Qualification *and Certification*

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20 July 2022

SME Aerospace Composite Forum

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Content/Context

- Terminology
- “Navy Protocol”
- DARPA Accelerated Insertion of Materials – Composites
- Industry specifications, test methods and data sets
- Building Block
- What is needed in material qualification and airframe certification?
  - *Stable material, stable process, with validated process window (physical data, not model extrapolation) is needed.*
  - *Building block to cover scale up, training, scatter and repeatability, and manufacturing capability, in addition to airframe certification specifics.*
  - *Add to that in today’s post-Covid world, real-world experience so that engineers and program managers have a basis for intelligent qualification (similar to “slide rule judgement”).*

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Terminology

- Successful implementation of material and process technologies requires successful **qualifications**. Yes, the word “qualifications” is plural.
- There are qualifications of constituent materials, processing to make product forms, fabrication processes, suppliers, consumable materials, etc.
  - Address stability, variability, uncertainty, and error
  - What are emerging opportunities – new practices, new definitions, and new cases?
  - How does successful qualification/certification provide the foundation for knowledge-driven manufacturing?

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Terminology

Materials and processes are qualified. Material system characteristics, properties, and processes are controlled for a system's operational requirements for predictable and repeatable quality.

- Stabilized materials and processes
- Demonstrated producibility
- Characterized mechanical properties
- Consistency of structural performance
- Demonstrated supportability

Structures are certified. Certification requirements focus exclusively on safety.

From "Certification Perspective" by Tim Jennewine, presented at the Persh Conference Oct 2009

