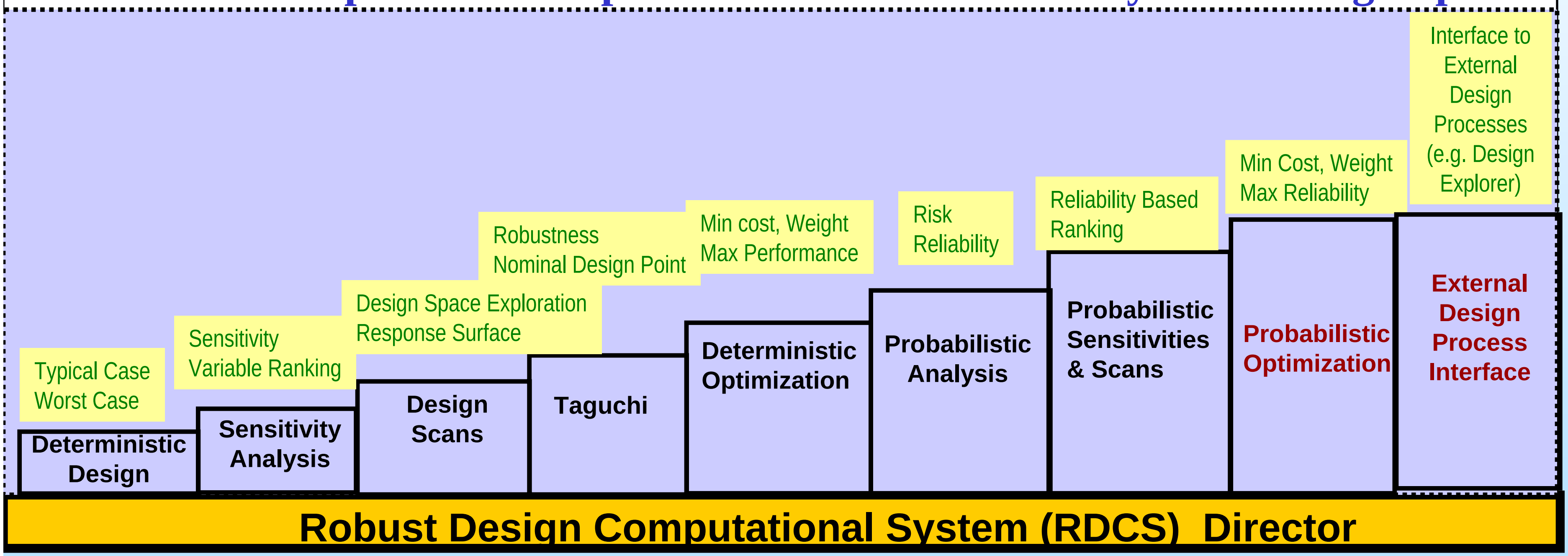
Computational Tools & Distributed Computing

A Domain Independent Comprehensive Tool Set to Analyze the Design Space



Runs on Linux, HP, and Sun

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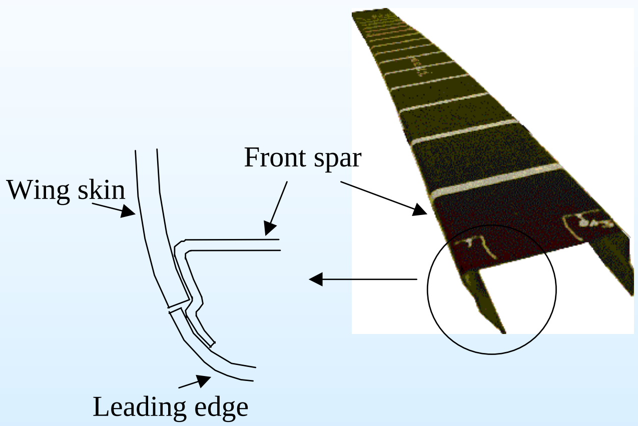
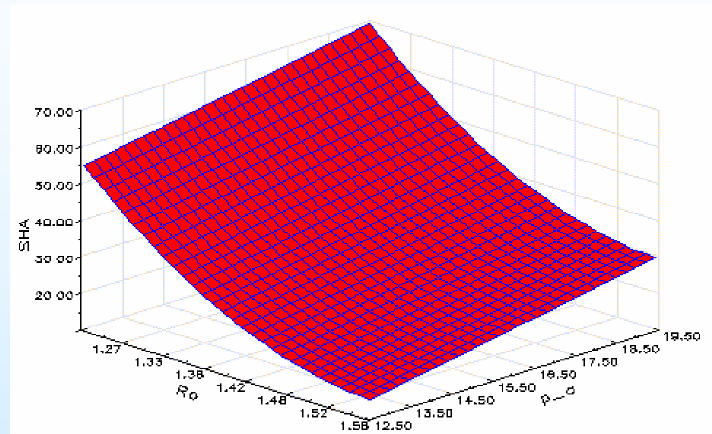
Computational Tools: COMPRO* Software Integration with RDCS

