



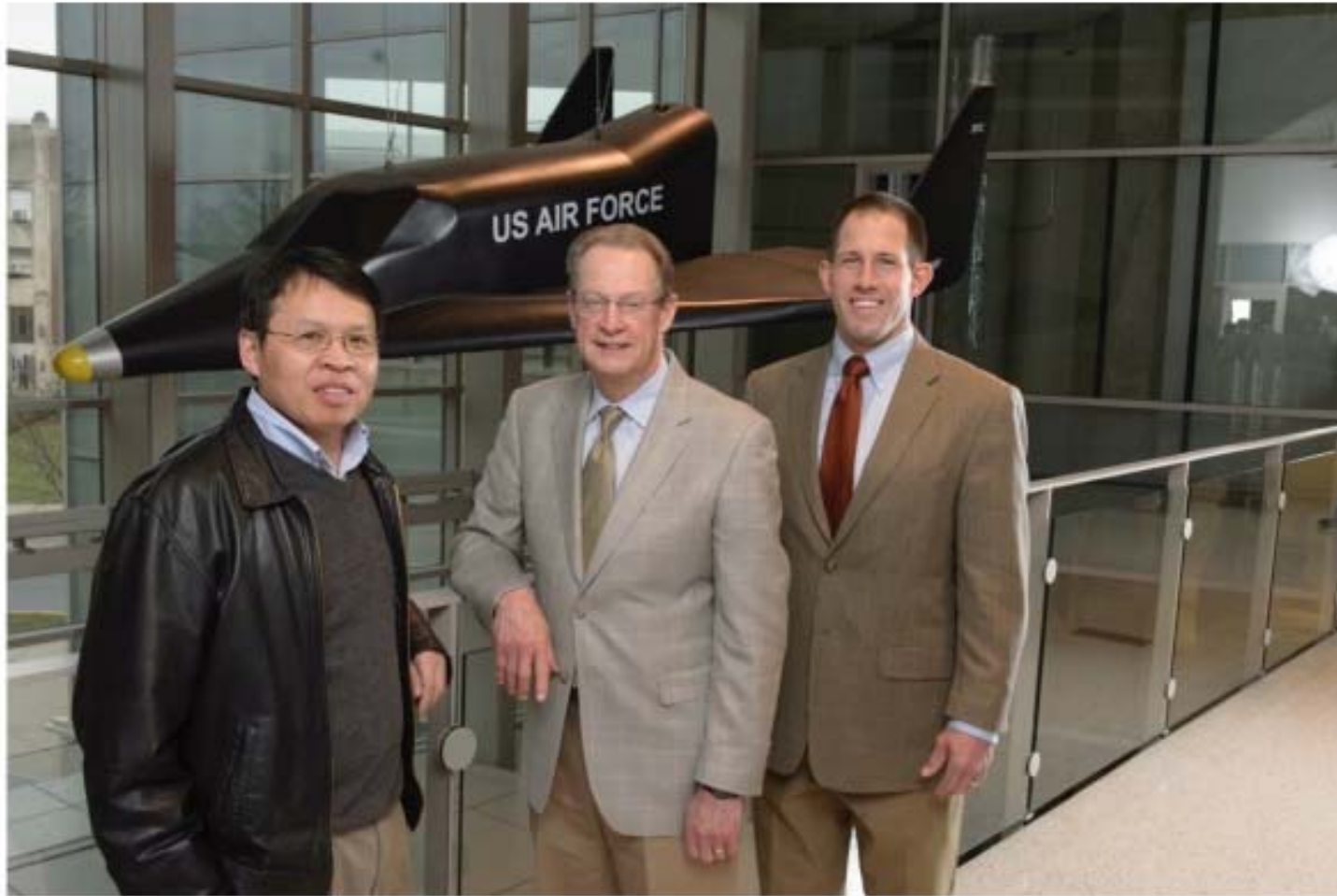
# cdmHUB.org

## The Composites Design & Manufacturing HUB

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



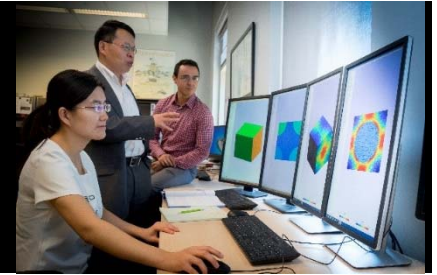
# The Leadership Team



**PURDUE**  
UNIVERSITY

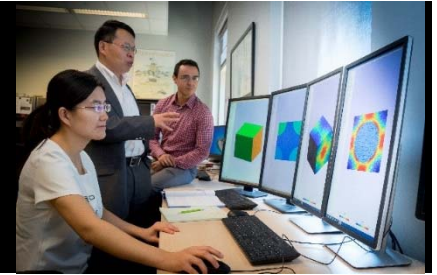
**COMPOSITES  
DESIGN &  
MANUFACTURING  
HUB**

# The Vision

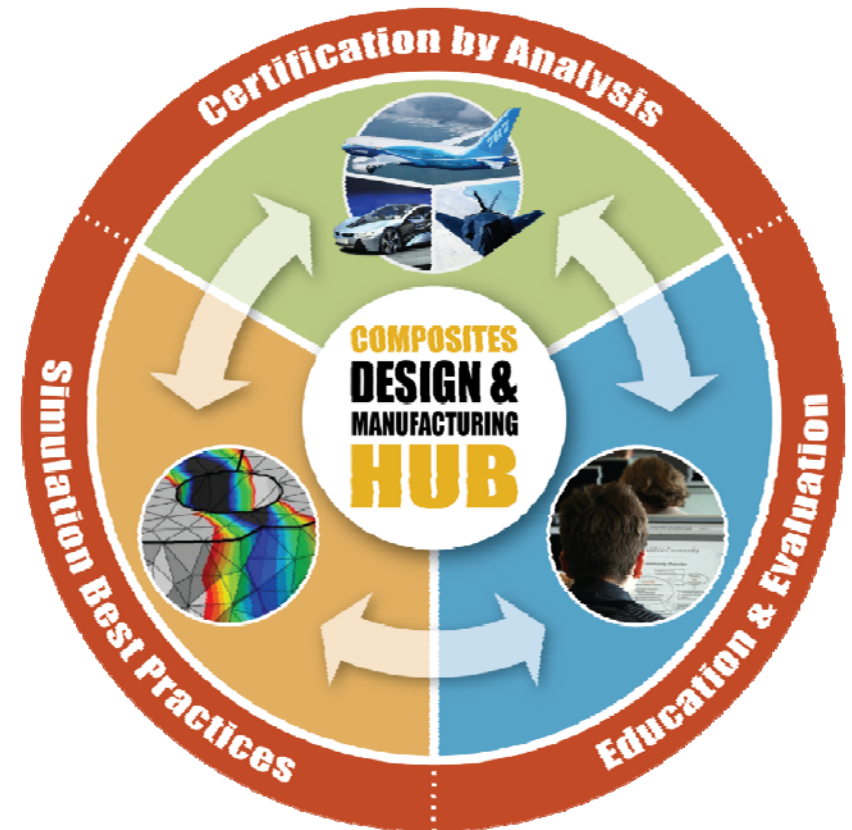


- Simulation can *provide the foundation* for a revolution in composites design, manufacturing and certification
- *Finger tip access* to composites simulation tools anywhere anytime on any devices – research codes, open source codes, or commercial codes connected to HPC resources in the cloud.
- *Certifying*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

