cdmHUB.org

The Composites Design & Manufacturing HUB

R. Byron Pipes, John Bray Distinguished Professor
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Johnathan Goodsell, Research Assistant Professor

DARPA

DASSAULT SYSTEMES

Henkel

BOEING

CYTEC

Rolls-Royce

MSC Software

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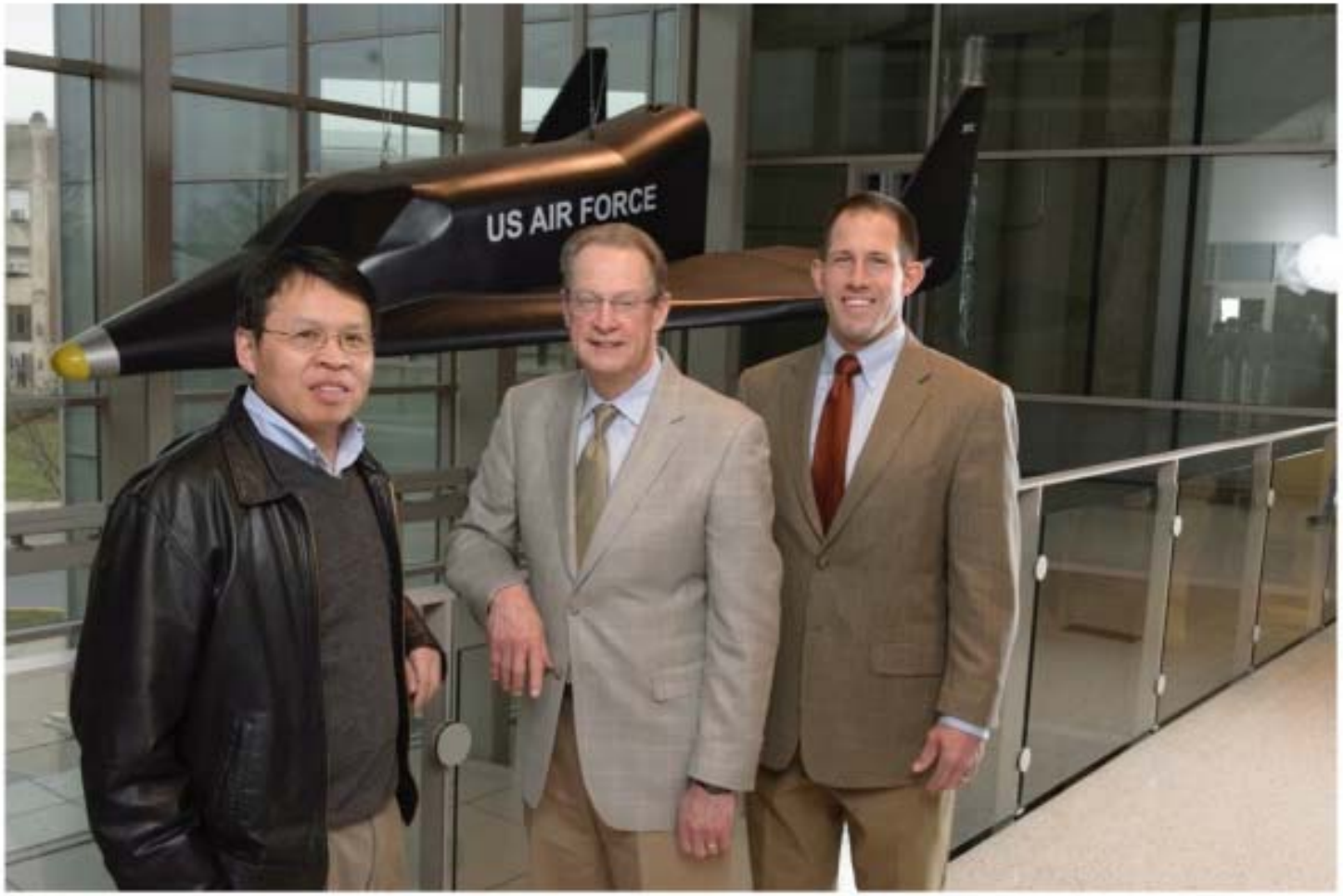
The Leadership Team



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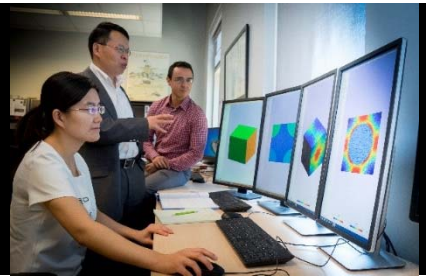
The Vision



- Simulation can *provide the foundation* for a revolution in composites design, manufacturing and certification
- *Finger tip access* to composites simulation tools anywhere anytime on any devices – research codes, open source codes, or commercial codes connected to HPC resources in the cloud.
- *Certifying* composite product manufacturing and performance *by simulation* is clearly within reach
- *Accelerated pervasive learning* about composites and the tools necessary for their design

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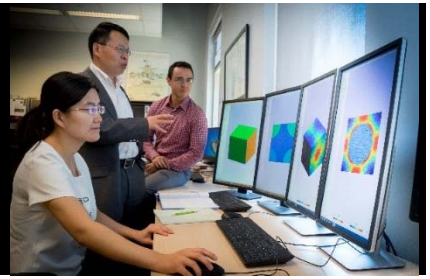
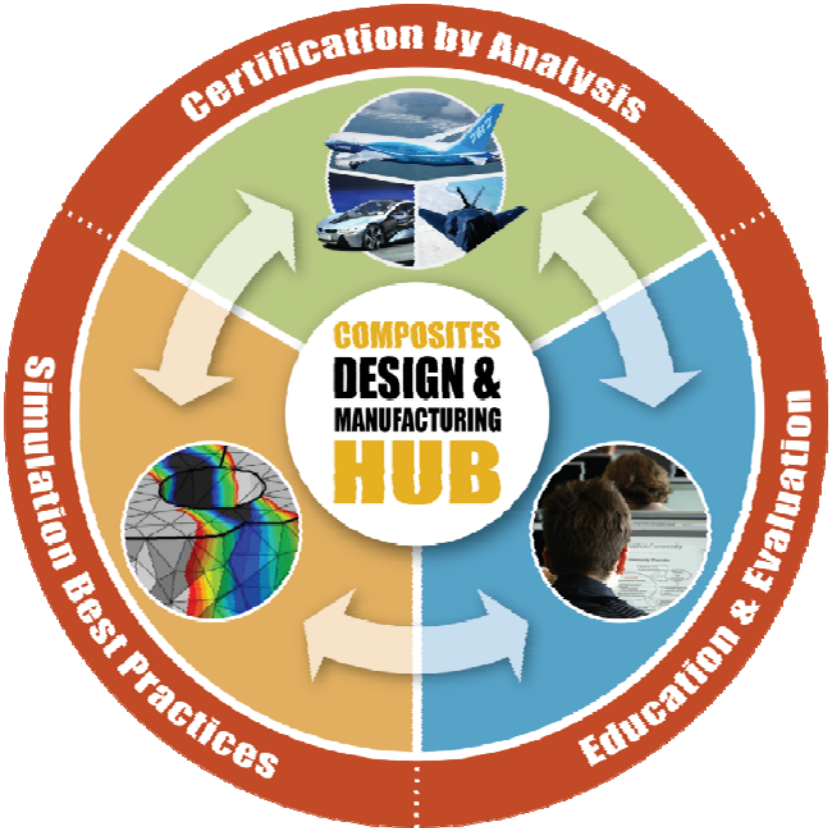
The Mission



Convene the composites community to advance certification by analysis by education and evaluation of composites simulation tools and establishing simulation best practices.