2D FEM Cure Simulation of Wingtip Spar

767-400 Raked Wingtip Front Spar DOE Sensitivity Analysis



RDCS Sensitivity Analysis Plus Design Scan



Order of Magnitude Increase in Problem Solving Efficiency

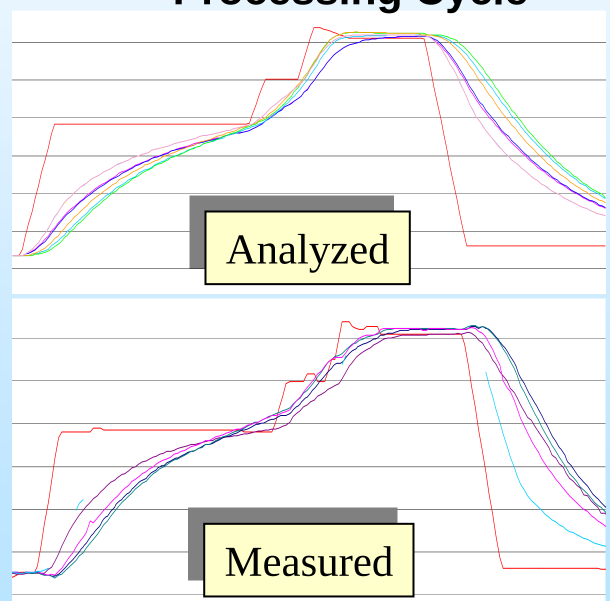
* Composites Processing (COMPRO) software is commercial software copyright protected by Convergent Manufacturing Technologies of British Columbia

B

Computational Tools:
Process Design by Analysis

2D FEM Cure Simulation of a Thick Composite Laminate

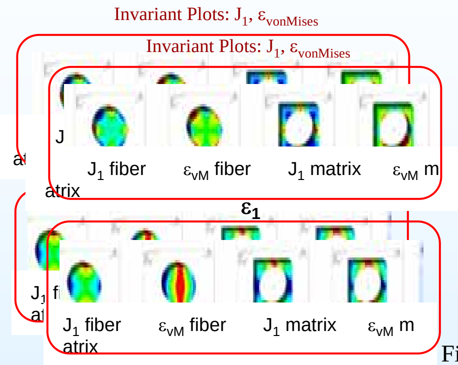
Processing Cycle



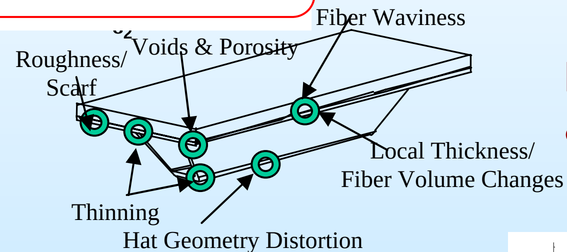
Analysis Yielded Robust Cure Cycle -- Verified by A Single Test
Original Plan Called For a Costly 6-Part Build Experimental Study

Analysis and Test Ties Across Functions: Structures Failure Prediction

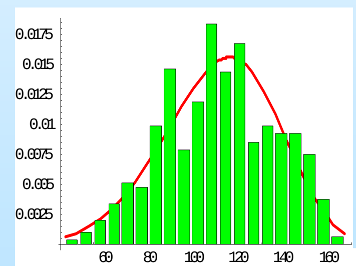
- Use Physics-Based or Mechanistic Analysis Methods
- Link with Manufacturing Processes to allow Prediction of Real Component Properties
- Integrate with Statistical and Computational Methods; RDCS, Sensitivity Analysis
- Validate



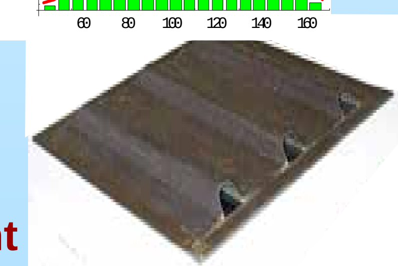
3D Strain Invariant Failure Theory (SIFT) & Fracture-Based Failure Theories



