Accelerated Insertion of Materials – Composites

Presented at

Mil-Hdbk-17 Forum

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Jointly accomplished by BOEING and the U.S. Government under the guidance of NAST

This program was developed under the guidance of Dr. Steve Wax and Dr. Leo Christodoulou of DARPA. It is under the technical direction of Dr. Ray Meilunas of NAVAIR.

Report Documentation Page

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The AIM-C Team

- Boeing – Seattle and St. Louis – AIM-C CAT, Program Management
- Boeing – Canoga Park – Integration, Propagation of Errors
- **Boeing – Philadelphia** – Effects of Defects

CMT

- Convergent Manufacturing Technologies – Processing
- Cytec Engineered Materials – Constituent Materials, Supplier

- Materials Sciences Corporation – Structural Analysis Tools
- MIT – Dr. Mark Spearing – Lamina and Durability
- MIT – Dr. David Wallace – DOME, Architecture
- Northrop Grumman – Bethpage – Blind Validation
- Northrop Grumman – El Segundo – Producibility Module
- **Stanford University** – Durability – Test Innovation

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

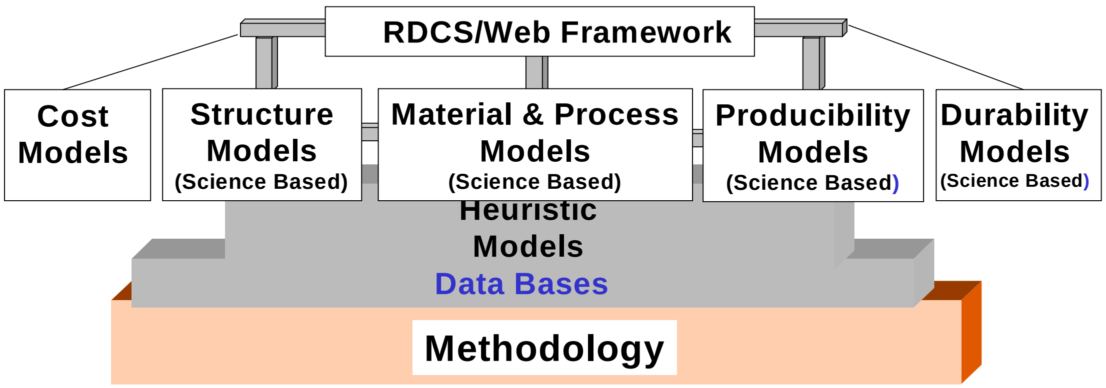
Methodology - ***We will evaluate the historical roadblocks to effective implementation of composites and offer a process or protocol to eliminate these roadblocks and a strategy to expand the use of the systems and processes developed.***