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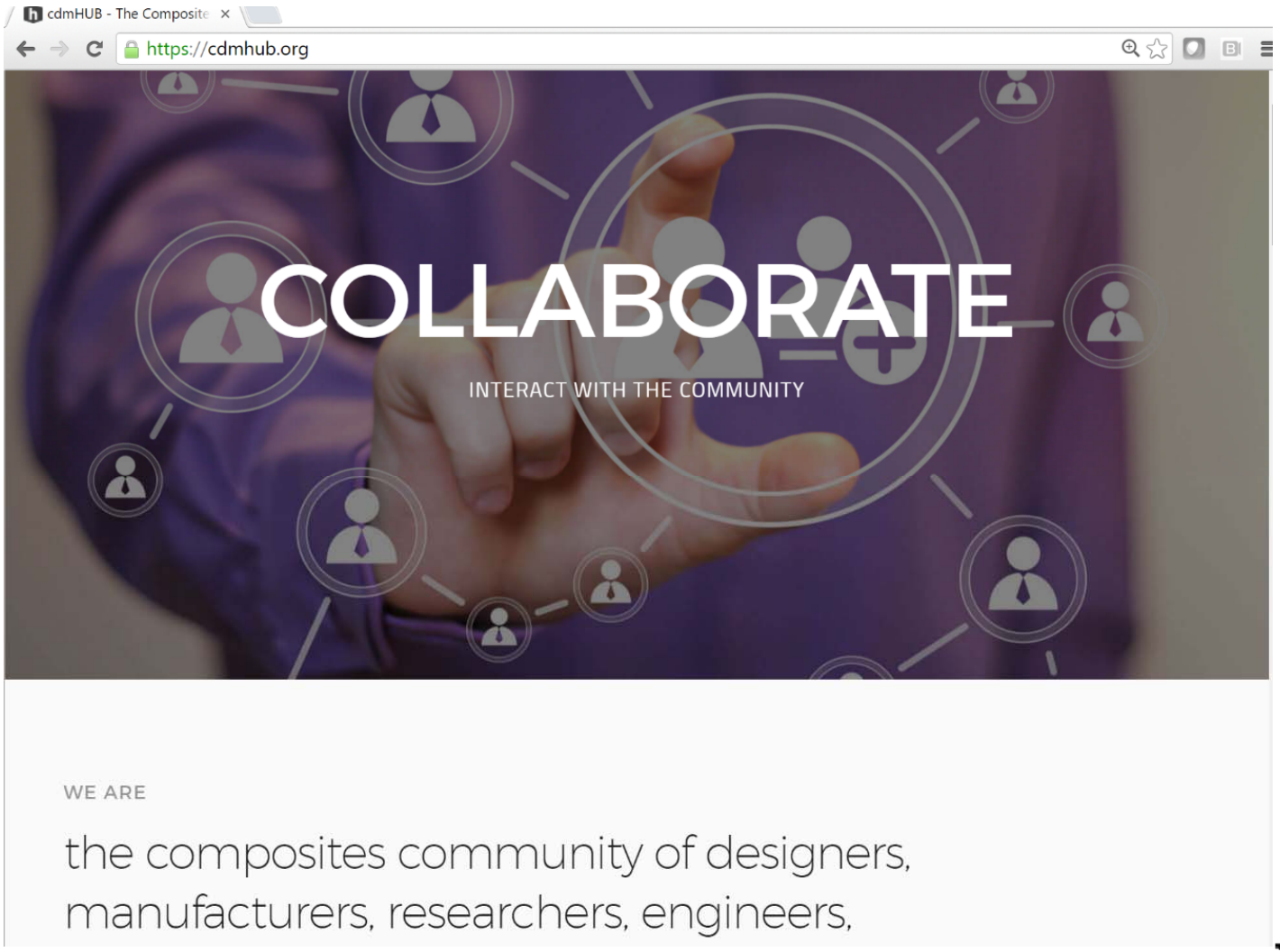
The Online Composites Community



Over 1800 Users to Date!

On our way to 10,000!

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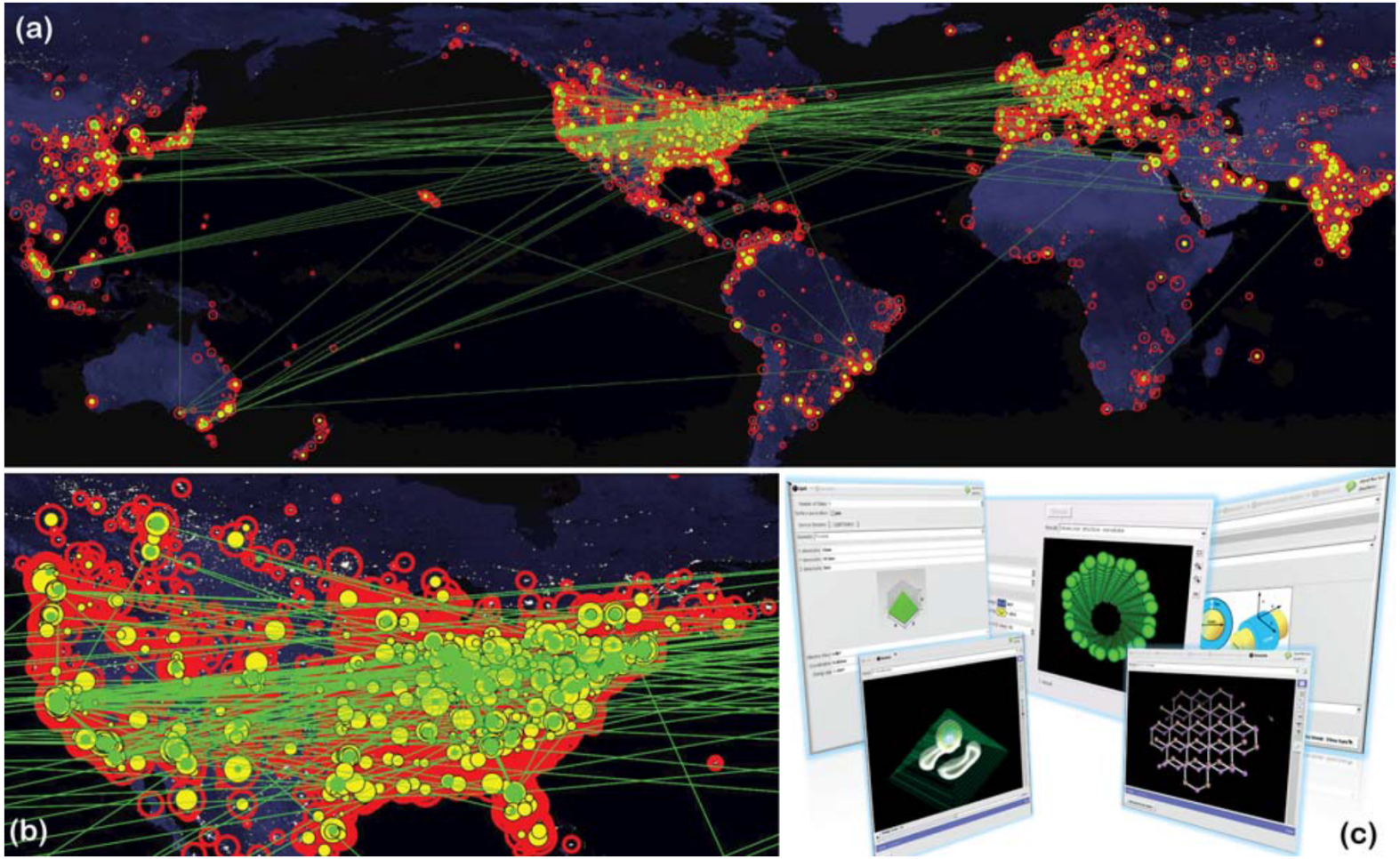
HUBzero, Platform for Scientific Collaboration



