



TPS Certification by Analysis: Model-Driven Characterization of Properties and Failure in Woven Thermal Protection Systems

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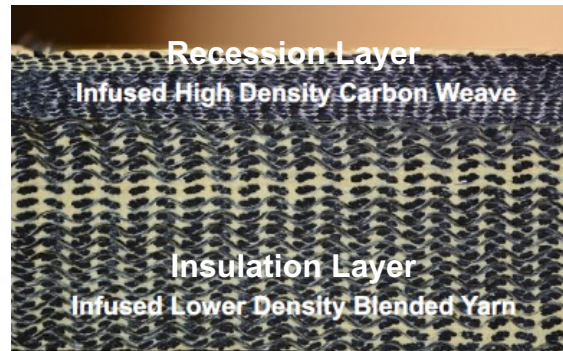
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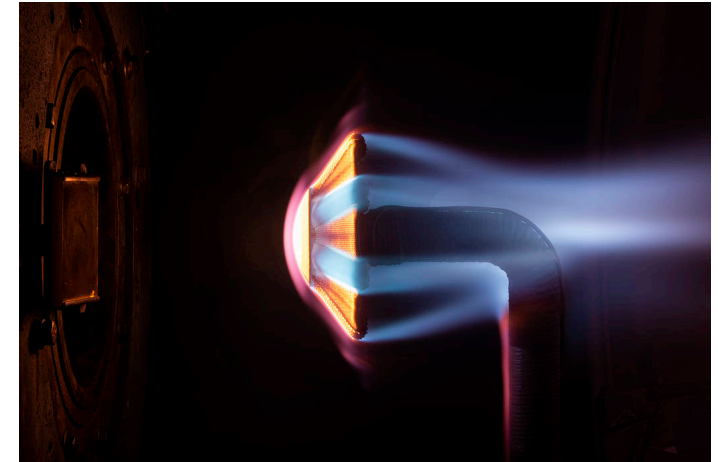
Woven thermal protection systems (TPS)



Heat Shield for Extreme Entry Environment Technology (HEEET)

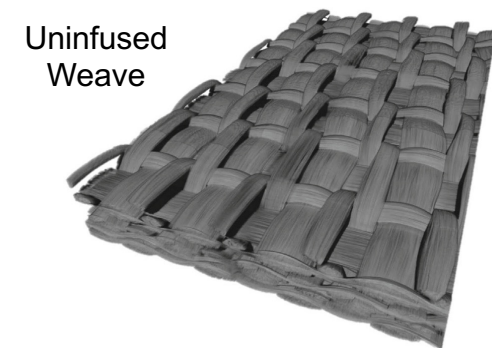


Adaptable Deployable Entry and Placement Technology (ADEPT)



3D Woven Mid-Density Carbon Phenolic (3MDCP):

- Derived from HEEET insulation layer
- Mars Sample Return Earth Entry System (MSR-EES)



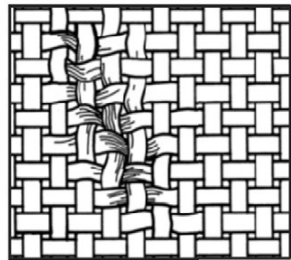
Certification by analysis of woven TPS materials



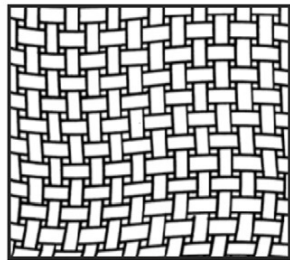
Entry Systems Modeling (ESM) project – TPS Certification by Analysis efforts:

- Computational tools, models, and analysis to support certification of woven TPS materials
- Focus on influence of material variability, defects, and impacts on properties and performance