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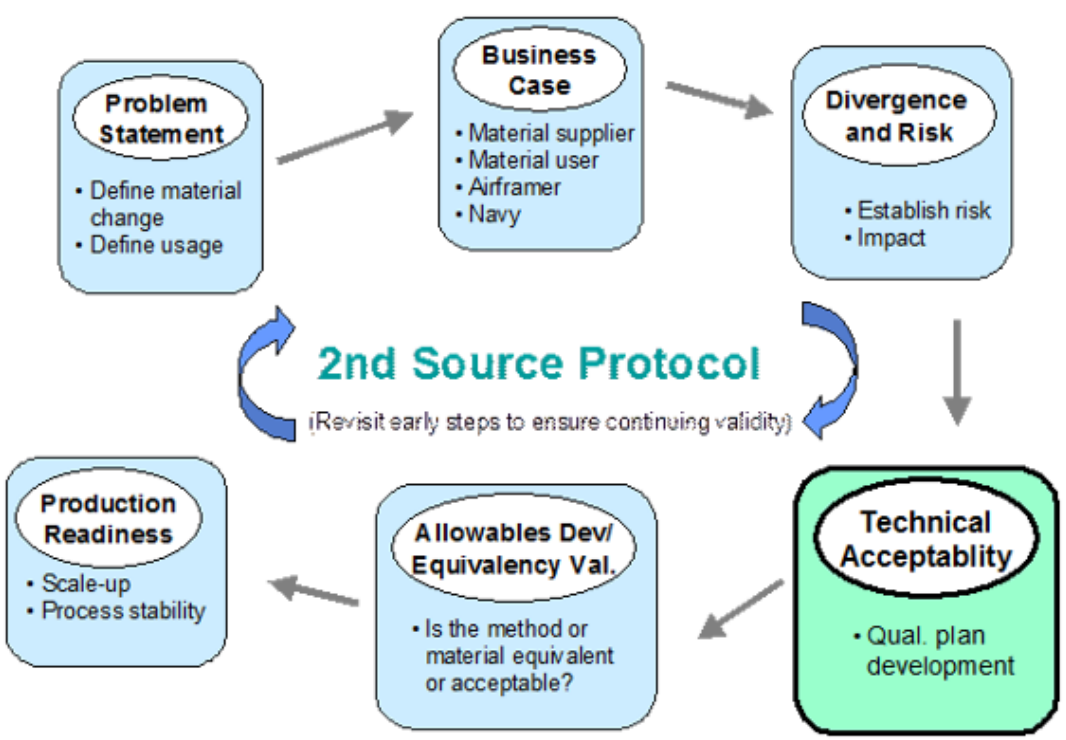
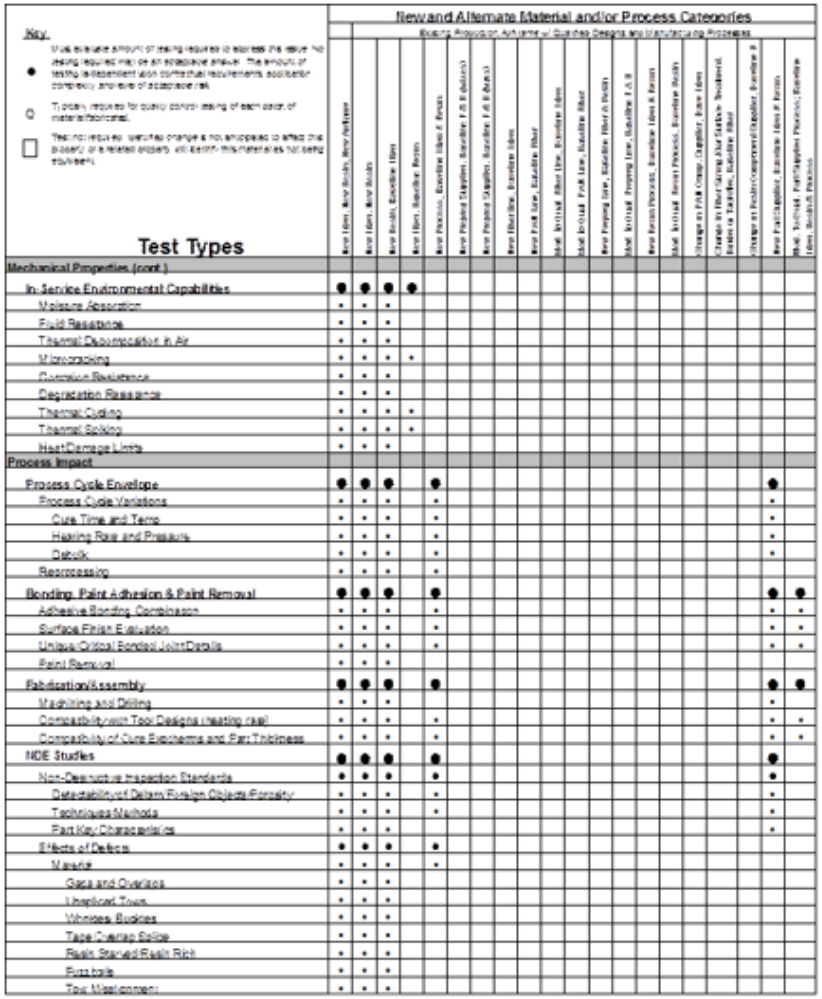
"Navy Protocol" (N00014-97-C-0417)

Protocol methodology – some sections became part of CMH-17





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Accelerated Insertion of Materials – Composites (AIM-C)

Methodology – evaluated historical roadblocks, offered process/protocol

- Scale up
- End of life properties
- Unplanned rework
- Transition of the knowledge base
- Uncertainty management

Product Development – software tools, documentation and test cases with configuration control

Demonstration/Validation – third party; testing

Explored combining heuristic, analytical, and test data
(Conditional Value-at-Risk (CVaR) Quantile Regression)

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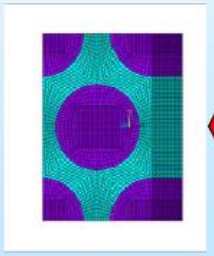
Accelerated Insertion of Materials – Composites (AIM-C)

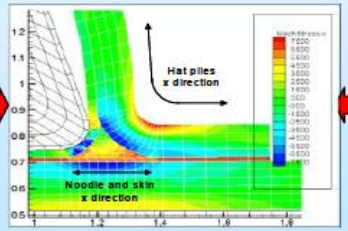
Accomplishments

Web-Based System Delivery

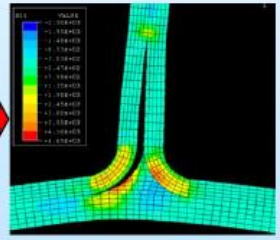
Process Guidance and Risk Reduction Status