# The Mission



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

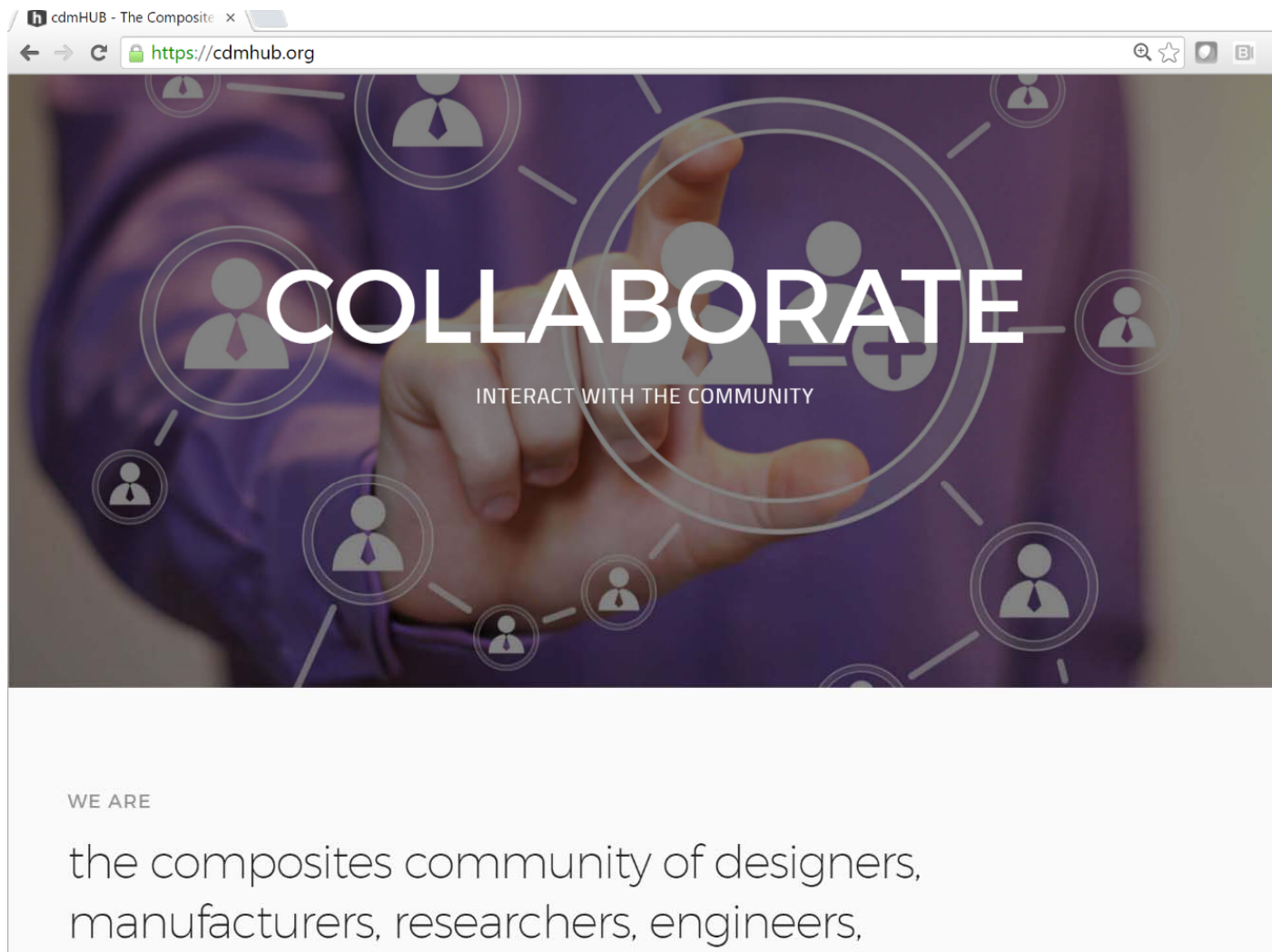


**PURDUE**  
UNIVERSITY

**COMPOSITES  
DESIGN &  
MANUFACTURING  
HUB**



# The Online Composites Community



*Over  
1800  
Users to  
Date!*

*On our  
way to  
10,000!*

# HUBzero, Platform for Scientific Collaboration



**PURDUE**  
UNIVERSITY

**COMPOSITES  
DESIGN &  
MANUFACTURING  
HUB**

# cdmHUB Platform Overview

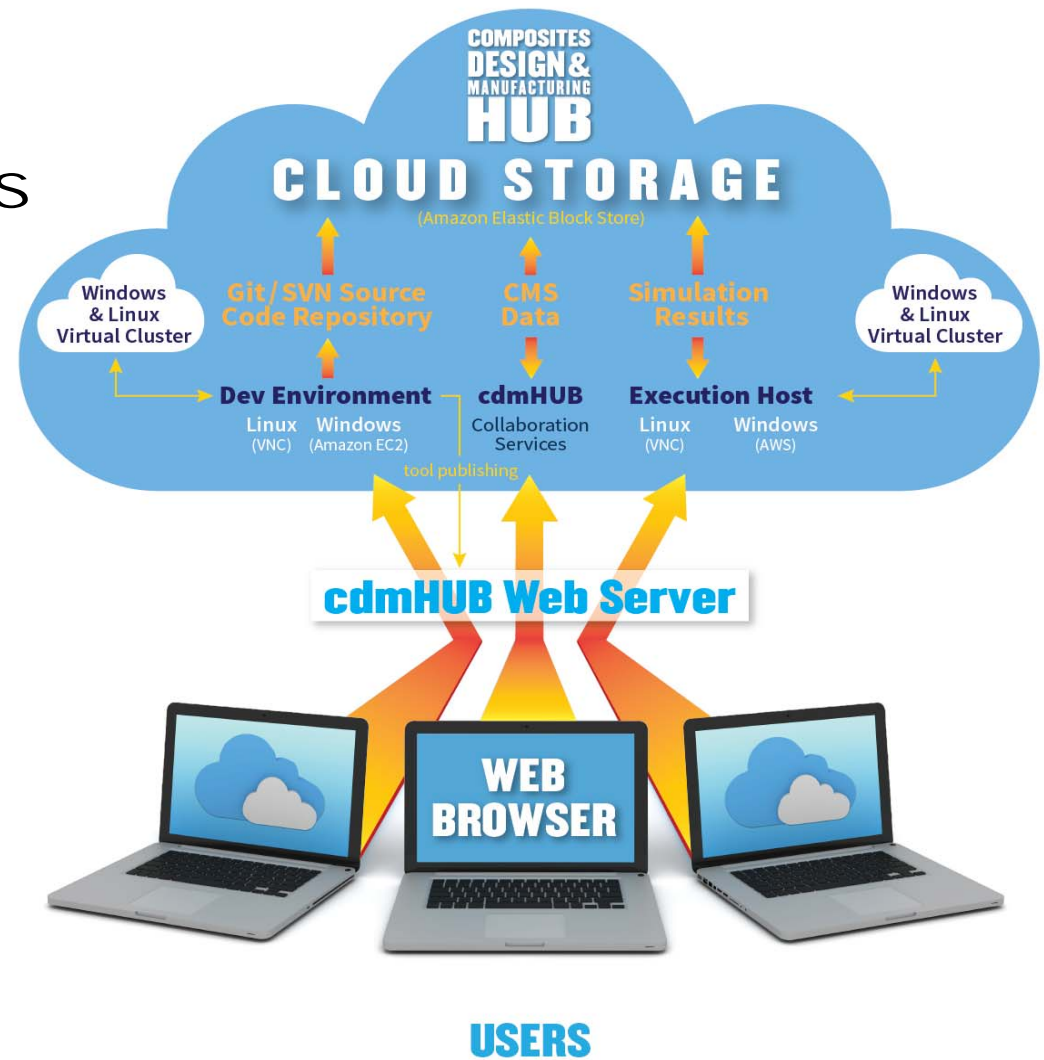
Collaboration Services

Dev Environment

Execution Host

HPC

Cloud storage



Researchers | Engineers | Manufacturers | Educators

# 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



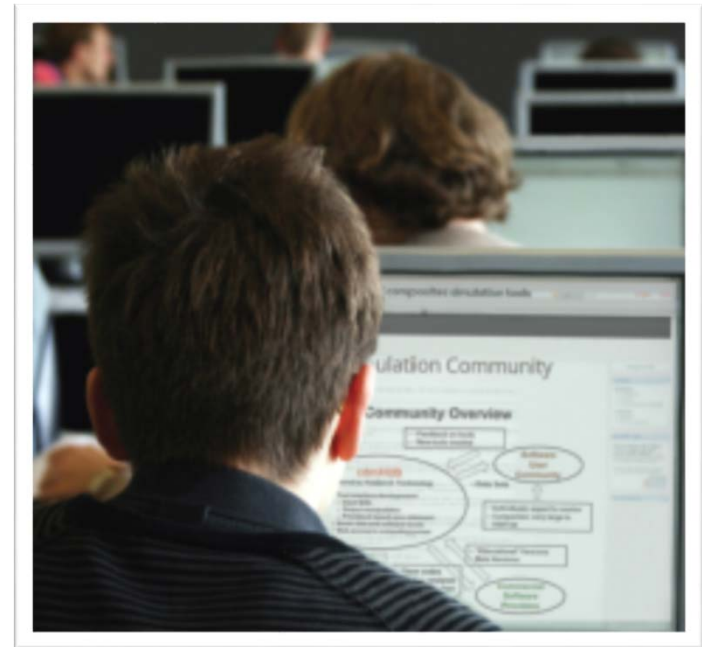
# Benefits to the cdmHUB Community

- 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