Effects of Defects & Residual Stress



Parametric Statististical & Processing Variability



Reduced Amount of Testing for Component Certification

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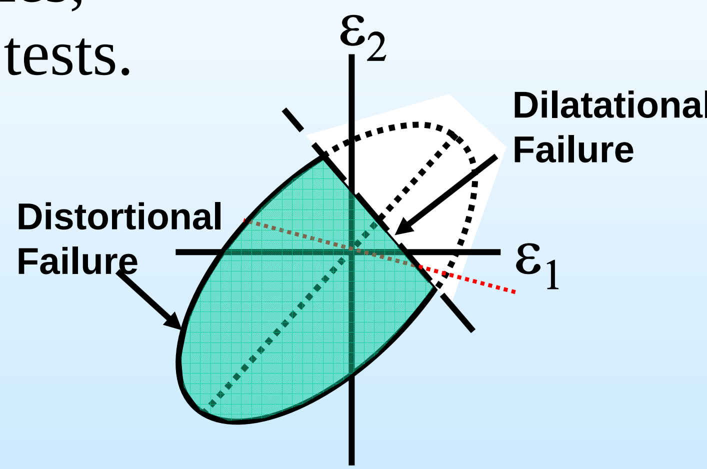
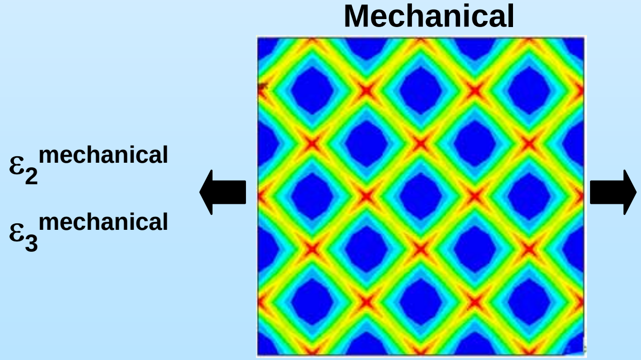
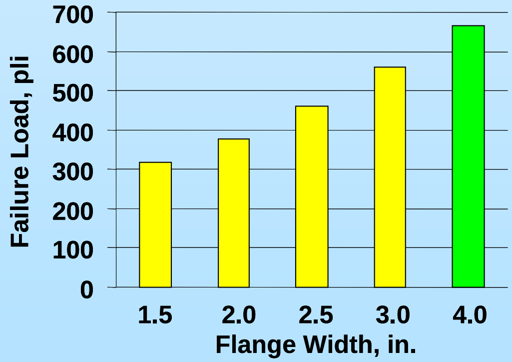
Analysis and Test Ties Across Scales

- Examples include SIFT and Advanced Fracture Methods
- Can Predict Complex Structures with arbitrary loading
- Use **only** Intrinsic Material Properties, obtained from simple, inexpensive tests.
- Predict Structural behavior and failure mode, not just failure load
- Take advantage of knowledge at constituent/lamina level





- Trend correctly with **all** variables



Knowledge Management and Feature Based Studies: Producibility*

Definition:

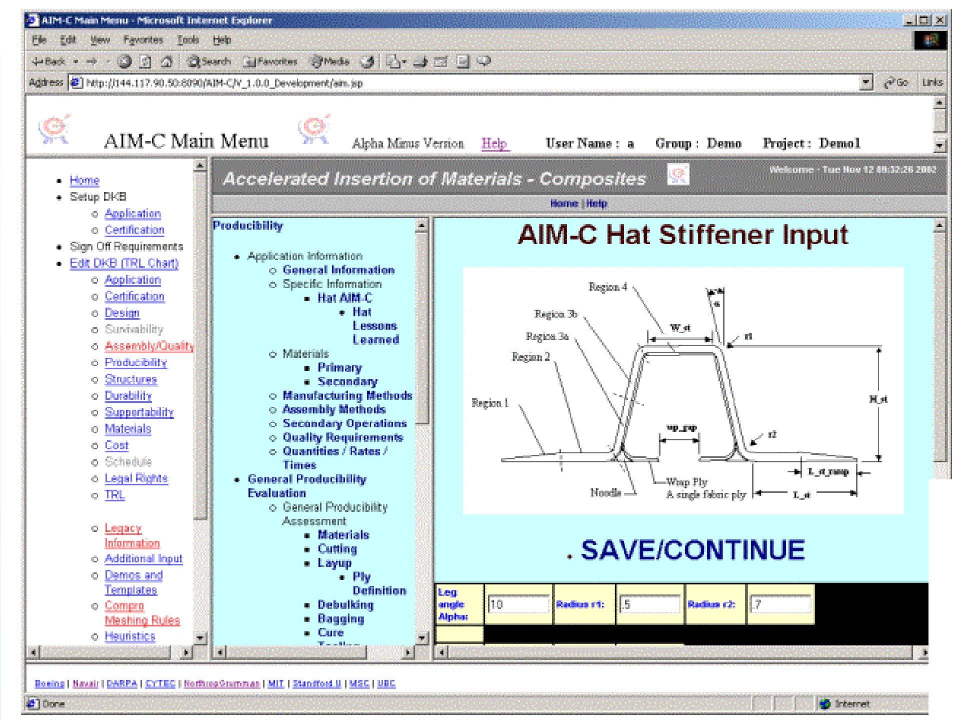
A Controller Module to Compare Requirements to Manufacturing Capabilities For Quality Components