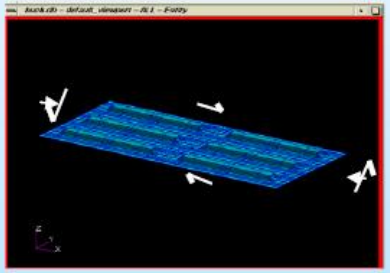
AIM-C Contains Analytical Models From Constituents



To Processing



To Effects of Defects



To Structural Requirements

To Provide Analysis Supported by Test To Technology Readiness

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AIM Accelerated Insertion of Materials

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Industry Specifications, Test Methods and Data Sets

Now more prevalent in composites

Beneficial

Do not eliminate the need for company-specific or program specific specifications, methods, or data.

Typically consider nominal conditions more than the processing window.

Often do not adequately cover use environments – in manufacturing and in the final product.

Often do not consider family of product forms or family of processes and equipment or consumables, etc.

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Processing Window

Simple example for kinetics (cure/consolidation) at isothermal temperature:

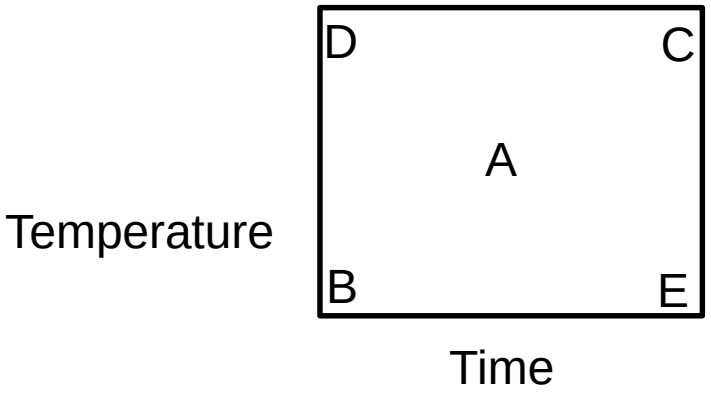
350 F +/- 10 F for 40 +/- 10 minutes

A - Nominal is 350 F for 40 minutes

B - Least thermal history is 340 F for 30 minutes

C - Most thermal history is 360 F for 50 minutes.

D&E - The other corners of the window are 340 F for 50 minutes and 360 F for 30 minutes.



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A New Material System Needs to Be Understood Throughout Its Life Cycle

