# cdmHUB.org

## The Composites Design & Manufacturing HUB:

A Platform for Pervasive Composites Learning in the Cloud

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Wenbin Yu
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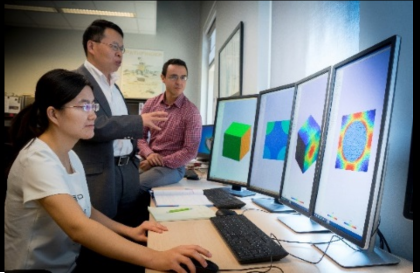
# The Vision



- 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 - real 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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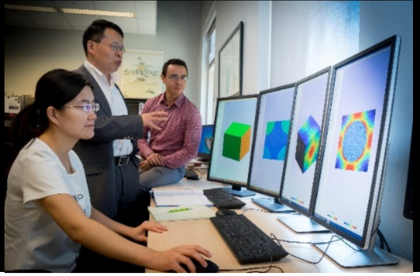
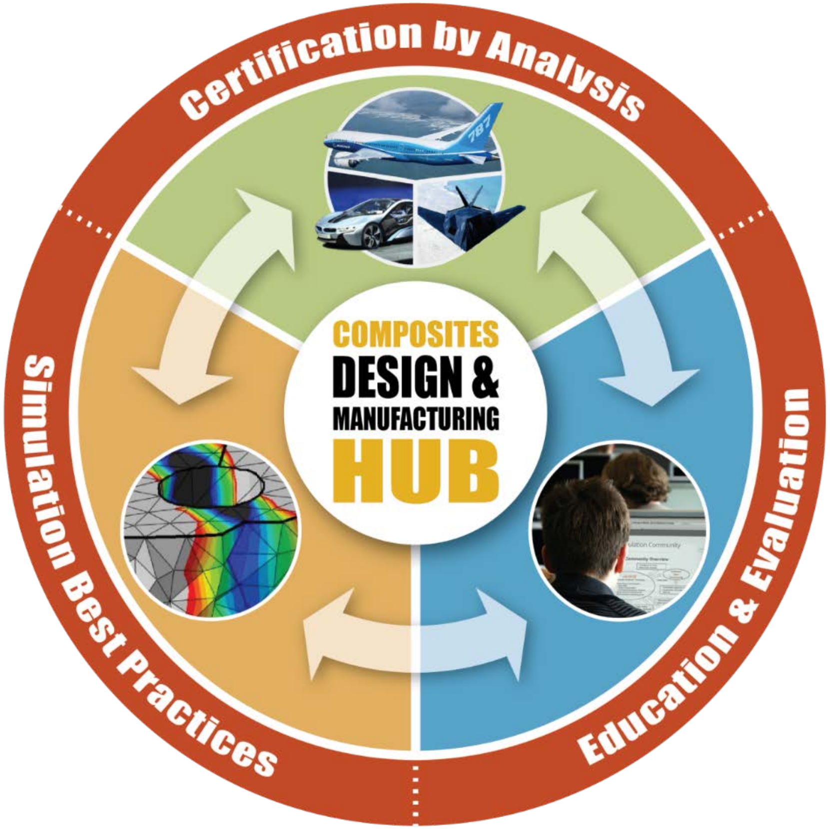
# The Mission



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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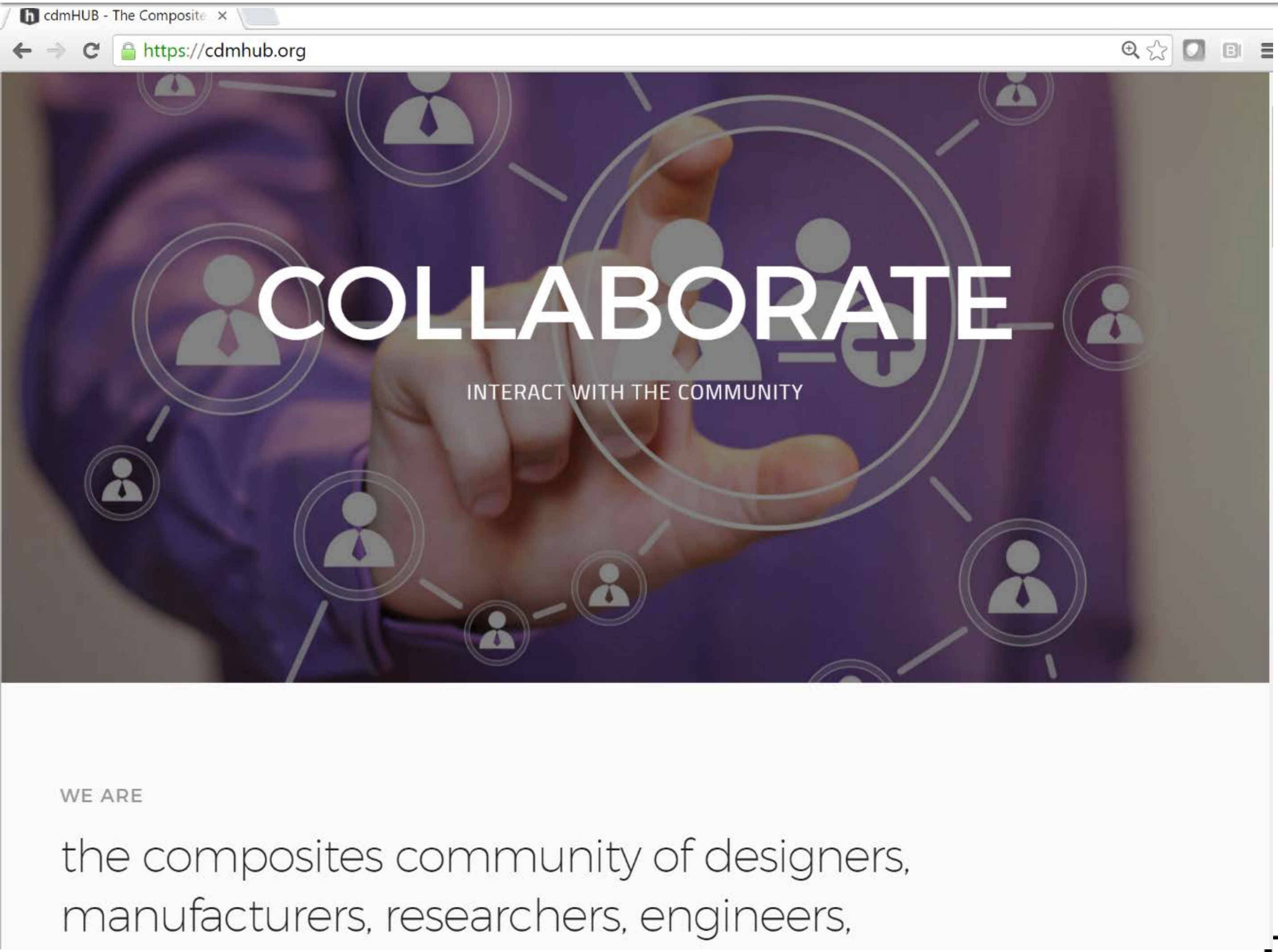
# The Online Composites Community




