AMTAS
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Background

- Just this year, the aerospace industry will spend several hundred million dollars on structural design and certification

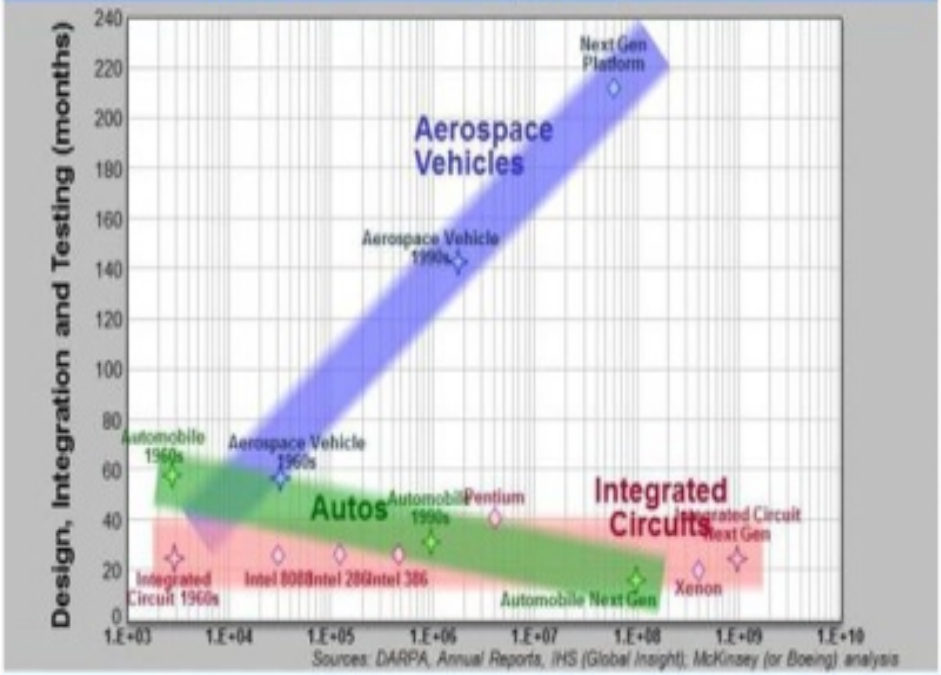
- From academia to industry, large efforts are underway (under several initiatives) to advance and develop Progressive Failure Analysis (PFA) methods and tools to Perform Smart Testing to Decrease Cost of Production

- Current method and tool development process often does not provide the end-user community with adequate information to validate methods and implement them into production. Often methods prove to be impractical to implement.

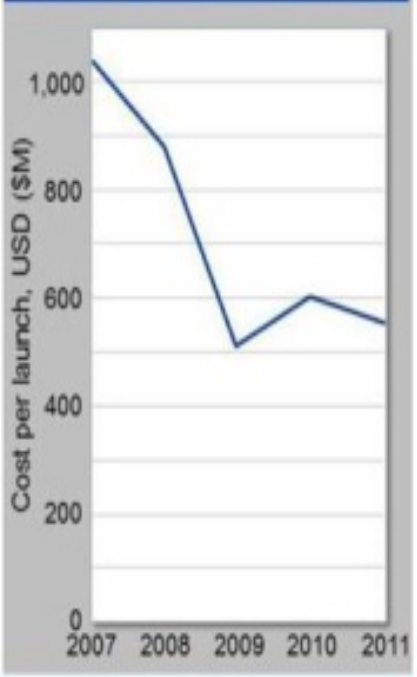
Cost Check

Development Trends in Different Industries

Trend in Time to Develop, Build, and Test



German Automaker Cost Trend



Industries with similar challenges are containing (even reducing) development costs

"Pyramid of Tests" Leading to Certification

– Rouchon (1990), Mil HDBK 17 (2002) –

~ Number of Tests	
1980s	2000s
2	2
2	15
25 - 500	2,500 - 10,000
5,000	100,000

Costs to Test

~$100M total

From: Rouse & Jegley, N
Building-Block presenta

List of Challenges

Some But Not All

- Lack of consistent process for verification and validation of progressive damage analysis methods
- Lack of comprehensive standard benchmark problems for method validation.
- Method to demonstrate scalability (i.e. larger more complex structures)
- Method compatibility with common CAE toolsets (e.g., Abaqus)
- Demonstrating method applicability to multiple material systems and different designs and fabrication processes
- Company Proprietary data restrictions limit sharing

