



Entry Systems and Technology Division
Ames Research Center

National Aeronautics and
Space Administration



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

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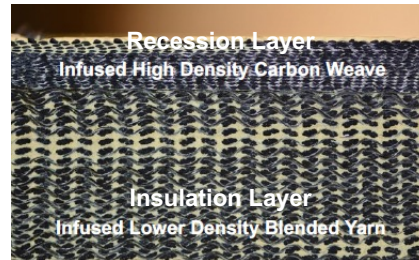
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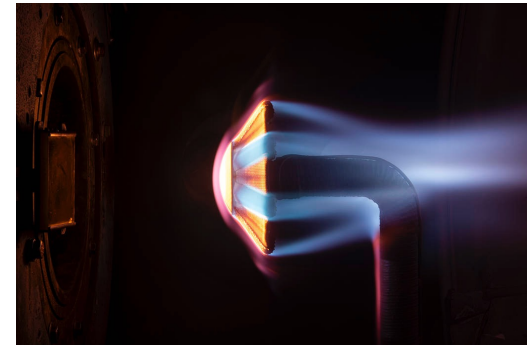
Woven thermal protection systems (TPS)



Heat Shield for Extreme Entry Environment Technology (HEEET)



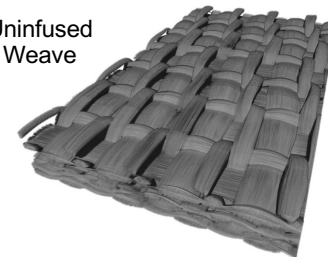
Adaptable Deployable Entry and Placement Technology (ADEPT)



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

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

Unfused Weave



Outline



- TPS Certification by Analysis for weaves
- Modeling approaches for woven TPS properties
 - Yarn-level Approach
 - Fiber-level Approach
- Highlights of other TPS Certification by Analysis efforts

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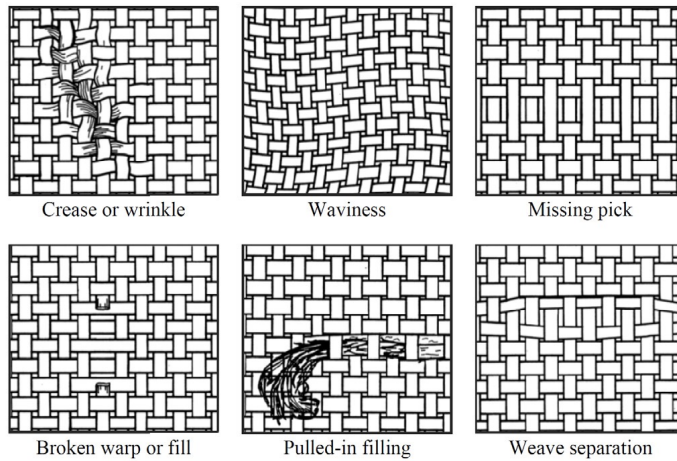
Certification by analysis of woven TPS materials



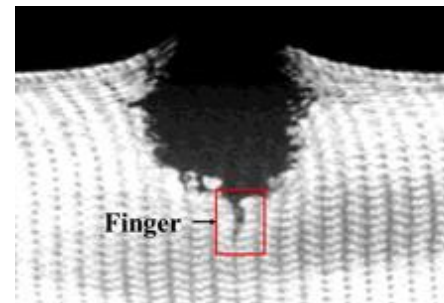
Entry Systems Modeling (ESM) project – TPS Certification by Analysis efforts:

- 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

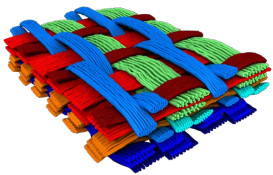
Weave features or defects



Impact from micrometeoroids and orbital debris (MMOD)



TPS Certification by Analysis efforts and team

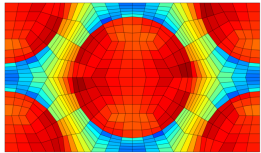


Multiscale Materials Modeling

Ames Research Center
Thermal Protection Materials Branch

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Sergio Fraile Izquierdo

Sander Visser
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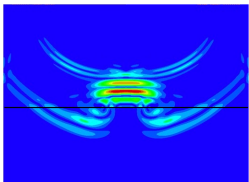


Multiscale Materials Modeling

Glenn Research Center
Multiscale & Multiphysics Modeling Branch

Trenton Ricks
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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

