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Modeling of Materials – Getting to a Smaller Scale

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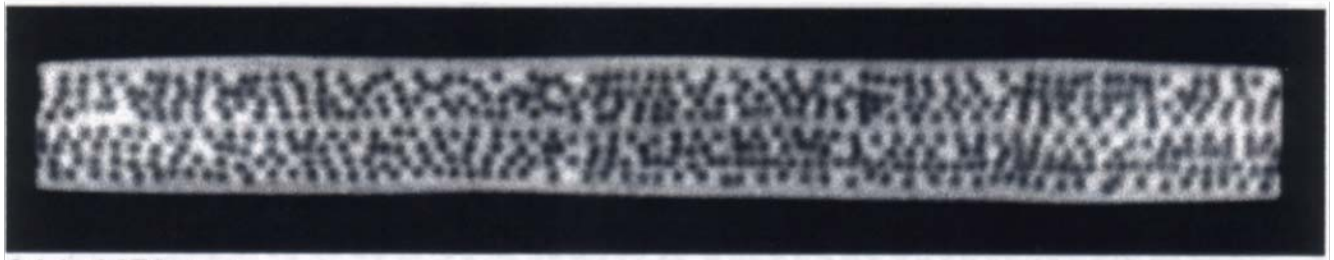
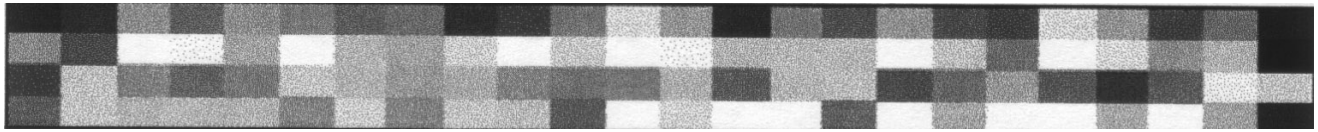
Outline

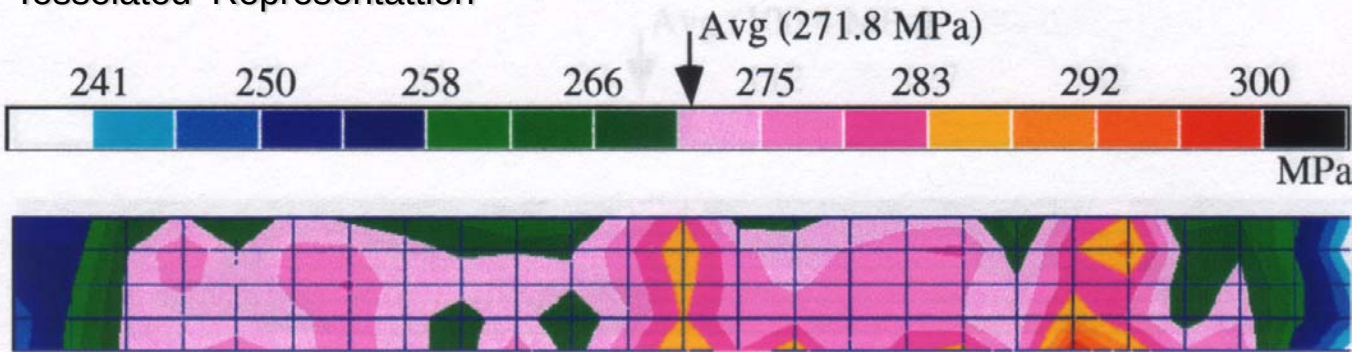
- Background
- Current Research
- Pre- and Post-Processing Requirements
  - Guiding the Analyst
  - Setting up the Analysis
  - Statistical Variation of Material Properties
  - Results Visualization
- Optimization
- Learning from our Kids
- Conclusions

Past Research





Tesselated Representattion



Von Mises Stress Plot

Major Findings

- Fiber Spacing has a significant effect on stresses between fibers
- Areas with tight fiber spacing produce highest stresses between fibers as well as highest local composite stresses
- Thermal stresses upon cool down can cause cracking between fibers
- Micromechanical model is important in predicting damage initiation and propagation

Current Research

- Multi-Level Mechanics Modeling
  - S. Ghosh – Ohio State – Voronoi Cell FEM
  - Firehole Technologies – Multicontinuum Technology
  - Alpha Star Corp. – Multiscale Heiarchical Modeling
  - Others