*Over 2000 Users to Date!*

*On our way to 10,000!*

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# cdmHUB Platform Overview

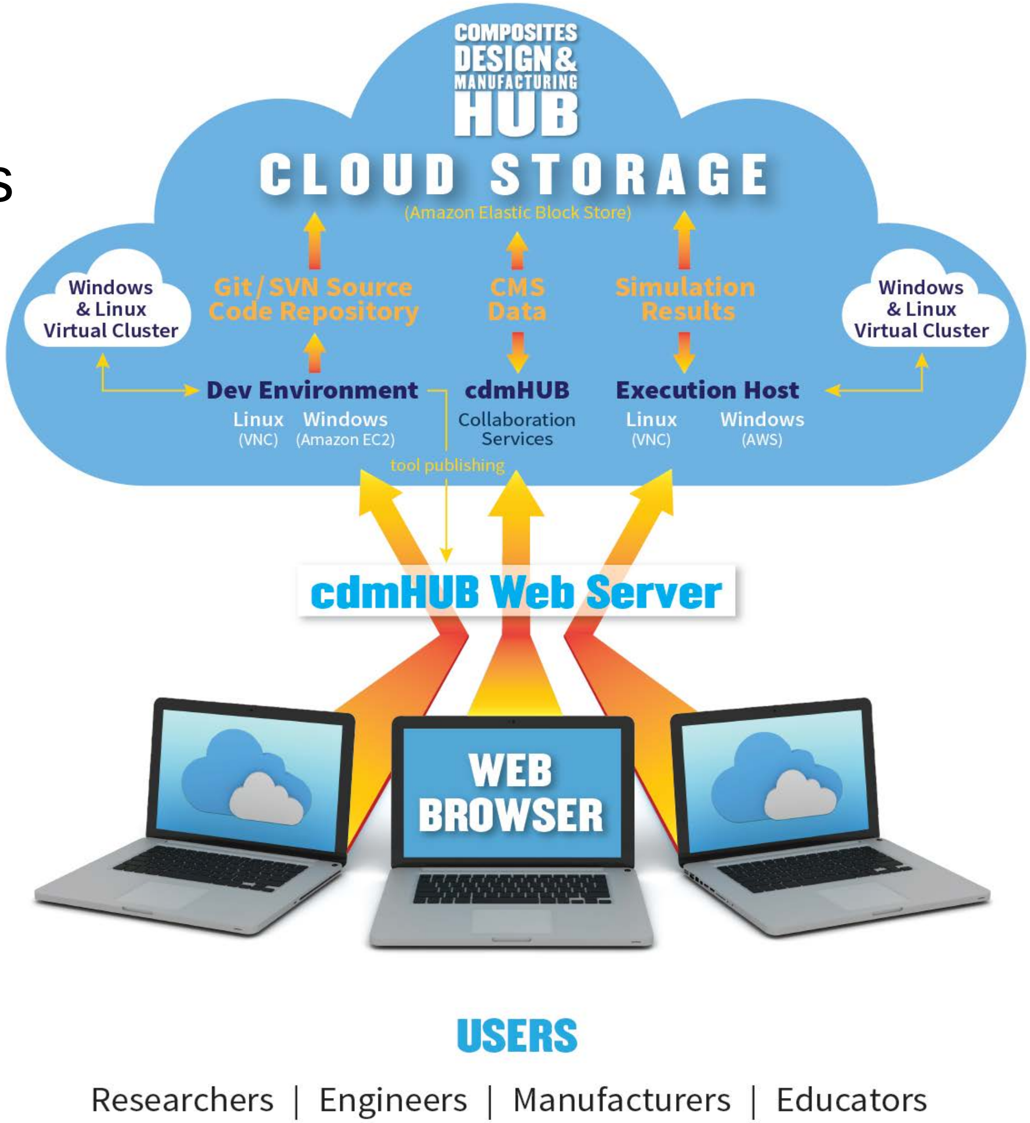
Collaboration Services

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 the tool functionalities?*
  - *How is a particular tool connected with other tools?*
- Tool development for manufacturing and processing 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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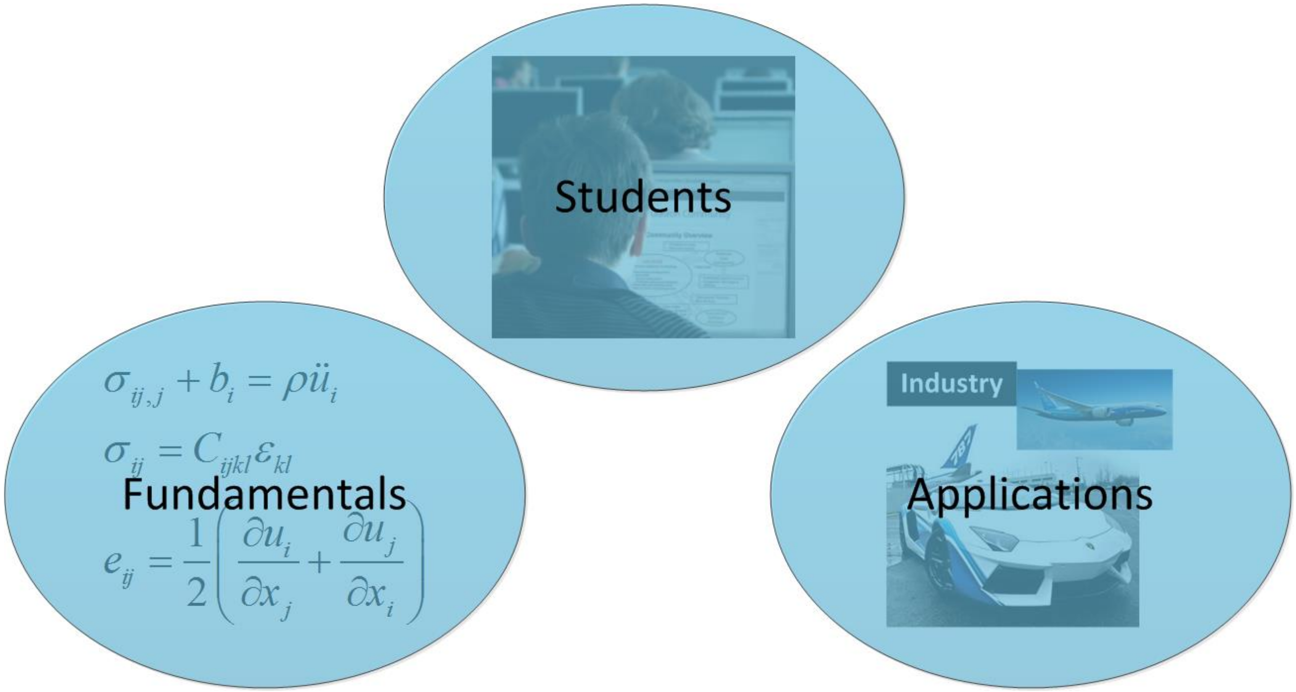
# Simulation Tools Advance Composites Education