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cdmHUB Platform Overview

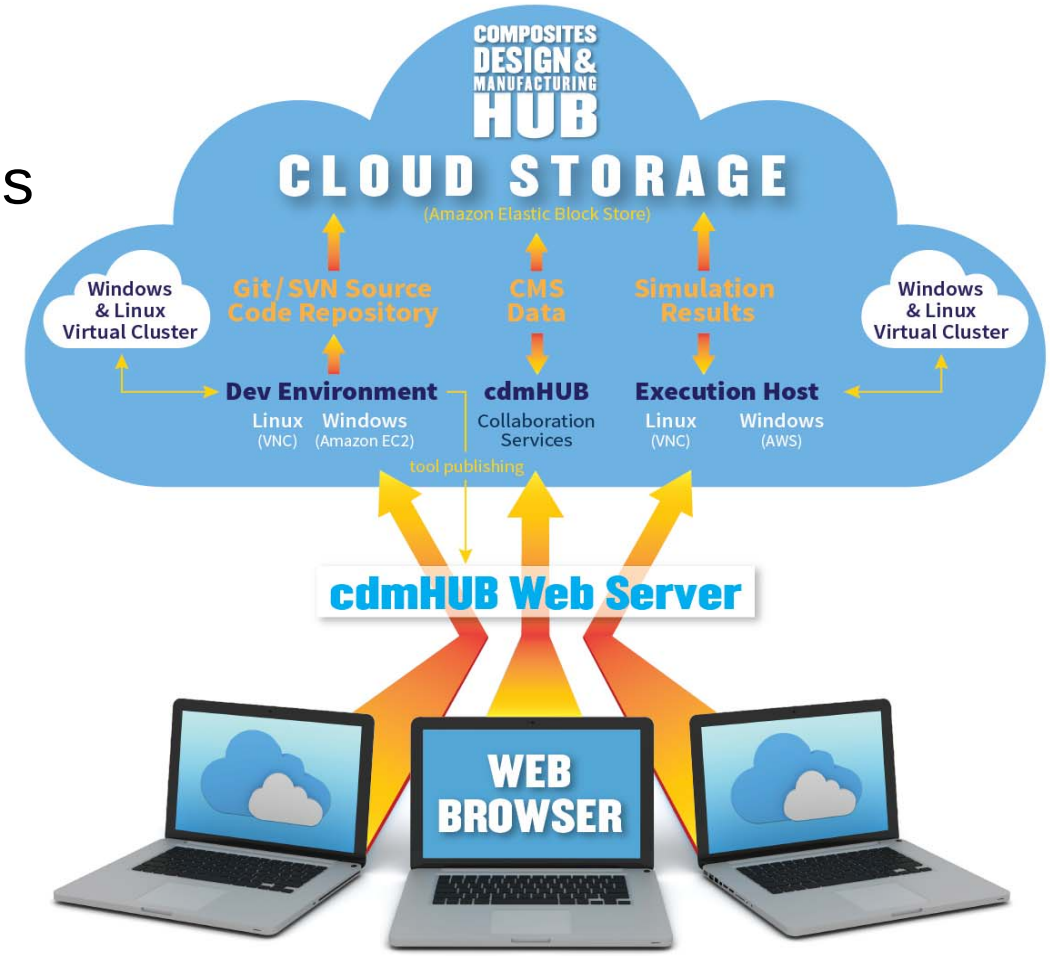
Collaboration Services

Dev Environment

Execution Host

HPC

Cloud storage



cdmHUB Goals

- Increase in the rate of development and deployment of composites simulation tools and the user community **by an order of magnitude**
- Launch a platform
  - Host and integrate existing simulation tools
  - Create a new array of simulation tools
  - Develop the human talent to support composites design and manufacturing simulation
- Create for composites
  - Virtual classroom
  - Virtual lab
  - Virtual factory

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Benefits to the cdmHUB Community

- Education in the use of composites simulation tools
  - What tools are available?
  - What tool is best for a specific problem?
  - What are functionalities and limitations of a particular tool?
  - How is a particular tool connected with other tools?
  - What areas cannot be simulated currently?
- Tool development for composites manufacturing and performance simulation
- Expert evaluation of simulation tool taxonomy and Tool Maturity Level (TML)
- Establishment of protocols for simulation tool validation and verification (V&V)
- Access to data sets required for TML and V&V

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Compiled Industry Simulation Tool Need

- Certification by Analysis
  - Verified, validated tools
  - Strength and lifetime prediction
- Understanding how each tool fits within the entire process
- Simulation of composites manufacturing, processing and performance
- Assemble the composites simulation community for best practices

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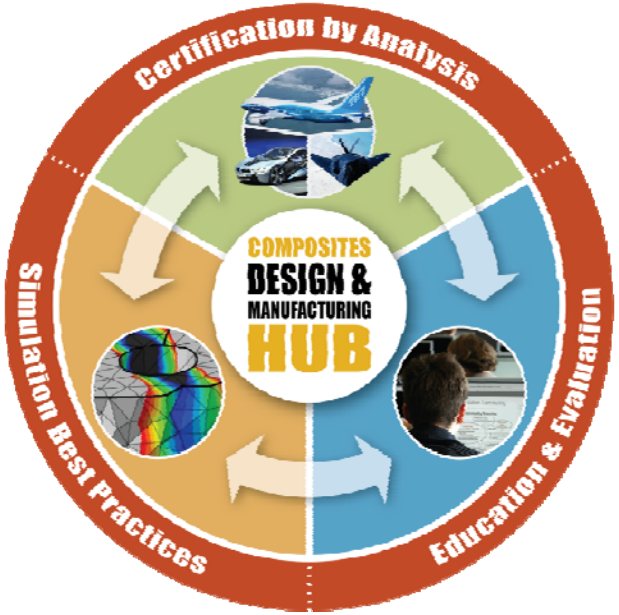
cdmHUB Statistics

1. 1880 members
2. 23 Computer tools (2 commercial tools)
3. 333 resources
4. 25 Groups including NAFEMS, Altair, AnalySwift, DIGIMAT, HyperSizer, IACMI, cvfHUB, etc



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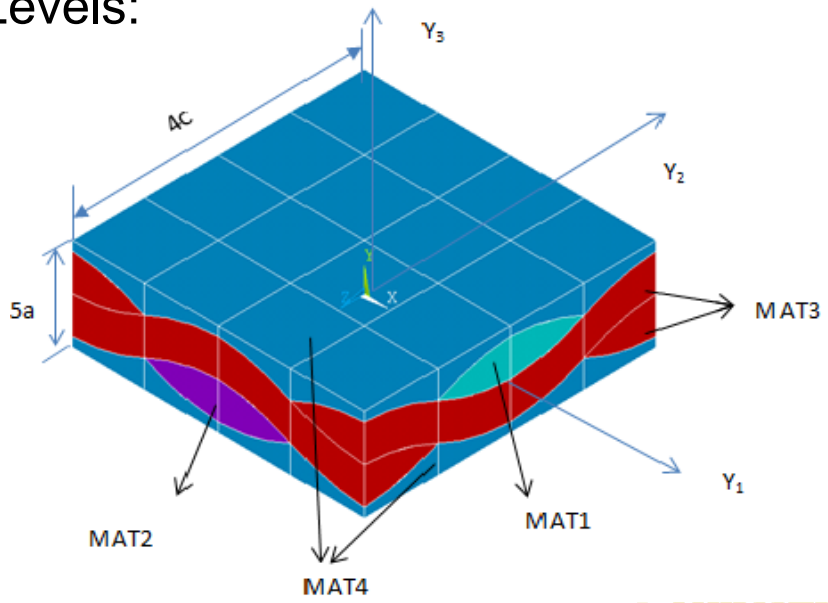
Micromechanics Simulation Challenge

