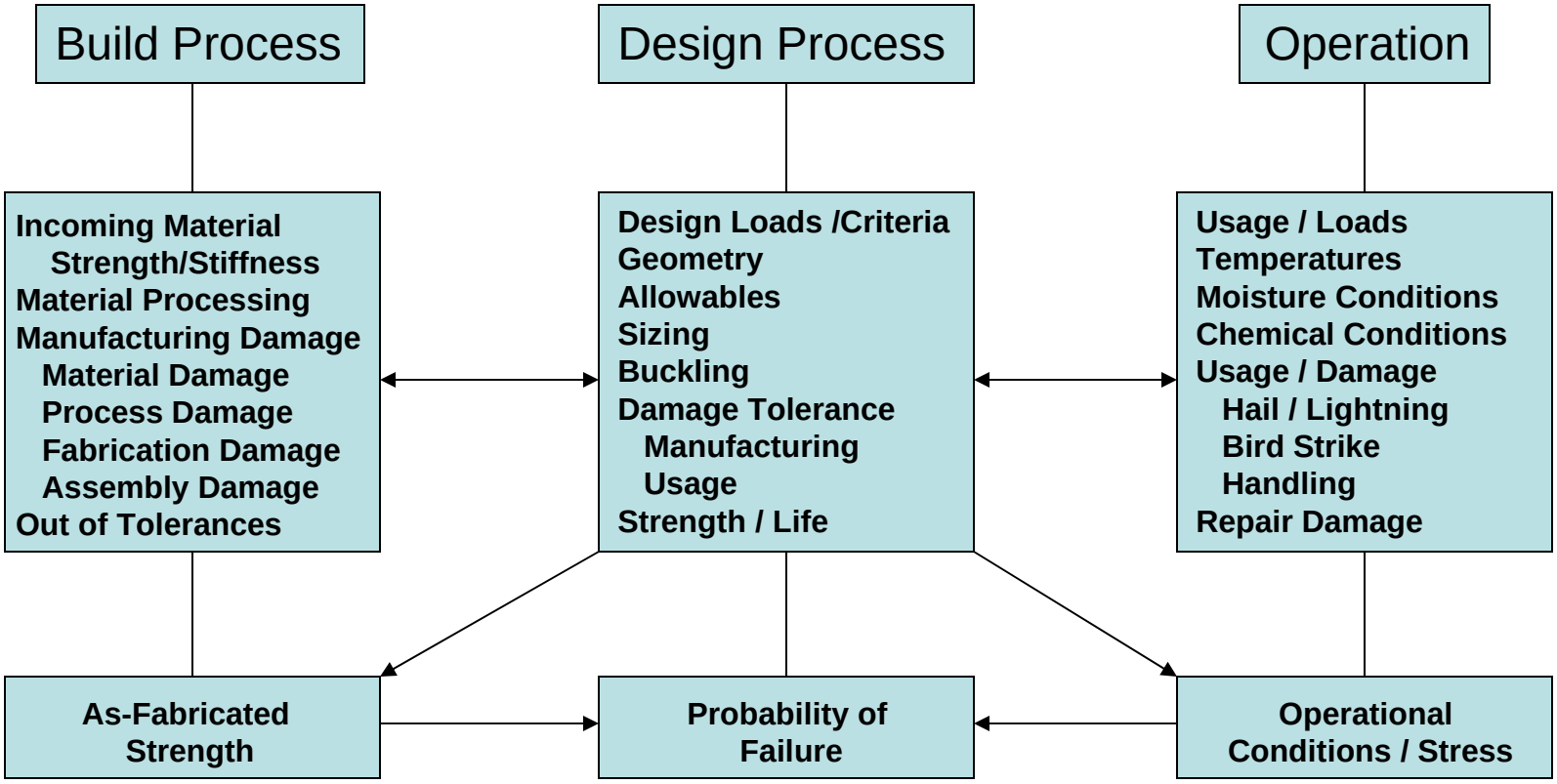
Some Thoughts on Probabilistic Design

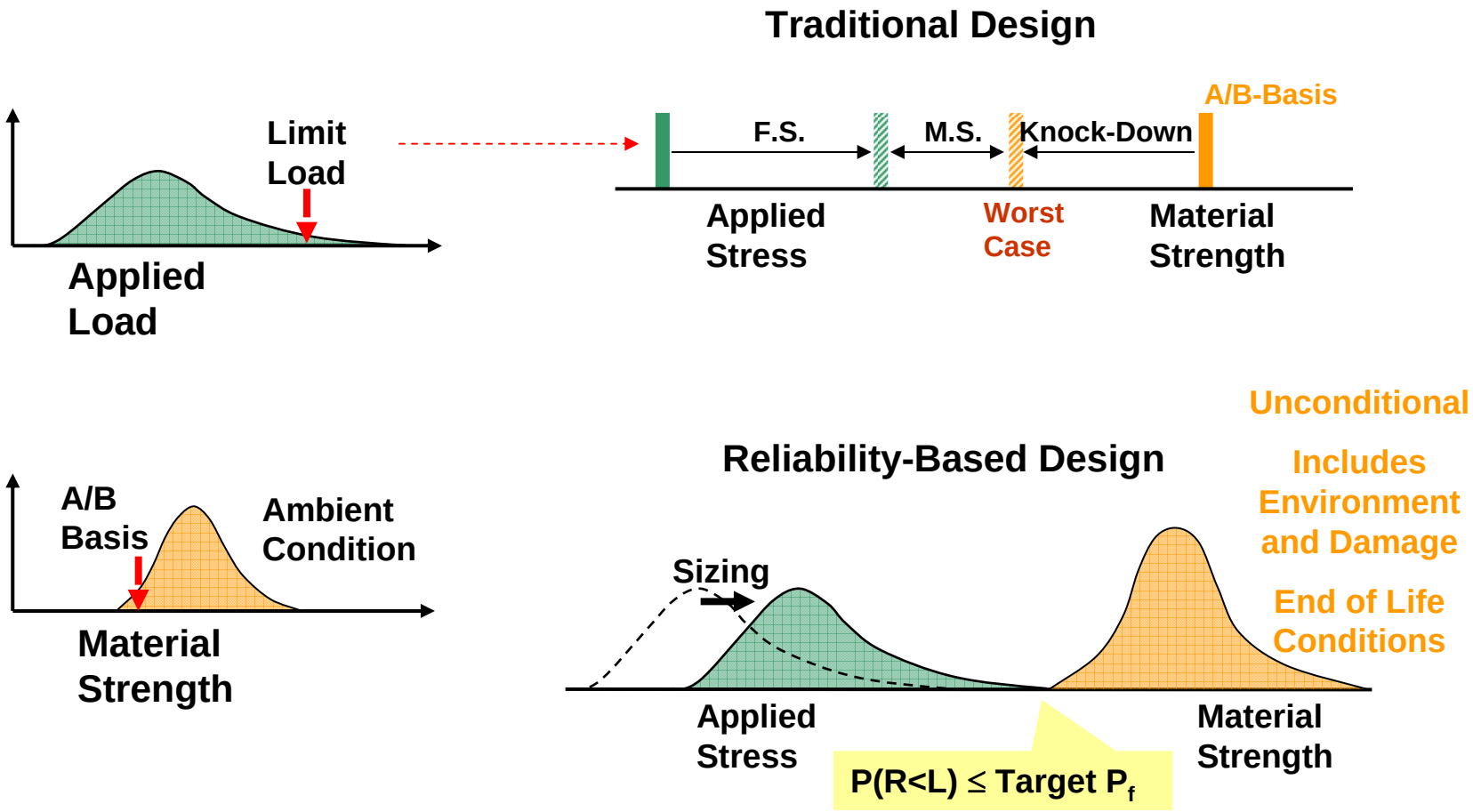
Charles Saff – Boeing – Phantom Works



Revised from Mil-Hdbk-17

Design's Function is to *Ensure* the As-Fabricated Strength Is Greater Than The As-Used Loads Throughout the Life

