Composite Safety & Certification Initiatives Progress and Plans for Bonded Structure

Presented at 9/18/02 FAA Workshop (Chicago, IL)

FAA

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CS&TA, Composites

- Overview
  - Applications of bonding
  - Technical thrust areas and timelines
- Benchmark bonded structures
  - Plans, deliverables and technical scope
- Past progress
  - Research
  - Action groups
- Technical issues
  - Material and process control
  - Manufacturing and design integration
  - Product development and substantiation
- Discussions

State-of-the-Art in Structural Joining and Attachments

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Small airplanes

- Extensive bonding in propeller-driven airplanes (sandwich skin panels and major joints to close wing torque box, attach main spars & fuselage skin splices)
- Business jets use bonded sandwich in fuselage (major fuselage splices include bolted redundancy)

Rotorcraft

- Combination of bolted and bonded structures in airframe and dynamic parts (major splices are bolted, many bonded attachments)

Transport aircraft

- Bonded attachments (e.g., stringers) are common, but major joints remain bolted
- Bonded fiberglass/aluminum (GLARE) laminate fuselage panels are planned for the A380 (major fuselage panel splices remain bolted)

All CS&CI Technical Thrust Areas will be Active for Bonded Structure Efforts

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NASA

Advancements depend on close integration between areas

Material Standardization and Shared Databases

Structural Substantiation

- Advances in analysis & test building blocks
- Environmental effects
- Manufacturing integration

FAA and NASA R&D is currently active in most of these areas

Damage Tolerance and Maintenance Practices

- Critical defects
- Bonded repair issues
- Fatigue & damage considerations
- Quantitative NDE
- Equivalent levels of safety

Bonded Joint Processing Issues

Advanced Material Forms and Processes

Significant progress, which has relevance to all aircraft products, has been gained to date

FAA Composite Team Members

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Represented Group	Team Member Name	FAA Organization Number & Routing
FAA Tech. Center	*Curtis Davies*	AAR-450 (FAA Technical Center)
	Peter Shyprykevich	AAR-450 (FAA Technical Center)
International	John Masters	AEU-100 (Brussels Aircraft Certification Staff)
Directorates	*Lester Cheng*	ACE-111 (Small Airplane Directorate)
	Mark James	ACE-111 (Small Airplane Directorate)
	Richard Monschke	ASW-111 (Rotorcraft Directorate)
	Richard Yarges	ANM-115 (Transport Airplane Directorate)
	Hank Offermann	ANM-115 (Transport Airplane Directorate)
	Jay Turnberg	ANE-110 (Engine & Propeller Directorate)
Flight Standards	William Henry	AFS 350 (Aircraft Maintenance Division)
ACOs & MIDOs	Randy Blosser	ANM-100D (Denver ACO)
	Roger Caldwell	ANM-100D (Denver ACO)
	Fred Guerin	ANM-120L (Los Angeles ACO)
	Angie Kostopoulos	ACE-116C (Chicago ACO)
	David Ostrodka	ACE-118W (Wichita ACO)
	Richard Noll	ANE-150 (Boston ACO)
	David Swartz	ACE-115N (Anchorage ACO)
CSTA	*Larry Ilcewicz*	ANM-115N (CSTA, Composites)

Composite Team has placed an emphasis on a need to address bonded structure issues (metal & composite)

