

Composite Allowable
Requirements
for
Structures Analysis/Design Tools
Workshop

Tom Freeman
NASA LaRC
12/1/2009

Growing Up with Graphite Composite Materials

Birth

- Freeman, W. T. and Campbell, M. D.: Thermal Expansion Characteristics of Graphite Reinforced Composite Materials, ASTM STP 497, 2nd ASTM Conference on Composite Materials: Testing and Design, Anaheim, CA April 20-22, 1971
- Freeman W. T. and Kuebler G. C.: Mechanical and Physical Properties of Advanced Composites, ASTM STP 546, May 21-22, 1973

Teens

- 1989- 1995 NASA ATCAS - Larry Ilcewicz PI
- 1995- 2001 AGATE ID&M - John Tomblin materials PI
- 2002- 2010 COTR NCAMP - John Tomblin PI
- 1995 AGATE Vision now a 15 year NCAMP Reality

Composites at 40years old

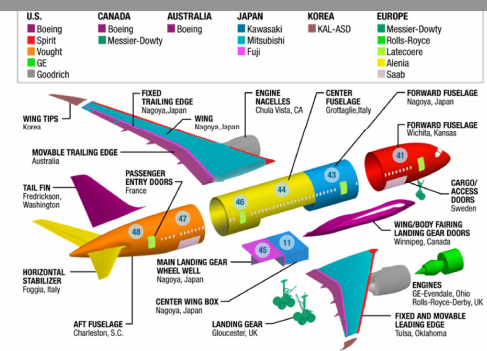
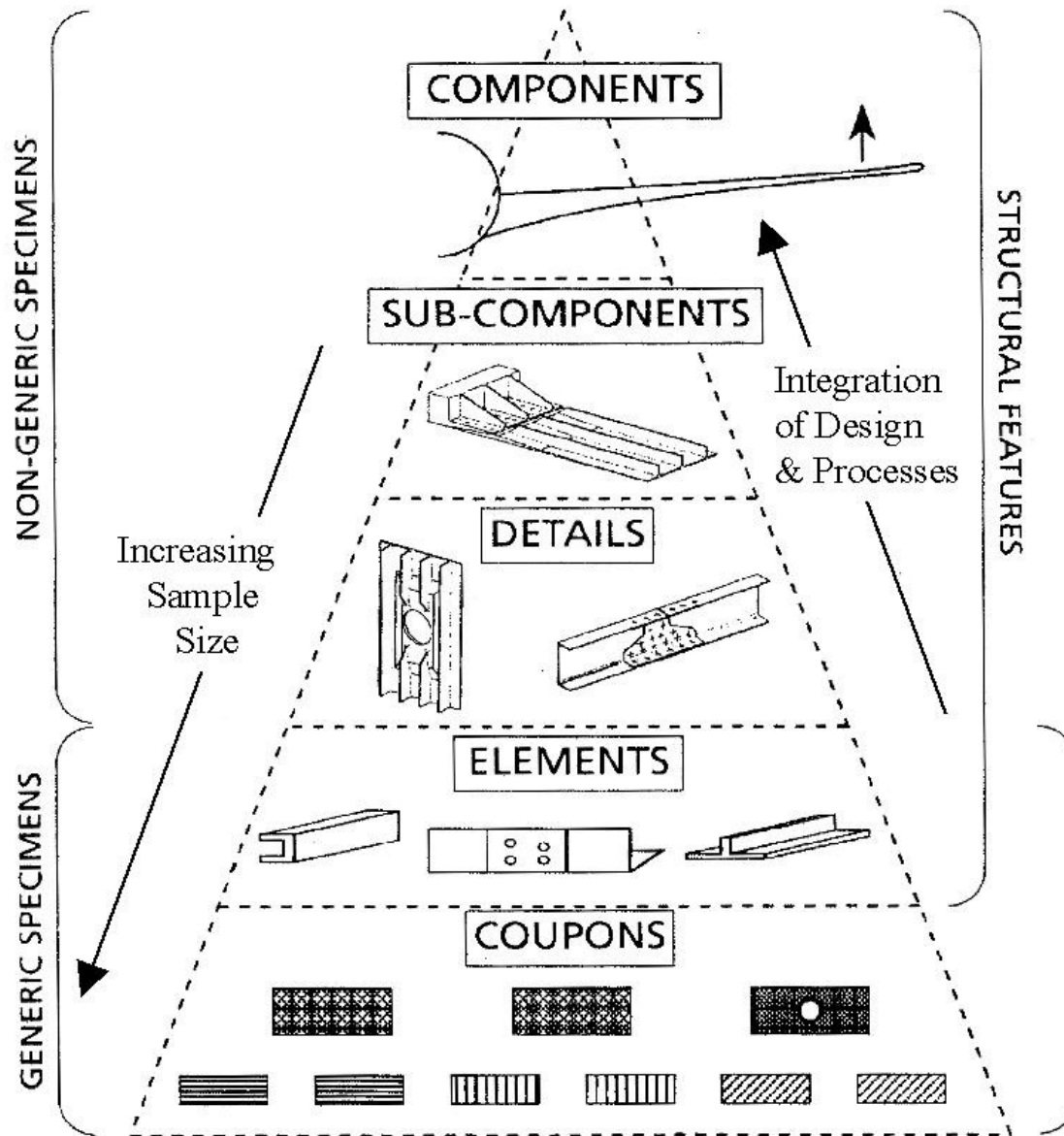
- Boeing 787
- Initiate 2020 Composites Reliable Design Reality this week

