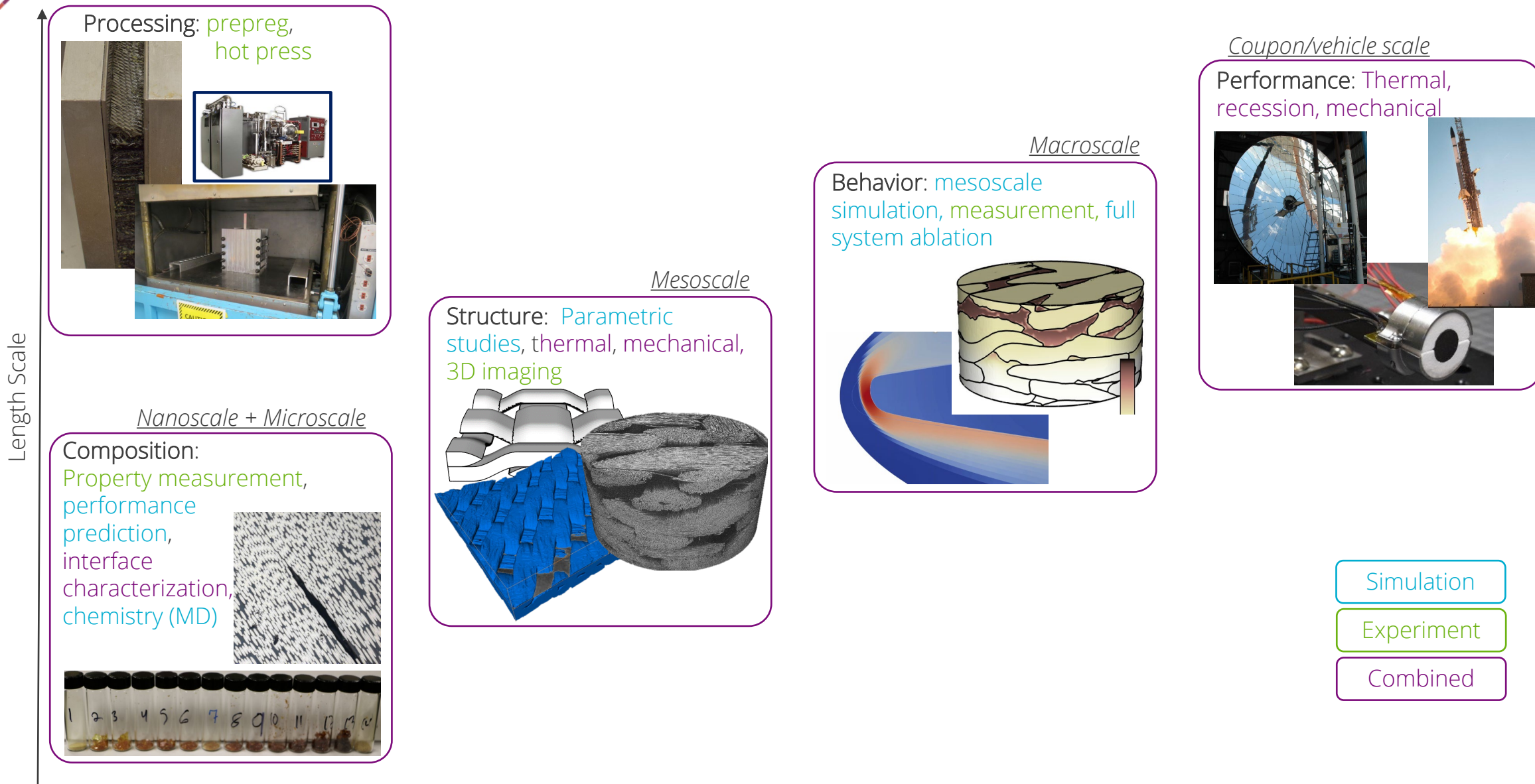
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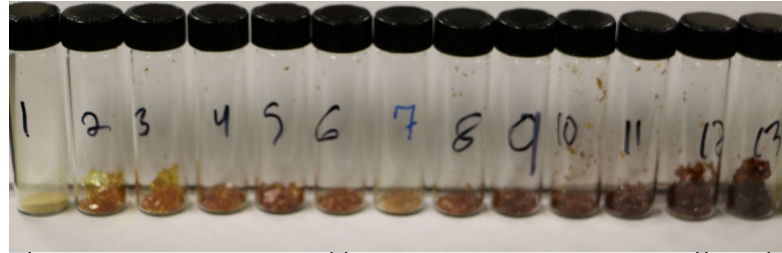
# Sandia's multi-scale, multi-disciplinary approach to ablation



