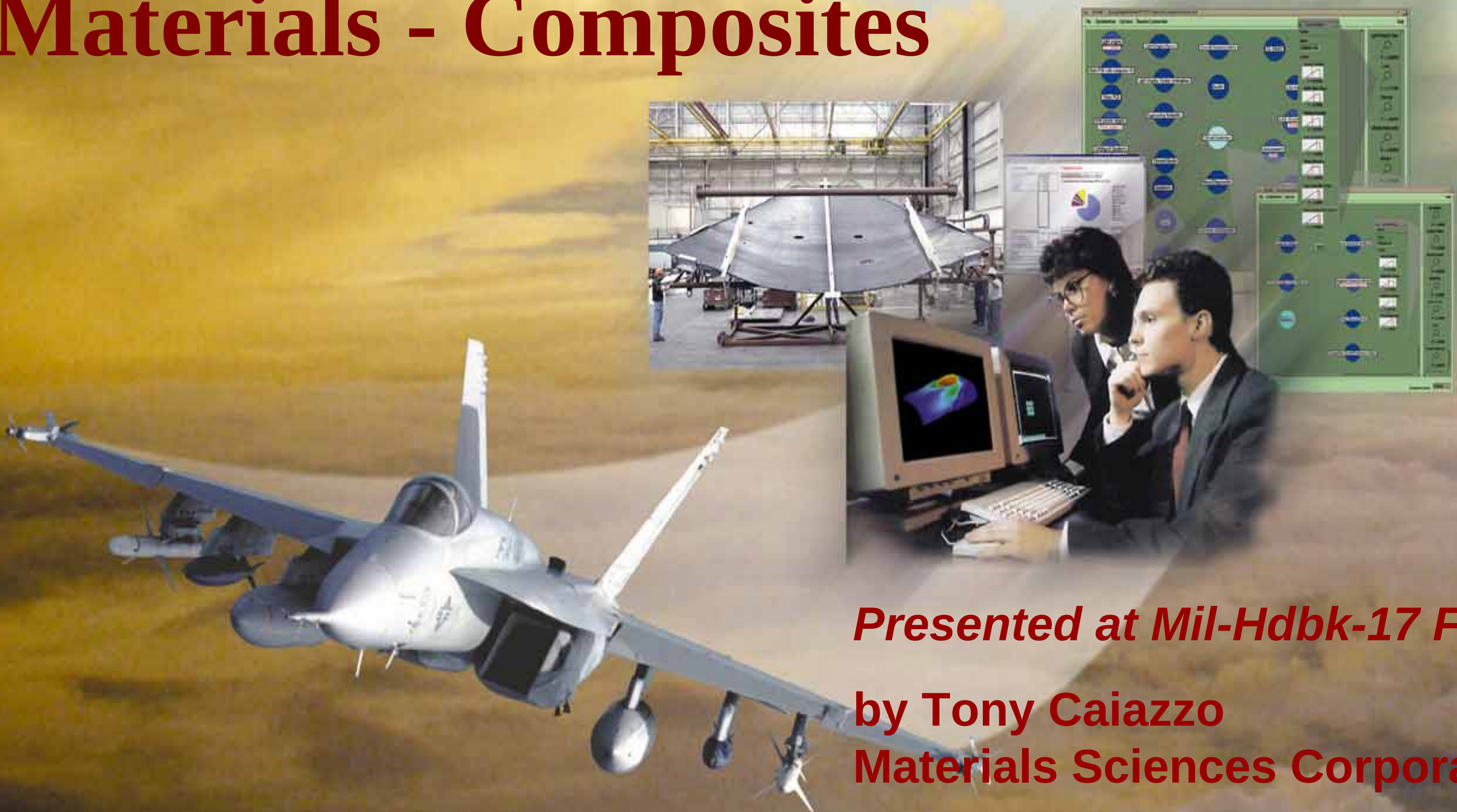
Accelerated Insertion of Materials - Composites



Presented at Mil-Hdbk-17 Forum

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AIM-C Team - Boeing (St. Louis, Seattle, Canoga Park, Philadelphia), Northrop Grumman, Materials Sciences Corporation, Convergent Manufacturing Technologies, Cytec Fiberite, Inc, Massachusetts Institute of Technology, Stanford & NASA (Langley)

AIM-C Alignment Tool

The objective of the AIM-C Program is to provide concepts, an approach, and tools that can accelerate the insertion of composite materials into DoD products

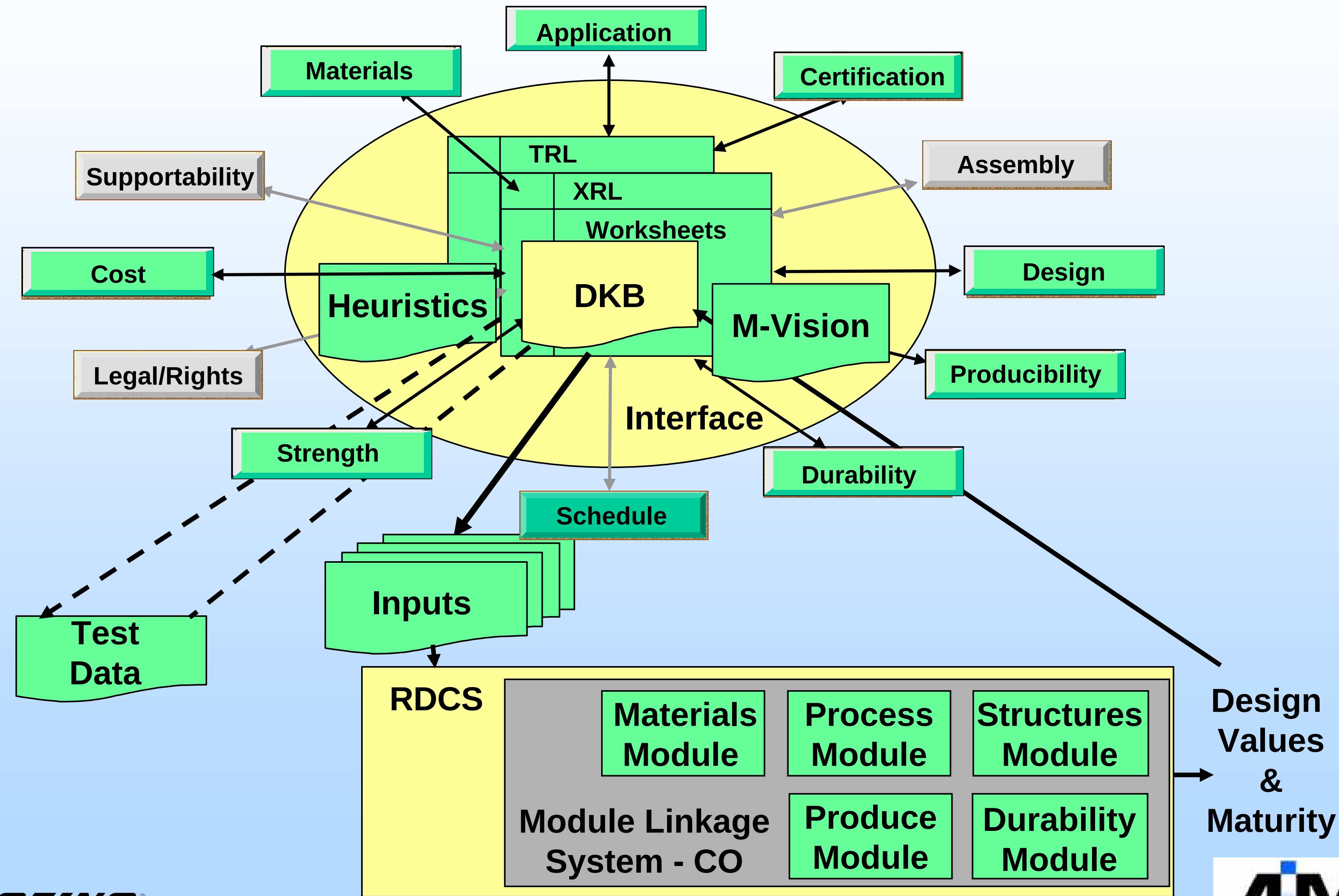
AIM-C Will Accomplish This Three Ways

Methodology - ***We will evaluate the historical roadblocks to effective implementation of composites and offer a process or protocol to eliminate these roadblocks and a strategy to expand the use of the systems and processes developed.***