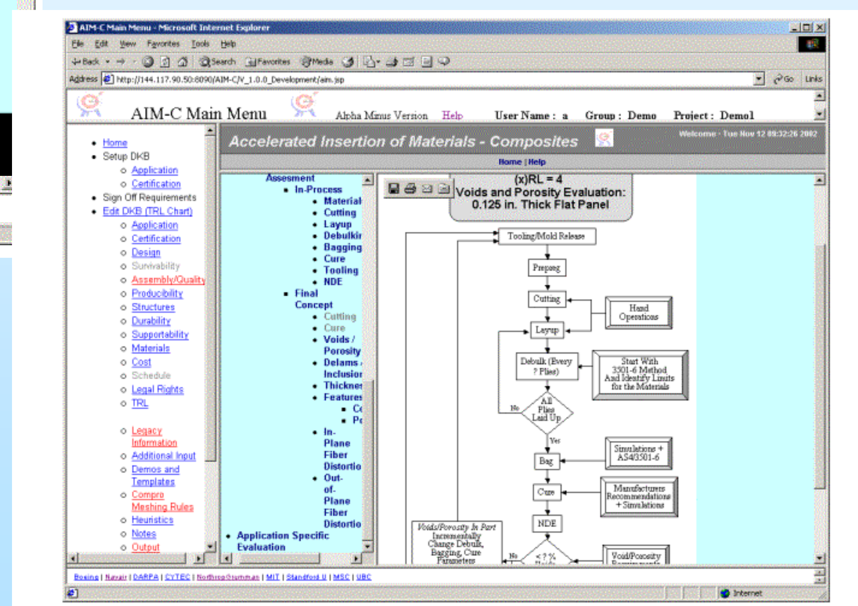
Corollaries:

- ***Can I Make It?***
- ***With What Degree of Success?***
- ***How Can I Make It?***
- ***By Which Manufacturing Sequence Should It Be Made?***

***Addresses scale up, part geometry, planned rework and avoidance of unplanned rework, provides for knowledge transfer.**

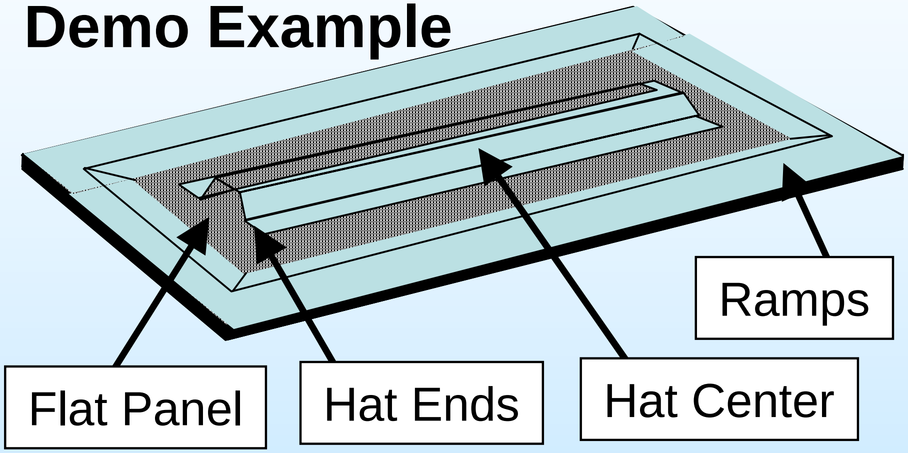
Producibility Module Interface





Knowledge Management and Feature Based Studies: Producibility

Hat Stiffened Demo Example



Feature Based Assessment Steps

1. Define Configuration
2. Identify Features/ Characteristics
3. Identify Defects Associated With Features/ Characteristics
4. Identify Tooling Options
5. Associate Defects to Tooling, Producibility and Material Areas
6. Quantify Defects Relative to Tooling, Producibility and Material Areas