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.***

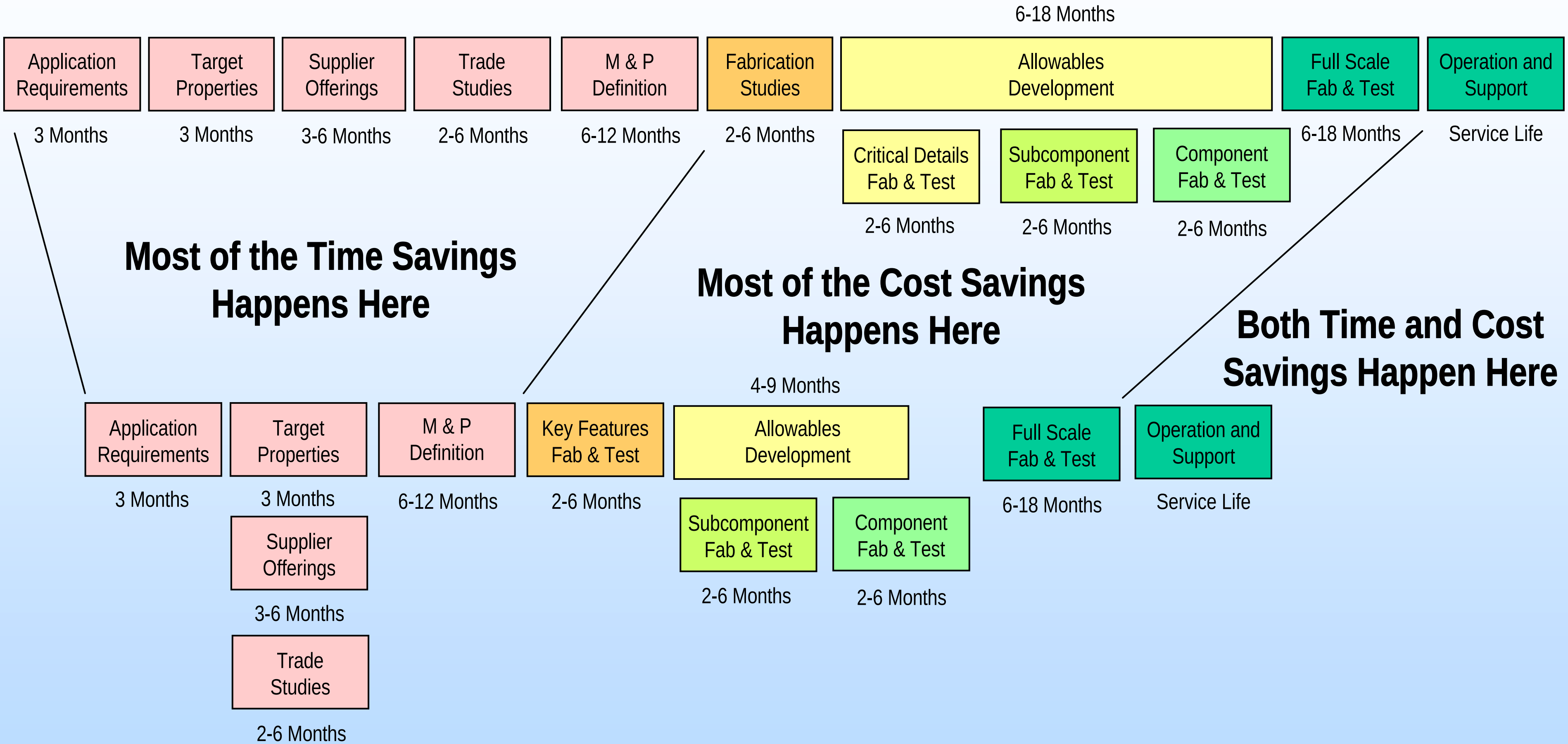
Demonstration/Validation - ***We will provide a mechanism for acceptance by primary users of the system and validation by those responsible for certification of the applications in which the new materials may be used.***

The Plan

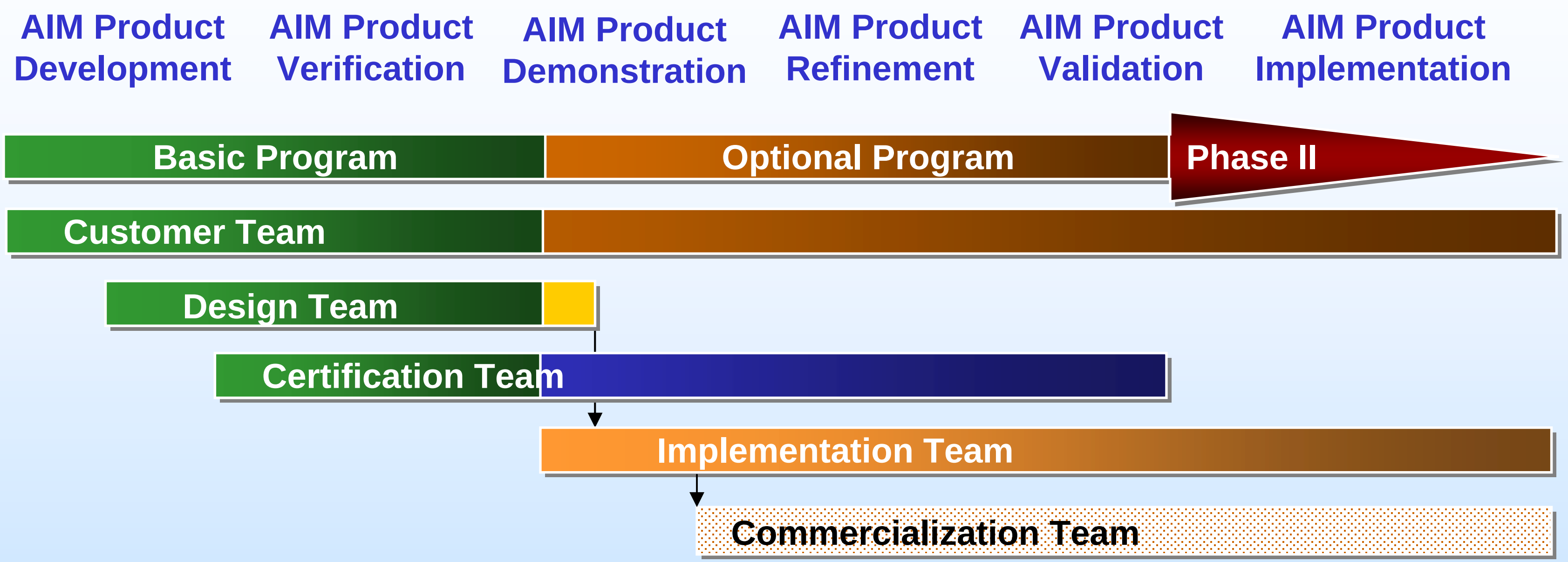
- Incorporate methodology into an interface that guides the user and tracks the progress of technology maturation to readiness
- Deliver software in steps toward a useable system as analysis modules are completed
- Demonstrate capability through system validation, compelling technical demonstration, and a 'blind validation' to insure usability