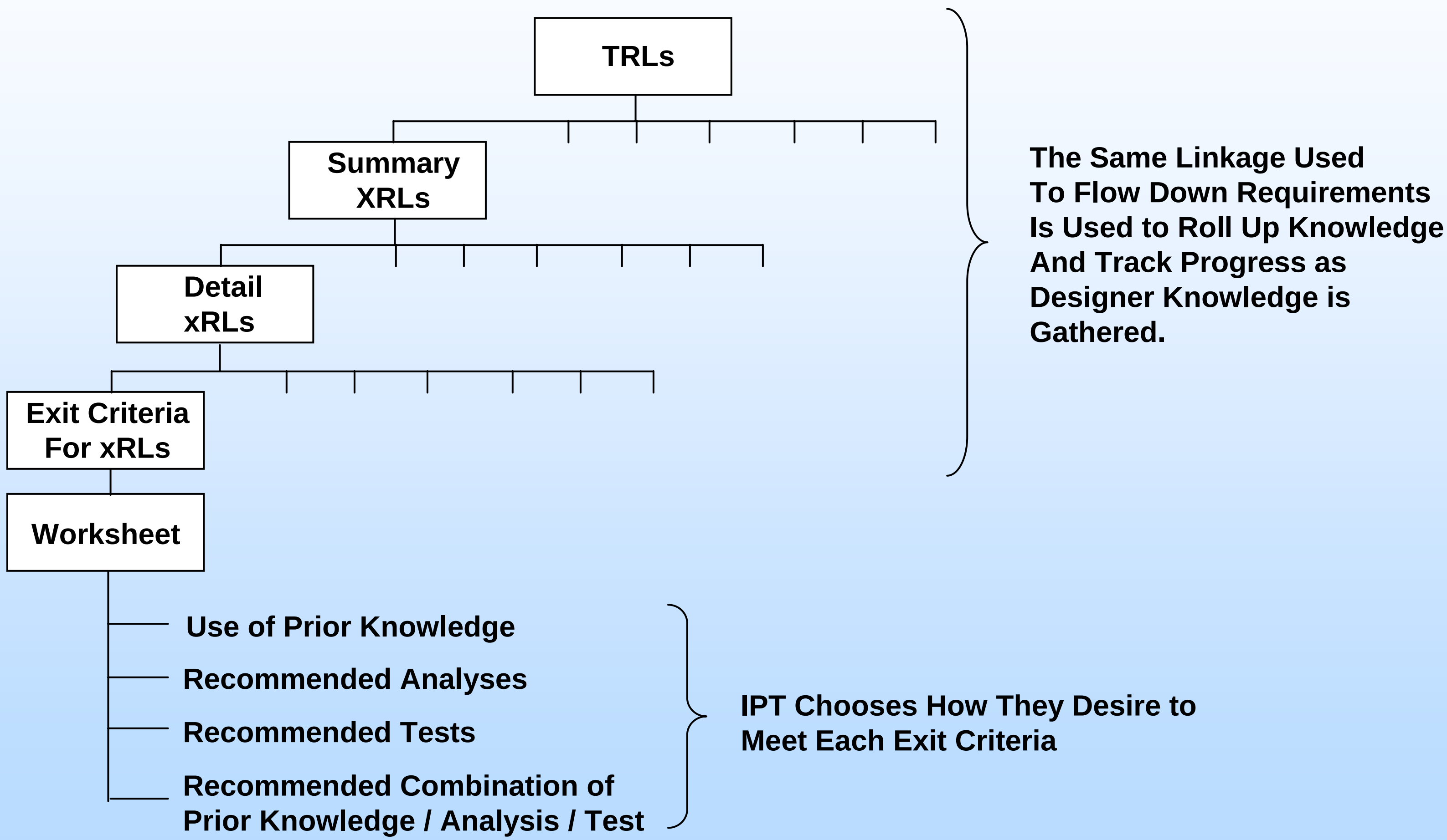
Product Development - ***We will develop a software tool, resident and accessible through the Internet that will allow rapid evaluation of composite materials for various applications.***

Demonstration/Validation - ***We will provide a mechanism for acceptance by primary users of the system and validation by those responsible for certification of the applications in which the new materials may be used.***

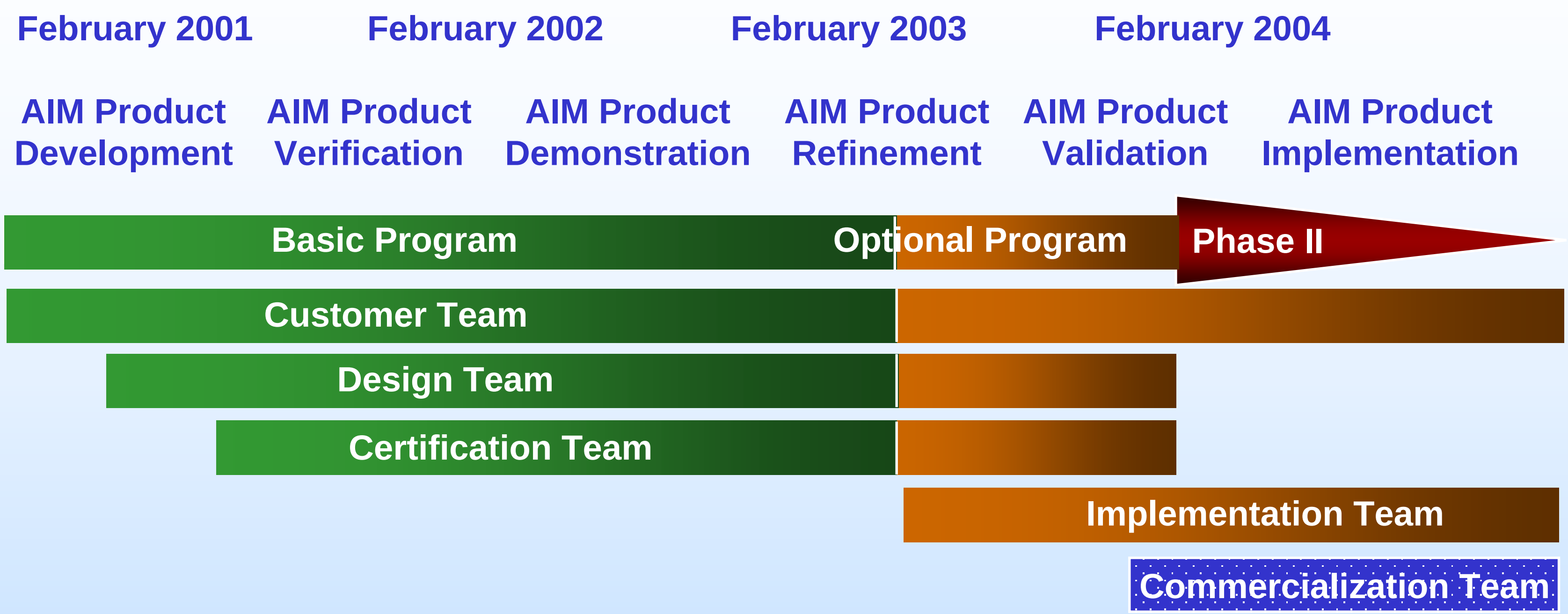
AIM-C System Vision



AIM Methodology Becomes a Requirements Flow Down and a Completion Roll Up



AIM-C Transition Plan



Customer Team – To ensure that the product meets the needs of the funding agents

Design Team – To ensure acceptance among users in industry

Certification Team – To ensure acceptance among the certification agents for structures