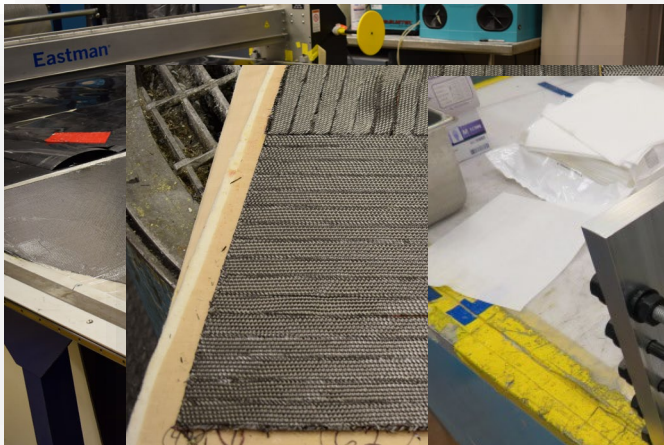
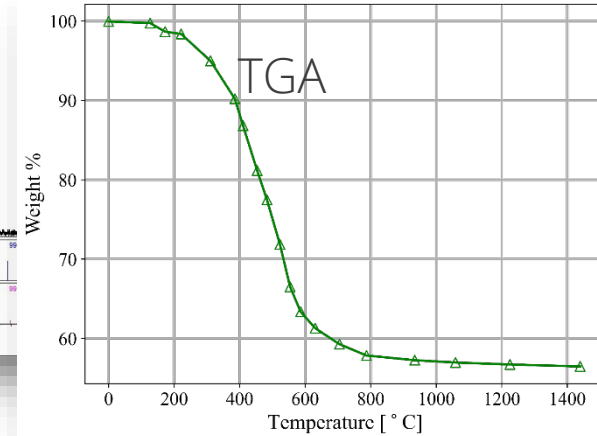
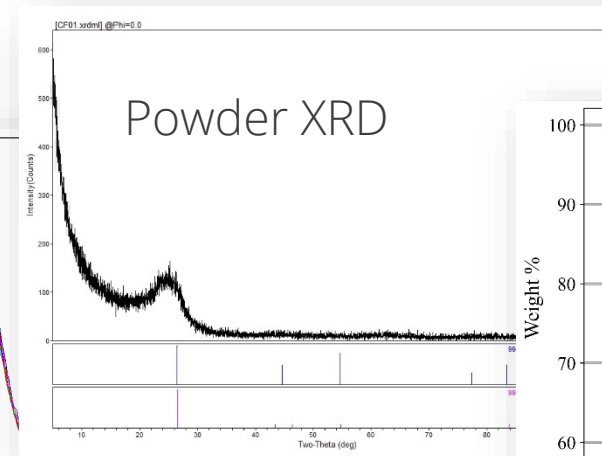
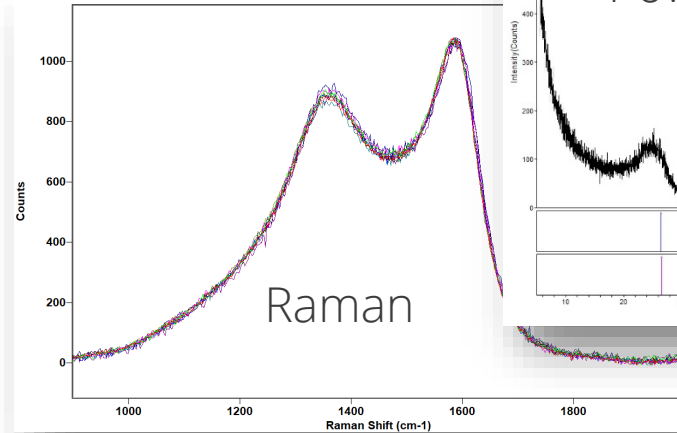




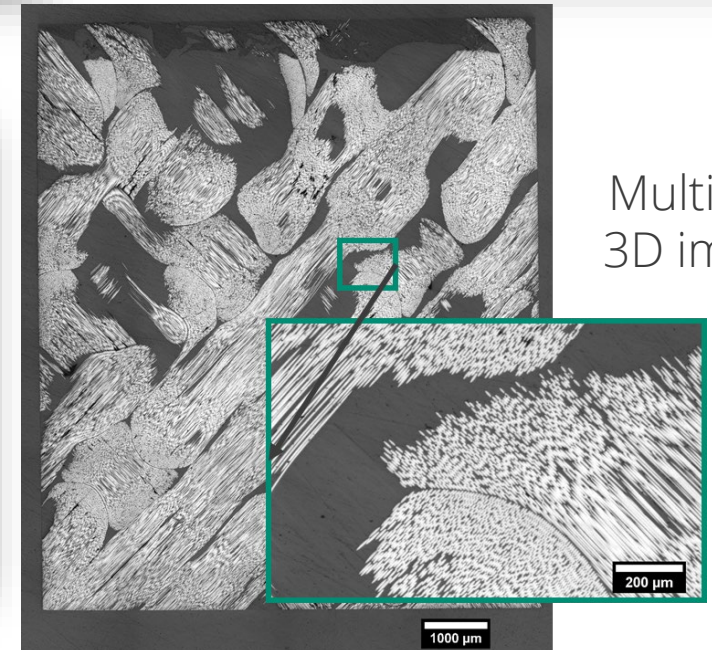
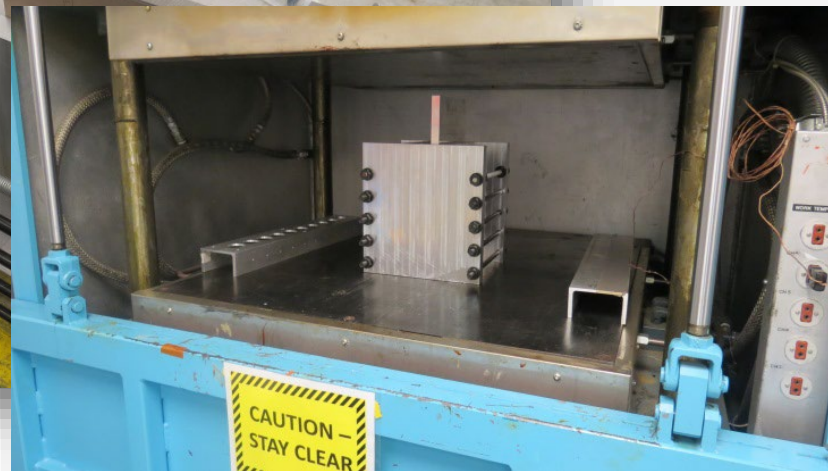
# Materials and manufacturing research