The Future

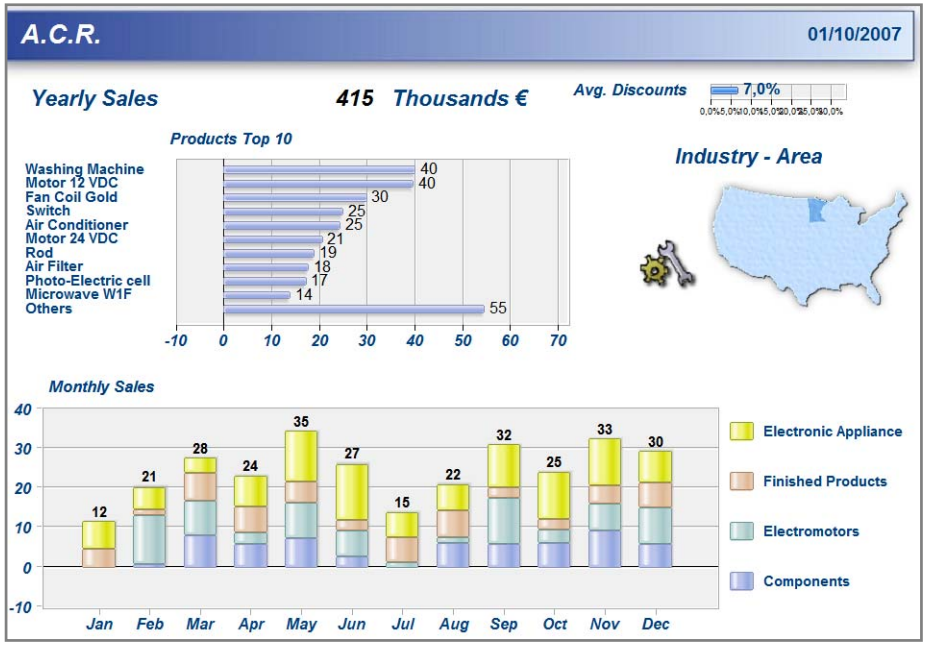
- MultiScale Modeling provides value, especially for damage modeling
- Computer technology is making multiscale modeling more practical
- Pre- and Post-processing technology needs to advance to address the unique issues with multiscale modeling

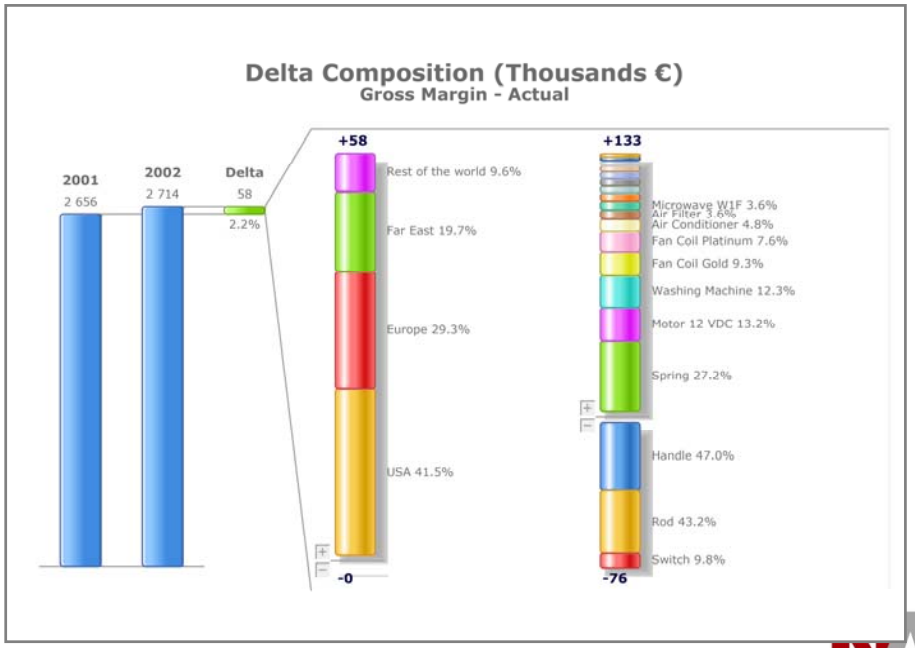
Guiding the Analyst

- Modeling of every molecule is not practical
- Molecular Level Model may be needed in selected areas
- What information does the analyst need to make decisions on model refinement?