Simulation Tools enable Students to connect the Fundamentals to the Applications

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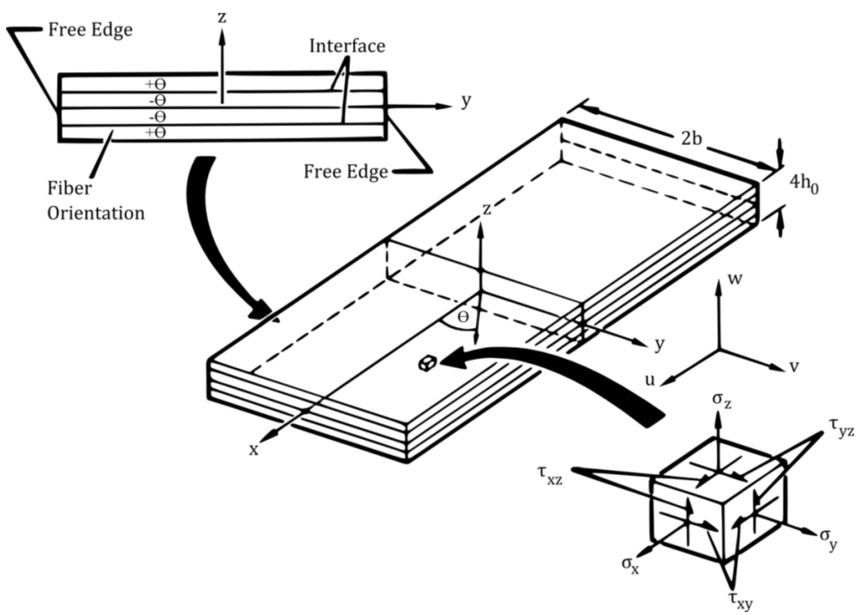
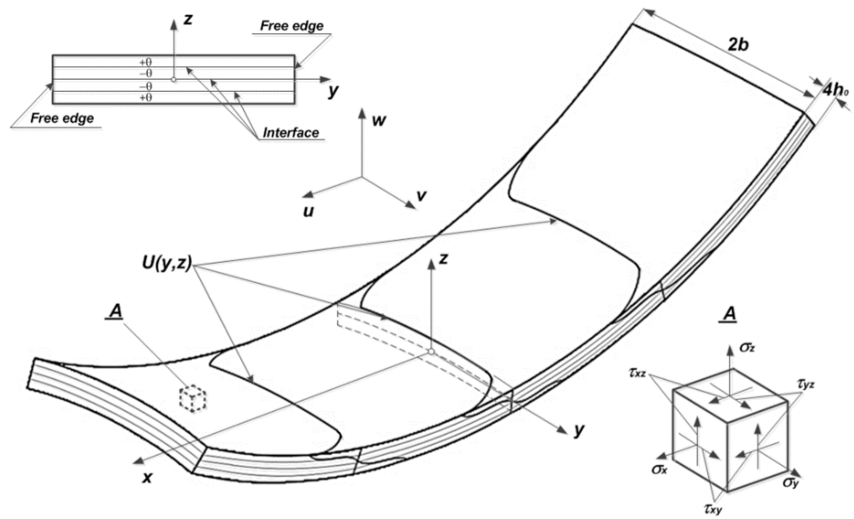
# The Pipes-Pagano "Free-Edge" Interlaminar Stress Problem





Pipes, R. B. and Pagano, N. J., "Interlaminar Stresses in Composite Laminates Under Uniform Axial Extension," J. Comp. Matl., 1970

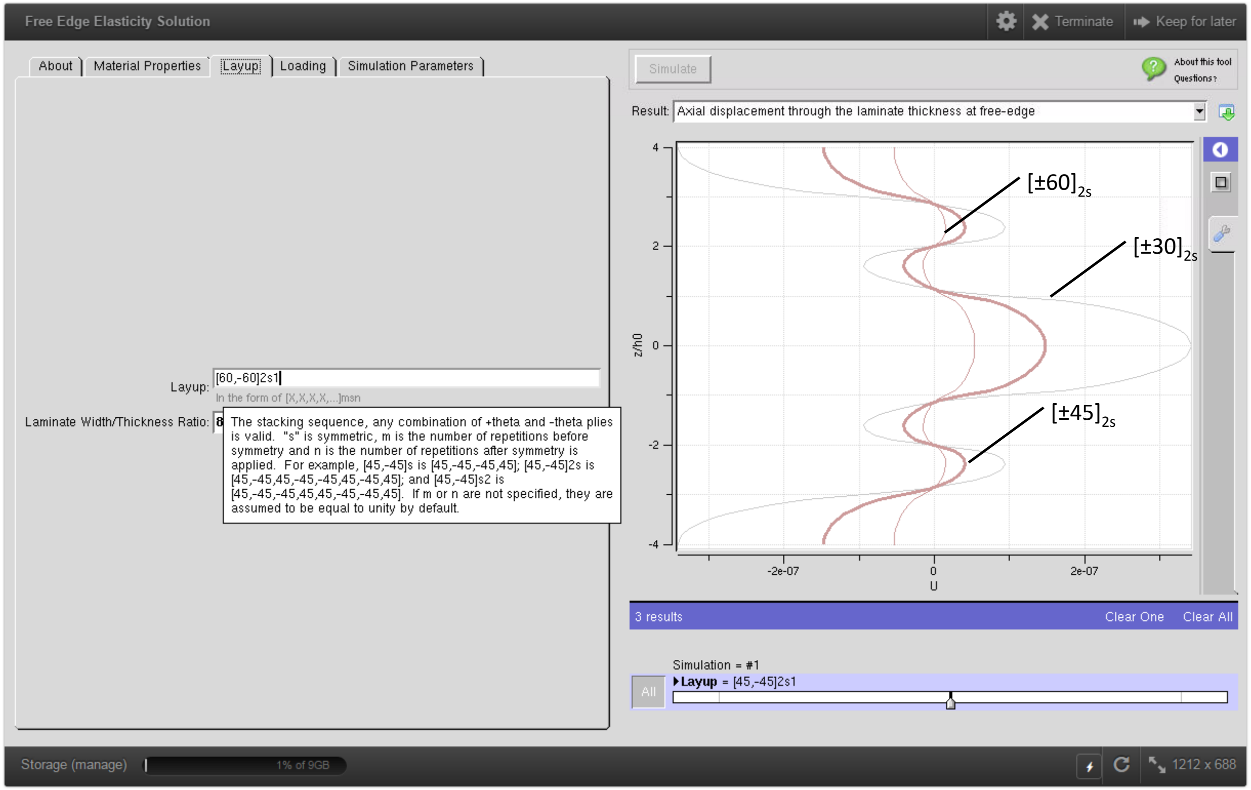
Pipes, R. B., and Pagano, N. J., "Interlaminar Stresses in Composite Laminates-An Approximate Elasticity Solution," J. App. Mech., 1974

