Materials and Process WG

CMH-17

COMPOSITE MATERIALS HANDBOOK

- Characterization and control of fiber reinforced composite materials (including adjacent ones like film adhesive and core, and processing materials), so expected, consistent properties are delivered, and
- Developing and managing the associated manufacturing processes, both for fabrication of the structural non-metallic materials themselves, and completing the material's final transformation into parts
- Task groups for major activities:
  - P-17 – Industry specifications for V2 published materials
  - Bonding – New Rev H content on structural adhesive bonding
- Contacts: Dr. Margaret Roylance, Dan Ruffner

Other M&P Tasks

- Resins Content - Howard Creel
  - A draft was balloted in the last YP with new paragraphs on the fiber resin interface
  - All affirmative votes
  - Currently reconciling comments for final draft
  - No further action for Rev H
- Shipping and Storage Processes (Nathan Collins – Balloted and comments resolved
- Proposed Tasks post Rev H – lively discussion

Proposed M&P WG Tasks Post Rev H

- Shared database tutorial
- Nested qualification statistics
- Additional shelf life out-time content – life extensions, porosity as metric for processability, rheology, mfr w (tack, drape), non-epoxy react diff, fiber v resin shelf life
- Lot Testing - adding and/or setting aside coupons, wean off from R&D to production, do and do not represent
- Specification acceptance values v allowables
- Heat surveys (tool) – cure vessel, then tool, then family (vessel loading, position), soft upgrades, thermal profile (part)?, tool plate, simulation accept, TC placement, tool material change, order of operations,
- Process control traveler coupons, witness (cure), diff stat approaches for accept values,
- Other suggestions?

P17 Status

- Restarting efforts on V2 specifications
- 6565 IM7 PW fabric NSN for composite repair wet layup – new Navy potential user
- AMS3846 E quartz fabric std (Eric Smith), proposed changes and feedback being coordinated w affected parties - expect to happen for end of May

M&P WG, P17 TG and Bonding TG

- **M&P Working Group -** Margaret Roylance and Dan Ruffner
  Wednesday 3:30p – 4:20p
  - **Resins Content -** Howard Creel
  - **Shelf Life and Out-time -** Nathan Collins, Margaret Roylance
  - **New M&P Content beyond Rev H**
- **Joint M&P/P-17/QPG Meeting -** Shannon Jones and Margaret Roylance - Wednesday 4:30p to 5:30p
  - **Status update of P-17 Specification Activities -** Shannon Jones
  - **P-17 Qualified Product Group Updates -** Shannon Jones
- **Bonding Process Task Group Working Joint Meeting**
  Howard Creel and Molly Stone, Thursday 1:15p to 3:15p Open
  - **Finalize Rev H bonding M&P content**

Major M&P Efforts/Task Groups

CMH-17
COMPOSITE MATERIALS HANDBOOK

- Bond Process Task Group
  - Howard Creel, Molly Stone, Lisa McHugh
- SAE P-17 (and QPG – NDAs required)
  - P-17: Shannon Jones, Margaret Roylance
  - P-17 QPG: Shannon Jones, David Pate

Bonding Process Task Group

Howard Creel (hscreel@mmm.com) and Molly Stone (molly@mtechengservices.com)

CMH-17 COMPOSITE MATERIALS HANDBOOK

The Bonding Process Task Group was formed in the M&P Working Group to create all new content covering bonding of materials for aerospace structures.

The BPTG is focused on completing **Section 5.9 Assembly Processes for Bonded Joints** in Volume 3 for Rev H. All new content - not currently in the Handbook. The BPTG is on track for completion of the section for Rev H.

Bonding Process Task Group Working Meeting
Thursday April 25 1:15-3:15PM

Agenda

30 Min **Overview of the BPTG and the development of Section 5.9 for Rev H**

45 Min **Status of remaining Section 5.9 content to be completed for Rev H**

45 Min **Future focus for BPTG post Rev H** tasks with areas of interest that include defining adhesive chemistries; developing testing recommendations for amine blush screening; issues related to wet peel ply (WPP) compatibility, wettability, material handling, etc...; process verification travelers; Tg DOE approach; and other aspects of the bonding process.

Bonding Process Task Group

Howard Creel (hscreel@mmm.com) and Molly Stone (molly@mtechengservices.com)

CMH-17
COMPOSITE MATERIALS HANDBOOK

Section	Title	Primary Author(s)	Status
5.9	Introduction	Howard Creel	Complete
5.9.1	**General Considerations**	**Dan Ruffner**	**Resolve comments from F23 YP1**
5.9.2	Adhesive and Substrate Selection	Chad Franks	Complete
5.9.3	Surface Preparation for Secondary Bonding	Ashley Tracey, Will Grace, Jim Mazza, Kara Storage	Complete
5.9.4	**Application and Assembly Processes for Secondary Bonding**	**Scott Leeman, Molly Stone**	**Resolve comments from F23 YP1**
5.9.5	Cocuring	Dan Ruffner	Incorporate YP
5.9.6	Cobonding	Dan Ruffner	Complete
5.9.7	Multi-stage Bonding	Dan Ruffner	Complete
5.9.8	**Bond Quality Assurance**	**Lisa McHugh**	**Resolve comments from F23 YP1**
5.9.9	**Considerations for a Bonding Process Specification**	**Lisa McHugh**	**Resolve comments from F23 YP1**
5.9.10	**Structural Bond Certification**	**Chad Franks, Molly Stone**	**Resolve comments from F23 YP1**

Sections in Bold may be discussed in the BPTG Working Meeting

CMH-17 Bonding Process Task Group Meeting
April 25, 2024

Howard Creel – out-going Chair

History of Section 5.9 development for context

Organization of the current section

Plan for closing out Rev H

Molly Stone – incoming co-chair

Summary of response to most recent YP process

Post Rev H focus

Chapter 5 Materials and Processes - The Effect of Variability on Composite Properties

2016

Project 2: Create New Section

5.9 Assembly Processes

5.9.1 Fastened Joints

5.9.2 Bonded Joints

5.9 ASSEMBLY PROCESSES

Assembly processes are not conventionally covered within composite material characterization, but can have a profound influence on the properties obtained in service. As seen with test coupons, edge and hole quality can dramatically affect the results obtained. While these effects are not usually covered as material properties, it should be noted that there is an engineering trade off between part performance and the time and effort expended toward edge and hole quality. These effects need to be considered along with the base material properties.

CMH-17-3G Volume 3, Chapter 5 - 135 pages

5.9 ASSEMBLY PROCESSES

Assembly processes are not conventionally covered within composite material characterization, but can have a profound influence on the properties obtained in service. As seen with test coupons, edge and hole quality can dramatically affect the results obtained. While these effects are not usually covered as material properties, it should be noted that there is an engineering trade-off between part performance and the time and effort expended toward edge and hole quality. These effects need to be considered along with the base material properties

Section 5.9 Focus

Key M&P considerations for bonded joints
Topical overview organized as a primer
Best available knowledge
Recognized best practice/industry consensus
Recognition of emerging technology/processes

The Route to Volume 3 Section 5.9

2016

- ✓ Small group brainstorm outline for assembly processes based on best available knowledge
- ✓ Create a draft outline for Section 5.9, circulate and ballot
- o Seek SMEs to assemble content – working group
- o Working group input via e-mail initially
- o Working group session at next CMH-17 meeting
- o Develop draft document for ballot including input from outline

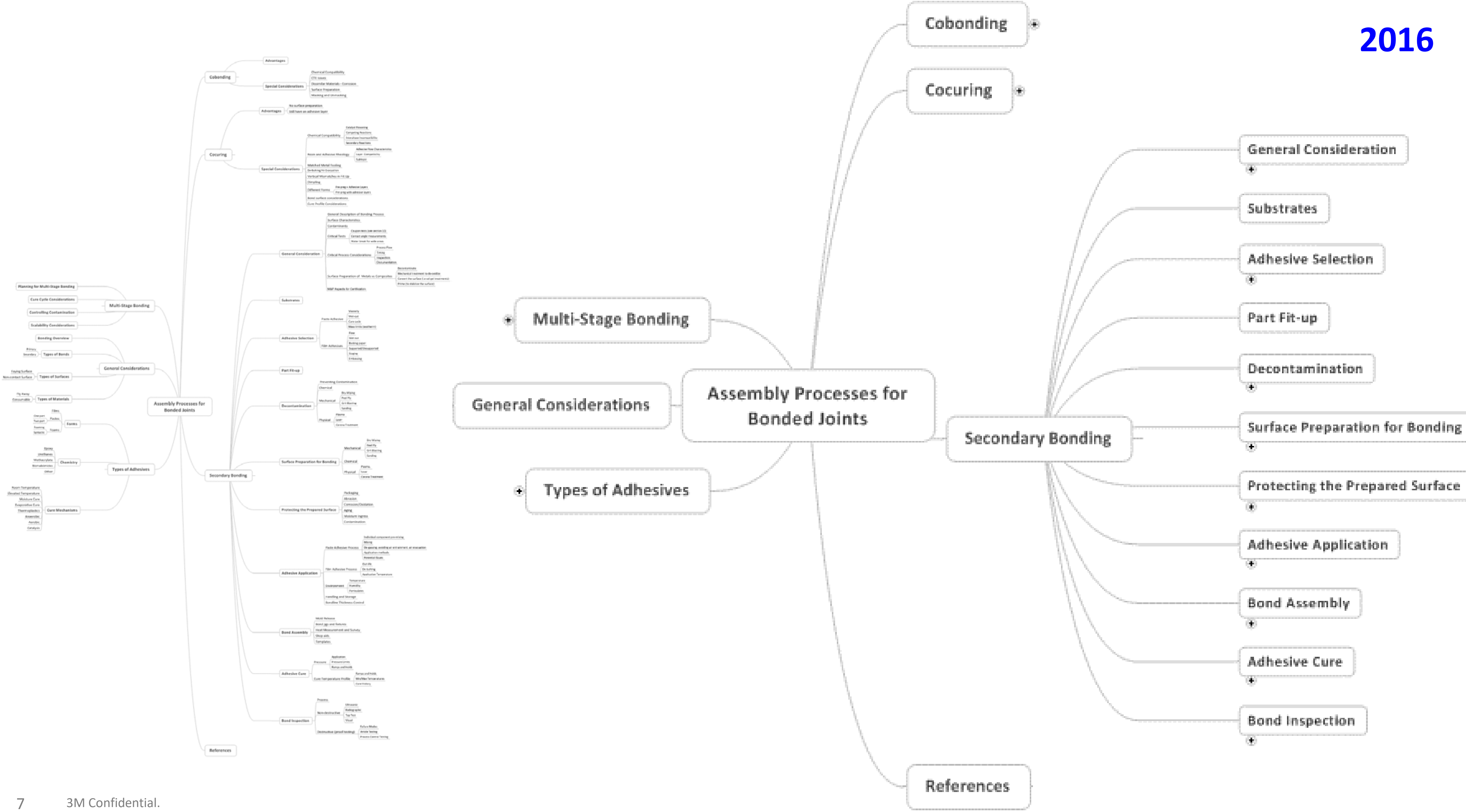
Steering Team
Holly Thomas
Margaret Roylance
Dan Ruffner
Scott Leemans
Carl Rousseau
Howard Creel - POC

Volunteers: It's Simple, Really:

Two Paragraphs and a Reference

Sign up today!

2016


Assembly Processes for Bonded Joints
Cobonding
Cocuring
Multi-Stage Bonding
General Considerations
Types of Adhesives
Secondary Bonding
General Consideration
Substrates
Adhesive Selection
Part Fit-up
Decontamination
Surface Preparation for Bonding
Protecting the Prepared Surface
Adhesive Application
Bond Assembly
Adhesive Cure
Bond Inspection
References

Expanded Vision: New Volume focused on Bonding

2016

CMH-17 Volume 7 Bonding of Thermoset Composite Structures

1. General Information
2. Material Data
3. Guidelines for Property Testing
4. Design and Analysis of Bonded Joints
5. Assembly Processes
6. Quality Control
7. Supportability
8. References

Current Vol 3 Section 5.9 becomes Vol 7 Section 5 with simultaneous optimization to Volume 3 Rev H

- Volume 3 Section 5.9.1 points to Volume 7
- New content for bolted and hybrid joints?
- Many revisions under development
- Relevant adhesive and join content moved to Volume 7 with pointers from Volume 3

By CMH-17 Meeting in August:

- General Outline for discussion and comment
- Existing content map with proposed changes to Vol 3
- Gap analysis

5 Assembly Processes

- **5.1 Introduction**
- **5.2 General Considerations**
  - **5.2.1 Types of Bonds**
  - **5.2.2 Definitions**
- **5.3 Secondary Bonding**
  - **5.3.1 General Considerations**
  - **5.3.2 Quality Considerations for Bonding**
  - **5.3.3 Surface Preparation**
  - **5.3.4 Protecting the Prepared Surface**
  - **5.3.5 Adhesive Application**
  - **5.3.6 Bond Assembly**
  - **5.3.7 Adhesive Cure**
  - **5.3.8 Bond Inspection**
- **5.4 Co-curing**
  - **5.4.1 Advantages**
  - **5.4.2 Special Considerations**
- **5.5 Co-bonding**
  - **5.5.1 Advantages**
  - **5.5.2 Special Considerations**
- **5.6 Multi-Stage Bonding**
- **5.7 References**

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CMH-17 Bonding Process Task Group

Current Status The complete draft will be assembled to deadline 2Q 2021 for Volume 3A Rev H

Bonding Process Task Group Coordinators

Howard Creel	3M
Dwayne McDaniel	FIU
Tanila Faria	Embraer

M&P Work Group Sponsor

Margaret Roylance – CMH-17 M&P Lead

Bonding Process Task Group Champions

Curt Davies	FAA
Rachael Andrulonis	CMH-17

Special Thanks to the Founding Members

Holly Thomas, Margaret Roylance, Dan Ruffner
Scott Leemans, Carl Rousseau

Primary Authors

Dan Ruffner	Boeing Retired/Consultant
Jim Mazza	AFRL
Kara Storage	AFRL
Will Grace	Boeing
Ashley Tracey	Boeing
Kay Blohowiak	Boeing
Chad Franks	GA-ASI
Holly Thomas	Boeing
Lisa McHugh	Northrop Grumman
Rick Cole	NRC Aerospace
Shannon Jones	Textron
Scott Leemans	X
Graham Ray	Surfx

1.3 Secondary Bonding

1.3.1 General Consideration
1.3.2 Substrates
1.3.3 Adhesive Selection
1.3.4 Part Fit-up
1.3.5 Pre-cleaning and Decontamination
1.3.6 Surface Preparation for Bonding
1.3.7 Protecting the Prepared Surface
1.3.8 Adhesive Application
1.3.9 Bond Assembly
1.3.10 Adhesive Cure
1.3.11 Bond Inspection

Incorporating metal bonding content into Section 5.9

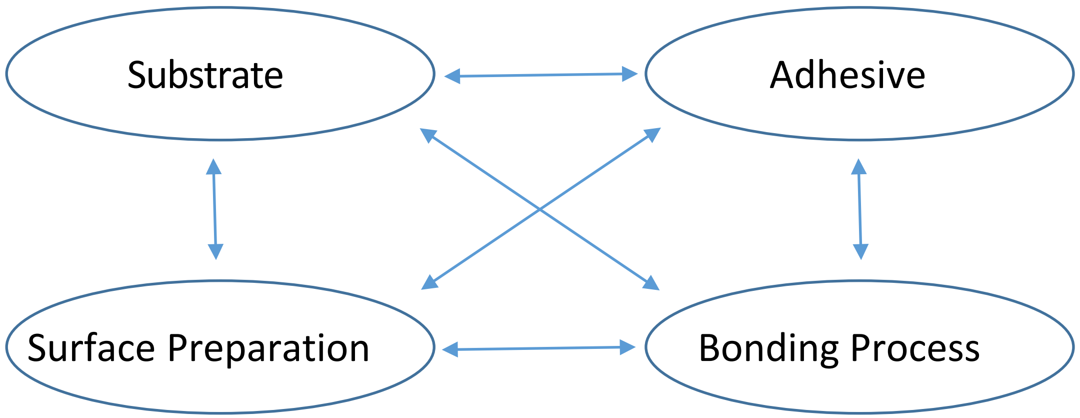
- General Considerations
- Secondary Bonding
  - Substrates
  - Adhesive Selection
  - Part Fit-up
  - Precleaning and Decontamination
  - Surface Preparation
    - Composites
    - Metals
      - Aluminum
      - Titanium
      - Steel
      - Others
  - Protecting Surfaces
  - Bond Assembly
  - Adhesive Cure
  - Bond Inspection
- Cocuring
- Cobonding
- Multistage Bonding
- References

5.9 Assembly Processes for Bonded Joints

- 5.9.1 General Considerations
- 5.9.2 Substrates and Adhesives
- 5.9.3 Surface Preparation for Secondary Bonding
- 5.9.4 Assembly Processes for Secondary Bonding
- 5.9.5 Co-curing
- 5.9.6 Cobonding
- 5.9.7 Multi-stage Bonding
- 5.9.8 Adhesive Bond Quality

“Qualified” Bonding System

Bonding System Validation– validate system performance at corners of material and process variables – this results in a Qualified Bonding System



Substrate

Material Specification
- Mat’l-specific process variables

Supplier Qualifications
- Process Control Document

Adhesive

Material Specification
- Mat’l-specific process variables

Supplier Qualifications
- Process Control Document

Materials

Surface Preparation

Process or/and Material Specification
- Process/material variables

Supplier Qualifications
- PCD for Materials

Bonding Process

Process Specification
- Facility Control, Contact Materials Control, Personnel Certification, Requirements, Quality Control (NDI, etc), Processing Limits (Cure cycle, etc)

Facility Qualifications

Part Qualifications

Process

Section	Title	Primary Author(s)	Status
5.9	Introduction	Howard Creel	Complete
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5.9.10	**Structural Bond Certification**	**Chad Franks, Molly Stone**	**Resolve comments from F23 YP1**

BPTG Starting Drafts ---> BPTG Final Draft to Secretariat July 2024					BPTG Final Draft ----> Rev H Published TBD		
	Title	BPTG Final Draft Established	Grammar & Formatting	Combine Drafts, Content Locked	Editorial and Continuity	Cross References Confirmed	Section 5.9 Locked
5.9.1	**General Considerations**	**5/17/2024**	**6/1/2024**	Section 5.9 BPTG Locked Draft	Section 5.9 BPTG Final Draft	Section 5.9 Final Draft	Rev H Published
5.9.2	Adhesive and Substrate Selection	12/1/2023	3/1/2024				
5.9.3	Surface Preparation for Secondary Bonding	12/1/2023	3/1/2024				
5.9.4	**Application and Assembly Processes for Secondary Bonding**	**5/17/2024**	**6/1/2024**				
5.9.5	Cocuring	12/1/2023	3/1/2024				
5.9.6	Cobonding	12/1/2023	3/1/2024				
5.9.7	Multi-stage Bonding	12/1/2023	3/1/2024				
5.9.8	**Bond Quality Assurance**	**5/17/2024**	**6/1/2024**				
5.9.9	**Considerations for a Bonding Process Specification**	**5/17/2024**	**6/1/2024**				
5.9.10	**Considerations for Structural Bond Substantiation**	**5/17/2024**	**6/1/2024**				

Closing out Section 5.9 for Rev H

Next Two Weeks – Check the Forum for revised sections from the most recent YP cycle

Looking for several volunteers willing to read the assembled draft for continuity and cross reference.

Thanks for all the support.

Current Rev H Content - Edit and Refine

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- Vol 3, Section 5.9 was completed over an 8-yr period by various authors. Post Rev H, there is a need to:
  – Review all content for continuity and consistent/clear guidance.
  – Bolster current content by improving internal CMH17 cross-references and adding supporting academic and industry references.
  – Identify overlap or gaps in information.

Bonding Process Task Group Post-Rev H Activities

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COMPOSITE MATERIALS HANDBOOK

- Bonding Process Task Group (BPTG) will continue post Rev-H.
  - Molly Stone and Lisa McHugh co-chairs.
- Initiatives and ideas for new content or revised content are being identified and discussed. Input is welcome.

Future Content: Post-Cure Operations

- Populate / add detail to Post-Cure Operations section:
  - Demolding / removal from the bonding fixture
  - Clean-up and flash removal
  - End of part (EOP) edge trimming
  - Follow-on sequential bonding or lamination operations

Future Content: Adhesive Cure Cycle Verification

- How to confirm entire bondline area reaches the specified cure cycle?
- Thermal heat survey / tool survey
- Tooling design should consider the ability to withstand assembly loads.

Future Content: Amine Blush Testing

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- Amine blush – testing approach, how to confirm temp/humidity space.

Future Content: Surface Characterization

- Contact Angle Measurement – Usage and application
- Surface Free Energy Characterization
- Wettability Envelope

Future Content: Process Control Mentality

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- PCD (process control document) for adhesive bonding
- Key Process/Performance Parameter (KPP)
  - Connect to manufacturing process step, defined target (PS requirement) and QA measure.
- Process control travelers / witness panels
  - Application and limitations

Future Content: Changes to a Qualified Bond System

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- Expand and provide examples and recommendations of substantiation approaches.

5 Materials and Processes – The Effects of Variability on Composite Properties

5.1 Introduction

5.2 Purpose

5.3 Scope

5.4 Constituent Materials

5.4.1 Fibers

5.4.2 Resins

- 5.4.2.1 General considerations
- 5.4.2.2 Thermoset Resins for Polymer Matrix Composites
  - 12
- 5.4.2.3 Thermoplastic Resins for Polymer Matrix Composites
  - 7
- 5.4.2.4 References
  - 3

Focus for Section 5.4.2 Resins

By consensus, it was decided that the section would describe both **thermoset and thermoplastic resin materials used in polymer matrix composites for aerospace application** within a framework of the M&P aspects of resin chemistry, composite fabrication with the resins, and composite properties.

Overall Status of Section

Final Draft Complete for Rev H

A draft was balloted in the last YP with new paragraphs on the fiber resin interface.

All affirmative votes.

Currently reconciling comments for final draft.

No further action for Rev H.

- 5.4.2 Resins
  - 5.4.2.1 General considerations
  - 5.4.2.2 Thermoset Resins for Polymer Matrix Composites
    - Overview of thermoset resins for aerospace composites
    - The interplay between viscosity, process, time, and temperature
    - General considerations of thermoset resin processing
    - Consideration of the fully cured state of thermoset resins
    - Resins
      - Epoxy
      - Bismaleimide
      - Polyimide
      - Cyanate Ester
      - Phthalonitrile
      - Phenolic
      - Benzoxazine
      - Polyester
  - 5.4.2.3 Thermoplastic Resins for Polymer Matrix Composites
    - Overview of thermoplastic resins for aerospace composites
    - General considerations of thermoplastic resin processing
    - Comparison of thermoplastic resins versus thermosets
    - Resins
      - Polyaryletherketone
      - Polyphenylene sulfide
      - Polyetherimide
      - Polyamide
  - 5.4.2.4 References

Section 5.4.2 Resins: Key considerations

The focus of the section is on resins used in the aerospace industry for fiber-reinforced composites primarily for structural applications.

The overall intention is to present a primer on resin selection, properties, and processing with sufficient background to enable a general understanding.

The text was written as the consensus of numerous references including review and journal articles, trade literature and technical data sheets, online resources, and encyclopedia and book chapters.

The focus, resin selection, and overall outline was the subject of a YP approval. The draft has been through two YP cycles and considered complete.

The resins highlighted in the section were selected after extensive discussion with interested members of the CMH-17 M&P group CMH-17 meetings. Other relevant resins are included where appropriate.

The reference to resins was kept generic with no tradenames included except when needed to reference to historically important polymers.

A bibliography will be included that will include critical references for additional background and detail

SAE INTERNATIONAL

SAE P17
POLYMER MATRIX COMPOSITES

Hybrid Meeting

Joint with CMH-17 PMC

M&P Working Group

24 April 2024

AMS Standardization as a strategic driver for aerospace materials & structures…

AGENDA – P17 – 24th April 2024

1. Welcome and Introductions
2. Review/Approval of the Minutes from Last Meeting (19 October, 2023)
3. Specification Activity Since Last Meeting
4. New Business / Active Development Work
5. Non-Current Documents
6. Other Specifications
7. Wrap-Up

SAE P17 – Meeting Minutes

[SAE P17 Draft Minutes 19_Oct_23]

SAE P17 – Specification Activity Since Last Meeting

1. AMS3846 Rev E – Quartz Fabric (Eric Smith) nearing ballot

2. AMS6562 /2 - MTM45-1/6781 S-2 Fabric (passed ballot)
3. AMS6562 /3 - MTM45-1/HTS40 3K PW Fabric and /7 carbon fiber (passed ballot)

4. AMS6562 /4 – MTM45-1/HTS40 12K UD and corresponding fiber
5. AMS6562 /5 – MTM45-1/AS4 12K UD and corresponding fiber
6. AMS6562 /6 – MTM45-1/IM7 12K UD and corresponding fiber

SAE P17 – New Business / Active Development Work

1. **AMS6565 – IM7 Plain Weave Fabric**
2. **AMS6567 Base (5320-1) , /1 (T650 6K UD), /2 (T650 6K PW)**
3. **AMS3107 Revision or new specification for non-chromated bonding primer**
4. **Slash Sheets for AFP Slit Tape Product Forms vs. Broadgood UD Tape**
5. **"Forever Chemical" Product Implications**
6. **AMS6891 Revisions for longer shelf life**

SAE P17 – Non-Current, AMS3901 Related

Document Number	Title
AMS3901C	Organic Fiber (Para-Aramid), Yarn and Roving, High Modulus
AMS3901/10C	Yarn, Organic Fiber (Para-Aramid), High Modulus, 1140 (1270 d tex) Denier, 1.2% Finish
AMS3901/11C	Yarn, Organic Fiber (Para-Aramid), High Modulus, 1420 (1580 d tex) Denier, 1.2% Finish
AMS3901/12C	Yarn, Organic Fiber (Para-Aramid), High Modulus, 2160 (2400 d tex) Denier, 1.2% Finish
AMS3901/13B	Yarn, Organic Fiber (Para-Aramid), High Modulus, 2450 (2720 d tex) Denier, 0.6% Finish
AMS3901/14B	Yarn, Organic Fiber (Para-Aramid), High Modulus, 2840 (3160 d tex) Denier, 0.6% Finish
AMS3901/15B	Roving, Organic Fiber (Para-Aramid), High Modulus, 7350 Denier, (8200 d tex), 0.6% Finish
AMS3901/16B	Roving, Organic Fiber (Para-Aramid), High Modulus, 8520 Denier, (9500 d tex), 0.6% Finish
AMS3901/17B	Yarn, Organic Fiber (Para-Aramid), High Modulus, 720 Denier, (800 d tex), 1.2% Finish
AMS3901/1D	Yarn, Organic Fiber (Para-Aramid), High Modulus, 195 (215 d tex) Denier, 0.6% Finish
AMS3901/2D	Yarn, Organic Fiber (Para-Aramid), High Modulus, 380 Denier,(420 d tex), 0.6% Finish
AMS3901/3D	Yarn, Organic Fiber (Para-Aramid), High Modulus, 1140 Denier, (1270d tex), 0.6% Finish
AMS3901/4D	Yarn, Organic Fiber (Para-Aramid), High Modulus, 1420 Denier, (1580 d tex), 0.6% Finish
AMS3901/5D	Roving, Organic Fiber (Para-Aramid), High Modulus, 7100 Denier, (7900 d tex), 0.6% Finish
AMS3901/6D	Roving, Organic Fiber (Para-Aramid), High Modulus, 4560 Denier, (5070 d tex), 0.6% Finish
AMS3901/7D	Yarn, Organic Fiber (Para-Aramid), High Modulus, 2160 Denier, (2400 d tex), 0.6% Finish
AMS3901/8C	Yarn, Organic Fiber (Para-Aramid), High Modulus, 195 Denier, (215 d tex), 1.2% Finish
AMS3901/9C	Yarn, Organic Fiber (Para-Aramid), High Modulus, 380 Denier, (420 d tex), 1.2% Finish

SAE P17 – Non-Current, Others

Document Number	Title	Sponsor	Status
AMS3711E	Core, Honeycomb, Fibrous, Aramid Base, Phenolic Coated	S. Jones	Draft
AMS3713D	Core, Flexible Honeycomb, Polyamide Paper Base, Phenolic Coated	S. Jones	Draft
AMS3830	Silica Cloth B-Staged Phenolic Resin Impregnated High Pressure Molding	CANCELLED	
AMS3914A	Advanced Composites Prepreg - Nominal 250 °F Cure – 12K Tow Carbon Fiber and Epoxy Resin, Plain Weave Fabric	Lemmers	WIP
AMS3915A	Advanced Composites Prepreg – Nominal 250 °F Cure –Glass Fiber and Epoxy Resin, 7781 Weave Fabric	Lemmers	WIP
AMS3960A	Advanced Composites Prepreg - Nominal 250 °F Cure - Carbon Fiber and Epoxy Resin, Unidirectional Tape	Lemmers	WIP
AMS3961	350 °F Autoclave Cure, Low Flow Toughened Epoxy Prepregs	S. Jones	Draft
AMS3961/1	350 °F Autoclave Cure, Low Flow Toughened Epoxy Prepregs, Type 38, Class 2, Grade 193, Style 3K-70-PW, Fiber 1	S. Jones	Draft
AMS3961/2	350 °F Autoclave Cure, Low Flow Toughened Epoxy Prepregs, Type 35, Class 1, Grade 190, Fiber 2	S. Jones	Draft
AMS3961/3	350 °F Autoclave Cure, Low Flow Toughened Epoxy Prepregs, Type 35, Class 1, Grade 190, Fiber 1	S. Jones	Draft
AMS-STD-401	Sandwich Constructions and Core Materials; General Test Methods	TBD	
ARP1524A	Surface Preparation and Priming of Aluminum Alloy Parts for High Durability Structural Adhesive Bonding	S. Jones	WIP
ARP1675	Structural Weldbonding of Aluminum Structures		

SAE P17 – Other Specifications

Document Number	Title	Sponsor	Ballot Plan
AMS6566	TC250 based products (NMS 688)		
AMS6568	BT250E-6 based products (NMS 250)		
AMS6569	EP2202 based products (NMS 220)		
AMS3962	2511 based products (No NMS)		

Document Number	Title	Sponsor	Ballot Plan
AMS-STD-401	Sandwich Constructions and Core Materials; General Test Methods	TBD	
AMS3892	Fibers, Carbon Tow and Yarn, for Structural Composites (and 12 slash sheets)	Teijin	
AMS2750/1	Pyrometry for Composite Cure Devices (unofficial)	Andrew Bassett	

SAE P17 – Wrap-Up

Questions / Comments:

Next Meeting:

Backup Slides

SAE P17 –Ballot Plan Tracking for 2023

Document Number	Title	Sponsor	Ballot Plan
AMS3711E	Core, Honeycomb, Fibrous, Aramid Base, Phenolic Coated	S. Jones	4/23
AMS3713D	Core, Flexible Honeycomb, Polyamide Paper Base, Phenolic Coated	S. Jones	4/23
AMS6562	Medium Temperature, Out-of-Autoclave, Oven-Vacuum-Bag Cure Epoxy Resin Impregnated Fiber Reinforced Composite Materials	Ruffner	5/23
AMS6562/1	Medium Temperature, Out-of-Autoclave, Oven-Vacuum-Bag Cure Epoxy Resin Impregnated Fiber Reinforced Composite Materials, Type 35, Class 4, Grade 293, Style 7781 (MTM45-1/7781)	Ruffner	5/23
AMS3914A	Advanced Composites Prepreg - Nominal 250 °F Cure – 12K Tow Carbon Fiber and Epoxy Resin, Plain Weave Fabric	Lemmers	6/23
AMS3915A	Advanced Composites Prepreg – Nominal 250 °F Cure –Glass Fiber and Epoxy Resin, 7781 Weave Fabric	Lemmers	6/23
AMS3960A	Advanced Composites Prepreg - Nominal 250 °F Cure - Carbon Fiber and Epoxy Resin, Unidirectional Tape	Lemmers	6/23
AMS6562/2	Medium Temperature, Out-of-Autoclave, Oven-Vacuum-Bag Cure Epoxy Resin Impregnated Fiber Reinforced Composite Materials, Type 35, Class 4, Grade 298, Style 6781 (MTM45-1/6781)	Ruffner	6/23
AMS6565	Dry Carbon Plain Weave Fabric	David Stone	6/23
AMS6562/3	Medium Temperature, Out-of-Autoclave, Oven-Vacuum-Bag Cure Epoxy Resin Impregnated Fiber Reinforced Composite Materials, Type 36, Class 2, Grade 193, Style 3k-70-PW (MTM45-1/HTS40 3K PW)	Ruffner	7/23
AMS6562/X	Carbon Fiber for AMS6562/3 (AMS6562/AB)	Ruffner	7/23
~~AMS6562/AB~~	~~Carbon Fabric for AMS6562/3~~	~~Ruffner~~	~~7/23~~
AMS3846E	Cloth, Quartz, Finished for Resin Laminates	Eric Smith	7/23
AMS3961	350 °F Autoclave Cure, Low Flow Toughened Epoxy Prepregs	S. Jones	8/23
AMS3961/1	350 °F Autoclave Cure, Low Flow Toughened Epoxy Prepregs, Type 38, Class 2, Grade 193, Style 3K-70-PW, Fiber 1	S. Jones	8/23
AMS3961/2	350 °F Autoclave Cure, Low Flow Toughened Epoxy Prepregs, Type 35, Class 1, Grade 190, Fiber 2	S. Jones	8/23
AMS3961/3	350 °F Autoclave Cure, Low Flow Toughened Epoxy Prepregs, Type 35, Class 1, Grade 190, Fiber 1	S. Jones	8/23
AMS6562/4	Medium Temperature, Out-of-Autoclave, Oven-Vaccum-Bag Cure Epoxy Resin Impregnated Fiber Reinforced Composite Materials, Type 32, Class 1, Grade 145, Standard Modulus Fiber 1 (MTM45-1/HTS40 12K UD)	Ruffner	9/23
AMS6562/Y	Carbon Fiber for AMS6562/4	Ruffner	9/23
AMS6562/5	Medium Temperature, Out-of-Autoclave, Oven-Vaccum-Bag Cure Epoxy Resin Impregnated Fiber Reinforced Composite Materials, Type 32, Class 1, Grade 145, Standard Modulus Fiber 2 (MTM45-1/AS4 12K UD)	Ruffner	10/23
AMS6562/Z	Carbon Fiber for AMS6562/5	Ruffner	10/23
AMS6562/6	Medium Temperature, Out-of-Autoclave, Oven-Vaccum-Bag Cure Epoxy Resin Impregnated Fiber Reinforced Composite Materials, Type 32, Class 1, Grade 145, Intermediate Modulus Fiber (MTM45-1/IM7 12K UD)	Ruffner	11/23
AMS6562/AA	Carbon Fiber for AMS6562/6	Ruffner	11/23

CMH-17 Durability & Damage Tolerance Task Group

April 2024 TG Overview

Scottsdale

Prepared for

CMH-17 Damage Tolerance Task Group

Scottsdale Meeting
April 2024

Prepared by

NSE Composites
1101 North Northlake Way, Suite 4
Seattle, WA 98103
(206) 545-4888
www.nsecomposites.com

Allen Fawcett
DM Hoyt

CMH-17 D&DT TG – Task Group Definition

Task Group Definition

- The Durability and Damage Tolerance group is a Task Group under Safety Management.
- The group determines an overall strategy for the handbook to address durability and damage tolerance.
- The task group will examine methodologies in support of AC20-107B, FAA policy memos, ARAC material and other documentation focusing on polymer matrix composites.
- Benchmarking our approach includes the work done by the IRCWG (Industry Regulatory Composite Working Group) as well as industry best practices done at FAA/EASA/TCCA workshops over the years.
- The group will review the existing documents to assure that the sections related to durability and damage tolerance are up-to-date and provide maintenance for those sections.
- Appropriate interfaces will be made with existing groups to address identified gaps, in particular Bonding under Material and Process WG and the Disbonding and Delamination task group. The creation of new sections may be recommended if the current outline does not meet the needs of the strategic approach.