Implementation Team – To ensure acceptance among the user community

“Commercialization” Team – To ensure support of users

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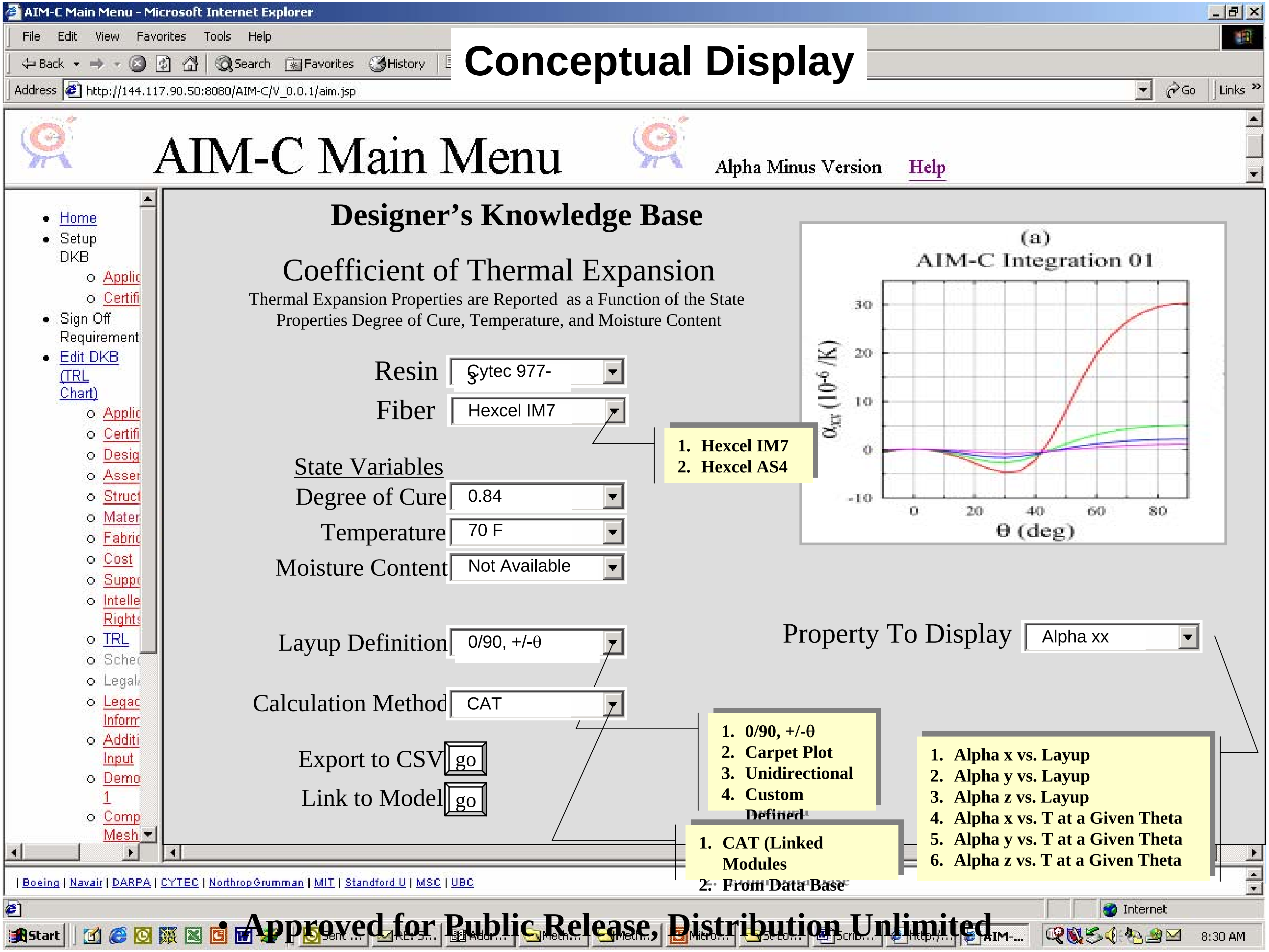
CC30033.01

AIM-C Certification Team

Agency	Integration	Structures	Materials	Producibility
Boeing	Charley Saff	Eric Cregger	Pete George	John Griffith
Navy	Don Polakovics	Dave Barrett	Kathy Nesmith	Steve Claus
Air Force	Tim Jennewine	Dick Holzwarth	Katie Thorp	Bob Reifenberg
FAA	Curt Davies	Larry Ilcewicz	David Swartz	Dave Ostrodka
Army	Mark Smith	Jon Schuck	Marc Portanova	Steve Smith
NASA	Mark Shuart	Jim Starnes	Tom Gates	Tom Freeman

To Insure That the Methodology, Verification, and System Validation We Do Satisfies Certifying Agencies

Conceptual Display



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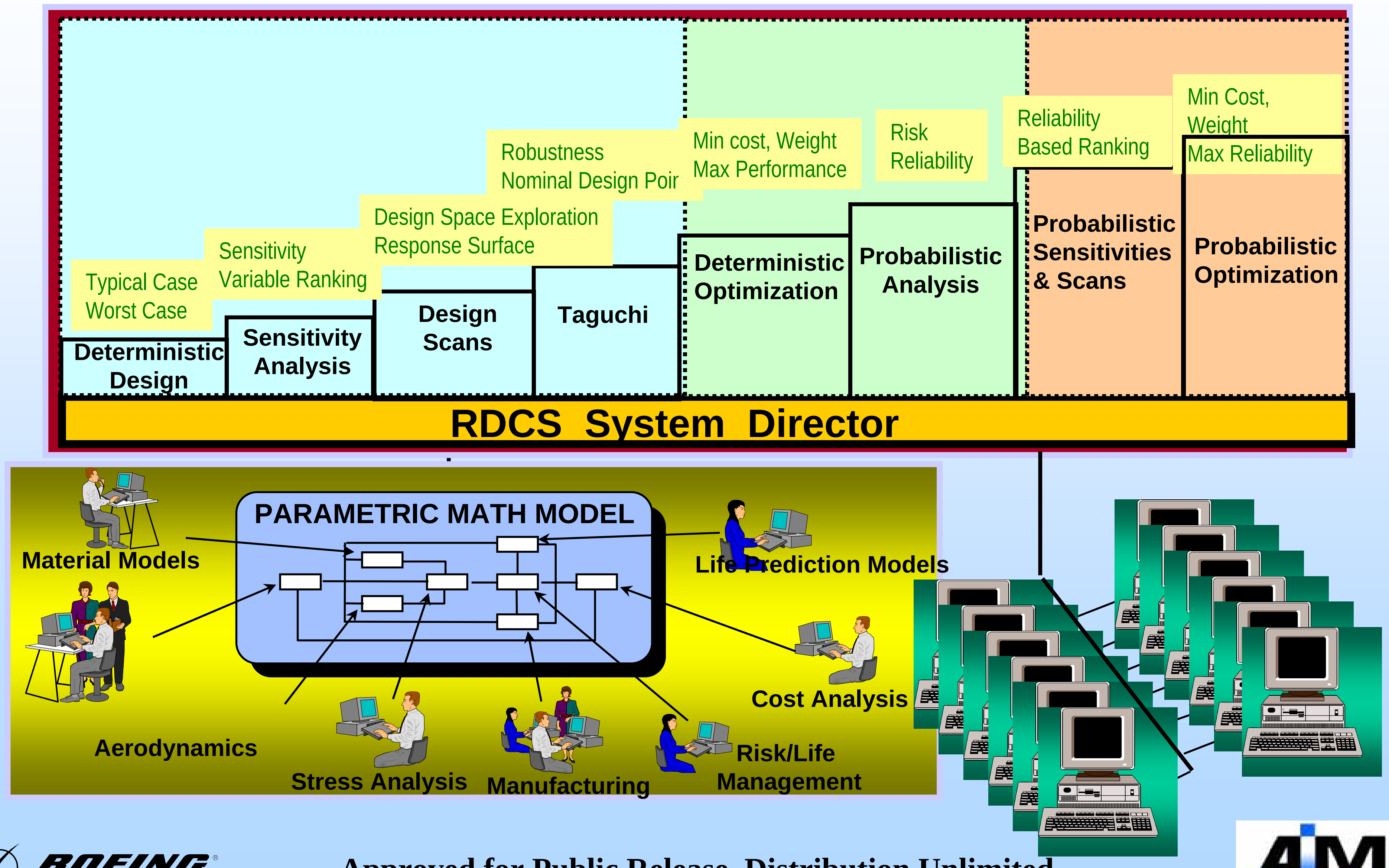
Robust Design Computational System



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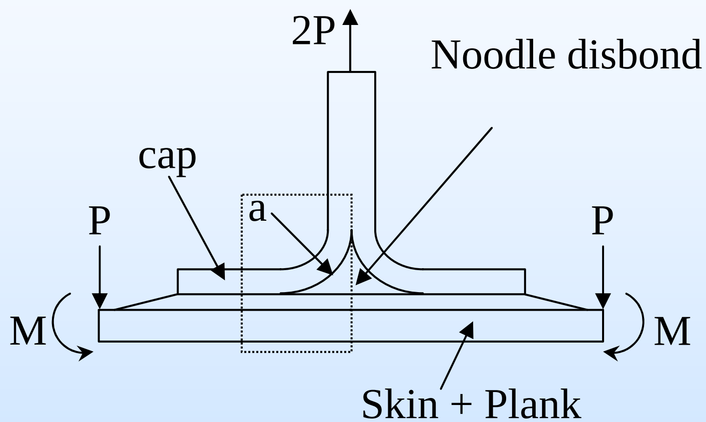
RDCS Edge of Flange Disbond Study

The Problem

Application Objective

- Investigate the effect of skin-stringer panel geometric parameters on maximum moment at the flange and margin of safety for stringer pull-off
- To aid in the selection of appropriate stiffener geometry and spacing



High Level Description

- **Design variables:** Skin Thickness, Flange Thickness, Stiffener Height, Total Flange Width
- **Response Variables**: Maximum Flange Moment, Pull-off Margin
- **Solvers/Methods:** RDCS, ANSYS/LEFM