Fabrication

Assembly

Surface Preparation for Finishing

Retire Part/Product

In-service Maintenance & Repair

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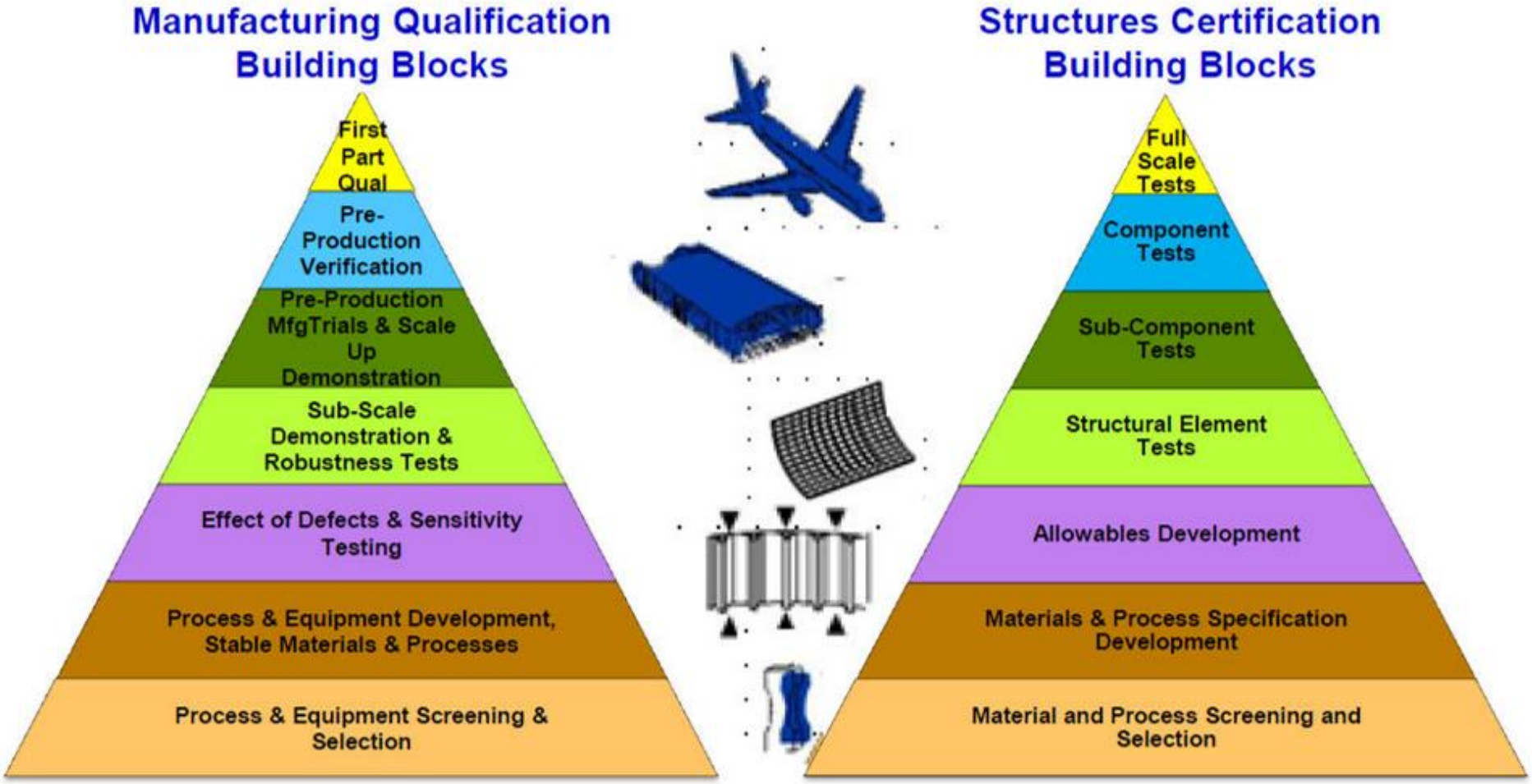
Building block - different perspectives, and ultimately, certification
Uses can include addressing scale, rate, supply chain



From “Challenges for Composites” by Jerry Young
Presented at the DARPA-NSF Composites Workshop August 2013

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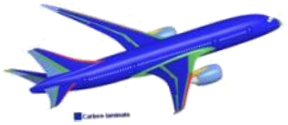
Materials & Process to Application

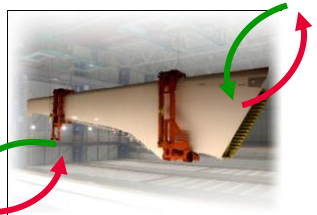
Materials & Process and Manufacturing system designed and qualified in digital form with requirements driven by system & life-cycle requirements

Vehicle

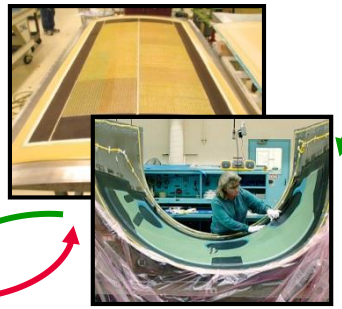


Assembly

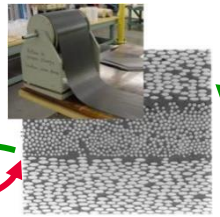
Scale Up



Process Development



Material System & Forms



Constituent Design

Computational Materials

- **Material Development**
- **Process Development**

Material Models

- **Mat'l & Process Capability**
- **Initial Accept & Reject Criteria**

Processing and Quality Simulation

- **Producibility**
- **Inspection Standards**
- **Quality & Effects of Defects**
- **Process Tolerances**

Process and Manufacturing Simulation for Quality Aspects of Full Size Parts

- **Manufacturing Scale up**
- **Full size fabricated elements**
- **Effects of Defects**
- **Expanded Mfg Limits**

Tolerances & Assembly Simulation

- **Production System**

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What is needed in material qualification and airframe certification?