Names in italics are present at the 9/16 to 9/18/02 FAA Workshop

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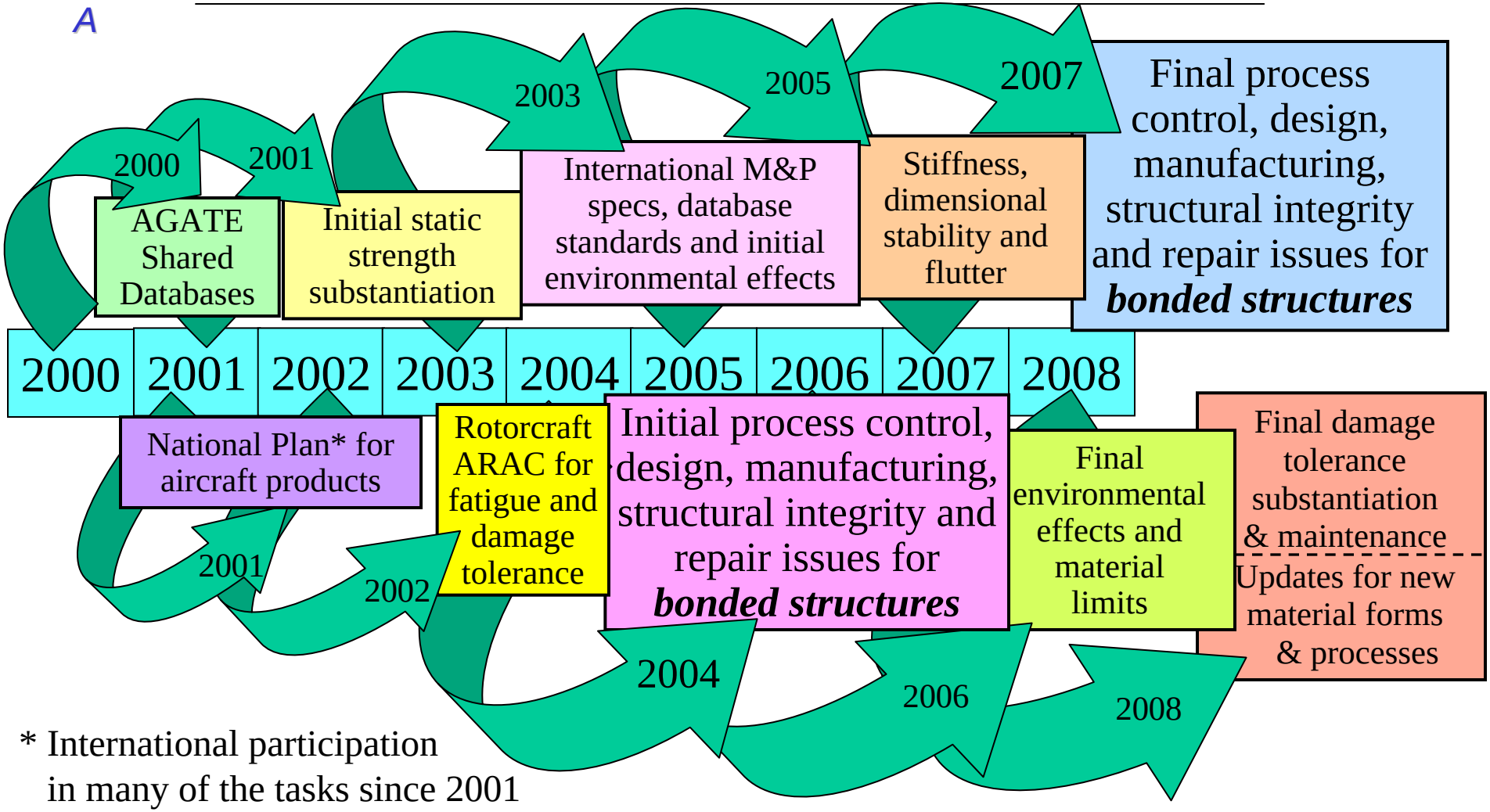
But we also have some spies present who shall remain nameless

Major Milestones for Bonded Structure Policy, Guidance & Training in 2004 + 2007



* International participation in many of the tasks since 2001

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Benchmark Bonded Structures
Primary Deliverables

- Development of a FAA Technical Center Document on “best engineering practices” for bonded structure
- Bonded Structure Workshop in 2004 to review the draft FAA Technical Center Document
  - To be coordinated with joint meetings of Mil-17 & CACRC (May or early June)
- FAA policy covering the different engineering aspects of bonded structure

Benchmark Bonded Structures
Technical Scope

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- Commercial general aviation, rotorcraft and transport aircraft (coordinated with military groups)
- Secondary bonding in structural applications
  - Composite to composite
  - Metal to metal
  - Composite to metal
- Functional areas to be covered
  - Control of raw materials & process (raw material manufacturing)
  - Bonding process controls
  - Manufacturing
  - Design
  - Product development and structural substantiation