Knowledge Management and Feature Based Studies

Producibility Area: Final Part Quality - Thickness

Application Info
- Minimum and Maximum Part Thicknesses
- Tolerances in Inches
- Design Per Ply Thickness
- Materials

Fiber
- Density

Resin
- Density

Prepreg
- FAW
- RAW/ Resin Content

Materials Modules/Data Base
- Averages/Means/Medians
- Standard Deviations
- Min
- Max

Producibility Module

Outputs
- Total Plies for Thinnest Part
- Total Plies for Thickest Part
- The Number of Plies Where Design Thickness Plus or Minus Tolerance is Exceeded With…
  - Average Material Thickness & Std Deviation
  - Minimum Material Thickness
  - Maximum Material Thickness

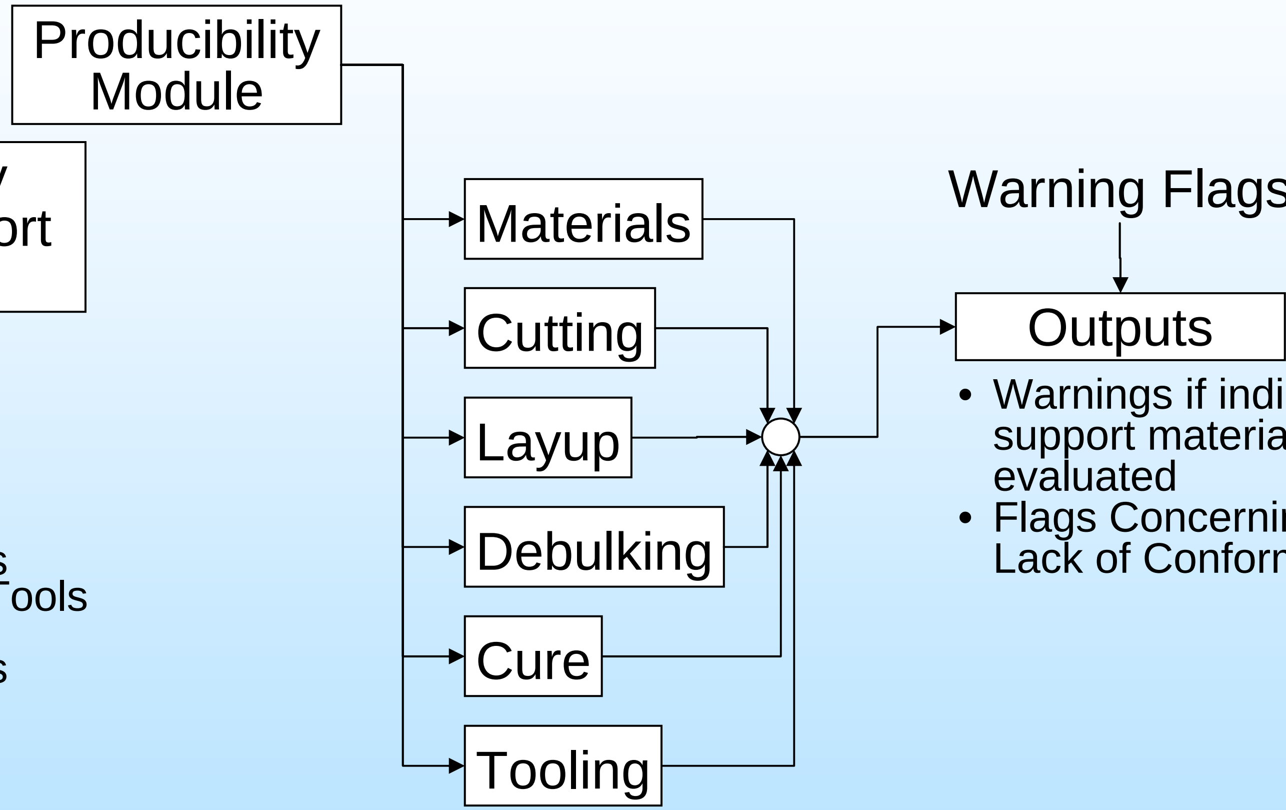
Knowledge Management and Feature Based Studies