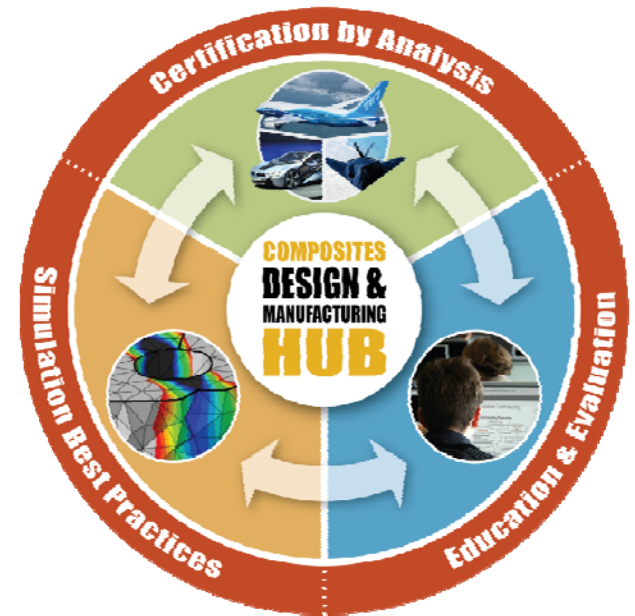
# Compiled Industry Simulation Tool Need

- 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



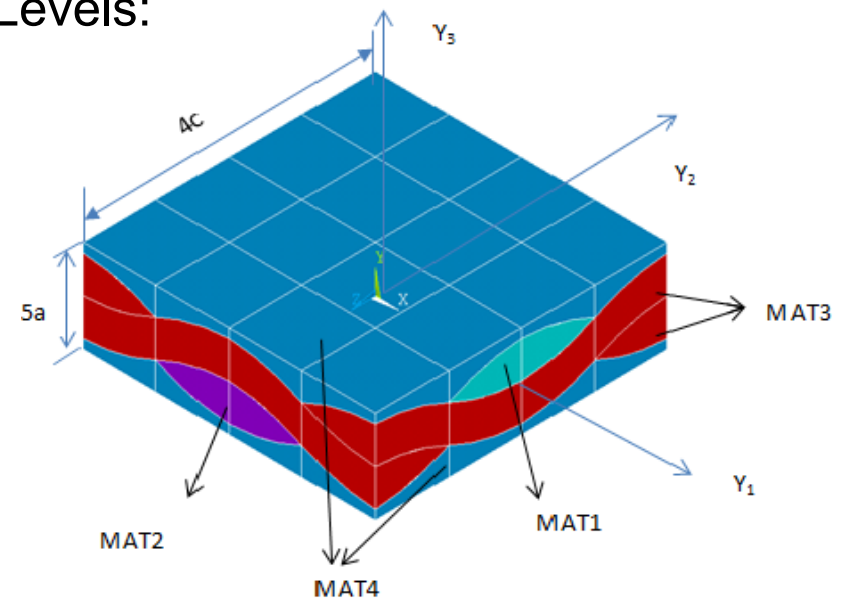
# cdmHUB Statistics

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



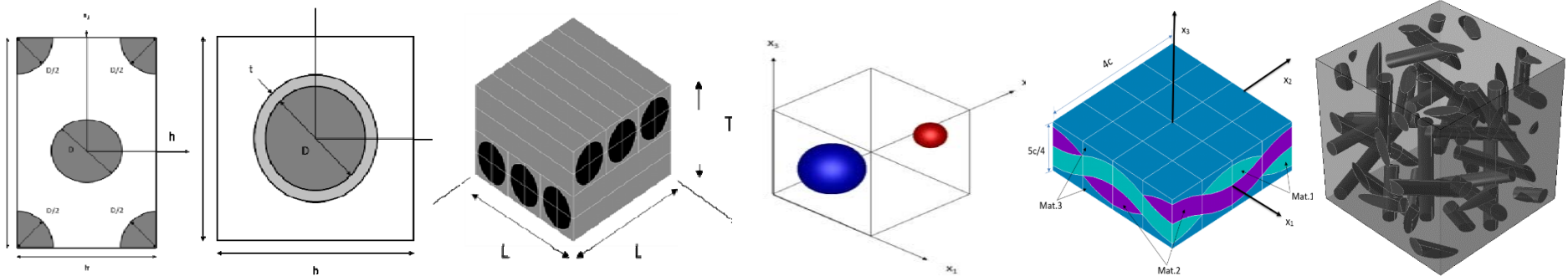
# Micromechanics Simulation Challenge

- 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



# 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](http://cdmhub.org/resources/948).
- All data needed for reproducing the results: [cdmhub.org/members/project/mmsimulationchalleng/view](http://cdmhub.org/members/project/mmsimulationchalleng/view)
- Level I: accuracy and efficiency of linear thermoelastic properties and local fields.