Approach Used for Initial Bonded Structures Efforts

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Timeline

2a) Focussed research to draft "best engineering practices"

1) Start with input from certification, production and service experiences, plus research performed to date

2b) Workshop & industry review to release detailed documentation on "best engineering practices"

3) Rules, policy and/or guidance as necessary

4) Training for industry and government workforce

» Initial research and industry review *(light yellow boxes)*, used to generalize industry experiences and identify longer-term research needs

Progress and Plans to Benchmark Bonded Structure Technology

FAA

Oct. 2004 Draft FAA policy for Certification of Bonded Structure

Jul. 2004 Update FAA TC Bonded Structures Document

May 2004 Conduct FAA/NASA/industry workshop to review draft document following joint Mil-17/CACRC mtg.

Mar. 2004 First draft of Bonded Structures Document

Nov. 2003 to Jan., 2004 Select team, establish AACE grant, develop detailed outline and start to draft the benchmark document

Oct., 2003 Meet with transport, rotorcraft and military groups to develop detailed plans and ID experts to support work

Sep., 2003 Introduce plans & collect inputs at M&P control workshop

July, 2003 Meet with GA companies on their involvement

May, 2003 Developed strategy and resource requests for near term work

2000 to 2003 FAA research per the ***"Don Oplinger Plan"***

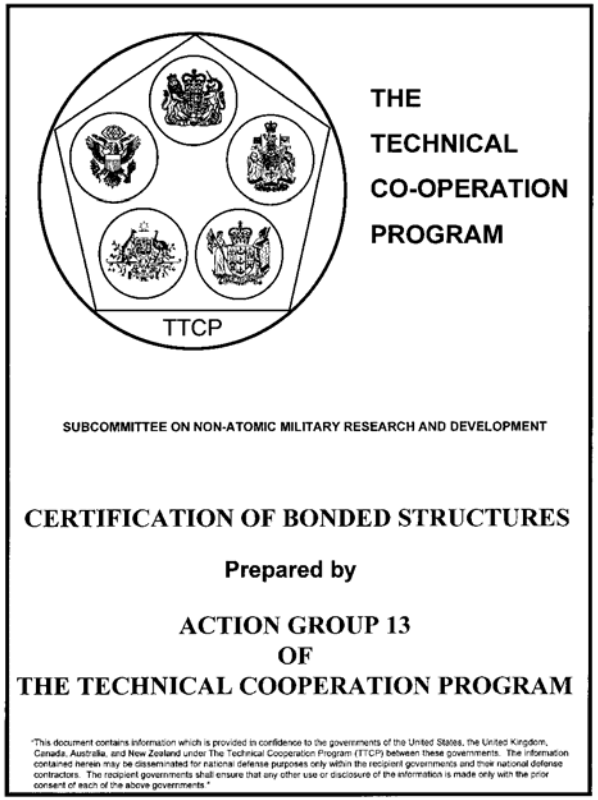
Progress for Bonded Structures
FAA and NASA Research

- Surface prep studies on removable plies and abrasion
  - Clarify terminology for peel plies and release fabrics
  - In-process control testing
- Advances in test methods for adhesive joint shear and peel
- Characterization of environmental effects, fatigue and creep for a wide range of adhesives used by industry
  - Consideration of temperature guidelines used for material selection
- Evaluation of structural analysis methods for strength and damage tolerance
  - Development & test validation of methods suitable for design
  - Evaluation of realistic structural detail (e.g., thick and variable bondlines, joggles) and load cases (e.g., shear flow)

Progress for Bonded Structures
Action Groups for Detailed Documentation

FAA

- Some guidance for bonded structures, which comes from military and commercial aircraft experiences, are documented in a TTCP report
  - Composite and metal bonding
  - Starting point for current effort
- Mil-17 Debond & Delamination Task Group since 2000
  - T.K. O'Brien, K. Kedward and Hyonny Kim are Co-chairman