- Stable material, stable process, with validated process window (physical data, not model extrapolation) is needed.
- Building block to cover scale up, training, scatter and repeatability, and manufacturing capability, in addition to airframe certification specifics.
- Real-world experience so that engineers and program managers have a basis for informed qualification (similar to “slide rule judgement”) in addition to benefits of models for analysis.
- Relevance to a program
- Maturity of processes, tools, data for program engineers

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DESIGN TEAM'S NEEDS

Requirements are Multi-Disciplinary

Structural

- Strength and Stiffness
- Weight
- Service Environment
  - Temperature
  - Moisture
  - Acoustic
  - Chemical
- Fatigue and Corrosion Resistant
- Loads & Allowables
- Certification

Manufacturing

- Recurring Cost, Cycle Time, and Quality
- Use Common Mfg. Equipment and Tooling
- Process Control
- Inspectable
- Machinable
- Automatable
- Impact on Assembly

Supportability

- O&S Cost and Readiness
- Damage Tolerance
- Inspectable on Aircraft
- Repairable
- Maintainable
  - Accessibility
  - Depaint/Repaint
  - Reseal
  - Corrosion Removal
- Logistical Impact

Material & Processes

- Development Cost
- Feasible Processing Temperature and Pressure
- Process Limitations
- Safety/Environmental Impact
- Useful Product Forms
- Raw Material Cost
- Availability
- Consistency

Miscellaneous

- Observables
- EMI/Lightning Strike
- Supplier Base
- Applications History
- Certification Agency Expectations

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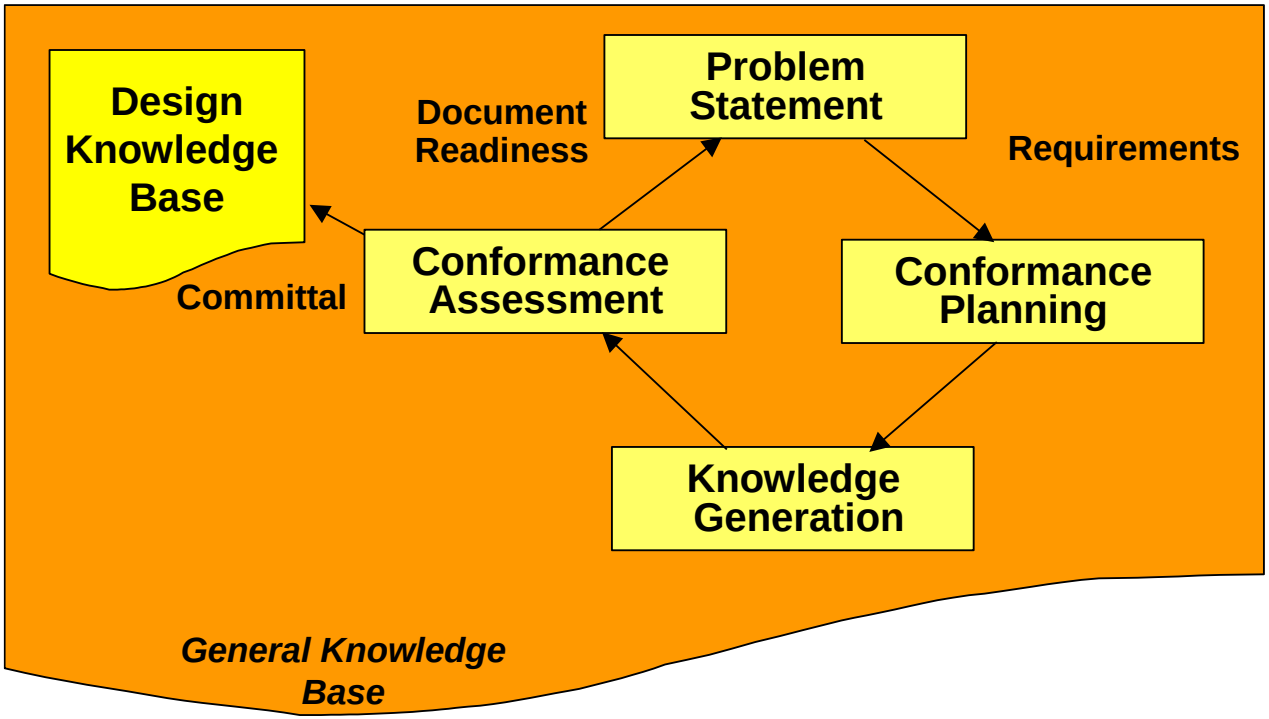
Methodology/Process Iteration