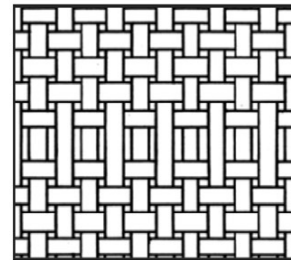
Weave features or defects



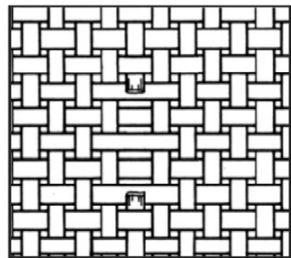
Crease or wrinkle



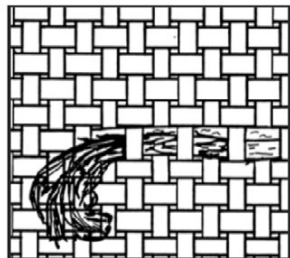
Waviness



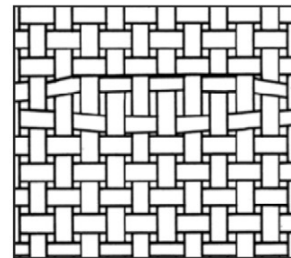
Missing pick



Broken warp or fill

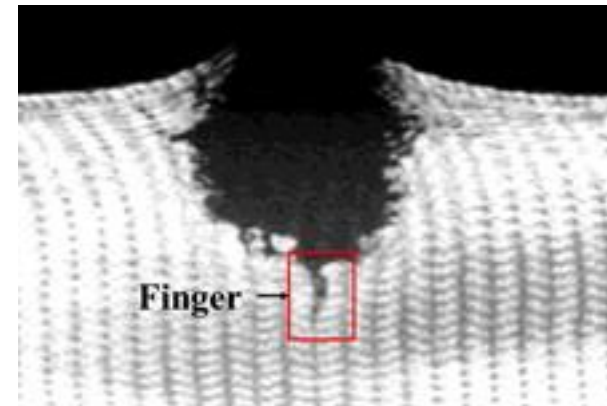


Pulled-in filling

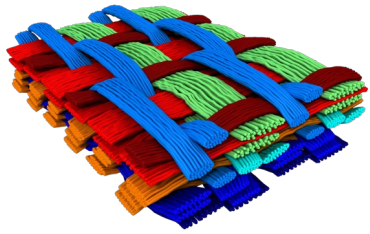


Weave separation

Impact from micrometeoroids and orbital debris (MMOD)