Composite Design

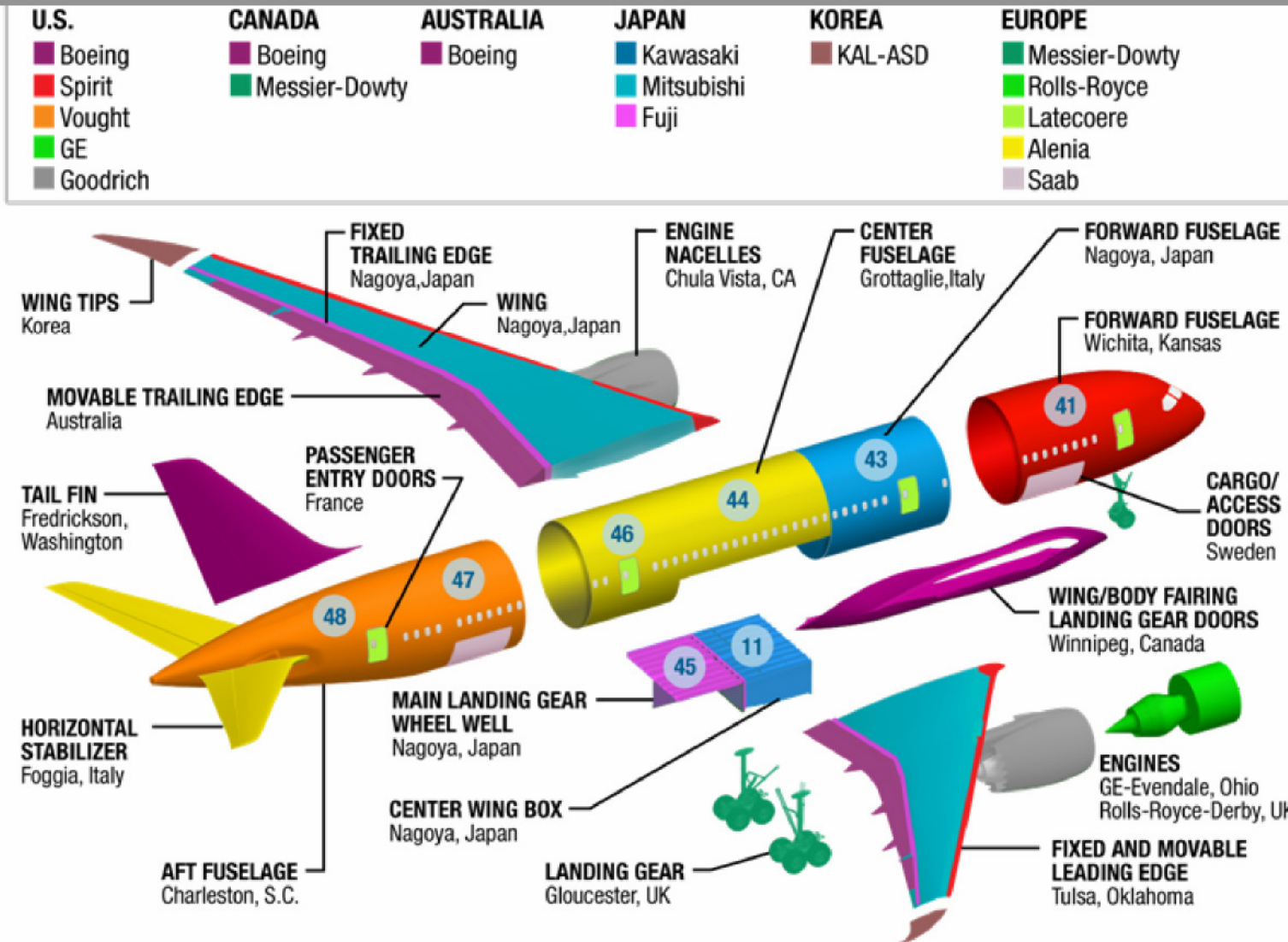
Sources of Variation

- **Software** – Machine intelligence
 - Helius:MCT Hypersizer, Peridyamics, Nastran,...
- **Genius** – Human intelligence
 - Experience – Model - Assumptions
- **Data**
 - Statistically Reliable with Pedigree
 - Everyone use NCAMP datasets

Increase Fidelity Between Predictions & Assembled Vehicle



Partners Across The Globe Are Bringing The 787 Together



North Charleston, South Carolina

An automated fiber placement machine is loaded with aft section 47. In the background is Vought's second automated fiber placement machine.



2007



This all-composite 787 section is 21 feet (6.4 m) in diameter, and 42 (12.8) feet long. Fiber path, stacking sequence variation, cutouts, fasteners, joints, interference fits, 30+ year life...COMPLEXITY

North Charleston, South Carolina

Vought's aft section 48 FPQ (first part qualification) is loaded into a pre-NDI (nondestructive inspection) production cell.