AIM-C Material Maturation Methodology Cuts Time But Retains the Discipline



Technology 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 commercial support of users

The 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	TBD	Dick Holzwarth	Katie Thorp	Bob Reifenberg
FAA	Richard Yarges	Larry Ilcewicz	David Swartz	Dave Ostrodka
Army	Kevin Rotenberger	Jon Schuck	TBD	TBD
NASA	TBD	Jim Starnes	Tom Gates	Tom Freeman

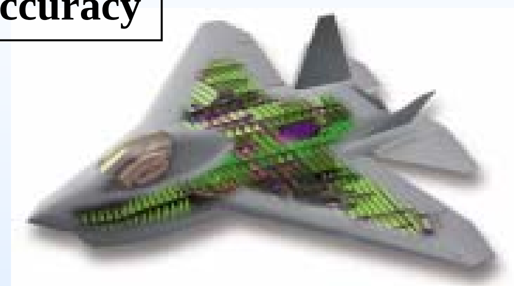
To Insure That the Methodology, Verification, and System Validation We Do Satisfies Certifying Agencies

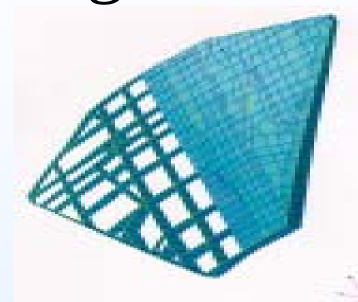
DARPA

NAVAIR

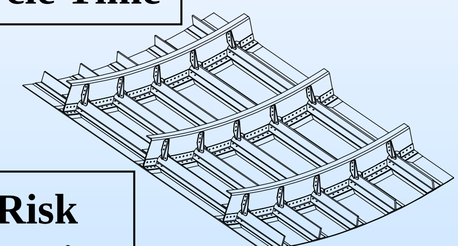
Structures Task – Long Range Goals

Increase Accuracy





Decrease Cycle Time

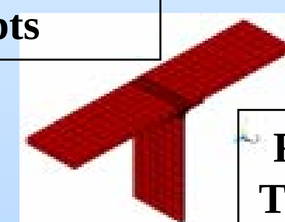


Supporting Technologies

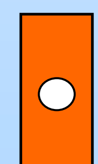
Analysis

- Full-Scale Tests (1 to 3)
- Component Tests (3 to 10)
- Subcomponent Tests (~250)
- Element Tests (~2000)
- Coupon Tests (~8000)