THE TECHNICAL CO-OPERATION PROGRAM

TTCP

SUBCOMMITTEE ON NON-ATOMIC MILITARY RESEARCH AND DEVELOPMENT

CERTIFICATION OF BONDED STRUCTURES

Prepared by

ACTION GROUP 13
OF
THE TECHNICAL COOPERATION PROGRAM

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TTCP Teammates

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Preface

This publication is the result of three years of deliberations by Action Group 13 chartered by The Technical Cooperation Program to provide guidance on the important subject of certification of bonded structures. Bonded structures are being used to reduce mass and cost in new aircraft, particularly in unmanned applications. They are also a major factor in the safe and economic life extension of aging fleets of military aircraft. This document is intended to fill a void by addressing the essential elements that aircraft designers and owners must address in the certification of bonded structures.

The document is truly a team effort by a group of engineers dedicated to ensure successful applications in the future of this valuable technology. The chairman of the team is grateful for the contributions of the following individuals and for their dedication to making this document useful:

Australia

Dr. Alan Baker	Aeronautical and Maritime Research Laboratory
Dr. Francis Rose	Aeronautical and Maritime Research Laboratory
Mr. Maxwell Davis	Royal Australian Air Force

Canada

Mr. David Simpson	National Research Council

United Kingdom

Dr. Peter Poole	Defence Research Agency

United States

Dr. Larry Ilcewicz	Federal Aviation Administration
Mr. James Mazza	USAF Research Laboratory Materials Directorate
Mr. Eric Robeson	U. S. Army Aviation & Troop Command
Mr. Edward Rosenzweig	Naval Air Warfare Center Aircraft Division
Mr. Joseph Soderquist	Federal Aviation Administration

The team is appreciative of Lt Col James Greer and Mr. Kees Guijt from the United States Air Force Academy in Colorado Springs, Colorado and Mr. William Schweinberg from the Warner Robins Air Logistics Center at Robins Air Force Base in Georgia. They provided many constructive comments through their participation in this effort.

John W. Lincoln, Chairman
Aeronautical Systems Center
Wright-Patterson Air Force Base, Ohio
USA

FAA

TTCP TOC

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Technical Issues
Material and Process Control *

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- Adhesive qualification
  - Type (film and paste) and filler materials
  - Test methods for requirements
  - Adhesive preparation
- Raw material (adhesive and substrate) M&P controls
  - Receiving inspection & equivalency testing/acceptance criteria
  - Supplier/user relationships
  - Distribution, handling and storage
- Bonding process qualification and control
  - Substrate and adhesive selection/compatibility
  - ***Surface preparation (cleaning, abrading, removable plies)***
  - ***Test methods (static, durability and damage tolerance)***
  - Process steps
  - Cure cycle variables

* Applies to production and repair

Technical Issues

Manufacturing and Design Integration *

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- Manufacturing scaling
  - Tooling and equipment
  - Environmental and cleanliness controls
  - ***Cured part dimensional tolerance and warpage control***
  - ***Large scale surface preparation and adhesive application***
  - ***Implementation of bonding process steps (sequence, timing)***
- Cure process variables
  - Bondline thickness control
  - Local part variations in temperature, pressure and vacuum
- In-process controls and tests
- Structural design considerations
  - Part lay-up and mating surface details
  - Relationships with manufacturing scaling issues
  - ***Redundant design features***