Forward Fuselage

Spirit Aerosystems

Annual Investor Conference | Boeing Commercial Airplanes



**Line #2 in CS449
Structures Installation**



**Line 9998
Structures Installation**



Line #3 in CS 449



Line #4 Deburr & Edge Seal



Line #5 Mandrel Extraction



Line #6 C Axis Leak Check

Vought Aft Fuselage Sections in Join for AP



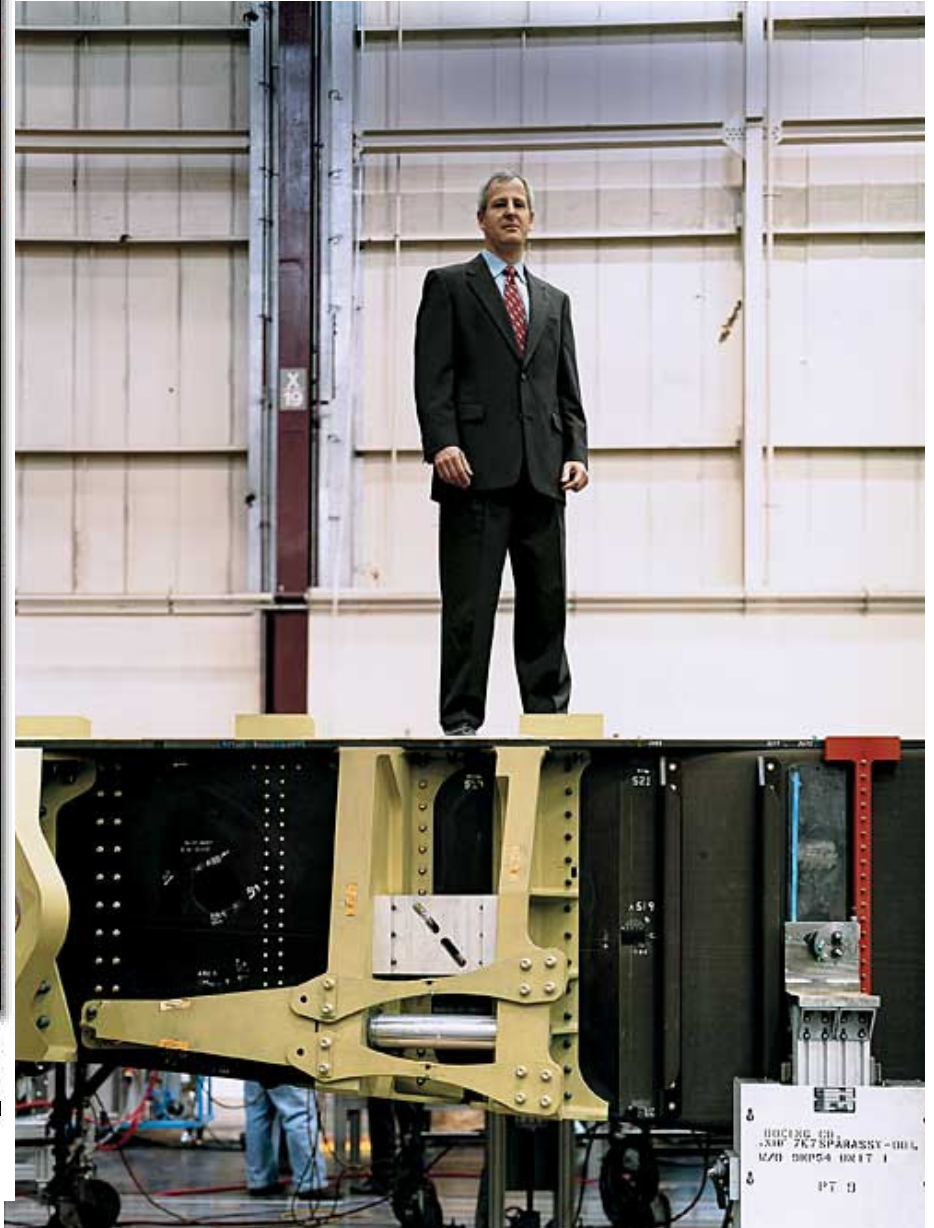




2006



MARIAN LOCKHART PHOTO
Members of the 787 Dreamliner wing team prepare the wing box for its move to its test location. At the bottom (from left) are Steve Reames, Tim Colligan and Lamar Dearth; at the top (from left) are Wes Davis and Vince Romero.