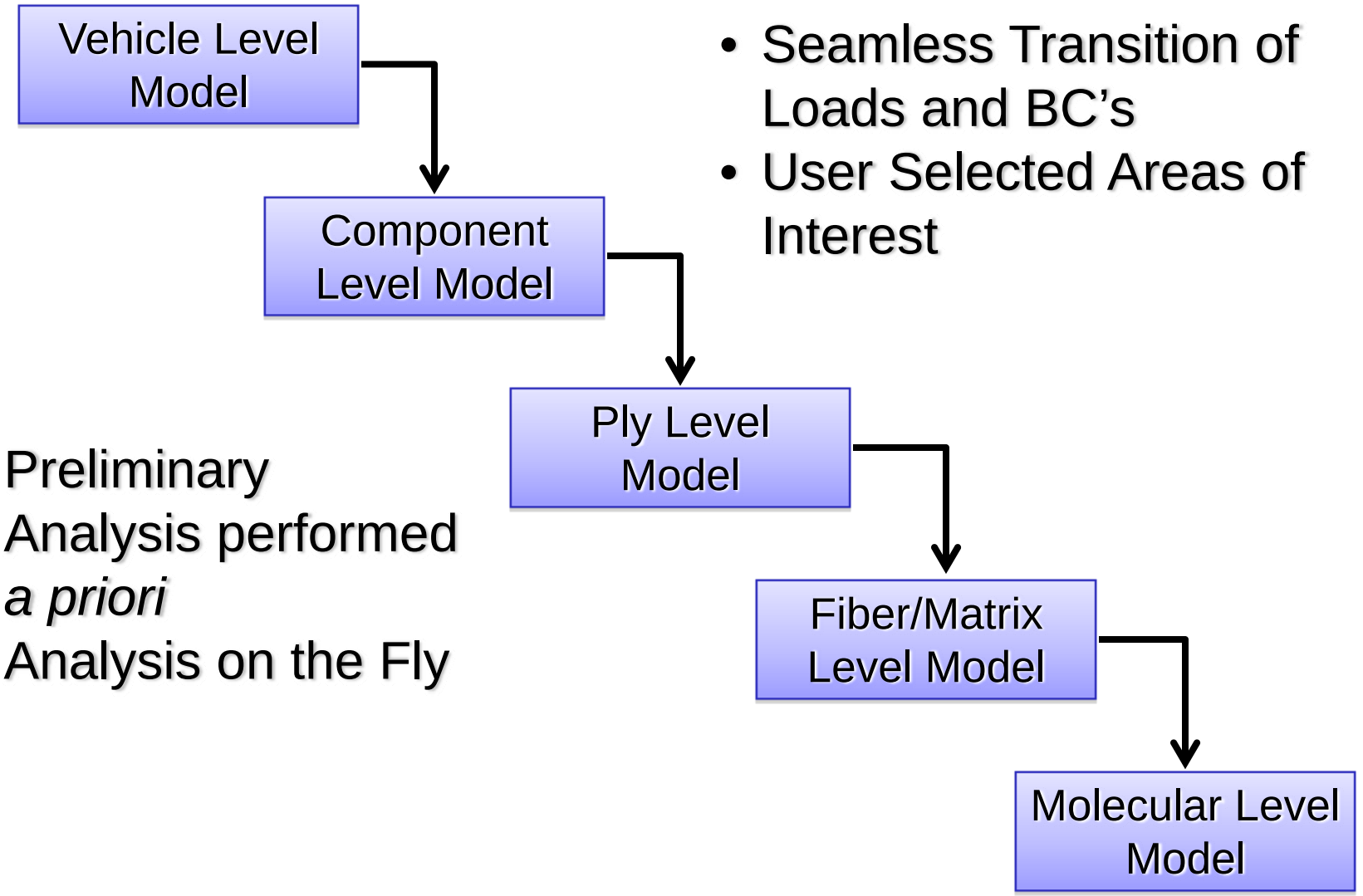
Drilling Down Thru the Data

- Business Data can be Analyzed at Many Levels
- Business decisions are made based on rapid interrogation of the available data





Modeling Guide



- Seamless Transition of Loads and BC's
- User Selected Areas of Interest

- Preliminary Analysis performed *a priori*
- Analysis on the Fly

Setting up the Analysis

- Analysis Today is set up with Geometry
- Composites analysis requires a lot of non-geometric entities
  - Plys
  - Fiber Volume Fraction
  - Fiber Angles
  - Void Content
  - Particulate Distribution
- Detailed Analysis requires the Details!