Traditional vs. Reliability-Based Static Strength Design



Revised from Cliff Chen

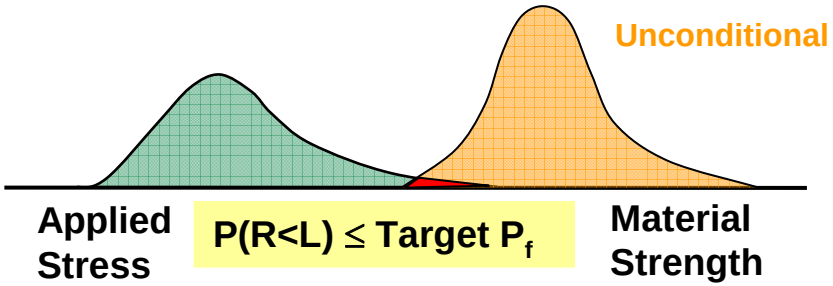
Can we *Ensure* That the Probability of Catastrophic Failure is Acceptably Low Throughout the Life?

Reliability-Based Design - Issue 1

- **Acceptable probability of failure levels differ for the same criteria from military to commercial aircraft because of numbers of aircraft and flights per lifetime differ**

	Military	Commercial
Primary Structures	10^{-7}	10^{-9}
	(one failure per lifetime per fleet)	
Secondary Structures	10^{-4}	10^{-5}
	(one failure per lifetime per aircraft)	

- **Today these levels are almost as arbitrary as the 1.5 factor of safety we so often use**

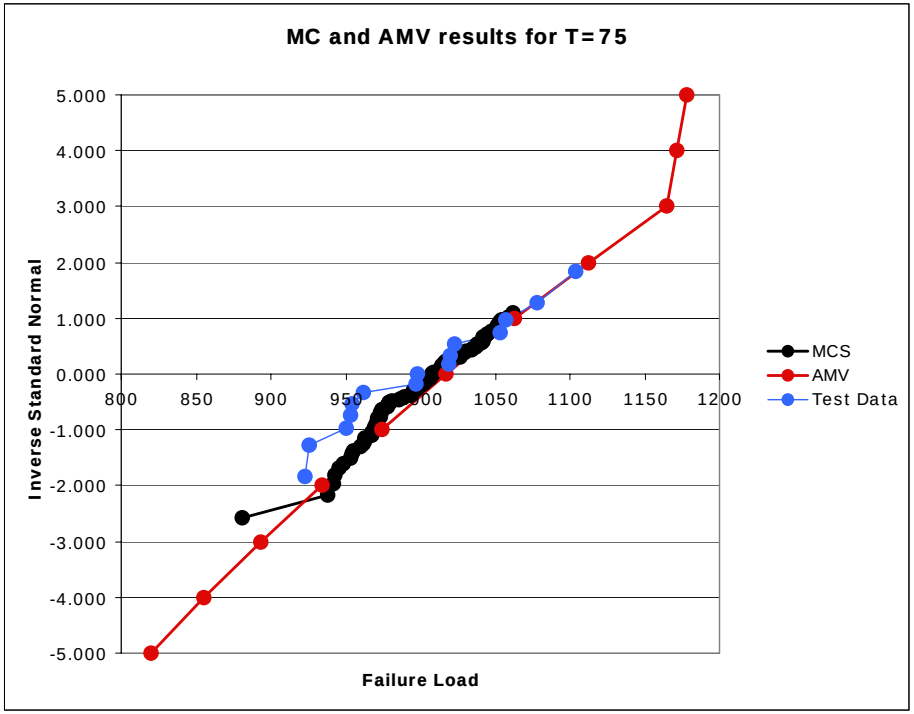


Revised from Cliff Chen

What Are the Criteria for Acceptable Probabilities of Failure?