Goodsell, J., Pipes, R.B., "Interlaminar Stresses in Angle-Ply Laminates: a Family of Solutions," Journal of Applied Mechanics, Vol. 83, No. 5, (2016).

Pipes, R. B., Goodsell, J., Ritchey, A., Dustin, J, and Gosse, J., "Interlaminar Stresses in Composite Laminates: Thermoelastic Deformation," Comp. Sci. Tech., 2010

Goodsell, J., Pagano, N. J., Kravchenko, O., and Pipes, R. B., "Interlaminar Stresses in Composite Laminates Subjected to Anticlastic Bending Deformation," J. App. Mech., 2013

# Multiple solutions at your fingertips

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# Accelerate Exploration and Learning

$$U(y,z)=\sum_{n=1}^{\infty}\frac{2\alpha^{1/2}}{n\pi\upsilon^{2}}\Lambda_k\frac{e^{-\upsilon\alpha^{-1/2}(b-y)}-e^{-\upsilon\alpha^{-1/2}(b+y)}}{1+2e^{-2\upsilon\alpha^{-1/2}b}}\cos\upsilon\left(z+\frac{mh_0}{2}\right)$$

$$U_y(y,z)=\sum_{n=1}^{\infty}\frac{2}{n\pi\upsilon}\Lambda_k\frac{e^{-\upsilon\alpha^{-1/2}(b-y)}+e^{-\upsilon\alpha^{-1/2}(b+y)}}{1+2e^{-2\upsilon\alpha^{-1/2}b}}\cos\upsilon\left(z+\frac{mh_0}{2}\right)$$

$$U_z(y,z)=-\sum_{n=1}^{\infty}\frac{2\alpha^{1/2}}{n\pi\upsilon}\Lambda_k\frac{e^{-\upsilon\alpha^{-1/2}(b-y)}-e^{-\upsilon\alpha^{-1/2}(b+y)}}{1+2e^{-2\upsilon\alpha^{-1/2}b}}\sin\upsilon\left(z+\frac{mh_0}{2}\right)$$

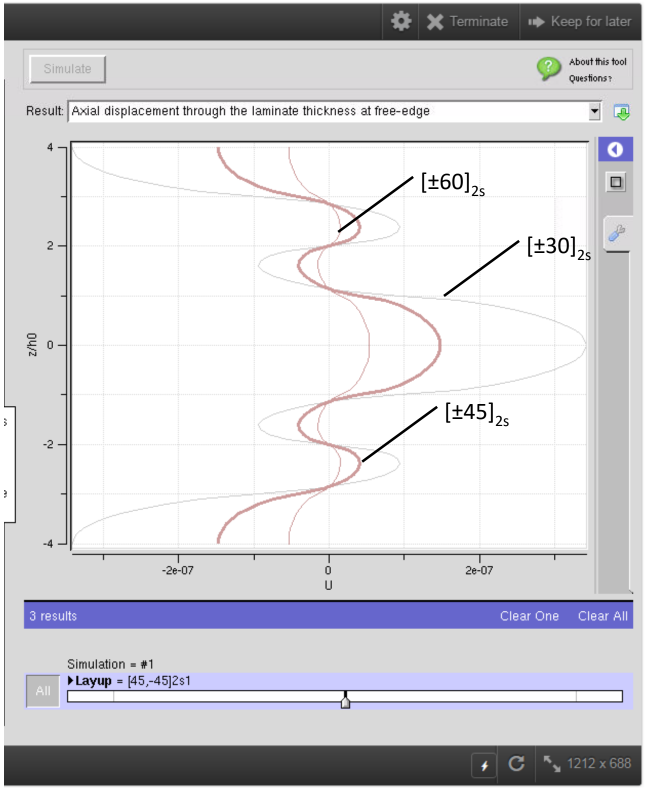
$$\upsilon=\frac{n\pi}{mh_0}$$

$$\Lambda_k=\sum_{k=1}^{m}\left\{\begin{array}{l}\upsilon\left(\Phi_E+\Phi_T\right)\left[\sin\upsilon\left(z+\frac{mh_0}{2}\right)\right]_{(k-1)h_0}^{kh_0}\\ +\Phi_B\left[\cos\upsilon\left(z+\frac{mh_0}{2}\right)+\upsilon z\sin\upsilon\left(z+\frac{mh_0}{2}\right)\right]_{(k-1)h_0}^{kh_0}\end{array}\right\}$$