<u>Producibility Area:</u> In-Process Quality – Producibility Operations

Final Part Quality – Inclusions & NDE

Producibility Indirect Support Materials

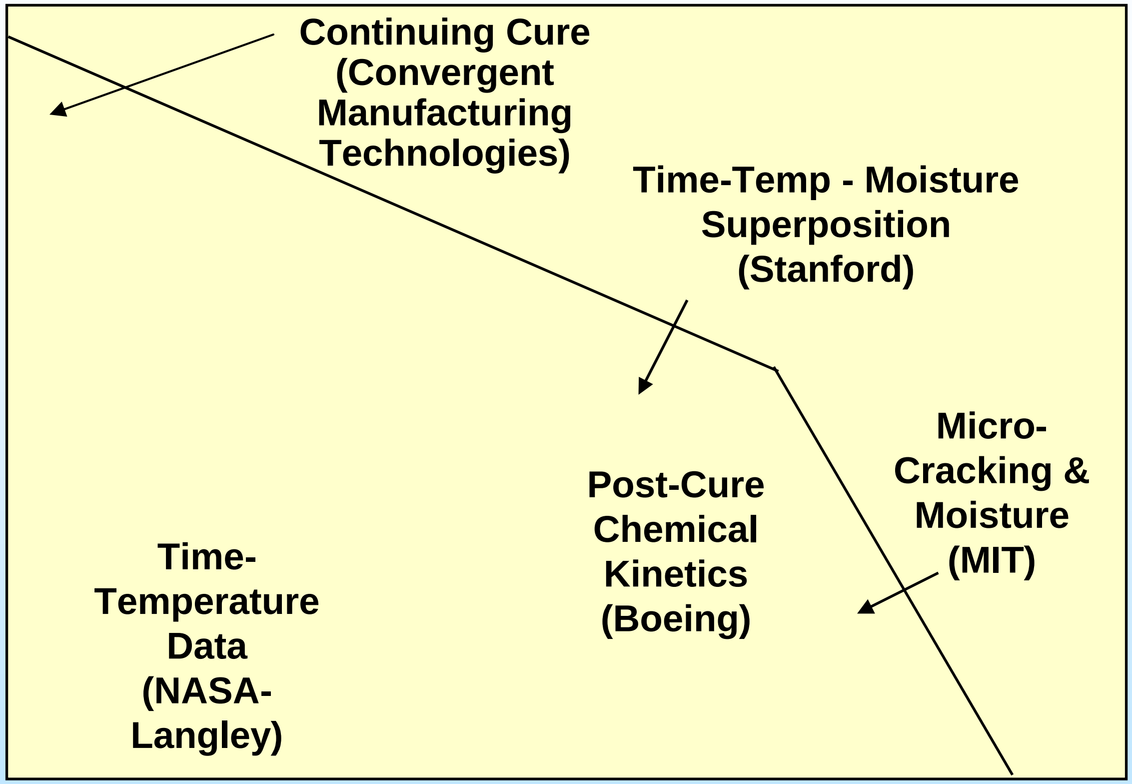
- Prepreg
  - Backing
  - Separator
- Cutting
  - Separator
- Layup
  - Separators
  - Shop Aid Tools
- Debulking
  - Separators
  - Breathers
  - Bleeders
  - Bagging
- Cure
  - Separators
  - Breathers
  - Bleeders
  - Bagging
- Tooling
  - Mold Release



- Warnings if indirect support materials not evaluated
- Flags Concerning Lack of Conformance