Reliability-Based Design Issue-2

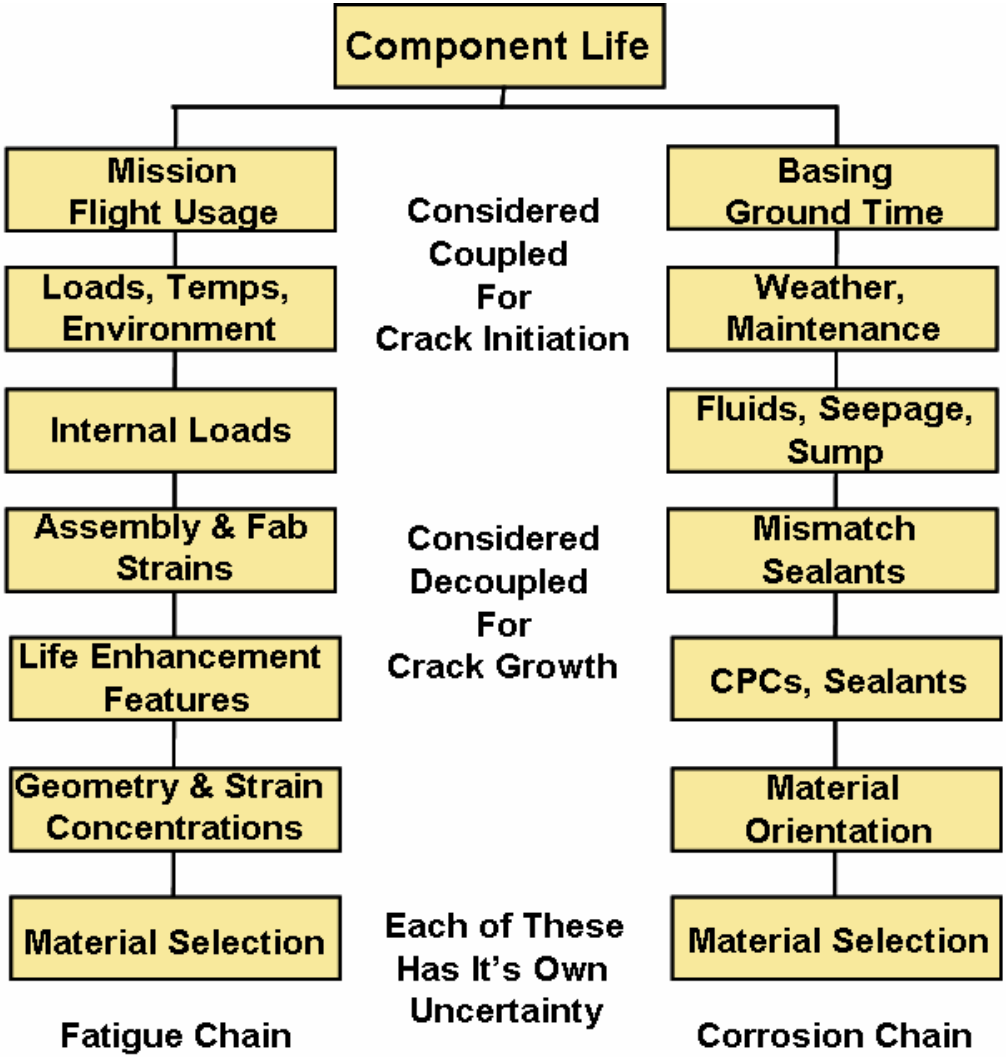
- Current Methods to Obtain the Tails of Material Strengths – e.g., A-Basis Requires
  - 300+ physical tests for standard statistical approaches
  - 300+ Monte Carlo simulations
  - 50-60 simulations for Adv. Mean Value Approach
  - All should represent material capabilities after manufacturing and assembly and after a lifetime of usage temperatures and environments
  - This is an Area for continued R&D Exploration