$$\Phi_E=\frac{S_{16}}{S_{11}}\varepsilon_0$$

$$\Phi_T=\frac{S_{55}}{\alpha S_{66}}\alpha_{xy}\Delta T$$

$$\Phi_B=\frac{S_{16}}{S_{11}}\kappa_x$$

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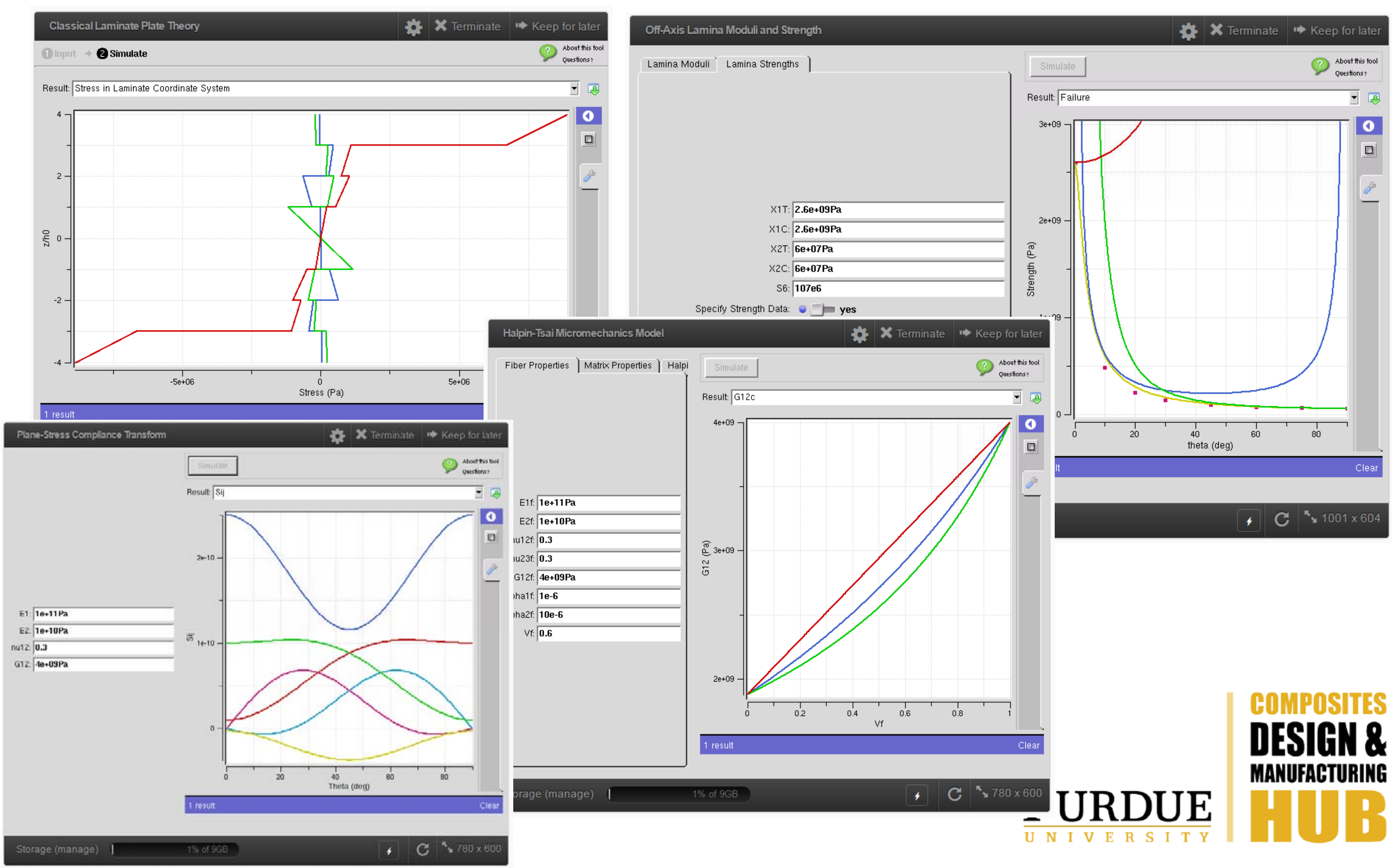
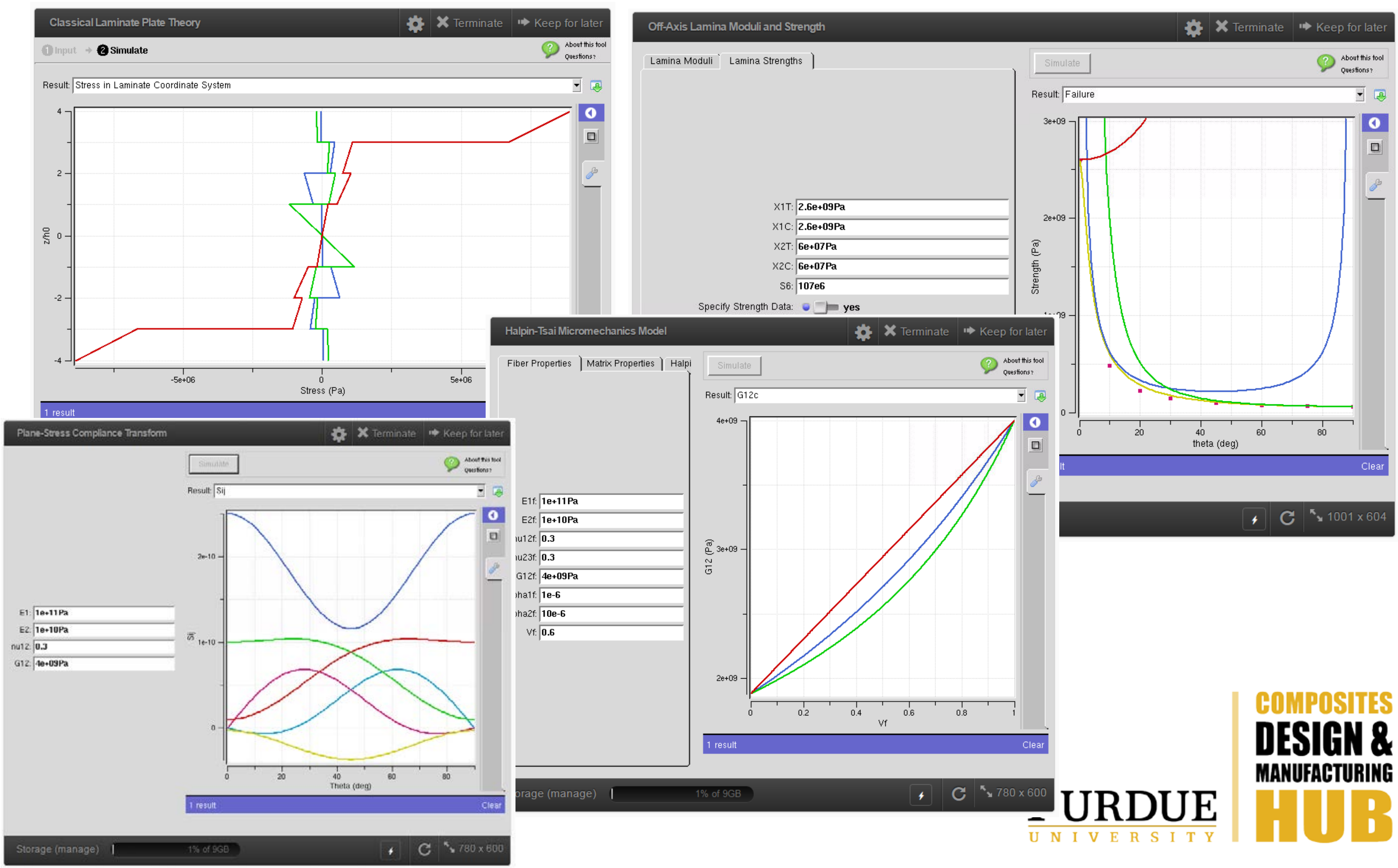
# Composites Fundamentals