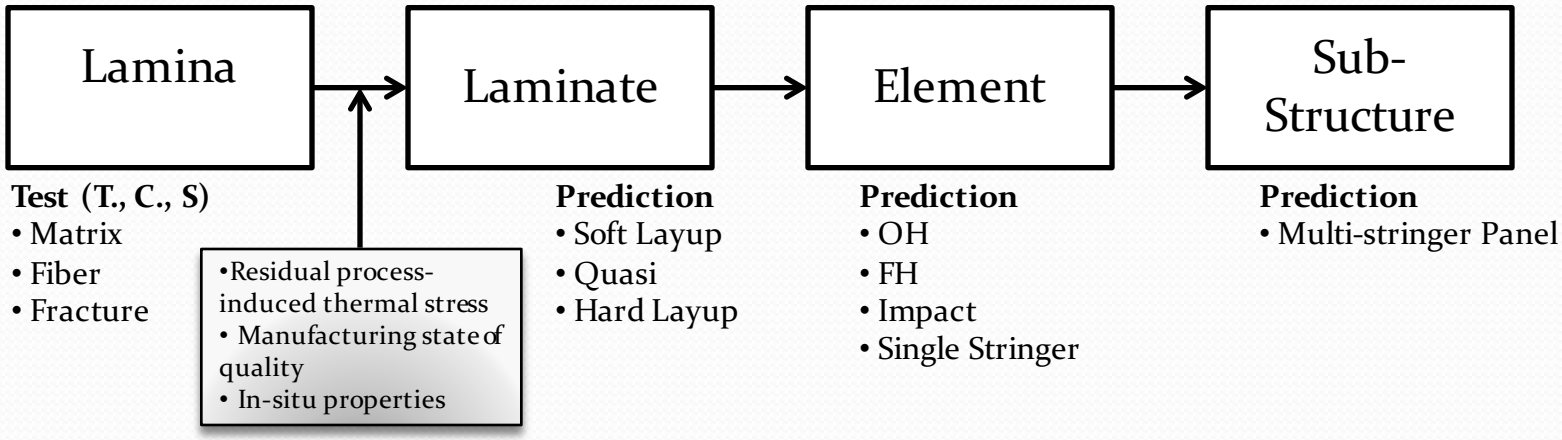
What Do we Need

- How do we verify and validate the airframe with more efficient analysis and smart tests?
- How do we better integrate design and analysis tools to minimize change, error and rework?
- How do we minimize the use of labor intensive tools/methods?

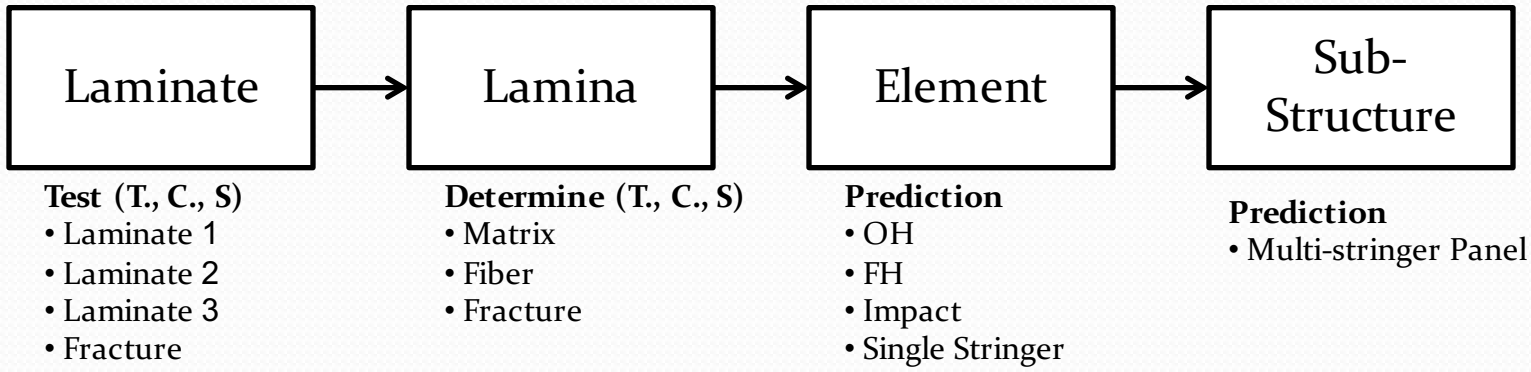
Validation Approach

- Standard Bench Mark Verifications and Validation Example Depends on Building Block Approach

Option 1



Option 2



Lessons Learned from Bottom-Up V&V Approach

- Calibrated models at one tier are not always extendible to next building-block tier
- Upper tiers of the building block typically rich in unknowns
- False confidence generated for predicting upper-tier response leading to an under-estimate of resource requirements/priorities.

Possible Uncertainties

- Fabrication
  - Fabrication tolerance/variability
  - Material properties variation
  - Fiber/layer waviness
  - Thickness variations
  - Etc
- Test
  - Failure initiation mode/mechanism
  - Damage progression mode
- Analysis
  - Idealization
  - Boundary conditions
  - Inclusion of generalized imperfection
  - Prediction of damage initiation and propagations
  - Mesh sizes

Starnes' Bottom up V&V Implementation Approach

- Unstiffened Flat Panels
  - Different laminates, knife-edge BCs, Compression loaded, shear loaded, etc
- Stiffened Flat Panels
  - Different stiffener geometry and spacing, limited tests, Skin-stringer separation at buckle node line, single postbuckling analysis using buckling modes as imperfections, etc
- Gaps Identified
  - Measured surface imperfections
  - Generalized imperfections
  - Influence/interactions of combined loads
  - Impact damage simulation/modeling

Criteria

Material Strength and Design Value

Typical Composite Graphite laminate

Typical laminate strain at failure

Soccer Ball

ε_typ=1

Adjusted to meet Criteria

ε_ohc/BVID =0.42

Adjusted to B-basis

ε_b.ohc=0.371

Adjusted to critical Environment

Golf ball

ε_b.ohc=0.33

Deterministic – Probabilistic

- The biggest knockdown to design strain is coming from design criteria.
- Often criteria are conservative and result adding weight and unnecessary testing
- Several thousand in-factory and in-service data have been collected last 20-30 years which can be used to develop design requirement