D&DT group formed in 2001 with Tom Walker (NSE) as chair.

Focus = benchmarking accepted industry practice and providing expanded guidance

CMH-17 D&DT Task Group – Co-chairs/Contributors

Co-chairs (active):

Allen Fawcett (NSE)	afawcett@nsecomposites.com
Pactrick Enjuto (Boeing)	patrick.enjuto2@boeing.com
Mike Smeets (Fokker)	mike.smeets@fokker.com
Simon Waite (EASA)	simon.waite@easa.europa.eu
Doug Cairns	dcairns@me.montana.edu

Significant contributors:

Hoyt (NSE)	hoyt@nsecomposites.com
Larry Ilcewicz (FAA)	larry.ilcewicz@faa.gov

CMH-17 Volume 3 Chapters

1. General Information
2. Introduction to Composite Structure Development
3. **Aircraft Structure Certification and Compliance**
4. **Building Block Approach For Composite Structures**
5. Materials and Processes
6. Quality Control of Production Materials and Processes
7. Design of Composites
8. Analysis of Laminates
9. Structural Stability Analyses
10. Design and Analysis of Bonded Joints
11. Design and Analysis of Bolted Joints
12. **Damage Resistance, Durability, and Damage Tolerance**
13. **Defects, Damage, and Inspection**
14. **Supportability, Maintenance, and Repair**
15. Thick-section Composites
16. Crashworthiness and Energy Management
17. Structural Safety Management
18. Environmental Management
19. Launch Vehicles and Spacecraft
20. Engine Applications

Supporting discussions (chapters 3–4)

Main D&DT content (chapter 12)

Supporting discussions (chapters 13–14)

Chapter 12: Damage Resistance, Durability, and Damage Tolerance

12.1 Introduction

12.2 Rules, Requirements and Compliance for Aircraft

12.3 Design Development and Substantiation

12.4 Inspection for Defects and Damage

12.5 Damage Resistance

12.6 Durability and Damage Growth Under Cyclic Loading

12.7 Residual Strength

12.8 Application/Examples

12.9 Supporting Discussions

Chapter 12 Section Outline

Related Topics Covered Elsewhere

- Bonded joints and bonded repairs – Chapter 10
- Bonded joint M&P – Chapter 5
- Supportability and bonded repair – Chapter 14
- Sandwich disbond – Volume 6

Related topics in other chapters

CMH-17 D&DT TG – Meeting Agenda – Scottsdale – Meeting 4/24/24

Wednesday D&DT Task Group Meeting

12.5 Damage Resistance - Status of YP resolution of comments
- 12.5.2.7 Lightning
- 12.5.2.11 Fire Protection, Flammability and Overheating
- 12.5.3.13 HEWABI

12.3 Design Development and Substantiation - Status of YP resolution of comments.
- 12.3.1 Damage Threat Assessment
- 12.3.2 Damage Design Criteria
- 12.3.3 Substantiation
- 12.3.4 Addressing Category 5 Damage

12.8.8 ILX-34 Wingbox Technology Demonstrator - Status of YP resolution of comments

Key Takeaways - Discussed

New material post revision H - Discussed

CMH-17 D&DT TG – Key Accomplishments for Rev H

- **Aging, LOV, and Damage Accumulation**
  - *New section summarizing aging issues with input from ARAC, other new content including sections on environmental cycling and visco-elastic effects.*
- **Hybrid Issues & Thermal Loads**
  - *Extensive new sections for hybrid structure, large scale testing, and use of analysis for thermal load substantiation.*
  - *Two applications examples for addressing thermal loads.*
- **Repeated Load Tolerance & LEF Guidance**
  - *LEF guidance for complex structures and hybrids.*
  - *Test spectrum development, 5 x 5 blocking approach*
- **Damage Threat Assessment & Damage Resistance**
  - *New introduction relating damage threat assessment to criteria and substantiation.*
  - *Extensive new section covering all types of damage and defect threats.*
  - *Includes Part 25 and Part 23 application examples.*
  - *Updates to damage resistance sections.*
- **Categories of Damage & SDC**
  - *Updated design criteria and substantiation sections for Categories of Damage, including specific updates for bonded joints.*
  - *SDC and fail-safe design explained, minimum damage sizes discussed.*
  - *New section on relationship among categories.*
- **Category 5 & HEWABI**
  - *HEWABI policy statement incorporated with updated sections on addressing Category 5 damage, including damage resistance.*
- **Inspection for Defects & Damage**
  - *Inspection programs, EDR/ADR, MSG-3 and fleet leader programs discussed.*
  - *Chapter 13: Defects, Damage, and Inspection – updated.*
- **Additional Topics**
  - *Added discussion of AC 25.307-1.*
  - *Analysis - Industry practices section complete.*
  - *Residual Strength - Rewrite of analysis section complete.*
  - *Other application examples mostly complete.*

CMH-17 D&DT TG – Future Initiatives Post Rev H (1 of 3)

Additional initiatives may be added based on recent YP comments that will be addressed in next revision.

- 12.3.1 – Add bonded repair processing threats to Damage Threat Assessment
  - *Add new sub-section for post-Rev H*
  - *May be partly covered in Chapter 14 (14.3)*
- 12.3.2 – Updates to address comments to approved text that don't make Rev H.
- 12.3.3 – Updates to address comments to approved text that don't make Rev H.
  - *Add discussion on LEF usage for larger damage states (Cat 2) and revisit large scale test requirements table. Start with proposed text that was deleted for Rev H.*
  - *Helicopter example of full-scale test sequence (updates per Airbus comment)*
- 12.4 – Generalize inspection protocols and practices to all categories of aircraft
  - *Current write-up is Transport Category (Part 25) centric and based on MSG-3/ADR/EDR and Part 25 ARAC activities*
- 12.5 – Damage resistance test issues and analysis methods
  - *12.5.2 Design issues and guidelines – Expand on fire section? Need experts on both to help with write-up. See also separate bullet on lightning.*
  - *12.5.3 Test issues – intro, impact under load, and HEWABI testing input from UCSD/Bishop*
  - *12.5.4 Analysis methods – industry practice, analysis examples including HEWABI*

CMH-17 D&DT TG – Future Initiatives Post Rev H (2 of 3)

- 12.6.3 – Fatigue testing – update with additional guidance for multi-LEF and deferred spectrum approach (more emphasis and/or training, WFE)
- 12.6.4 – Fatigue analysis methods updates
  - *Coordinate with Engines Working Group*
- 12.8.x – Application Examples
  - *Epic case study?*

- Lightning – Add more content to cover design practices and protection
  - *12.5 has a significant write-up moved from Volume 3, Chapter 3*
  - *Also currently covered in 12.3.1, 12.3.2, and 12.4.4.2*
  - *Possibly add more detailed systems-related content in Chapter 7 (see placeholder in section 7.5.10 in detailed design section), possibly a new initiative?*
  - *Also detailed design guidance for lightning protection (could also go in Chapter 7)*

CMH-17 D&DT TG – Future Initiatives Post Rev H (3 of 3)

- Review and expand content for non-Part 25 categories of aircraft (all of Chapter 12)
- Review and expand content for thermoplastics
- SLP vs. MLP
  - *ARAC inputs on single load path (SLP) and multi-load path (ML) structures*

- Definitions for in context of Category 1 damage
  - *“defect”, “flaw”, “anomaly”, “indication”*
  - *Review Section 12.3 and entire Chapter 12*
  - *25.603 AMC Simon addition of “defects” (see amendment)*
  - *Coordinate with definitions in Chapter 17*
  - *Should definitions be in intro to Volume (existing definitions section)?*

CMH-17 PMC
Data Review Working Group
Wednesday April 25, 3:30-5:30 pm MT

Working Group Chairs

Royal Lovingfoss, NIAR

Michael Hempowicz, Toray CMA

Data Review Working Group (DRWG) Agenda

CMH-17 COMPOSITE MATERIALS HANDBOOK

Introduction and Welcome – Royal Lovingfoss, Michael Hempowicz

1. Overview of Data Review Working Group (DRWG)

a. DRWG Voting Members – Voting Group Expectations

b. DRWG Data Source Data Submittal – Data Confidentiality – Data Approval Process

2. Data Review Schedule

a. Data in Ballot/ Review/ Upcoming

- Fracture Toughness tables– Additional Voters Needed
- Toray 3900-2C/T800s Slit Tape
- Victrex AE 250 T-071 AS4 12k Unitape

b. Available Datasets

c. Additional Datasets

3. Old/ New Business

Data Review Working Group (DRWG)

CMH-17
COMPOSITE MATERIALS HANDBOOK

Goal

- Establishes data documentation requirements, develops formats for data presentation, and provides the final technical and editorial review of all data prior to inclusion in the Handbook.

Activities

- Data Review Working Group (DRWG) performs data review according to a set of published procedures that have been developed by the working group.
- To facilitate the data review process, the DRWG has established an electronic voting protocol that allows data reviews between CMH-17 formal meetings.
- DRWG works closely with NCAMP in order that the data generated by that organization meets the requirements of CMH-17.
- Future tasks will address data requirements and formats for data presentation for adhesives, core, and other new material forms.

DRWG Voting Members

- Sub-group of Data Review formed to focus on data set approval
- Requirement to join are:
  1. Volunteer to join
  2. Have a background in Polymer Matrix Composites
  3. Intend to review at least 1 of 3 consecutive ballots
- This group has access to vote on Phase I and Phase II Reviews before the dataset is released for Yellow Page Ballot by the general CMH-17 population.
- Current voting members list includes 27 members

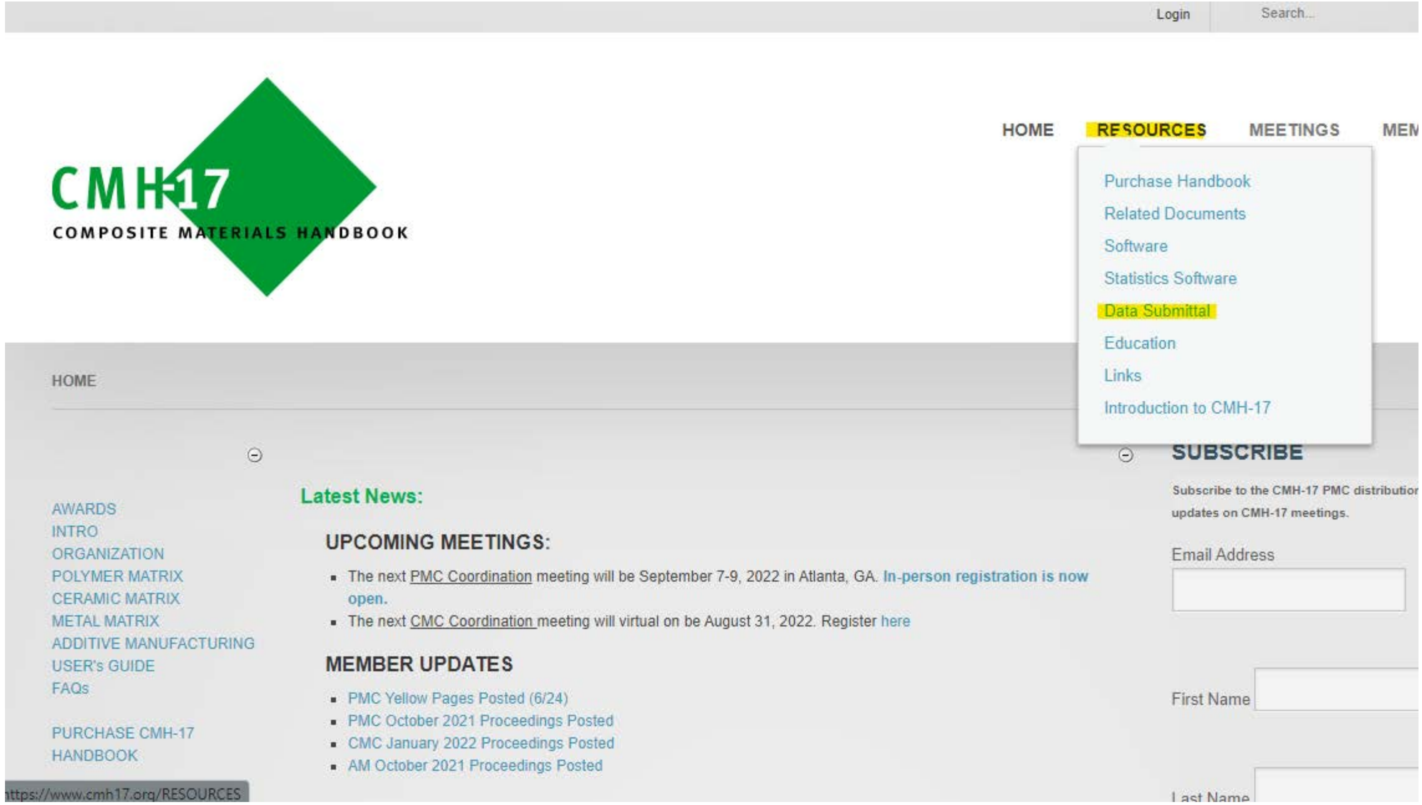
Expectations for DRWG Voting Members

- Majority of Voting Members must vote for the review to be valid
- Single phase (vote within 4-6 weeks)
  - If supported by NCAMP-style Summary Report and Statistics Report
  - CMH-17 Data tables (generated from Statistics Report)
- Two phase
  - New Material to DRWG
  - Supported by Reports of unfamiliar format
  - Requires CMH-17 Secretariat to generate allowables
  - 1st Phase (vote within 4-6 weeks): Review just report(s) – maybe just data
  - 2nd Phase (vote within 4-6 weeks): CMH-17 Data tables (using Statistics generated by the Secretariat)
    - 2nd Phase does not necessarily start immediately after 1st Phase approval.

DRWG Data Source Data Submittal

CMH-17 COMPOSITE MATERIALS HANDBOOK

- Establish NDA with NIAR Secretariat
- Review process and duration
- Data classes/sampling
- Units, properties to be reported
  - Raw material (fiber, prepreg, etc.)
  - Mechanical
- Distribution Limitation
  - (EAR, ITAR, etc.)



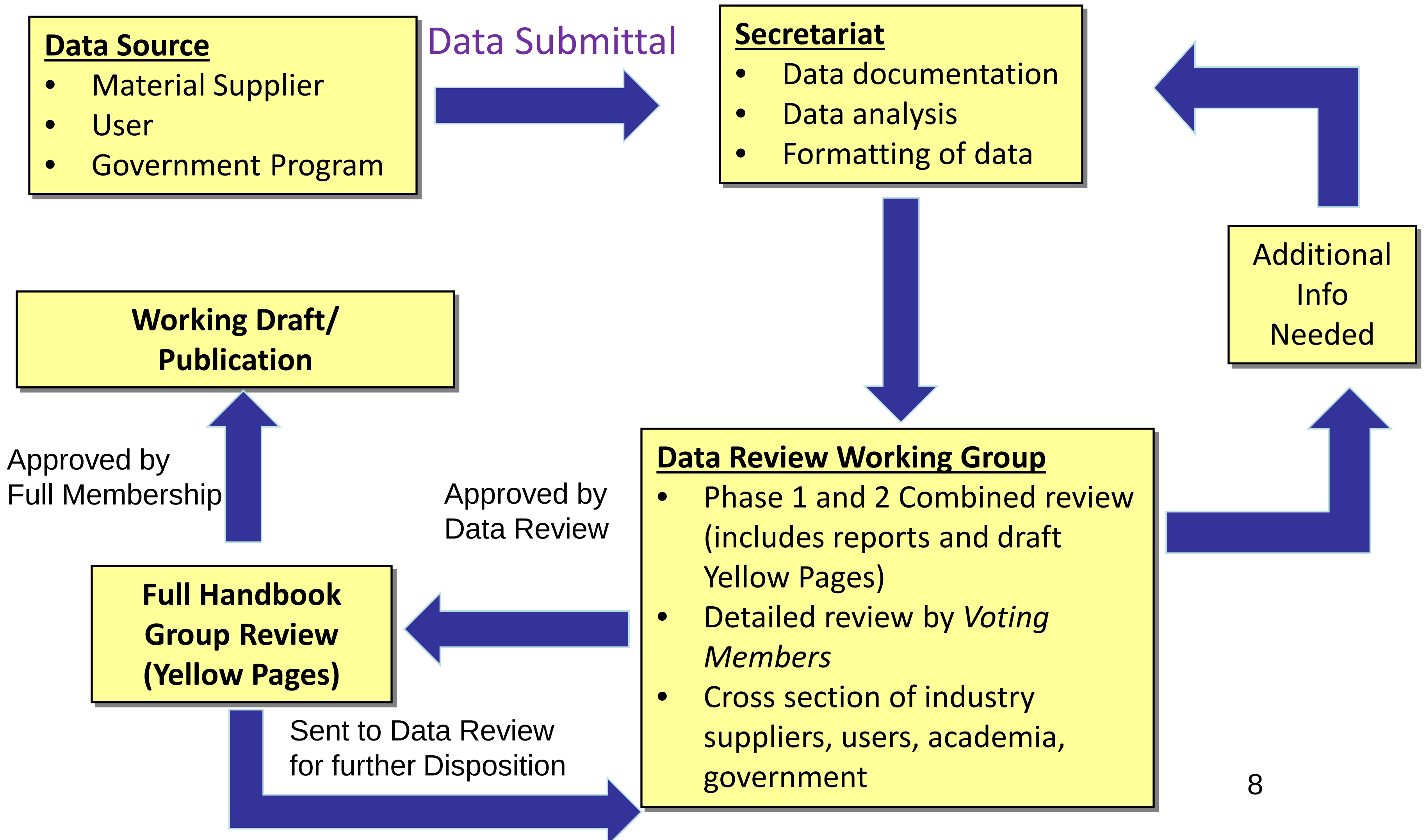
- Link:

  https://www.cmh17.org/RESOURCES/Data-Submittal

Data Confidentiality

- Content for review is to DRWG Voting Group use only
  - Do not distribute content shared within DRWG Voting Group to non-DRWG Voting Group members without written consent of content supplier/submitter
  - Delete data from all locations outside of CMH-17 control after DRWG Phase review is complete

Data Approval Process



Data Review Schedule

A look at upcoming activity

Data in Ballot/ Review/ Upcoming

In Ballot

- Fracture Toughness tables
  - 1 Phase Review
  - CMH-17 Data Table

In Review

- Toray 3900-2C/T800s Slit Tape
  - 1 Phase Review
  - NCAMP reports available
  - CMH-17 Data Table
- Victrex AE 250 T-071 AS4 12k Unitape
  - 2 Phase (Thermoplastic)
  - Phase 1: NCAMP Report Available

Upcoming

- Hexcel 8552 AGP 370 8HS
  - 1 Phase Review
  - NCAMP reports are available
  - CMH-17 data tables in work
- Solvay MTM 45-1 7781
  - 1 Phase Review
  - NCAMP reports are available
  - CMH-17 Tables in work
- Victrex AE 250 T-071 AS4 12k Unitape
  - 2 Phase (Thermoplastic)
  - Phase 2: CMH-17 Tables not started

Available Datasets

CMH-17 COMPOSITE MATERIALS HANDBOOK

CMH 17 Submittal	Type	Product	Dataset Status
Updates needed	Thermoset	Hexcel 8552 IM7 UT - IPS Tables	NCAMP Approved
		Solvay 5320-1 T650 PW repair Qual	NCAMP Approved
Future Review		Hexcel 8552 AGP370 8HS	NCAMP Approved
Updates needed		Solvay MTM45-1 7781 retest	NCAMP Approved
	Thermoplastic	TenCate T700/TC1225 (thermoplastic) – discontinued (new fiber – diff manuf process)	NCAMP Approved
Future Review		Victrex AE 250 T-071 AS4 12k Unitape	NCAMP Approved
Future Review		Schappe Techniques TPFL Yarn 714 tex Carbon AS4D with PEEK	Testing completed

(Changes since Fall 2023 are highlighted)

Additional Datasets

Type	Product	Status
Adhesive	Solvay FM300-2M Film Adhesive Qual	Ready for NCAMP review
	Henkel EA9394 Paste Adhesive Qual	Being reviewed by NCAMP internally
Thermoset	Solvay 5320-1 8HS	Testing complete, data has not been submitted to NCAMP
	Solvay EP2190 IMS65 UNI	Being reviewed by NCAMP internally
	Solvay EP2190 T650 PW	Being reviewed by NCAMP internally
	Solvay FM309-1M Adhesive	On hold by Solvay
	Solvay EP2750 8HS	On going, planning stage
	EP2400 VARTM with Tenax® Dry Reinforcements	
Core	Hexcel HRH-10-1/8-3.0', Hexcore	On going, 80% complete
Thermoplastic	**Tenax®-E TPWF PEEK-4-40 HTA40 E13 3K DT-5HS-285 (thermoplastic)**	NCAMP Approved

(Changes since Fall 2023 are highlighted)

Old/ New Business

Old Business

- None

New Business

- Fracture Toughness submission
  - Additional Voters Needed- Reaching out to those who didn't vote to update voter list.
- Core data format
  - Task Group will be opened to discuss after NCAMP Internal Review completes.
  - Data Submission Requirements
- Adhesive data format
  - Task Group will be opened to discuss after NCAMP Internal Review completes.
  - Data Submission Requirements
  - End of June the Task Group will probably kick off.
- Solvay MTM 45-1 7781
  - Retest/replace of Fill Compression Data (failed equivalency significantly between multiple facilities)
  - Re-site equivalency
- DRWG Standard Operating Procedures will be posted to the CMH-17 Members forum for review and discussion. Plan to discuss in the Fall.

PMC Design

An Overview of the SM WG/GWG Composite Design Initiative

Thursday, April 25, 2024

<u>Design Team Members</u>

**Larry Ilcewicz, Patrick Enjuto, Mike Rush, Larry Gintert, Rick Cole,
Charlie Seaton, Cindy Ashforth, Eric Stenne, Eric Pomerleau, Simon Waite,
Jean-Luc Leon Dufour, Emilie Morteau, Melanie Herman and Isabelle Paris
Plus Special Guest: Christos Kassapoglou: Rotorcraft Design Studies**

CMH-17 COMPOSITE MATERIALS HANDBOOK

Design TG Objectives

- **Purpose** Develop an appreciation for the phases of design from the start of product development through life cycle challenges, including product value assessments of related costs and performance objectives essential for certifiable applications. These efforts started with an introduction to *Composite Design Criteria, Requirements and Other Constraints* as related to design development and structural substantiation. Principles of size and product scaling will be applied, including the necessary success criteria to attain product readiness and complete product definition, certification, production and service needs during the product life cycle.
- **Volume 3, Chapter 7, Revision H**
  - Sections 7.1 (Design Requirements, Criteria and Constraints) through 7.2.2.3 (Design Phase Success Criteria for *Product Design Readiness*), 7.2.2.4 (Differences for Aircraft Types) and Section 7.2.5.1 (Transport Aircraft Design Process Example)
- **Post Revision H**
  - Section 7.2.3 (Integrated Product Team, IPT), Section 7.2.4 (Integrated Product Team Challenges), 7.2.5 (Design Process Examples), 7.3 (Material and Process Selection), 7.4 (Structural Concepts), 7.5 (Detailed Part Design) and 7.6 (Optimization)
  - ***Post-Rev H sections will benefit from more team members with diverse product value needs***

Task Group Meeting (Thursday, April 25 8:00-10:00 AM)

1. **Welcome, Introduction**
2. **Task Group Meeting Objectives/Purpose, Ilcewicz, 3 Minutes**
3. **Overview of Composite Design Chapter 7 Rev. H Content, Ilcewicz, 7 Minutes**
4. **Brief Overview of Approved Content, Rush & Ilcewicz, 10 Minutes**
   a. Section 7.1 – Overview of Unique Issues Associated with Composite Structural Design
   b. Section 7.2 – Structural Design Process
5. **Review Latest Progress to consolidate Sections 7.1 and 7.2 , Rush & Ilcewicz, 40 Minutes (Rev. H Yellow Page Updates/dispositions and chapter consolidation)**
6. **Plans for Future of CMH-17 – Design Task Group Initiatives (Summary of Tuesday April 23 Meeting),**
   a. DRAFT Section 7.2.3 Integrated Product Team Update and Overview, **Larry Gintert, 15 Minutes**
   b. Different Product Types (Rotorcraft), **Christos Kassapoglou, 40 Minutes**
   c. Next Steps in Advancing Content, **Larry Ilcewicz, 5 Minutes**
7. **Closure/Actions**

A

Top-Level Chapter 7 Outline in Content Development

7.1 Overview of Unique Issues Associated with Composite Structural Design

Sub-team led by P. Enjuto & L. Ilcewicz

- 7.1.1 Design Requirements, Criteria and Constraints
  - 7.1.1.1 Definition of terms
  - 7.1.1.2 Purpose and justification
- 7.1.2 Typical Aerospace Composite Structural Design Requirements and Criteria
  - 7.1.2.X *7.1.2.1 through 7.1.2.14 Technical Areas*
- 7.1.3 Other typical aerospace design constraints (2022, YP2)
  - 7.1.3.1 Systems interface
  - 7.1.3.2 Design options affecting costs and structural weight
  - 7.1.3.3 Other constraints affecting cost & weight trades

7.2 Structural Design Process

Sub-team led by L. Ilcewicz & P. Enjuto

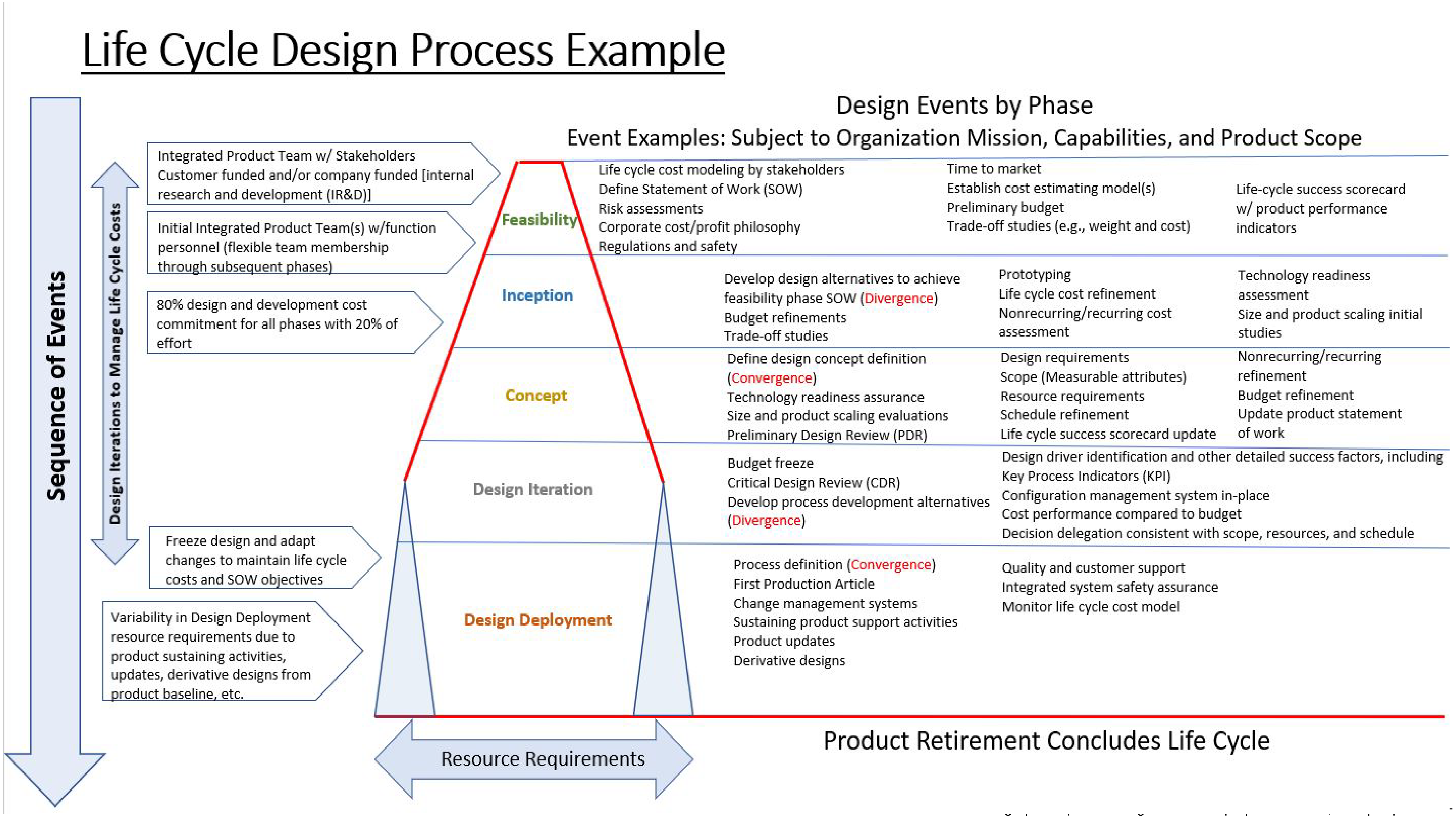
- 7.2.1 Product & Process Development: 5 Phases…
- 7.2.2 Technology Development and Product Implementation
  - 7.2.2.1 Product life cycle costs and customer value
  - 7.2.2.2 Practical size and product scaling issues
  - 7.2.2.3 Success criteria (2022, YP2)
  - 7.2.2.4 Differences for aircraft product types (2022, YP2)
- 7.2.3 Integrated Product Teams (in work, L. Gintert)
  - 7.2.3.1 Typical structural design membership
  - 7.2.3.2 Design phase changes
  - 7.2.3.3 Simplifications for smaller products
- 7.2.4 IPT Challenges
  - 7.2.4.1 Technology/Product Readiness
  - 7.2.4.2 Verified size and product scaling
  - 7.2.4.3 Financial considerations
  - 7.2.4.4 Other Issues (marketing, customer interface)
- 7.2.5 Design Process Examples
  - 7.2.5.1 Transport Aircraft
  - 7.2.5.2 Business Jet
  - 7.2.5.3 Rotorcraft
  - 7.2.5.4 Small Airplanes
  - 7.2.5.5 Others (eVTOL, Tiltrotor, supersonic)