Knowledge Management and Feature Based Studies: End of Life Properties

Strain Capability

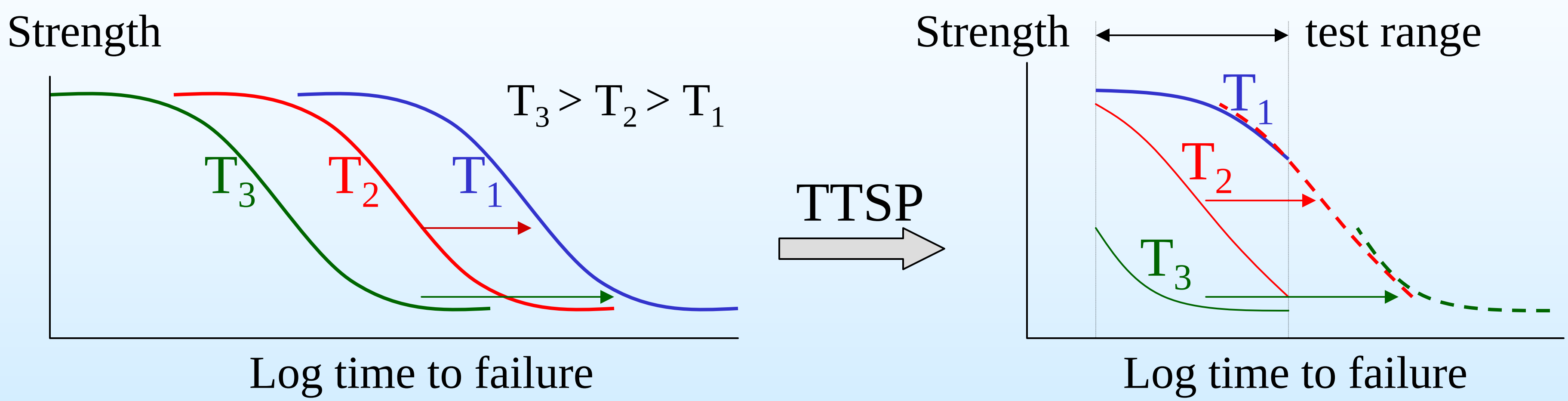


Log Time at Load

This Approach Predicts the Effects of Four Competing Failure Modes – Time, Temperature, Environment and Chemical Degradation

Knowledge Management & Feature Based Studies: End of Life Properties

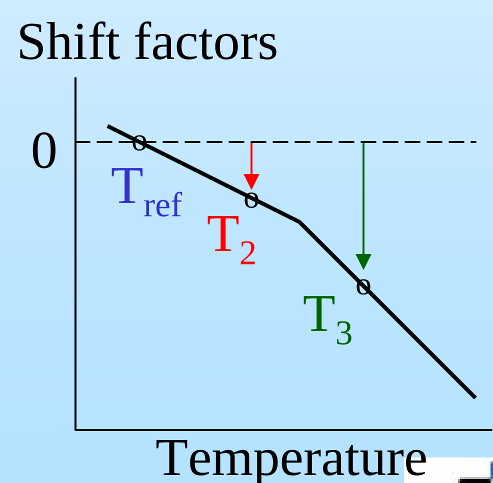
Assumption: Same shape for any temperature = Master Curve



Curves can be superposed by horizontal shifts

⇒ Master curve can be generated from the fragments of curves at different temperatures

⇒ Accelerated evaluation of long term performance

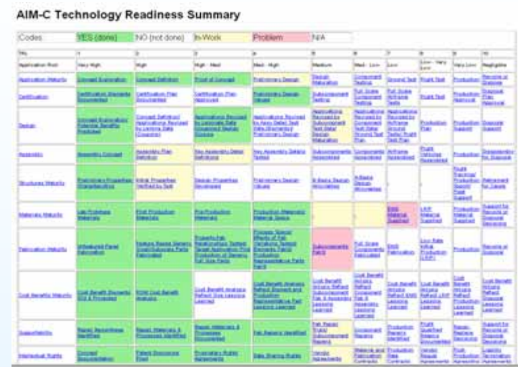


What about major obstacles to insertion?

Define and Address Scale Up Issues
Assess and Validate End of Life Properties
Understand the Drivers of Part Geometry
and Manage Them
Plan Maturation Cycles and Eliminate
Unplanned Rework
Facilitate Transition and Support
Via Well-Documented Knowledge Base

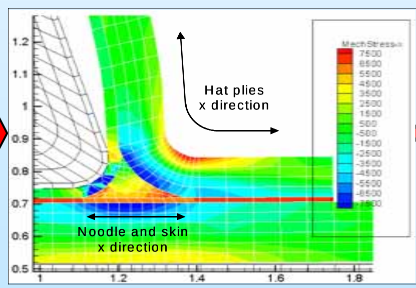
How Do I Accelerate Technology Insertion?