TPS Certification by Analysis efforts and team

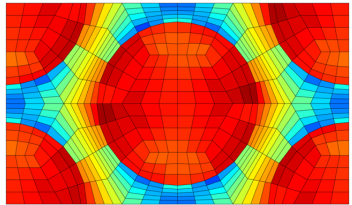


Multiscale Materials Modeling

Ames Research Center
Thermal Protection Materials Branch

Justin Haskins
Lauren Abbott
Sergio Fraile Izquierdo

Sander Visser
Andrew Santos
William Tucker

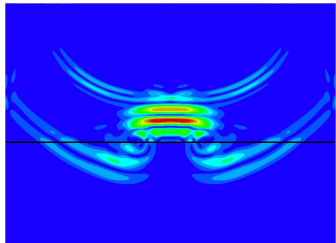


Multiscale Materials Modeling

Glenn Research Center
Multiscale & Multiphysics Modeling Branch

Trenton Ricks
Brett Bednarcyk
Subodh Mital

Pappu Murthy
Evan Pineda



Machine Learning and Nondestructive Evaluation

Ames Research Center
Intelligent Systems Division

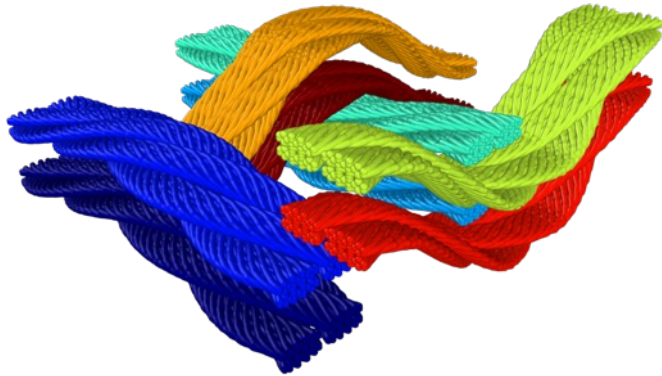
Kevin Wheeler
Vasyl Hafiychuk

Michael von Pohle
Karan Doss

Modeling approaches for weaves with varying fidelity

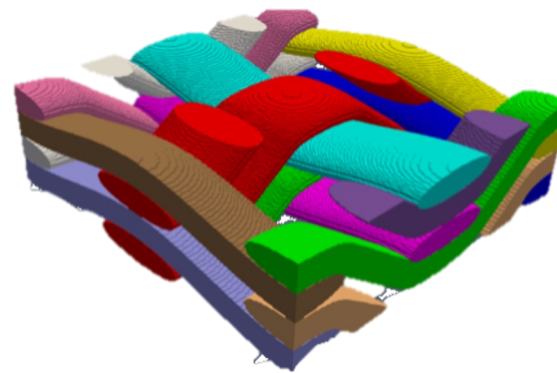


Fiber-level Resolution



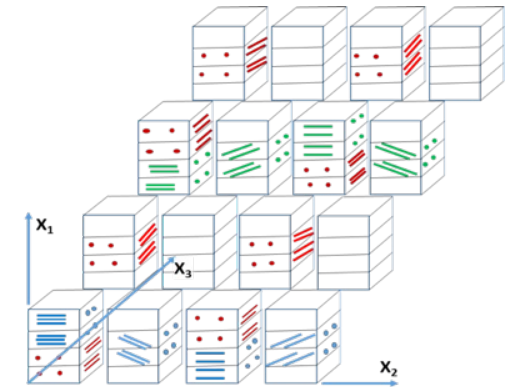
LAMMPS / HYDRA
NASA Ames

Yarn-level Resolution



PuMA
NASA Ames

Simplified Cell Structure



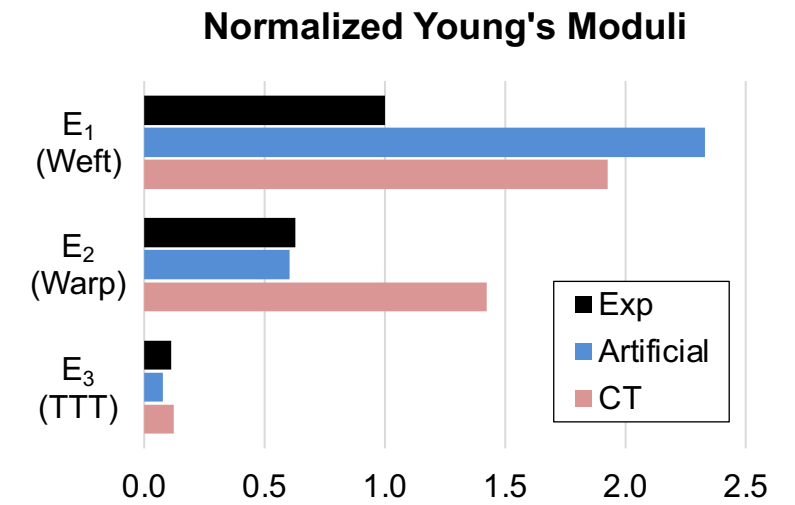
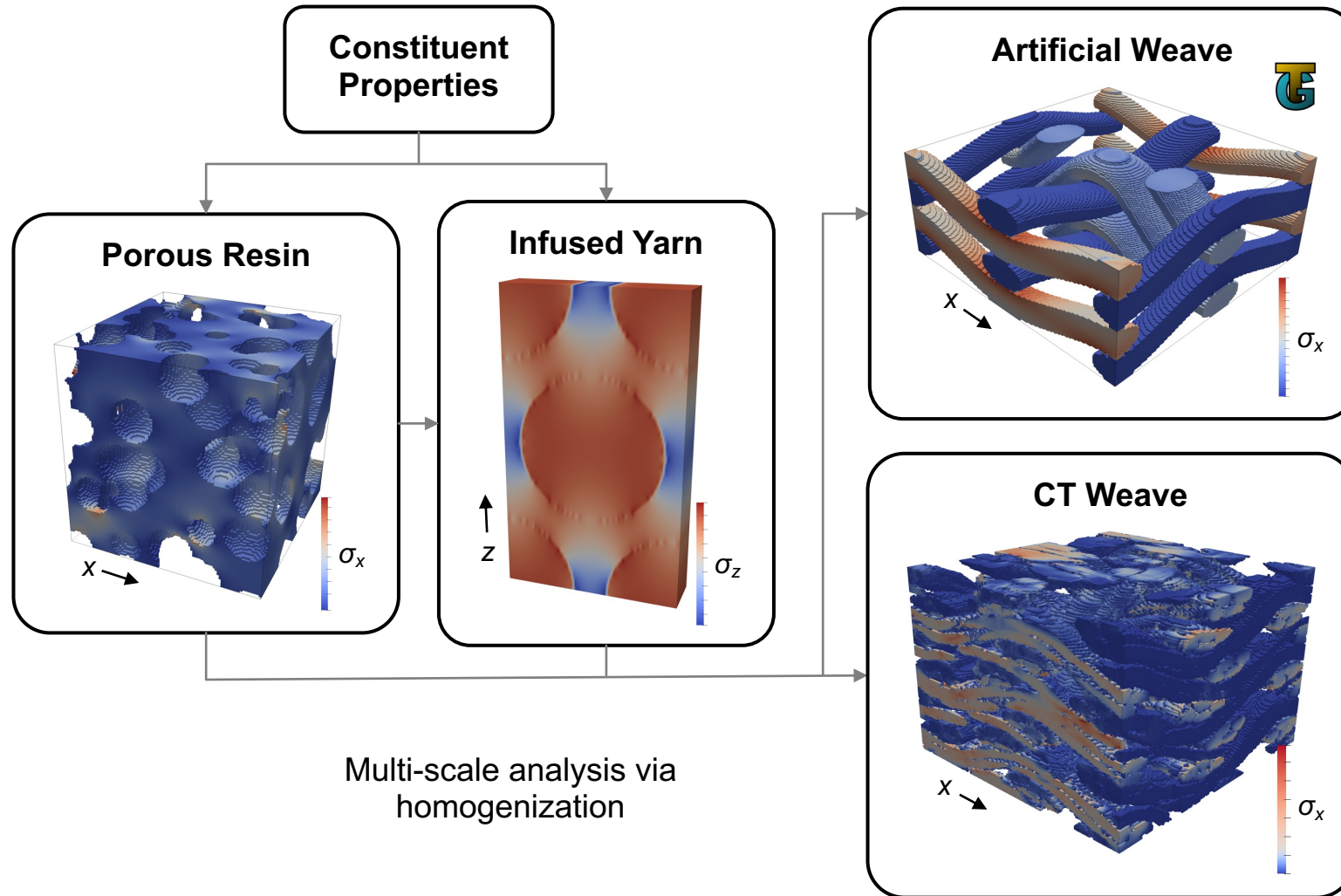
NASMAT
NASA Glenn