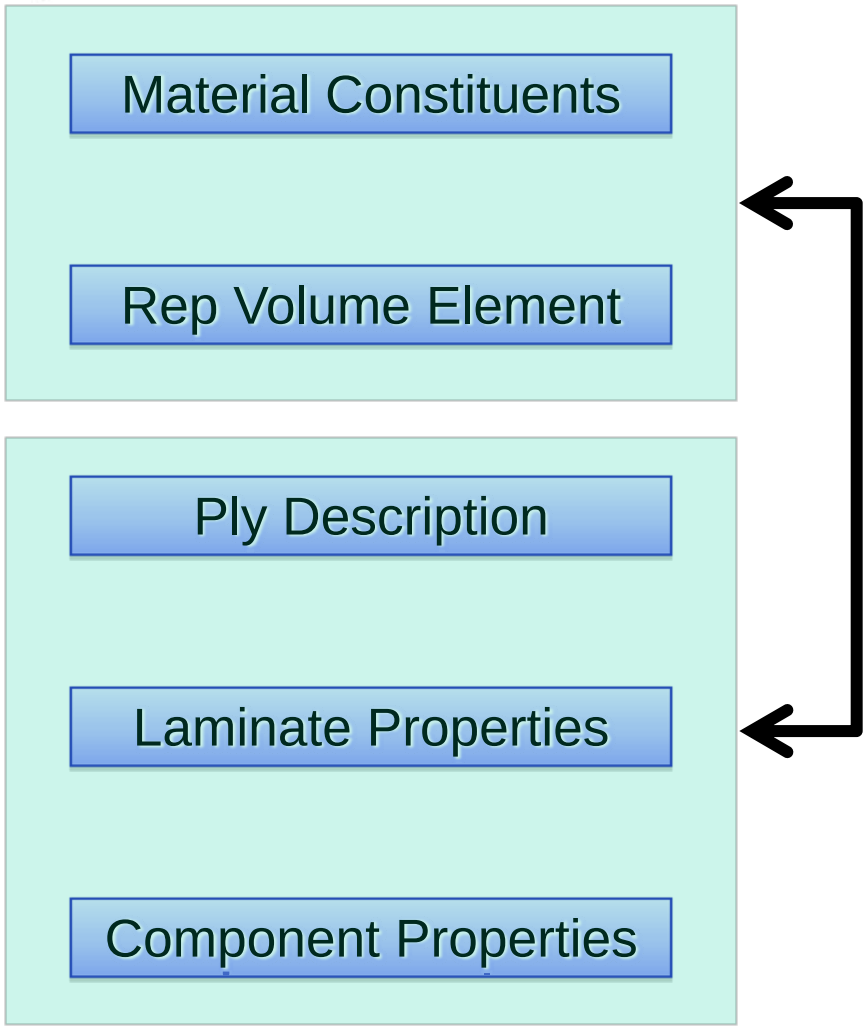
User Inputs

- Data Input for Composites

PCOMP	100	-0.5		1.E5	STRN	100			
		120	0.2	0.0	YES	120	0.6	0.0	NO
		120	0.2	0.0	YES				
		1.0							

- Data does not Conform to traditional Geometric Description
- CAD Companies are adding Entities that describe plies