* Applies to production and repair

Building Block Approach to Product Development & Structural Substantiation

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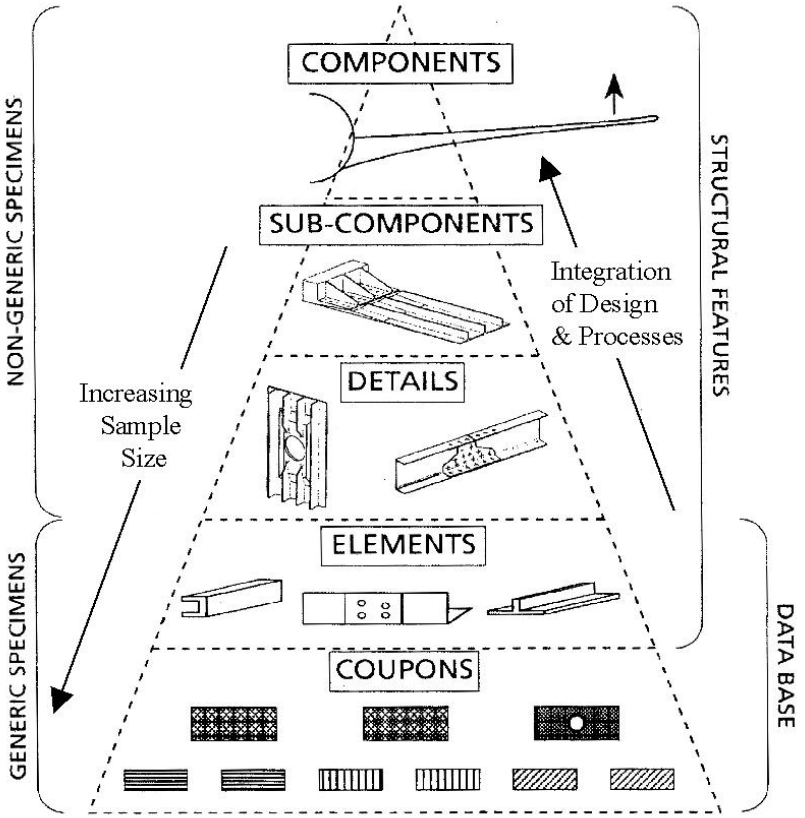
- Protect large non-recurring costs for certification and production
- Risk mitigation for design-specific detail and complex internal loads
- *Establish material & process control*
- *Design/manufacturing integration*