Solution Scope

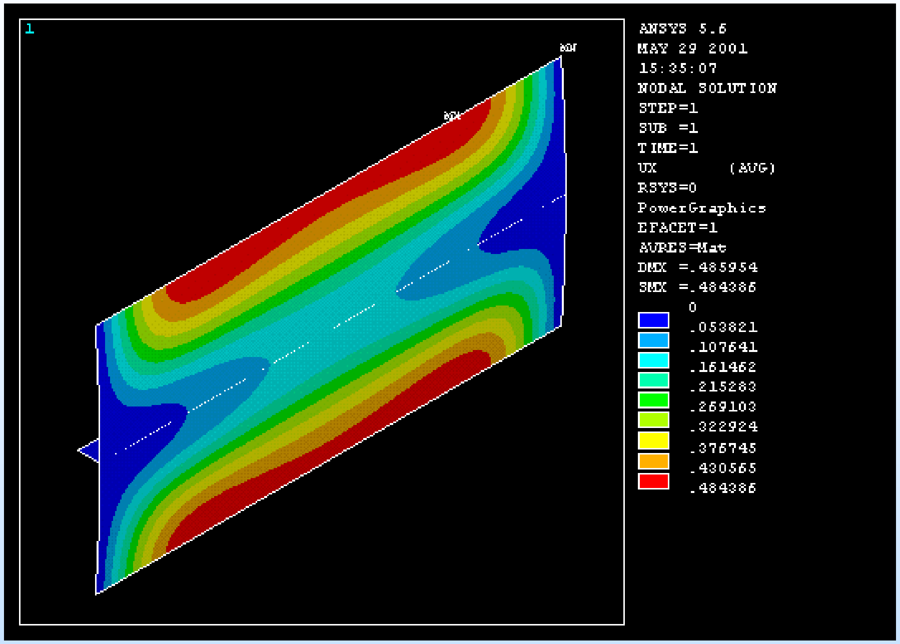
- **RDCS:** Sensitivity analysis, Factorial Design Space Explorations
- **ANSYS**: Static non-linear large deflection analysis
- **Solution Cases**: 81 Large Scale FEM Solutions

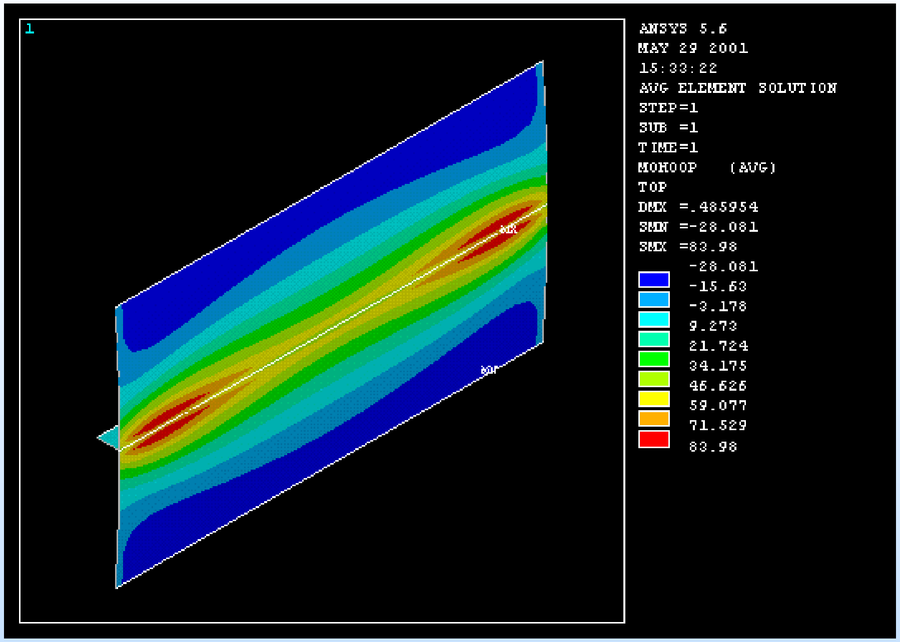
RDCS Application Benefits

- **Rapid factorial design calculations for external ANOVA study and response surface with significant cycle time reduction**
- **ANOVA helps identify critical factors and interactions**
- **Accurate surrogate response surface model helps simplify the design process**

RDCS Edge of Flange Disbond Study

The Problem



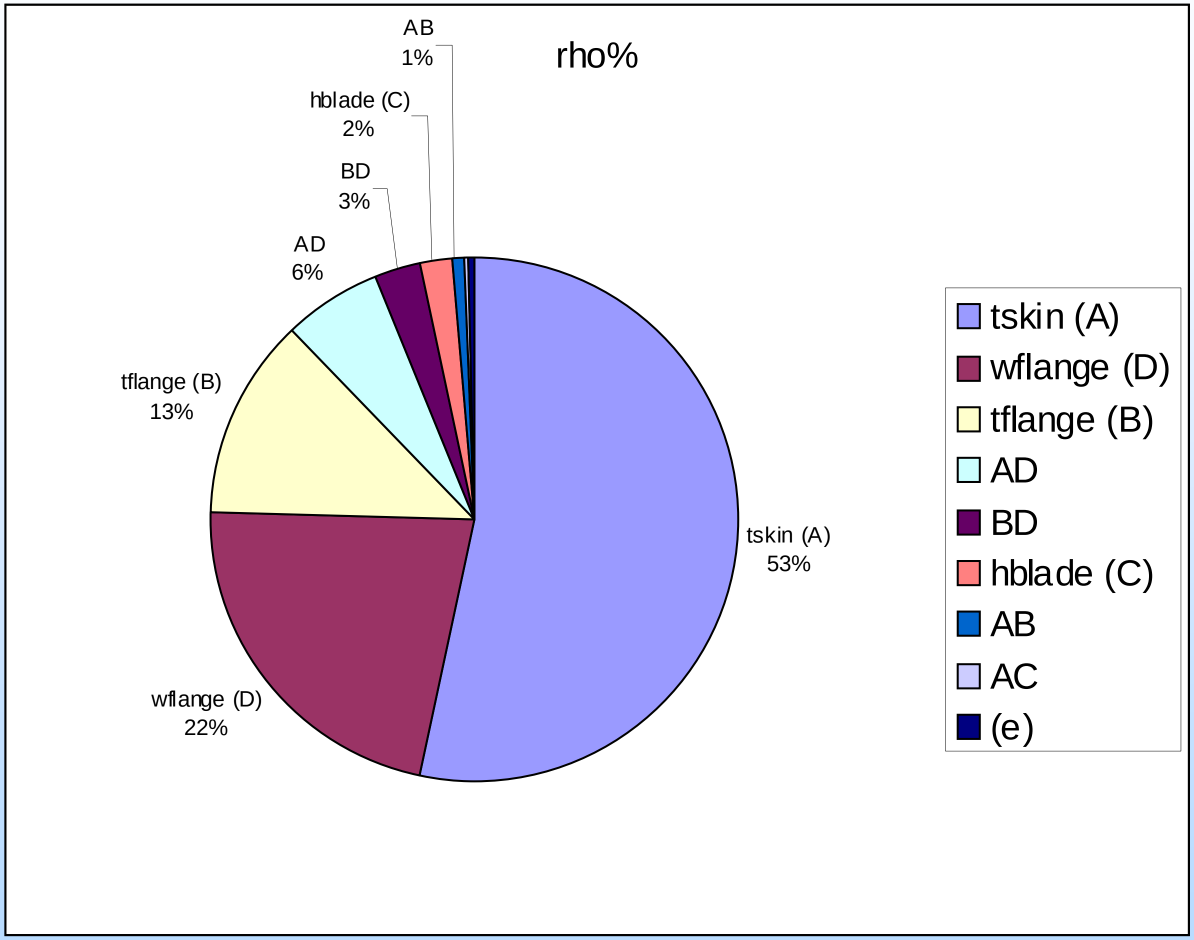


Internal Pressure (or postbuckling) create large pillowing deflections between stringers

These deflections create high moments at the skin-to-stringer bondline. The loads don't vary tremendously along the length – can be analyzed as a 2D problem using the maximum loads (conservative)