Reduce the Risk Of Using Innovative Concepts



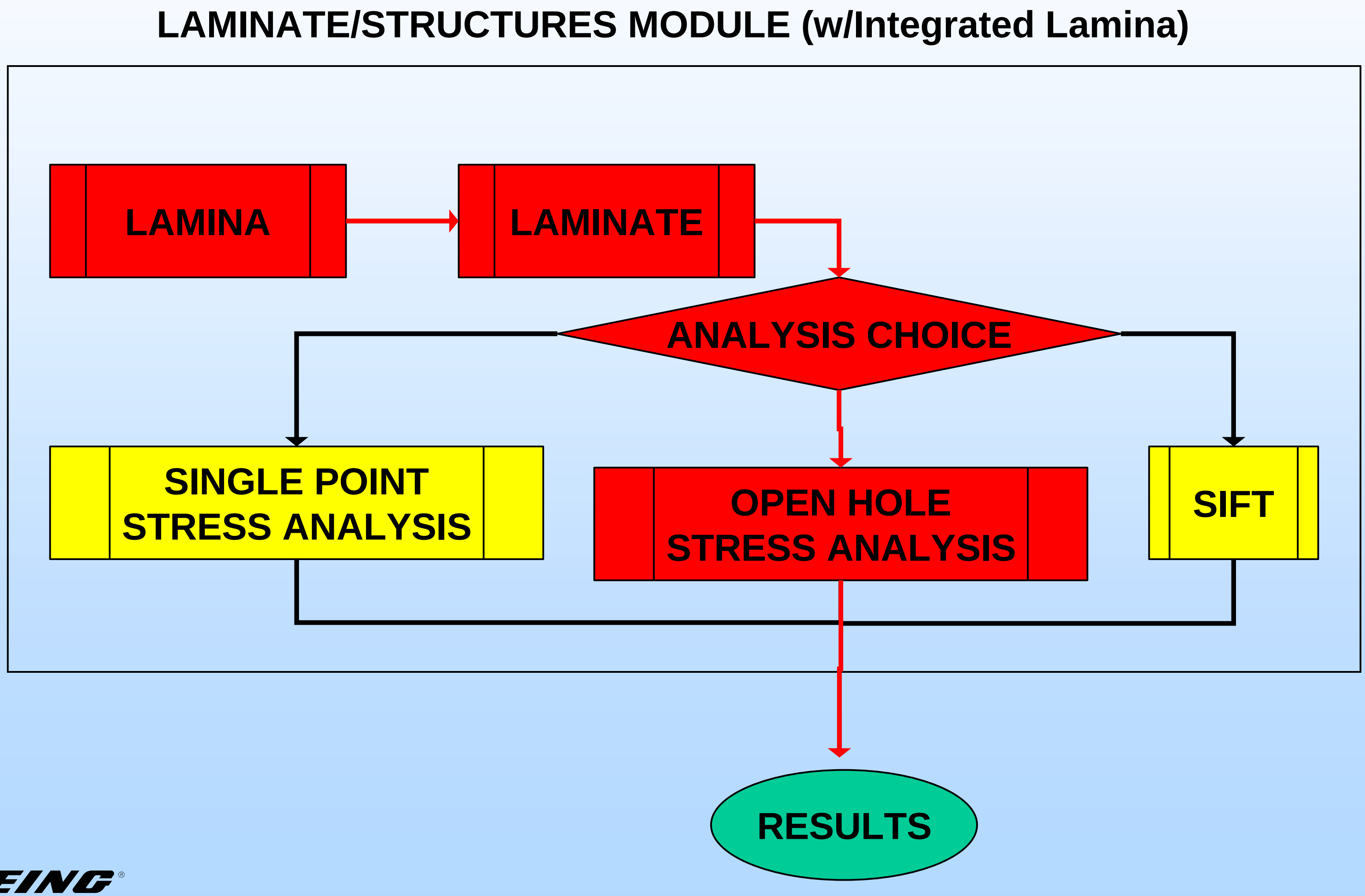
Focus Testing



Aid Material Developers

BOEING

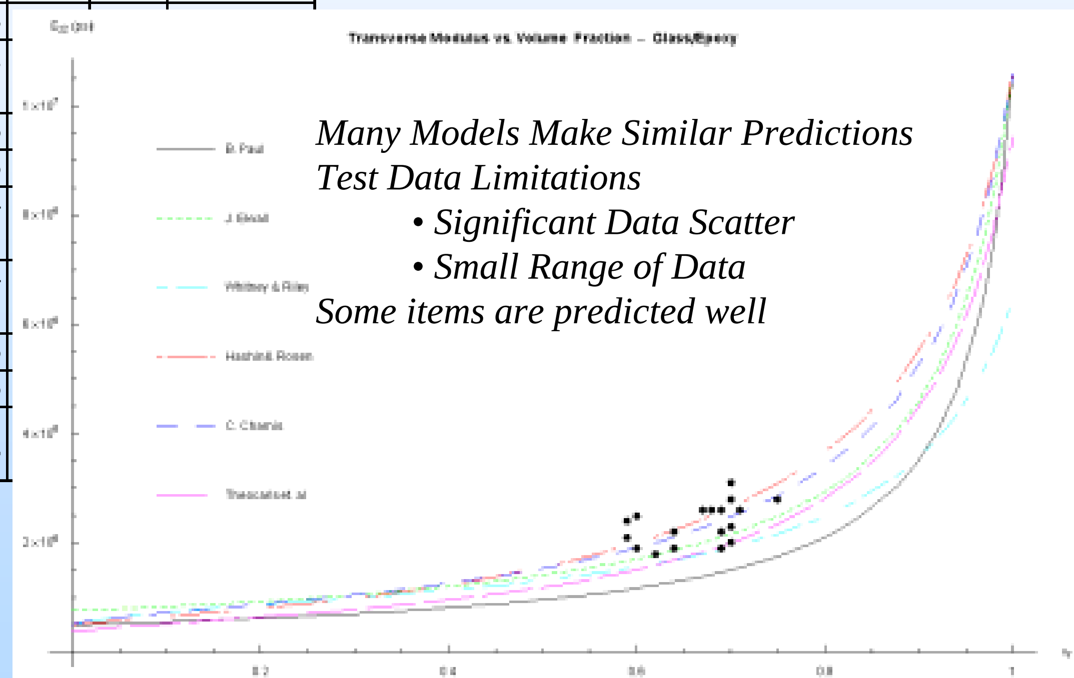
Structures Module Process



Methods – Lamina Prediction

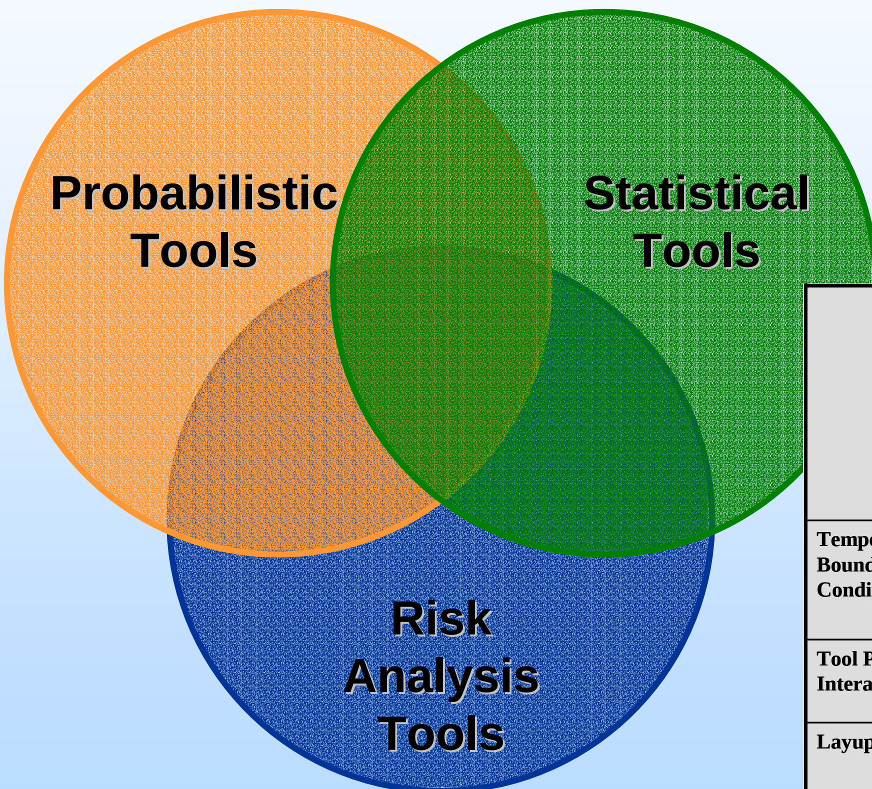
Attribute	Attribute Weight	Mechanics of Materials - Stress Equilibrium/	Variational Elasticity - Contiguity/Tsai	Mechanics of Materials - Restrained Matrix/Ekvall	Exact Elasticity Solution - Finite Difference Method/ Adams and Doner
Strong physical basis	10	3			
Good comparison with experiments	10	2			
Low data gathering cost/time	6	5			
Low computational cost	5	5			
Applicability to all continuous fibrous systems	5	4			
Clear approach, documentation, implementation	3	4			
No "tuning" requirement	3	5			
High simplicity/usability	1	5			
Total = Sum of (assigned values X attribute weight)		**157**			