Data from Herb Smith
AIAA SDM 2006

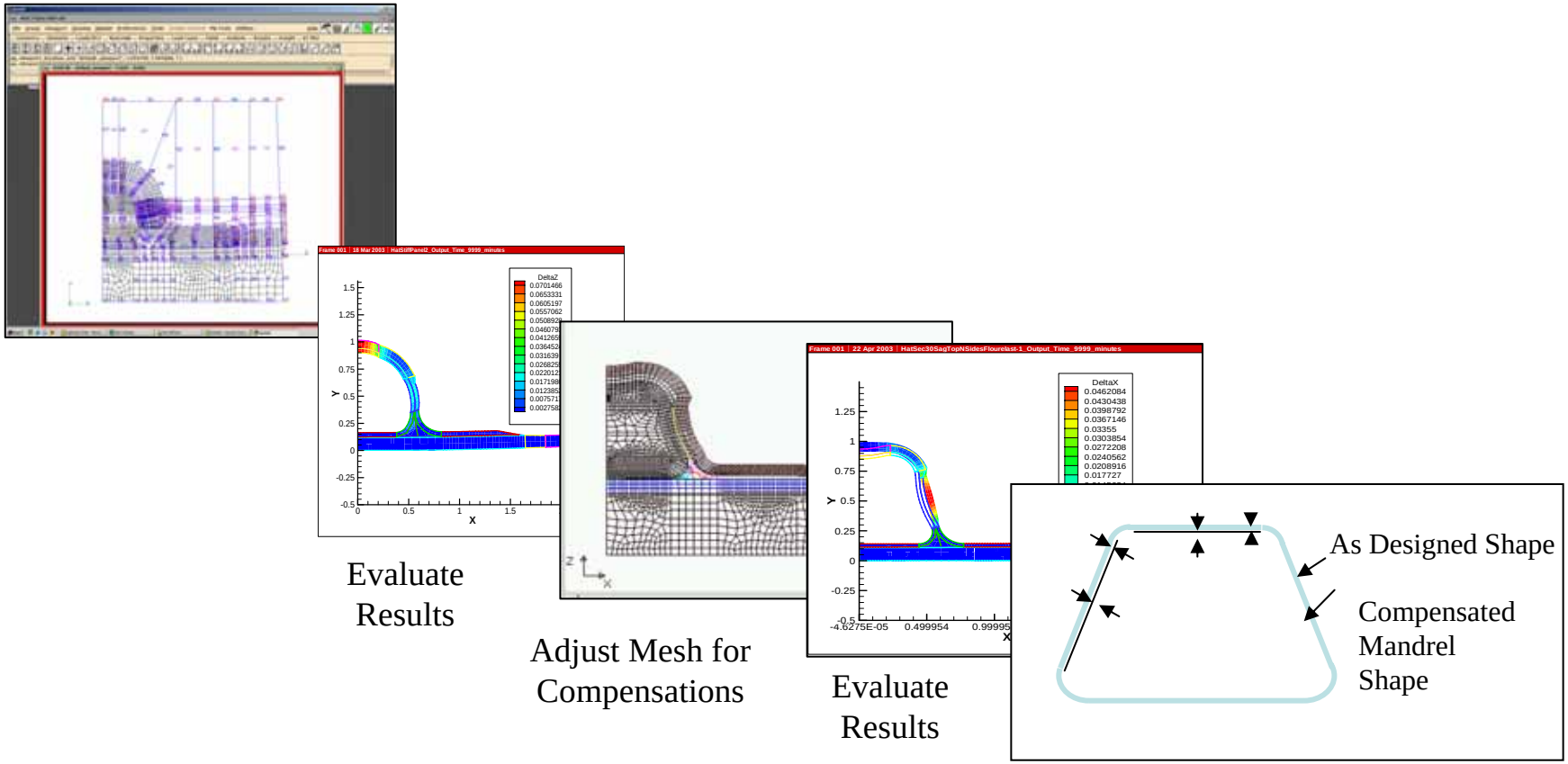
Can We Define the Extremes Of the Material Strength Population with Fewer Tests?

Reliability-Based Design Issue-3



Can We Rationally Bookkeep the Relationships Between the Large Number Of Variables That Affect Material Strength?