# 2014 cdmHUB Workshop

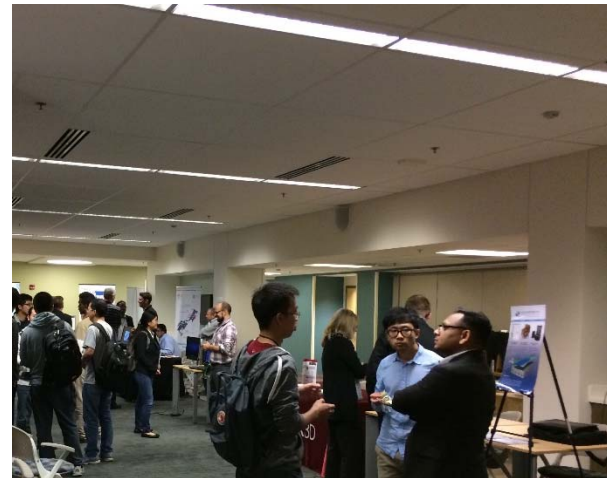
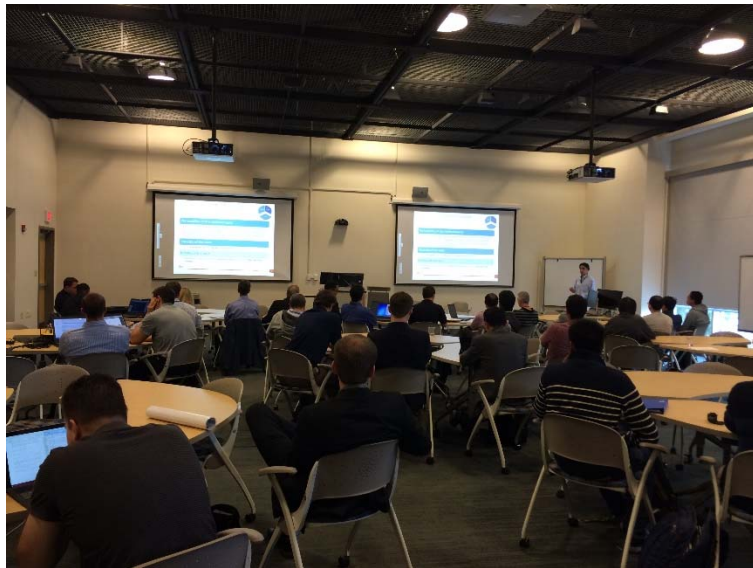
- On-line presentations and videos
- Hands-on labs in composite manufacturing and testing
- Demonstrations of composites simulation software
- Theory of composites analysis, manufacturing and testing





# 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



# 2016 cdmHUB Workshop

**COMPOSITES  
DESIGN &  
MANUFACTURING  
HUB**

## **Composites Simulation Workshop**

*Multi-scale Composites Analysis to Meet Tomorrow's Opportunities*

October 26–27, 2016



**PURDUE**  
UNIVERSITY

**COMPOSITES  
DESIGN &  
MANUFACTURING  
HUB**

# Our Sponsors



# Proud to Sponsor AIAA ICME Prize

MSC Software Corp x cdmHUB - The Comp x Integrated Computat x Wenbin

www.aiaa.org/icme/

**AIAA**  
Shaping the Future of Aerospace

MY AIAA • DONATE • PRESS ROOM • RENEW • VIEW CART • LOGIN

Search

Events Publications Membership & Communities Education & Careers Public Policy About AIAA

The American Institute of Aeronautics and Astronautics (AIAA)  
is the world's largest technical society dedicated to the global aerospace profession.

Join Login

**GOVERNANCE**

**ARC**

**AIAA FOUNDATION**

**INDUSTRY GUIDE**

Home • Membership & Communities • Honors and Awards

**AIAA**  
Shaping the Future of Aerospace

**COMPOSITES DESIGN & MANUFACTURING HUB**

**NASA**

**Rolls-Royce**

## Integrated Computational Materials Engineering (ICME) Prize

The AIAA Materials Technical Committee (TC) with the support of Composite Design and Manufacturing HUB (cdmHUB), NASA (National Aeronautics and Space Administration) and Rolls-Royce Corporation funding have established an ICME prize for the [best aerospace-focused ICME project](#).

This contest is open to any person or person(s) regardless of gender, race, nationality or organization.

This bi-annual award, the first to be presented at AIAA SciTech 2018, will not only include recognition at an AIAA SciTech forum itself, but will also provide a \$1,500.00 team award. Furthermore, each winning project and project team will be given special consideration for internship or follow-on effort to further realize the benefit of the proposed project with one or more of the sponsoring organizations: cdmHUB, NASA, and/or Rolls-Royce.



# Proud to Sponsor ASC 31<sup>st</sup> Technical Conference

Wenbin

HomeASC 2016

mech.utah.edu/ASC2016/

  **American Society for Composites  
31<sup>st</sup> Technical Conference and  
ASTM Committee D30 Meeting**  
September 19-22, 2016  
Williamsburg, Virginia

Home Program Registration Paper Submission Venue/Hotel Student Competitions Travel Entertainment

SPONSORS:

  **COMPOSITES  
DESIGN &  
MANUFACTURING  
HUB**  **NAFEMS**  **Syracuse  
University  
University  
of Utah**



Honored to  
Host the  
ASC 32<sup>st</sup>  
Technical  
Conference



## American Society for Composites 32<sup>nd</sup> Technical Conference

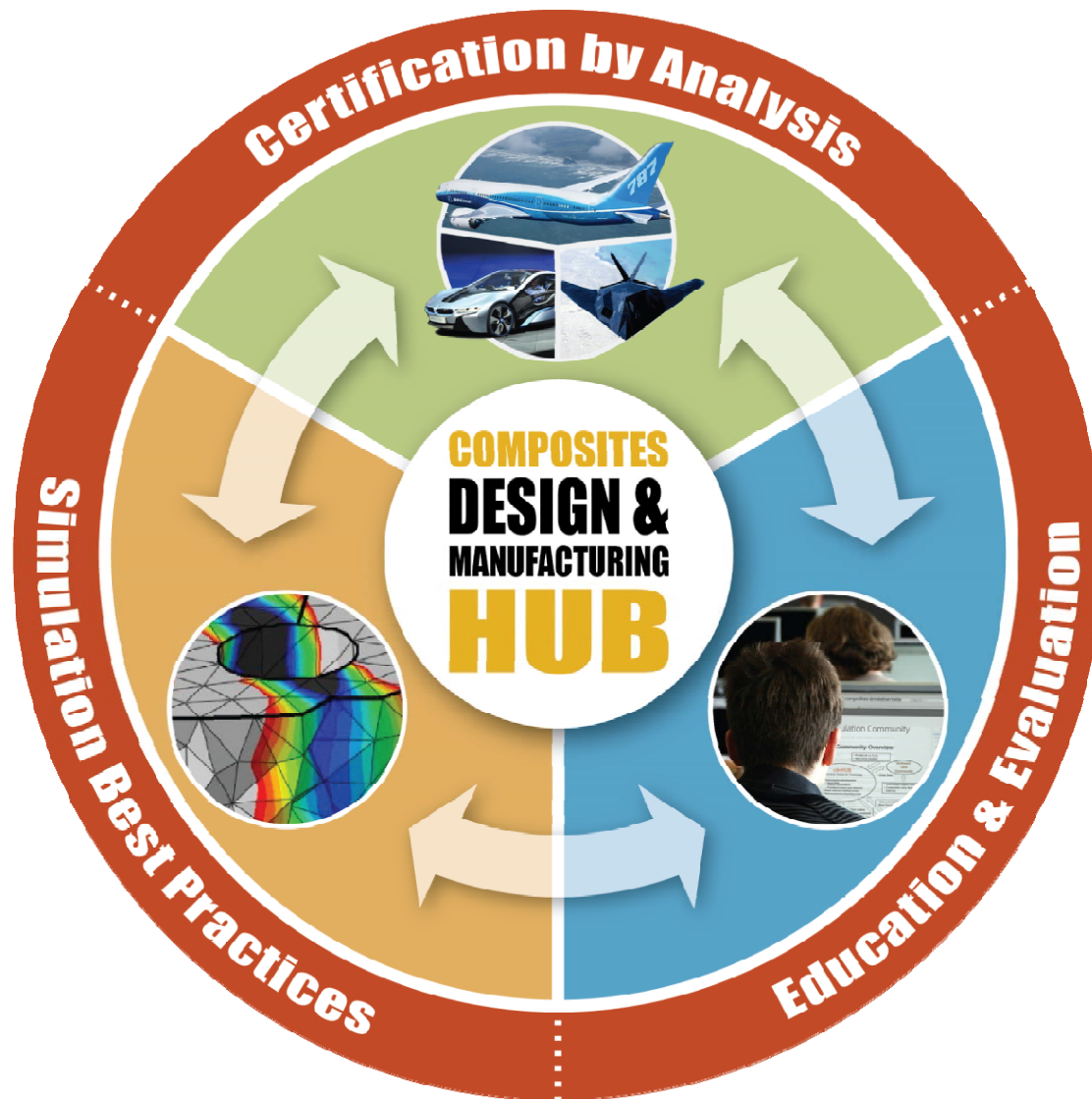
**October 22-25, 2017** West Lafayette, Indiana, USA

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

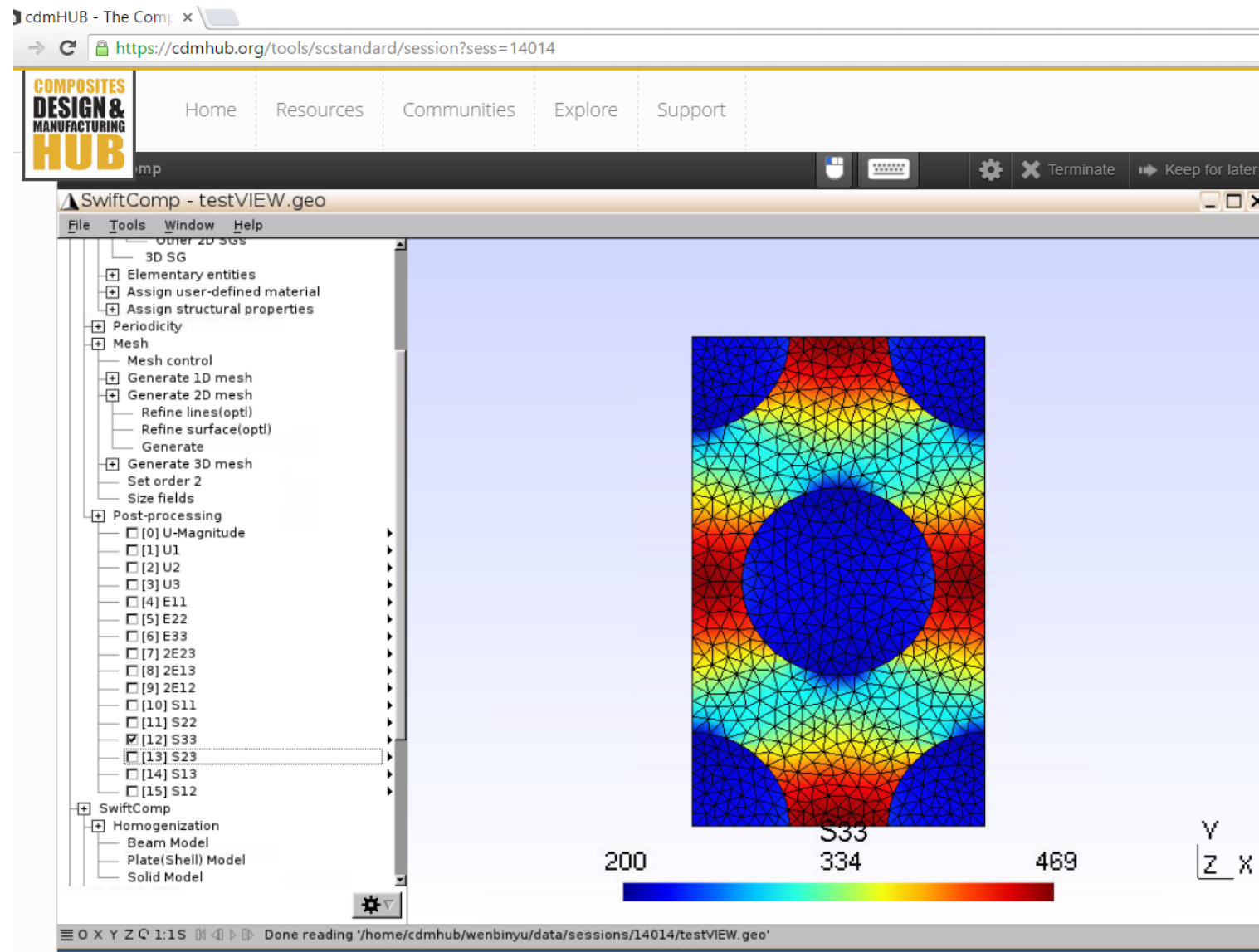


Visit [cdmHUB.org](http://cdmHUB.org) for more info.

# Composites Are the Future



# SwiftComp on cdmHUB



# LAMMPS on cdmHUB

cdmHUB - The Composites Design & Manufacturing Hub

Home Resources Communities Explore Support

**LAMMPS**

1 Input → 2 Simulate

Examples: New

Commands Data Simulation

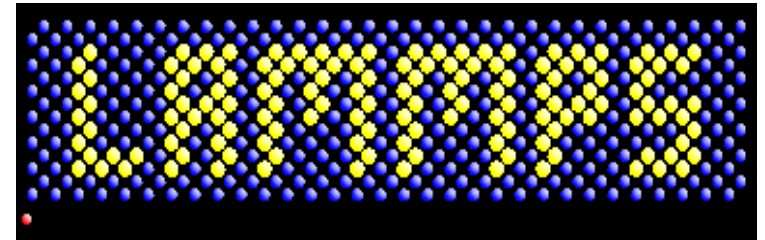
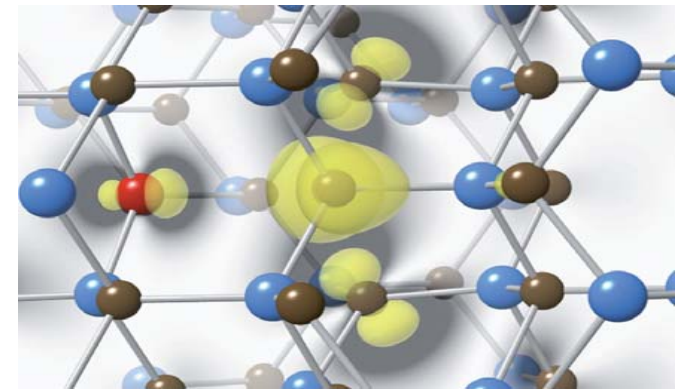
Log file name: log.lammps  
If you use the log command in your script, this value should match.