Outline

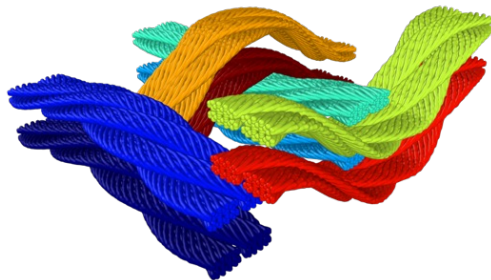


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Modeling approaches for weaves with varying fidelity

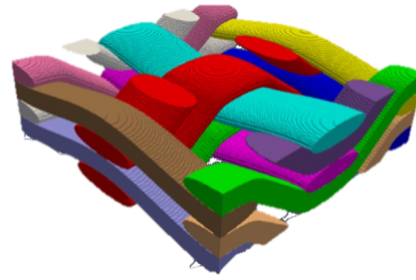


Fiber-level Resolution



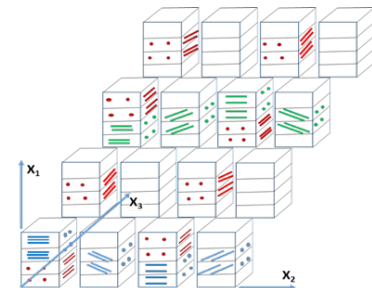
LAMMPS / HYDRA
NASA Ames

Yarn-level Resolution



PuMA
NASA Ames