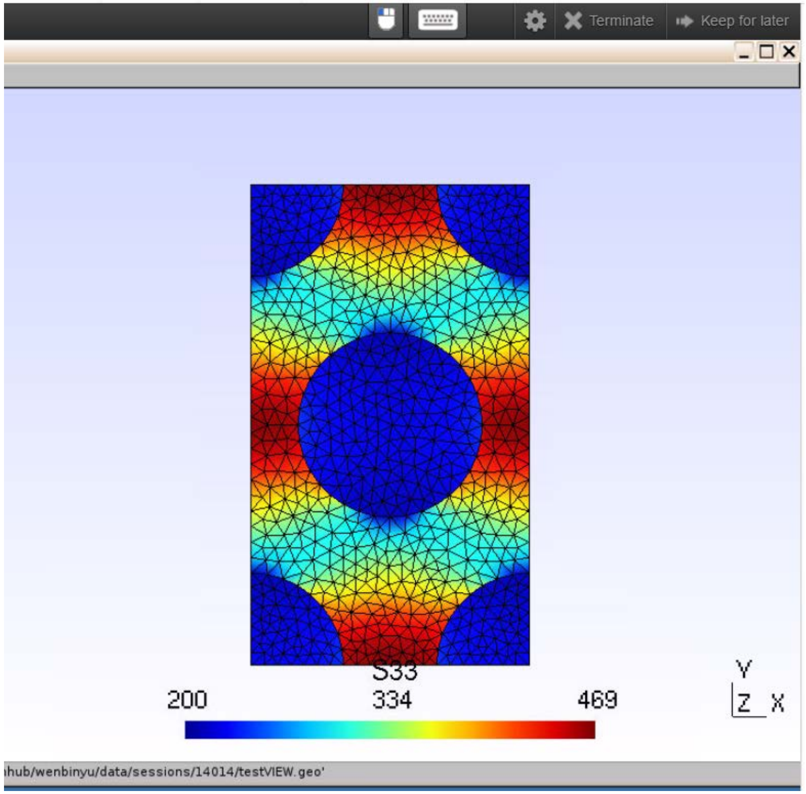


# Composites Fundamentals



# And More…

| Classical Composites Analysis | Advanced Composites Analysis | Processing |
|---|---|---|
| Classical Laminate Plate Theory | Free Edge Elasticity Solution | Autocatalytic Degree of Cure (Cure Kinetics) |
| Effective Lamina and Laminate Properties | Geometrically Exact Beam Theory | DiBenedetto Equation (Tg) |
| Fiber Spacing and Volume Fraction | LAMMPS (Molecular Dynamics) | |
| Fiber Volume Fraction | SwiftComp | |
| G_to_K Orthotropic Conversion & K_to_G Conversion | SwiftComp Pro | |
| Halpin-Tsai Micromechanics Model | Variational Asymptotic Beam Analysis | |
| Laminate Failure Analysis | Viscoelastic Shear Lag | |
| Off-Axis Lamina Moduli and Strength | | |
| Plane-Stress Compliance Transform | | |

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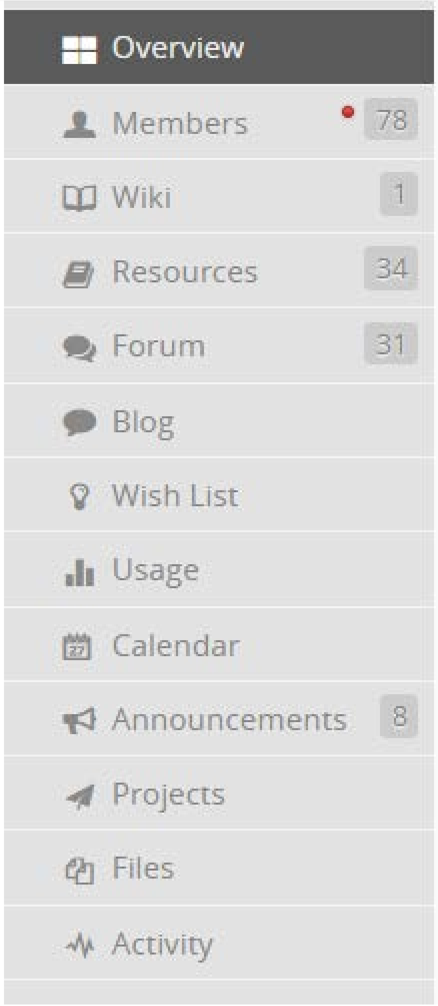
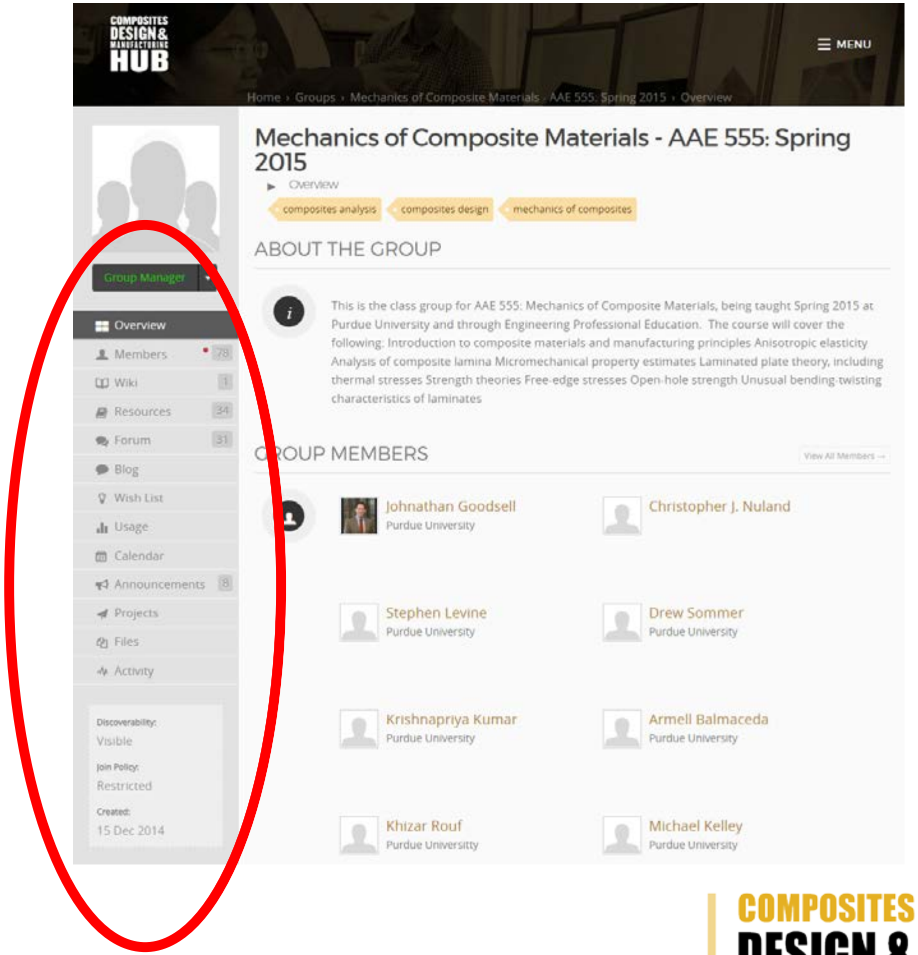
# A Full-Range of Course Management Features