10 min      20 min      30 min  
Constituent material characterization



Composite manufacturing

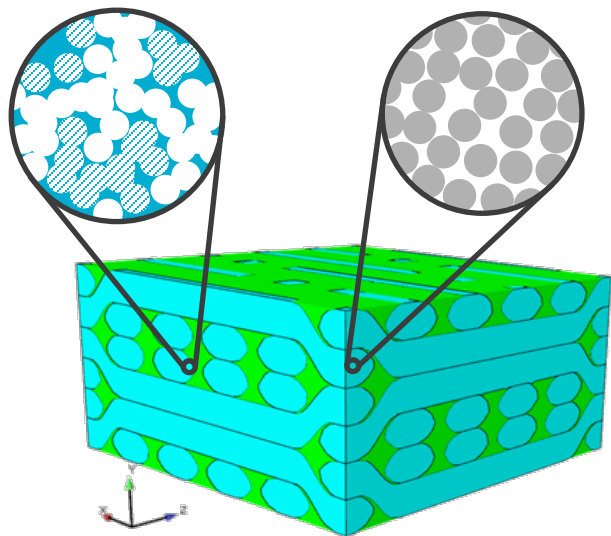


Multi-scale  
3D imaging

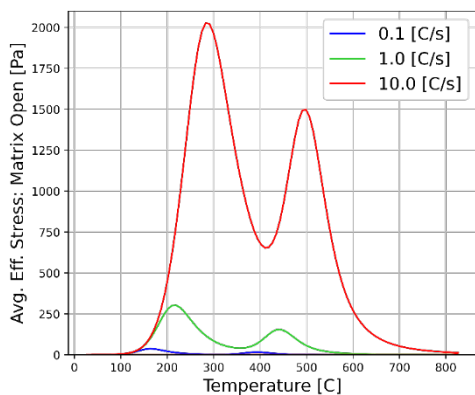




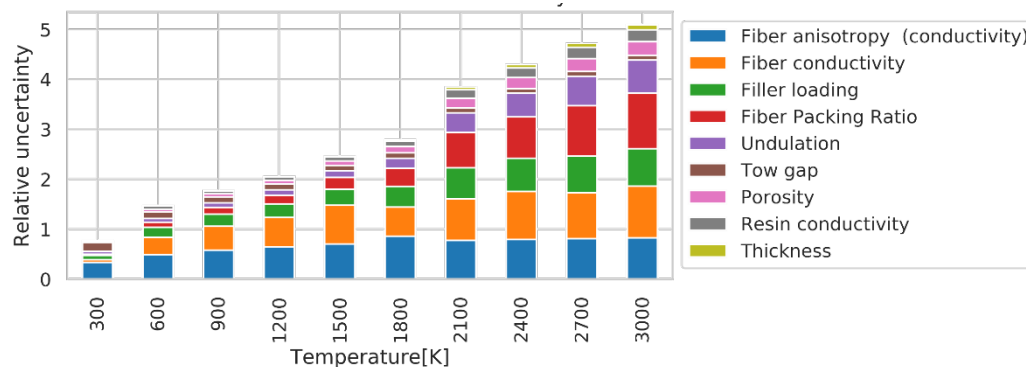
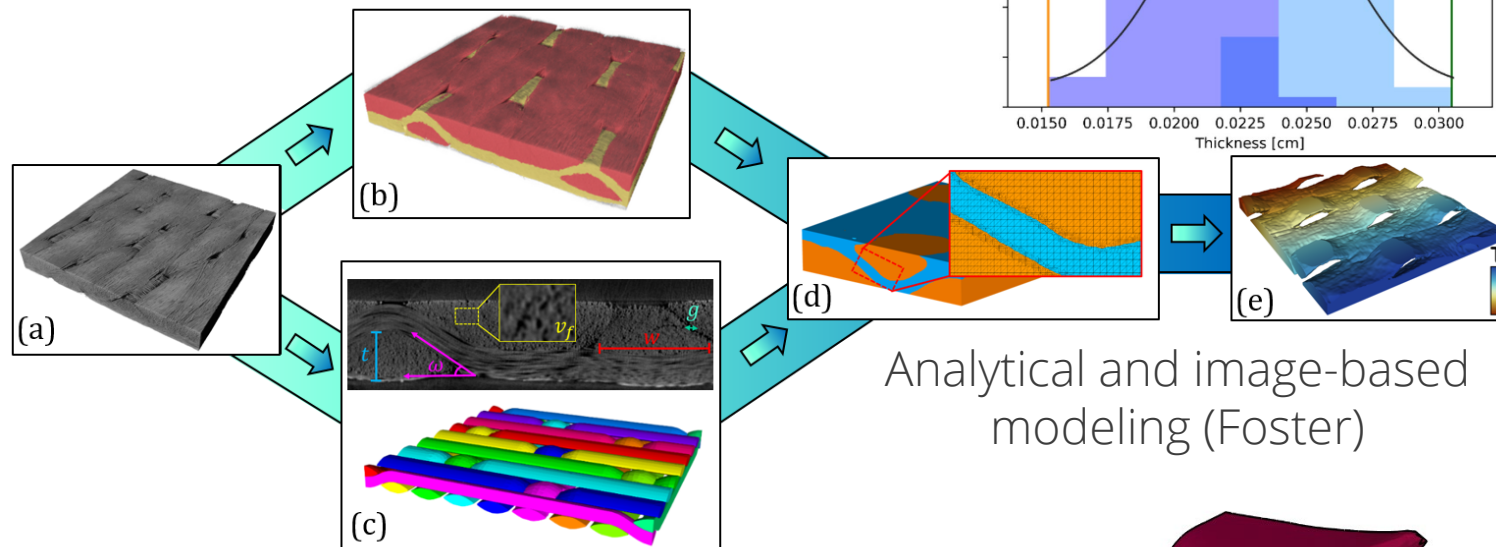
# Microscale and mesoscale modeling