Simplified Cell Structure



NASMAT
NASA Glenn

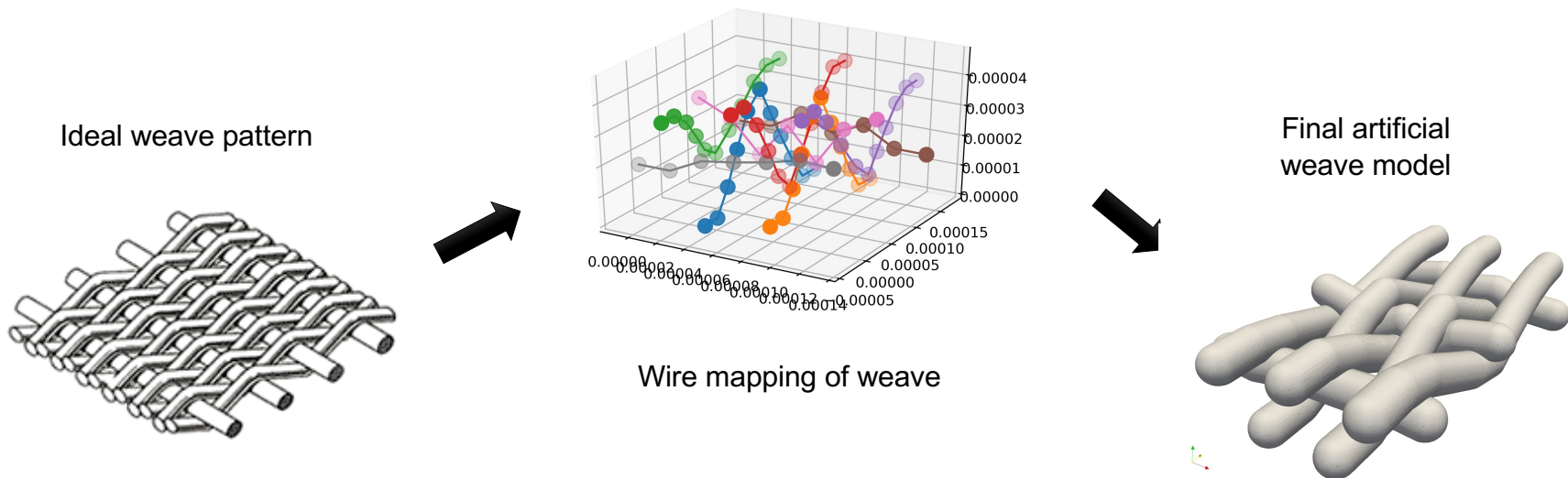


Generation of yarn-level models: artificial weaves

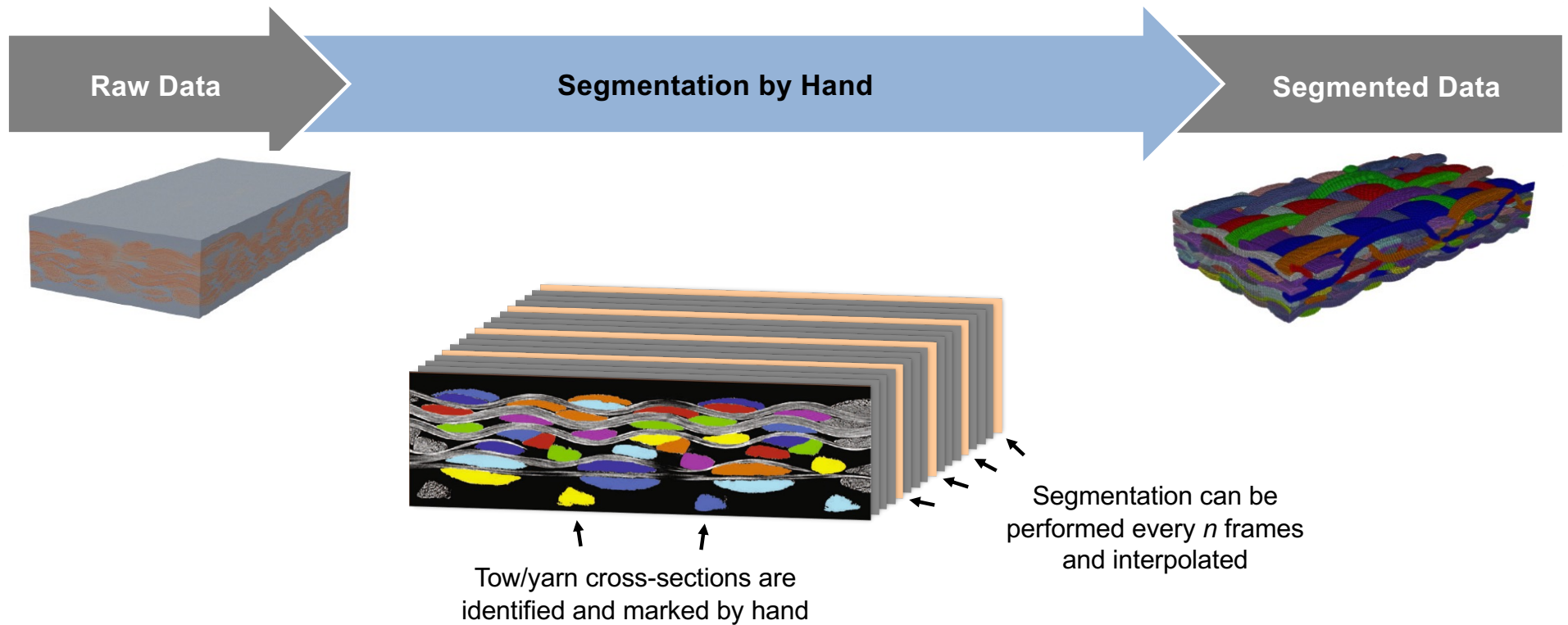


Sander Visser

- “Artificial” weave models constructed based only on the ideal weave pattern
- Nuances of weave structure may not be captured fully