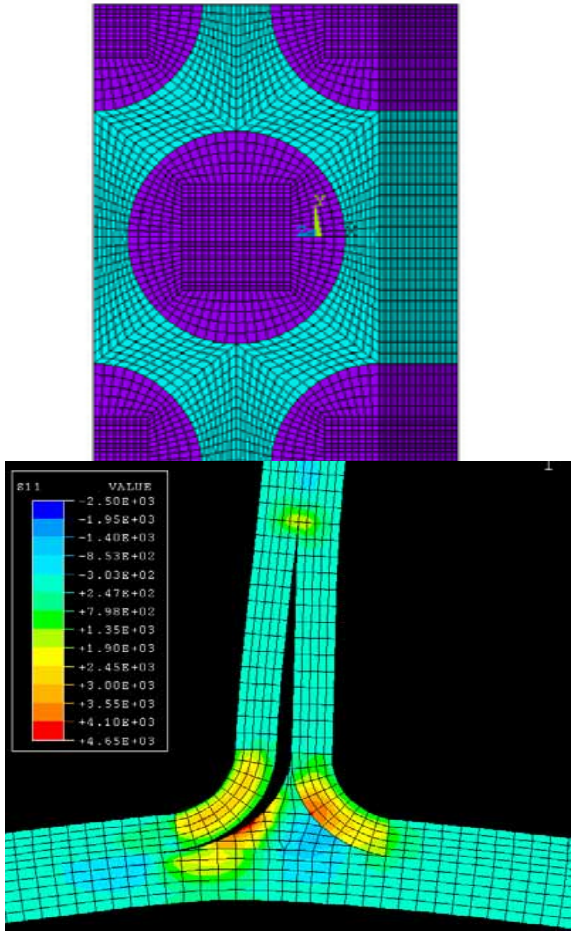
As Our Ability to Model Fabrication Processes Improves

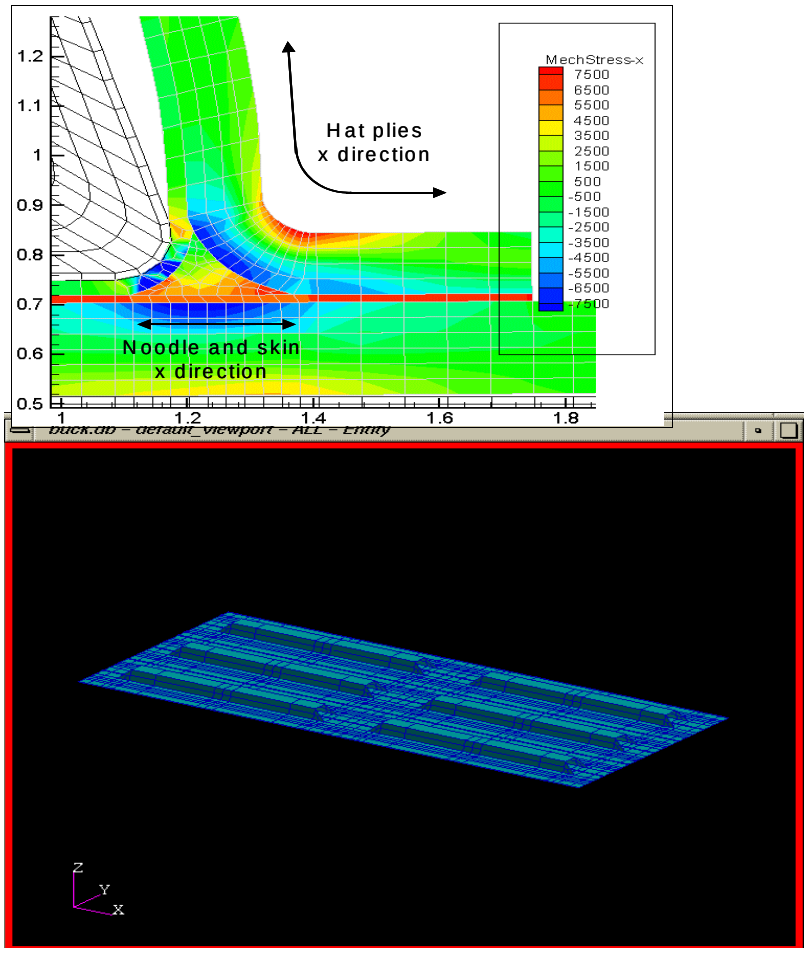


From DARPA/Navy AIM-C

We Now Model Tooling and Manufacturing Processes to Attempt to Get Excellent Quality from Fabrication