Multi-scale analysis of composite mechanical properties



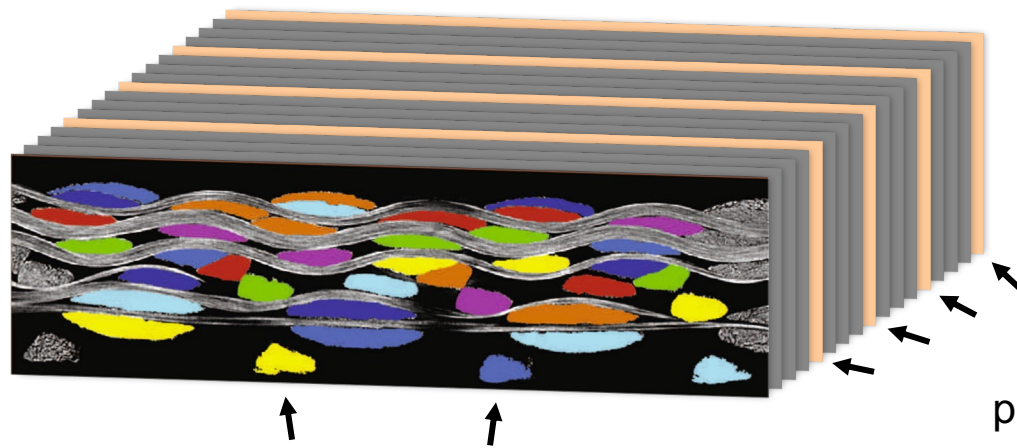
Sergio Fraile Izquierdo



Finite volume anisotropic stress analysis in PuMA



Segmentation of CT images by hand



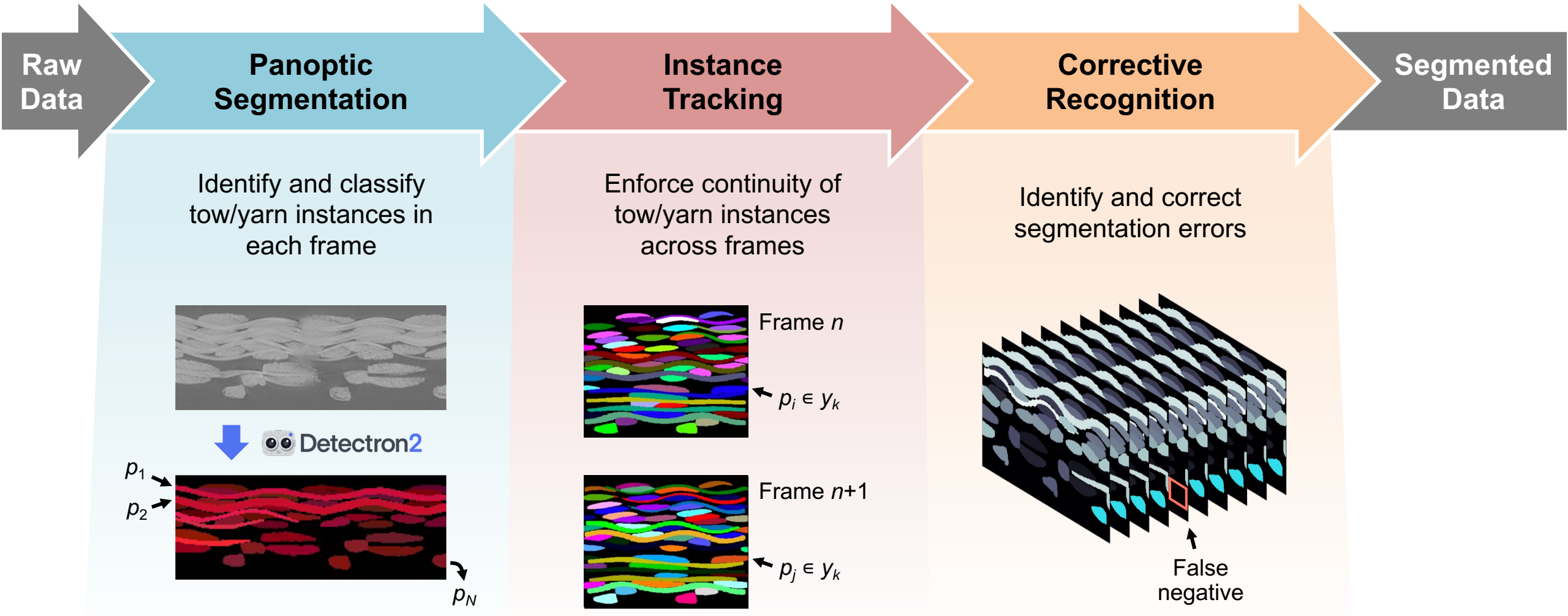
Tow/yarn cross-sections are identified and marked by hand