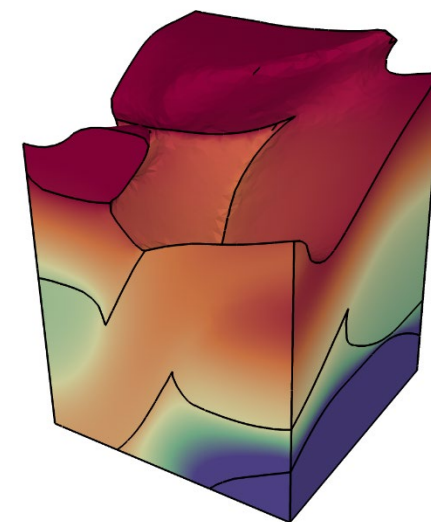
Micro- and meso-scale modeling



Manufacturing of C-C



Property prediction, interpolation, and UQ

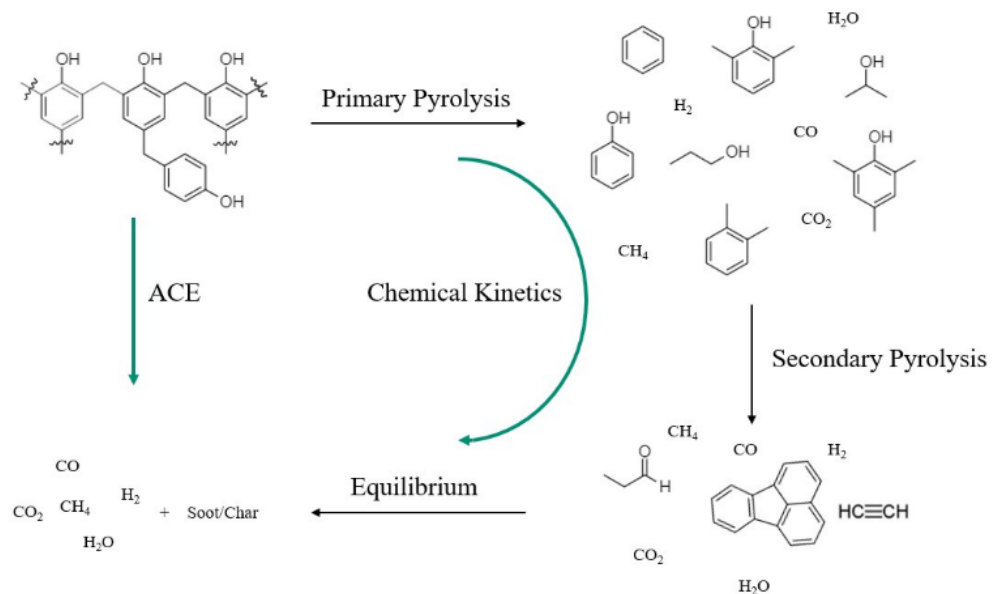


Ablation predictions (Collins)