Sub-team led by P. Enjuto & L. Ilcewicz

Section 7.2.5.1 Will not be added Until updated for Post-Rev H

Design Chapter 7 last Rev H YP: 2022, YP2

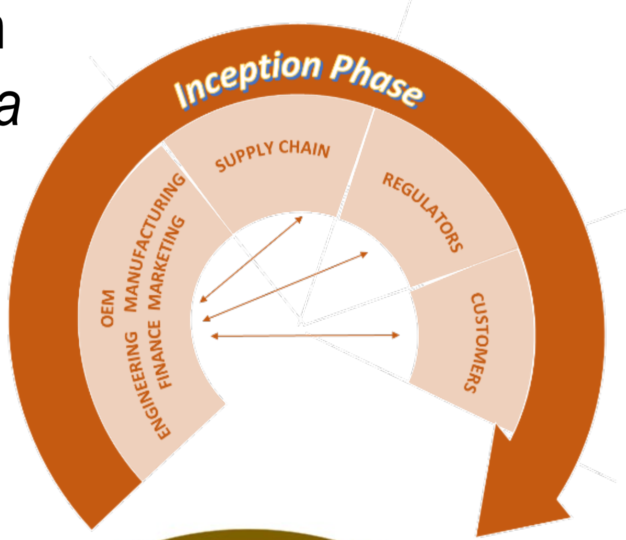
Figure 7.2. Examples of events & considerations at different phases of the design process applied from start and throughout the life cycle of a product



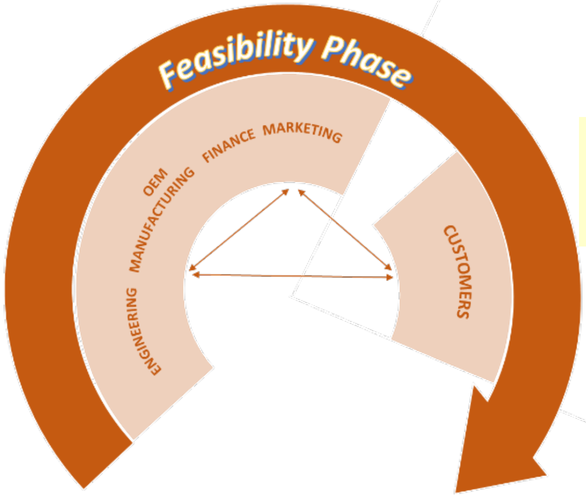
Schematics of Five Phases of Design

7.2.1 Introduces 5 Phases of Design

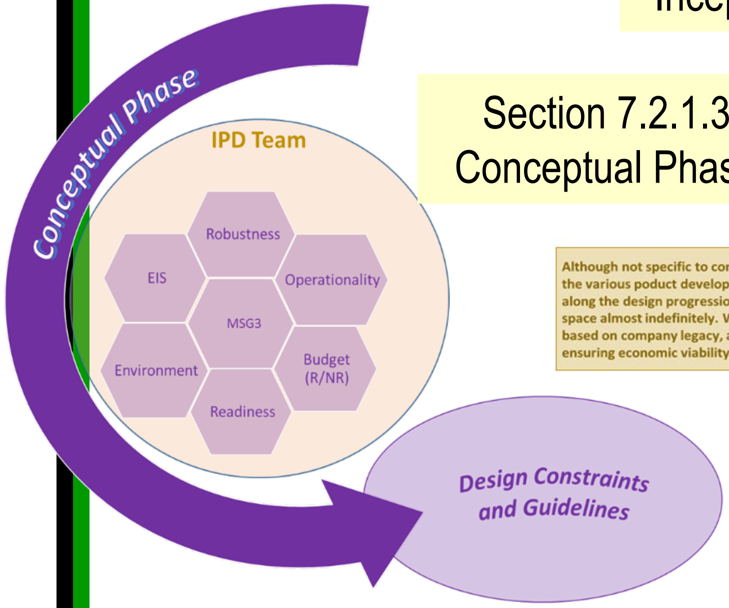
7.2.2.3 Gives gated success criteria for the first three phases



Section 7.2.1.2
Inception Phase

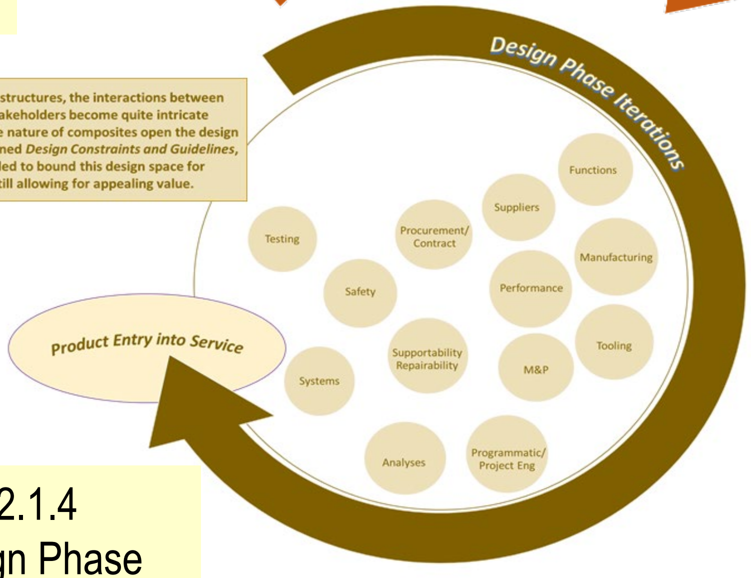


Section 7.2.1.1
Feasibility Phase



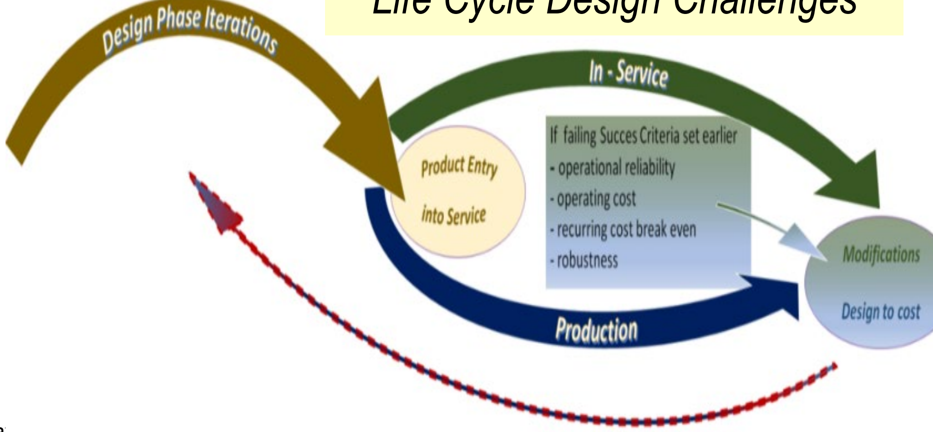
Section 7.2.1.3
Conceptual Phase

Although not specific to composite structures, the interactions between the various product development stakeholders become quite intricate along the design progression, as the nature of composites open the design space almost indefinitely. Well defined *Design Constraints and Guidelines*, based on company legacy, are needed to bound this design space for ensuring economic viability while still allowing for appealing value.



Section 7.2.1.4
Detailed Design Phase

Section 7.2.1.5
Deployment Phase
Life Cycle Design Challenges



7.2.2.2 Practical size and product scaling issues [Figure 7.2.2.2(a)]

- **Three stages of development and three stages of implementation**

Different Types of Scaling to Support Applications

Six Stages of Concept Development and Application

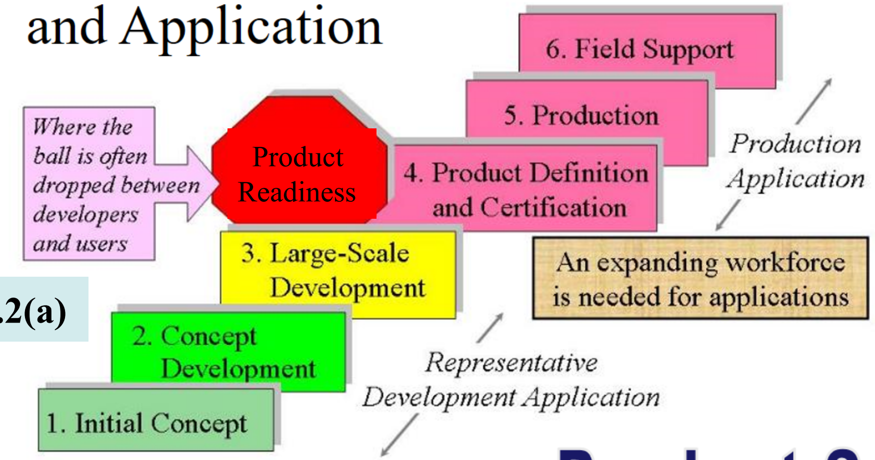


Figure 7.2.2.2(a)

Size Scaling

Efforts to apply information at one scale of study to predict the behavior at a larger, more complete level

The two main areas covered are size and product scaling, which are intimately tied together. It's important to couple what is done in these arenas as they impact cost.

From Ilcewicz and Ashforth Composite Book Chapter

Product Scaling

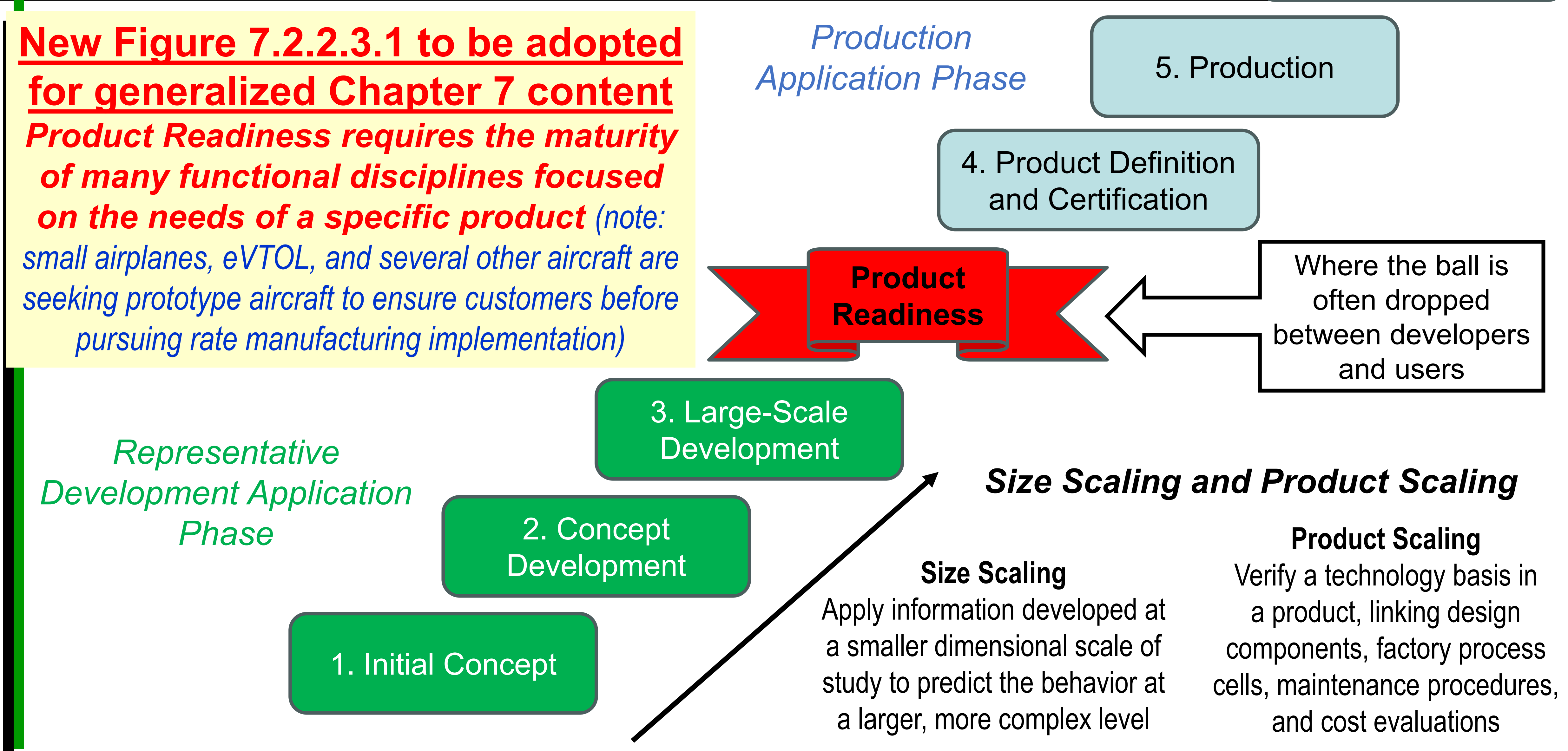
Efforts to verify a technology basis, which links design components, factory process cells, maintenance procedures, and cost evaluations

- Product and size scaling are coupled with design and ***highly dependent on product costs and value***

Final Section 7.2 YP reviews 2021 YP3 and 2022 YP2

- Total Votes – 83
- Affirmative – 43
- Affirmative with Comment – 20
- Negative with Comment – 0
- Abstain – 20

Six Stages of Technology Development & Implementation as Focused on a Specific Product



Overview of Approved Revision H Content (7.1.X)

7.1 Overview of Unique Issues Associated with Composite Structural Design

7.1.1 Design Requirements, Criteria and Constraints

- 7.1.1.1 Definition of terms
- 7.1.1.2 Purpose and justification

7.1.2 Typical Aerospace Composite Structural Design Requirements and Criteria

- 7.1.2.1 Laminate and other structural details
- 7.1.2.2 Environmental and other time-related effects
- 7.1.2.3 Manufacturing, incl. M&P specs + Mfg. plans
  - 7.1.2.3.1 Design for manufacturing, incl. inspection
  - 7.1.2.3.2 Design within costs
- 7.1.2.4 Inspection and Repair
  - 7.1.2.4.1 Design for inspection and repair
  - 7.1.2.4.2 Design of repairs
- 7.1.2.5 Handling and storage
- 7.1.2.6 Stiffness and stability
- 7.1.2.7 Strength
- 7.1.2.8 Bolted & bonded joints
- 7.1.2.9 Durability & Damage Resistance
- 7.1.2.10 Damage tolerance
- 7.1.2.11 Aero-elastic considerations (flutter, instabilities)
- 7.1.2.12 Crashworthiness
- 7.1.2.13 Flammability
- 7.1.2.14 Conductivity, EMI shielding and lightning strike protection

7.1.3 Other typical aerospace design constraints

- 7.1.3.1 Systems interface
- 7.1.3.2 Design options affecting costs and structural weight
- 7.1.3.3 Other design constraints essential to cost and weight trades

Emilie Morteau
Isabelle Paris
Eric Stenne
Eric Pomerleau
Alain Douchant
Michael Rush
Melanie Herman
Jean-Luc Leon-Dufour
Larry Ilcewicz
Patrick Enjuto

7.1 Overview of Unique Issues Associated with Composite Structural Design

Yellow Page (YP) review

- Exceptional engagement from CMH-17 community in review process is a testament to the design team's work
- 3 Yellow Page Cycles

Section 7.1

- Total Votes – 153
- Affirmative – 79
- Affirmative with Comment – 50
- Negative with Comment – 1
- Abstain – 23

Volume 3, Section 7.1

Vote	Comments	CMH-17 Member
Affirmative with Comment	7.1.2.7 - add "For additional information on composite stress analysis refer to volume 3 chapters 8 and 9" or similar. 7.1.3 - the majority of this discussion is not unique to composites. Consider adding the caveat "... while not unique to composites..." in certain places.	Carl Rousseau
Affirmative		Steve Ward
Affirmative		Jason Gibson
Affirmative with Comment	valid results and by the other hand, few tests to a level like coupon tests to derive only composite material properties can be used uncertainly to support a stress analysis which can remain unvalid, these examples possible to occur are being avoided by the FAA AC 20.107B.1 which requires for a new composite structure tests up to critical ultimate loading, therefore I suggest to use the term tests and structural analysis supported by tests which is in accordance with FAA AC and is being used by pratically all manufacturers certifying new airplane models. The following change is proposed, as follows: 7.1.2.7 Strength The strength of the composite structure is typically evaluated using tests or structural analysis supported by tests. The tests and the structural analysis need to take into account all applicable aspects that have a significant influence on the strength and load level. 2 - In the section 7.1.2.7 fourth paragraph, some minor change in the material system level can be evaluated by section 2.3.4 Alternate material equivalence test matrices and therefore I propose the following change: In the event that changes are made to the original specifications, it is necessary to evaluate and/or rationalize the minor changes to a level of material system to provide by section 2.3.4 an alternate material by equivalency tests matrices and also, to all the other type of changes to evaluate and/or rationalyze their structural effects. 3- In the section 7.1.2.7 fifth paragraph. Some improvements are needed to reflect the actual use and applicability, as follows: The characteristics of all damage that are included in the ultimate load capability assessment are quantified by area, depth, number of damaged laminas, resin and/or fiber damages. Typically, damage resulting from manufacturing defects, such as: saw cuts (open holes cuts, border cuts), drill nicks, gauges and scratches, open and filled holes and impact damages such as: runway debris, tool drops and hailstone and to the test specimen component by design criteria at least one barely visible damage-BVID up to threshold of visibility (0.1 inch or 136 joules, whichever occurs first), where for all impact damage a non-visible small delaminations regions may occur below the damaged regions. Critical damage locations and events, and the associated damage scenarios are determined based on the specific structural detail considering stress levels and exposure to likely damage threats. 4 - In the section 7.1.2.8.2 Bonded Joints I propose the following improvements taken from FAA Transport Airplane Metallic and Composite Structure Working Group TAMCSWG - Bonding Structure final report, as follows: Attributes specific to bonded joint need to be taken into account in order to design efficient and durable bonded joints. The bonded joint design process typically involves the consideration of: • the adherends (geometry, size, materials, elastic behavior, coefficients of thermal expansion) • the adhesive (temperature dependent properties, non-linear behavior) • the magnitude and modes of loading • the curing temperature and operating environment • the potential modes of failure Bonded joints are generally designed to fail in the adherend rather than in the adhesive, in order to achieve maximum performance. Adhesion failures, which indicate the lack of chemical bonding between substrate and adhesive materials, are considered an unacceptable failure mode for any type of structure structure in all test types and under any design environment. Changes to qualified bonding systems (substrate, surface preparation, adhesive or processing) should be assessed for risk and validated by test as appropriate. Their design also aims to minimize/alleviate peel stresses, for example by tapering adherends, since the adhesive strength is lower in tension than in shear. Another goal of bonded joint design is to reduce peak stresses at joints ends and, to this end, stiffness imbalance between the adherends should be minimized.	Marco Villaron
Affirmative with Comment	Section 7.1.3.1 c) expand on final sentence by replacing (e.g., insulation systems) with (e.g. insulation, surface protection and/or drainage systems)	Mike O'Sullivan
Abstain		Jan Waleson
Affirmative with Comment	7.1.2.8.2 Bonded Joints: They can also be used to reduce peel stress at the ends *and/or at any other neutral axis shifts in bonded joints*. - It is not clear to me what the italized text means. Perhaps split the sentence in two and provide more details.	Ronald Krueger
Affirmative		Isaac Rusch
Affirmative		Baruch Bloch
Affirmative		Hai Wang
Affirmative		Jay Yeakle
Affirmative with Comment	Add Vibration to 7.1.2.7	Joe Spangler
Affirmative with Comment	Suggestion: connect 4th paragraph in page 8 with Category 1.	Richard Sarzi
Affirmative with Comment	Great job. Please consider only some comments: 7.1.2.7 bullet points: "*local strain levels and gradients*" instead of "*local strain gradients*" "*thermally induced loads*" instead of "*thermally induced load*" "*out of plane loads*" instead of "*out of plane load*" last paragraph: "*strain levels*" instead of "*stress levels*" 7.1.2.8.2 bullet points: Include moisture. A bonded joind design is also typically influenced if the joint is likely or not exposed to moisture or other fluids (it can impact in the adhesive selection, desing allowables, surf. prep. process, sealants, for instance)	Guilherme Garcia Momm
Affirmative		Larry Gintert
Affirmative		Jeff Standerfer
Affirmative	Important addition to the Handbook.	Rick Cole
Affirmative		Nathan Collins
Affirmative		David Motley
Affirmative with Comment	"It is important to consider that a composite material is composed of two main constituents, fiber and resin, of different strength, stiffness and ductility." recommend using modulus rather than stiffness. "Additional information on environmentally induced loads and their combination with mechanical loads may be found in chapter 12.3.3.6.1." Are residual stresses due to sub-ambient use of parts cured at 250F - 600F addressed in 12.3.3.6.1? "Attributes specific to bonded joint need...." joints, not joint. "Bonded joints are generally designed to fail in the adherend rather than in the adhesive, in order to achieve maximum performance." Is this discussion limited to composite adherends? Highly unlikely to be able to achieve failure in a metallic adherend. 7.1.2.13 Flammability. Should reference Vol 1, Section 6.6.18 Flammability and smoke generation? Should reference Vol 3, Section 3.4.10 Fire protection, flammability, and thermal issues? "Additionally, some systems (e.g., hydraulic systems) may expose the composite structure to contact with fluids such as oil. Those conditions need to be considered in the evaluation of the composite structure." Should reference other handbook sections that address fluid exposure.	Todd Bullions
Affirmative		John Tomblin
Affirmative with Comment	7.1.2.8.2 - can we add surface treatment / finish? Propose the following: the adherends (geometry, size, materials, elastic behavior, coefficients of thermal expansion, surface treatment / finish) 7.1.2.13 "In-flight fires initiated from ignition sources (e.g. electrical systems) and fuel hazard (e.g. flammable materials, liquids and vapors) are avoided to ensure passenger protection and allow for safe evacuation if necessary." This sentence doesn't quite make sense, as it doesnt imply how fires are avoided. I think a couple of words are missing from the sentence. 7.1.2.13 Final paragraph - should it mention that fire burnt composites should be inspected with the appropriate PPE, especially from a respiratory point of view?	David Groves
Affirmative with Comment	In Section 7.1.2.7 Strength, for the applicable aspect bulleted list please be clear as to which aspects are being addressed in the paragraphs that follow. Not all aspects listed are exbounded upon such as local strain gradients, out of plan load, environment, and competing failure modes. What is meant by 'competing failure modes' as it can be mis-interpreted if not clarifed. If an aspect listed is not going to be explained later, then leave it out of the list.	Lynn Bowman
Affirmative		Lamia Salah
Affirmative		Carol Meyers
Affirmative		Molly Stone
Affirmative with Comment	Typo in the last paragraph of section 7.1.2.6. "For related information on environmental and time-related considerations refer to Section 7.1.2.1." Should this be 7.1.2.2?	France Theriault (Bombardier)
Affirmative		Steven G. Russell
Abstain		DM Hoyt
Abstain		Stephan Botzki
Affirmative		Scott Finn
Affirmative		Tanila Faria
Affirmative with Comment	Chapter references should be verified. Access to the full V3 working draft at the TOC level at least will help in assessing some of these sections.	Paul Brey
Affirmative with Comment	7.1.2.13 at end of last paragraph - reference 14.10 section on incipient heat damage detection (14.10.2.3 in current draft).	Steve Starnes
Affirmative with Comment	7.1.2.7, 3rd para; Change "the most conservative combinations" to "a conservative combination" Probability of the event can be taken into account. 7.1.2.8.2; Please add a bullet for Bond Prep!	Allen Fawcett
Affirmative with Comment	we attached pdf	John Keune (Boeing)
Affirmative with Comment	7.1.3.1c says: "As for induced loads, this shall include as per a) consideration of system failure conditions." but this is in the "Induced Environmental Conditions" section, not the induced loads. The content immediately after seems correct for the section, but the intro sentence referenced seems incorrect.	Michael Hempowicz
Affirmative with Comment	Recommend expanding on "variability" in the bulleted list under 7.1.2.7. Variability of what?	Jodi Turnblade
Affirmative with Comment	7.1.2.8.2 - this sentence needs rewording for clarity "Mechanical fasteners can be used to allow limit load strength to be achieved with the bonded joint when it has failed between [illegible] design features [illegible]." 7.1.2.13 - This sentence needs to be reworded for clarity - "The combustion of polymer composites should ~~avoid leading to~~ not result in the rapid propagation of a fire or the generation of hazardous quantities of toxic by-products and smoke that could incapacitate passengers."	Lisa McHugh
Affirmative with Comment	7.1.2.8 last sentence "...Chapters 10 & 14 "?, 7.1.2.13 and 7.1.12 [illegible]	Dan Ruffner
Affirmative with Comment	In list at the beginning of §7.1.2, you could add in "the list is not intended to be exhaustive" "the static strength: it has after well described in 7.2.7 [illegible] 7.1.2.8.2 proposed to add a new bullet in list of consideration: surface preparation [illegible] 7.1.2.13 is relevant for FAR25/CS25 but there are no smoke and toxicity requirements for helicopter in the airworthiness regulations Part 27 and Part 29. COuld you highlight that this section is relevant for CS 25	LEON DUFOUR Jean Luc
Affirmative		Curtis Davies
Affirmative		Bob Zhou
Affirmative with Comment	Very well-written content relating to important areas of design criteria and constraint considerations. [illegible]	Larry Ilcewicz
Affirmative with Comment	Editorial: Section 7.1.2.7, last paragraph should be "The characteristics of isolated damage that ARE included in the ultimate..., not the characteristics of isolated damage that is included" [illegible] Section 7.1.2.8.2 would be clearer by regrouping bullet points to adhesion/adherends/adhesive process, and loading/failure modes per suggestion: "the adherends..." "the adhesive..." "the curing temperature and operating environment" "the magnitude and modes of loading" "the potential modes of failure"	Jennifer Galvin
Affirmative	Are there any plans for citations for the claims in these sections? [illegible]	Wayne Huberty
Affirmative with Comment	Section 7.1.2.13: Please revise for typographical errors (ex. Missing comma in the first sentence) and general readability.	Billy Cheng
Affirmative		Stefan Kloppenborg
Affirmative		John Moylan

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- **7.1.2.1 Laminate and other structural details**
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- 7.1.2.3 Manufacturing, incl. M&P specs + Mfg. plans
  - 7.1.2.3.1 Design for manufacturing, incl. inspection
  - 7.1.2.3.2 Design within costs
- 7.1.2.4 Inspection and Repair
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- 7.1.2.13 Flammability
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7.1.3 Other typical aerospace design constraints

- 7.1.3.1 Systems interface
- 7.1.3.2 Design options affecting costs and structural weight
- 7.1.3.3 Other design constraints essential to cost and weight trades

7.1.2 Typical Aerospace Composite Structural Design Requirements & Criteria

7.1.2.1 Laminate and other structural details

- Laminates can be tailored to better sustain the predominant loads
  - However, ply orientations and stacking sequence also need to be chosen to limit adverse effects resulting from lower transverse and interlaminar strengths
  - increased testing effort since it multiplies the possible layups, for analysis method validation
- minimize undesirable deformation coupling effects
- ply drop/additions
- layup also affects the performance of laminates in bolted joint areas
- Supportability in-service should also be kept in mind when selecting laminates, as insufficient thickness might not allow bolted repairs

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7.1.2 Typical Aerospace Composite Structural Design Requirements & Criteria

Electromagnetic Effects

- Electrical properties (e.g., paint thickness effects)
- Protection features
- Direct and indirect effects
- Industry standards (e.g., EUROCAE, SAE ARPs) and regulatory guidance
- Structural and economic considerations
- Electrostatic, HIRF, EMC and electric fault management – Brief discussion

7.1.2.14 Electromagnetic Effects (EME)

Electromagnetic effects (EME) typically refer to electromagnetic-based environmental and system considerations and their implications to aircraft functionality and performance. EME includes considerations related to lightning, electrostatics, high-intensity radiated fields (HIRF), and electromagnetic compatibility (EMC). It can be extended to the management of the electrical currents and voltages resulting from faults of the distribution networks. Design solutions that address EME typically involve elements of airframe design, system design, system installation, and/or electrical bonding and grounding processes.

In general, as related to EME it is important to recognize the influence of material electrical properties. As an example, the dielectric characteristics of painted aircraft surfaces (e.g., paint thickness), location and size of decals and other similar considerations may affect the electrical behavior of an aircraft and should be properly considered and assessed. Similarly, concerning fuel systems integral to the composite structure, specific protection features on the external composite surfaces, joints, fasteners, and structural supports for fuel system plumbing and components should be considered to eliminate penetration of electrical energy, arcing due to gaps, and sparks that could lead to ignition of the fuel source and/or vapors.

Since polymer composites are, for the most part, made with inherently highly resistive fibers (carbon) or non-conductive fibers (e.g. glass and aramid) embedded in a non-conductive polymer matrix, a lightning strike to composite structure can lead to damage due to an inability to avoid heat release in the material as a result of the high electrical currents and high resistive properties and to properly dissipate this heat because of reduced thermal properties compared to metal. For this reason, design features and lightning protection measures (e.g. metal wires, straps, meshes) that improve the structure's response to the effect of lightning (e.g. improve conductivity, prevent arcing) and static charge accumulation are incorporated. Lightning protection of structure should consider both the direct (e.g., heat and shock wave damage) and indirect effects (e.g., electromagnetic interference with aircraft systems) lightning strike on the aircraft.

As discussed in Section 12.5.2.7, there are a number of regulatory requirements that directly pertain to lightning. Guidance material includes, AC20-155A which provides guidance on aircraft lightning environment and test waveforms, aircraft lightning zoning, aircraft lightning test methods, and aircraft lightning direct effects; AC 20-53B provides guidance concerning fuel system lightning protection; and AC 20-136B provides guidance concerning protection of aircraft electrical and electronic systems from the effects of lightning.

Lightning zones are used to identify the likely locations where lightning will attach to the aircraft (i.e., determining the locations on the airframe where initial attachment is likely to occur, and the locations, external or internal, through which lightning currents flow between attachment points). An appropriate lightning environment is defined for each type of zone (i.e. understanding the lightning flash conditions expected in each lightning strike zone and the electrical currents that can be generated). A series of SAE Aerospace Recommended Practices (ARPs) and European Organization for Civil Aviation Equipment (EUROCAE) industry documents present detailed information on aircraft lightning environment and test waveforms, aircraft lightning zoning method, aircraft lightning test methods, and aircraft compliance methodologies for both lightning direct effects and indirect effects.

As it relates to the direct effects of lightning, both structural (damage tolerance) and economic (service and repair) considerations are taken into account. Lightning considerations may be necessary for secondary composite structure for economical reasons or when their damage can represent an indirect threat (e.g., engine cowls, where the effect of a strike could be detrimental to engine operation in the case of a puncture). It is typical industry practice to establish damage criteria and make use of lightning protection systems such that the induced damage on composite structure resulting from the direct effects of a lightning strike is enveloped by impact damage.

In the case of indirect effects of lightning, systems (e.g., power and electronic) that are susceptible to electromagnetic interference resulting from these events should be properly assessed and protected with means specific to system installation (e.g., cable routing, shielding) or specific to system equipment design (e.g., filtering, software processing).

The electrostatic threats of most significance to aircraft structural design are generally characterized as precipitation static (electrical charge deposition onto the surfaces of the aircraft) and refueling static (resulting from electrical charge being introduced during refueling operations). Precipitation static considerations include adequate conductivity and bonding processes, as well as the use of static dischargers; while refueling static considerations include proper electrical bonding as well as careful consideration of the use of dielectric materials, in addition to architectural and operational constraints imposed to the refueling system (e.g., use of diffusers, flow rate limitation).