- *Manufacturing process scaling*
- *Analysis validation*
- Study variability, environmental effects, damage and repair as important parts of product development and structural substantiation

Schematic from a structures perspective



Bonded Primary Structure

Product Development and Structural Substantiation

FA
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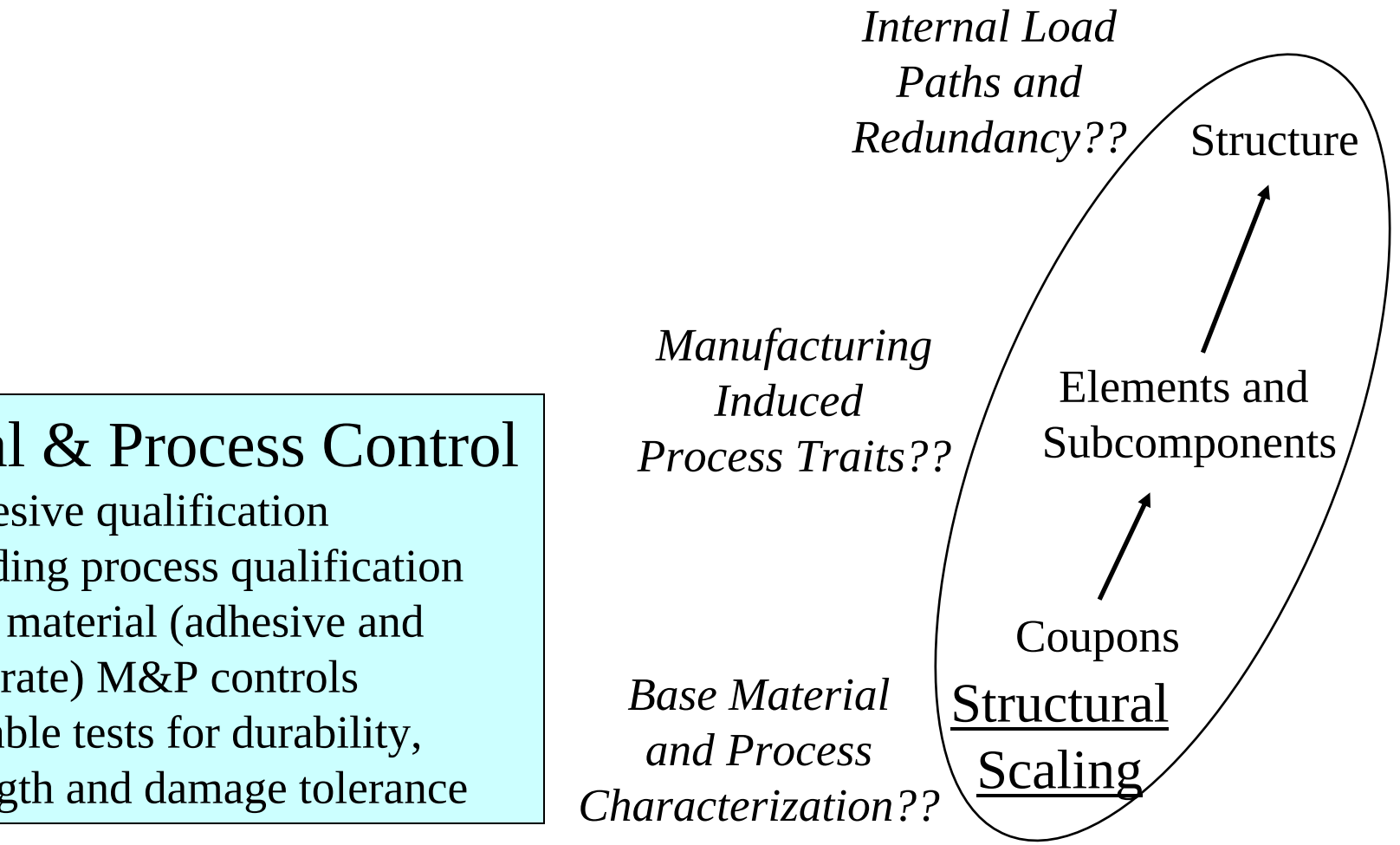