- Define Problem and Capture Requirements/Needs (Why are activities done?)
- Plan Activities for Conformance (Who, What, How and When conformance will be done?)
- Conduct Conformance Activities to Generate Knowledge Required for Problem
- Assess Conformance Knowledge for Acceptability in Meeting Requirements and Problem Statement
- Commit Knowledge and Documentation to Design Knowledge Base. Refine Problem Statement and Plans by Iterating the Process at the Next Maturity Level.

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Problem Statement Definition Checklist

Is the objective clearly identified?

Has the information necessary to solve the problem been identified

Has extraneous information been identified as such?

Is this statement an identification of the problem or erroneously identification of a desired or anticipated solution?

Are the critical checks/issues being captured for the next stage of the qualification/certification process, conformance planning?

Are all of the appropriate stakeholders (including internal and external customers) involved and concurring to the statement?

Have applicable assumptions, compromises, and contingencies been identified in writing?

Is the problem statement in a useable form for a Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis?

Was a check made of past showstoppers/major issues related to problem statements of a similar nature?

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Conformance Planning – Process/Producibility

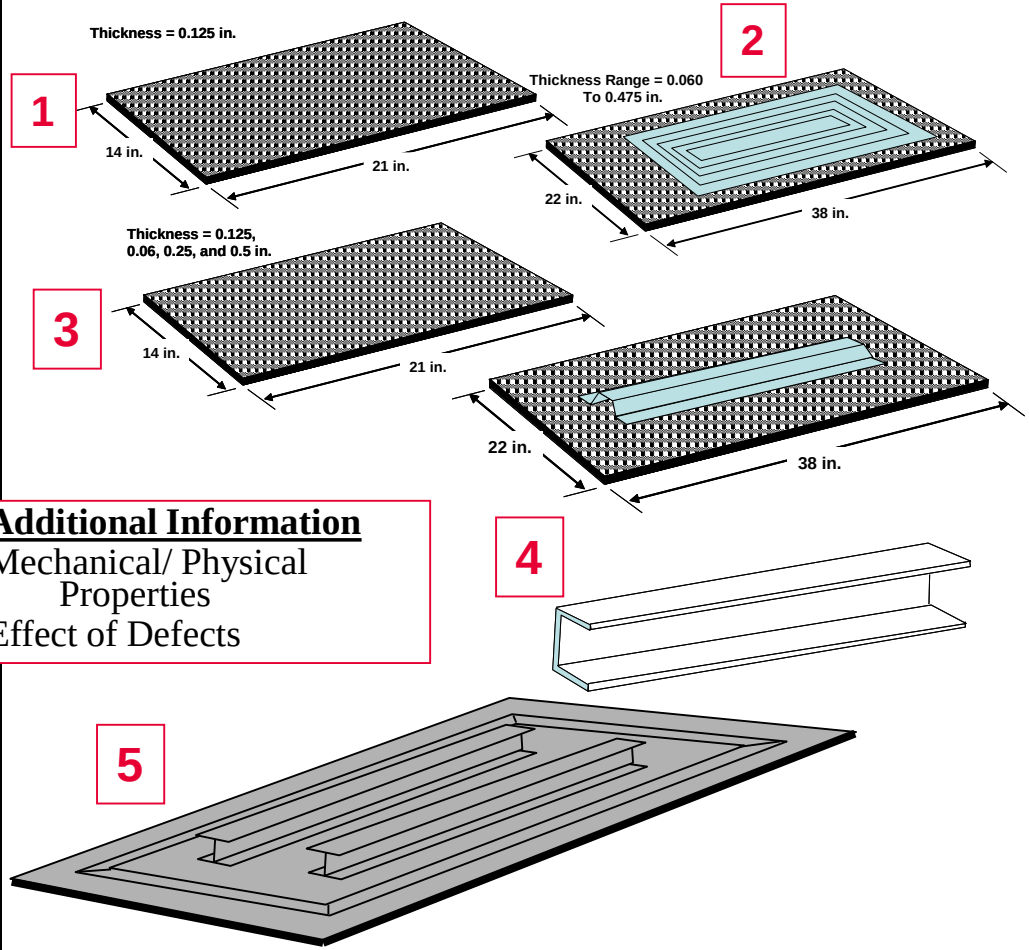
Producibility Item Assessments
Producibility Items/Areas