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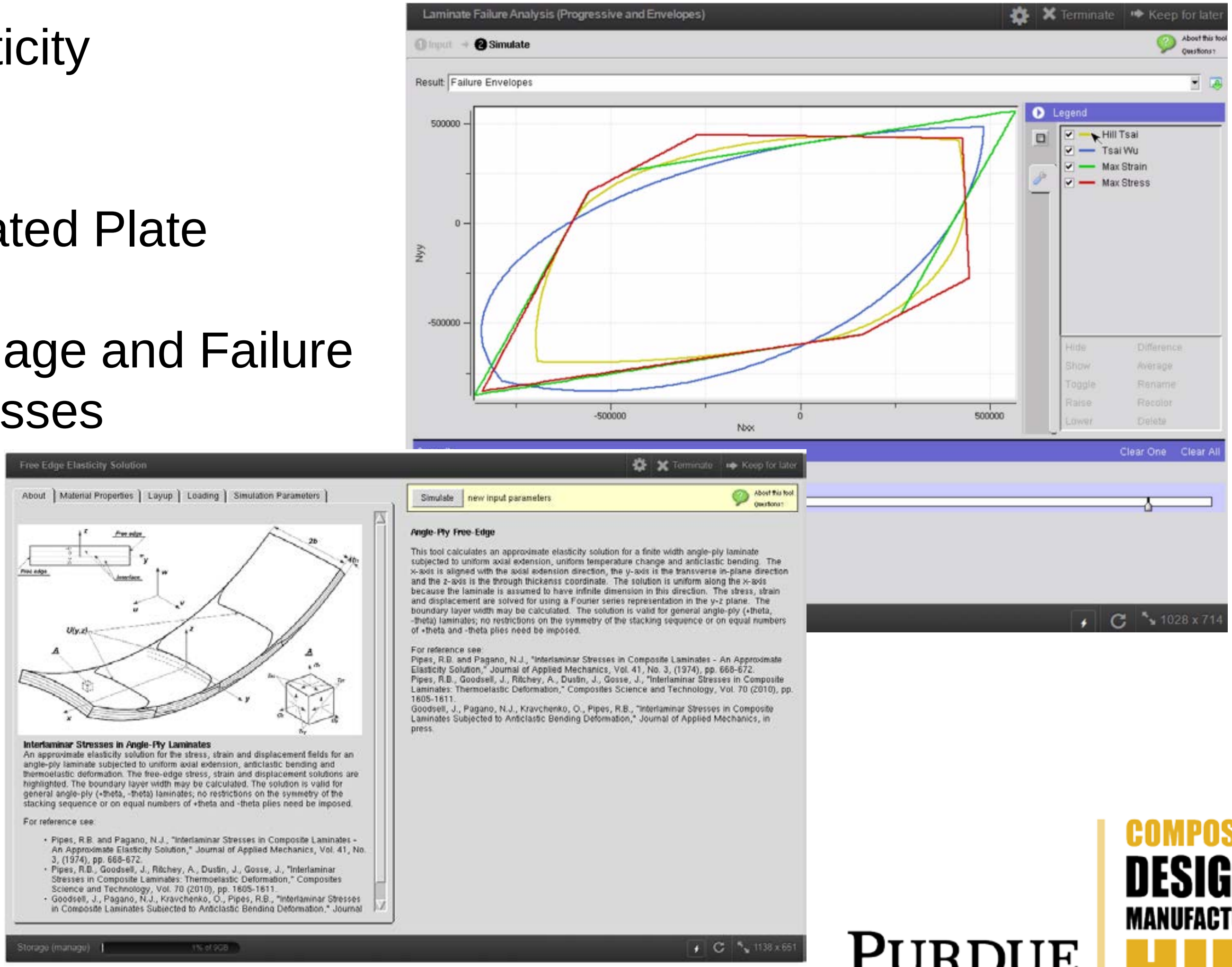
# Mechanics of Composite Materials

- Anisotropic Elasticity
- Lamina Analysis
- Micromechanics
- Classical Laminated Plate Theory
- Elementary Damage and Failure
- Interlaminar Stresses

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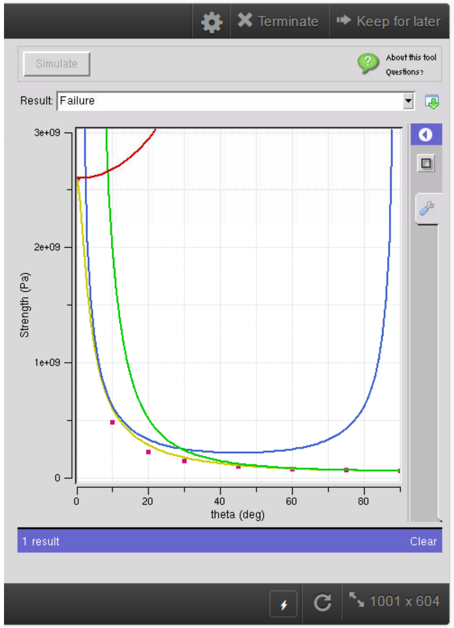
# Experimental Characterization of Advanced Composite Materials