The remaining EME considerations (i.e., HIRF, EMC and electrical fault management) are primarily system focused where the primary role the structure plays in protection for these environments and threats is in providing some level of electromagnetic shielding, and providing an electrical current return or ground path for equipment and system referencing.

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  - **7.1.3.3 Other design constraints essential to Cost and weight trades**

Other typical aerospace design constraints

Intended to be introductory material

- **7.1.3.1 Systems interface**
  - Systems effect on structure/Structure effect on systems
  - Integrated product development
  - System failure conditions
  - Induced loads
  - Induced environmental conditions
  - Induced damage threat
  - Induced design requirements

- **7.1.3.2 Design options affecting costs and structural weight**
  - Structural Architecture
  - Producibility and Performance
  - Build Plan Requirements
  - Robustness Requirements
  - Total Life Cycle Cost

- **7.1.3.3 Other design constraints essential to cost and weight trades**
  - Product Family Strategy
  - Production Rate Requirements
  - Technology and Manufacturing Readiness
  - Supply Chain Considerations
  - Scaling

7.2 Overview of Structural Design Process

7.2 Structural Design Process

- **7.2.1 Five Phases of Design**
- **7.2.2 Technology Development and Product Implementation**
  - **7.2.2.1 Product life cycle costs and customer value**
  - **7.2.2.2 Practical size and product scaling issues**
  - **7.2.2.3 Success criteria**
  - **7.2.2.4 Differences for aircraft product types**

Yellow Page (YP) review

- Section 7.2.2 through 7.2.2.4 (30 pages)
- 2 Most Recent Yellow Page Cycles
  (2021 YP3 and 2022 YP2, Most of Section 7.2- 7.2.2.4)

Section 7.2 (last two Yellow Page Cycles)

- Total Votes – 83
- Affirmative – 43
- Affirmative with Comment – 20
- Negative with Comment – 0
- Abstain – 20

Table 7.2.2.3.2(a) Success Criteria for Structural Design and Substantiation

CMH-17 COMPOSITE MATERIALS HANDBOOK

Design Phase/ Development Stage	Feasibility/ Initial Concept	Inception/ Concept Development	Concept/ Full-Scale Development
Deliverable		*Representative Development Application*	
Integrate efforts of all functional areas with product schedules	Assemble draft schedules, integrating representative development tasks	Gain team acceptance of schedule details (continuously update as conceptual development proceeds in each functional area)	Complete functional tasks to a level of technology readiness (all functional areas for product definition)
Define loads, environmental conditions and other service considerations	Initial loads & environmental assessments for product range/usage limits and any special application needs	Update internal loads and environmental exposures with early design advances, while further identifying special needs	Final internal loads and environmental exposure limits from full scale assessments of representative design
Design requirements, criteria and other constraints applied in design definition	Draft design requirements, criteria and constraints for representative design development efforts	Advance design requirements, criteria and constraints based on analysis/tests/trials for related functional developments	Draft document for product design requirements & objectives and related design criteria, guidelines & constraints for structural manuals
Design definition and manuals (electronic drawings, build notes, maintenance instructions)	Document trade studies, selected concepts (structural configurations, materials & processes) and related needs.	Detailed design to further advance program objectives (cost/weight savings and refine development plans from results)	Update detailed design, from size & product scaling results (e.g., manufacturing trials and large-scale structural tests/analyses)
Structural analysis methods, sizing and margins of safety documentation	Identify sizing methods (existing & additional needs) and supporting input data for representative design detail	Support conceptual design trades with structural sizing & integrated manufacturing trials, yielding measurements & tests/	Draft structural sizing methods that yield repeatable and reliable results as demonstrated by large scale, as-manufactured structure
Design data development (material properties, design values and structural assessments)	Identify structural data to support scaled design detail developments (integrated with manufacturing & maintenance)	Refine design data needs as appropriate to cover the design space (based on cost/weight trades & scaled structural results)	Update design analyses and supporting data needs (based on full scale development results and refined product value assessments)
Customer and partner interfaces (including technical SOW for contracts and other relations, coordinated with both procurement and legal groups)	Identify special customer needs and design/build relationships essential for integrated representative product development	Ensure sufficient knowledge transfer of early design efforts with customers and suppliers essential to product value and total cost assessments	Share updated representative full scale design deliverables within customers & partners as appropriate for different parts of the aircraft where such knowledge is needed
Systems interface and other flight safety issues (e.g., crashworthiness, fire safety, lightning strike protection & aging)	Identify systems interface and flight safety issues with an influence on structural design and substantiation to start planning related efforts	Support conceptual design and substantiation plans needed to ensure inclusion in design and start supporting assessments per substantiation plans	Support full scale representative design development and substantiation needed to proceed with product development and draft initial certification plans
Structural substantiation & certification documents, for other considerations (e.g., composite fuel tank safety not previously addressed)	Outline substantiation plans, incl. representative design detail data (integrate efforts for structures, manufacturing, maintenance & other areas)	Update conceptual design based on early data, identifying details affecting product value and related cost centers. Update substantiation plans.	Update full scale design based on representative data, further refining details affecting product value and related cost centers. Draft related certification plans.
Instructions for continued airworthiness	Identify factors requiring regular service & preventive maintenance. Study aging to establish retirement criteria.	Plans for data and assessments to draft instructions and criteria for continued airworthiness.	Draft initial instructions for continued airworthiness (screening data on aging for selected materials, processes and degradation modes)

Success Criteria for structural design and substantiation during the first three stages of representative development leading to product readiness.

Table 7.2.2.3.1 Success Criteria for Product Value and Cost Assessments

CMH-17 COMPOSITE MATERIALS HANDBOOK

Other Product Type Success Criteria?

← Key Time Period to Consider Prototyping →

Design Phase/ Development Stage	Feasibility/ Initial Concept	Inception/ Concept Development	Concept/ Full-Scale Development
Deliverable		***Representative Development Application***	
Total cost evaluation and product value assessment	Initial concepts have potential to meet product value goals	Representative design advanced with product goals still met after detailed updates	Product value goals verified with representative design detail and large scale manufacturing data
Nonrecurring manufacturing cost estimates	Initial estimates compiled. Manufacturing partner and supplier needs identified.	Updated estimates compiled. Manufacturing partner, supplier and related contracts drafted.	Firm nonrecurring costs confirmed within allowances to execute equipment/tooling/facility purchase
Manufacturing cost data tied to Fab/Assy. Trials and factory simulations	Available manufacturing cost data compiled and future plans established	Manufacturing cost data updated per design detail inputs & enhanced factory cell models	Manufacturing cost data continues to ensure product value estimates per representative design trades.
Design cost estimating methods calibrated within design constraints	General relationships of design and manufacturing costs identified & plans set	Initial models developed for realistic design detail and early trials calibrated within constraint	Design cost models updated for proven design detail & mfg. trials, associated constraints established
Product performance cost metrics (fuel costs, range, speed, special options)	Promising product benefits identified and initial plans to evaluate questionable areas	Product benefits updated with design, Structural/Aero/Mfg. data & initial scaling efforts	Product value confirmed with all necessary functional technologies at full-scale readiness levels
Customer maintenance cost estimates (nonrecurring and recurring)	Initial estimates compiled. Maintenance partner and supplier needs identified.	Launch candidate customers approve full maintenance cost estimates as accurate.	Maintenance technology accepted as meeting customer maintenance needs and total cost allowances
Actual cost accounting updated vs. allowances at each development stage	Initial allowances for the first three development stages/ design phases estimated.	Total costs updated and remain acceptable to yield product value accepted by customers.	Total costs updated per full-scale data of a representative design to proceed with customer contracts.

Success criteria for product value and cost assessments of a representative design during the first three stages of development leading to product readiness.

Table 7.2.2.3.2(a) Success Criteria for Structural Design and Substantiation

Stop

Design Phase/Development Stage	Concept/Full-Scale Development
Deliverable	**Product Readiness Gate ↓**
Integrate efforts of all functional areas with product schedules	Complete functional tasks to a level of technology readiness as applied to product (all functional areas for product definition)
Define loads, environmental conditions and other service considerations	Final internal loads and environmental exposure limits from full scale assessments of representative design
Design requirements, criteria and other constraints applied in design definition	Draft document for product design requirements & objectives and related design criteria, guidelines & constraints for structural manuals
Design definition and manuals (electronic drawings, build notes, maintenance instructions)	Update detailed design, from size & product scaling results (e.g., manufacturing trials and large-scale structural tests/analyses)
Structural analysis methods, sizing and margins of safety documentation	Draft structural sizing methods that yield repeatable and reliable results as demonstrated by large scale, as-manufactured structure
Design data development (material properties, design values and structural assessments)	Update design analyses and supporting data needs (based on full scale development results and refined product value assessments)
Customer and partner interfaces (including technical SOW for contracts and other relations, coordinated with both procurement and legal groups)	Share updated representative full scale design deliverables within customers & partners as appropriate for different parts of the aircraft where such knowledge is needed
Systems interface and other flight safety issues (e.g., crashworthiness, fire safety, lightning strike protection & aging)	Support full scale representative design development and substantiation needed to proceed with product development and draft initial certification plans
Structural substantiation & certification documents, for other considerations (e.g., composite fuel tank safety not previously addressed)	Update full scale design based on representative data, further refining details affecting product value and related cost centers. Draft related certification plans.
Instructions for continued airworthiness	Draft initial instructions for continued airworthiness (screening data on aging for selected materials, processes and degradation modes)

Success Criteria for structural design and substantiation during the third stage of representative development leading to product readiness.

Consolidation of Revision H Content (7.1.X)

7.1 Overview of Unique Issues Associated with Composite Structural Design

- 7.1.1 Design Requirements, Criteria and Constraints
  - 7.1.1.1 Definition of terms
  - 7.1.1.2 Purpose and justification
- 7.1.2 Typical Aerospace Composite Structural Design Requirements and Criteria
  - 7.1.2.1 Laminate and other structural details
  - 7.1.2.2 Environmental and other time-related effects
  - 7.1.2.3 Manufacturing, incl. M&P specs + Mfg. plans
    - 7.1.2.3.1 Design for manufacturing, incl. inspection
    - 7.1.2.3.2 Design within costs
  - 7.1.2.4 Inspection and Repair
    - 7.1.2.4.1 Design for inspection and repair
    - 7.1.2.4.2 Design of repairs
  - 7.1.2.5 Handling and storage
  - 7.1.2.6 Stiffness and stability
  - 7.1.2.7 Strength
  - 7.1.2.8 Bolted & bonded joints
  - 7.1.2.9 Durability & Damage Resistance
  - 7.1.2.10 Damage tolerance
  - 7.1.2.11 Aero-elastic considerations (flutter, instabilities)
  - 7.1.2.12 Crashworthiness
  - 7.1.2.13 Flammability
  - 7.1.2.14 Conductivity, EMI shielding and lightning strike protection
- 7.1.3 Other typical aerospace design constraints
  - 7.1.3.1 Systems interface
  - 7.1.3.2 Design options affecting costs and structural weight
  - 7.1.3.3 Other design constraints essential to cost and weight trades

Emilie Morteau
Isabelle Paris
Eric Stenne
Eric Pomerlau
Alain Douchant
Michael Rush
Melanie Herman
Jean-Luc Leon-Dufour
Larry Ilcewicz
Patrick Enjuto

Yellow Page Results

Yellow Page (YP) review

- Exceptional engagement from CMH-17 community in review process is a testament to the design team's work
- 3 Yellow Page Cycles

Section 7.1

- Total Votes – 153
- Affirmative – 79
- Affirmative with Comment – 50
- Negative with Comment – 1
- Abstain – 23

Comment Categories

- Editorial
- Reorganization of Content
- Brief Content Expansion

Volume 3, Section 7.1

Vote	Comments	CMH-17 Member
Affirmative with Comment	7.1.2.7 - add "For additional information on composite stress analysis refer to volume 3 chapters 8 and 9" or similar. 7.1.3 -the majority of this discussion is not unique to composites. Consider adding the caveat "... while not unique to composites..." in certain places.	Carl Rousseau
Affirmative		Steve Ward
Affirmative		Jason Gibson
Affirmative with Comment	[illegible]	Marco Villaron
Affirmative with Comment	Section 7.1.3.1 c) expand on final sentence by replacing (e.g. insulation systems) with (e.g. insulation, surface protection and/or drainage systems)	Mike O'Sullivan
Abstain		Ian Waleson
Affirmative with Comment	7.1.2.8.2 Bonded Joints: They can also be used to reduce peel stress at the ends *and/or at any other neutral axis shifts in bonded joints*. - It is not clear to me what the italized text means. Perhaps split the sentence in two and provide more details.	Ronald Krueger
Affirmative		Isaac Rusch
Affirmative		Baruch Bloch
Affirmative		Hai Wang
Affirmative		Jay Yeakle
Affirmative with Comment	Add Vibration to 7.3.2.7	Joe Spangler
Affirmative with Comment	Suggestion: connect 4th paragraph in page 8 with Category 1.	Richard Sarz
Affirmative with Comment	Great job. Please consider only some comments: 7.1.2.7 bullet points: "*local strain levels and gradients*" instead of "*local strain gradients*" "*thermally induced loads*" instead of "*thermally induced load*" "*out of plane loads*" instead of "*out of plane load*" last paragraph: "*strain levels*" instead of "*stress levels*" 7.1.2.8.2 bullet points: Include moisture. A bonded joint design is also typically influenced if the joint is likely or not exposed to moisture or other fluids (it can impact in the adhesive selection, design allowables, surf. prep process, sealants, for instance)	Guilherme Garcia Momm
Affirmative		Larry Gintert
Affirmative		Jeff Standerfer
Affirmative	Important addition to the Handbook.	Rick Cole
Affirmative		Nathan Collins
Affirmative		David Motley
Affirmative with Comment	"It is important to consider that a composite material is composed of two main constituents, fiber and resin, of different strength, stiffness and ductility." recommend using modulus rather than stiffness. "Additional information on environmentally induced loads and their combination with mechanical loads may be found in chapter 12.3.3.6.1" Are residual stresses due to sub-ambient use of parts cured at 250F - 600F addressed in 12.3.3.6.1? "Attributes specific to bonded joint need..." joints, not joint. "Bonded joints are generally designed to fail in the adherend rather than in the adhesive, in order to achieve maximum performance." Is this discussion limited to composite adherends? Highly unlikely to be able to achieve failure in a metallic adherend. 7.1.2.13 Flammability. Should reference Vol 1, Section 6.6.18 Flammability and smoke generation? Should reference Vol3, Section 3.4.10 Fire protection, Flammability, and thermal issues? "Additionally, some systems (e.g., hydraulic systems) may expose the composite structure to contact with fluids such as oil. These conditions need to be considered in the evaluation of the composite structure." Should reference other handbook sections that address fluid exposure.	Todd Bullions
Affirmative		John Tomblin
Affirmative with Comment	7.1.2.8.2 - can we add surface treatment / finish? Propose the following: the adherends (geometry, size, materials, elastic behavior, coefficients of thermal expansion, surface treatment / finish) 7.1.2.13 "In-flight fires initiated from ignition sources (e.g. electrical systems) and fuel hazard (e.g. flammable materials, liquids and vapors) are avoided to ensure passenger protection and allow for safe evacuation if necessary." This sentence doesn't quite make sense, as it doesn't imply how fires are avoided. I think a couple of words are missing from the sentence. 7.1.2.13 Final paragraph - should it mention that fire burnt composites should be inspected with the appropriate PPE, especially from a respiratory point of view?	David Groves
Affirmative with Comment	In Section 7.1.2.7 Strength, for the applicable aspect bulleted list please be clear as to which aspects are being addressed in the paragraphs that follow. Not all aspects listed are expounded upon such as local strain gradients, out of plane load, environment, and competing failure modes. What is meant by 'competing failure modes' as it can be mis-interpreted if not clarified. If an aspect listed is not going to be explained later, then leave it out of the list.	Lynn Bowman
Affirmative		Lamia Salah
Affirmative		Carol Meyers
Affirmative		Molly Stone
Affirmative with Comment	Typo in the last paragraph of section 7.1.2.6. "For related information on environmental and time-related considerations refer to Section 7.1.2.1." Should this be 7.1.2.2?	France Theriault (Bombardier)
Affirmative		Steven G. Russell
Abstain		DM Hoyt
Abstain		Stephan Botzki
Affirmative		Scott Finn
Affirmative		Tanila Faria
Affirmative with Comment	Chapter references should be verified. Access to the full V3 working draft at the TOC level at least will help in assessing some of these sections.	Paul Brey
Affirmative with Comment	7.1.2.13 at end of last paragraph - reference 14.10 section on incipient heat damage detection (14.10.2.3 in current draft)	Steve Starnes
Affirmative with Comment	7.1.2.7, 3rd para; Change "the most conservative combinations" to "a conservative combination" Probability of the event can be taken into account. 7.1.2.8.2; Please add a bullet for Bond Prep!	Allen Fawcett
Affirmative with Comment	see attached pdf	John Keune (Boeing)
Affirmative with Comment	7.1.3.1.c says: "As for induced loads, this shall include as per a) consideration of system failure conditions." but this is in the "Induced Environmental Conditions" section, not the induced loads. The content immediately after seems correct for the section, but the intro sentence referenced seems incorrect.	Michael Hempowicz
Affirmative with Comment	Recommend expanding on "variability" in the bulleted list under 7.1.2.7. Variability of what?	Jodi Turnblade
Affirmative with Comment	7.1.2.8.2 - this sentence needs rewording for clarity "Mechanical fasteners can be used to allow limit load strength to be achieved with the bonded joint when it has failed between crack arresting design features (in the repair or base structure)." 7.1.2.13 - This sentence needs to be reworded for clarity – "The combustion of polymer composites should ~~avoid leading to~~ not result in the rapid propagation of a fire or the generation of hazardous quantities of toxic by-products and smoke that could incapacitate passengers."	Lisa McHugh
Affirmative with Comment	7.1.2.8.2 last sentence "... Chapters 10 & 14."?, 7.1.2.13 and 7.1.3.1 d) and e) sb "...e.g., ..."?,	Dan Ruffner
Affirmative with Comment	In list at the beginning of §7.1.2, you could add in "the list is not intended to be exhaustive:" the static strength : it has after well described in 7.2.7,. 7.1.2.8.2 proposed to add a new bullet in list of consideration : surface preparation : it is a key point for bonding, with a particular attention with validation of combination between, adherend, adhesive, surface preparation and manufacturing process 7.1.2.13 is relevant for FAR25(CS25" but there are no smoke and toxicity- requirements for helicopters in the airworthiness regulations Part 27 and Part 29. COUld you highlight that this section is relevant for CS 25	LEON DUFOUR Jean Luc
Affirmative		Curtis Davies
Affirmative		Bob Zhou
Affirmative with Comment	Very well-written content relating to important areas of design criteria and constraint considerations. The other section references with details are evident. The systems interface section really helps to realize that many of the necessary design criteria and constraints directly relate to structural design detail in the interface with numerous aircraft systems, which cannot be ignored in efficient design development.	Larry Ilcewicz
Affirmative with Comment	Editorial: Section 7.1.2.7, last paragraph should be "The characteristics of isolated damage that ARE included in the ultimate...., not the characteristics of isolated damage that is included.Editorial: Section 7.1.2.8.2 would be clearer by regrouping bullet points to adhesion/adherends/adhesion process, and loading/failure modes per suggestion:* the adhereends...* the adhesive.....* the curing temperature and operating environment* the mganitude and modes of loading *the potential modes of failure	Jennifer Galvin
Affirmative	Are there any plans for citations for the claims in these sections? I think it would be awesome if claim X had a citation so we could go see the data. I believe the claims herein but "trust but verify".	Wayne Huberty
Affirmative with Comment	Section 7.1.2.13: Please revise for typographical errors (ex. Missing comma in the first sentence) and general readability.	Billy Cheng
Affirmative		Stefan Kloppenborg
Affirmative		John Moylan

Revision H Content (7.1.X)

CMH-17 Member	DM Hoyt
Vote	Affirmative with Comment
Comment	Thank you for addressing many of my previous comments. In 7.1.1.2, please consider changing the term "inception phase" to "conceptual design phase" (assuming that's what it refers to?). Or at least explain what it is. Standard phases for aircraft design are "conceptual design", "preliminary design", and "detailed design". If we are going to use different terms I think they should be introduced and defined relative to the standard phases to avoid confusion.
Action	Adopted

reasonable return on investment. Thus, justification of the design requirements, criteria and constraints lies in the need for delineating a design space which will allow for the product to meet design objectives -safety, operational reliability, operating costs, and operating sustainability ~~(without neglecting the life cycle "green" goal, which can be another field of competition with metallic designs)~~- at an acceptable price to the customer, ~~while ensuring reasonable economic benefit and~~ with adequate industrial return to the manufacturer. These objectives, which are further discussed at the start of Section 7.2, arise early in product development.~~during the inception phase and should encompass the product value to be delivered~~

Revision H Content (7.1.X)

CMH-17 Member	Marco Villaron
Vote	Affirmative with Comment
Comment	8- In the section 7.1.2.3 Manufacturing, Including Material & Process Specifications and Manufacturing Plan, 3rd paragraph. In accordance with AC 20-107B1 the categorization is about damage and not to defect and so, the correct wording should be, as follows: In order to minimize recurrent non-conformances and possible associated design changes, it is prudent to design robust structures with Category 1 defect assumptions that envelope common manufacturing defects and place those allowances in the associated process specifications.
Action	Adopted

~~In order t~~To minimize recurrent non-conformances and possible associated design changes, it is prudent to design robust structures with Category 1 defect assumptions that envelope common manufacturing defects and place those allowances in the associated process specifications (categories of damage are defined in Chapter 12, and as well in AC20-107B and AMC20-29). It is good practice to target Structural Repair Manual (SRM) Allowable Damage Limits (ADLs) of a size large enough to ensure high robustness with respect to the most common threats as well as to ease requirements on the level of performance of the NDI methods (e.g., damage sizes that can be found with general visual inspection rather than detailed visual or ultrasound inspection). The design should aim to be inspectable by the simplest methods possible; joint and sub-structure complexity and difficult access locations can result in more challenging inspectability.

Revision H Content (7.1.X)

CMH-17 Member	Cindy Ashforth
Vote	Affirmative with Comment
Comment	7.1.2.3 I don't think we need this sentence. All materials and processes need to be controlled by well-documented material and process specifications (See Chapter 6).
Action	Adopted

manufacturing process ~~envisioned for the product~~. Furthermore, there are cost and risk advantages ~~for the design and its associated processes~~ to building on the manufacturing reliability and consistency capability ~~built~~ developed by the company over past production and development projects. Similar considerations are applicable to material selection, where there are cost and risk advantages to ~~the use of~~using materials covered by existing material specifications ~~within the company~~ or ~~evolutions of these in regard to~~selecting new or modified material and process specifications. For example, there is less risk in selecting and slitting an existing approved prepreg for AFP (~~Advanced~~ Automatic Fiber Placement) than using an all-new material. ~~All materials and processes need to be controlled by well-documented material and process specifications (See Chapter 6).~~

Revision H Content (7.1.X)

CMH-17 Member	Cindy Ashforth
Vote	Affirmative with Comment
Comment	7.1.2.2 The list below does not look like “requirement and constraints” to me. The list needs to be concise. For example, the first bullet item is “Operating Environment” the second “Hygrothermal cycling” etc. The extended discussions don’t really seem appropriate for a list.
Action	Adopted

- ~~Environmental conditions are determined based on the flight profile, configuration of the structure and its location (taking into account system installation that may be a source of heat) in nominal and extreme conditions. This evaluation should include cycling consideration.~~
- ~~Consideration is given to the potential effects of hygrothermal cycling and freeze-thaw cycling (see Volume 1, Section 6.6.15 and Volume 3, Section 12.6).~~
- ~~Materials are selected such that the maximum operating temperatures are sufficiently below the material's wet glass transition temperature (Tg) to ensure that material properties and structural performance are not significantly degraded by exposure to maximum operating environments (temperature and moisture content).~~
- ~~Materials are selected ensuring their compatibility with the fluids that may come in contact with the composite parts.~~
- ~~The effect of defined operating environments (e.g. max temperature, max moisture content, thermal cycling, exposure to fluids) on structural strength are determined and evaluated for static strength and fatigue strength (when relevant), often leading to the development of design requirements and criteria applied for test simulation and structural substantiation purposes.~~
- ~~When protective systems are used to prevent damage or deterioration (e.g. paint system, glass fiber), the short-term and long-term environmental effects on the protective system need also to be determined and they should be sufficiently durable to provide protection between major maintenance intervals consistent with the inspection technique and intervals. Specific success criteria are often defined and applied to candidate protective systems, including details for processing (e.g., paint thickness, which is a well-known variable affecting cracking in service).~~
- ~~Sandwich design should avoid fluid ingression into the core.~~
- ~~Joints between parts which are galvanically incompatible should be designed to avoid galvanic corrosion problems (e.g. fiberglass interface ply).~~
- ~~Inspections may be defined based on the susceptibility to environmental exposure and based on the sensitivity to damage/deterioration from environmental exposure (see Section 12.4).~~

The environment that a composite is exposed to in service is an important parameter to be accounted for during the design as it may affect the performance of the structure. Environmental conditions are determined based on the flight profile, configuration of the structure and its location (taking into account system installation that may be a source of heat) in nominal and extreme conditions. This evaluation should include cycling consideration.

For polymer composite, the main environmental considerations ~~which~~ that affect material and structural properties are the temperature and the moisture (see Section 2.2.4). Thermoset ~~M~~materials are selected such that the maximum operating temperatures are sufficiently below the material's wet glass transition temperature (Tg) to ensure that material properties and structural performance are not significantly degraded by exposure to maximum operating environments (temperature and moisture content), and to avoid time-dependent changes in the internal stress states that could affect failure mode and strength (see Section 12.6).

However, ~~some~~ others like UV exposure, or exposure to hydraulic, fuel, cleaning and de-icing fluids also need to be considered, but in most cases are shown to be less critical~~in many cases to show it is not as critical as other exposures that control design~~. In particular, ~~M~~materials are selected ensuring their compatibility with the fluids that may ~~come in~~ contact ~~with~~ the composite parts.

For sandwich construction, fluid ingress (e.g. water from air humidity, fuel, oil) can impact critical properties such as stiffness, mass, and damping for aero-elastic stability of the airplane. Sandwich design should use design details shown by experience to be resistant to fluid ingression (e.g., panel edge ramp down) (see Volume 6 for additional detail on the subject). Also, potential effects of hygrothermal cycling and freeze-thaw cycling (see Volume 1, Section 6.6.15 and Volume 3, Section 12.6) are considered. A large portion of the interior structure is sandwich construction with specific considerations.

The effect of defined operating environments (e.g. max temperature, max moisture content, thermal cycling, exposure to fluids) on structural strength are determined and evaluated for static strength and fatigue strength (when relevant), often leading to the development of design requirements and criteria applied for test simulation and structural substantiation purposes.

When protective systems are used to prevent damage or deterioration (e.g. paint system, glass fiber), the short-term and long-term environmental effects on the protective system need also to be determined and they should be sufficiently durable to provide protection between major maintenance intervals consistent with the inspection technique and intervals. Specific success criteria are often defined and applied to candidate protective systems, including details for processing (e.g., paint thickness, which is a well-known variable affecting cracking in service).

Revision H Content (7.1.X)

- ~~Environmental conditions are determined based on the flight profile, configuration of the structure and its location (taking into account system installation that may be a source of heat) in nominal and extreme conditions. This evaluation should include cycling consideration.~~
- ~~Consideration is given to the potential e~~ ~~cycling (see Volume 1, Section 6.6.15 a~~
- ~~Materials are selected such that the max~~ ~~below the material's wet glass transition~~ ~~properties and structural performance ar~~ ~~maximum operating environments (tem~~
- ~~Materials are selected ensuring their co~~ ~~contact with the composite parts.~~
- ~~The effect of defined operating environments (e.g. max temperature, max moisture content, thermal cycling, exposure to fluids) on structural strength are determined and evaluated for static strength and fatigue strength (when relevant), often leading to the development of design requirements and criteria applied for test simulation and structural substantiation purposes.~~
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- ~~Sandwich design should avoid fluid ingression into the core.~~
- ~~Joints between parts which are galvanically incompatible should be designed to avoid galvanic corrosion problems (e.g. fiberglass interface ply).~~
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Revision H Content (7.1.X)

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- ~~Materials are selected ensuring their c~~ ~~contact with the composite parts.~~
- ~~The effect of defined operating enviro~~ ~~content, thermal cycling, exposure to~~ ~~evaluated for static strength and fatigu~~ ~~development of design requirements a~~ ~~substantiation purposes.~~
- ~~When protective systems are used to p~~ ~~glass fiber), the short-term and long-te~~ ~~need also to be determined and they s~~ ~~between major maintenance intervals consistent with the inspection technique and intervals. Specific success criteria are often defined and applied to candidate protective systems, including details for processing (e.g., paint thickness, which is a well-known variable affecting cracking in service).~~
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Revision H Content (7.1.X)

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For polymer composite, the main environmental considerations ~~which~~ that affect material and structural properties are the temperature and the moisture (see Section 2.2.4). Thermoset ~~M~~materials are selected such that the maximum operating temperatures are sufficiently below the material's wet glass transition temperature (Tg) to ensure that material properties and structural performance are not significantly degraded by exposure to maximum operating environments (temperature and moisture content), and to avoid time-dependent changes in the internal stress states that could affect failure mode and strength (see Section 12.6).

Revision H Content (7.1.X)

- ~~Environmental conditions are determined based on the flight profile, configuration of the structure and its location (taking into account system installation that may be a source of heat) in nominal and extreme conditions. This evaluation should include cycling consideration.~~
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However, ~~some~~ others like UV exposure, or exposure to hydraulic, fuel, cleaning and de-icing fluids also need to be considered, but in most cases are shown to be less critical~~in many cases to show it is not as critical as other exposures that control design~~. In particular, ~~M~~materials are selected ensuring their compatibility with the fluids that may ~~come in~~ contact ~~with~~ the composite parts.

Revision H Content (7.1.X)

- ~~Environmental conditions are determined based on the flight profile, configuration of the structure and its location (taking into ac~~
~~heat) in nominal and extreme condition~~
~~consideration.~~
- ~~Consideration is given to the potential e~~
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~~below the material's wet glass transition~~
~~properties and structural performance a~~
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- ~~Sandwich design should avoid fluid ingression into the core.~~
- ~~Joints between parts which are galvanically incompatible should be designed to avoid galvanic corrosion problems (e.g. fiberglass interface ply).~~
- ~~Inspections may be defined based on the susceptibility to environmental exposure and based on the sensitivity to damage/deterioration from environmental exposure (see Section 12.4).~~

The effect of defined operating environments (e.g. max temperature, max moisture content, thermal cycling, exposure to fluids) on structural strength are determined and evaluated for static strength and fatigue strength (when relevant), often leading to the development of design requirements and criteria applied for test simulation and structural substantiation purposes.