Use Methodology Document or Software Interface
For Thorough Assessment of All Requirements

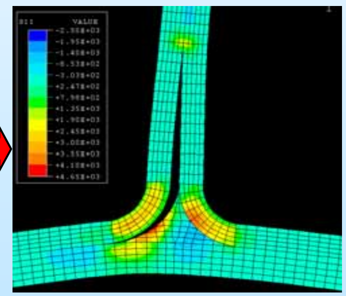


Assessment and
Maturity Status

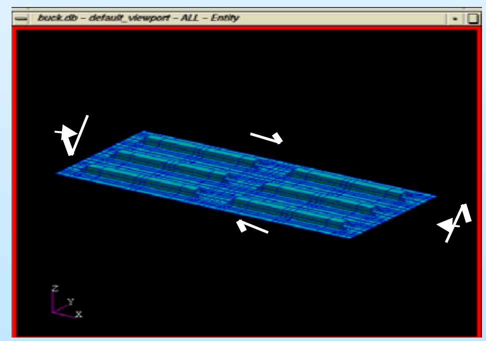
Analytical Models
From Constituents



To Processing



To Effects of
Defects



To Structures

To Provide Analysis
Supported by Test
To Accelerate
Readiness

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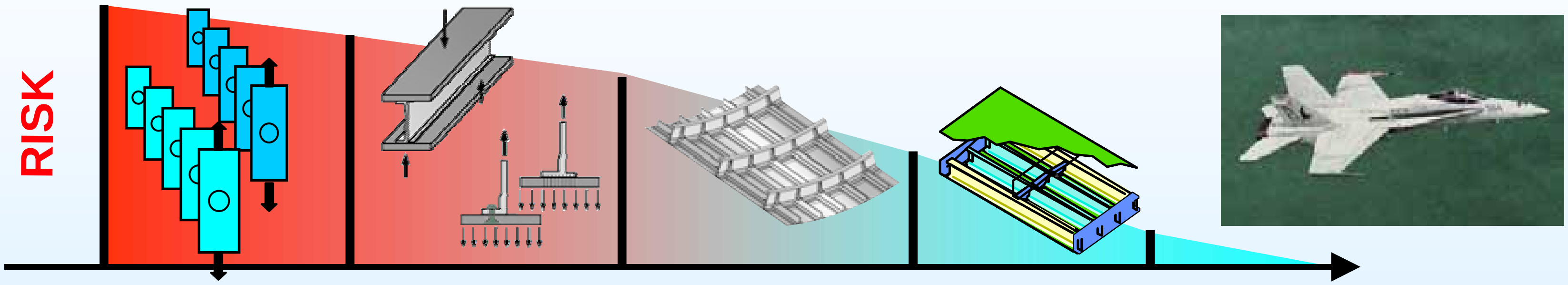
Accelerated Insertion of Materials Is Achieved in AIM-C Methodology by

- Development and characterization focused on design knowledge base needs.
- Coordinated use of
  - Existing Knowledge
  - Validated Analysis tools
  - Focused Testing
- Use of Physics Based Material & Structural Analysis Methods
- Use of Integrated Engineering Processes & Simulations
- Uncertainty Analysis and Management
  - Early Feature Based Assessment/Demonstration
  - Tracking of Variability and Error Propagation Across Scales
- Rework Acknowledgement and Avoidance
- Disciplined approach for pedigree management

Orchestration to efficiently tie together the above elements to a design knowledge base for qualification and certification.

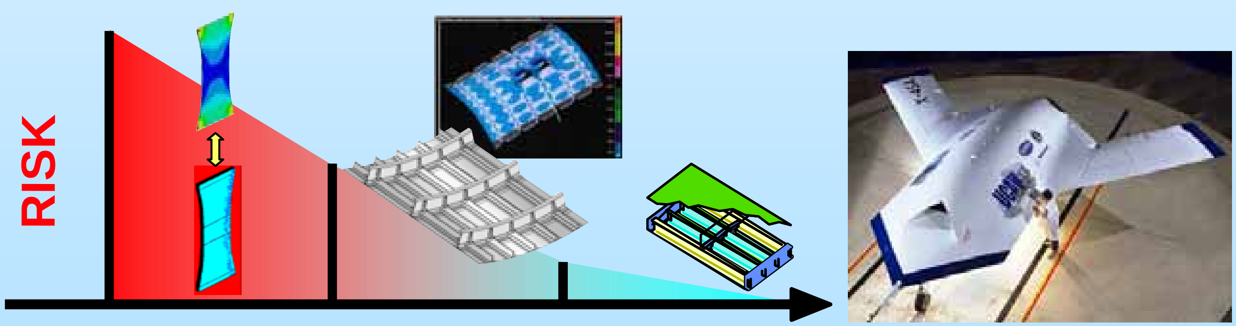
What's the Benefit of Integrated Assessment, Development, and Characterization?

Traditional Test Supported by Analysis Approach



Time to Insertion Readiness

AIM Provides an Analysis Approach Supported by Experience, Test and Demonstration



Time to Insertion Readiness

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