tape laying machines

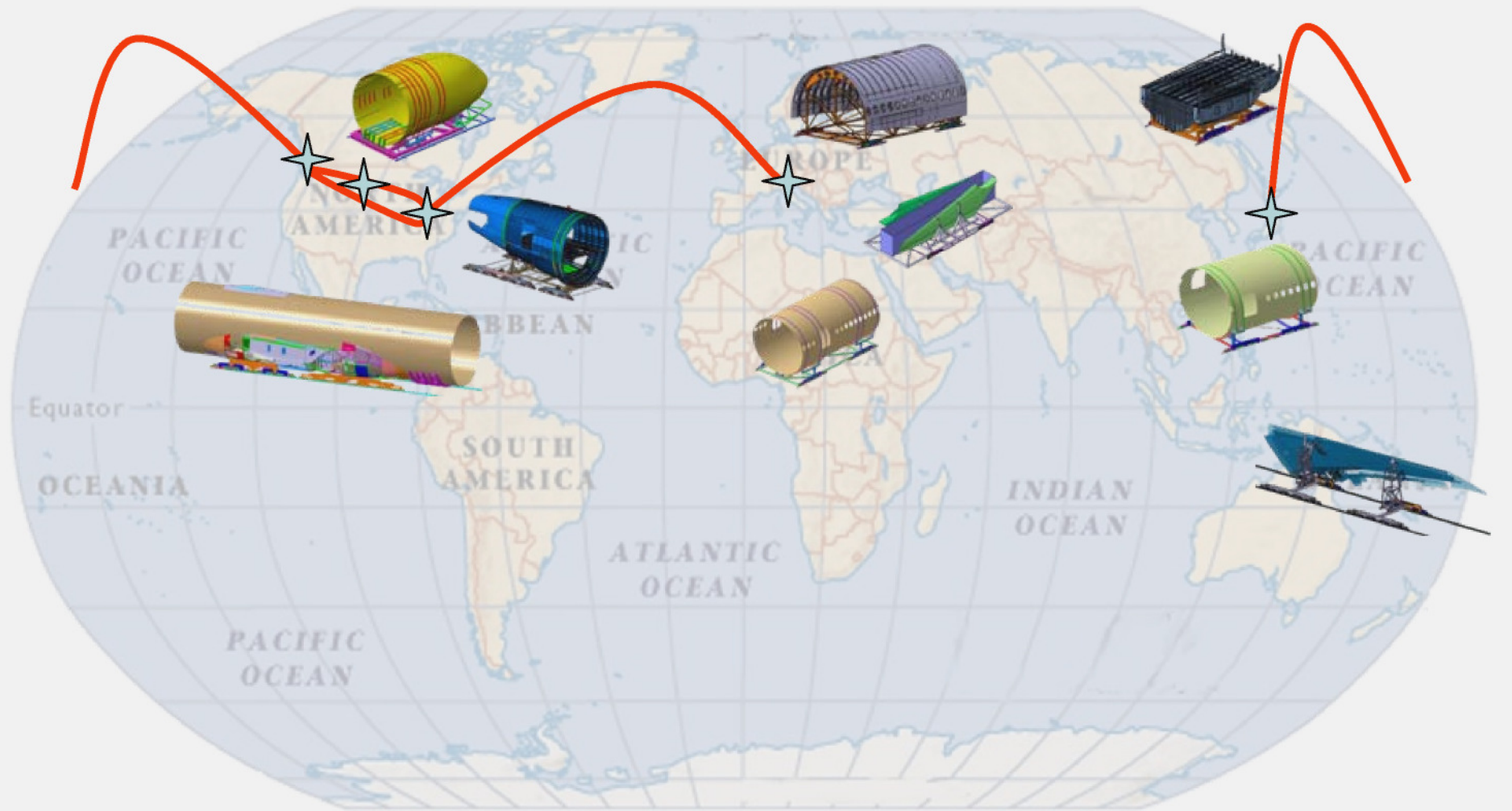
One of four Linear ATLAS machines manufactured by Forest-Liné (Paris, France) to lay up the Boeing 787 wingskins at the Mitsubishi Heavy Industries 787 plant in Nagoya, Japan.