Segmentation can be performed every n frames and interpolated

Machine learning for automated image segmentation



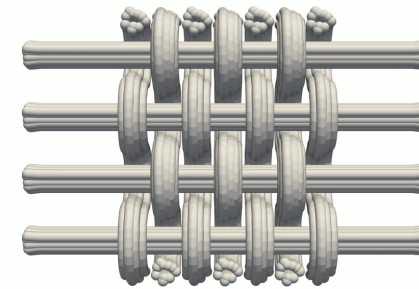
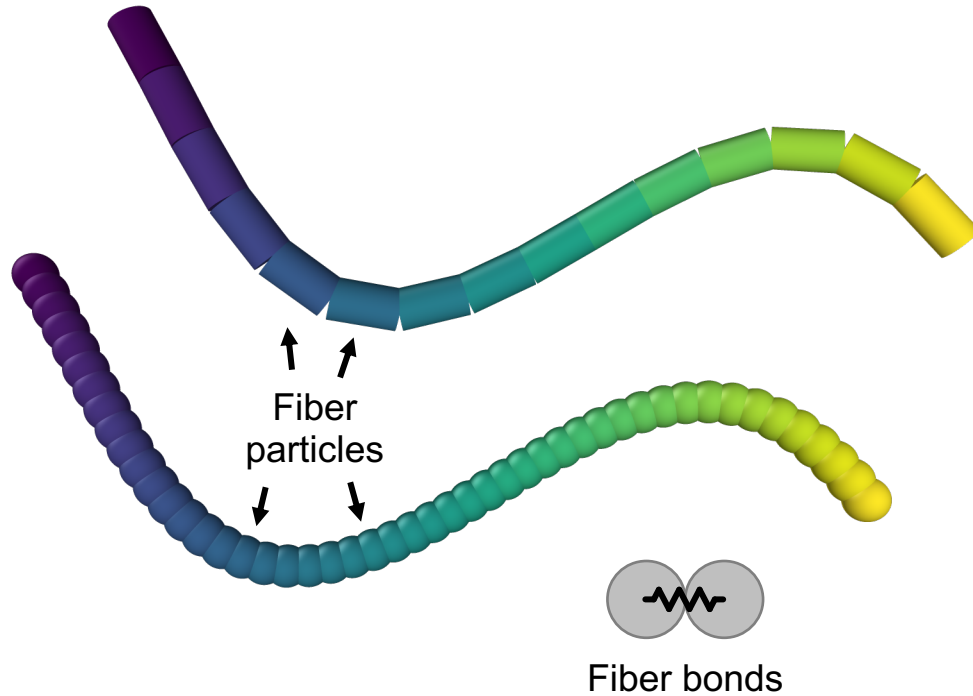
Aaron Allred



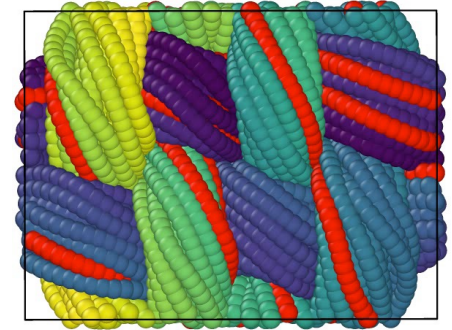
Higher fidelity models with explicit fiber representation



Andrew Santos, Sander Visser



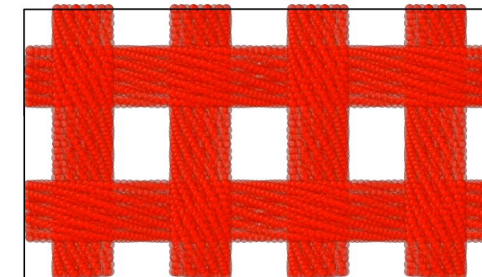
In-house code



LAMMPS

Model interactions include:

- Contact – elasticity, viscosity, cohesion, friction
- Bonded – stretch, bend, twist, shear, rupture



LAMMPS

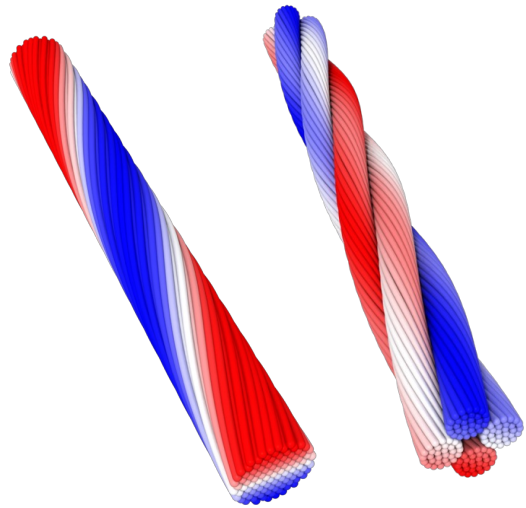
Generation of fiber-level models of yarns and weaves