RDCS Edge of Flange Disbond Study

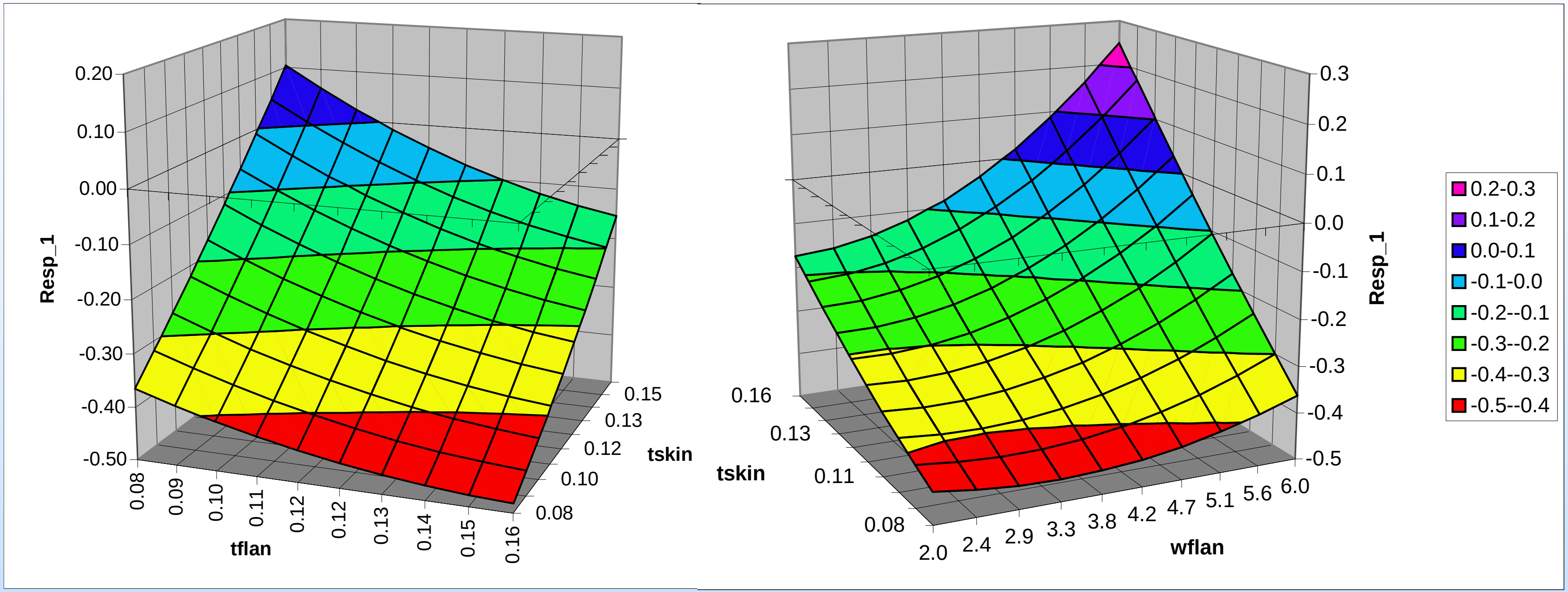
ANOVA Results



The major influences are skin thickness, flange width, flange thickness, and their interactions

RDCS Edge of Flange Disbond Study

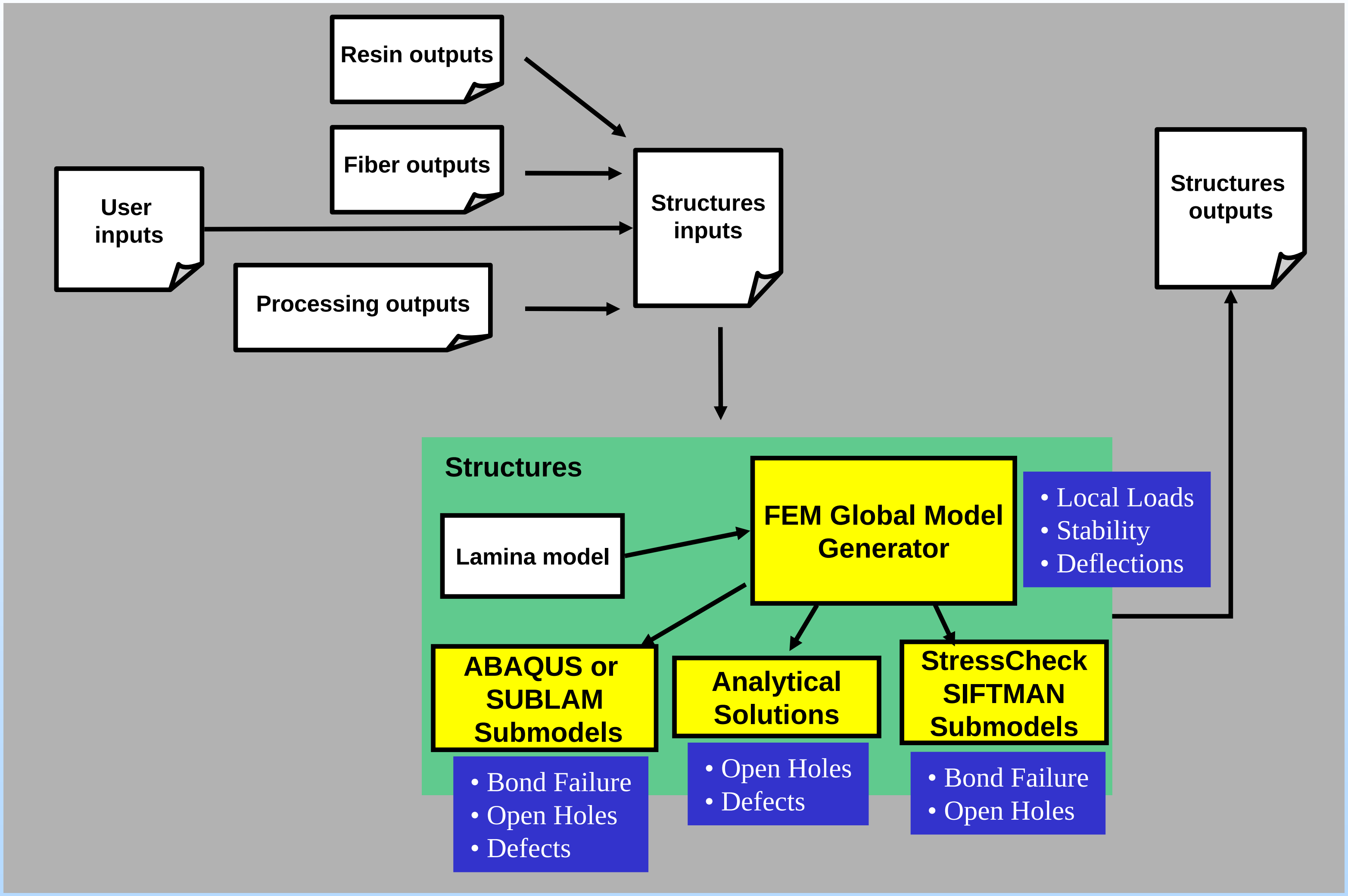
Interaction Results



- **Best edge-of-flange peel margin of safety is when skin is thick and flange is thin**
- **Flange width has a much greater effect on the margin when skins are thick. The effect is highly nonlinear.**

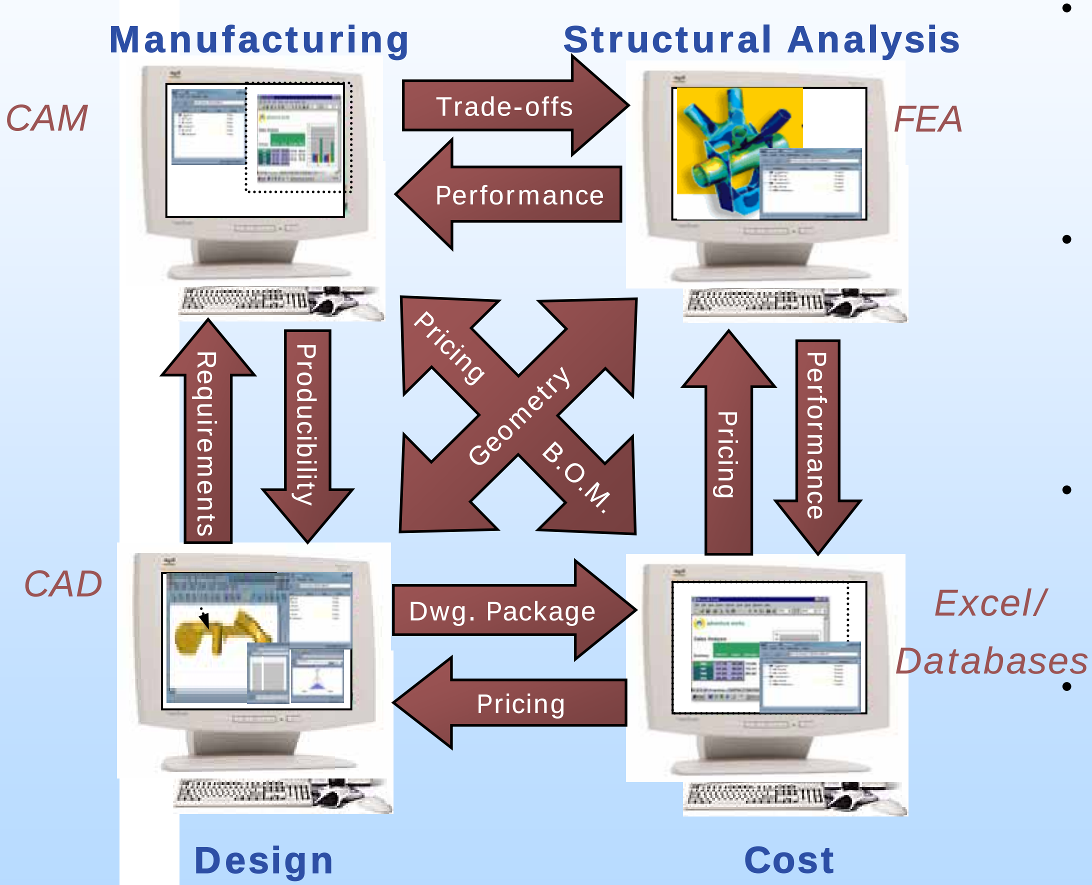
Schematic of Design/Analysis Framework

Long term Strategy



The Oculus Integration System

CO™: A Plug & Play Modeling Environment



- **Integrates Data and Software Applications on-the-fly**
  - Drag & Drop, Plug & Play
  - Simple to create, modify, manage, maintain
- **Enables Real-time data sharing between applications**
  - Secure
  - Controlled
  - Intra/Internet
- **Platform Independent**
  - Distributed
  - Neutral to Platforms and Applications
- **Increases Value of Previous Investments**
  - Software
  - Hardware
  - Networks