Command script: Right click to upload a LAMMPS command script

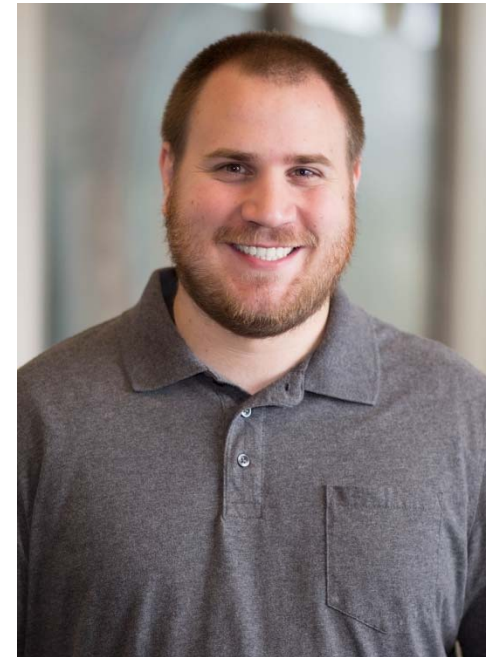
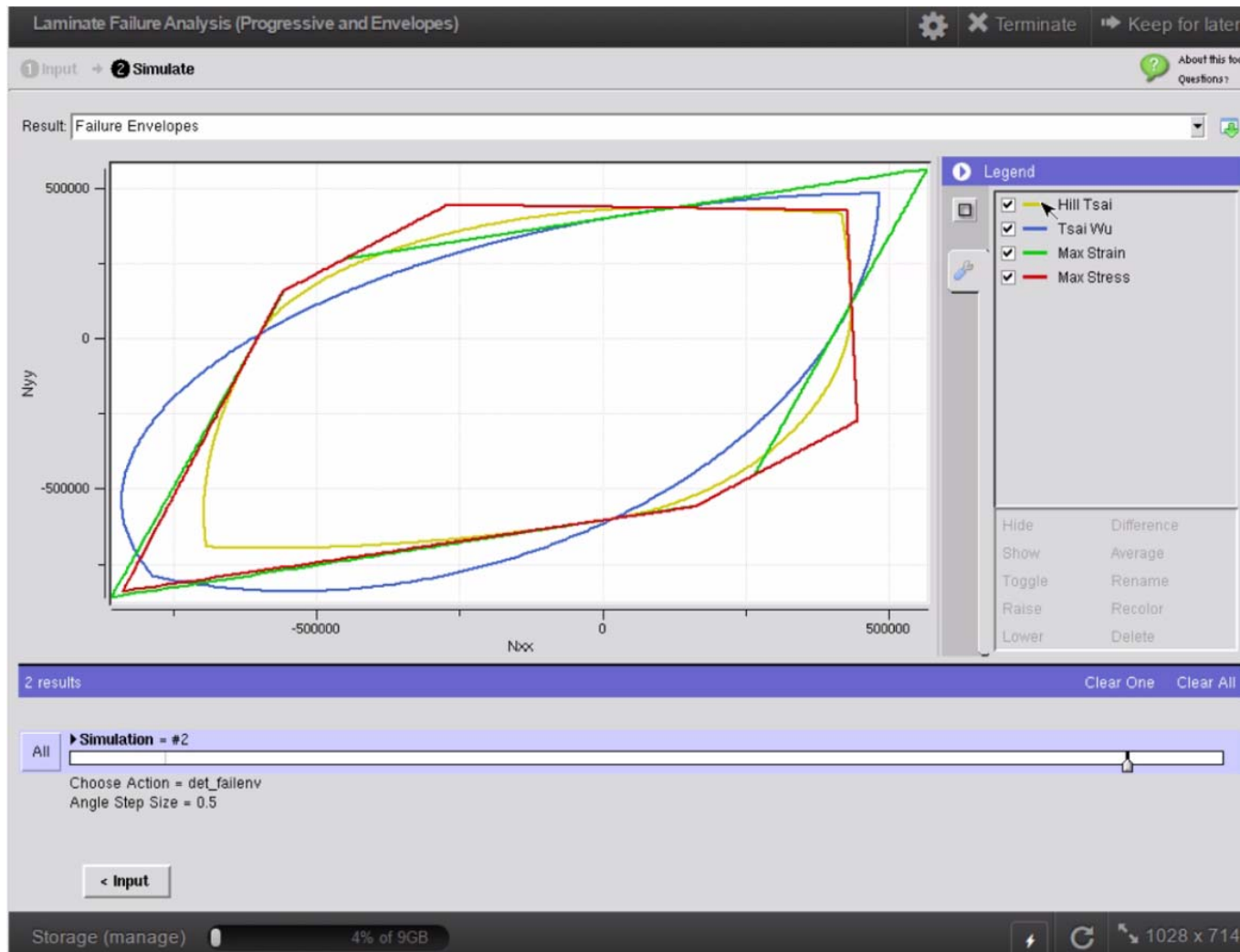
Simulate >