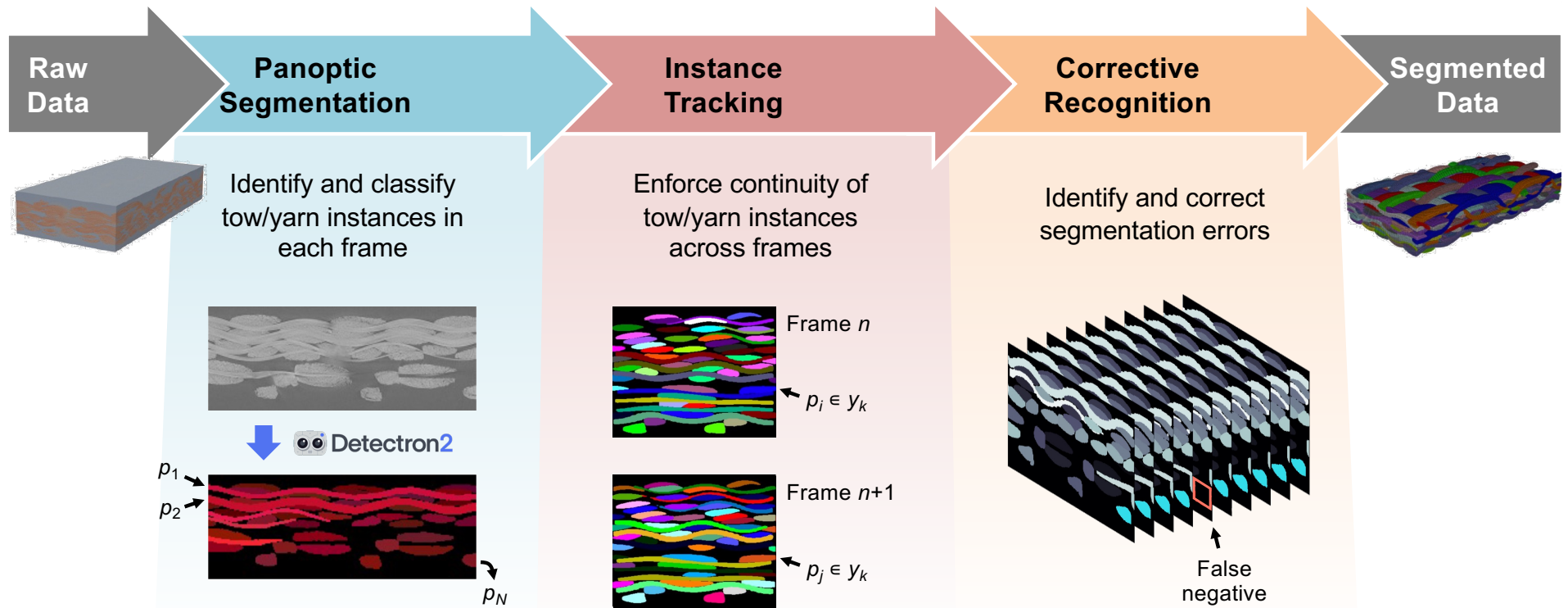
Generation of yarn-level models: segmented weaves (hand)



Generation of yarn-level models: segmented weaves (machine learning)



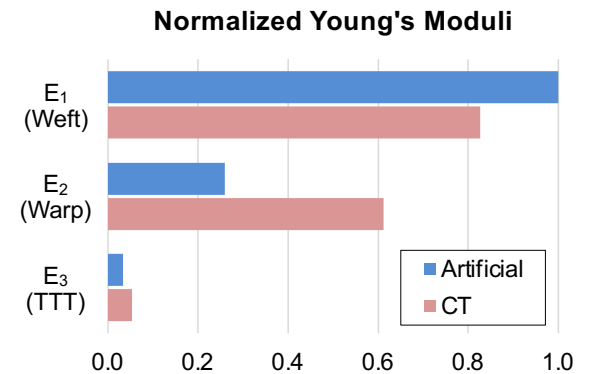
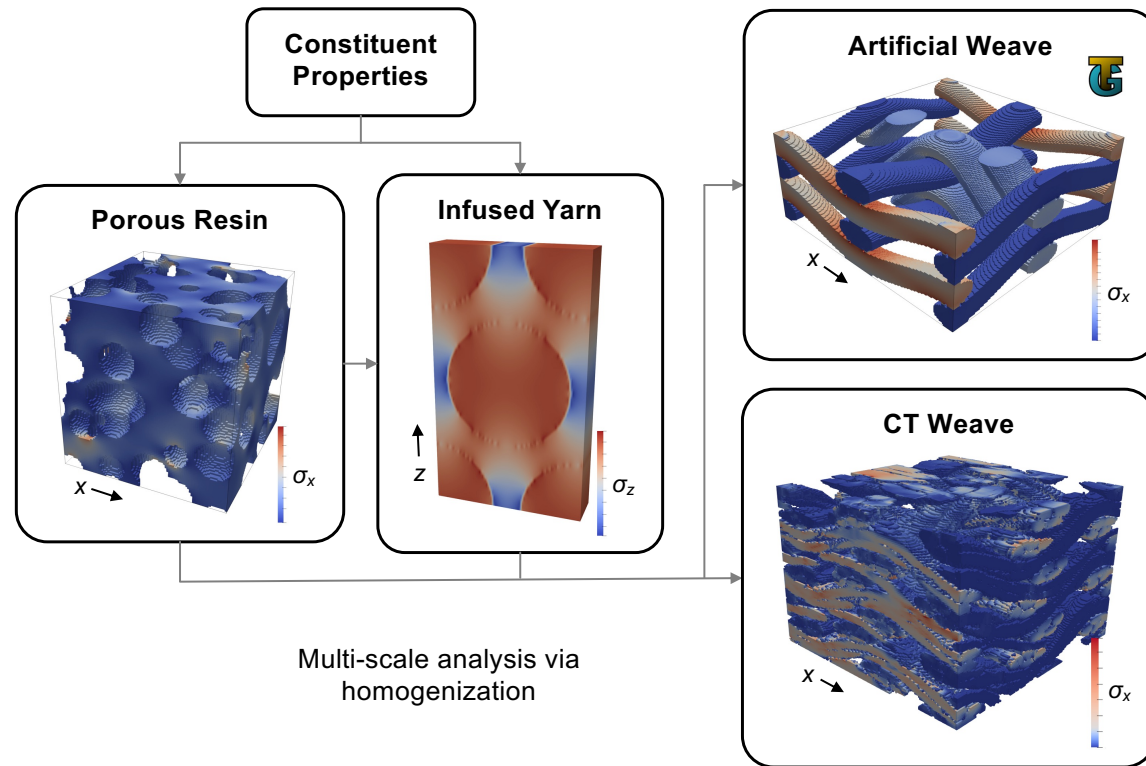
Aaron Allred, Lauren Abbott