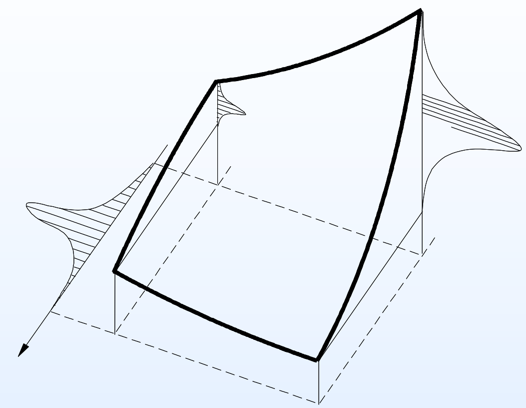
Model Investigation, Ranking, And Selection



Model Accuracy Verification

Understanding Uncertainty –
The Benefit of Linked Simulation Tools and Methodology



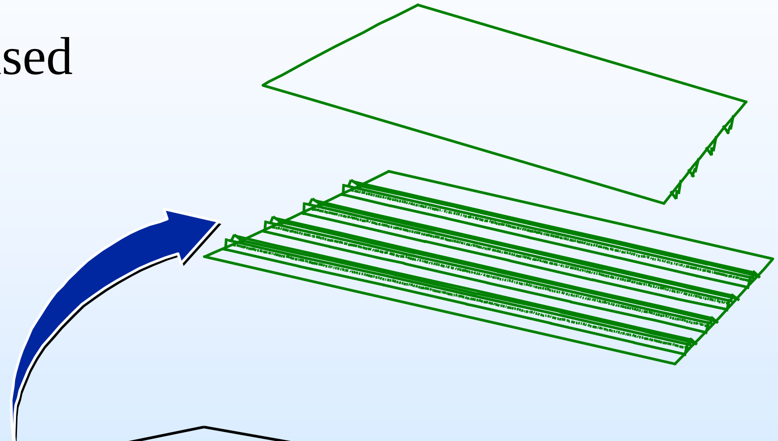


Modeling of the Process

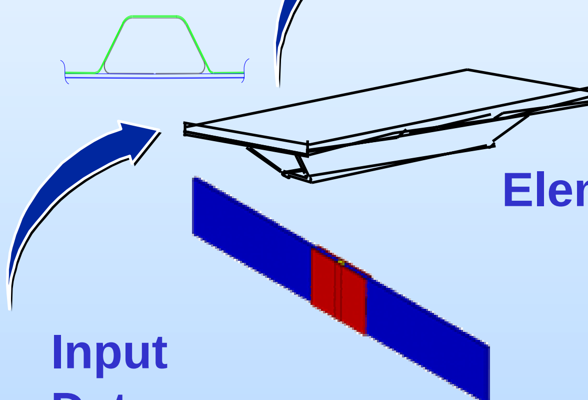
	Inherent variations associated with physical system or the environment (Aleatory uncertainty) Also known as variability, stochastic uncertainty E.G. manufacturing variations, loading environments	Uncertainty due to lack of knowledge (Epistemic uncertainty) inadequate physics models information from expert opinions.	Known Errors (acknowledged) e.g. round-off errors from machine arithmetic, mesh size errors, convergence errors, error propagation algorithm	Mistakes (unacknowledged errors) human errors e.g error in input/output, blunder in manufacturing
Temperature Boundary Conditions	Variation in temperature throughout an autoclave; variation in bagging thickness across part	Modeling of heat transfer coefficient of autoclave includes pressure effect but not shielding of part. Assumptions made about tool-part resistance.	Convergence of mesh must be checked. Time-steps and temperature steps must be small enough.	Errors in setup files, and other initialization procedures. Errors/bugs in code.
Tool Part Interaction	Part to part and point to point variations in tool finish and application of release agent	Tool-part interaction is very complex, and very local effects may at times be significant	Current model of tool-part interaction is too simple for large parts on high CTE tools.	Errors in calibrating the tool-part interaction
Layup	Variation in lay-up during hand or machine lay-up.	The layers are smeared within an element and it is assumed that the smeared response is representative		Error in defining layup, or alternatively errors in the manufactured part compared to model
Residual Stresses	Many parameters can affect residual stress: local fiber volume fraction, …	Micro-stresses are considered to be independent of meso-stresses; there are few independent measurements of residual stress.	The formulation is believed to be most accurate when the cure cycle temperature is higher than the Tg. Otherwise the residual stress calculated can be an overestimate.	Errors in material property definition, errors in coding, errors in integrating process and structural models.

Stiffener Runout
Analysis Validation Tests

Variables and interactions exercised include processing effects and defects.

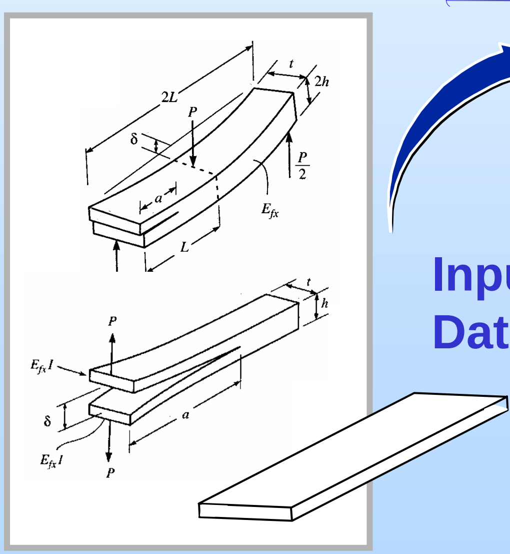


Analysis Validation Tests



Elements

- Static Strength
- Durability
- Damage Tolerance



Input Data

- DCB and ENF
- J_1 and ε_{eqv} Laminates/Joints

How Will the System Be Used?

Web-Driven

- Accessed via Internet
- Used via Internet
- Application file local
- DOME enabled
- Modules available anywhere
- Configuration controlled by user
- Application file contains configuration info