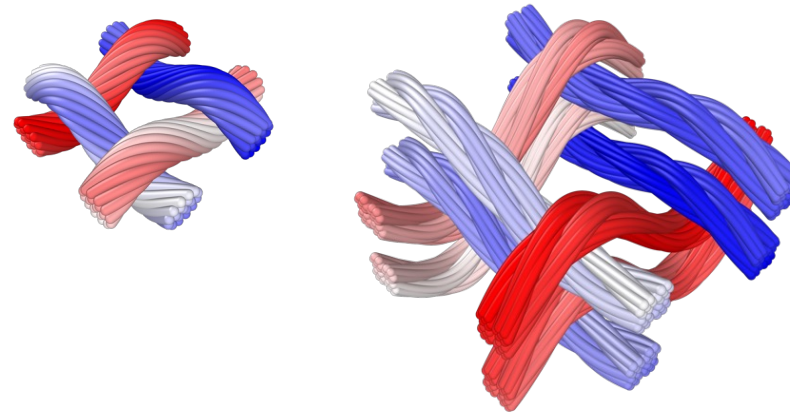
Lauren Abbott

Python package developed for model generation

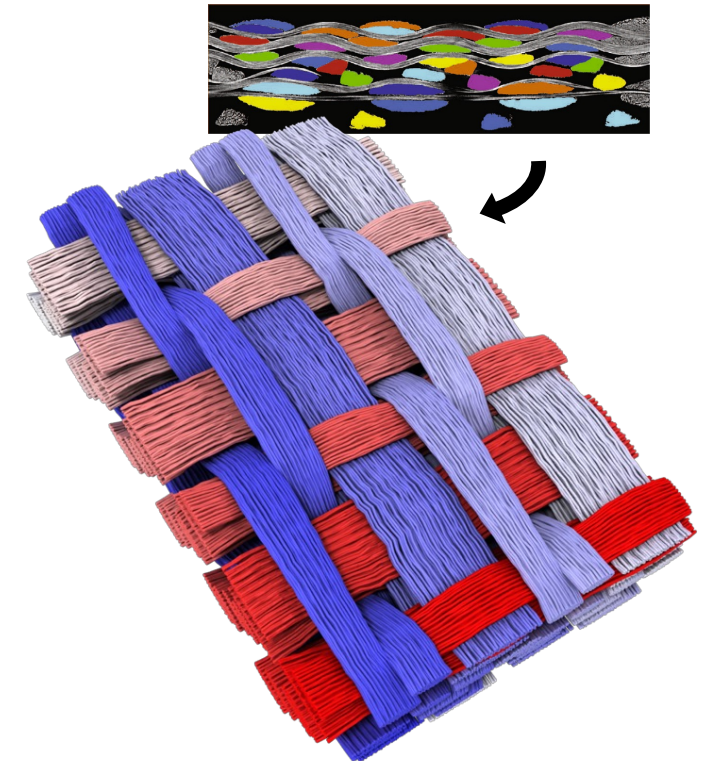
Single and plied yarns
with or without twist