Mitsubishi Heavy Industries (MHI) Nagoya AP #1 Wings – On Their Way

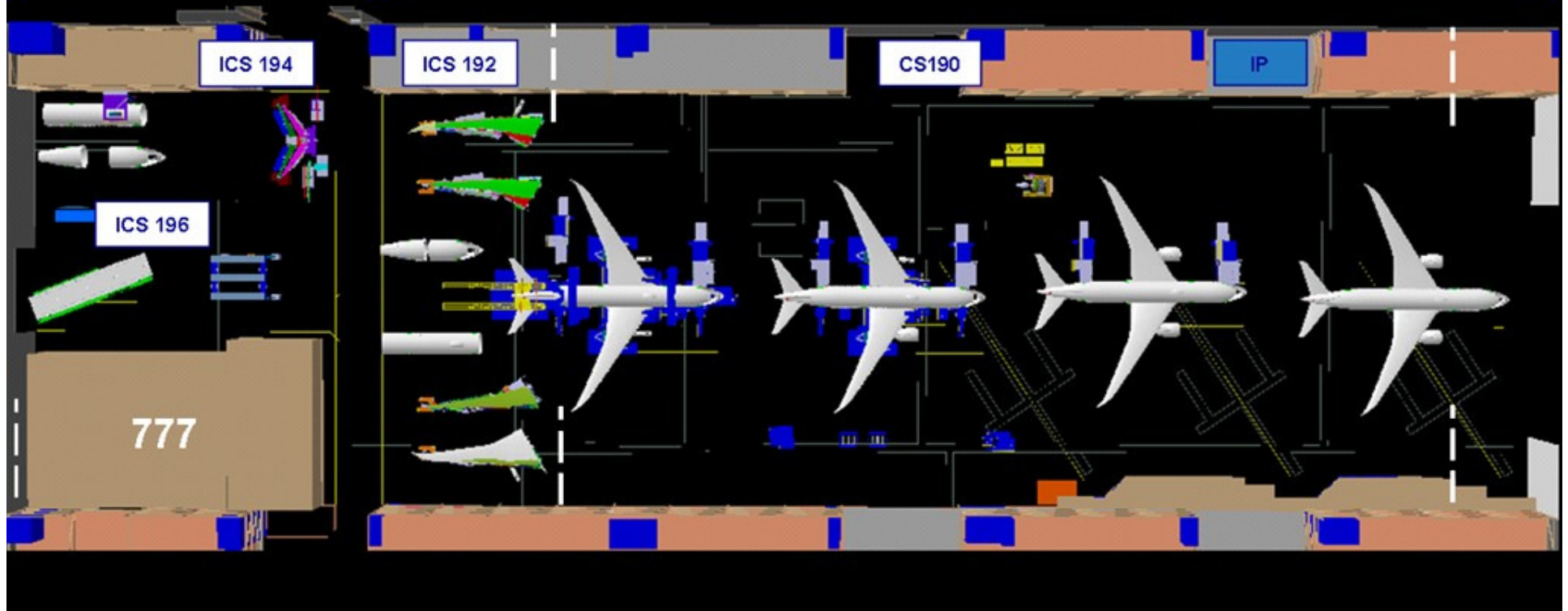


Dream Lifter Route Structure



40-36 Building

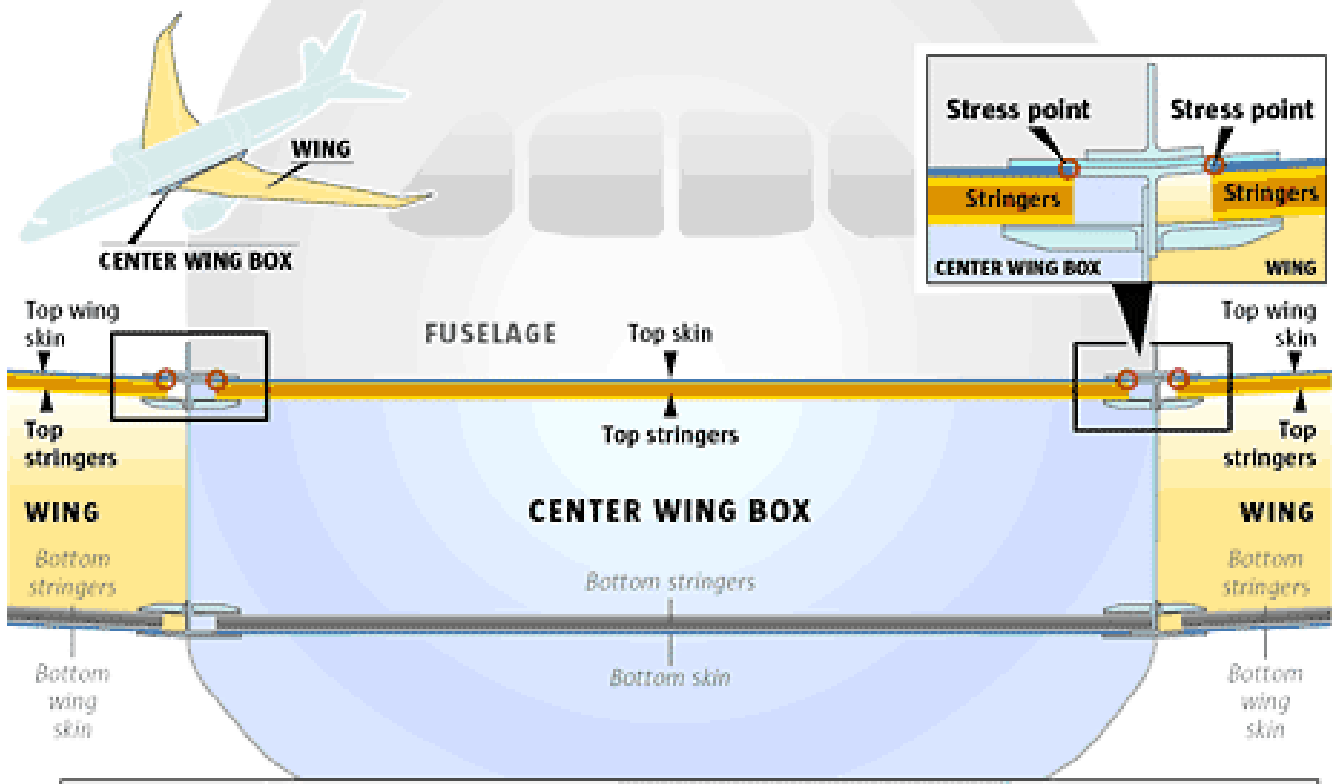
40-26 Building



Delamination

Double wing-box trouble

Preflight tests revealed structural flaws inside the 787's fuselage, as well as in the outer wing box. Damage occurred well below the stress level needed for certification, forcing another postponement of first flight.