PROs most flexible

Web-Based

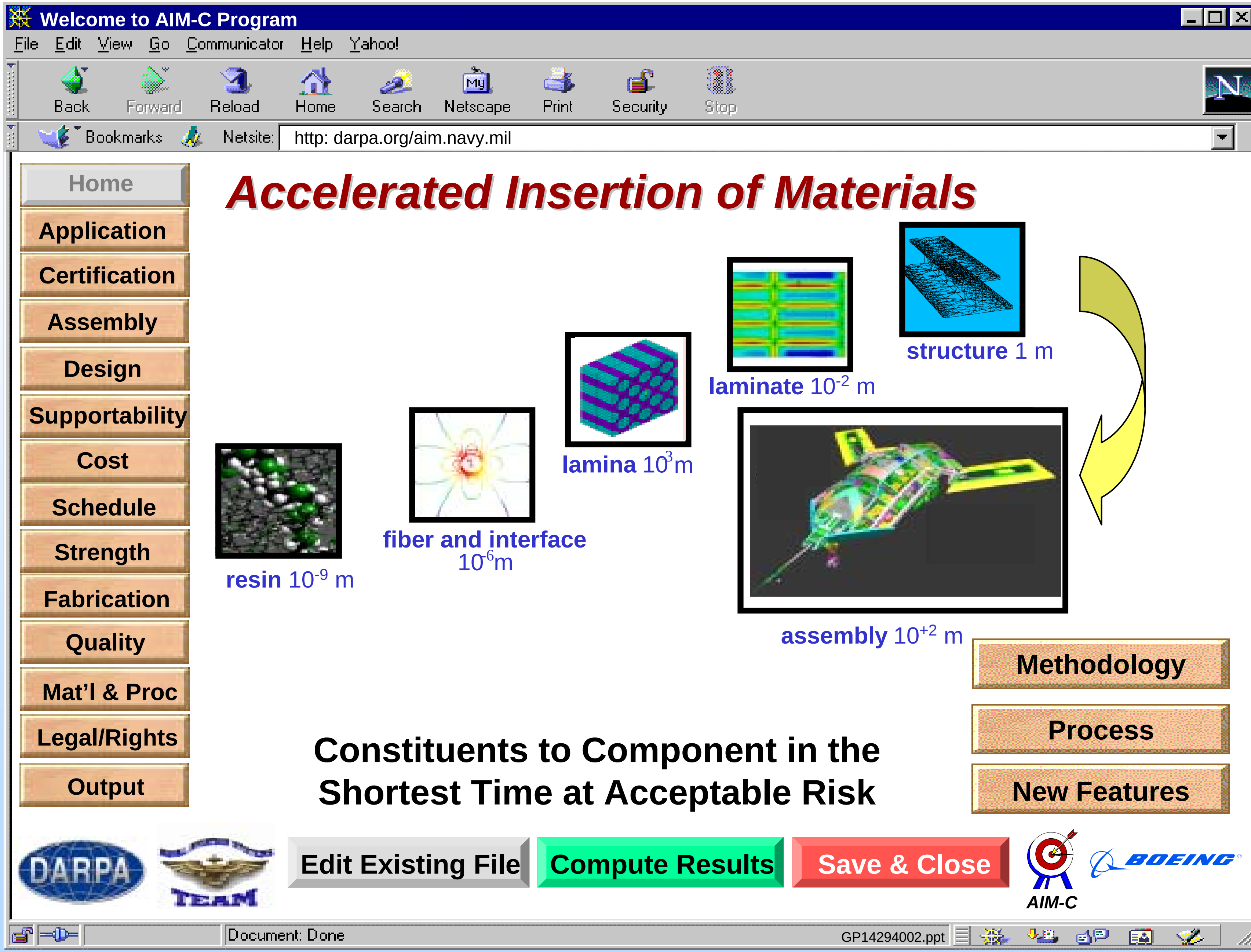
- Downloaded from Internet
- Used locally to create application file
- Application file local
- Modules & S/W available few locations
- Configuration controlled by application file
- DOME enables remote access to modules

PROs most controlled

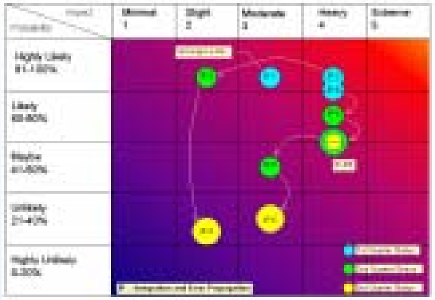
Stand Alone

- Accessed locally
- Used locally to create application file
- Application file local
- Modules & S/W available locally
- Configuration controlled by application file

PROs may be only way for classified programs to use AIM-C


Welcome to AIM-C Program
File Edit View Go Communicator Help Yahoo!
Back Forward Reload Home Search Netscape Print Security Stop
Bookmarks Netsite: http: darpa.org/aim.navy.mil
Home
Application
Certification
Assembly
Design
Supportability
Cost
Schedule
Strength
Fabrication
Quality
Mat'l & Proc
Legal/Rights
Output
Accelerated Insertion of Materials
resin 10-9 m
fiber and interface 10-6m
lamina 10-3m
laminate 10-2 m
structure 1 m
assembly 10+2 m
Methodology
Process
New Features
Constituents to Component in the Shortest Time at Acceptable Risk
DARPA
TEAM
Edit Existing File
Compute Results
Save & Close
AIM-C
BOEING
Document: Done
GP14294002.ppt

Knowing in part may make a fine tale, but wisdom comes from seeing the whole.*



* *Seven Blind Mice*
by Ed Young