2D and 3D weaves in
defined patterns



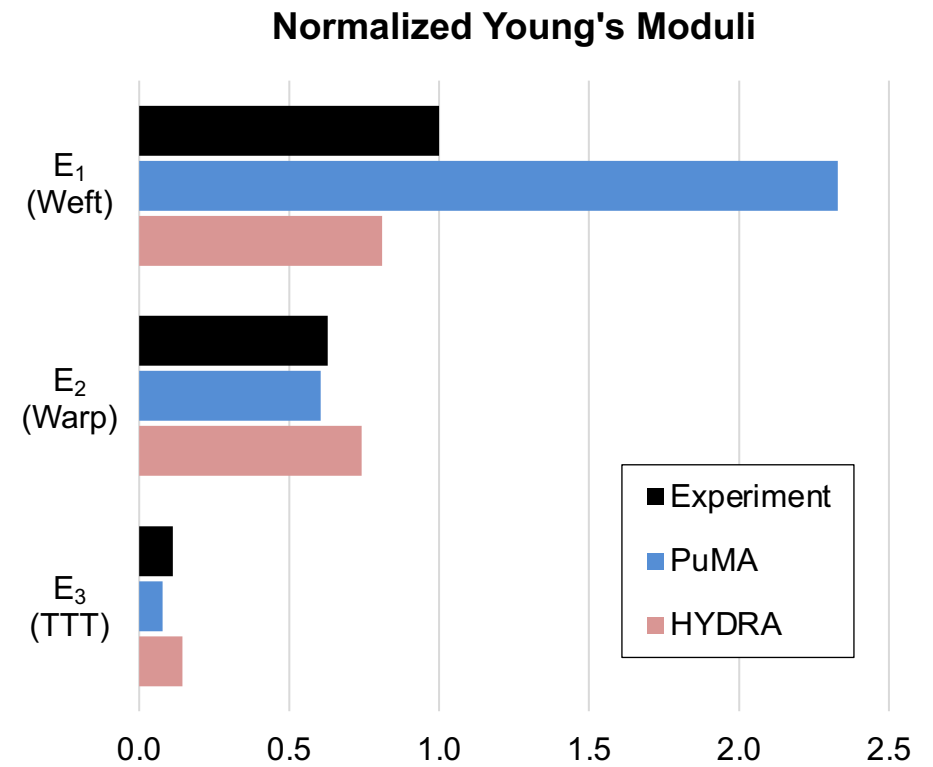
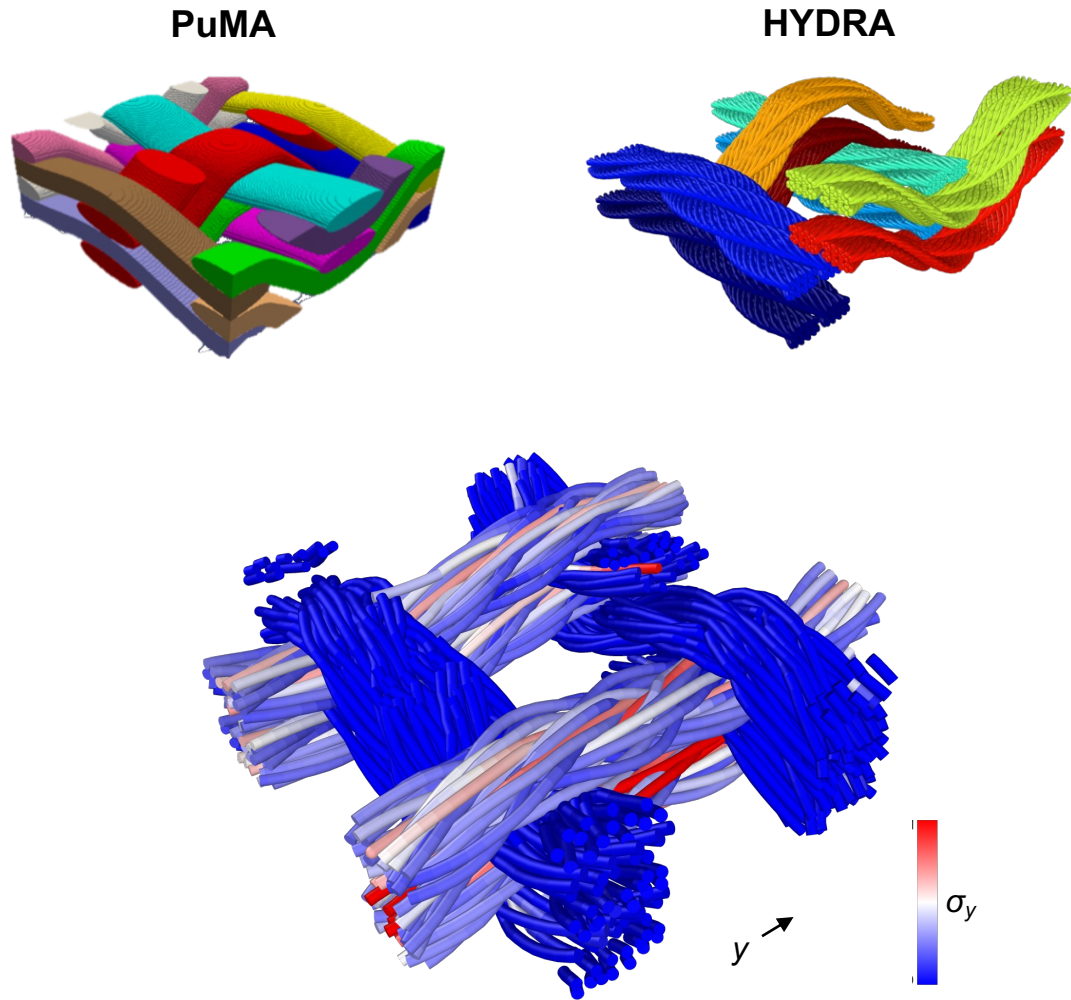
Weaves from CT scans