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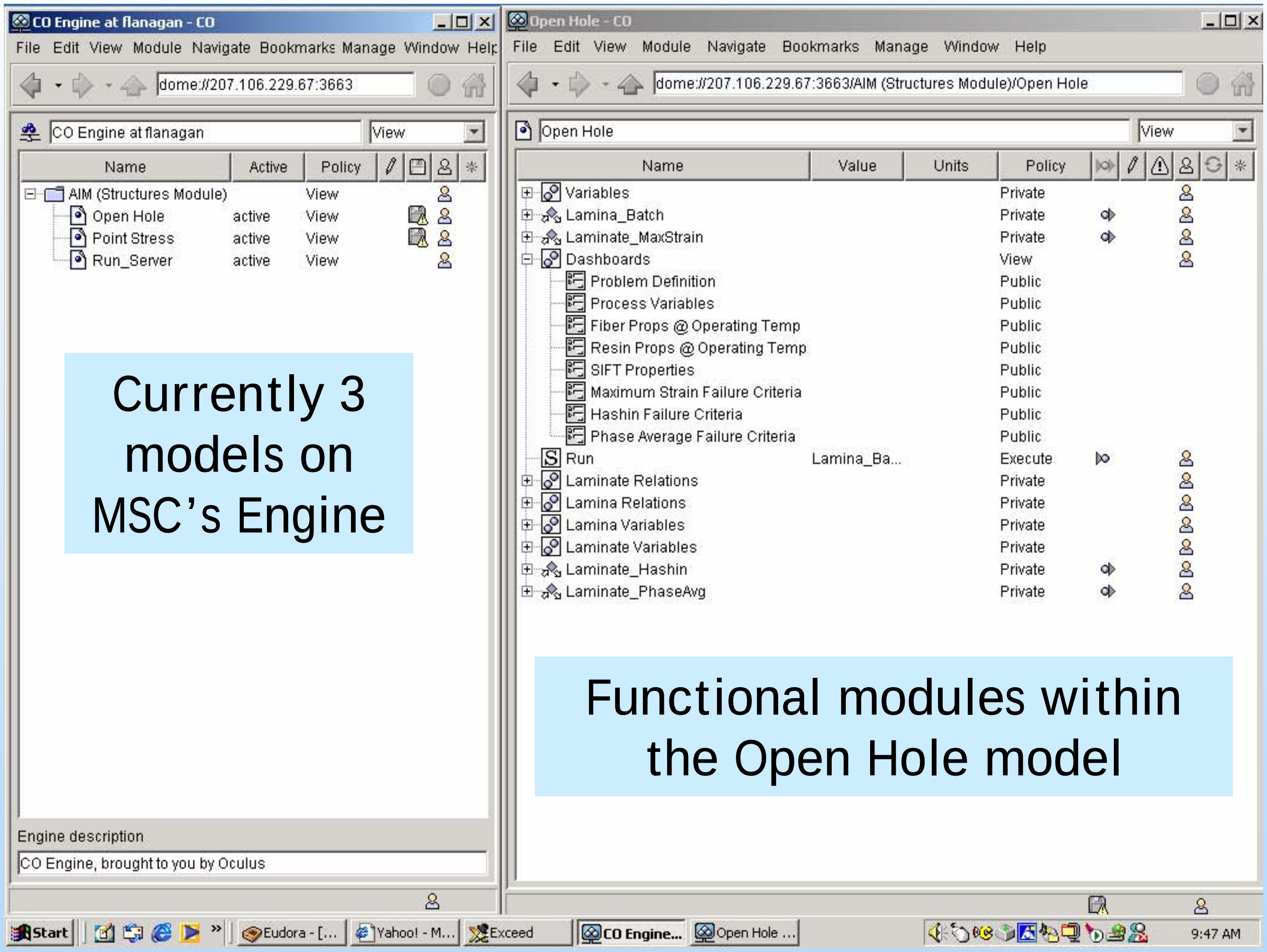
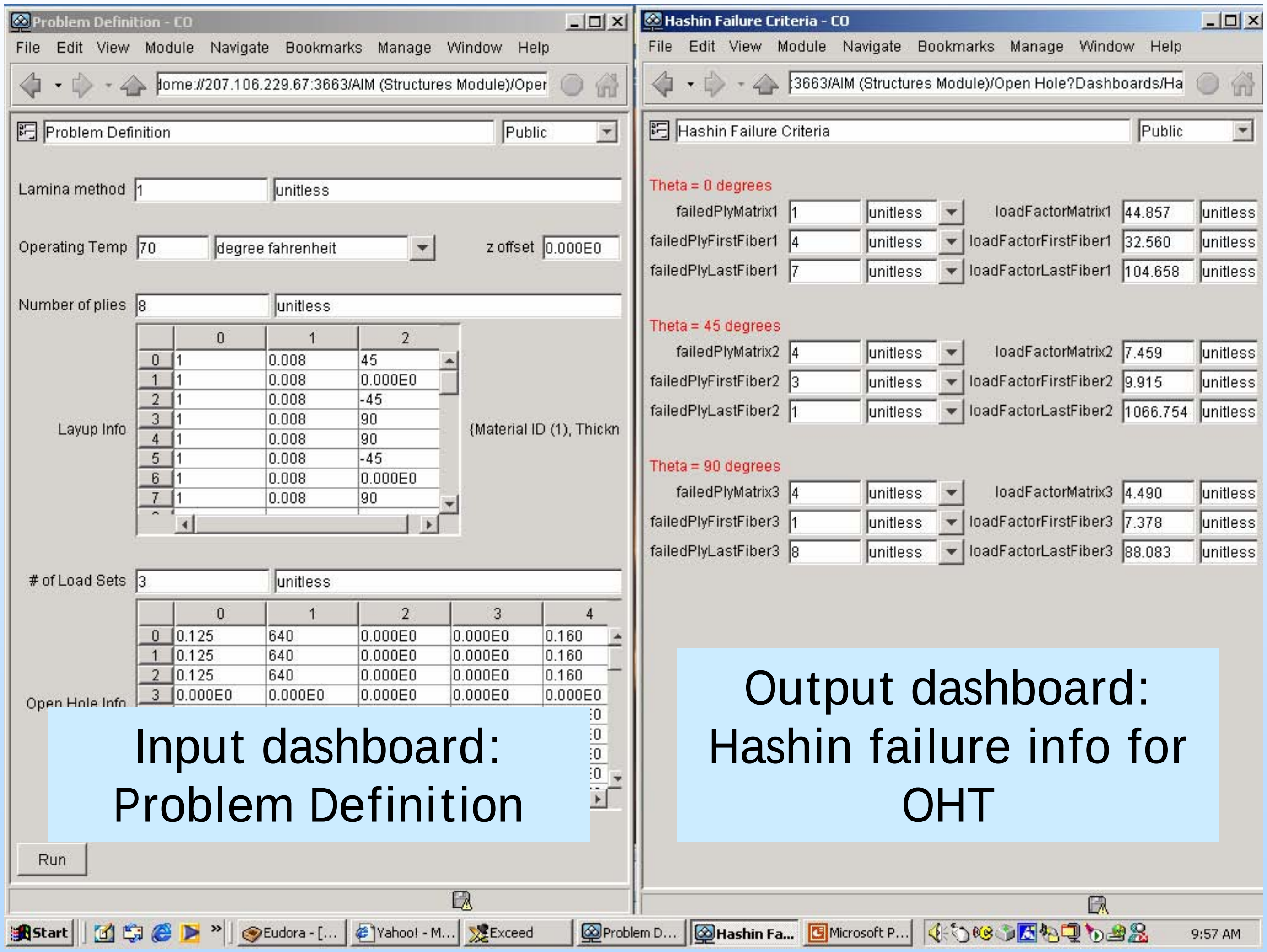
Oculus Models



Currently 3 models on MSC's Engine

Functional modules within the Open Hole model

Oculus Dashboards



Structures - Hat Stiffened Panel (HSP)