- Similar to World-Wide Failure Exercise
- Vehicle to compare and evaluate simulation tools, and identify the current strengths and needs of the composites simulation community as a whole
- Micromechanics Simulation Challenge Levels:
  - **Level 1:** 2D and 3D microstructures with linear elastic constituents
  - **Level 2:** 3D microstructures (short fiber composites, woven composites, etc.), elasto-plastic constituents
  - **Level 3:** damage and failure (including fatigue) prediction for 2D or 3D microstructures; multi-physics; environmental effects
- Treat both homogenization and de-homogenization



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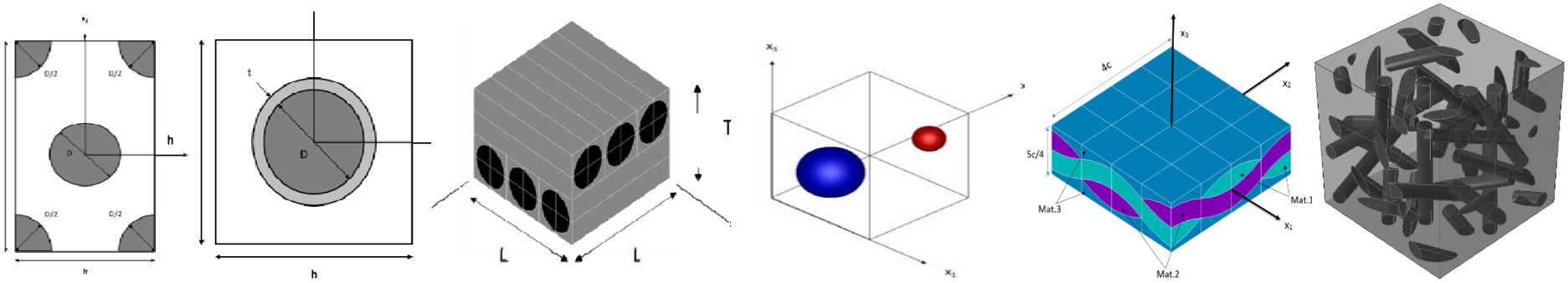
Micromechanics Simulation Challenge – Level I Results

- MAC/GMC, MAC/HFGMC, DIGIMAT, Altair MDS, FVDAM, SwiftComp, ESI,3D FEA of RVE with periodic BCs.
- Final report: cdmhub.org/resources/948.
- All data needed for reproducing the results: cdmhub.org/members/project/mmsimulationchalleng/view
- Level I: accuracy and efficiency of linear thermoelastic properties and local fields.



2014 cdmHUB Workshop

- On-line presentations and videos
- Hands-on labs in composite manufacturing and testing
- Demonstrations of composites simulation software
- Theory of composites analysis, manufacturing and testing

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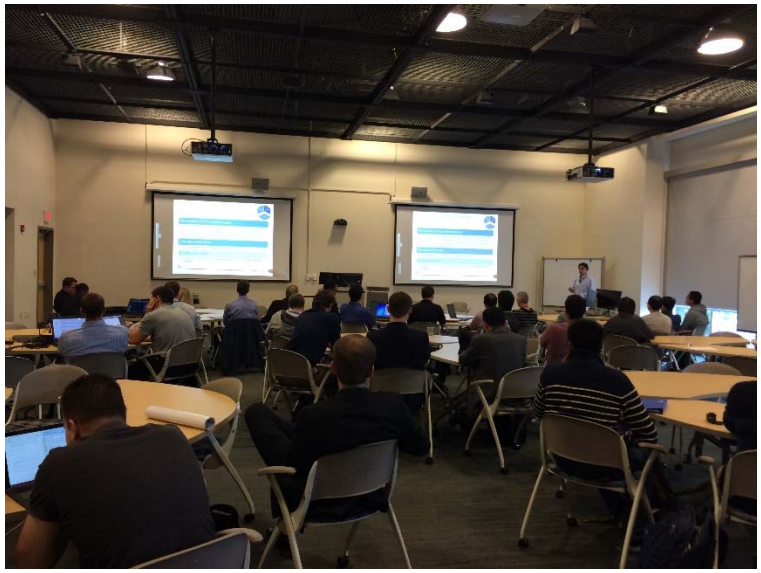
2015 cdmHUB Workshop

- Hands-on workshop with multi-scale composites analysis
- Presentations on composites manufacturing and performance simulation software and capabilities
- Simulation Fair showcasing simulation software



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2016 cdmHUB Workshop

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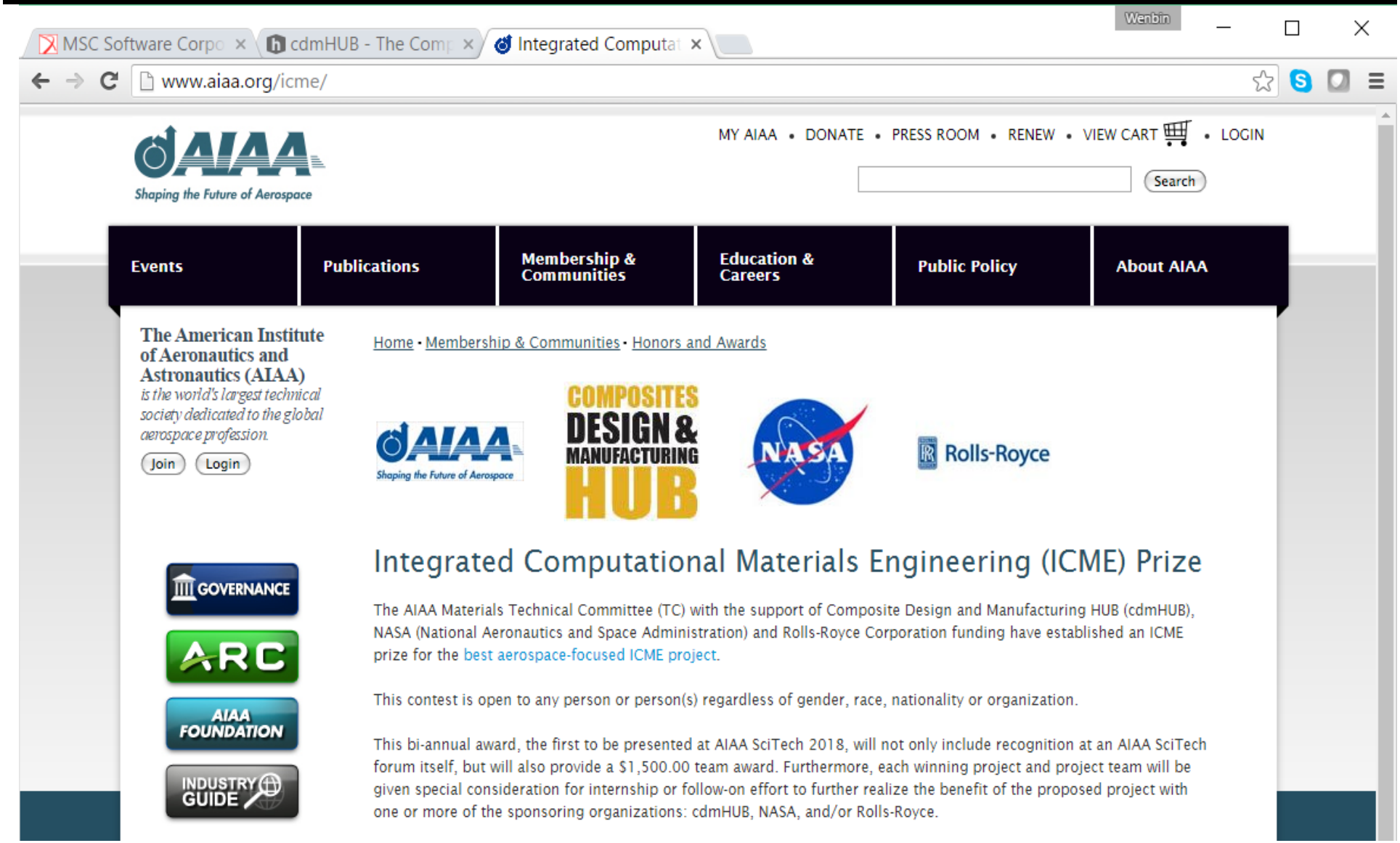
Our Sponsors