Yarn-level analysis of composite mechanical properties



Sergio Fraile Izquierdo



Finite volume anisotropic stress analysis in PuMA



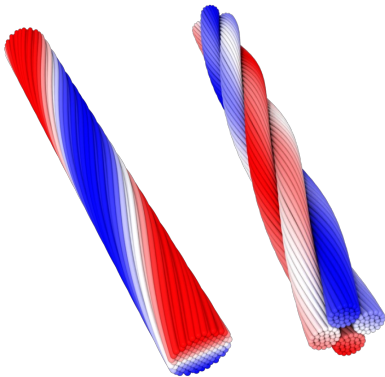
Generation of fiber-level models



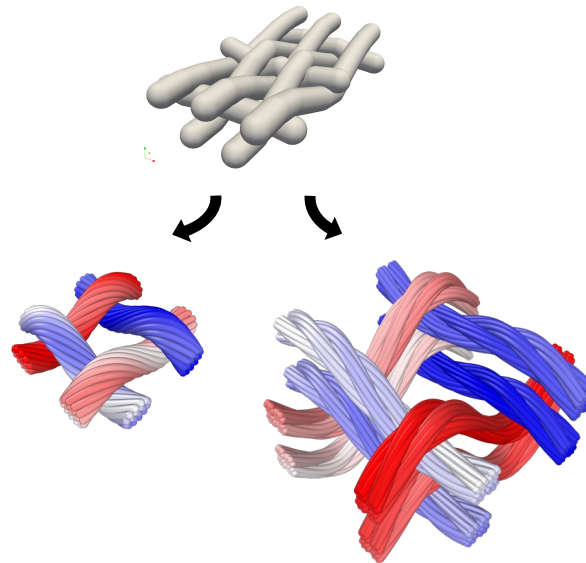
Lauren Abbott

- Fiber-level models can be generated from yarn-level artificial or CT-based weave models

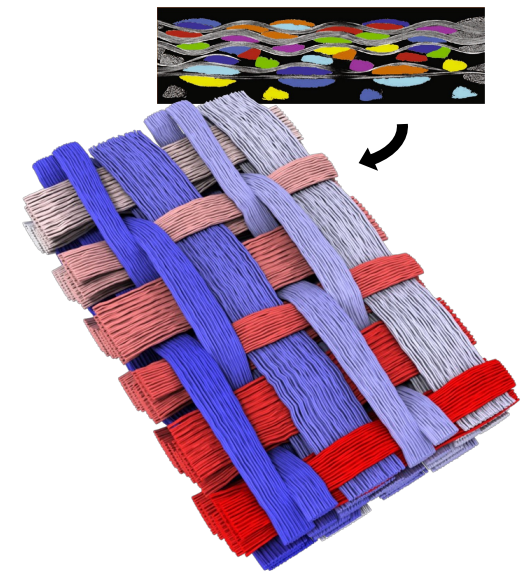
Single and plied yarns
with or without twist