Material & Process Control

- Adhesive qualification
- Bonding process qualification
- Raw material (adhesive and substrate) M&P controls
- Suitable tests for durability, strength and damage tolerance

Bonded Primary Structure

Product Development and Structural Substantiation

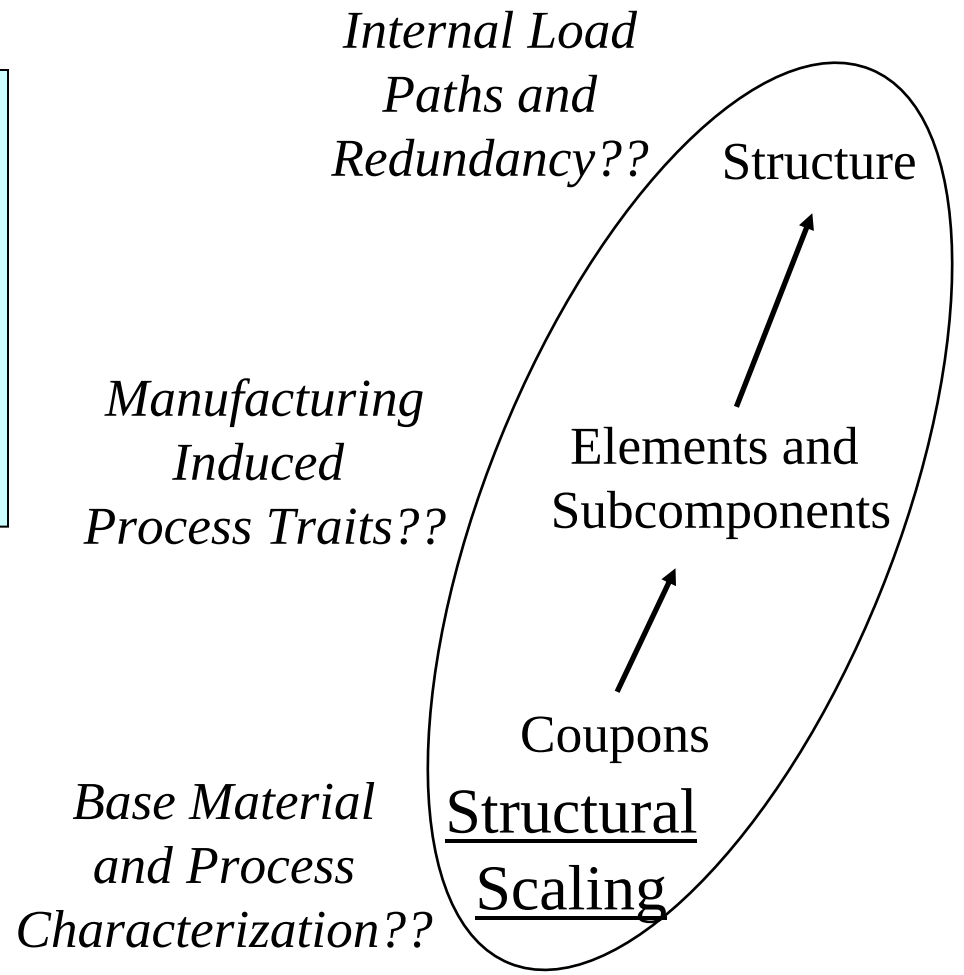
FA
A

Manufacturing and Design Integration

- Manufacturing scaling
- Cure process variables
- In-process controls and tests
- Structural design considerations

Material & Process Control

- Adhesive qualification
- Bonding process qualification
- Raw material (adhesive and substrate) M&P controls
- Suitable tests for durability, strength and damage tolerance



Bonded Primary Structure

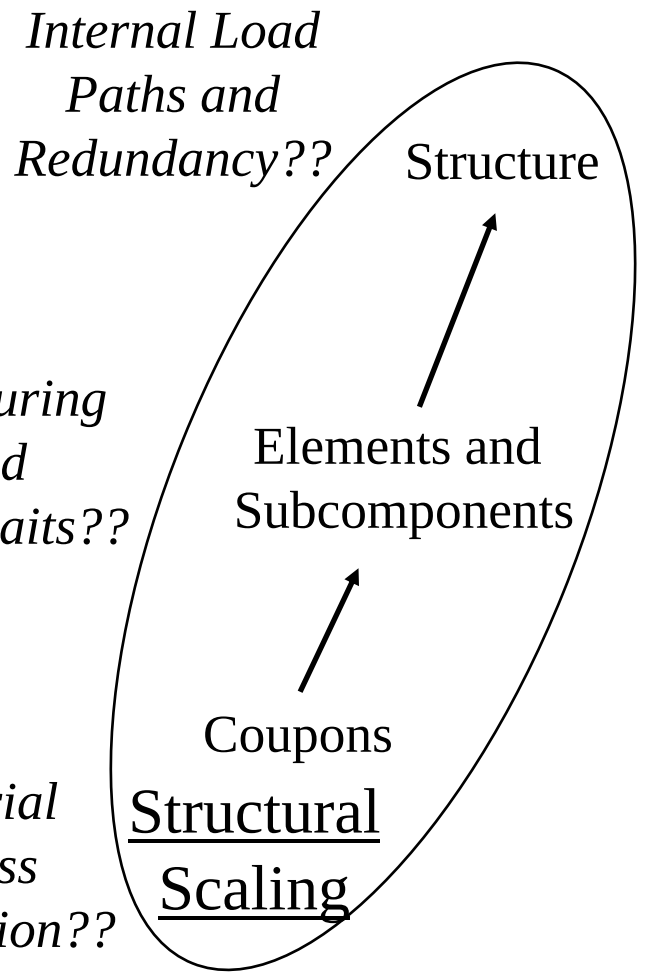
Product Development and Structural Substantiation

FA

Strength and Damage Tolerance
- Building block test selection
- Analysis validation
- Full-scale test conditions

Manufacturing and Design Integration
- Manufacturing scaling
- Cure process variables
- In-process controls and tests
- Structural design considerations

Material & Process Control
- Adhesive qualification
- Bonding process qualification
- Raw material (adhesive and substrate) M&P controls
- Suitable tests for durability, strength and damage tolerance



Bonded Primary Structure

Product Development and Structural Substantiation

Long-Term, Environmental Durability
- Building block test selection
- Critical environment and acceleration factors
- Considerations of full-scale structural detail