Proud to Sponsor AIAA ICME Prize



Proud to Sponsor ASC 31st Technical Conference

[redacted]

Honored to Host the ASC 32st Technical Conference

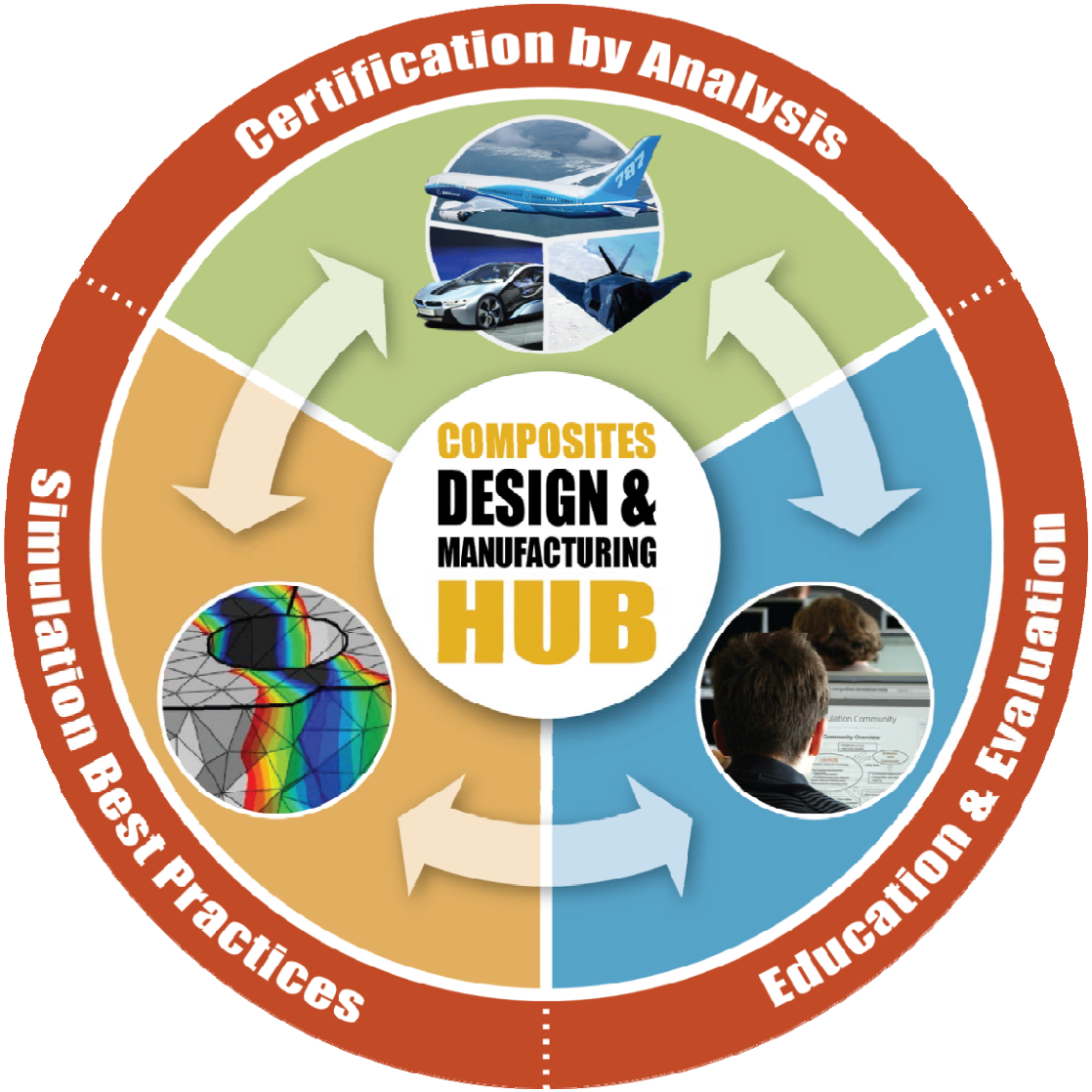
American Society for Composites 32nd Technical Conference

October 22–25, 2017 West Lafayette, Indiana, USA

Conference Chairs: Wenbin Yu and Byron Pipes **Conference Secretary:** Johnathan Goodsell

Visit **cdmHUB.org** for more info.