- Manufacturing/Processing
  - Cutting
  - Layup
  - Debulking
  - Bagging
  - Cure
  - Unbagging
  - NDE
  - Tooling
- Quality
  - In-Process
  - Final Part

Feature Based Part Producibility Methodology/Process Steps

1. Flat Panel, Constant Thickness
2. Ramped Panel
3. Flat Panel, Multiple Thicknesses
4. Elements (Hats, C's, I's, etc.)
5. Scale-up, Size

Feature Based Part Approach



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Conformance Assessment

Review available knowledge: heuristics, lessons-learned, information on similar problems or applications, public literature, analyses, and test results

Address every question/requirement, functional/disciplinary issue

Address interdisciplinary issues/assumptions/decisions as an IPT with all stakeholders

Determine divergence risk on existing information

Evaluate the handling of error and uncertainty

Assess the conformance of existing knowledge with requirements

Determine additional knowledge needed based on knowledge gaps/unacceptable risk

Audit documentation, marking, completeness of information, version controls, etc

Secure agreement from all stakeholders

Commit appropriate files to the master database

Make a plan for corrective action

Make the committals of maturity advancement in the readiness level files

Address the business case as appropriate

Make the decision to continue maturing on the problem statement or revise the problem statement as appropriate

If the problem is not continued, prepare and commit the decision and rationale to the knowledge base for archival purposes and future lessons learned

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Problem Statement for Key Features Article

A few guidelines:

What key features must be accommodated by this article?
Biggest set of unknowns at least time and lowest cost

Must contain the most challenging issues defined by each discipline in the IPT

Must support the overall problem statement

Must be an article close to the size of the largest application foreseen

The article can be dissected into several test articles and measured to assess as-manufactured condition - defects - and structural test articles

Must be fabricated using processes representative of those planned for production