Revision H Content (7.1.X)

<u>When protective systems are used to prevent damage or deterioration (e.g. paint system, glass fiber), the short-term and long-term environmental effects on the protective system need also to be determined and they should be sufficiently durable to provide protection between major maintenance intervals consistent with the inspection technique and intervals. Specific success criteria are often defined and applied to candidate protective systems, including details for processing (e.g., paint thickness, which is a well-known variable affecting cracking in service).</u>

- ~~Environmental conditions are determined based on the flight profile, configuration of the structure and its location (takir~~
  ~~heat) in nominal and extreme c~~
  ~~consideration.~~
- ~~Consideration is given to the p~~
  ~~cycling (see Volume 1, Sectior~~
- ~~Materials are selected such tha~~
  ~~below the material's wet glass~~
  ~~properties and structural perfo~~
  ~~maximum operating environm~~
- ~~Materials are selected ensuring~~
  ~~contact with the composite parts.~~
- ~~The effect of defined operating environments (e.g. max temperature, max moisture content, thermal cycling, exposure to fluids) on structural strength are determined and evaluated for static strength and fatigue strength (when relevant), often leading to the development of design requirements and criteria applied for test simulation and structural substantiation purposes.~~
- ~~When protective systems are used to prevent damage or deterioration (e.g. paint system, glass fiber), the short-term and long-term environmental effects on the protective system need also to be determined and they should be sufficiently durable to provide protection between major maintenance intervals consistent with the inspection technique and intervals. Specific success criteria are often defined and applied to candidate protective systems, including details for processing (e.g., paint thickness, which is a well-known variable affecting cracking in service).~~
- ~~Sandwich design should avoid fluid ingression into the core.~~
- ~~Joints between parts which are galvanically incompatible should be designed to avoid galvanic corrosion problems (e.g. fiberglass interface ply).~~
- ~~Inspections may be defined based on the susceptibility to environmental exposure and based on the sensitivity to damage/deterioration from environmental exposure (see Section 12.4).~~

Revision H Content (7.1.X)

- ~~Environmental conditions are determined based on the flight profile, configuration of the structure and its location (taking into account system installation that may be a source of heat) in nominal and extreme conditions. This evaluation should include cycling consideration.~~
- ~~Consideration is given to the potential effects of hygrothermal cycling and freeze-thaw cycling (see Volume 1, Section~~
- ~~Materials are selected such that~~ ~~below the material's wet glass t~~ ~~properties and structural perfor~~ ~~maximum operating environme~~
- ~~Materials are selected ensuring their compatibility with the fluids that may come in contact with the composite parts.~~
- ~~The effect of defined operating environments (e.g. max temperature, max moisture content, thermal cycling, exposure to fluids) on structural strength are determined and evaluated for static strength and fatigue strength (when relevant), often leading to the development of design requirements and criteria applied for test simulation and structural substantiation purposes.~~
- ~~When protective systems are used to prevent damage or deterioration (e.g. paint system, glass fiber), the short-term and long-term environmental effects on the protective system need also to be determined and they should be sufficiently durable to provide protection between major maintenance intervals consistent with the inspection technique and intervals. Specific success criteria are often defined and applied to candidate protective systems, including details for processing (e.g., paint thickness, which is a well-known variable affecting cracking in service).~~
- ~~Sandwich design should avoid fluid ingression into the core.~~
- ~~Joints between parts which are galvanically incompatible should be designed to avoid galvanic corrosion problems (e.g. fiberglass interface ply).~~
- ~~Inspections may be defined based on the susceptibility to environmental exposure and based on the sensitivity to damage/deterioration from environmental exposure (see Section 12.4).~~

Inspections may be defined based on the susceptibility to environmental exposure and ~~based on~~ the sensitivity to damage/deterioration from environmental exposure (see Section 12.4).

Revision H Content (7.1.X)

CMH-17 Member	Guilherme Garcia Momm
Vote	Affirmative with Comment
Comment	7.1.2.8.2 bullet points: Include moisture. A bonded joind design is also typically influenced if the joint is likely or not exposed to moisture or other fluids (it can impact in the adhesive selection, design allowables, ***surf. prep. process***, sealants, for instance)
Action	Adopted

CMH-17 Member	Allen Fawcett
Vote	Affirmative with Comment
Comment	7.1.2.8.2; Please add a bullet for ***Bond Prep***!
Action	Adopted

CMH-17 Member	LEON-DUFOUR Jean-Luc
Vote	Affirmative with Comment
Comment	7.1.2.8.2 proposed to add a new bullet in list of consideration : ***surface preparation*** : it is a key point for bonding, with a particular attention with validation of combination between, adherend, adhesive, surface preparation and manufacturing process
Action	Adopted

Revision H Content (7.1.X)

7.1.2.8.2 Bonded Joints

Unique ~~Attributes specific to~~ bonded joint attributes need to be ~~taken into account~~considered in order to design efficient and durable bonded joints. The bonded joint design process typically involves the consideration of:

- the adherends (geometry, size, materials, elastic behavior, coefficients of thermal expansion, surface treatment / finish)
- the adhesive (temperature dependent properties, non-linear behavior)
- bond preparation, process (e.g., surface preparation) and adhesion compatibility within the bond system, see Chapter 5
- the magnitude and modes of loading
- the curing temperature and operating environment (e.g., moisture)
- the potential modes of failure
- • and other manufacturing considerations (e.g., paste adhesive thickness tolerances)

John Keune (Boeing) 2022 YP2 Sections

There are a few instances where the language used sounds like a requirement, consider 'softening'.

7.2.2.3.1 Manufacturing "All ten areas listed below are needed to build and assemble the product."

Changed to read: 7.2.2.3.1 Manufacturing "All ten areas listed below ~~are needed to~~ support the build and assemble ~~ly~~ of the product."

7.2.2.3.1 Product Value and Cost Assessments "All seven areas below are needed...“

Changed to read: 7.2.2.3.1 Product Value and Cost Assessments

"All seven areas below ~~are needed~~ help to..."

7.2.2.4 "...contain minimum content on the success criteria...“

Changed to read:: 7.2.2.4 "...contain ~~minimum~~ some recommended content on the success criteria..."

Ronald Krueger 2022 YP2 Sections

page 15, last paragraph: "... Sections 7.2.2.3 & 7.2.2.4 finish content..." not clear - "Table task headings remain in moving to success ..." not clear

In summary, Sections 7.2.2.3 & 7.2.2.4 finish content on the initial design and development phases for a product. Table task headings remain in moving to success criteria for subsequent design and application that cover the last three stages shown in Figure 7.2.2.3.1. After covering Integrated Product Teams (IPT) in Section 7.2.3, related product application challenges appear in Section 7.2.4.

"Column headings for the five tables in Sections 7.2.2.3.1 and 7.2.2.3.2 only cover the first three design/development stages. Success criteria Tables for subsequent design phases, which span the three product application stages shown in Figure 7.2.2.3.1 are covered in Section 7.2.4, which comes after covering Integrated Product Teams (IPT) in Section 7.2.3."

Cindy Ashforth Review of Sections 7.1.X and 7.2 through 7.2.2.X

- **Cindy's review, which was made in a word document, became the basis of our final updates for new content at the start of Chapter 7.**
  - Many of the edits were editorial and accepted
  - Other edits removed redundant content
  - Some edits sought clarification and asked questions, which led to changes
  - Some Section 7.2.X graphics were improved

- **Also note numerous other reviewer comments to improve the readability of some tables and graphics were addressed**

Volume 3, DRAFT Section 7.2.3 Integrated Product Team Update and Overview

Larry Gintert

Thursday April 25th, 2024

Discussion Topics (15 min)

- **Outline Flow into 7.2.3**
- **7.2.3 Content Overview**
  - **Disciplines**
  - **IPT Changes Through Product Design Life Cycle**
  - **Simplification for Smaller Products**

Feedback/Discussion

Chapter 7 Outline

Focus of this initiative is on the Top-Level of Chapter 7

CMH-17
COMPOSITE MATERIALS HANDBOOK

Top-Level of Chapter 7 Outline

CMH-17 COMPOSITE MATERIALS HANDBOOK

7.1 Overview of Unique Issues Associated with Composite Structural Design
- 7.1.1 Design Requirements, Criteria and Constraints
  - 7.1.1.1 Definition of terms
  - 7.1.1.2 Purpose and justification
- 7.1.2 Typical Aerospace Composite Structural Design Requirements and Criteria
  - 7.1.2.X *7.1.2.1 through 7.1.2.14 Technical Areas*
- 7.1.3 Other typical aerospace design constraints
  - 7.1.3.1 Systems interface
  - 7.1.3.2 Design options affecting costs and structural weight
  - 7.1.3.3 Other constraints affecting cost & weight trades

7.2 Structural Design Process
- 7.2.1 Product & Process Development: 5 Phases…
- 7.2.2 Technology Development and Product Implementation
  - 7.2.2.1 Product life cycle costs and customer value
  - 7.2.2.2 Practical size and product scaling issues
  - 7.2.2.3 Success criteria
  - 7.2.2.4 Differences for aircraft product types
- 7.2.3 Integrated Product Teams
  - 7.2.3.1 Typical structural design membership
  - 7.2.3.2 Design phase changes
  - 7.2.3.3 Simplifications for smaller products
- 7.2.4 IPT Challenges
  - 7.2.4.1 Technology Readiness
  - 7.2.4.2 Verified size and product scaling
  - 7.2.4.3 Financial considerations
  - 7.2.4.4 Other Issues (marketing, customer interface)
- 7.2.5 Design Process Examples
  - 7.2.5.1 Transport Aircraft
  - 7.2.5.2 Business Jet
  - 7.2.5.3 Rotorcraft
  - 7.2.5.4 Small Airplanes
  - 7.2.5.5 Others (eVTOL, Tiltrotor, supersonic)

Integrated Product Teams is discussed as part of the Structural Design Process and follows Product Development Life Cycle content

Life Cycle Design Process Example

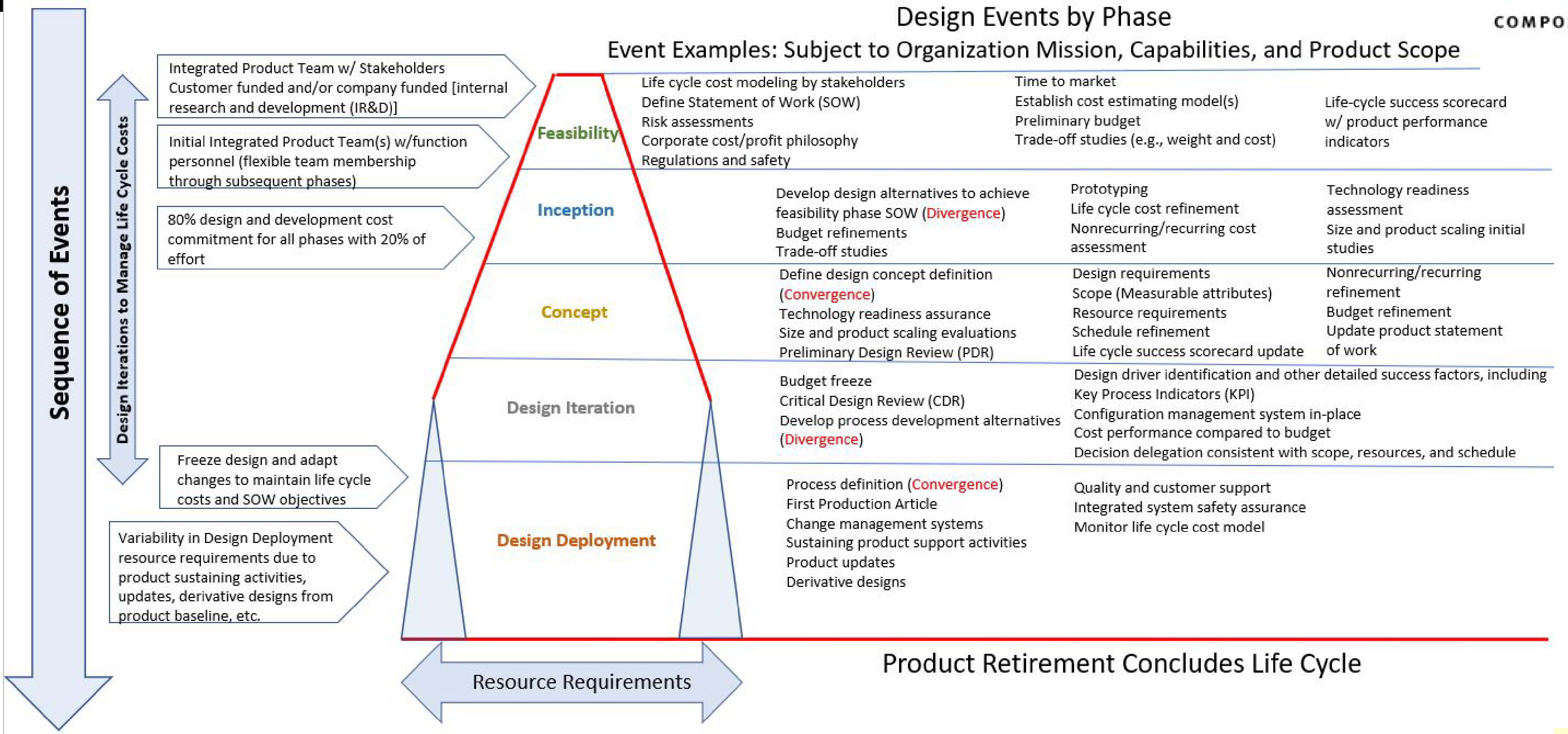


Figure 7.2 Examples of Events and Considerations at Different Phases of the Design Process Applied from the Start and Throughout the Life Cycle of a product.

IPT narrative addresses team involvement throughout Design Process Life Cycle

Excerpts from DRAFT 7.2.3

COMPOSITE MATERIALS HANDBOOK

IPT Disciplines discussed…

Disciplines involved in an IPT will vary based on many factors. The exact content of the early phases of a product, mainly the Feasibility and the Inception Phases, may fluctuate with the type and size of the project and of its promoting organization. … Depending on the scope of the development and company resources, an IPT participant may satisfy one or more of the following list of functions:

- Customer Representation and/or Marketing
- Contracts
- Customer Engineering [Together with above, this is the negotiating team during negotiations]
- Program and Project Management
-
- Product Design
- Materials and Process Engineering
- Qualify/Product Assurance, including Material Review Board
- Manufacturing Liaison
- Purchasing: Purchased Parts/Materials Liaison
- Purchasing: Major Outside Procurement Liaison, including risk-share partners
- After-market support
- Finance, including pricing decision ‘rates and factors’ policy
- Costing, including linkage with configuration

Design Phase Changes

7.2.3.2 Design Phase Changes

Throughout the design lifecycle, transitions from one phase to the next more mature phase represent opportunities to affect the product one way or another (e.g., thumbs-up or do not proceed as the product is not "feasible"). These opportunities are sometimes referred to as "gates" to the next phase and are defined by very specific criteria. This product design implementation criteria, objectives and constraints are not to be prescribed here, but exemplified by the narrative provided to enable the reader to understand how the different IPT members are critically involved during each of the design phases.

7.2.3.2.1 Implementing Requirements, Criteria and Constraints

The goal of the IPT is to meet the overall objectives of the design supporting the business case used to determine product viability throughout the design life cycle. Details of the various aspects of the product design are controlled by requirements, criteria and constraints prescribed as discussed earlier. It is important that the IPT establish clear direction in this regard such that cost and performance goals of the product have the best chance of being met

Design Phase Changes (cont'd)

7.2.3.2.2 Variations in IPT size and focus for a given product

During the Feasibility phase of the design for a given product, the IPT membership is often confined to a smaller group of high-responsibility individuals who are essentially making the initial business decisions for the product design and establishing what the scope of the effort will entail, including the budget, schedule and market opportunities and risks. Their effort typically may involve life cycle cost modelling, the identification and initial assessment of risks and threats, as well as opportunities and the product's overall chance of meeting business plan expectations. The ultimate delivery is the Statement of Work (SOW) for the product design, combined with the budget and schedule for proceeding to the next phase.

Design Phase Changes (cont'd)

During the Inception phase of the design the IPT membership may shift to more full-time, focused efforts from the Product Design, M&P and Manufacturing disciplines to explore alternatives of the design concepts, conduct trade-off studies, and refine the budgets needed to proceed to the next phase. A keen and thorough understanding of the overall design life cycle is important during this phase in order to properly conduct the required trade-off studies, ensuring that facilities and tooling for rate production are understood along with the associated supply chain implications. This phase results ultimately in a sort of assurance that the product design has merit to proceed to a more mature phase, and a refinement of the SOW, budget and schedule as appropriate.

Design Phase Changes (cont'd)

During the Concept phase of the design, the focus of the IPT remains on concept definition and all size and scaling issues associated with designing the product are assessed and resolved, or consciously planned for near-term resolution in order to proceed. The Design, M&P and Manufacturing disciplines should work together during the Concept phase to assure the Technology Readiness Level (TRL) of all materials and processes, including tooling, assembly and finishing details are adequate for reliable, sustained manufacturing in support of the product business plan. Configurations should be laid out in detail to ensure that overall systems requirements (for a relatively complex product like an aircraft, where structural clearance for controls and systems components can drive design details), are considered during concept definition. Requirements/Criteria discipline representatives should stay involved throughout the Concept phase to ensure details of the SOW are not overlooked in the design planning. The ultimate goal of the IPT at the end of the Concept phase is to complete a Preliminary Design Review (PDR), with draft drawings and draft specifications defining the product that is worthy of proceeding to the next phase. This PDR typically also establishes the initial plans for tooling, facilities and all other details associated with delivering the product to a customer, but also the supportability, maintenance and repair aspects of the product throughout its life cycle.

Design Phase Changes (cont'd)

During the Design Iteration phase the final concepts and configurations are established and commitments are made that lead to the Critical Design Review where product configurations and primary materials and processing requirements, including tooling for accurate cost estimating are established. The Design, M&P and Manufacturing disciplines continue to focus on finalizing initial product configurations with regular reviews and inputs from the Requirements/Criteria and Field Support disciplines representing initial aspects along with evolving needs and trends. During this phase, processing alternatives may be identified and evaluated concurrently with the primary design options in order to maximize benefits to cost for the overall product throughout its life cycle. The successful completion of this phase will identify all the related costs for additional work needed to meet product objectives versus the realistic benefits to product value for the options considered.

Design Phase Changes (cont'd)

The Design Deployment phase the team has shifted focus to produce the configuration of the product that was documented during the CDR and demonstrating the value of the product ensuring that it meets the requirements, criteria and constraints established. This includes testing and analyses with associated documentation to officially record results. Materials and processes are frozen for the baseline design, but other configuration variants are often introduced and incorporated into the product along with improvements and upgrades identified during the life cycle of the product "family". All IPT functional disciplines are involved during this phase, but their specific support demands are staged by the detailed events included during this phase. For example, the Requirements/Criteria Discipline personnel are involved to ensure the product is indeed aligned with those aspects and meeting customer expectations for delivery, but this is a brief duration requirement compared to the ongoing support of Design, M&P, Manufacturing and Field Support Disciplines throughout the majority of the product's remaining life cycle. This is the phase where the product is delivered, operated and maintained throughout its life cycle, often causing resource requirements to experience a degree of divergence, depending on the product family's overall success with consumers and operators.

Simplification for Smaller Products

CMH-17 COMPOSITE MATERIALS HANDBOOK

7.2.3.3 Simplification for Smaller Products

For smaller, simpler products, perhaps at a component or subsystem level as part of the supply chain for a larger, more complex product, the IPT membership may look quite different with some disciplines being represented by an individual "wearing several hats" and covering the essence of the responsibility for each. The phases are still applicable, but alignment of the phases may be driven largely by customer needs and/or schedules. Likewise, if a technology for a product has been previously proven, a producer may benefit largely from that prior experience and data to facilitate the advancement to the next phase.

Ideas for Improvement/Enhancement

- Narrative inputs
  - Missing topics or thoughts?
  - Terminology check (How's my lingo?)
  - Other?

- Graphics to improve or enhance content??

- Ecodesignlyst

Constructive inputs are GREATLY APPRECIATED!!

Wrap-Up

THANK YOU!!!

Design and Analysis Considerations for Helicopters

Connect to [Christos Kassapoglou Rotorcraft Presentation]

Advancing existing content as valid for Different Product Types, Parts and Suppliers

- **Chapter 7 development for Rev. H was halted after realizing that different product types require different product development philosophies based on product value to a unique customer base**
  - Not all product types use traditional building block approaches (regulators considering composite guidance changes)
  - Numerous examples of products needing an early emphasis on prototype demos (later in this TG Mtg.)
- **Other considerations, realized by all manufacturers, including the large transport OEM**
  - New Figure 7.2 was generalized to cover all phases of design, occurring during a product's life cycle
  - Some reorganization of Section 7.2 content to be discussed in this segment of the Design TG Meeting
- **Section 7.1.X.X may need some changes and additions in the *Design Requirements, Criteria and Other Constraints* covered** (e.g., early phases of development when practical design optimization are beneficial)
  - Small prototype/experimental aircraft can be optimized, while still maintaining structural integrity, particularly those flying in UAV mode to evaluate performance attributes
  - Section 7.1.X.X has had very strong and positive reviews in the few CMH-17 Yellow Pages to date
  - Many applicants are realizing that such expectations are product specific internal company decisions
- **First Section 7.2 content to be fully developed independent of aerospace product type will be Section 7.2.3** (to be covered by Larry Gintert next and on Thursday, April 25)
- **Plan a new Section 7.2.4 basis and move approved transport detailed design content (Section 7.2.5)** (covered by L. Ilcewicz & M. Rush next and on April 25)

Section 7.2 Content Development Plans and Strategies

Current Outline review & update needs
(Priority, *outline discussion needs,* future updates**)**

7.2.3 Integrated Product Team: Content Development

7.2.4 IPT Challenges (including plans for other product types)

- *Product Readiness updates involving prototypes*
- *More case studies for small airplanes and eVTOL*
- *Differences for rotorcraft*
- *Supersonic challenges*
- *Size and product scaling for unique parts (COPV)*

7.2.5 Design Process Examples (Design Phases 4 and 5)
(others, with renumbering from 7.2.5.1 (Transport)
to 7.2.5.X (Small Airplane, Rotorcraft, TBD)

7.2.2 Product Development needs for other
product types (building of Transport Airplanes)

- **Section 7.2.4 was originally intended to cover Design Phases 4 and 5 for Transport Airplanes**
- **Rick and Charlie's charts and testimonials from April 23 suggest a handbook need to develop design case studies for other product types and unique parts** (including system solutions)
  - Product development and implementation needs for other product types
  - New flight envelops (loads and environments)
  - Alternate materials and processes (related updates to AC 20-107B and AMC 20-23)
  - Unique part design challenges
  - Other challenges (ecosystem, safety challenges)
- **Design Phases 4 and 5 can be covered for all selected product types in Section 7.2.5.X**

PMC Design TG Closure/Actions

- **Design TG is preparing to expand with volunteers interested in finite additions to Chapter 7, which meet the design needs of all interested product types, including other volumes**
  - Post Rev-H Volume 3, Chapter 7 proposals will involve efforts to generalize existing content
  - *Future of CMH-17* reorganizational decisions will help decide the most efficient path to an end
    - One path has generalized content specific to the existing products for the different material types/forms documented in their corresponding volumes (e.g., many transport airplane parts are made from CMC and polymer AM)
- **A large design team of individuals with special skills can solve many unique design challenges of interest to CMH-17 Users** (Margaret and Dan always wanted to advertise "stump the Experts" on CMH-17 website)
- **Next Meeting will follow compilation of final Chapter 7 content for Revision H**

Actions (from April 23 and 25, Design TG Meetings)

1. **Collect names from those interested in supporting the Design TG**
2. **Publish notes and share charts from both Scottsdale Design TG meetings on the website by Secretariat**
3. **Prepare a CMH-17 proposal for work to update and complete Section 7.2.3 (Integrated Product Teams)**
4. **Design TG meetings to discuss Section 7.2.4 content outline updates for other product types and unique parts**

Summary of Scottsdale Design TG Meeting Outcomes

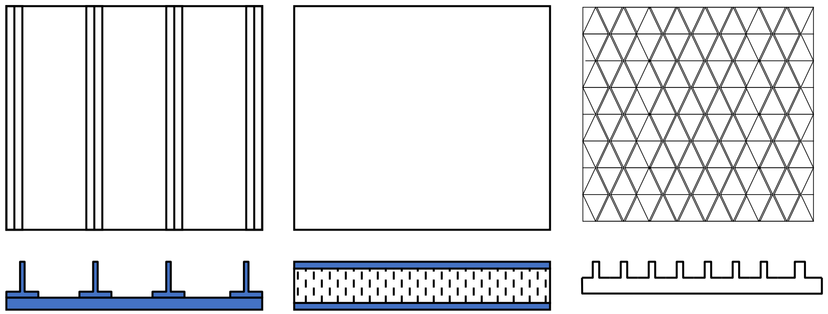
- **Sections 7.1 and 7.2 has effective content in Product Development to Readiness Levels needed for Detailed Design Phases of Transport Aerospace Applications**
  - Yellow page reviews & related working group content updates are advancing to final Rev. H delivery to Secretariat
  - Design TG presentations and selected testimonials from other product types and part levels indicated design process needs not fully recognized in existing Rev. H content or current documented industry protocols (e.g., prototyping)
  - Final design phases, including life cycle considerations (production and service) may best be addressed with case studies addressing sufficient design challenges to accumulate knowledge in documented examples
- **Section 7.2.3** (Integrated Product Teams) **to be drafted for numerous part & product needs**
- **List of tasks for virtual Design TG Meetings to define teams, efficient plans & priorities**
  - *Product Readiness updates involving prototypes*
  - *More case studies for small airplanes and eVTOL*
  - *Differences for rotorcraft*
  - *Supersonic challenges*
  - *Size and product scaling for unique parts (COPV)*
- **Several proposals will be developed for submittal to new CMH-17 Development Process**

Design and analysis approaches for composite helicopter structures

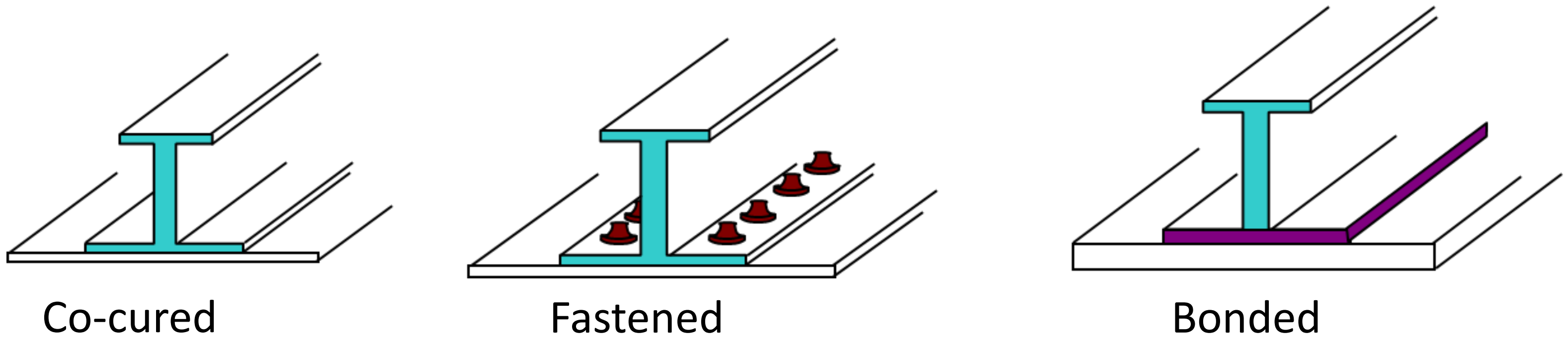
Christos Kassapoglou

Too many options…

- At each location to be designed, there are at least 3 design concepts
  - e.g. skins: stiffened panel
    sandwich panel
    isogrid



- For each concept you may want to consider, on the average, 3 fabrication processes/material combinations

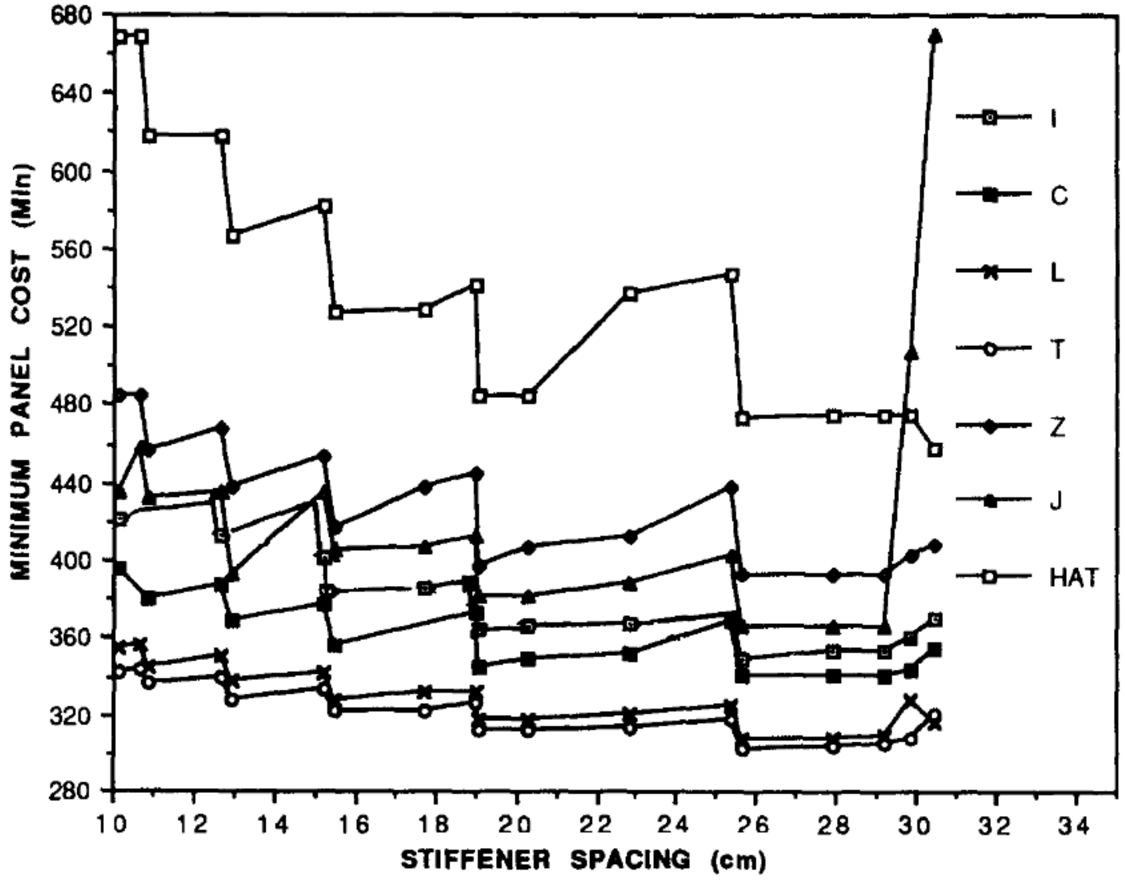


…too little time!