Storage (manage) 24% of 9GB

780 x 600



# CLT-based Progressive Failure Analysis on cdmHUB





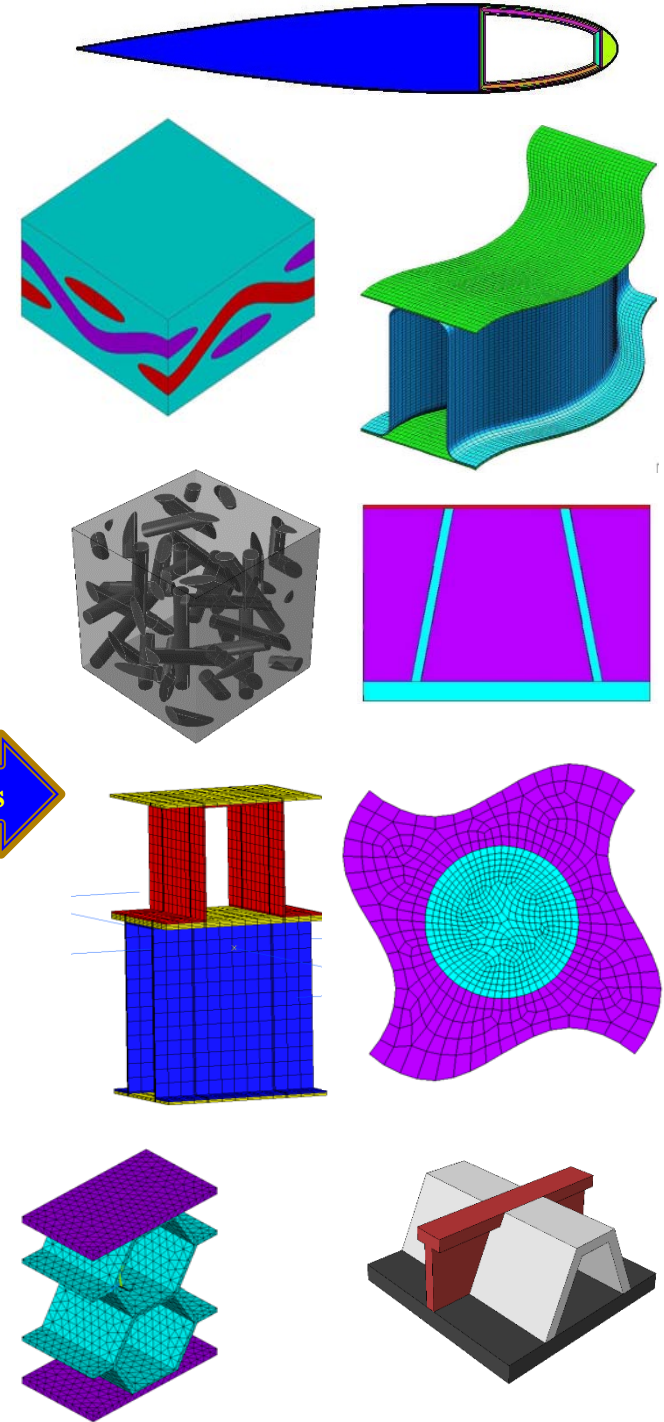
Right Results  
Right Away



SwiftComp™  
A Purdue Technology

Principle of Minimum Information Loss

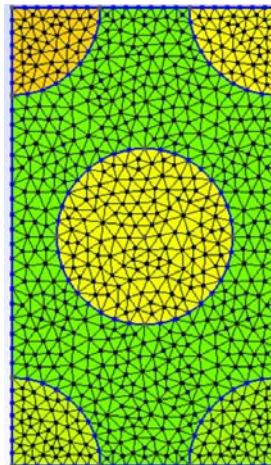
- **Virtual testing of composites**
  - Mechanical properties
  - Multifunctional properties
- **Multiscale modeling of composites**
  - 3D composite structures
  - Composite plates/shells
  - Composite beams



# SwiftComp Example #1: UD FRC

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

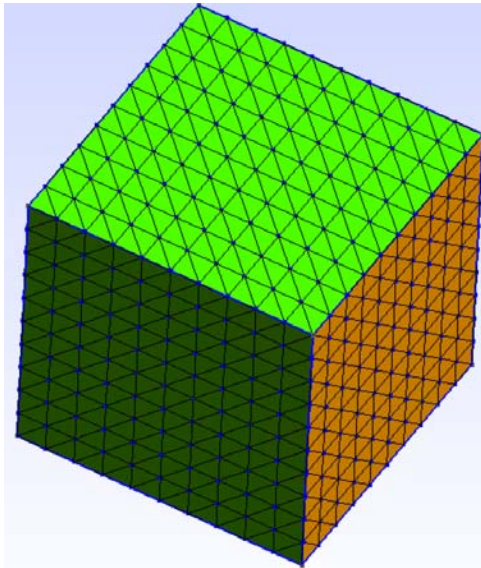
- Find the effective properties using a hexagonal packing microstructure
- Find the local stress distribution of the composites if it is under a biaxial strain loading with  $\epsilon_{11}=5 \text{ um/m}$  and  $\epsilon_{22}=2 \text{ um/m}$



# SwiftComp Example #2: PRC

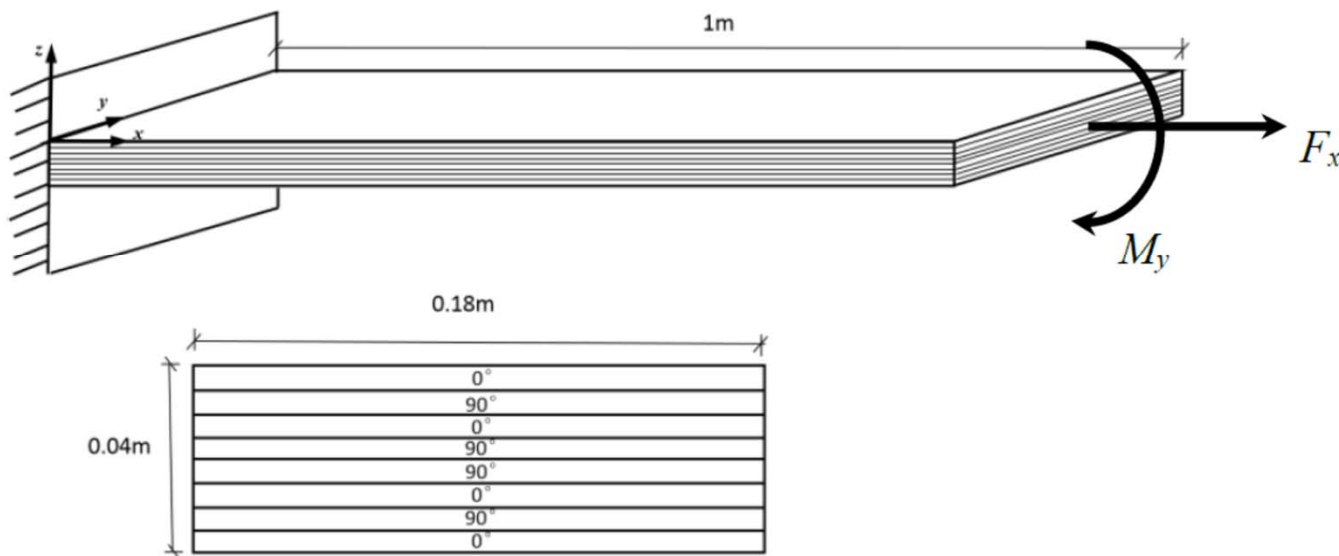
PRC: VOF: 50%, Particle E=400 GPa,  $\nu=0.3$ ; Matrix E=40 GPa,  $\nu=0.37$

- Find the effective properties
- Find the local stress distribution of the composites if it is under a biaxial strain loading with  $\epsilon_{33}=5 \text{ } \mu\text{m/m}$  and  $\epsilon_{23}=2 \text{ } \mu\text{m/m}$

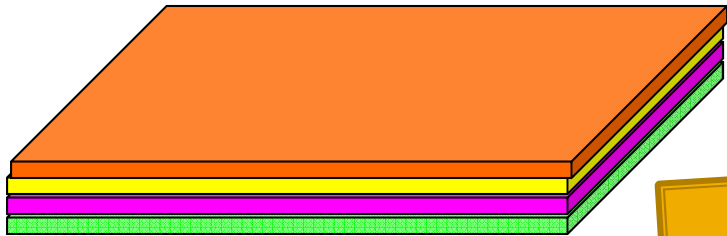


# SwiftComp Example #3: Laminate

$$E_1 = 110.5 \text{ GPa}, E_2 = E_3 = 13.64 \text{ GPa}, G_{12} = G_{13} = 3.92 \text{ GPa}, \\ G_{23} = 3.26 \text{ GPa}, \nu_{12} = \nu_{13} = 0.329, \nu_{23} = 0.400$$