Composites Are the Future



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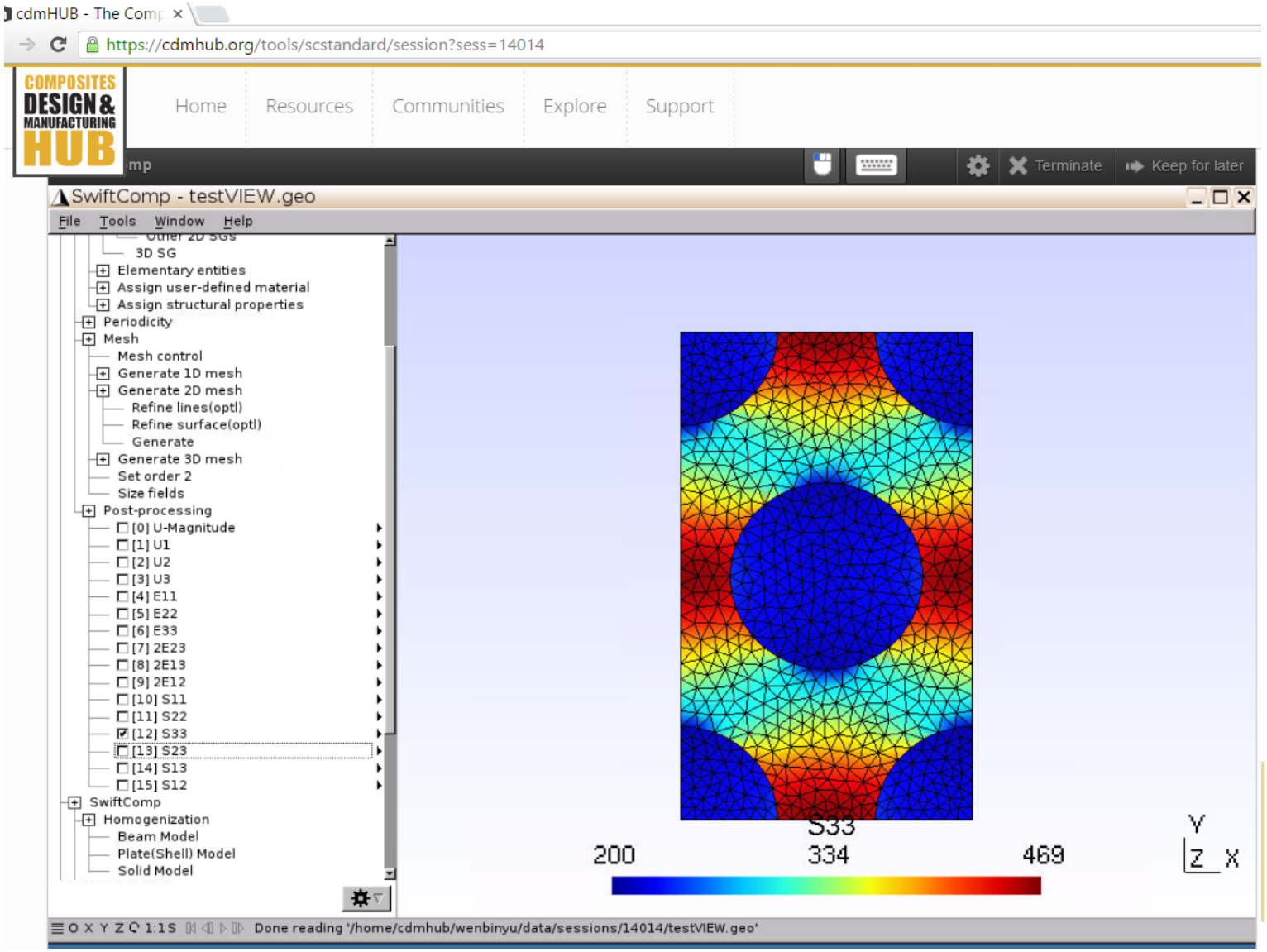
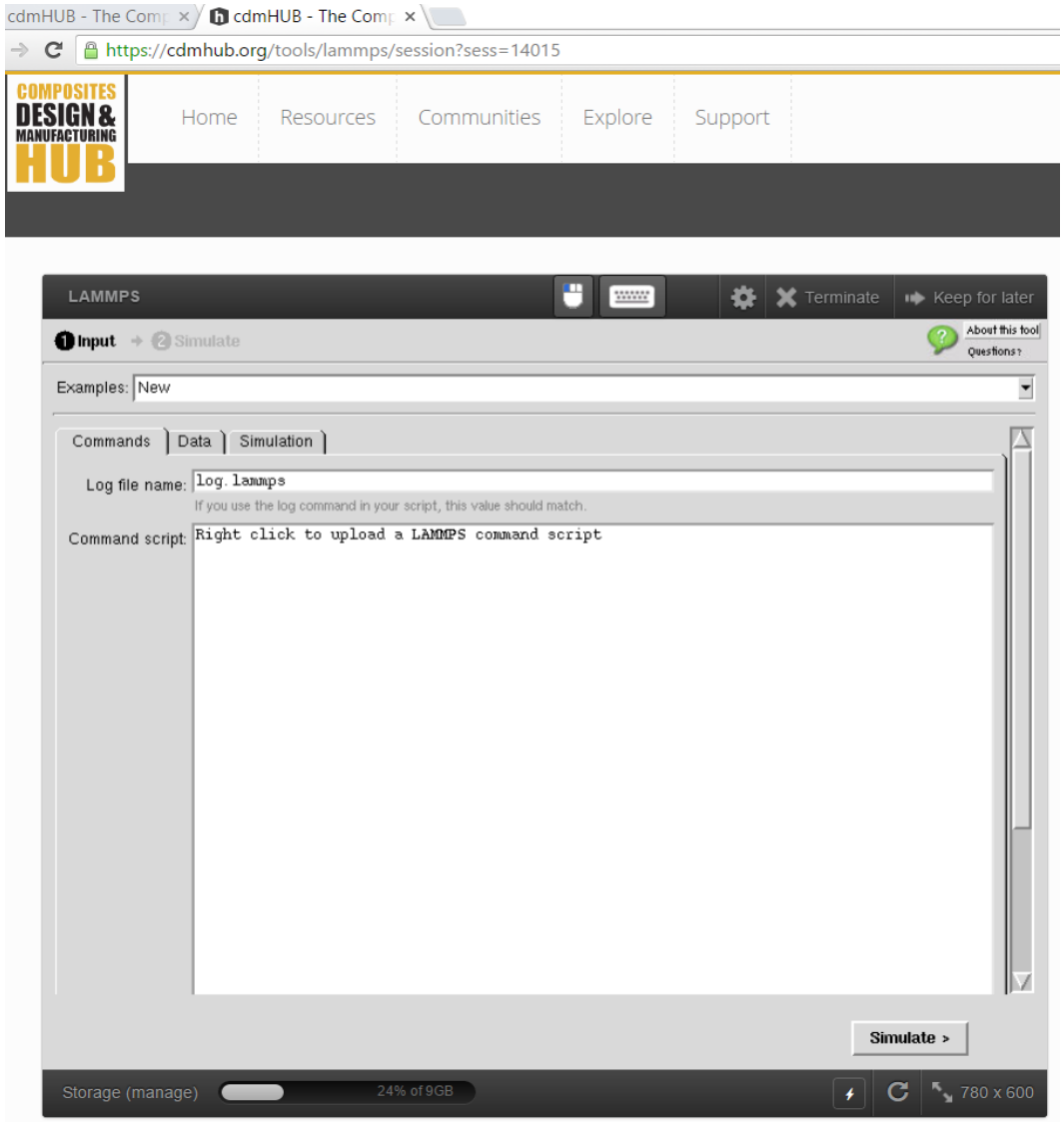
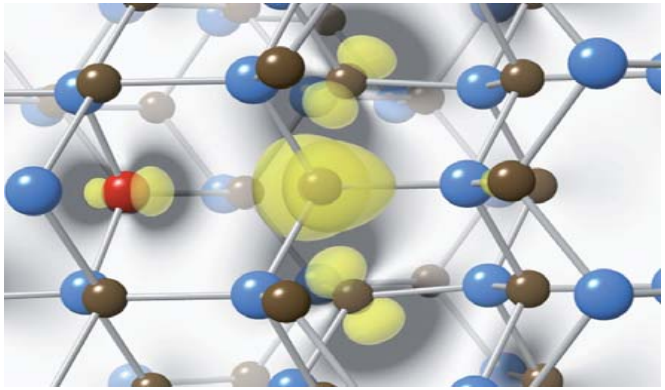
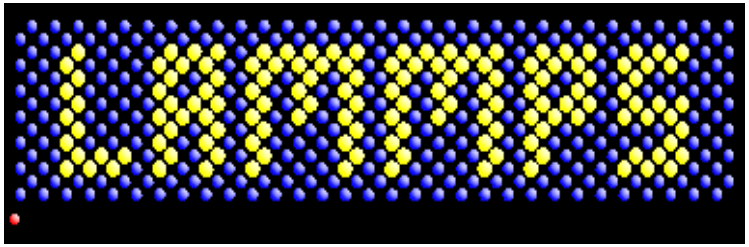
SwiftComp on cdmHUB