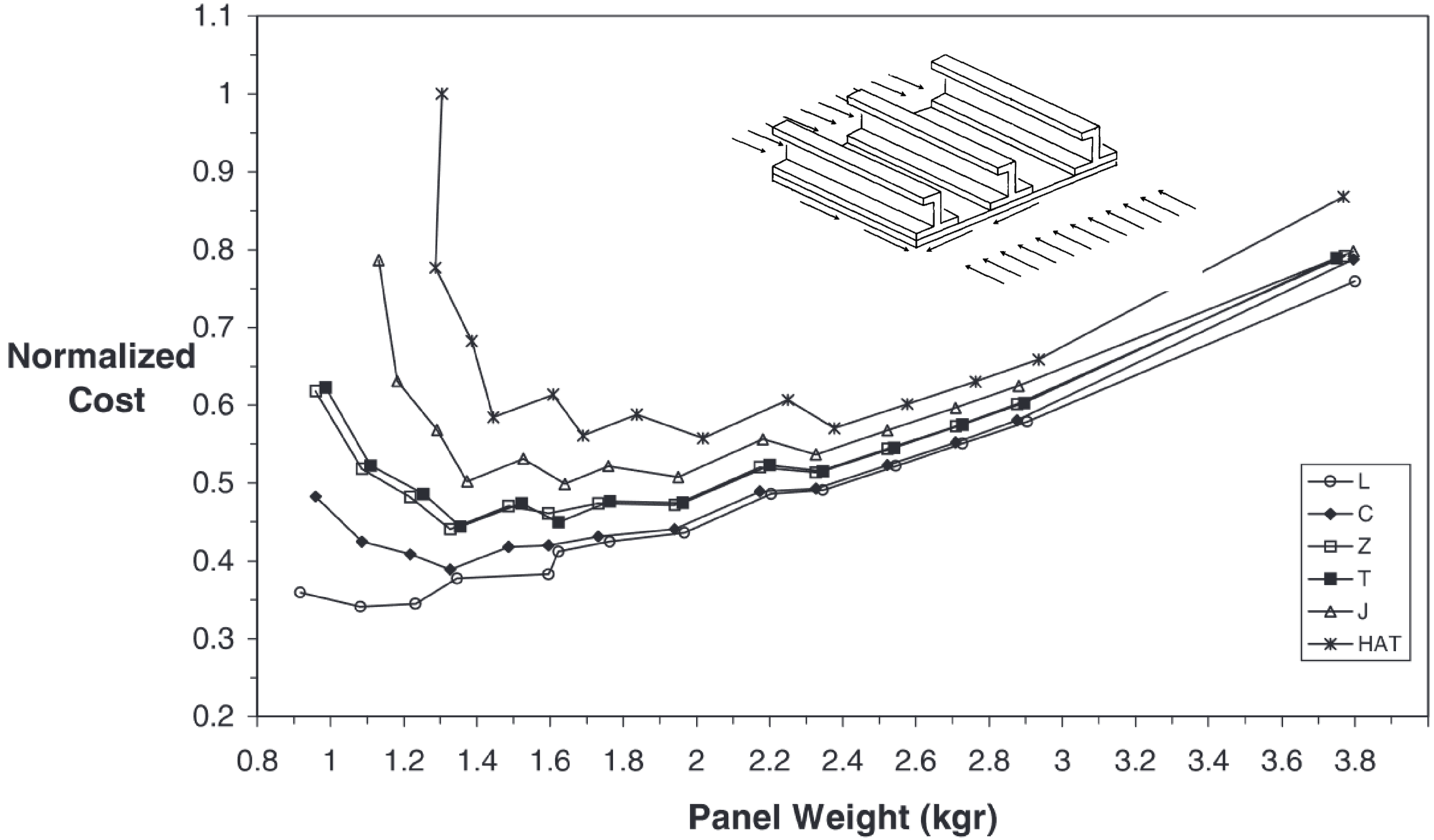
- Between the different locations, load cases, options, layups, and optimization, one would have to do hundreds of millions of analyses (FE or otherwise)
- Instead:
  - Create trend lines
  - Off the shelf designs
  - Response surfaces

Trend lines – fuselage skins (stiffened)-No post-buckling

- Mostly flat or nearly flat skins
- Analyzed for strength, buckling, crippling, inter-rivet buckling
- For representative load cases and panel sizes, select different stiffener types and for each case, determine minimum weight and cost (combined compression and shear)
- Once near optimum designs have been selected, more accurate and more detailed (FE-based) analysis must take over



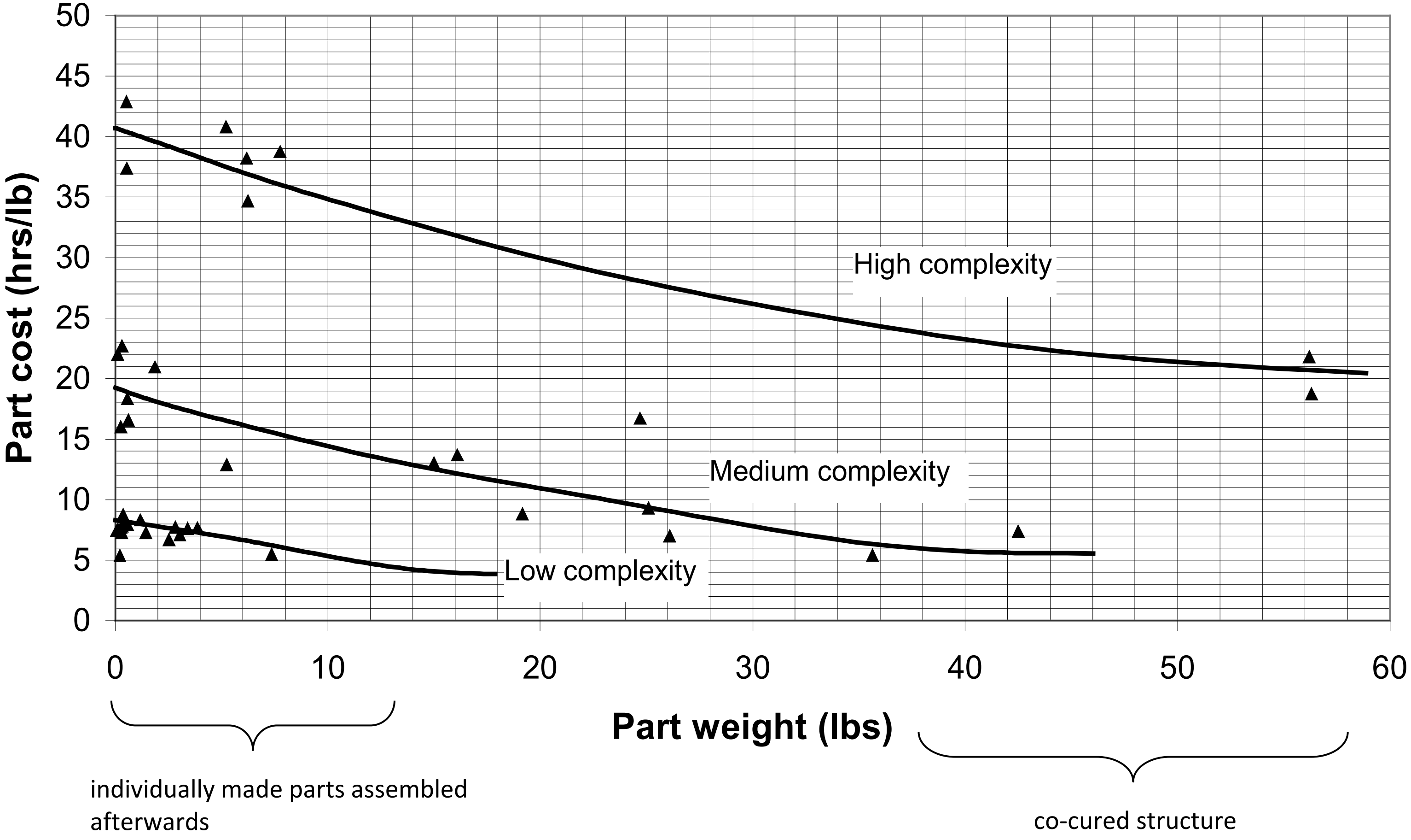
Trend lines – fuselage skins (stiffened)-With post-buckling



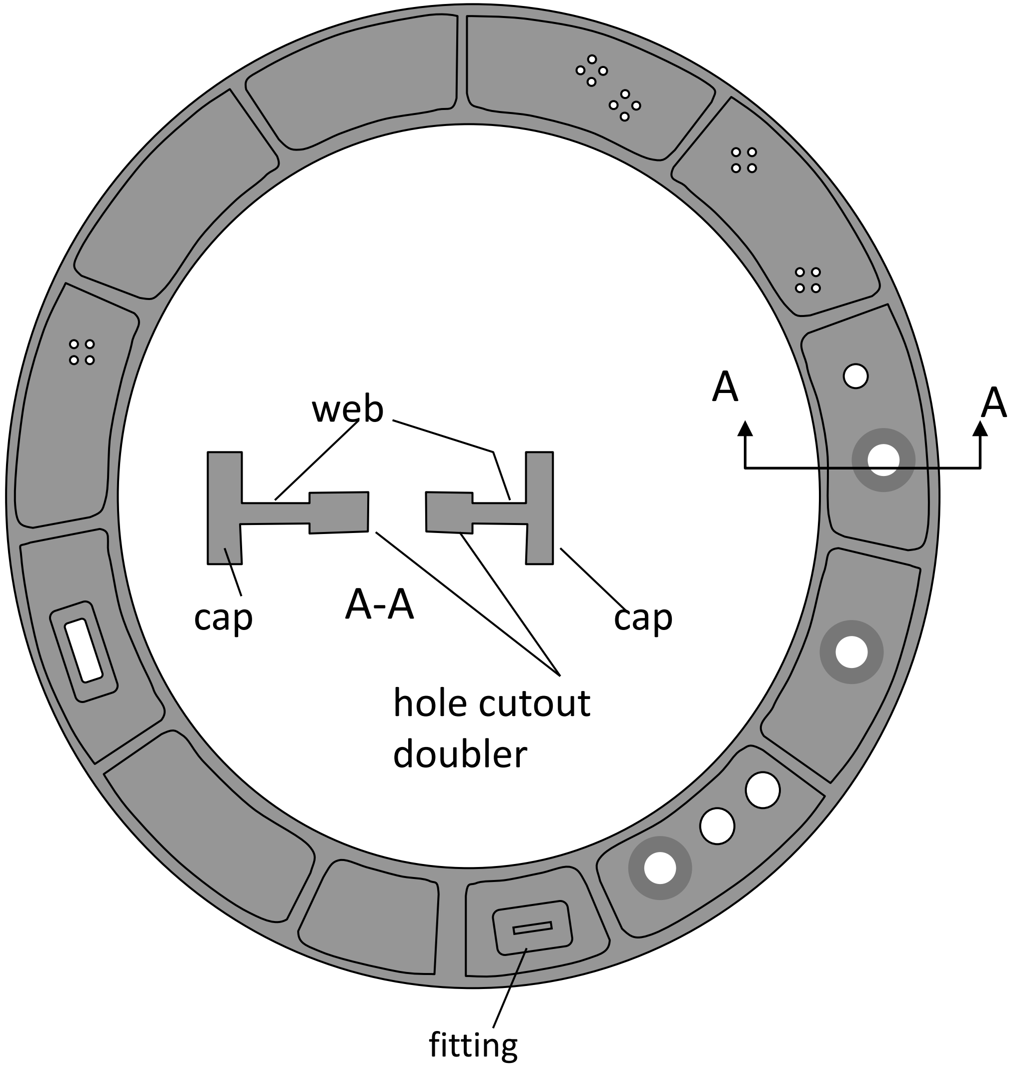
But fatigue concerns for L, C, Z

Bottoms-up cost equations

- Published cost equations (e.g. Northrop's ACCEM, software like SEER,…)
- Cost data available in-house



Trend lines - Frames, Bulkheads, Beams



- Analyzed for:
  - Material strength
  - Buckling of individual webs
  - Crippling of stiffeners or doublers
  - Crippling of caps
  - Include cut-outs
- Manufacturing considerations
  - For minimum cost, co-curing the entire frame and then assembling to the skin is preferred
  - High risk due to cost involved if repairs are needed or the part has to be scrapped
  - For minimum risk and easier contour matching between outer frame cap and skin, more than one pieces (sub-assemblies) are preferred→splices

Cost-Weight trades for composite frames-Examples

- Frame consisting of 50 bays (web sections separated by stiffeners)
- Fuselage with approximate diameter of 2 m
- Shear load 340 to 4565 lb/in
- Cap load 2 to 95743 lb (mostly compression)
- Manufacturing options considered: Hand layup (HLP) and Resin transfer molding (RTM) compared to sheet metal (SMT) and High speed machined (HSM) designs

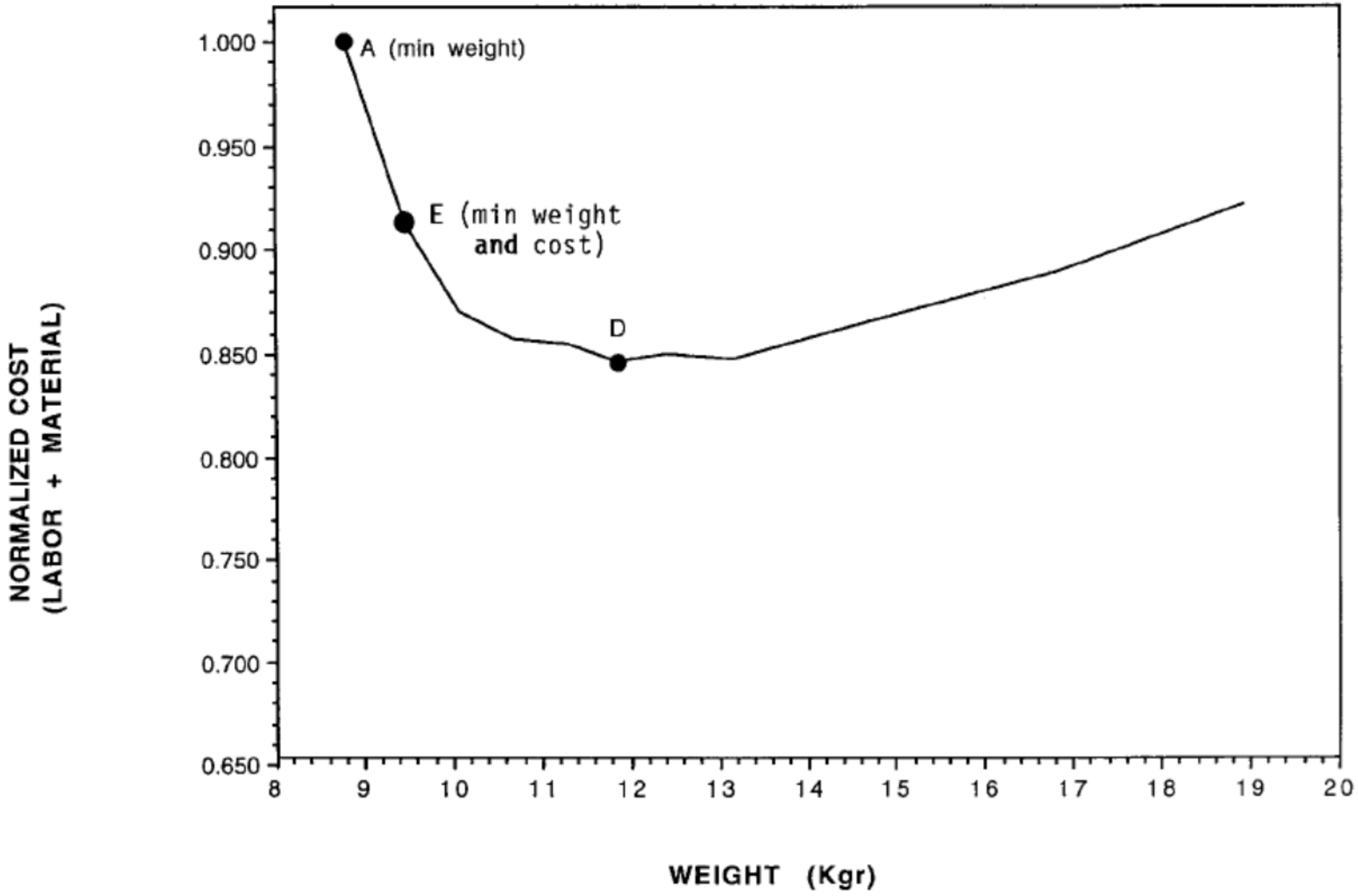
Considerations in the tradeoff

- RTM does not yield the same consistent fiber volume (65%) as HLP so, for some designs, allowables are reduced by 15-20% (compression and shear)
- Tape and fabric material for HLP is available in two thicknesses (thin and thick) the thin allows lower weights but higher cost
- Material for RTM is available in hand-made preforms (thick or thin) which are expensive to make or in automated (e.g. braided preforms) (thick or thin) which have much lower cost
- SMT is available only in the standard metal gages; assembly cost for SMT is a very high percentage of the total
- HSM can achieve any thickness greater than 0.03-0.04 inches

Considerations in the tradeoff

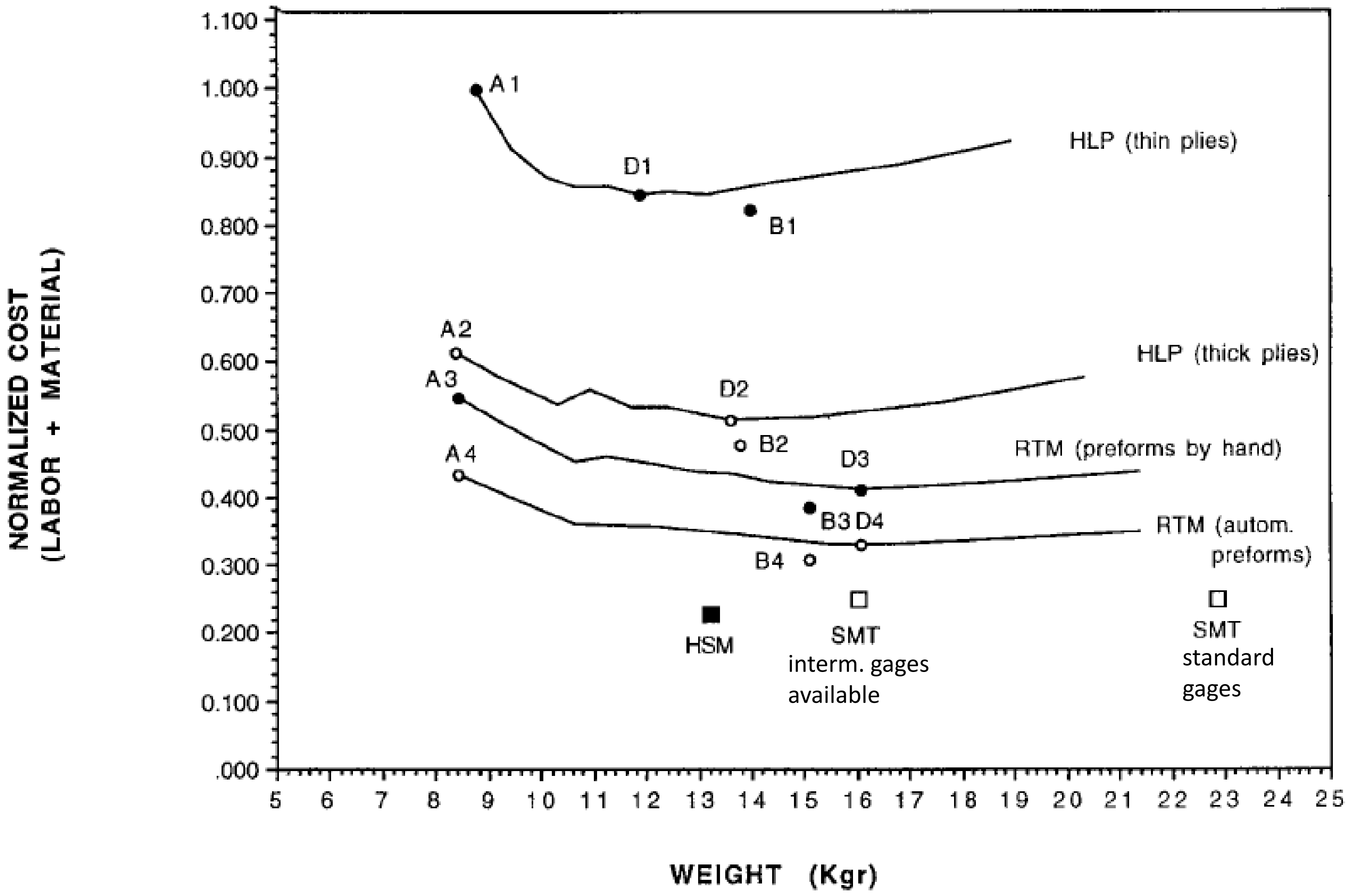
- Stiffeners in HSM have rectangular cross-sections (machined from a billet)
- Stiffeners in SMT, HLP, and RTM have angle cross-section
- Frame as a whole has channel (or C) cross-section
- Minimum flange widths for handling and attaching with fasteners are imposed.

Frames cost-weight trades - HLP



- Min weight and cost assumes weight and cost are equally important

Frames cost-weight trades – all options



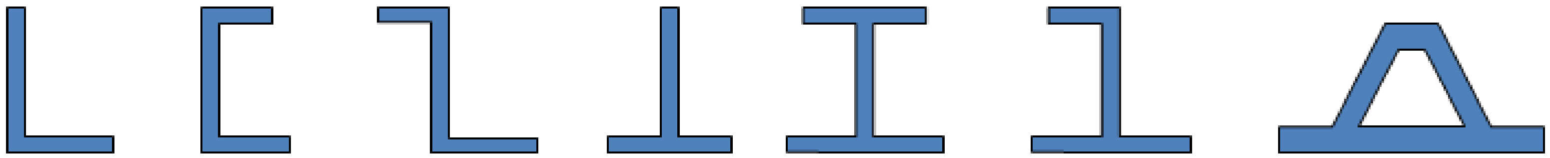
Frame trade study – some conclusions

- webs are designed by shear buckling
- most stiffeners, caps, and reinforcements are designed by crippling
- complete resin wet-out and uniform resin content (no higher than 35%) are crucial for efficient RTM parts
- minimum weight is rarely the same as minimum cost; some compromise is needed

Off the shelf designs – Modular designs

Design stiffeners for specific load and failure mode

- Stiffener crippling
- Select stiffener cross-section
- Start from low compressive loads and increase to a maximum value
- Design optimum (min weight) cross-sections for a number of applied loads, say 10 →10 off-the shelf designs
- For a given load in an application, use the off-the shelf design for the next highest load in the applied loads list

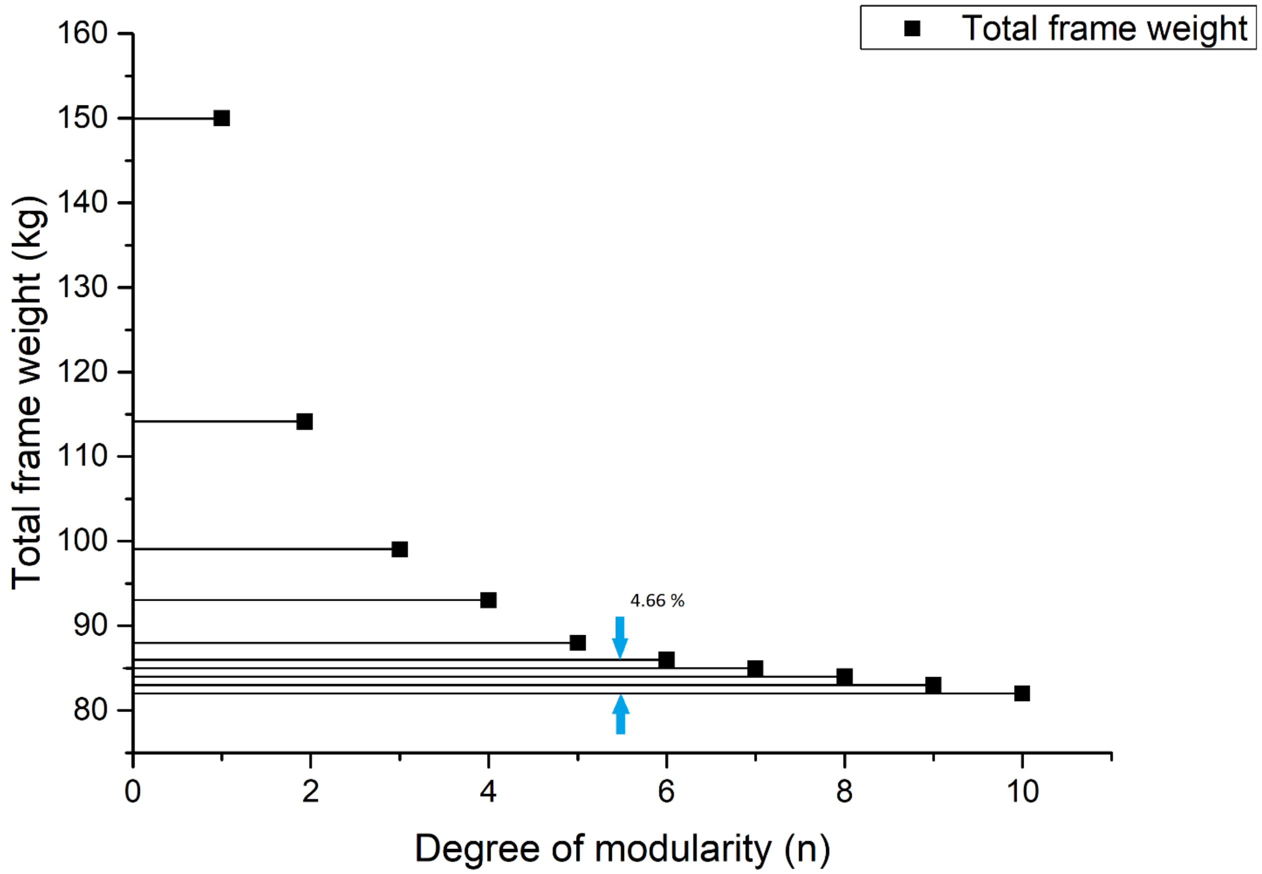


Modular design

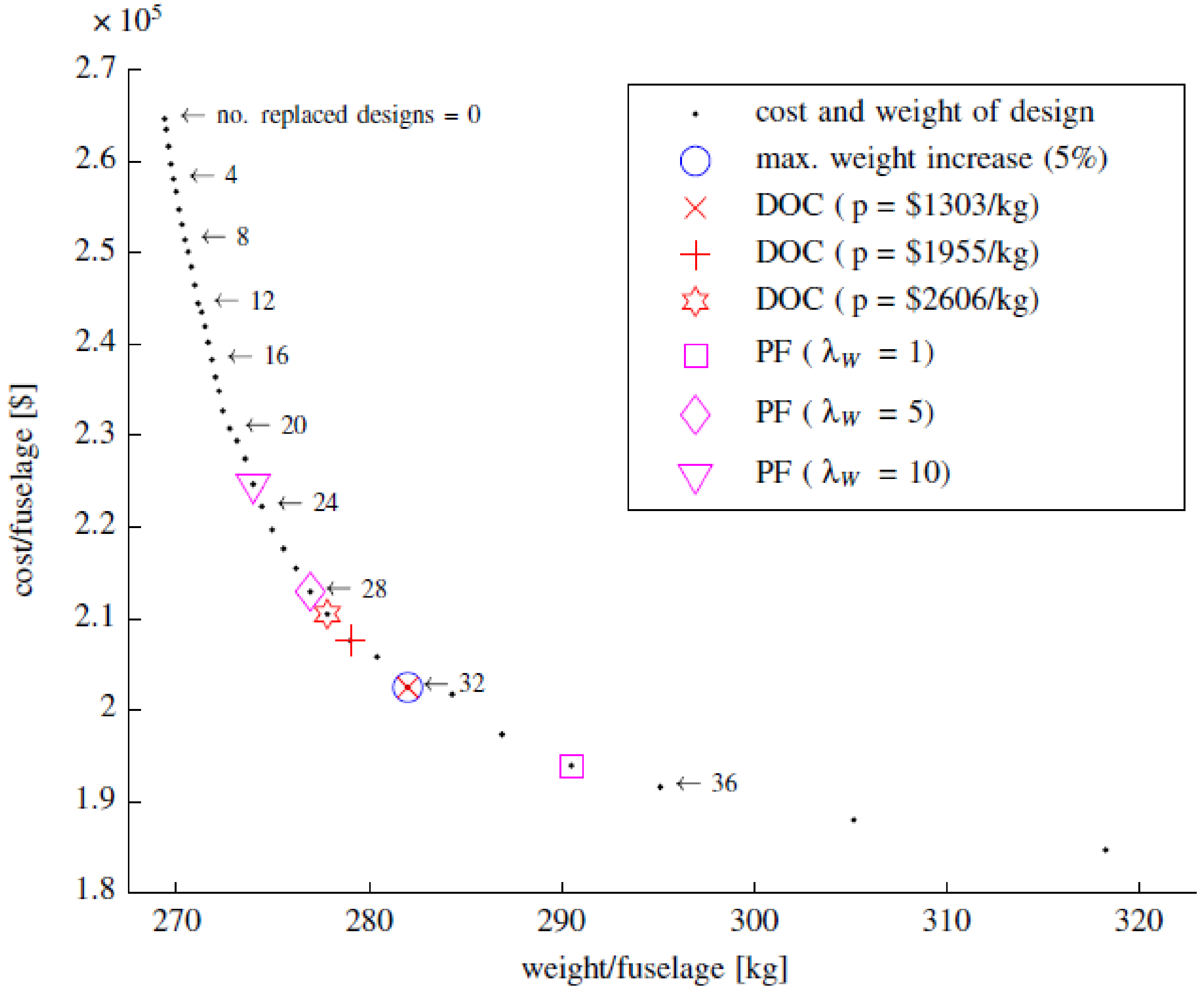
- Assign the same design in different locations
- Minimize number of tools
- Reduce fabrication cost (learning curve effects)
- Increase in weight
- Optimize so weight increase is minimized and cost decrease (recurring and non-recurring) is maximized

Frame case

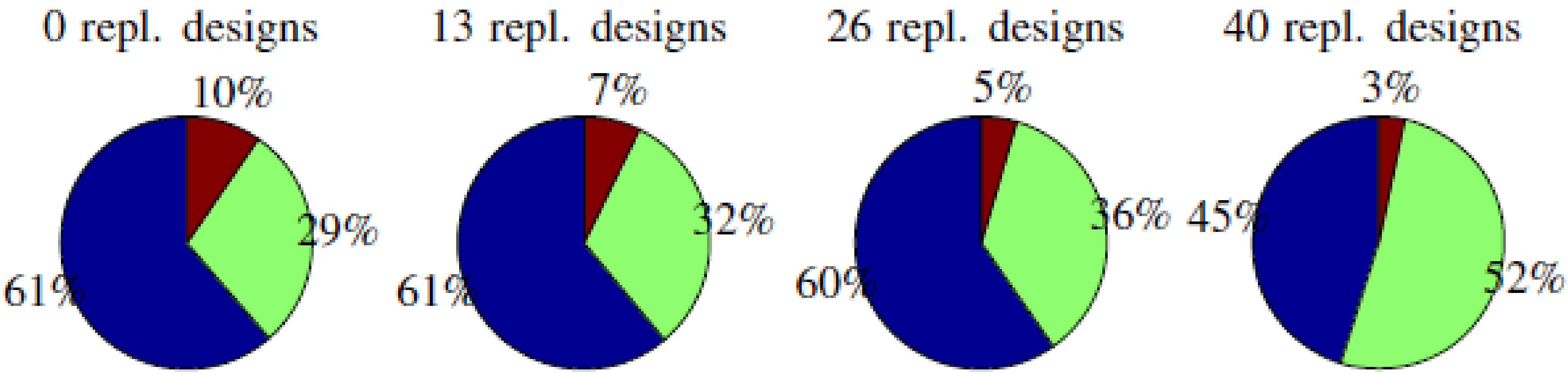
N/m	Kg
10/10	82
10/9	83
10/8	84
10/7	85
10/6	86
10/5	88
10/4	93
10/3	99
10/2	114
10/1	150



Stringer case



Cost break-down



Cost breakdown at different levels of modularity (blue: labor, green: material, red: tooling)

Cost: The management perspective – Combine everything into an entire fuselage

- Multiple options each requiring its own investment (capital and personnel) for technology and part design readiness
  - Hand layup
  - Autom. Fiber/Tow Placement
  - Filament Winding
  - Pultrusion
  - Resin Transfer Molding (RFI, VARTM, …)
  - Braiding
  - Knitting, weaving, …
  - Thermo-forming (thermoplastics)
  - Metal: Built-up sheet metal, machining, high speed machining
- Need a method to evaluate options

Problem considered

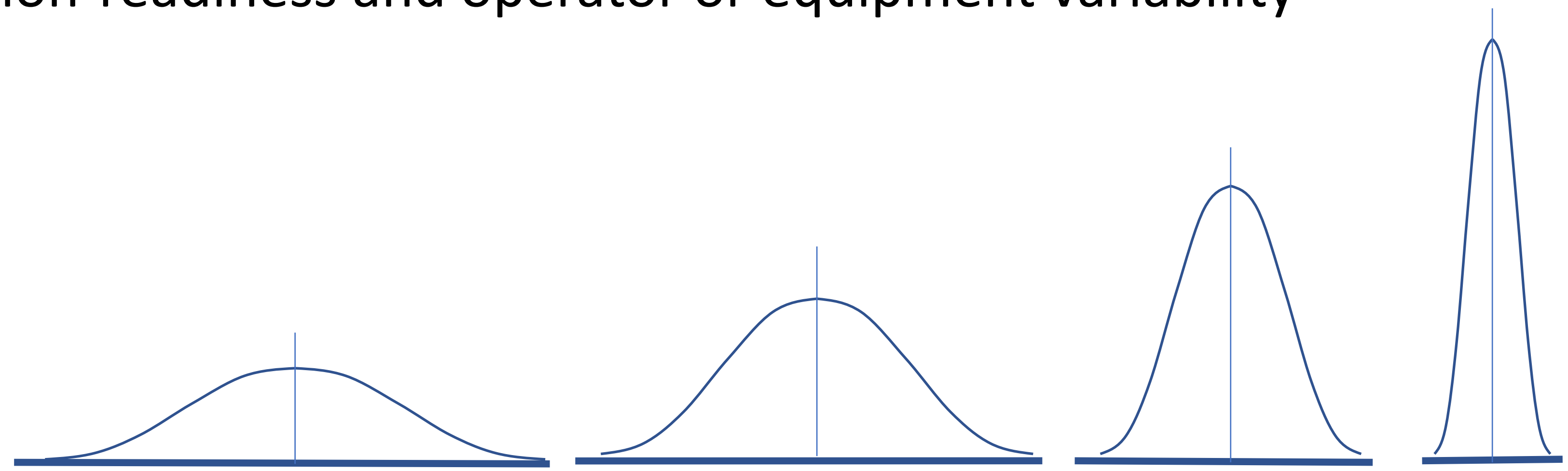
- A general case: A **complex product** like the airframe (structure) of an aircraft in which **multiple technologies** are possible
- Objective: Determine the **best combination of technologies** (optimum technology mix) for a given strategy
- Examine how results change with **amount of risk** and how they change with **time**
- Consider **weight, recurring and non-recurring cost**