Proposed fix
To reduce stress, a U-shaped cutout is made in the end of the stringers. Fasteners are also added between skin and stringer.



In June, Boeing postponed the new jet's first flight after engineers discovered delamination of the composite carbon fiber skin at the wing-body joint during tests that bent the wing.

The fix involves cutting out the ends of 17 stringers on each upper wing skin, as well as corresponding stringers on the wing box inside the fuselage, and then adding metal fittings to reinforce the stringer ends.

WSJ details issue with Boeing 787 bolts

November 13, 2009

- While Boeing engineers raced to [fix a side-of-body issue](#) that delayed first flight of the [787 Dreamliner](#) this summer, they found another issue with the composite material in the plane's wings, according to a Wall Street Journal [report](#).
- They found that metal bolts, called freeze plugs, inside the wings of one of the six test airplanes had slightly damaged the surrounding material, causing delamination, or cracking, the Journal said, citing "internal company documents and a person familiar with the matter."
- The damage was confined to a relatively small area, but engineers decided the plane couldn't fly until the problem was corrected, the Journal reported.
- The Journal quoted an unnamed Boeing official acknowledging that delamination occurred around the bolt holes, but saying that wouldn't affect the first flight or require a repair.

NCAMP Datasets / Analysis Requirements Brainstorming

- Identify data that's universally used
- Identify data that's not used at all
- Identify special data requirements
- Delamination, Transverse Tensile Peel, & Compression in complex interfaces and fastener interference fits
- Material Specific Standardization of Knockdown Factors
- Detailed Database of Composite Failure History Correlated to Material Properties, Design Factors, Manufacturing Details, Static and Dynamic Loading and Repair Life Cycle History
- Optimize Materials Life Cycle Data for Reliable Design Tools and Models
- SDM, NCAMP, CACRC, DOD MRO Joint Workshops to optimize incident based design tools - Focus attention on what's Important

The Next Decade

Ray Kurzweil - The Age of Intelligent Machines
- The Singularity is Near

- **IBM Gets Closer to Computer That Acts Like a Human Brain**

By: [Jeffrey Burt](#)

2009-11-18

- IBM researchers at the Supercomputing show say they and their university partners **have hit two key milestones in their efforts to develop a computer that can monitor data and act on it in ways similar to a human brain.** The development of such a computer could help businesses more logically act on the rapidly growing streams of data that are generated.

- **Want a Faster Interface? Put a Chip in Your Skull**

- Sharon Gaudin, Computerworld

- Nov 22, 2009 12:29 pm

- By the year 2020, you won't need a keyboard and mouse to control your computer, say Intel Corp. researchers. Instead, users will open documents and surf the Web [using nothing more than their brain waves.](#)

- Scientists at Intel's research lab in Pittsburgh are working to find ways to read and [harness human brain waves](#) so they can be used to operate computers, television sets and cell phones. **The brain waves would be harnessed with Intel-developed sensors implanted in people's brains.**

What Not to do with Composites

- Software that flags Design issues with composites
- Develop database of all negative experiences from life cycle use of composites
- Incorporate as flags for future users of design software

Composite Design Next Decade

- Software - Machine
 - Helius:MCT Hypersizer, Peridyamics, Nastran,..
 - Add incident based optimization to prevent future designers from repeating costly rework
- Genius – Human and Machine
 - Experience – Model – Assumptions
 - What not to do with composites database
- Data
 - Statistically Reliable with Pedigree
 - Everyone use NCAMP datasets
 - Database of material specific design, manufacturing and damage history with solutions
- Beyond 787, SpaceShip2, etc
- Composite design as reliable as metal design – No more knockdown factors