Artificial weave models



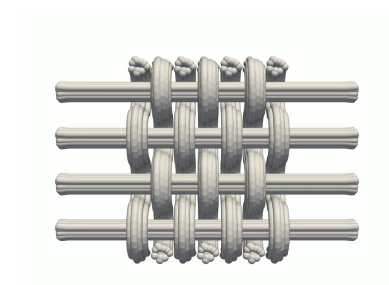
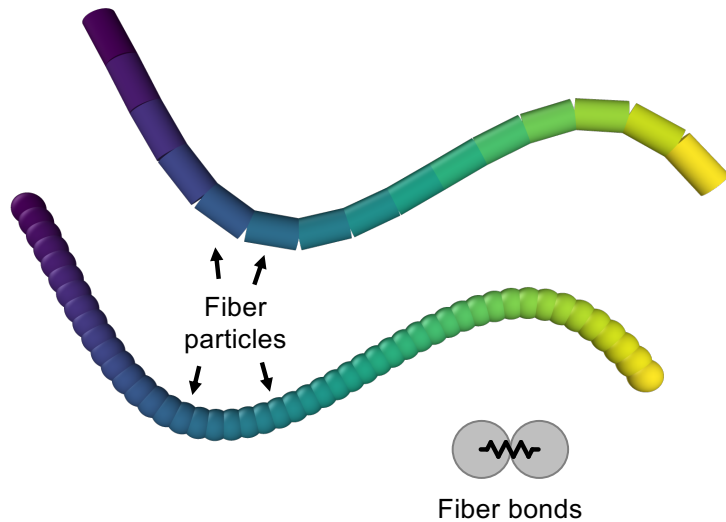
CT-based models



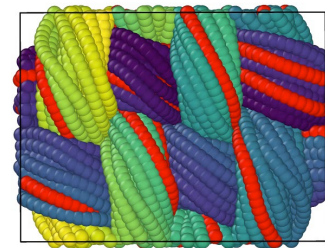
Detailed models with explicit fiber representation



Sander Visser, Andrew Santos



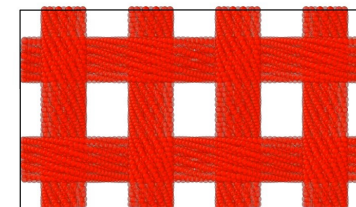
In-house code



LAMMPS

Model interactions include:

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

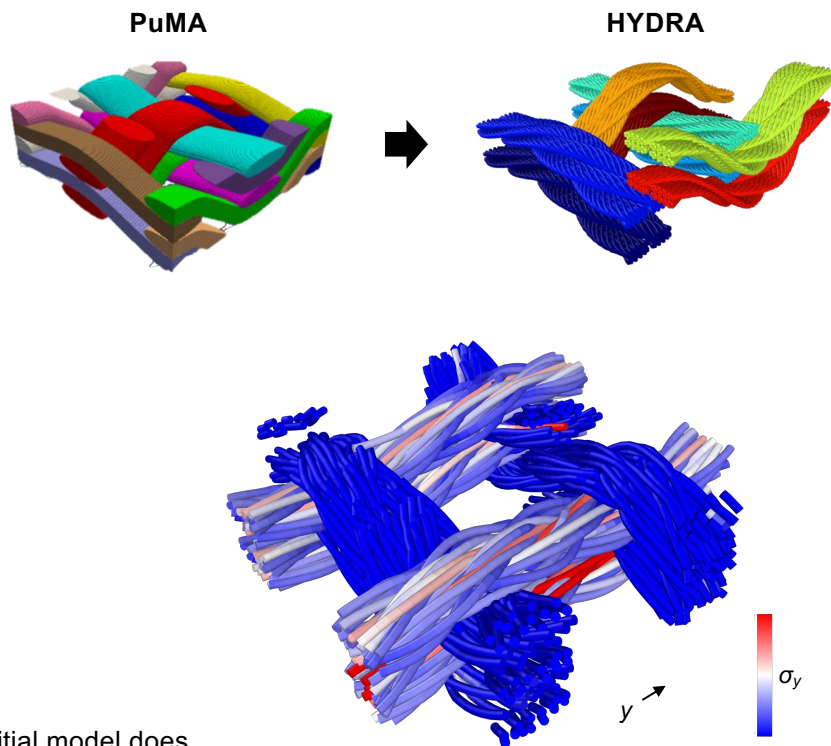


LAMMPS

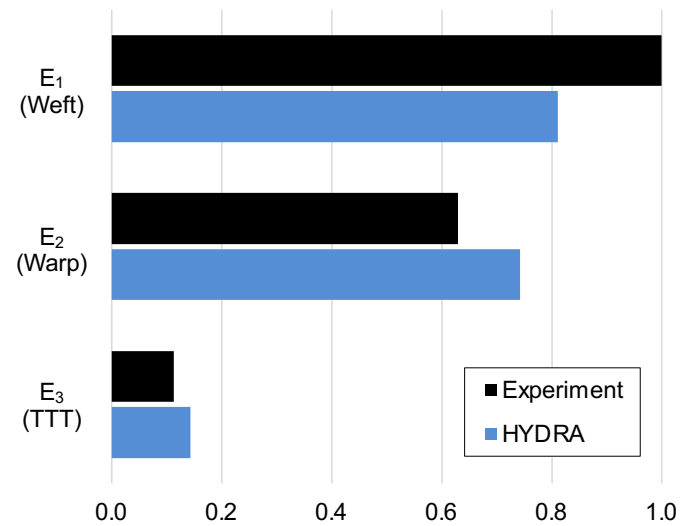
Fiber-level analysis of weave mechanical properties



Justin Haskins



Normalized Young's Moduli



*Initial model does not consider matrix

Outline

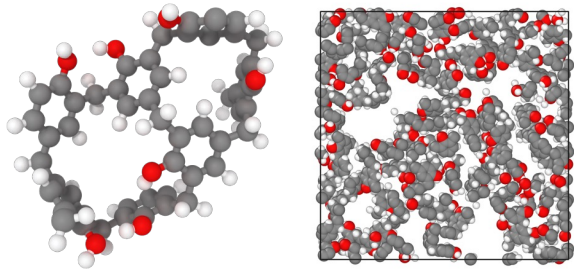


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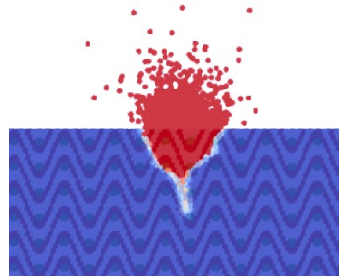
Other TPS Certification by Analysis activities



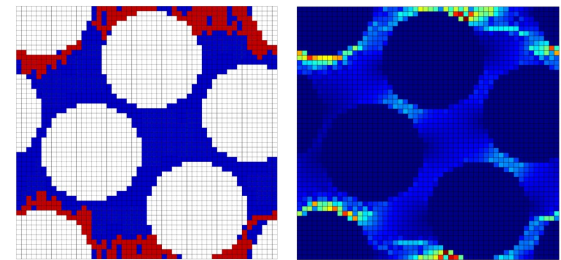
Phenolic Property Calculations



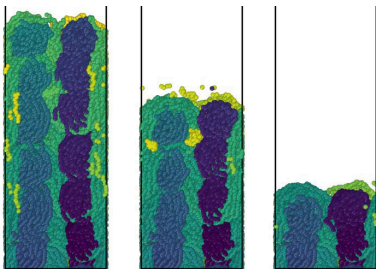
Impact Simulations



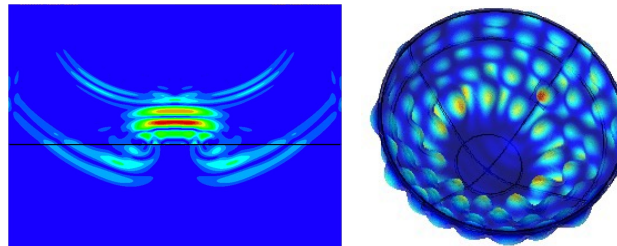
Progressive Damage Simulations



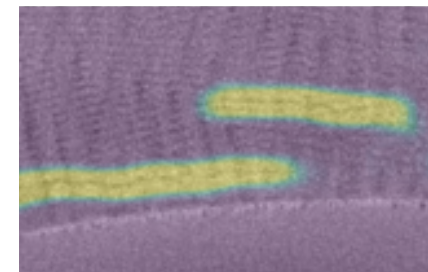
Ablation Simulations



Computational
Nondestructive Evaluation



Fault Detection



Acknowledgements



Entry Systems Modeling Project

TPS Certification by Analysis

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Questions?

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