Application to helicopter fuselage

- Decide on candidate technologies
- For each technology applied to each part family:
  - Determine applicability as a function of time
  - Determine expected cost and weight savings compared to baseline
- Select a combination of technologies to make each part family
- Combine the contributions over all part families to obtain cost and weight savings for entire fuselage
- Repeat for other technology combinations
- Optimization

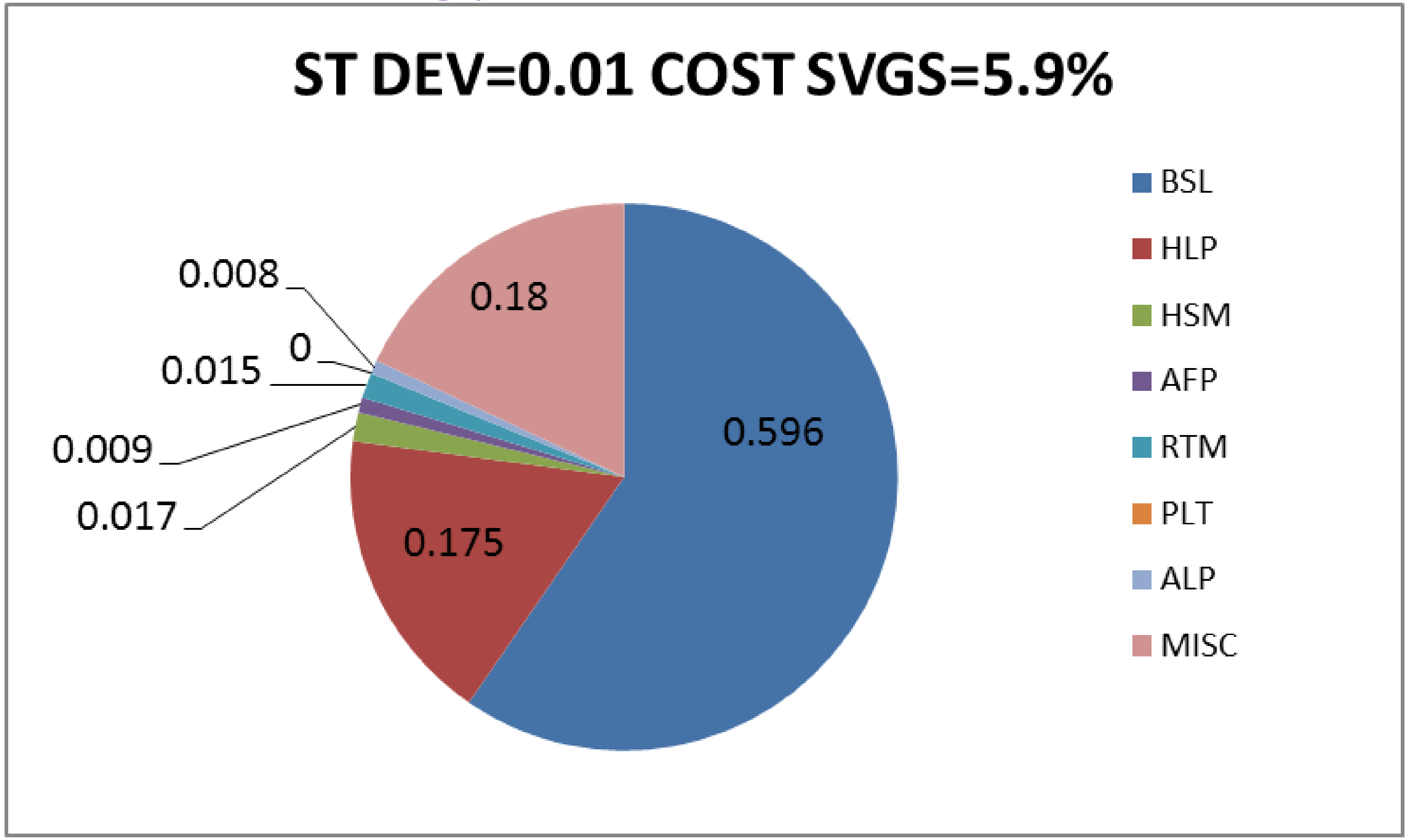
Risk in recurring cost

- Define risk as **the standard deviation, σ, or as the variance, σ^2, of the cost when part size and complexity are fixed**
- Risk is the cost variability due to uncertainties resulting from low levels of production-readiness and operator or equipment variability



In order of decreasing risk…

Optimum technology mix – Low risk



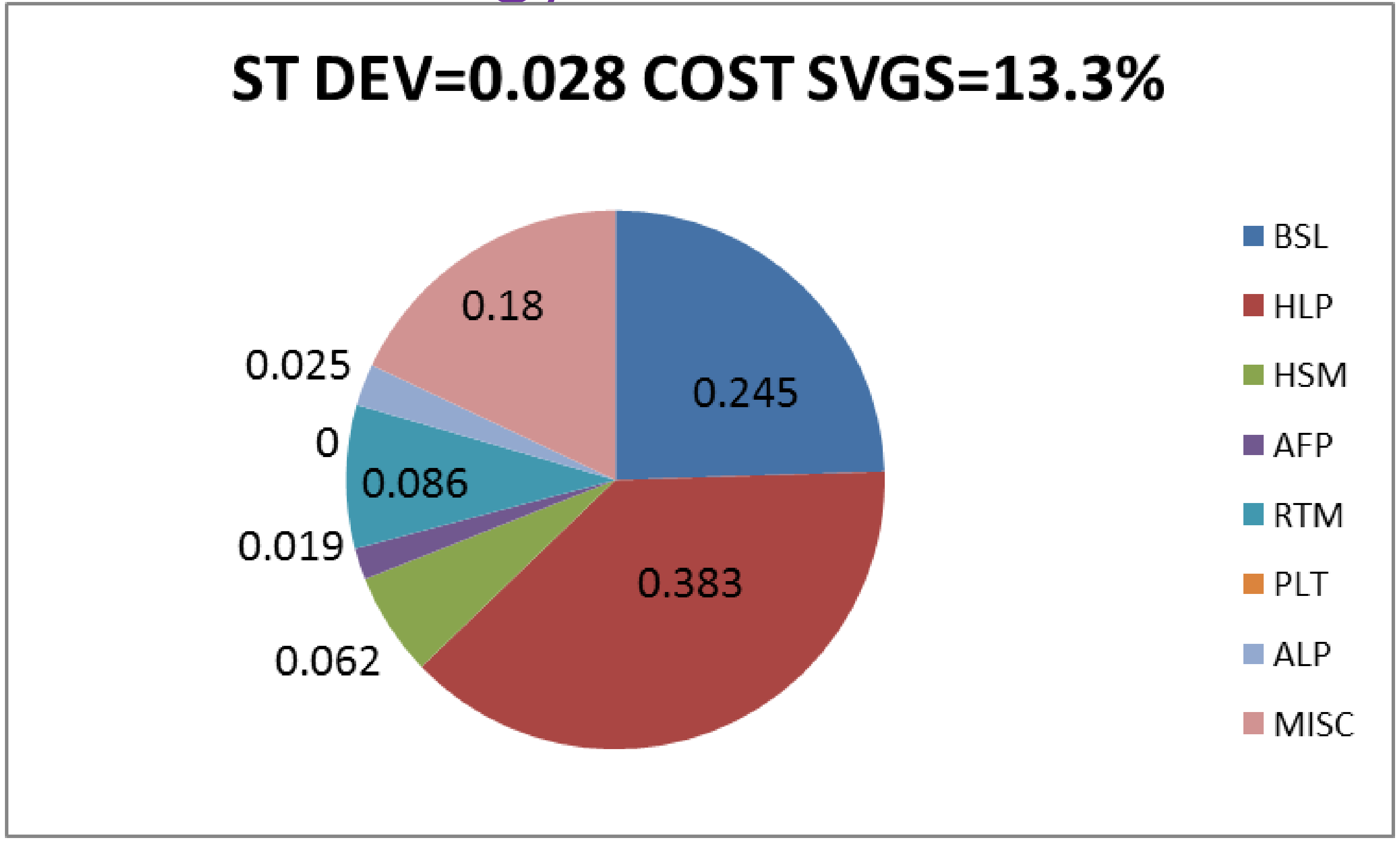
- As expected most of the fuselage stays with baseline technology

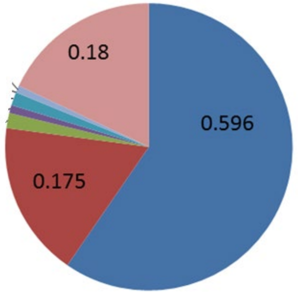
Optimum technology mix- Low risk: Split by part family

Family\Tech	**BSL**	**HLP**	**HSM**	**AFP**	**RTM**	**PLT**	**ALP**
Skins +	0.795	0.135	0.015	0.018	0.022	0	0.015
Frames +	0.51	0.424	0.036	0	0.03	0	0
Stringers	0.964	0	0	0	0	0	0.036
Fittings	0.901	0	0.099	0	0	0	0
Decks +	0.797	0.143	0	0.015	0.03	0	0.015
Doors +	0.818	0.152	0	0.015	0	0	0.015

- No applicabilities are violated

Optimum technology mix – Medium risk





Low risk

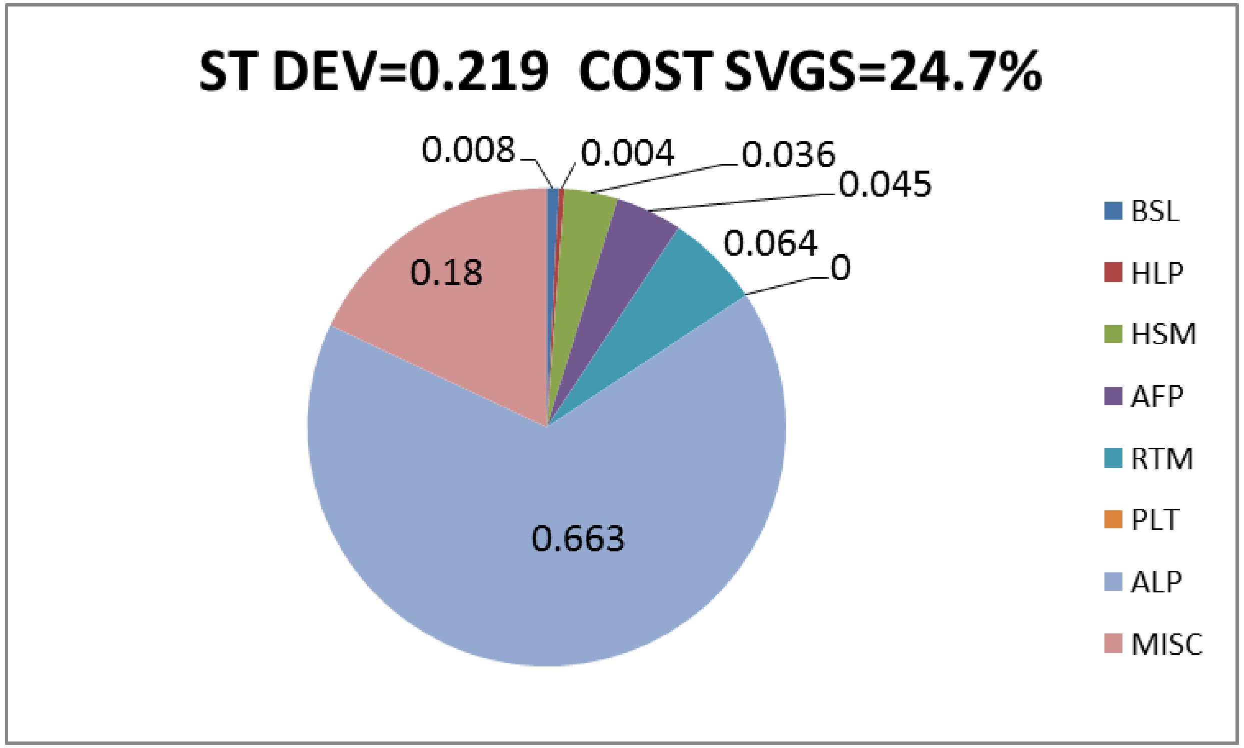
- Now less baseline technology and other higher risk technologies are used to some extent

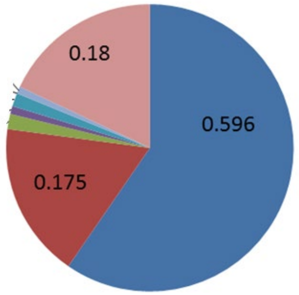
Optimum technology mix- Medium risk: Split by part family

Family\Tech	BSL	HLP	HSM	AFP	RTM	PLT	ALP
Skins +	0.345	0.435	0.045	0.024	0.121	0	0.03
Frames +	0	0.615	0.16	0	0.195	0	0.03
Stringers	0.888	0	0	0	0	0	0.112
Fittings	0.699	0	0.301	0	0	0	0
Decks +	0.382	0.453	0	0.045	0.09	0	0.03
Doors +	0.435	0.48	0	0.049	0.006	0	0.03

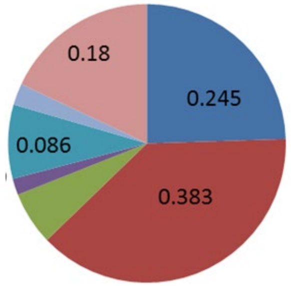
- Applicability of HSM fittings is exceeded (cannot be > 25%)
- Should remove 5% of the fittings from HSM and make them with different technologies
- Or, incorporate applicability in the software

Optimum technology mix – High risk





Low



Medium

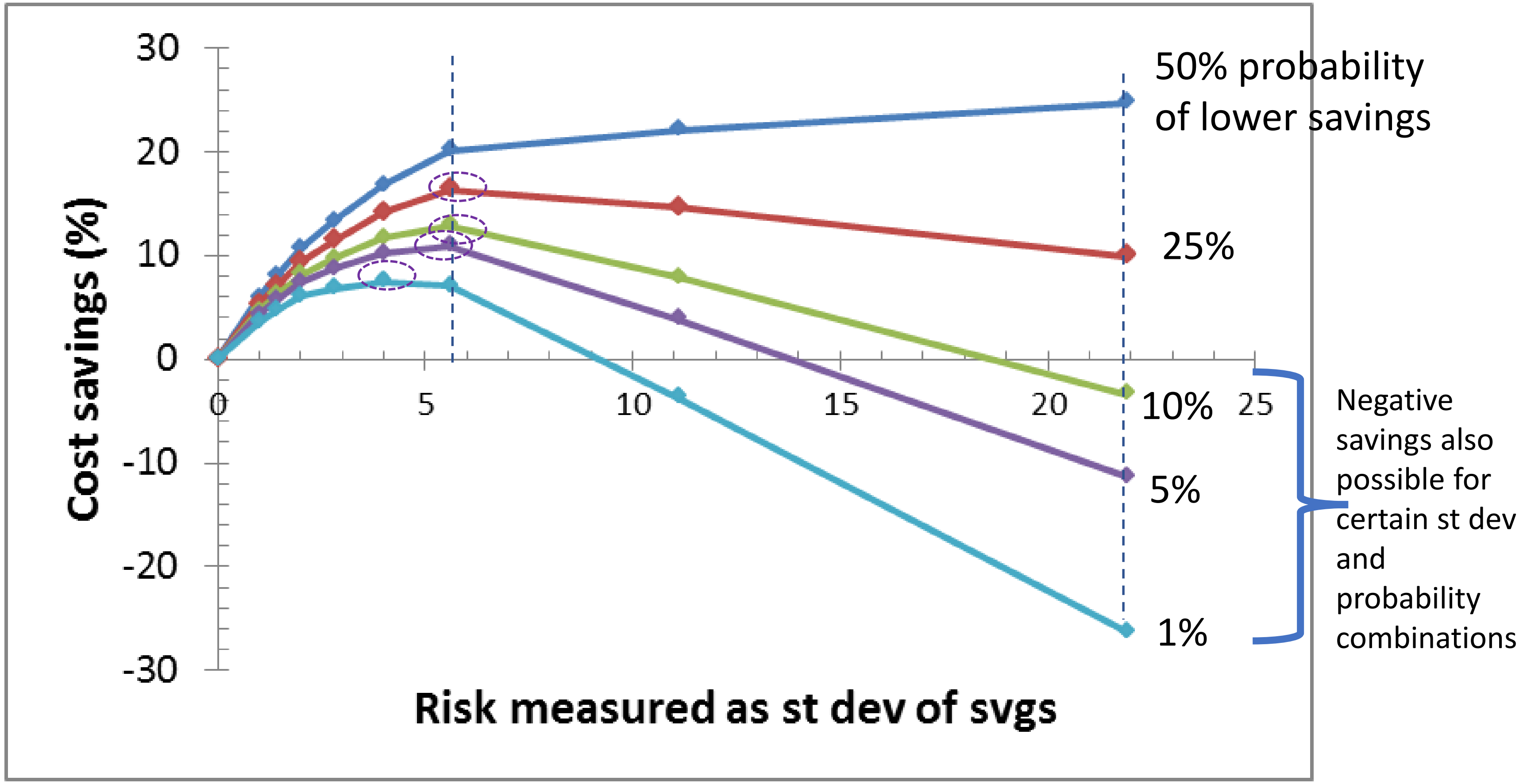
- Baseline technology almost completely eliminated from the mix

Optimum technology mix- High risk: Split by part family

Family\Tech	**BSL**	**HLP**	**HSM**	**AFP**	**RTM**	**PLT**	**ALP**
Skins +	0	0.015	0	0.09	0	0.001	0.894
Frames +	0	0	0	0	0.272	0	0.728
Stringers	0.103	0	0	0	0	0	0.897
Fittings	0.145	0	0.84	0	0	0	0.015
Decks +	0	0	0	0.039	0	0	0.961
Doors +	0	0.735	0	0.128	0.002	0	0.894

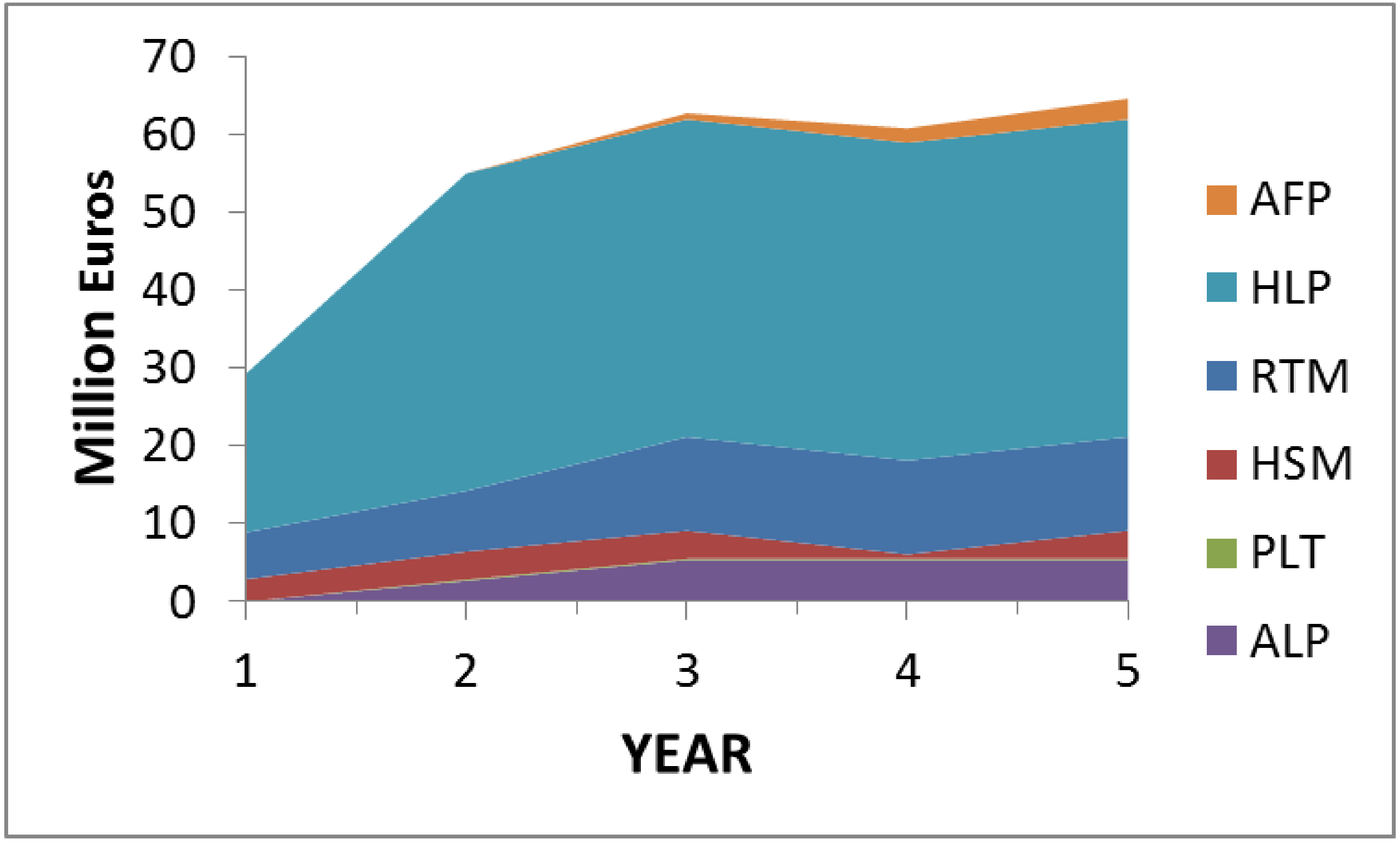
- Many applicabilities exceeded
- Either redistribute OR
- Modify technology to improve applicability (does the investment justify the expected return?)

Effect of risk on optimum mix selection



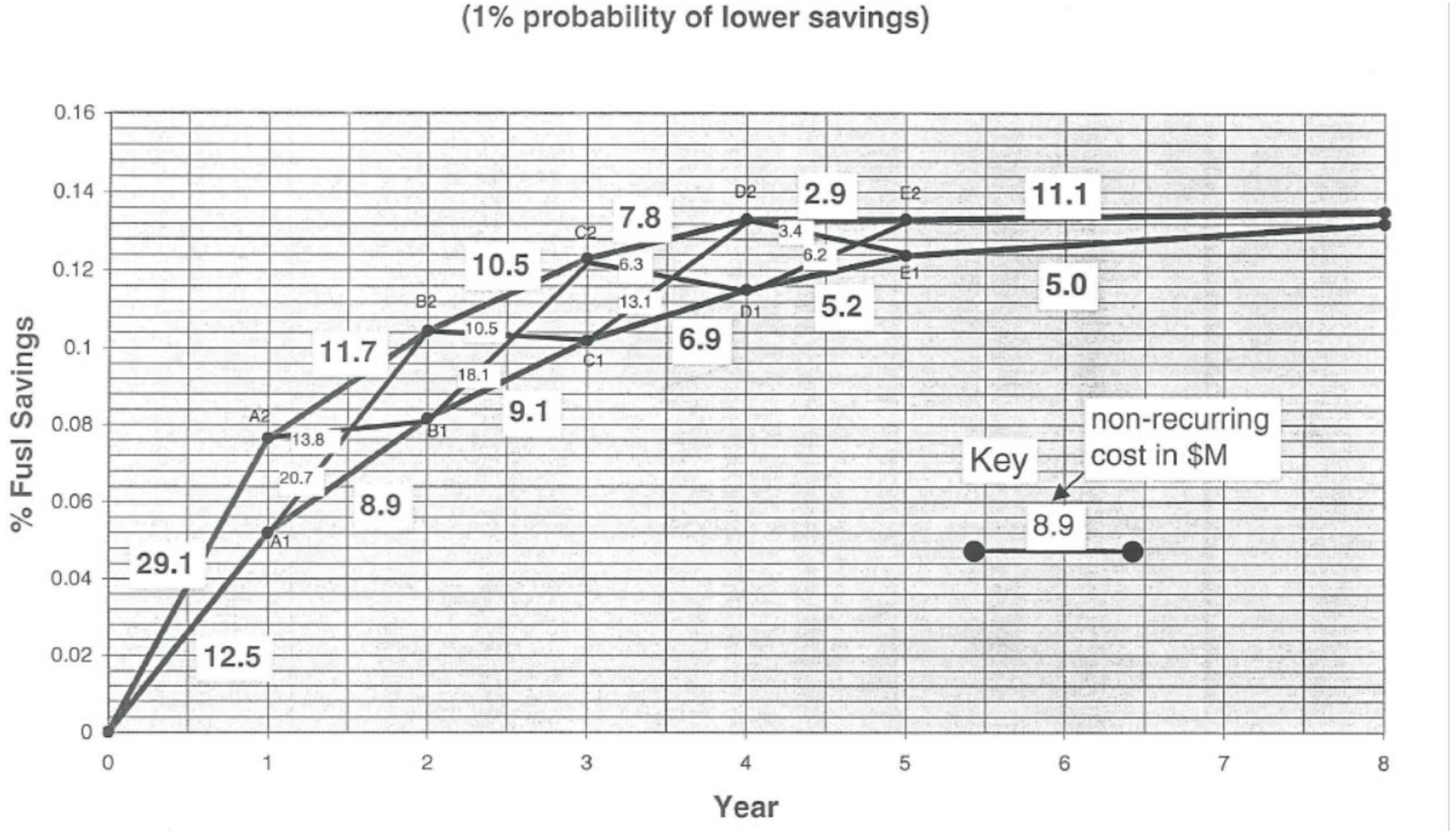
- Each point on the x axis corresponds to a different optimum mix
- “Best” mix is at around st dev = 6% svgs. For higer st dev, the increase in savings is small (24% versus 20% for 50th percentile) while the down side with negative savings is large 10% chance of svgs<0

Required investment by year by technology



- No equipment purchased

Investment options as a function of time (introducing composites to a fuselage)



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- Kassapoglou, C., "Selection of Manufacturing Technologies for Fuselage Structures for Minimum Cost and Low risk: Part B – Solution and Results", Journal of Composites Technology and Research, 21, 1999, pp. 189-196.
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From: Christos Kassapoglou <C.Kassapoglou@tudelft.nl>
Sent: Wednesday, April 24, 2024 10:59 AM
To: Ilcewicz, Larry (FAA) <Larry.Ilcewicz@faa.gov>
Cc: 'Andrew Pringle' <Andrew.Pringle@idp.wichita.edu>
Subject: RE: Small Airplane and Rotorcraft CMH-17 Design Needs

Saved Attachment: C:\Ilcewicz\CertIssu\DT&MaintWG\2011-WG\2020-Design Initiatives\Scottsdale2024-Inputs\ Design cosiderations for helicopters.pptx

Hi Larry, Attached is my presentation. I will try to connect about an hour early. Hopefully everything will run smoothly. Christos

From: Ilcewicz, Larry (FAA) <Larry.Ilcewicz@faa.gov>
Sent: woensdag 24 april 2024 18:37
To: Christos Kassapoglou <C.Kassapoglou@tudelft.nl>
Cc: 'Andrew Pringle' <Andrew.Pringle@idp.wichita.edu>
Subject: RE: Small Airplane and Rotorcraft CMH-17 Design Needs

Hi Christos, I checked with Andrew to ensure that you were sent the WebEx connection needed to virtually join the Design TG Meeting tomorrow. Your presentation will occur in the second hour of that meeting but it makes sense for you to join early to ensure that you can join the meeting and make your presentation when the time arises. In the even that you make the connection but have trouble controlling the presentation from your end, it also makes sense that you send me a copy of the charts so that we can show those charts from our end with you still talking them as we advance from chart to chart. Once I see you are present, I'll try to ensure you can be heard through a sound check. Best Regards, Larry

Mail: Federal Aviation Administration, 2200 S 216th St, 3W-450, Des Moines, WA 98198 USA Telephone: (206) 231-3147

From: Ilcewicz, Larry (FAA)
Sent: Wednesday, April 17, 2024 6:58 AM
To: Christos Kassapoglou <C.Kassapoglou@tudelft.nl>
Cc: Ashforth, Cindy (FAA) <Cindy.Ashforth@faa.gov>; Michelle Man <Michelle.Man@idp.wichita.edu>; Andrew Pringle <Andrew.Pringle@idp.wichita.edu>; John Tomblin <John.Tomblin@idp.wichita.edu>
Subject: RE: Small Airplane and Rotorcraft CMH-17 Design Needs

Non-Metallic AM Material & Process WG

CMH-17 Non-Metallic AM Material & Process WG – Spring 2024 Joint Coordination Meeting

Wednesday, April 24th @ 1:15pm – Room 2

Material & Process WG group meets the 2nd Thursday of the Month @ 10am EST / 7am PST

Next Meeting (Virtual) May 9th @ 10am EST / 7am PST

Co-Chairs:

Chloe McGuffin – Markforged

Eric K Moyer – Boeing

Fei Liang - Gulfstream

Non-Metallic AM Material & Process WG

CMH-17 Non-Metallic AM Material & Process WG – Spring 2024 Joint Coordination Meeting

Wednesday, April 24th @ 1:15pm – Room 2

Material & Process Working Group Objectives:

- Provide the framework of the overall process flow for polymer AM material qualification, machine qualification, facility qualification and part qualification.
- Provide guidance on key performance variable (KPV) identification and necessary KPV controls for polymer AM material qualification, machine qualification, facility qualification and part qualification.
- Provide guidance on employee training and quality assurance procedures for polymer AM material qualification, machine qualification, facility qualification and part qualification.
- Provide guidance on the use and incorporation of CMH-17 AM volume published data and processes into a company's production system.
- Update sections accordingly when developments in new feedstock materials and/or new polymer AM fabrication processes become available and mature for use in regulated applications

Non-Metallic AM Material & Process WG

CMH-17 Non-Metallic AM Material & Process WG – Spring 2024 Joint Coordination Meeting

Wednesday, April 24th @ 1:15pm – Room 2

Material & Process Working Group Key Future Work:

- Writing content for Selective Laser Sintering section(s) – need volunteers
- Complete terminology, abbreviations & nomenclature section(s) for M&P

Non-Metallic AM Material & Process WG

CMH-17 Non-Metallic AM Material & Process WG – Spring 2024 Joint Coordination Meeting

Wednesday, April 24th @ 1:15pm – Room 2

Material & Process Working Group Planned Meeting Agenda:

- Introductions
- Moving M&P meeting to start 1 hr later (i.e. 8am PST instead of 7am PST)
- Guidelines Carry-over: Sources of Variability (this may move)
- Fall YP2 Yellow Page Summarization w/ Proposed Disposition
- M&P Definitions – How To Deal with Industry Definitions (~20min)
- Review M&P Chapter/Section progress tracker (if time allows)

Potential Categories of Definitions

1. New/scratch definition. CHM-17 creates brand new definition.
2. Existing CMH-17 definition
   - Should if be fully copied in Volume 7 OR just referenced back to Volume
   - Should we "identify" CMH-17 carry over definitions as such?
3. Same name as existing CMH-17 definition BUT the definition is different.
4. Existing industry definition (i.e. ASTM 52900), used "as-is"
   - Should the definition be copied over and referenced OR just referenced.
5. Same name as existing industry definition BUT different definition.
   - Recommend denoting deviations from "industry" definitions as such.

Non-Metallic AM Material & Process WG

CMH-17 COMPOSITE MATERIALS HANDBOOK

M&P Definitions – How To Deal with Industry Definitions? (~20min)

Problem: The industry has already documented/defined common additive manufacturing terms (i.e. ISO/ASTM 52900). How should M&P capture these terms in our definition section?

Proposals:

- Do NOT include definition text, instead reference industry specification/source

Nozzle *– See ASTM Standard F3529 (References X.X.X.X)*

- Include definition text AND reference industry specification/source

Nozzle *– tip of the material extrusions head….. See ASTM Standard F3529 (References X.X.X.X)*

Open Questions:

- Are there any definitions that are NOT aligned with an industry specification OR with the definition from CMH-17 Volume 3.

Meeting Minutes

- Meeting started with group introductions and ice breaker exercise.
- Based on member feedback, presented proposal to move the start time of our monthly M&P back 1 hour (i.e. 8am PST start instead of the current 7am PST start)
  - No objections, Eric took action to send additional email with the goal to implement the new, later start time for June 13th Meeting.
- Group had long discussion on Sources of Variability, which was a carryover discussion from the earlier Guidelines meeting.
  - M&P to have more discussion on this topic in future working group meetings including working on a definition for variability and variation.