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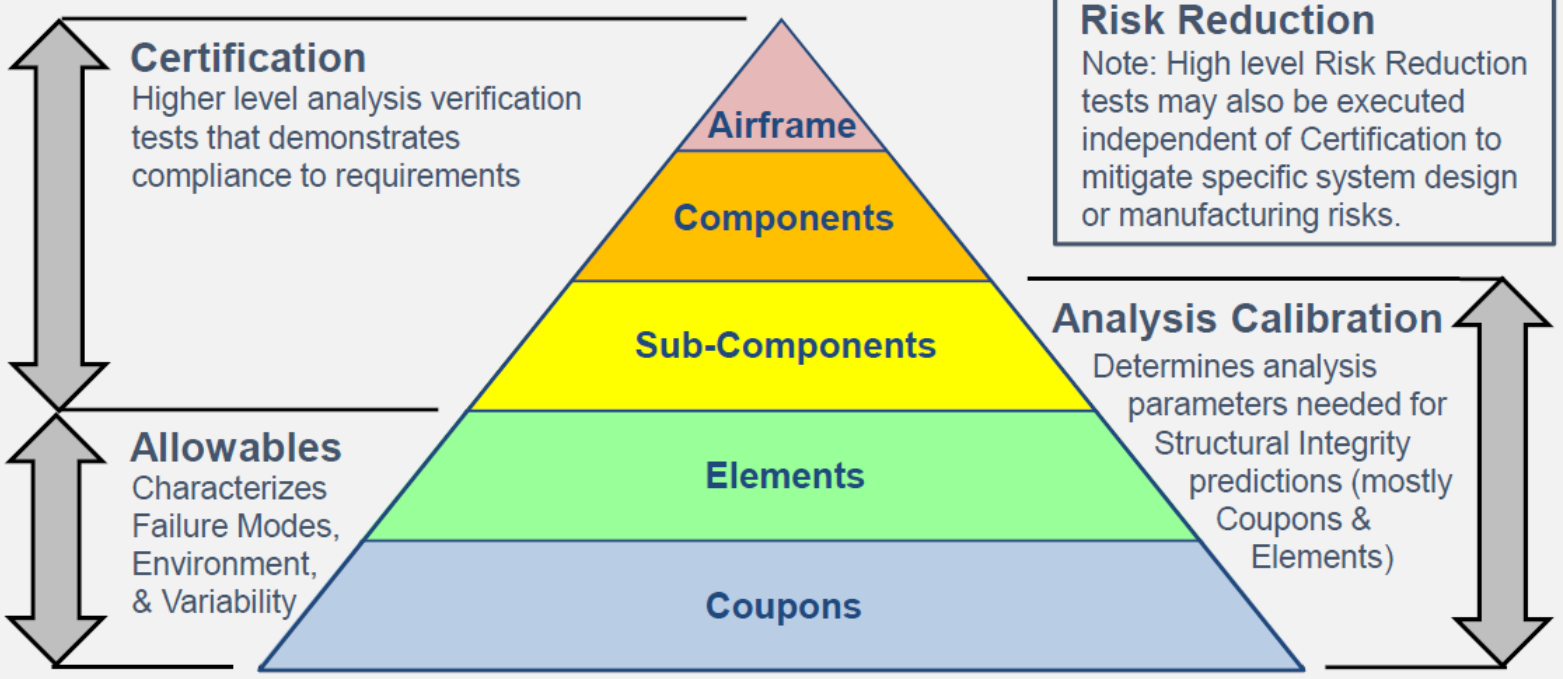
Building Block Development Test Program for Modern Military Aircraft (CAMX 2015)

Building Block Path to Certification



- Airframe Static Test
  - Correlates Finite Element Model and Internal Loads Predictions
  - Evaluates Static Strength and Stability at Room Temperature Ambient Conditions
- Airframe Durability Test
  - Verifies Predicted Metallic Fatigue Life at Airframe Control Points

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Building Block Development Test Program for Modern Military Aircraft (CAMX 2015)

Potential for Accelerating Material Insertion

- Current research efforts are in-work to develop integrated computational strategies for design and simulated testing of polymer composites
  - At present, these computationally intensive tools are ill-suited and inefficient to directly support airframe design, but failure predictions may provide a basis for more efficient solution strategies
  - These tools may also enable a reduction in BBT work-scope
- Potential Reductions in BBT Scope
  - More accurate failure predictions may reduce Element level test matrices where large numbers are required to cover the intended design space
  - Advanced analysis techniques may enable a reduction in larger sub-component and component level risk reduction tests
- Where BBT Scope Reductions are Unlikely
  - Composite Coupon allowable tests remain necessary as they reduce structural integrity risk, support analysis calibration and are cost-efficient
  - Composite Certification tests with environment remain necessary for Analysis Verification and mitigation of structural integrity risk
  - Full Scale Airframe tests remain necessary for the purposes stated previously

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Building Block Development Test Program for Modern Military Aircraft (CAMX 2015)

Lessons Learned

- Define clear record retention practices for test plans, reports, and results. Select stable data formats for long term use.
- Evaluate raw data and failure modes throughout testing. Communicate test changes thoroughly and promptly.
- Be sure to consider long lead test items such as tabs, gages, fixtures, fasteners, etc. as well as time required for moisture conditioning.
- Sequence test schedules so that manufacturing risk reduction activities occur early in the program.
- Maintain traceability and good documentation for constituent ingredients, completed panels, and failed test articles for investigation of test anomalies.
- Do not underestimate the time or expense required for the following:
  - Preparation of Materials & Process specifications including NDI standards
  - Tooling and consumable evaluations, Effects of defects tests
  - Evaluations of corrosion, thermal and/or oxidation protection schemes
- Leverage dual-use manufacturing and structures development test articles and legacy data whenever possible.
- Use of experienced out-of-house test vendors can be cost efficient, but requires good coordination initially and throughout testing.

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