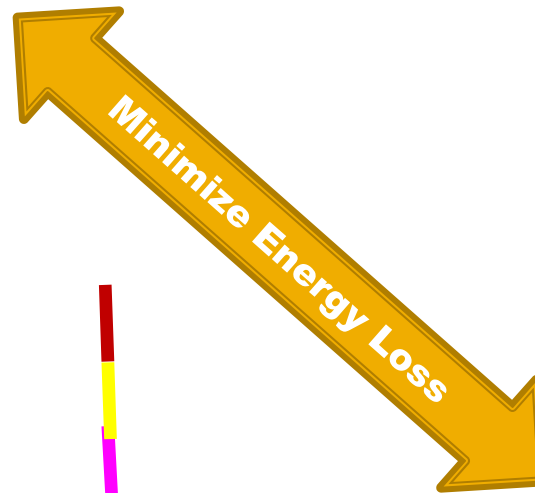


# Example 3.1: Model it as a Solid

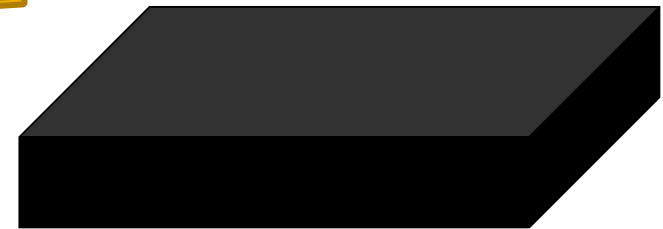


$$u_i, \varepsilon_{ij}, \sigma_{ij}, U$$

Original model: 3D continuum mechanics with layerwise heterogeneity



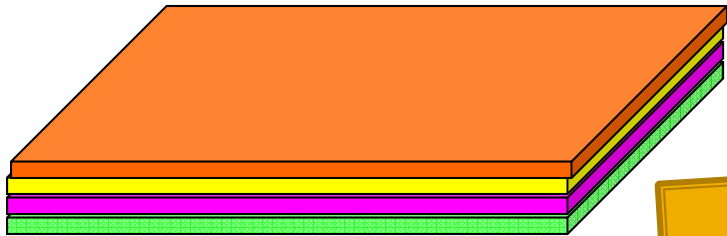
Macroscopic model: 3D continuum mechanics with homogenous solid



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

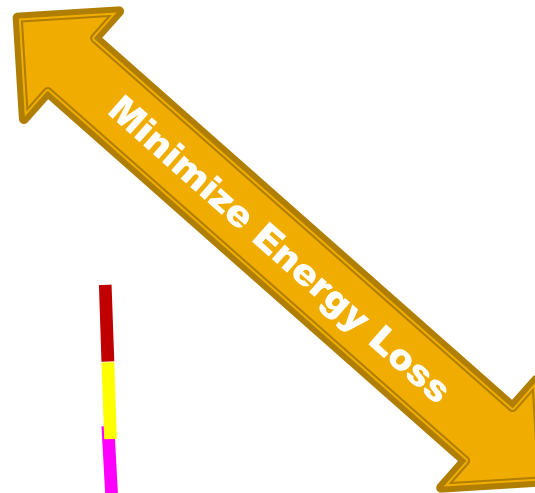


# Example 3.2: Model it as a Plate

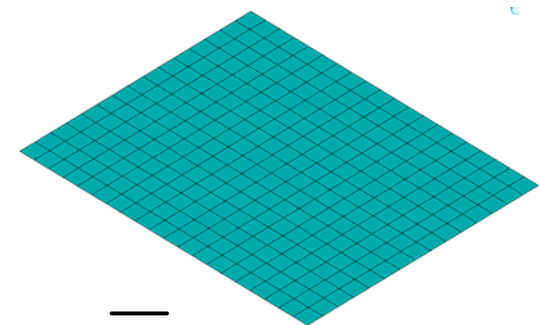


$$u_i, \varepsilon_{ij}, \sigma_{ij}, U$$

Original model: 3D continuum mechanics with layerwise heterogeneity

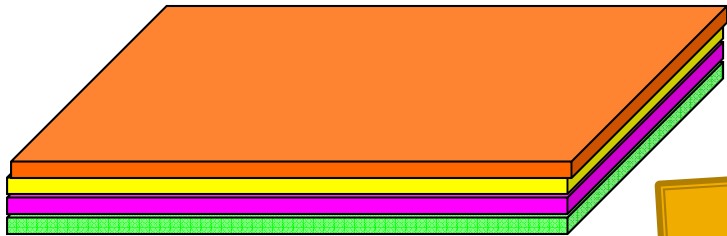


Macroscopic model:  
2D plate model



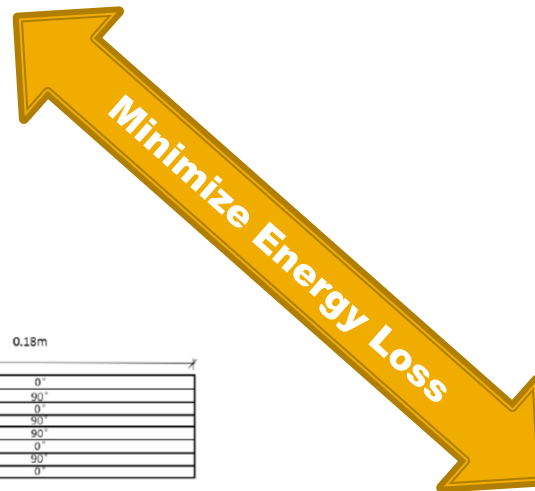
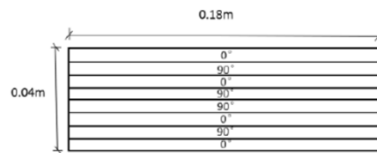
$$\bar{u}_i, \bar{\varepsilon}_{\alpha\beta}, \bar{K}_{\alpha\beta}, N_{\alpha\beta}, M_{\alpha\beta}, \bar{U}$$

# Example 3.3: Model it as a Beam

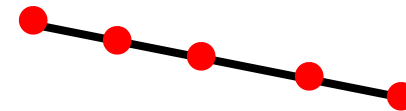


$$u_i, \varepsilon_{ij}, \sigma_{ij}, U$$

Original model: 3D continuum mechanics with layerwise heterogeneity



Macroscopic model: 1D beam model



# 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>

# If You Have Questions.....

## **Prof. Wenbin Yu**

**Director**, Composites Virtual Factory HUB

**Associate Director**, Composites Design & Manufacturing HUB

**CTO**, AnalySwift LLC

**Associate Professor**, Purdue/AAE

Follow Prof. Yu's research at

cdmHUB: <https://cdmhub.org/groups/yugroup>

LinkedIn: <https://www.linkedin.com/groups/8521014>

YouTube:

<https://www.youtube.com/channel/UCqilUid7Xj4JXIQskD7g7lw>



**PURDUE**  
UNIVERSITY

**COMPOSITES  
DESIGN &  
MANUFACTURING  
HUB**