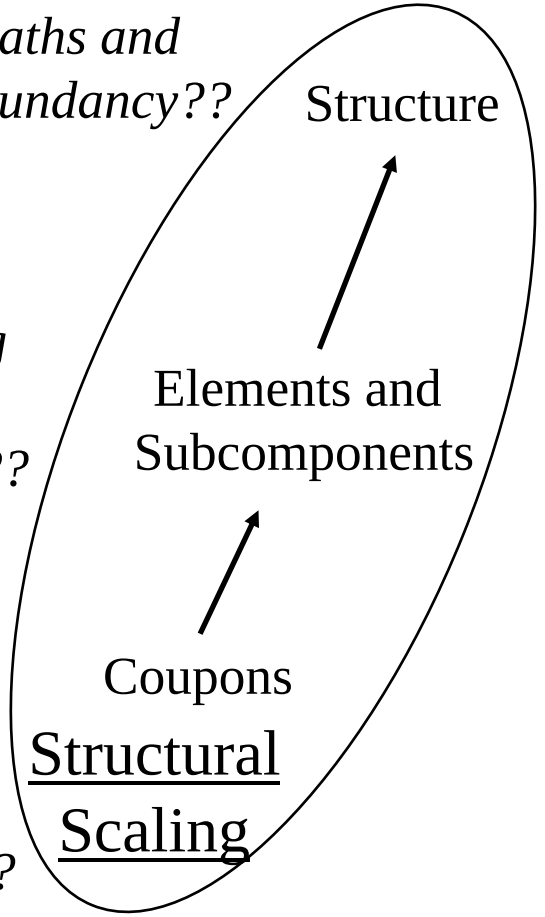
Manufacturing and Design Integration
- Manufacturing scaling
- Cure process variables
- In-process controls and tests
- Structural design considerations

Material & Process Control
- Adhesive qualification
- Bonding process qualification
- Raw material (adhesive and substrate) M&P controls
- Suitable tests for durability, strength and damage tolerance

Internal Load Paths and Redundancy??

Manufacturing Induced Process Traits??

Base Material and Process Characterization??



Inputs from Discussion
Material and Process Control *

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- Adhesive qualification
  - What tests need to be considered? Chemical, physical & mechanical
  - Candidate Experts: Peter Vanvoast (Boeing)
- Raw material (adhesive & substrate) M&P controls
  - What tests need to be considered? Chemical, physical & mechanical
  - Monitors and environmental controls for storage and working lives
  - Candidate Experts:
- Bonding process qualification and control
  - Links with adhesive qualification and raw material M&P controls (system approach, including application criticality)
  - What tests need to be considered? Static, environmental durability
  - Historical databases for successful applications (physical basis, e.g., what has worked)
  - NDI aspects
  - Candidate Experts: Kay B. (Boeing)

* Applies to production and repair

Inputs from Discussion
Manufacturing and Design Integration *

FAA

- Manufacturing scaling
  - Bondline thickness control
  - Nature of defects and their location (e.g., paste adhesive experiences) related to structural geometry
  - Training for critical details
- Cure process variables
  - Preload in real parts mating prior to cure (as developed in paste adhesive joints)
- In-process controls and tests
  - Wedge tests (utility of witness coupons)
  - Control of chemical tanks, shop cleanliness
  - Utility of proof loading
  - Records of problems
  - NDI aspects (including surface prep monitoring)

* Applies to production and repair

Inputs from Discussion
Manufacturing and Design Integration *

FAA

- Structural design considerations
  - Classification of joints for criticality
  - Critical defect locations and types must relate to real manufacturing considerations, as well as “high stress points”
  - Bolts versus bonding redundancy
- Product development
  - Considerations for sandwich structure
  - Inverted building block approach
  - Candidate Experts: Paul Brey (CDC)
- Structural substantiation
  - Failure prediction (static and damage tolerance, failure modes)
  - Allowables (what basic materials and joint data is needed for analysis procedures)
  - Impact damage affects (static/propagation)

* Applies to production and repair

FAA

Summary

- Composite safety & certification initiatives (CS&CI) are progressing with international help
  - Work for bonded structure integrates all technical thrust areas and both near- & longer-term research
- Best engineering practices and initial FAA policy for bonded structure will be documented in 2003 and 2004
  - TTCP document provides a starting point
  - Workshop in May or early June, 2004
  - Policy in late 2004
- Thank-you for your input on technical issues