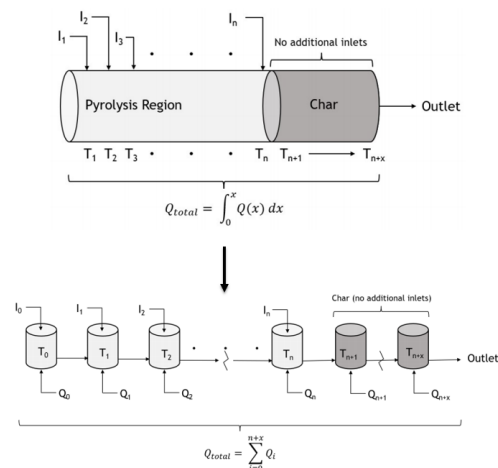




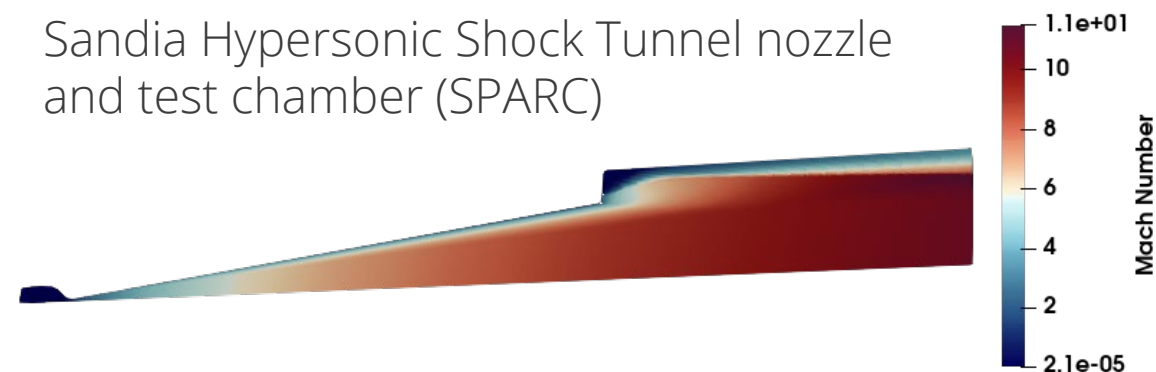
# Advanced chemistry modeling



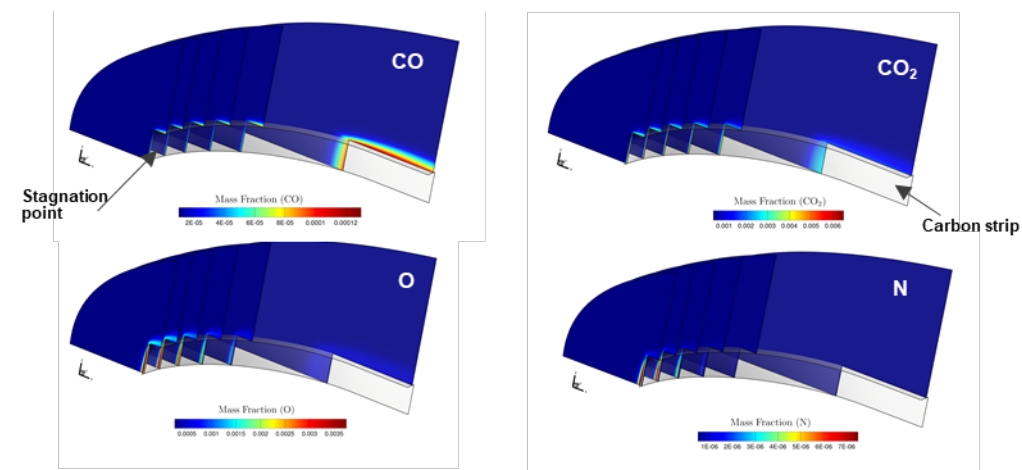
Evaluating equilibrium vs. finite-rate chemistry models for pyrolysis (Gosma) and surface chemistry



Sandia Hypersonic Shock Tunnel nozzle and test chamber (SPARC)



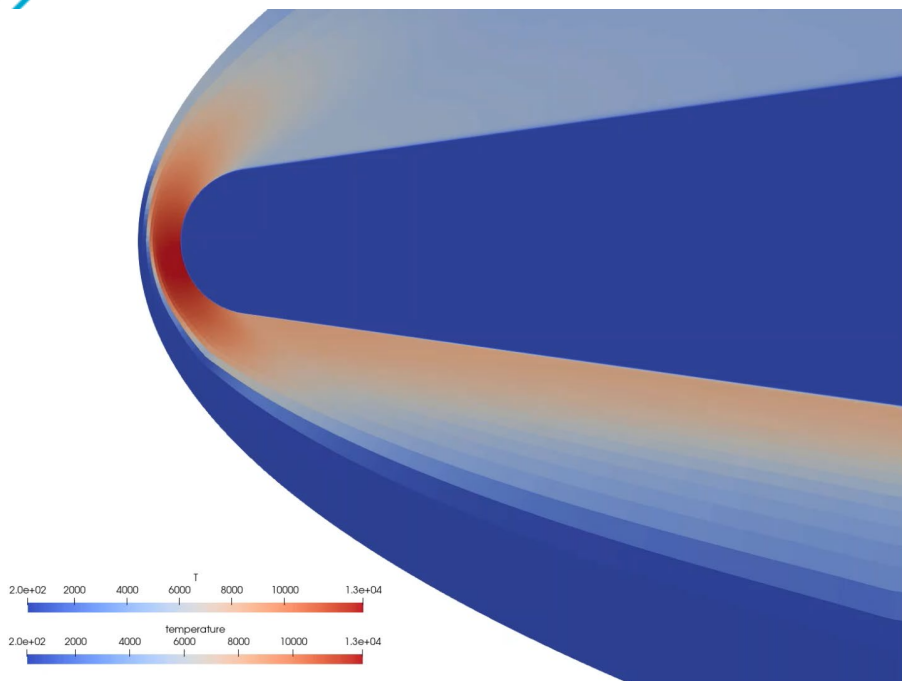
Mass fraction predictions of selected gas-species around carbon test sample (US3D)







# Vehicle-scale and aerothermal modeling

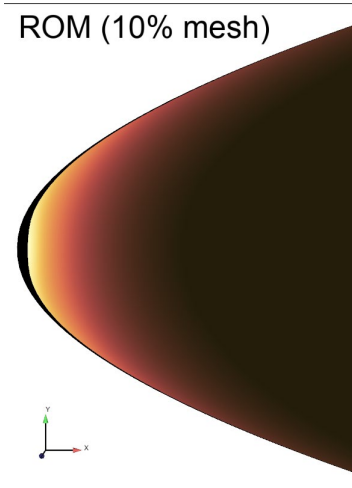
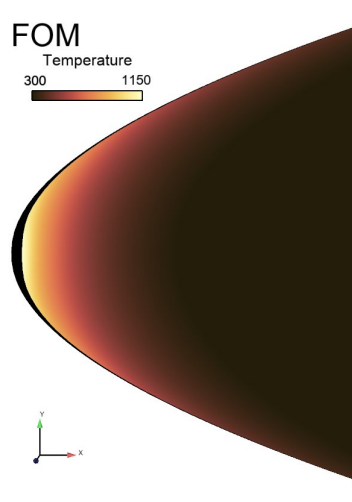