LAMMPS on cdmHUB







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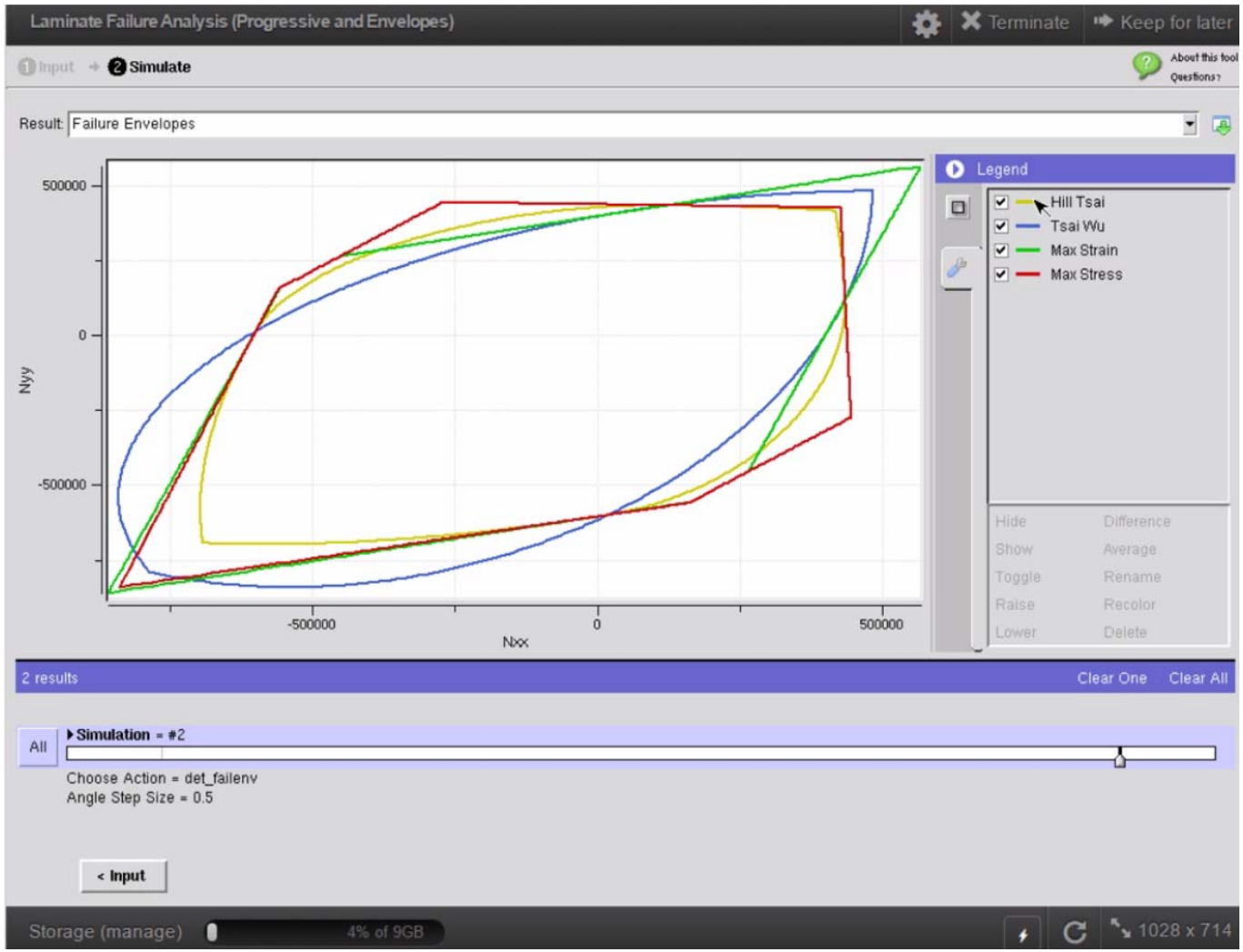
CLT-based Progressive Failure Analysis on cdmHUB



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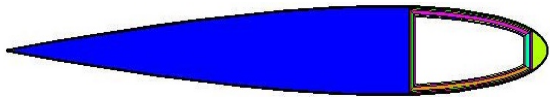
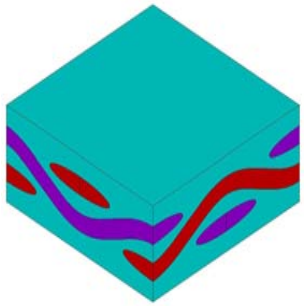
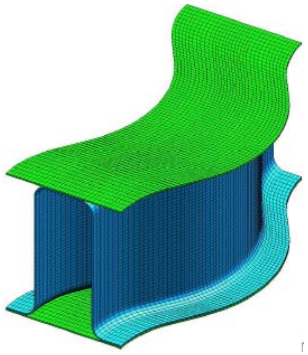
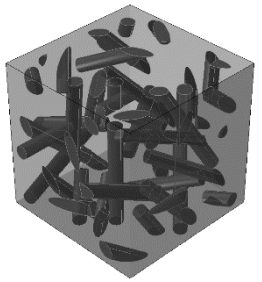
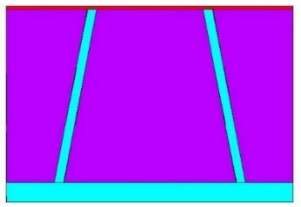
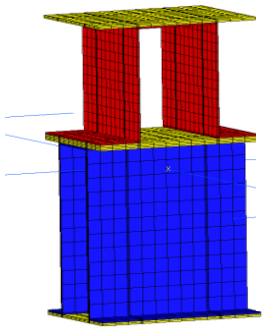
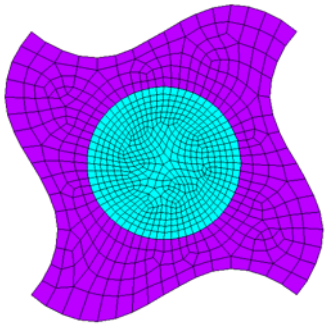
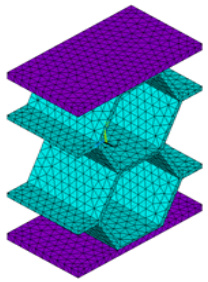
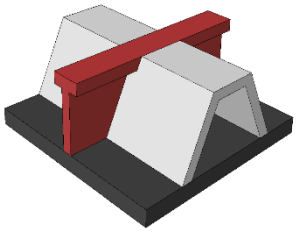
Right Results
Right Away

SwiftComp™

A Purdue Technology

Principle of Minimum Information Loss

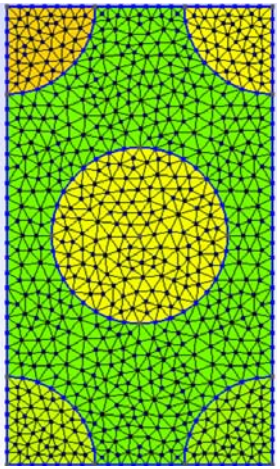
- **Virtual testing of composites**
  - Mechanical properties
  - Multifunctional properties
- **Multiscale modeling of composites**
  - 3D composite structures
  - Composite plates/shells
  - Composite beams

SwiftComp Example #1: UD FRC

UD FRC: VOF: 60%, Fiber E=276 GPa, nu=0.28; Matrix E=4.76 GPa, nu=0.37

- Find the effective properties using a a hexagonal packing microstructure
- Find the local stress distribution of the composites if it is under a biaxial strain loading with e11=5 um/m and e22=2 um/m



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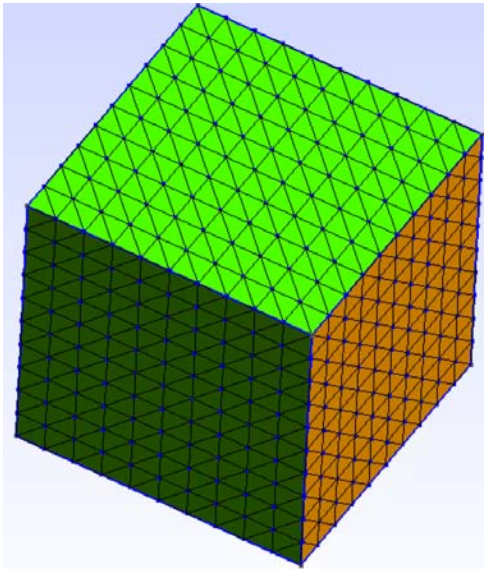
SwiftComp Example #2: PRC

PRC: VOF: 50%, Particle E=400 GPa, nu=0.3; Matrix E=40 GPa, nu=0.37

- Find the effective properties
- Find the local stress distribution of the composites if it is under a biaxial strain loading with e33=5 um/m and 2e23=2 um/m