Model Parameters



- Fiber Properties
- Matrix Properties
- Fiber – Matrix Interface Properties

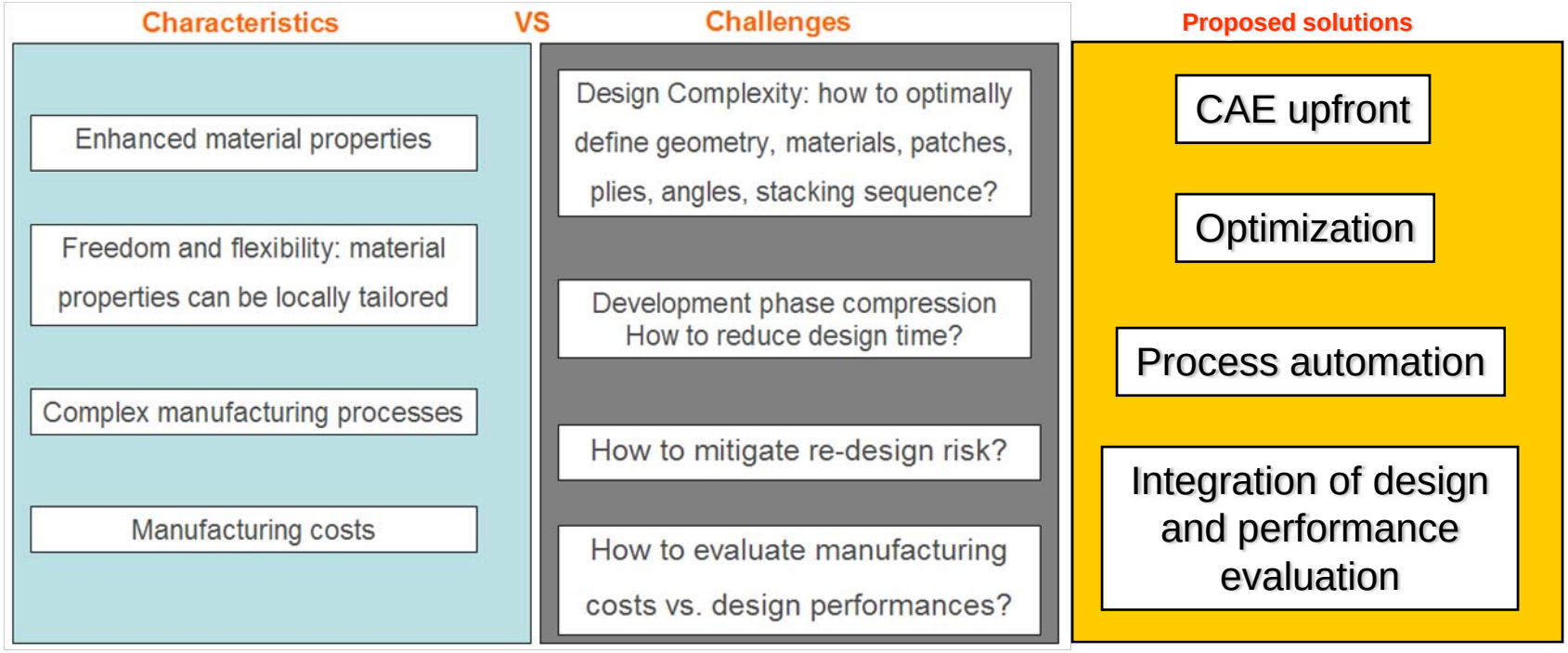
- Fiber/Particulate Volume Fraction
- Interface Zone Thickness
- Fiber/Particulate Distribution

- Ply Thickness
- Ply Content
- Directional Properties

- Laminate Stack Up Sequence
- Ply Angles

- Laminate Definitions
- Draping Angles

Optimization-Assisted Composite Design



- Optimization should be baked in from the beginning
  - Inputs should be available as variables
  - Outputs should be available as constraints

Statistical Variation of Material Properties

- CAE is traditionally a deterministic exercise
  - Material Properties
  - Geometry
- Robust Design involves the evaluation of statistical variations
  - Material Properties
  - Geometry
- Composites provide for more statistical entities
  - Fiber/Particulate Distributions
  - Fiber-Matrix Interface Properties
  - Ply Angles