Coupled aerothermal material thermal response with shape change using SPARC/Aria

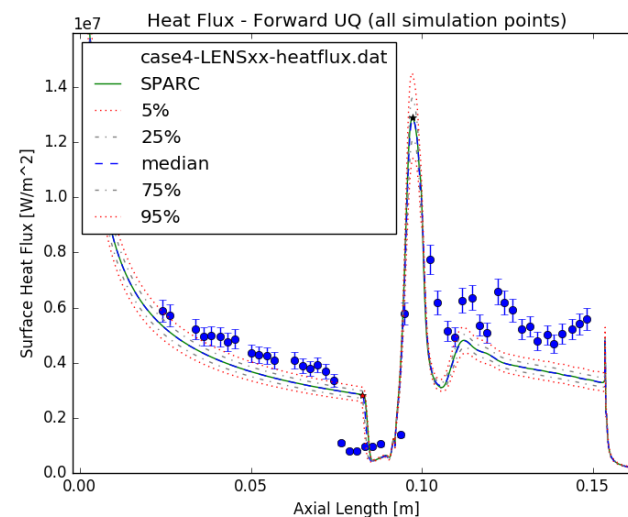
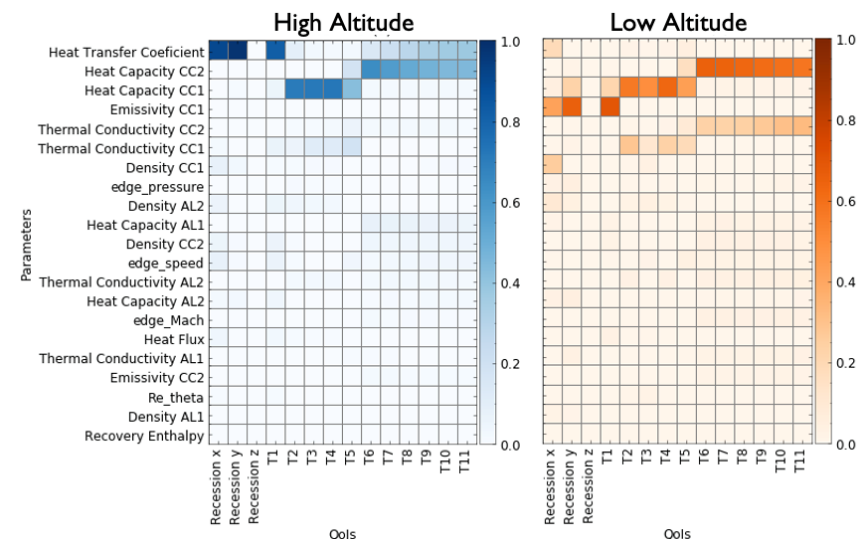
Enthalpy, HTC, Pressure, Wall Composition

MPMD

Temperature, Recession, Surface chemistry



Projection-based reduced order models

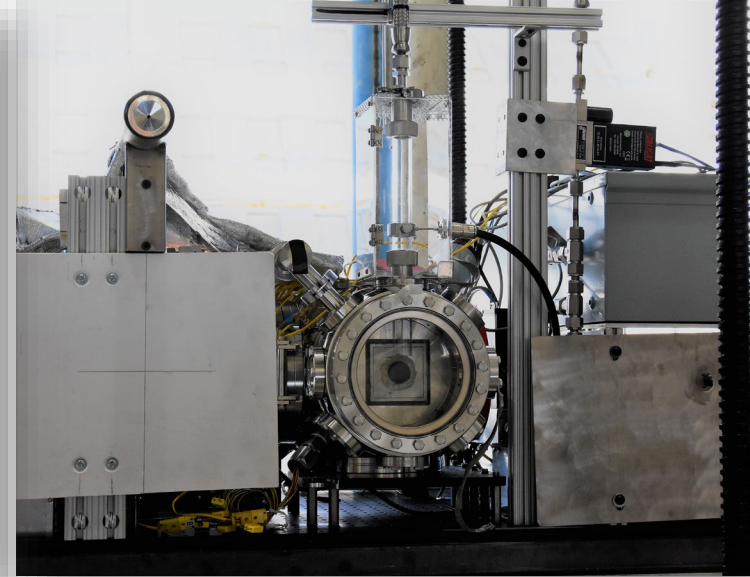
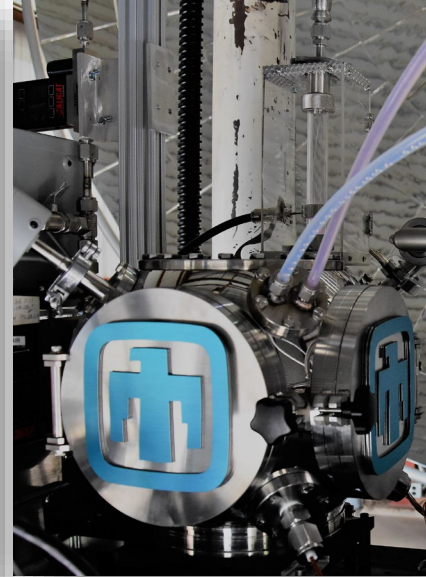


Credibility assessments:  
Sensitivity analysis (top, generic hypersonic flight), validation (bottom, CUBRC double-cone)