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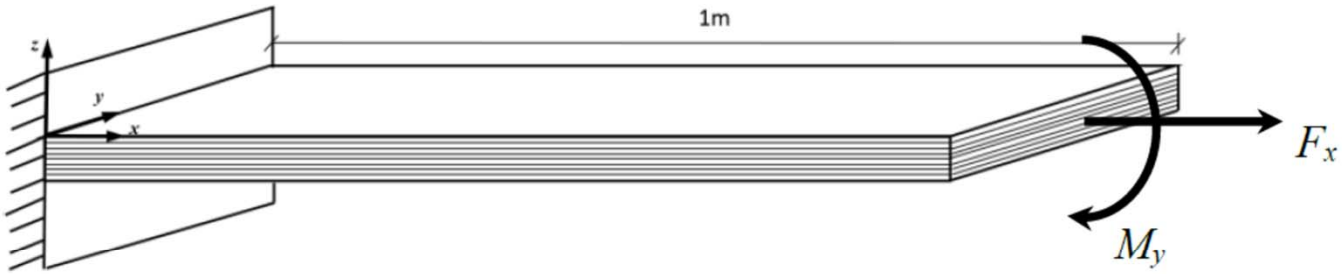
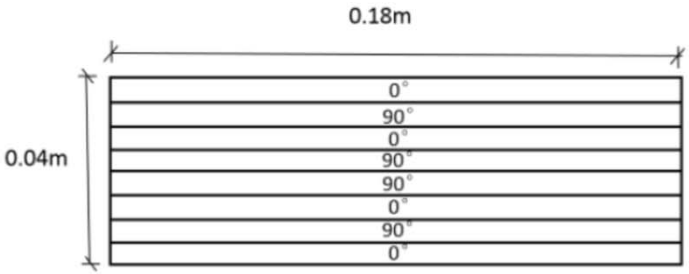
SwiftComp Example #3: Laminate

$$E_1 = 110.5\,\text{GPa},\ E_2 = E_3 = 13.64\,\text{GPa},\ G_{12} = G_{13} = 3.92\,\text{GPa},$$

$$G_{23} = 3.26\,\text{GPa},\ \nu_{12} = \nu_{13} = 0.329, \nu_{23} = 0.400$$





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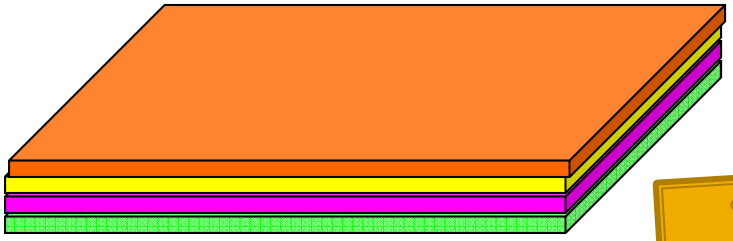
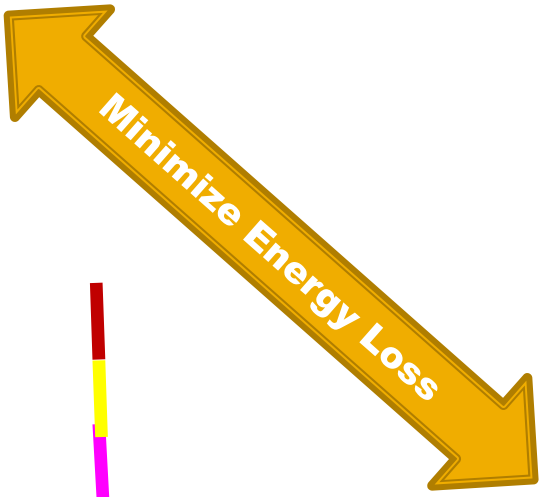
Example 3.1: Model it as a Solid



$u_i, \varepsilon_{ij}, \sigma_{ij}, U$

Original model: 3D continuum mechanics with layerwise heterogeneity



Macroscopic model: 3D continuum mechanics with homogenous solid

$\bar{u}_i, \bar{\varepsilon}_{ij}, \bar{\sigma}_{ij}, \bar{U}$

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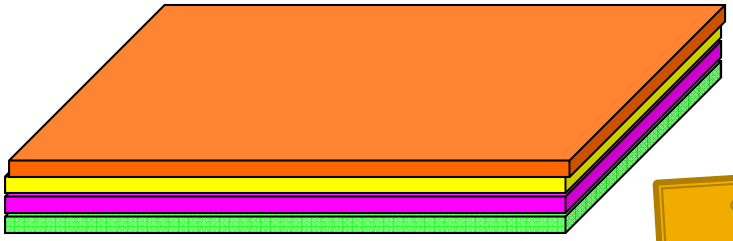
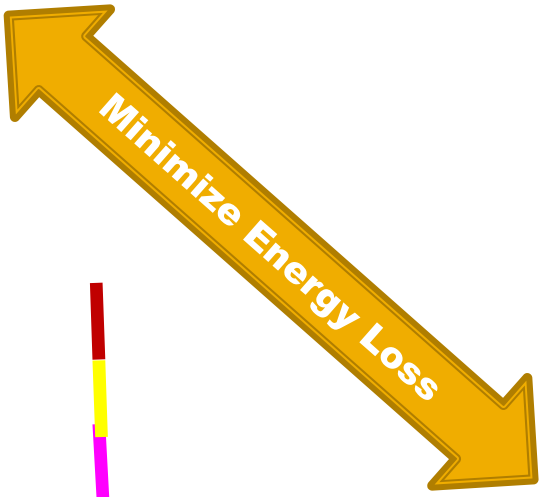
Example 3.2: Model it as a Plate

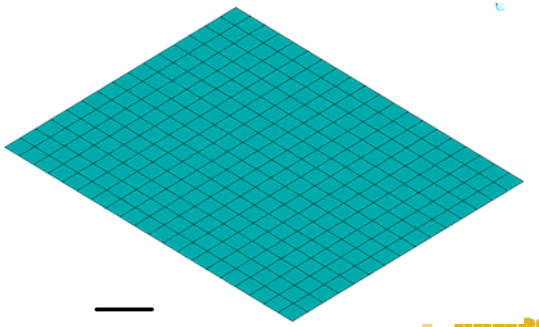


Original model: 3D continuum mechanics with layerwise heterogeneity

$$u_i, \varepsilon_{ij}, \sigma_{ij}, U$$



Macroscopic model: 2D plate model



$$\bar{u}_i, \bar{\varepsilon}_{\alpha\beta}, \kappa_{\alpha\beta}, N_{\alpha\beta}, M_{\alpha\beta}, \bar{U}$$

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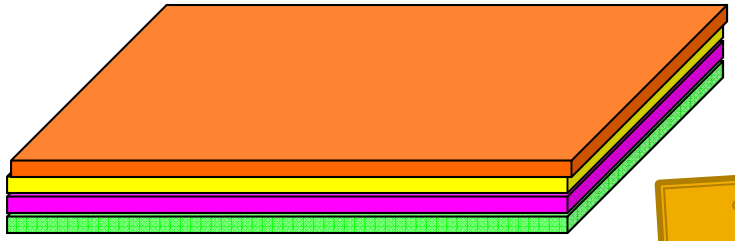
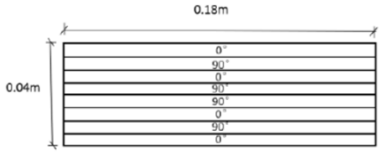
Example 3.3: Model it as a Beam



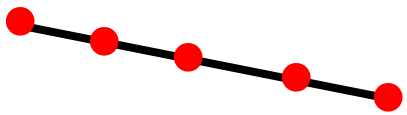
Original model: 3D continuum mechanics with layerwise heterogeneity

$$u_i, \varepsilon_{ij}, \sigma_{ij}, U$$

Minimize Energy Loss



Macroscopic model: 1D beam model



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If You Have More Time.....

- Go to https://cdmhub.org/resources/scstandard
- Download Gmsh4SCManual.pdf from supporting documents
- Follow the instruction to explore more capabilities of SwiftComp
- If you want to handle more complex microstructures, please download
  - ANSYS GUI: https://cdmhub.org/resources/1136
  - ABAQUS GUI: https://cdmhub.org/resources/1134

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If You Have Questions.....

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Director, Composites Virtual Factory HUB
Associate Director, Composites Design & Manufacturing HUB
CTO, AnalySwift LLC
Associate Professor, Purdue/AAE

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