Model Parameters +/-

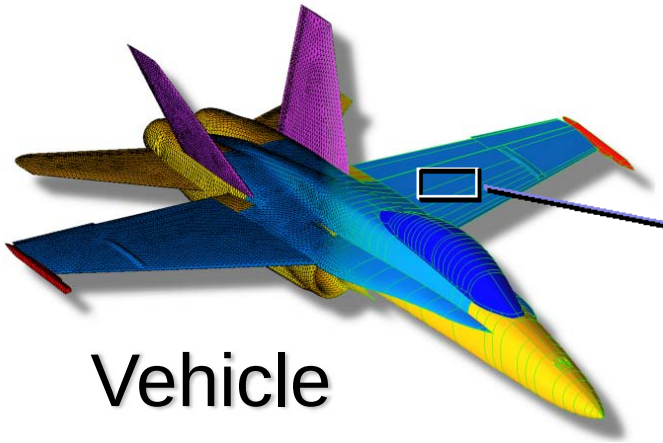
Material Constituents	• Fiber Properties • Matrix Properties • Fiber – Matrix Interface Properties
Rep Volume Element	• Fiber/Particulate Volume Fraction • Interface Zone Thickness • Fiber/Particulate Distribution
Ply Description	• Ply Thickness • Ply Content • Directional Properties
Laminate Properties	• Laminate Stack Up Sequence • Ply Angles
Component Properties	• Laminate Definitions • Draping Angles

Compute Power will allow for Analysis of Variations

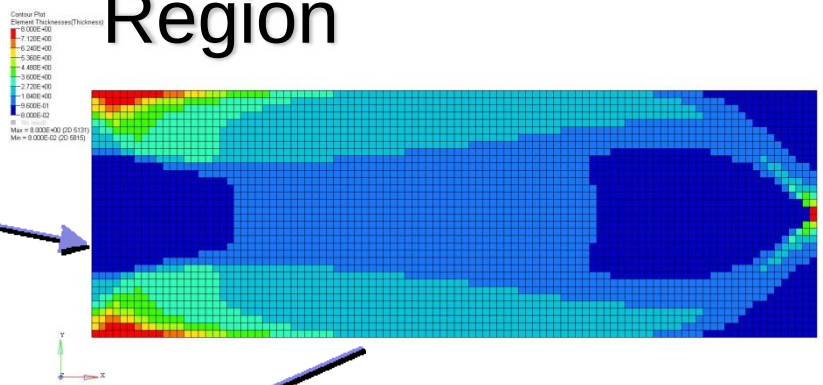
Visualization of Results

- Interactive visualization of results drives innovation
- Rapid feedback on actions taken leads to rapid learning
- Visualizing Composites Data presents challenges:
  - Thru-thickness information
  - Fiber/particulate level details