| Experiment | Output |
| --- | --- |
| **Microscopy** | **Fiber volume fraction, fiber spacing,** void content |
| **0-degree and 90-degree tension** | **Lamina tensile moduli**: $E_1$, $E_2$, $\nu_{12}$ **Lamina tensile strengths**: $X^T$, $Y^T$ |
| **±45-degree tension** | **Lamina shear moduli**: $G_{12}$ **Lamina shear strength**: S |
| **Off-axis tension (often 10-degree, 30-degree, 45-degree and 60-degree)** | **Lamina off-axis modulus**, $E_x$ **Lamina biaxial strength** |
| **Laminate tension (often [0/±45/90]s, [0/±45/0]s, [±25]s, etc…)** | **Laminate tensile modulus**: $E_x$ **Laminate uniaxial tensile strength** |
| **Lamina thermoelastic** | Lamina coefficients of thermal expansion: $\alpha_1$, $\alpha_2$ |
| **Laminate thermoelastic** | **Laminate coefficients of thermal expansion**: $\alpha_x$, $\alpha_y$, $\alpha_{xy}$ |
| **Lamina and laminate flexure** | Lamina and laminate flexure modulus Lamina and laminate flexure strength |
| **Laminate open-hole tension** | *Laminate open-hole strength* |
| **Lamina double-cantilever beam (DCB)** | Mode I energy release rate, $G_{Ic}$ |
| **Lamina end-notch flexure (ENF)** | Mode II energy release rate, $G_{IIc}$ |

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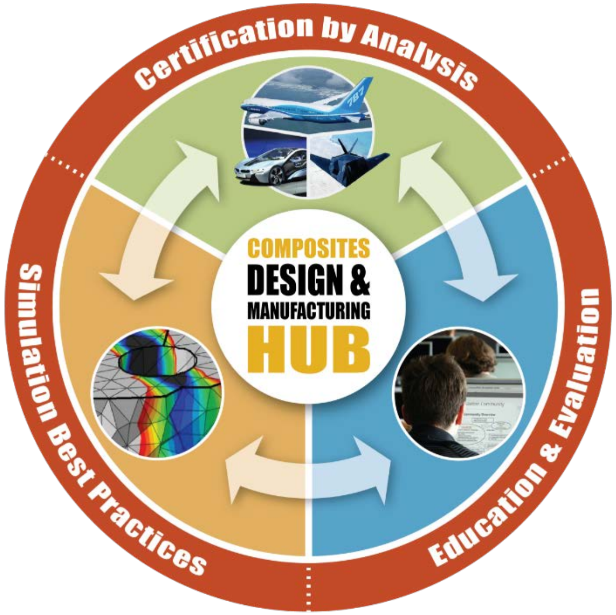
# Closing Remarks

1. Simulation can accelerate learning, in both a theory and experimental-based course
2. Education must address the “what-to” and the “where-to/when-to” as well as the “how-to”
3. Simulation must be grounded in validation
4. The cdmHUB provides tools and a platform for the above

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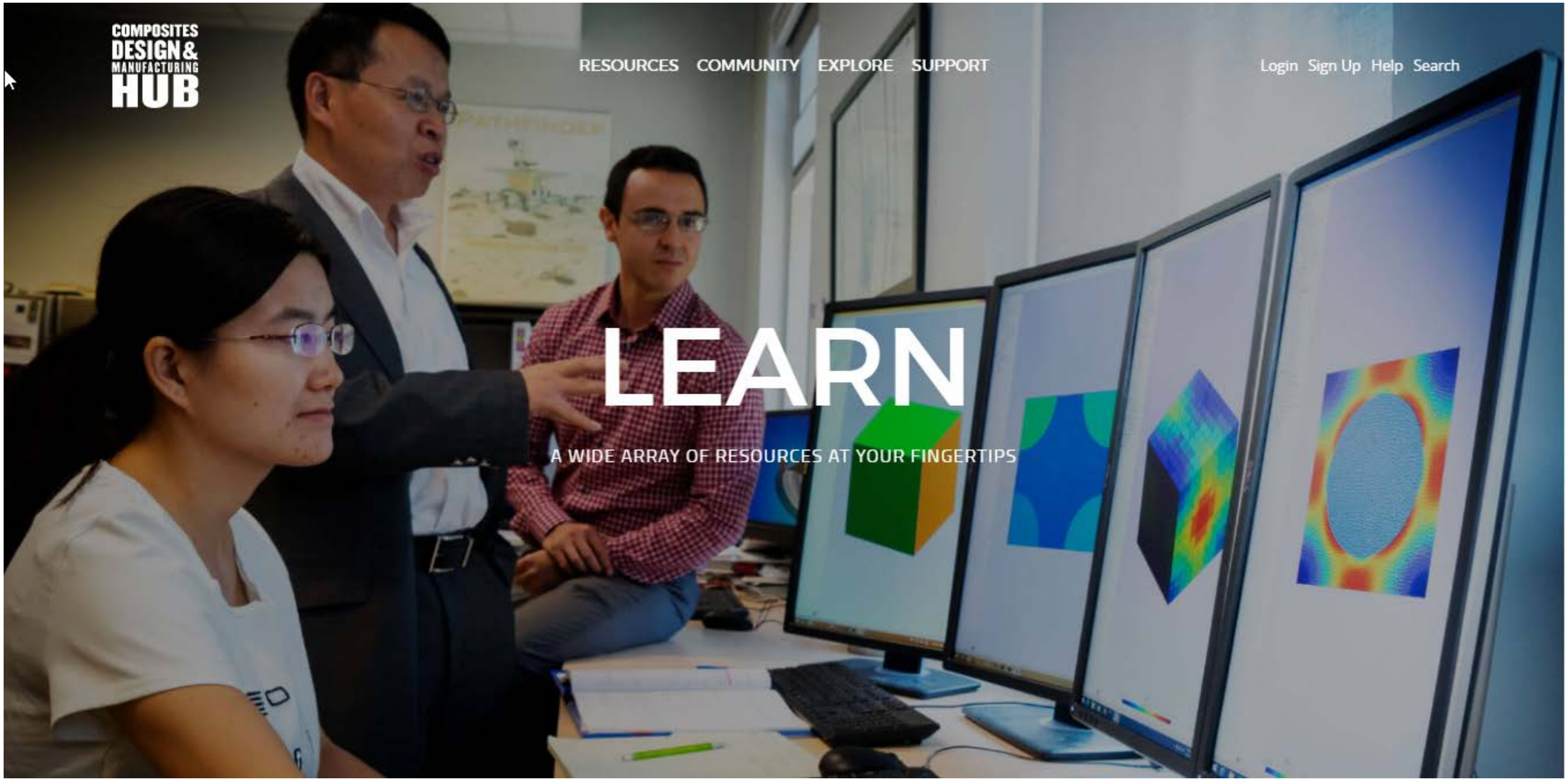
# cdmHUB.org: Learn Composites in the Cloud

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