Designing for As-Fabricated Strength Is Improving





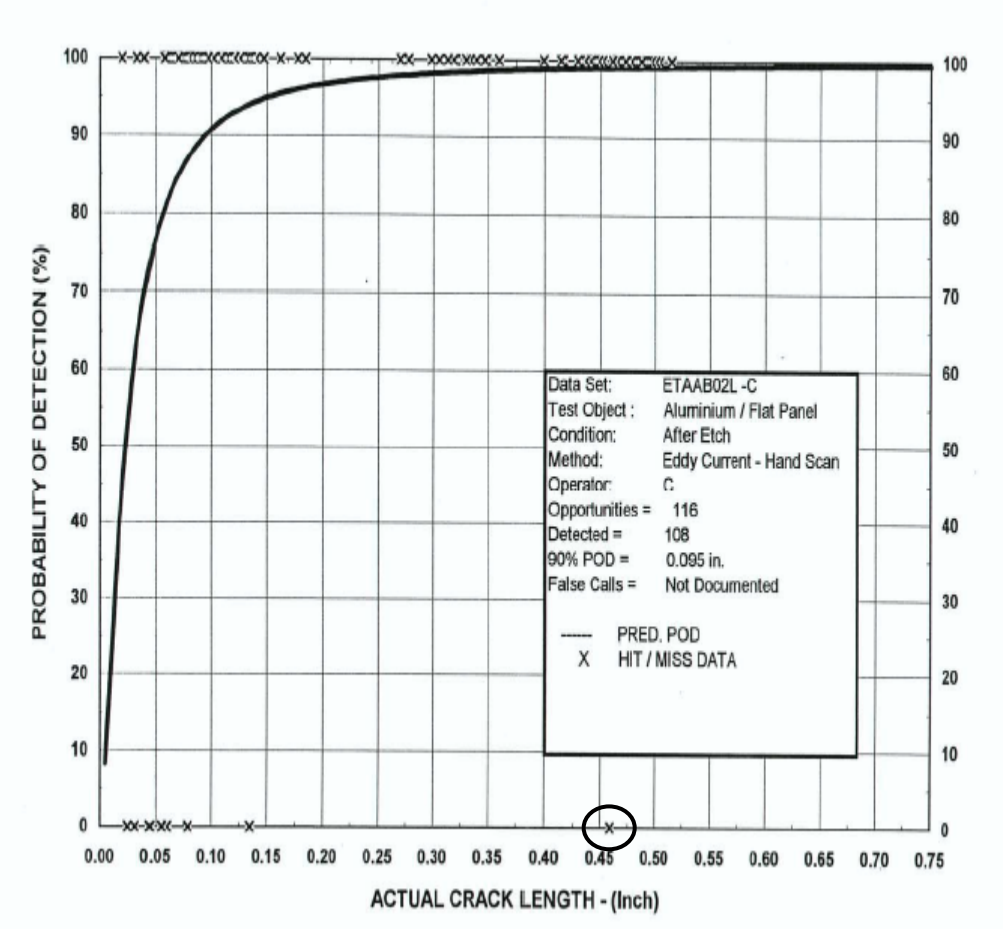
From DARPA/Navy AIM-C

Manufacturing Models Lead Us to Potentially Predict Defects That Might Be Induced in As-Fabricated Parts

Reliability-Based Design Issue-4

- But Our Ability to Predict Flaws Produced in Manufacturing New Configurations or By New Manufacturing Processes is Not Good At Present

- Our Ability to Find and Define Flaws in Advanced Structures is Not Perfect



From NTIAC NDT Capabilities Handbook

Are There Methods to Protect Structures from Large – Rogue Flaws Without Redundancy?