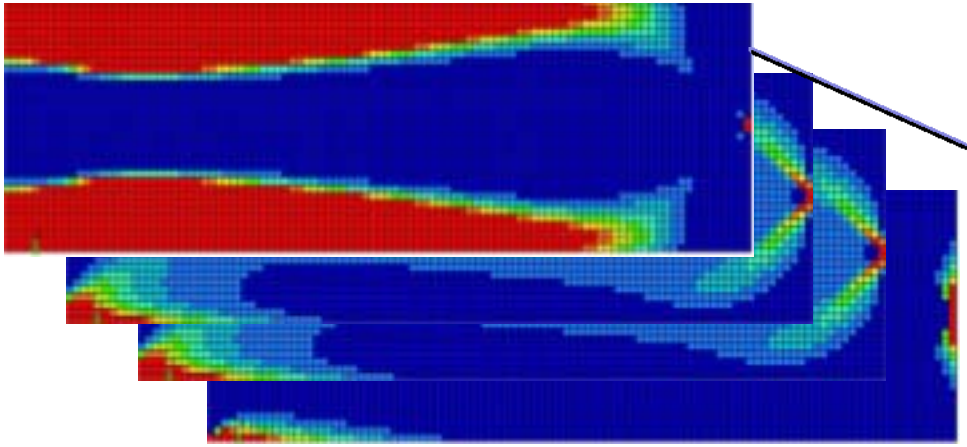
Multi-level Visualization



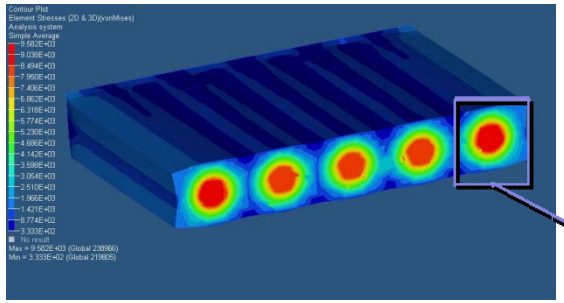
Vehicle



Region



Laminate

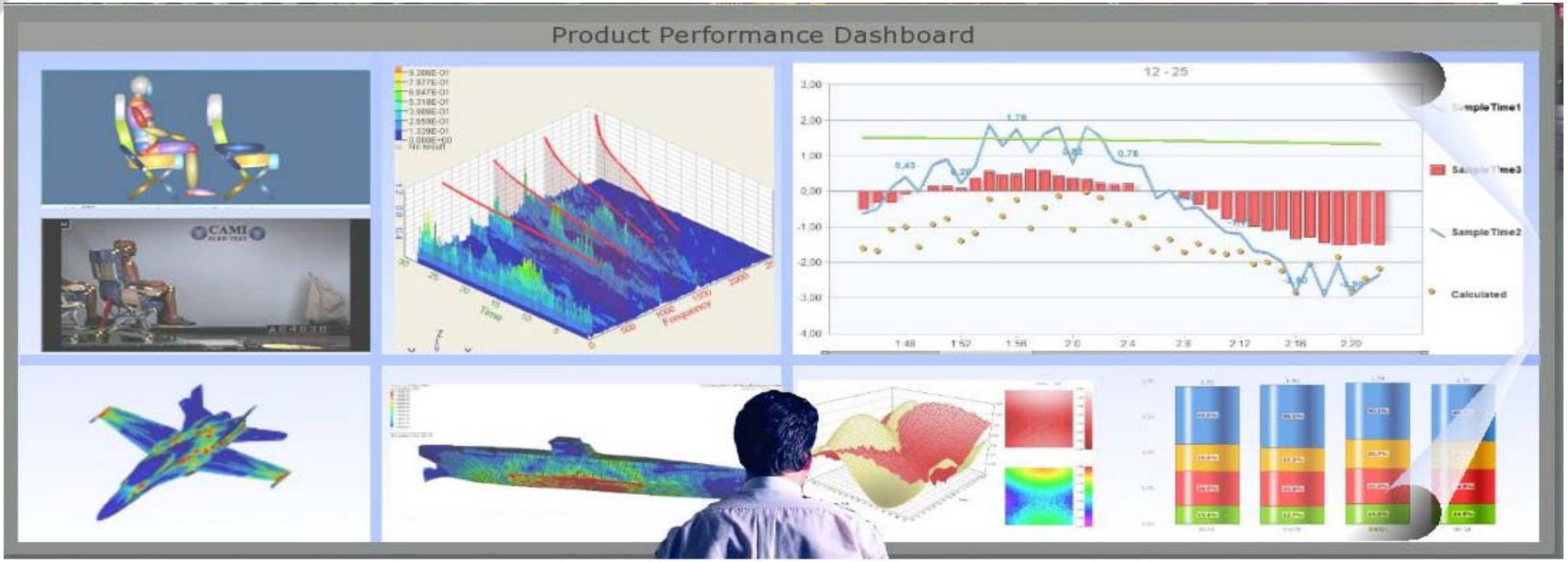


Ply

Visualization of Variations

- Modeling using Non-Deterministic Methods will require Higher Level Views of the Data
  - Lifetime
  - Warranty Costs
  - Performance Range
- Multi-Disciplinary Trade-Off Studies
  - Instantaneous Feedback on Variations
  - Business Parameters Included
  - Impact of Variational Control

Engineering Dashboard



Real-time Feedback on Effects of Changes

Cost, Performance, Schedule

Use Case Scenarios

- What effect will this design change have on my schedule?
- What effect will changing this material have on my cost and performance?
- What effect will this manufacturing process change have on reliability?
- How will this ply lay-up change effect manufacturing costs and performance?

What if we could get those answers instantaneously?

Learning from our Kids

- Video Games
  - Complex
  - Multi-Level
  - Simple, context sensitive Input Device
  - Instantaneous Feedback on Actions
- Interactive collaboration
  - Text messaging, chat rooms, blogs
- User Experience
  - Visual – Mimic Reality
  - Intuitive

Conclusions

- Interactive Learning is the Key
  - Multi-Level Views
  - Rapid *Cause and Effect* Feedback
  - Intuitive Controls
- Composites Presents Unique Challenges
  - Geometry is not enough
  - Thru-thickness Effects
  - Micromechanical Effects
- MultiScale Modeling will be important
- Optimization Enabled Modeling will drive innovation