Fiber-level analysis of weave mechanical properties



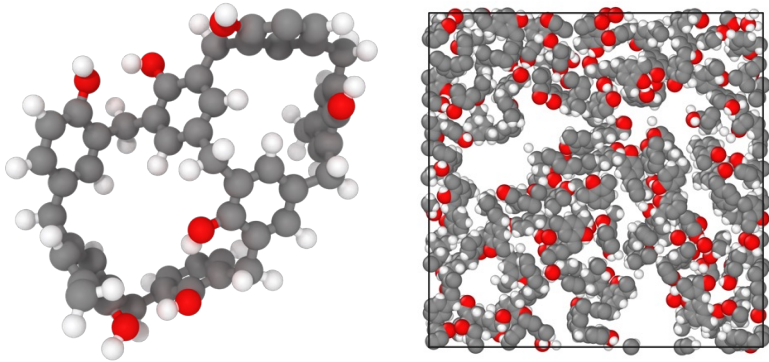
Justin Haskins



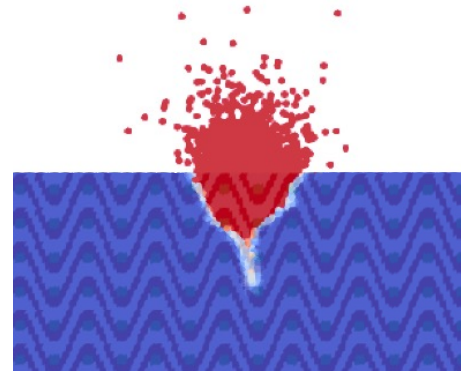
Other TPS Certification by Analysis activities



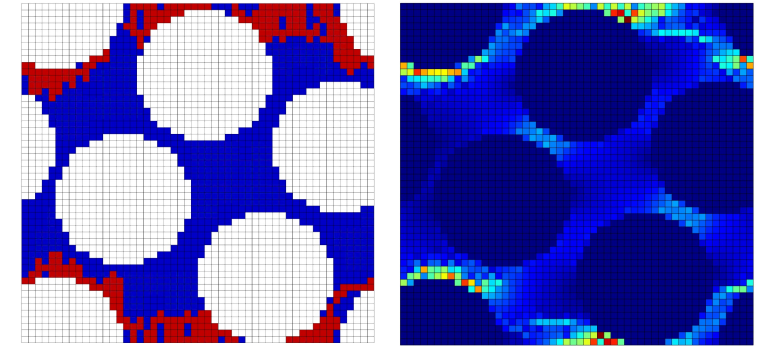
Phenolic Property Calculations



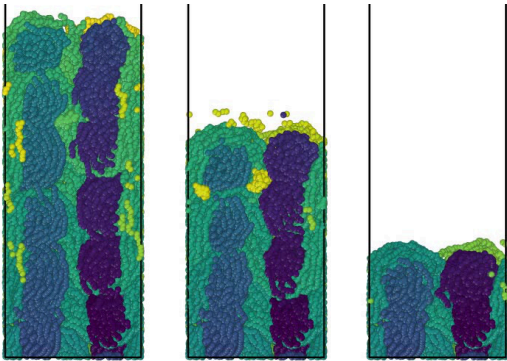
Impact Simulations



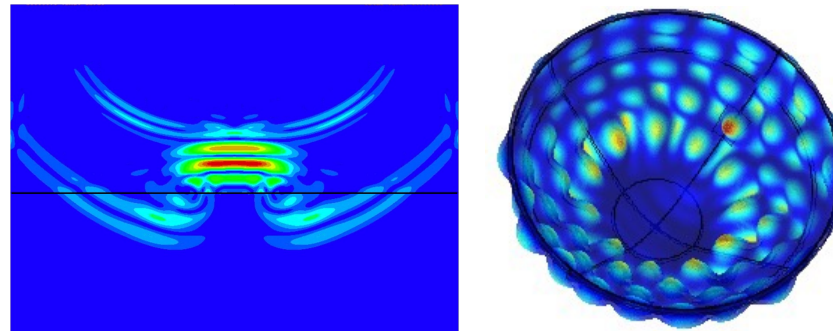
Progressive Damage Simulations



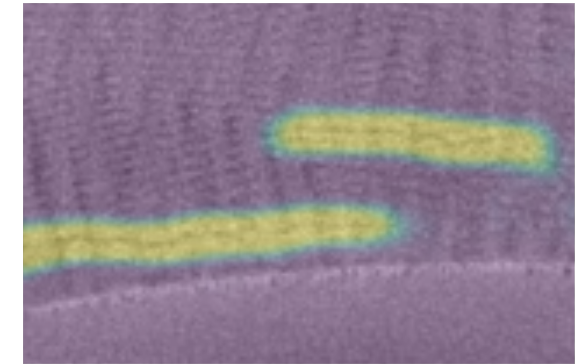
Ablation Simulations



Computational Nondestructive Evaluation



Fault Detection



Acknowledgements



ESM TPS Certification by Analysis

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Andrew Santos

William Tucker

Trenton Ricks

Brett Bednarcyk

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Evan Pineda

Kevin Wheeler

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Chloe Zeller, UMN

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Todd White

Jeremy Vander Kam

Questions?

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