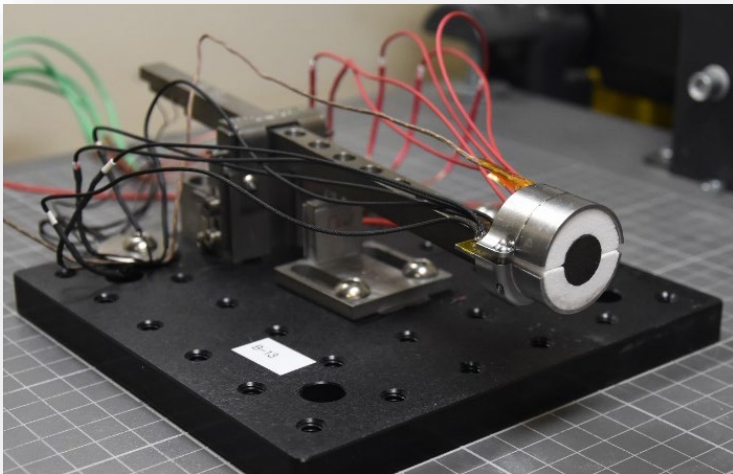




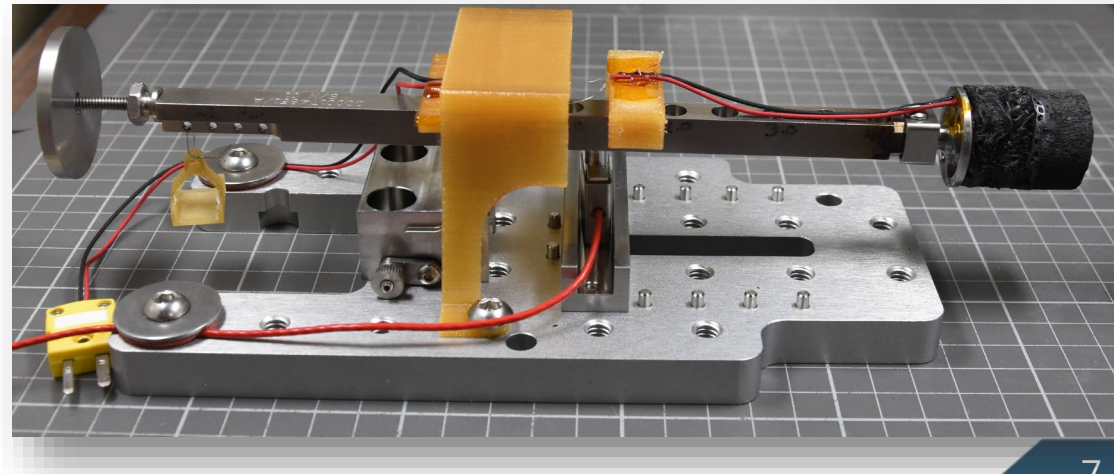
## Ground testing



Solar testing (solar furnace, chamber, and plasma facility [Anderson]) –  $600 \text{ W/cm}^2$ ,  $3000 \text{ C}$



Diagnostics and instrumentation  
(thermocouples, mass)



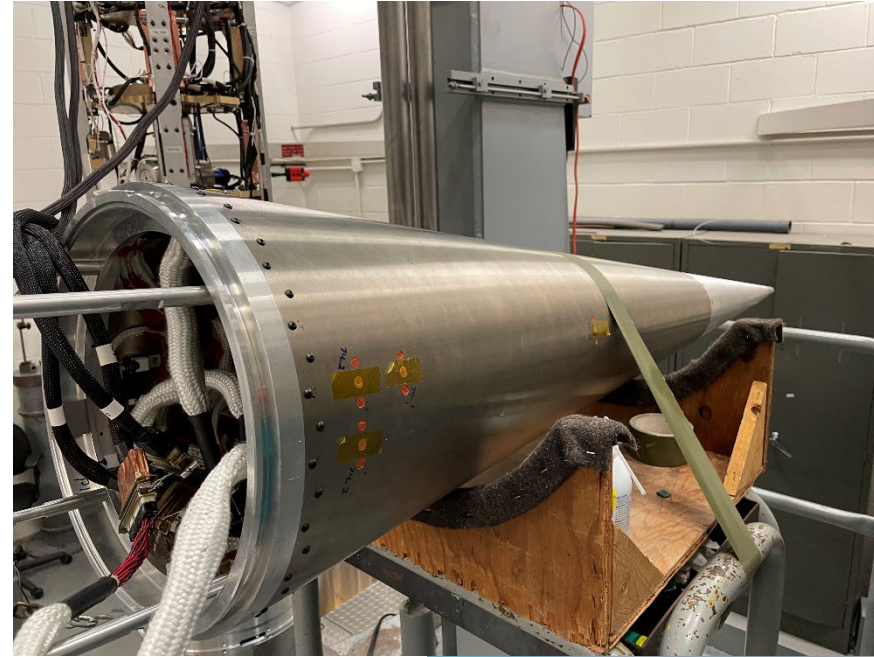




# Vehicle-scale manufacturing and testing



Tape winding of TPS materials



Sounding rocket tests  
(manufacturing, payload  
instrumentation)