Design/Analysis Procedure

- HSP is a large-scale, complex, detailed design problem
  - Draw on multiple AIM-C modules.
- Accurate results require very fine grid mesh or small element sizes
  - Problem is too large in scale to model with one finite element
  - Thus, a combination of global and local models will be used.
- Submodeling or local modeling capture design details and mfg. defects
  - Submodels are finely meshed cutouts of the global model.
  - Global Model results feed the submodels

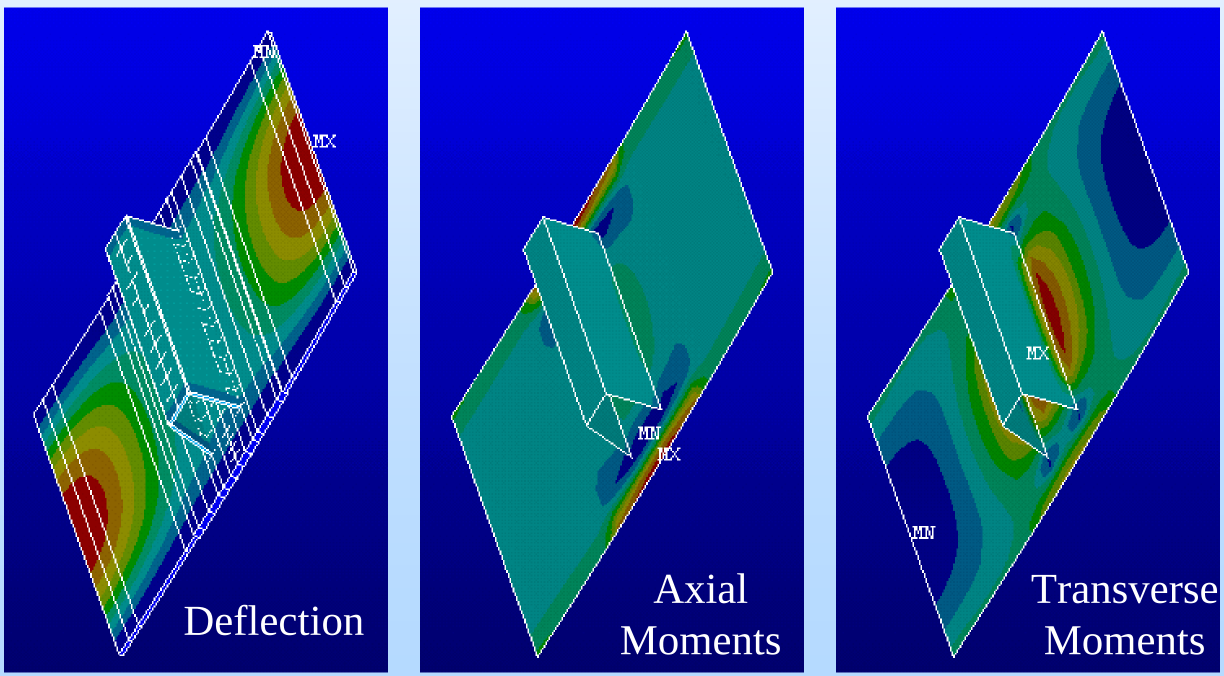
Parametric Global Structures Module

What do you gain from the Global Models?

- Accurate Load Distribution – Failures depend on correct local loads
- Identification of Local Model Requirements
- Easy assessment of Multiple Load Cases
- Rapid Design Iteration – Ability to perform quick geometry trades
- Assessment of Global Failure Modes – Stability, Deflection

How do they work? Demonstration using a simple one-bay hat model in ANSYS

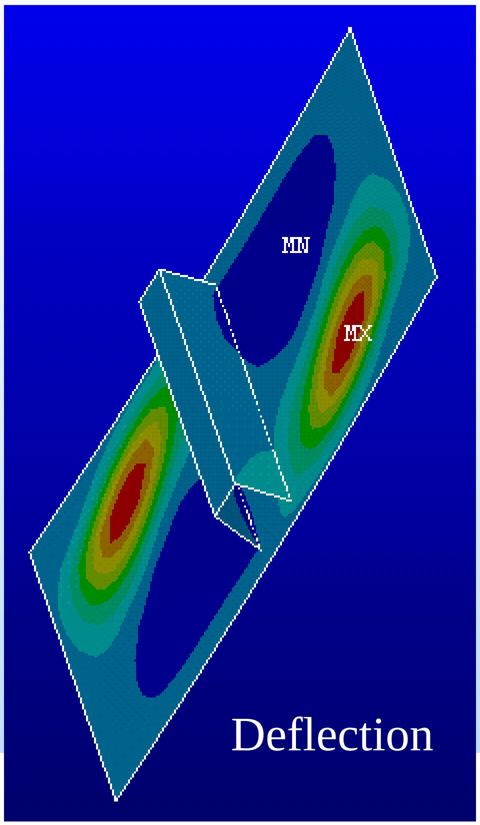
- Model and run a baseline…Hat under pressure (Linear)



Parametric Global Structures Module Demonstration

Global and Local Failure Modes

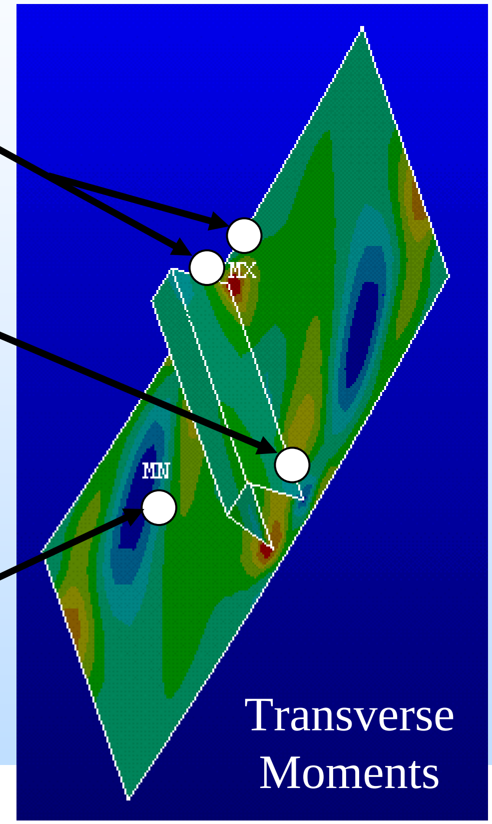
Another load case…Hat under in-plane shear (2500με)
(Nonlinear Large Deflection Solution)



Local Bondline Failure at Noodle Or Edge-of-Flange?

Radius Bending or Bow Wave Defect Failure?

OHC Strain Exceeded?



- Not buckled yet, but significant bending due to the eccentricity of the stiffener is beginning to form the first buckling mode shape. Max deflection is 0.034”. Okay for Aero?
- Identify local model requirements.

Local Models

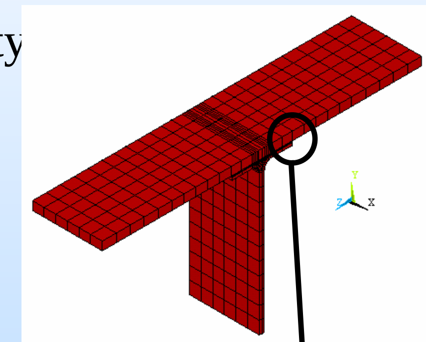
Design Details

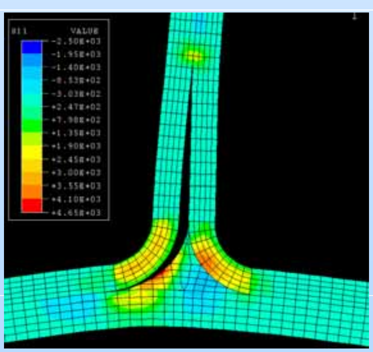
Local Models are used to perform detailed analysis in an area of interest, usually
A potential failure location – often an area of high loading near a structural discontinuity

Two kinds of Local Models:

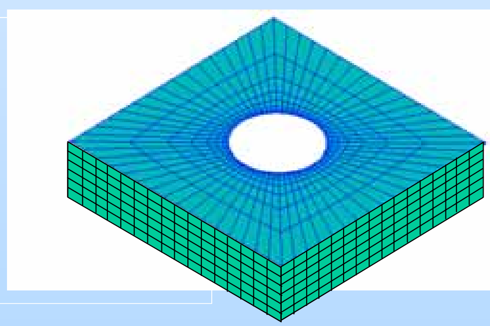
1. Design Details – a designed-in structural feature (e.g., Open Hole, Edge of Flange)
2. Mfg. Defect – an undesired "feature" produced as a side-effect of the manufacturing process (e.g., waviness, delamination, porosity)

Local Models for Design Details:

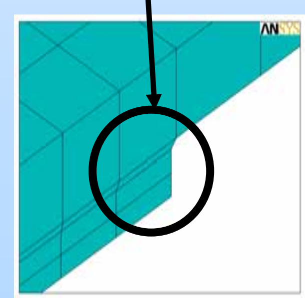




"Noodle" Models



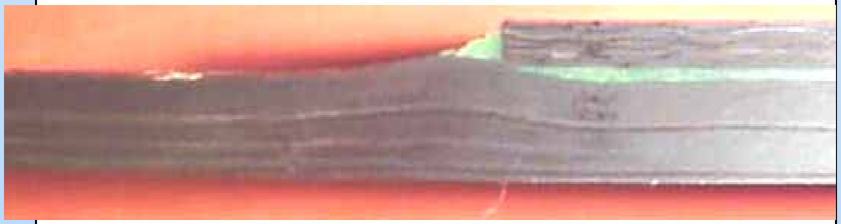
Open Hole Models



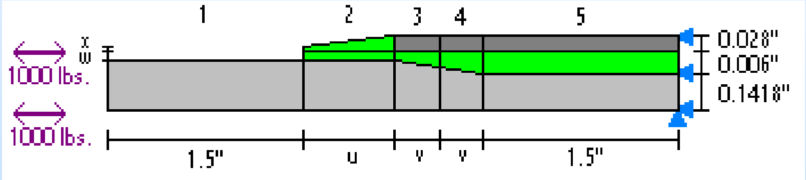
Edge-of-Flange Models

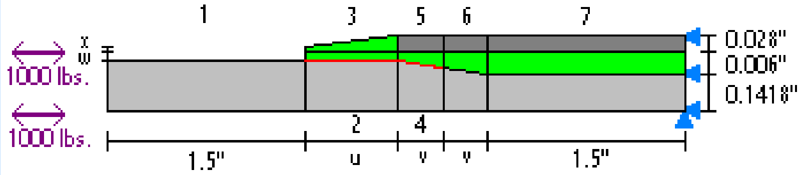
Bow Wave Defect Analysis Using SUBLAM Linked to RDCS

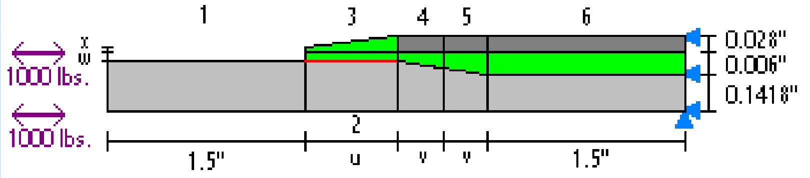
- SUBLAM was incorporated into RDCS to demonstrate the concept of creating a suite of "defect analysis handbooks" to be inserted in the AIM-C CAT.
- Full factorial design space scans were conducted to compute the sensitivity of local stresses and energy release rates under tensile and compressive loads to four geometric variables.



Variable		Lower Limit	Center Value	Upper Limit
u	Resin pool length	0.05"	0.175"	0.3"
v	Bow-wave length	0.05"	0.125"	0.2"
w	Adhesive thickness	0.0005"	0.00325"	0.006"
x	Resin pool height	0.0005"	0.01425"	0.028"

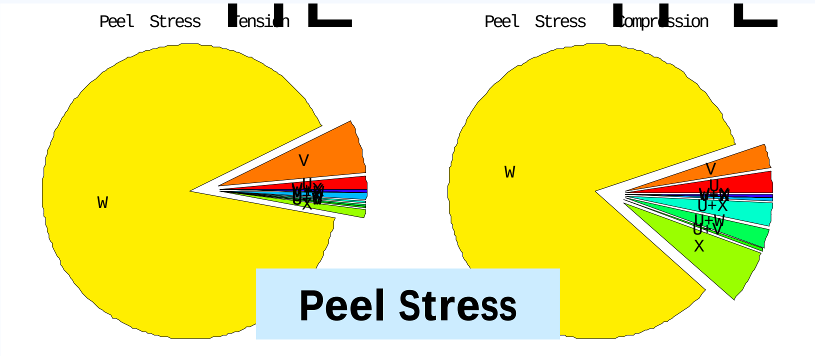




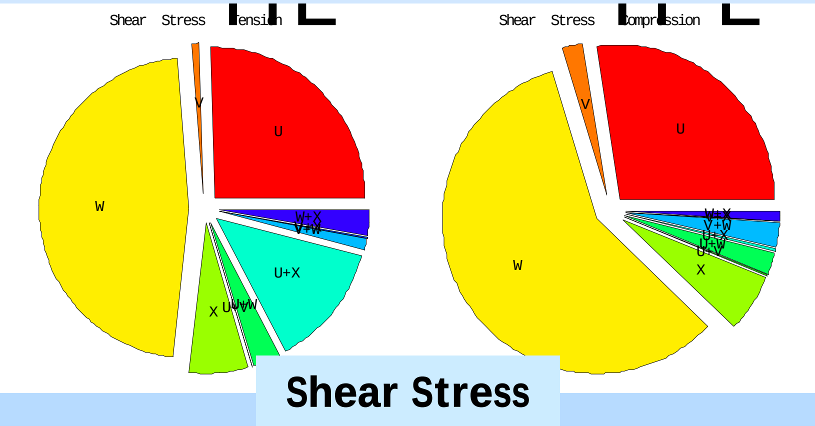


Bow Wave Defect Analysis – Sample Results

- Peel and shear stresses driven be adhesive thickness and resin pool length.
- Relative contributions depend only slightly on whether load is tensile or compressive.
- Some significant two-way interactions for shear stress, viz., resin pool length and height.
- Bow wave length not a big driver for range studied.



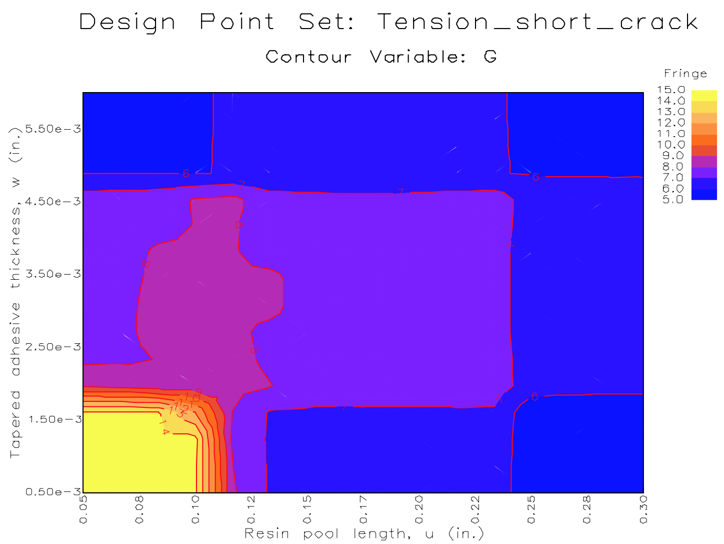
Peel Stress



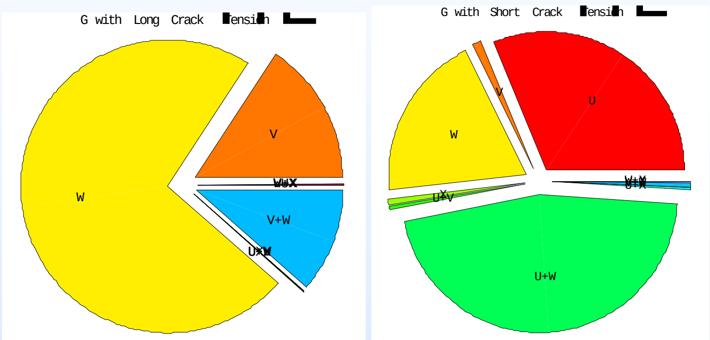
Shear Stress

Bow Wave Defect Analysis – Sample Results

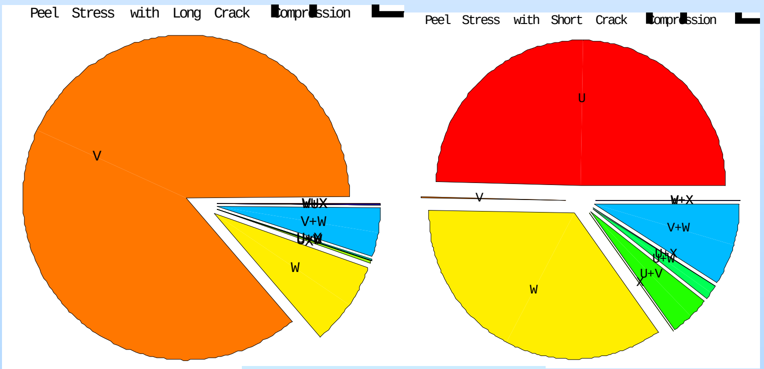
- Contributions to ERR (G) strongly dependent on whether load is tensile or compressive and initial crack (defect) size.



G (in-lbs/in^2) for tensile load as a function of initial defect size and adhesive thickness.



Tension



Compression