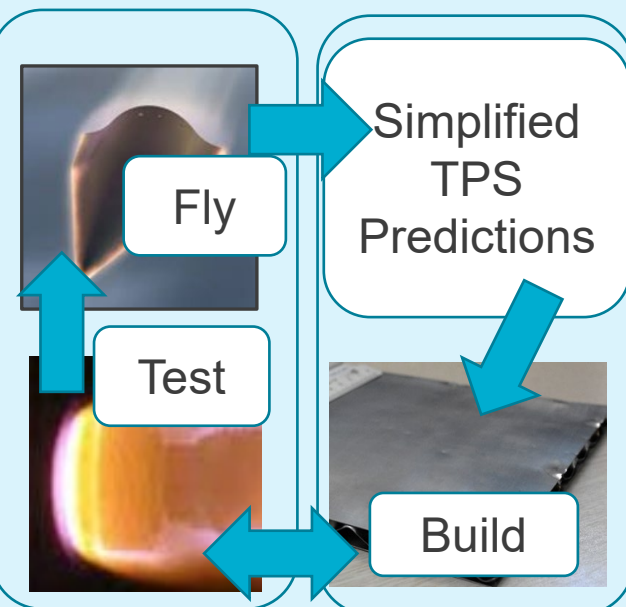




# Hypersonic TPS Grand Challenge LDRD

## State-of-the-Art

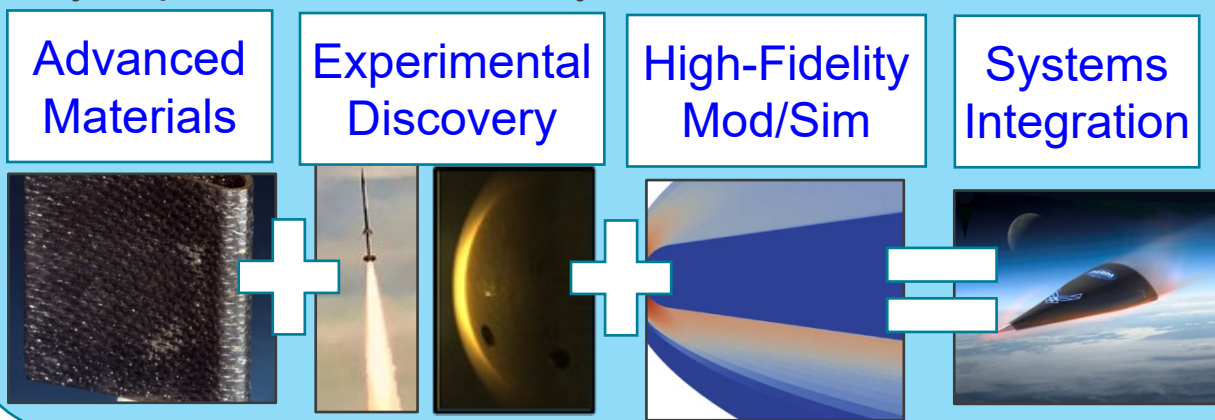
Qualification      TPS Design



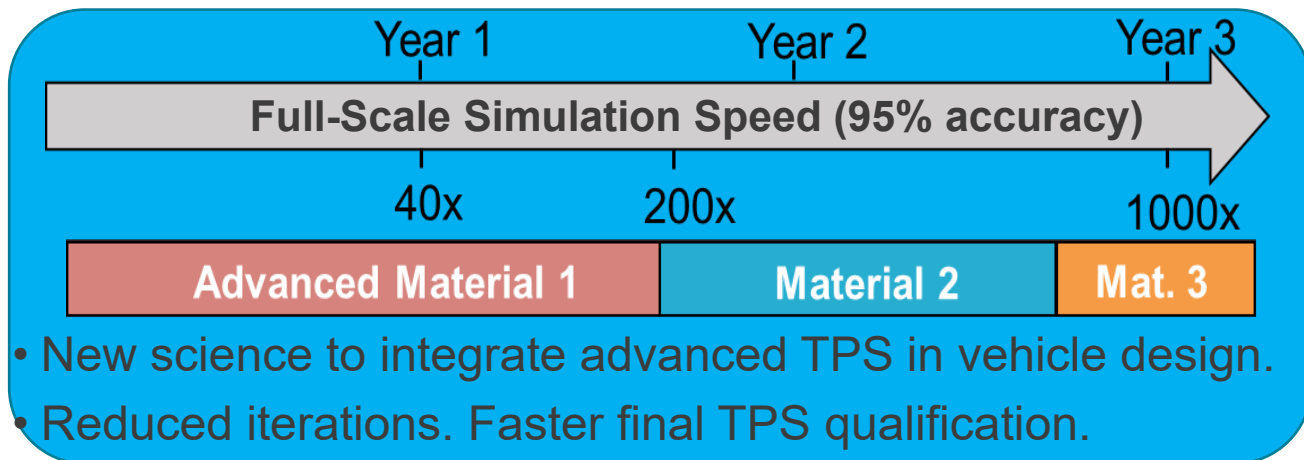
- Limited predictive capabilities lead to a build-test-fly approach that is *iterative*, slow, & risk averse.

## TPS Grand Challenge

- Fast-running, science-based TPS predictions informed by experimental discovery and novel materials methods.



## GC Outcomes







## Closing thoughts

Sandia is pushing forward on TPS and ablation research on all fronts.

- Looking forward to learning from you and discussing collaboration opportunities!

### Sandia talks

- Mesoscale modeling (Collins)
- Resin pyrolysis imaging (Foster/UIUC)
- Pyrolysis chemistry (Gosma/UIUC)
- Solar testing (Engerer)
- Ablation product instrumentation (Hargis)

### Sandia posters

- Resin pyrolysis (Guiles)
- Solar thermal testing in plasma (Anderson)

We're hiring in hypersonics/ablation/TPS!

<https://careers.sandia.gov>

- 4 post-docs in TPS material modeling, NM (Roberts/Collins, 685922)
- Thermal analysis in CA (Mussoni; early career, 685822; experienced 685821)
- Summer graduate internships (685933, NM; 686417, CA)
- Materials fabrication and characterization post-doc (NM, Hernandez-Sanchez)
- See Sandia SMEs for other opportunities