CMH-17 Volume 6 Revision A Planning Meeting

L. Gintert

04/24/2024

Proposed Agenda

- Introductions and Agenda Review - 5 min
- Brief overview of Vol 6 past, present and future - 20 min
- Volume 6A Proposed Task Groups and Plans - 25 min
- Results of Strategic Meetings, Team Plans/Discussion - 60 min
- Planning/Wrap-up - 10 min

Sandwich WG Goals Moving Forward

- Current Sandwich WG needs help populating new content consistent with other Volumes with combined contributions from global subject matter experts within CMH-17 (traditionally supporting other WGs and TGs)
- Ownership/maintenance of current content is out of balance compared to other WGs and associated Volumes
- Short term goal is to <u>initiate Volume 6 recruitment and engagement of new team members</u> leading up to face-to-face meetings in Scottsdale <u>and establish a plan based on team inputs</u> (note that proposed approach employs 5 TGs)
- Long term goal - establish a sustainable plan for Volume 6

Volume 6 Current Outline

- Chapter 1 General Information
- Chapter 2 Guidelines for Property Testing
- Chapter 3 Material Data
- Chapter 4 Design and Analysis of Sandwich Structures
- Chapter 5 Fabrication of Sandwich Structures
- Chapter 6 Quality Control
- Chapter 7 Supportability

Recent efforts to expand and balance outline; Chapter 4 division proposed

Present Revision A DRAFT

CMH-17 COMPOSITE MATERIALS HANDBOOK

- Chapter 1 General Information – Recent YP Ballot
  - Update as needed based on new content
  - Introduce sandwich disbond phenomena as a primary design consideration
  - Expand the discussion of damage tolerance as part of the introduction
- Chapter 2 Guidelines for Property Testing – Recent YP Ballot for Core Data protocol
  - Edited content for narrative
  - New test methods for Sandwich Disbond phenomena
  - Synopses of test methods to be added
- Chapter 3 Material Data
  - Core data protocol (requirements and review)
  - Published Core Data
  - Example sandwich attachment insert strength data
- Chapter 4 Design and Analysis of Sandwich Structures – Current initiative to divide Chapter 4 into 2 or 3 chapters.
  - Modified Outline to incorporate New Content on Disbond Analyses Tools and Damage Tolerant Design Approaches
  - Edited content for narrative in the chapter introduction (Sandwich Disbond and Damage Tolerance design philosophy discussion)
  - Improved introductory write-ups for sandwich-specific failure modes (face sheet wrinkling and shear crimping)
  - Example of threat levels (from AC20-107) applied to sandwich for design certification
  - New content for application of analyses methods and engineering solutions for Sandwich Disbond phenomena
- Chapter 5 Fabrication of Sandwich Structures
  - New content from NASA ACP program (process modeling)
- Chapter 6 Quality Control – Recent YP Ballot – resolution WIP
  - Edited content for narrative incorporating new technologies
- Chapter 7 Supportability
  - Edited content for narrative coordinated with revised sections in Vol 3
- Chapter 8 (NEW) Sandwich Design Case Studies – Recent YP Ballot – No Negatives!

Prior focus areas are shown in green font – before Outline Revision

CMH-17 VOL. 6A Updated DRAFT Outline

- Chapter 01 General Information
- Chapter 02 Guidelines for Property Testing
- Chapter 03 Material Data
- Chapter 04 Fabrication of Sandwich Structures
- Chapter 05 Quality Control
- Chapter 06 Design and Substantiation for Sandwich Structures
- Chapter 07 Internal Loads and Stresses
- Chapter 08 Analysis and Structural Design
- Chapter 09 Damage Assessment of Sandwich Structures
- Chapter 10 Supportability
- Chapter 11 Sandwich Design Case Studies
- Chapter 12 Supporting Data and Discussions

Key Points for Vol 6A

- Expanded discussion on damage tolerance and sandwich disbond phenomena as primary design considerations
- Established data review and acceptance protocols for published pedigree core data
- Divided Design and Analysis chapter into three chapters and added a NEW Chapter 9 for damage assessment of sandwich structures
- Coordination with new content from Vol 3 (new disbond analyses tools, repair, adhesive bonding and adhesives data, improved cross reference to/from other volumes)
- Added a new Chapter 11 for sandwich structures design case studies
- Revision of all chapters as needed and reorganization to align with Vol 3, adding Chapter 12 for design charts and supporting data

CMH-17 VOL. 6A
Detailed outline of new chapters 6 - 8

- **Ch 6 DESIGN AND SUBSTANTIATION FOR SANDWICH STRUCTURES**
  - 6.1 INTRODUCTION – **3 pages**
  - 6.2 DESIGN CRITERIA AND DAMAGE TOLERANCE – **9 pages (include sandwich disbond and related DT and design criteria)**
  - 6.3 SUBSTANTIATION FOR CERTIFICATION – **4 pages**
  - 6.4 SANDWICH PANEL FAILURE MODES – **12 pages**
- **Ch 7 INTERNAL LOADS & STRESSES**
  - 7.1 STIFFNESS AND INTERNAL LOADS – **9 pages**
  - 7.2 FLAT PANEL INTERNAL LOADS AND STRESSES - PRESSURE LOADING – **55 pages (~32 pages of charts)**
  - 7.3 CURVED SANDWICH PANEL INTERNAL LOADS AND STRESSES – **3 pages**
- **Ch 8 ANALYSIS & STRUCTURAL DESIGN**
  - 8.1 LOCAL STRENGTH ANALYSIS METHODS – **74 pages (19 pages of charts)**
  - 8.2 FLAT PANEL STABILITY ANALYSIS METHODS – **WAS 146 PAGES (move 90 pgs to “NEW CH 12” ~56 PAGES)**
  - 8.3 DESIGN OF FLAT RECTANGULAR SANDWICH PANELS UNDER COMBINED LOADS – **2 pages**
  - 8.4 DESIGN OF SANDWICH CYLINDERS – **39 pages (16 pages of charts)**
  - 8.5 WEIGHT-OPTIMIZED SANDWICH DESIGN – **12 pages (example component sizing for optimized weight)**
  - 8.6 FINITE ELEMENT MODELING OF SANDWICH STRUCTURE – **7 pages**

Word document with new outline was posted to the CMH-17 Sandwich Forum

CMH-17 VOL. 6A
Detailed outline of new chapter 9

CMH-17 COMPOSITE MATERIALS HANDBOOK

- **Ch 9 DAMAGE ASSESSMENT OF SANDWICH STRUCTURES** ***(May include structural-level testing/analyses and other damage types)***
  - 9.1 ENGINEERING DESIGN APPROACHES FOR SANDWICH DISBOND – **Proposed (15 pages?)**
    - 9.1.1 Introduction (Industry Best Practices - focused on assessment of damage verses pristine design - Holistic Approach)
    - 9.1.2 Load Cases for Disbond Problems (Standardized)
    - 9.1.3 Analysis Methods
      - 9.1.3.1 Energy-based (Rayleigh-Ritz)
      - 9.1.3.2 Cohesive Fracture Mechanics
      - 9.1.3.3 Linear Elastic Fracture Mechanics (CSDE and VCCT)
  - 9.2 ANALYSIS DEMONSTRATIONS FOR SANDWICH DISBOND – **Proposed (15+ PAGES? Likely to have subsections)**
    - 9.2.1 GAG combined with In-plane Loading (Uni-axial and bi-axial)
      - 9.2.1.1 Energy-based - NSE
      - 9.2.1.2 Cohesive Fracture Mechanics Mode I Approach - NIAR
      - 9.2.1.3 LEFM Linear Elastic Fracture Mechanics Mixed Mode Approach – Martin Rinker DTU/NASA – Point to Vol 3 for VCCT and CSDE
    - 9.2.2 Pure Bending Loading
      - 9.2.2.1 LEFM Load Case (4-Point Bending Case) - DTU
    - 9.2.3 Transverse Loading
      - 9.2.3.1 Flatwise Tension Loading of Beams and Panels – DTU

Volume 6, Rev A Working Draft Status

CMH-17
COMPOSITE MATERIALS HANDBOOK

CMH-17 Volume 6A - Files for Working Draft

Section - Subsection	Date of File
Chapter 01 General Information	
vol 6 chap 1_111620 LAG YP comments 030421	3/4/2021
Chapter 02 Guidelines for Property Testing	
Volume 6 Chapter 2 from Susan D and others updated insert data LAG 041520 changes accepted	3/23/2023
Chapter 03 Material Data	WORKING DRAFT CH3
Chapter 04 Fabrication of Sandwich Structures	WORKING DRAFT CH5
Chapter 05 Quality Control	
Vol. 6 - Ch. 6 Quality Control (Rev 4-10-2021) from Zhi LAG comments 041221	4/12/2021
Chapter 06 Design and Substantiation for Sandwich Structures	
Vol 6 Ch4 Rev A Intro and revised Outline content excerpts REDUCED SIZE LAG CHANGES ACCEPTED 122120	2/15/2023
Sections 4.1 - 4.4	
Chapter 07 Internal Loads and Stresses	WORKING DRAFT CH4
Sections 4.5, 4.7, 4.8	
Chapter 08 Analysis and Structural Design	WORKIONG DRAFT CH4
Sections 4.6, 4.9, 4.10, 4.11, 4.13, 4.12	
Chapter 09 Damage Assessment of Sandwich Structures	NEW CONTENT
Chapter 10 Supportability	
vol 6 chap 7_revised MZ_JFS	10/21/2019
Chapter 11 Sandwich Design Case Studies	
Volume 6 Chapter 8 Section 8.1 Introduction and 8.2_RK 032321	2/27/2023
Chapter 12 Supporting Data and Discussions	NEW CONTENT

- **Ch 6 CERTIFICATION & DESIGN CRITERIA** *(include design concepts/features, attachments, arrestment?)*
  - 6.1 INTRODUCTION – **3 pages**
  - 6.2 DESIGN AND CERTIFICATION – **9 pages (include sandwich disbond and related DT and design criteria)**
  - 6.3 CERTIFICATION – **4 pages**
  - 6.4 SANDWICH PANEL FAILURE MODES – **4 pages (does NOT include SW disbond failure modes)**
  - **include damage tolerance and design criteria and requirements and SW disbond failure modes (~12 pages)**
- **Ch 7 INTERNAL LOADS & STRESSES**
  - 7.1 STIFFNESS AND INTERNAL LOADS – **9 pages**
  - 7.2 FLAT PANEL INTERNAL LOADS AND STRESSES - PRESSURE LOADING – **55 pages (~32 pages of charts)**
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  - 8.2 FLAT PANEL STABILITY ANALYSIS METHODS – **WAS 146 PAGES (move 90 pgs to "NEW CH 12" ~56 PAGES)**
  - 8.3 DESIGN OF FLAT RECTANGULAR SANDWICH PANELS UNDER COMBINED LOADS – **2 pages**
  - 8.4 DESIGN OF SANDWICH CYLINDERS – **39 pages (16 pages of charts)**
  - 8.4 WEIGHT-OPTIMIZED SANDWICH DESIGN – **12 pages (example component sizing for optimized weight)**
  - 8.6 FINITE ELEMENT MODELING OF SANDWICH STRUCTURE – **7 pages**
- **Ch 9 DAMAGE ASSESSMENT OF SANDWICH STRUCTURES** *(May include structural-level testing/analyses and other damage types)*
  - 9.1 ENGINEERING DESIGN APPROACHES FOR SANDWICH DISBOND – **Proposed (15 pages?)**
    - 9.1.1 Introduction (Industry Best Practices - focused on assessment of damage verses pristine design - Holistic Approach)
    - 9.1.2 Load Cases for Disbond Problems (Standardized)
    - 9.1.3 Analysis Methods
      - 9.1.3.1 Energy-based (Rayleigh-Ritz)
      - 9.1.3.2 Cohesive Fracture Mechanics
      - 9.1.3.3 Linear Elastic Fracture Mechanics (CSDE and VCCT)
  - 9.2 ANALYSIS DEMONSTRATIONS FOR SANDWICH DISBOND – **Proposed (15+ PAGES? Likely to have subsections)**
    - 9.2.1 GAG combined with In-plane Loading (Uni-axial and bi-axial)
      - 9.2.1.1 Energy-based - NSE
      - 9.2.1.2 Cohesive Fracture Mechanics Mode I Approach - NIAR
      - 9.2.1.3 LEFM Linear Elastic Fracture Mechanics Mixed Mode Approach – Martin Rinker DTU/NASA – Point to Vol 3 for VCCT and CSDE
    - 9.2.2 Pure Bending Loading
      - 9.2.2.1 LEFM Load Case (4-Point Bending Case) - DTU
    - 9.2.3 Transverse Loading
      - 9.2.3.1 Flatwise Tension Loading of Beams and Panels – DTU

CMH-17 VOL. 6A

Proposed Task Groups for Content Development

CMH-17 COMPOSITE MATERIALS HANDBOOK

- Chapter 01 General Information
- Chapter 02 Guidelines for Property Testing
- Chapter 03 Material Data
- Chapter 04 Fabricatio
- Chapter 05 Quality Co
- Chapter 06 Design an
- Chapter 07 Internal Lo
- Chapter 08 Analysis and Structural Design
- Chapter 09 Damage Assessment of Sandwich Structures
- Chapter 10 Supportability
- Chapter 11 Sandwich Design Case Studies
- Chapter 12 Supporting Data and Discussions

SANDWICH TG1

The first three chapters are connected in a number of ways and need close coordination as they cover *intro* (Ch1) then *testing* for constituent/material/panel properties (Ch2), and then the *materials data* (Ch3).

CMH-17 VOL. 6A

Proposed Task Groups for Content Development

- Chapter 01 General Information
- Chapter 02 Guidelines for Property Testing
- Chapter 03 Material Data
- **Chapter 04 Fabrication of Sandwich Structures**
- **Chapter 05 Quality Control**
- Chapter 06 Design an
- Chapter 07 Internal Lo
- Chapter 08 Analysis a
- Chapter 09 Damage A
- Chapter 10 Supportab
- Chapter 11 Sandwich Design Case Studies
- Chapter 12 Supporting Data and Discussions

SANDWICH TG2

Then Fabrication of Sandwich Structures (Ch4) is essentially the processing (covering all sandwich-unique M&P) authored by Dan Ruffner - and he wants to lead the update. The following chapter (Ch 5) is Quality Control (and it really needs help!) and it should be closely aligned with the M&P section

CMH-17 VOL. 6A

Proposed Task Groups for Content Development

- Chapter 01 General Information
- Chapt
- Chapt
- Chapt
- Chapter 05 Quality Control

<u>SANDWICH TG3</u>

Then I think the (pristine) structure design and analyses chapters originally from Mil-Hdbk-23 (Ch 6 - 8) - mostly editorial changes

The last section is the *supporting data* (Ch12) cut and pasted from other design and analysis sections – detailed editorial review needed

- Chapter 06 Design and Substantiation for Sandwich Structures
- Chapter 07 Internal Loads and Stresses
- Chapter 08 Analysis and Structural Design
- Chapter 09 Damage Assessment of Sandwich Structures
- Chapter 10 Supportability
- Chapter 11 Sandwich Design Case Studies
- Chapter 12 Supporting Data and Discussions

CMH-17 VOL. 6A

Proposed Task Groups for Content Development

- Chapter 01 General Information
- Chapter 02 Guidelines for Property Testing
- Chapter 03 Material Data
- Chapter 04 Fabrication of Sandwich Structures
- Chapter 05 Quality Control
- Chapter 06 Design and Substantiation for Sandwich Structures
- Chapter 07 Internal Loads and Stresses
- Chapter 08 Analysis and Structural Design
- Chapter 09 Damage Assessment of Sandwich Structures
- Chapter 10 Supportab
- Chapter 11 Sandwich
- Chapter 12 Supportin

SANDWICH TG4

Updated content for *design and substantiation of pristine sandwich structure* (Ch6) and new content covering *assessment of damaged sandwich* structures (Ch9)

CMH-17 VOL. 6A

Proposed Task Groups for Content Development

- Chapter 01 General Information
- Chapter 02 Guidelines for Property Testing
- Chapter 03 Material Data
- Chapter 04 Fabrication of Sandwich Structures
- Chapter 05
- Chapter 06 … tures
- Chapter 07
- Chapter 08
- Chapter 09 Damage Assessment of Sandwich Structures
- Chapter 10 Supportability
- Chapter 11 Sandwich Design Case Studies
- Chapter 12 Supporting Data and Discussions

SANDWICH TG5

Supportability (Ch10) and Case Studies (Ch11) are sort of aligned in content already, but the update also needs to be coordinated with V3 Ch12-14, so I think that is our SANDWICH TG5

Task Groups and Initial Thoughts on Tasking

Proposed task groups:

- **TG 1** (Ch 1-3: General Info, Property testing, Material Data) - Testing WG and S. Jones already working on updates
- **TG 2** (Ch 4-5: Fabrication of Sandwich struct, Quality Control) - Ruffner and Chen and Ward had previously started the updates
- **TG 3** (Ch 7-8,12: Structural Design and Analyses - legacy content with supporting data/charts moving to Ch 12) lots of MSWord skills and checking needed. There are also updates initiated and planned, including new content on different materials, product types and analyses
- **TG 4** (Ch 6, 9: Design and Substantiation (Pristine) and Damage Assessment of Sandwich Structures) – Update design philosophy and Ch 9 new content with topics and developments ongoing from efforts led by Ronald, Christian, Hoyt, and Waruna
- **TG 5** (Ch 10-11: Supportability and Sandwich Design Case Studies) - Eric and Steve were both instrumental in V3, C14 w/comments and inputs

TG Leaders to be identified and modified as needed by each TG

Strategies and Planning

- Strategy review
- TG Lead commitments
- Recurring focused meetings planning
- Monthly virtual meetings have been demonstrated to be effective in recent efforts and assistance is available to TGs as needed for planning
- Thoughts/Feedback?

Expanded Team Leader Initial Candidates

- Cindy Ashforth
- Larry Ilcewicz
- Dan Adams (TG 1)
- Shannon Jones (TG 1)
- John Moylan (TG 1)
- Dan Ruffner (TG 2)
- Steve Ward (TG 2)
- Zhi Chen (TG 2)
- Larry Gintert (TG 3)
- Michelle Thomsen (TG 3)
- NIAR/Secretariat Support/Michelle Man or Andrew Pringle? (TG 3)
- Ronald Krueger (TG 4)
- Waruna Seneveratne (TG 4)
- Christian Bergreen (TG 4)
- Hoyt (TG 4)
- Eric Stenne (TG 5)
- Steve Starnes (TG 5)
-

Other Thoughts…

- Any additional teammates for new content on different materials, product types & analyses?
- Consider finite sub-TG tasks for various applications (spacecraft vs small airplanes) and part types (interiors, radomes, fairings)?
- New methods development can gain from other TG leaders on this page (share strategies recognizing a need for recruiting special skills, priority management, benefits from corporate member leadership).

Wrap-up and Actions

BACKUP SLIDES

CMH-17 VOL. 6A
Revised Vol. 6A Chapter Outline

CMH-17 COMPOSITE MATERIALS HANDBOOK

Page counts from Original Release Volume 6

- Chapter 01 General Information – **20 pages**
- Chapter 02 Guidelines for Property Testing – **23 pages**
- Chapter 03 Material Data – **36 pages**
- Chapter 04 Fabrication of Sandwich Structures – **62 pages (to be updated)**
- Chapter 05 Quality Control – **7 pages (to be updated)**
- Chapter 06 Design and Substantiation for Sandwich Structures – **32 pages (to be updated)**
- Chapter 07 Internal Loads and Stresses – **35 pages (32 pages of charts to NEW Ch 12)**
- Chapter 08 Analysis and Structural Design – **155 pages (125 pages to NEW Ch 12)**
- Chapter 09 Damage Assessment of Sandwich Structures – **30+ pages (new content)**
- Chapter 10 Supportability – **24 pages (to be updated)**
- Chapter 11 Sandwich Design Case Studies – (currently 4 pages - to be updated)
- Chapter 12 Supporting Data and Discussions (Structural Design and Stability Analysis Charts - ~157 pages)

Blue font indicates proposed changes from Original Release

Sandwich Application-Based Solutions

CMH-17 COMPOSITE MATERIALS HANDBOOK

- Tire rupture impact to flaps
- Heat-induced and environmental damage to nacelles
- Rotorcraft main rotor blade lessons learned – repair induced damage
- Arresting phenomena – Examples
  - Relatively constant load conditions (where point design loads are reasonable assumptions) require arresting characterization via physical features
  - Loads distribution management
  - Structural damage capability
- Fuselage, wing and empennage structures – Non constant cross-section and loading
- Flaps, other control surfaces and rotor blades loading examples – Critical load cases

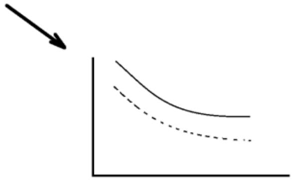
Industry SME inputs needed here!!!

SANDWICH DISBOND EFFECT ON DAMAGE TOLERANCE (FROM DTU 2023 WORKSHOP)

Example Solutions A, B, C … (A1 and F1 featured examples)

(Damage Threats – Process Failures (inner and outer face sheets), Blunt Impacts, Severe Impacts (impacts apply to outer face sheets))

- Analysis – Loads, Structural Design, Boundary Conditions
  - Database needs - - Damage Definition (size, geometry)
    - Design Variables (laminate details – thickness, layups, etc.)
    - Material Properties Needed (fracture, stiffnesses, *other failure modes*, etc.)
    - Design Criteria Guidelines
  - Problem Definition – for the range of variables
    - Residual Strength: ***A*** Ultimate, ***B*** Largest Flaw that won't grow – *f(problem variables)* , ***C*** Limit
  - Further Envelope Damage Types
    - Impact, Core Crush - - Blunt Impact Threat (K_{1C})
  - Inspection (Design Specific)
    - Most important to designs where inspection is needed for COS



FEATURED SANDWICH DISBOND EXAMPLES

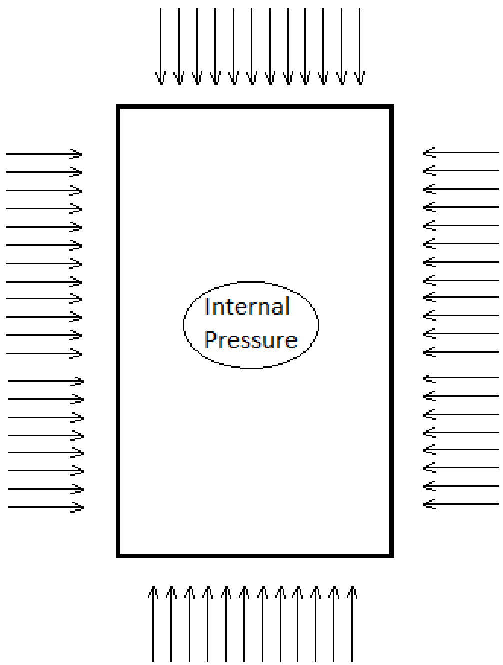
Current Studies

- **Uniform load (e.g., internal pressure and in-plane load)**

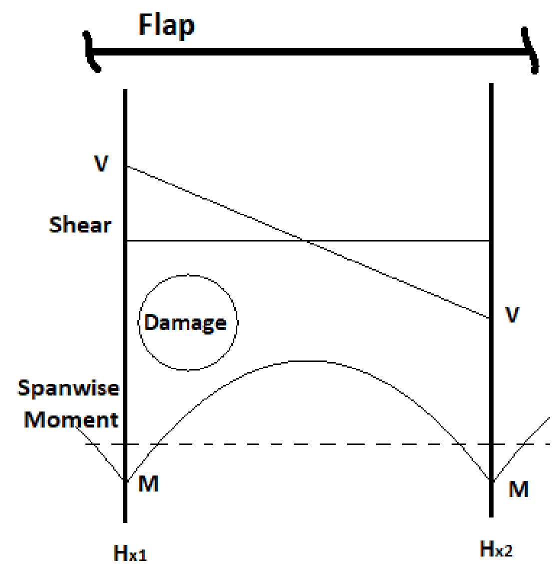
Future Studies

- **Non-uniform, varying load to represent real application cases (e.g., wing flap)**

A1



F1



Meeting Minutes
Sandwich Working Group Meeting, Scottsdale, AZ, April 24, 2024.

The Sandwich Working Group (WG) meeting was called to order at 1:15pm (AZ-time).

Participants in the room (45-50 people) introduced themselves.

Larry Gintert provided an overview of the Sandwich WG and the history of Vol. 6 reaching back to Mil-Hdbk-23 which was discontinued in 1981. The Sandwich WG owns the entire Vol. 6 which replaced Mil-Hdbk-23 and was released in 2012. Thanks were expressed for Melanie Violette and Rachael Andrulonis efforts to finalize the draft in preparation for the original release.

Larry pointed out that we are not working towards Volume 3 Revision H (the primary current focus of the PMC Coordination group) and thus our activities are not time critical. However, we need to identify willing subject matter experts to help with the planned updated/revised release of Vol. 6A. This meeting was intended to be an open discussion about the path forward on development of Rev A content for Volume 6. Open discussion was encouraged.

Larry Gintert introduced co-chair Zhi Chen (not in attendance) as well as the Core Data Task Group (TG) and its co-chairs Eric Stenne and Shannon Jones. This TG is part of the current Sandwich WG addressing the topic of core data publication in the Handbook, whose activities are currently paced by and linked to an FAA-funded program on core qualification at NIAR.

Vol. 6 is not intended to be polymer specific. Tanila asked about closed cell foam cores. These are indeed intended to be included in Vol. 6 along with other core materials and not just limited to honeycomb.

Vinay Goyal (The Aerospace Corp.) asked about NDE. This is currently discussed in connection with quality control within Vol 6.

Larry Gintert reviewed the current proposal planned for an integrated TG approach for Vol 6 Revision A using the current draft outline, showing the different chapters and how these will be developed and or revised. After some discussion, it was agreed that a minor change to the proposed work split would make more sense (specifically for TG3 and TG4, moving Ch6 to be worked as part of TG4) as follows:

Task Group 1 will focus on *testing* for constituent/material/panel properties (Ch2), and then the *materials data* (Ch3). The CMH-17 Testing WG (John Moylan) already posted content on the Forum with regard to existing test methods. Testing for core is progressing under the FAA-funded program on core qualification at NIAR (Shannon Jones).

Task Group 2 will focus on the Fabrication of Sandwich Structures (Ch4) covering all sandwich-unique M&P authored by Dan Ruffner - and he wants to lead the update. The following chapter (Ch 5) is Quality Control and it should be closely aligned with the M&P section. Concerns raised about the Climbing Drum Pell test will be addressed here or in ch2.

Task Group 3 will focus on the two (pristine) structure design and analyses chapters (Ch 7 - 8). The focus also includes the last section *supporting data* (Ch12) that needs to be cut and pasted from the previous design and analysis sections in Vol 6. Therefore, TG3 should have oversight as ch12's content complements Ch 7 - 8. The task involves more word processing and may be less technical and may be taken over by the CMH-17 secretariat.
Eric asked asked about the graphs in cp12 – old Vol. 6 ch4 – and the underlying equations. Are these graphs still valid? They were developed decades ago with certain assumptions. Are these assumptions still valid? Is anyone using these equations? Eric Stenne and Stefan Kloppenburg are still using them. What is still useful?

Task Group 4 will focus on the new content covering *design and substantiation of pristine sandwich structures* (Ch6) and *assessment of damaged sandwich structures* (Ch9). Content will include analysis examples of sandwich face sheet core disbonding. The team will include Ronald Krueger, D.M. Hoyt, Christian Berggreen, Waruna Seneviratne and Vishnu Saseendran.

Task Group 5 will focus on Supportability (Ch10) and Case Studies (Ch11) which are already aligned in content. These chapters need to be updated and harmonized with Vol 3H Ch12-14. Jeremy Jacobs may provide NASA examples for Ch11. Interiors may be covered by TG 5.

Eric Stenne mentioned that with the proposed task group structure TG4 versus TG5 things appear decoupled. Shannon mentioned that *assessment* in the heading for Ch. 9 may be misleading and may cause Eric to believe there is a decoupling. This *assessment* is not related to supportability. Hoyt and Eric discussed and came to a possible resolution that we may need to wordsmith chapter titles. Consider retitling of Chapter 9 to avoid confusion moving forward.

Eric Stenne asked questions about how we will cover validity of the legacy charts and curves as they pertain to assumptions made in the analysis methods, etc. This topic was agreed to be taken to the Executive Committee for guidance. Discussion ensued about whether people use those equations and charts, and a few acknowledged they do. It was mentioned that MIL-HDBK-23 while cancelled, can still be obtained and used if desired.

Additional questions captured during the discussion follow:

- Question was asked about properties that are higher level building block/panel data, and where that data will be housed, if included.
- How are we moving forward? Monthly virtual meetings? Ask Michelle for support.

A sheet/roster was passed around for members to indicate which TG they are interested in. The results from that sheet (including subsequent email correspondence) are shown below:

Volume 6 Revision A Task Group Volunteers

Name	TG1	TG2	TG3	TG4	TG5
Bazle Hageue			x		x
Shannon Jones	x				
Daniel Rust		x			
France Theriault	x	x			
James Matheson			x	x	
Eric Stenne					x
Tiffany Radford		x			
Stefan Kloppenborg	x				
Jake Gibbs	x	x			
Amit Chib				x	
Cezar Moisiade				x	
Eric Pomerleau			x	x	
Amanda Cordes	x				
Lisa McHugh	x	x			
Vinay Goyal	x	x			
Nicole Stahl	x	x			
Brock Strunk				x	x
Pouja Shah			x		
Joshua Graham			x		
Alexandra Desautels	x	x			
Hossien Ghiasi			x	x	
Kevin Dupuis	x	x			
Amanda Panikowski		x			
Steve Starnes					x
Nihar Desai				x	x
Isabelle Paris				x	x

Following CMH-17 members expressed their interest in participating in the task groups before and after the meeting:

- Alice MARIN Airbus Operations alice.marin@airbus.com Virtual
- Benoit Morlet Dassault-Aviation benoit.morlet@dassault-aviation.com In-person
- Kevin Dupuis Syensqo kevin.dupuis@syensqo.com In-Person
- Richard Liou Collins Aerospace richard.liou@collins.com In-Person

There is no timeline and no target, but a proposal will be drafted and sent to Leadership for consideration including a start and target completion date for each TG. We need to make sure we support the end user. Projected release for Vol 6A is in the 2026–2027-timeframe based on charts from the CMH-17 Secretariat.

Notes from the DTU 2023 workshop were presented briefly with other future topics presented and discussed resulting in the following notes taken:

- Coverage for other applications than aircraft, spacecraft, finite task groups focused on interiors, radomes, fairings, etc.
- Sandwich Application Based Solutions
- Tire rupture impact to flaps
- Heat induced environmental damage to nacelles
- Rotorcraft MRB lessons learned, repair induced damage (FWT samples from blades that need to be then repaired)
- Examples of arresting phenomena

- relatively constant load conditions require characterization via physical features
- loads distribution management
- -structural damage capability
- Fuselage, wing, and empennage structures non constant cross sections and loading
- Flaps, other control surfaces and rotor blades loading examples critical load cases.

Slides will be shared on the Sandwich Forum.

Meeting adjourned at roughly 3:15pm.

Safety Management Working Group

Joint CMH-17 Meeting

April 2024

Scottsdale, AZ

CMH-17

COMPOSITE MATERIALS HANDBOOK

Agenda

April 24, 2024
3:30-5:30 PM

- Welcome
- Disposition of Significant 2023 Fall YP1 Comments
- Efforts to Content for Rev H
- Candidate Future Initiatives
- Closure/Actions

Safety Management Working Group

Chairs:

Dr. Larry Ilcewicz, FAA Chief Scientific and Technical Advisor for Advanced Composite Materials

Cindy Ashforth, FAA Senior Technical Specialist for Advanced Composite Materials

+ Significant assistance from Charlie Seaton, FAA contractor, supporting content development and industry reviews

Overall Goal:

Describe safety management principles and how they are applied to aviation products and document best practices to promote standardization in aircraft certification and in aviation workforce education

Content:

Volume 3 Chapter 17 “Structural Safety Management”

Task Groups: (currently writing content in V3 Chapters 6, 12, and 13)

- Durability and Damage Tolerance
- Disbond and Delamination

For Rev H:

- Highlight content in other sections of the handbook that support safety management needs
- Define standards for a composite structural engineering technology (CSET) safety awareness course

V3 Chapter 17 Outline

- Chapter 17 addresses Safety Management Principles, which are used by industry and regulatory agencies to ensure continued operational challenges and other indications of safety concerns
- Some significant additions were made to Chapter 17 in several locations (shown in red) to reference Revision H content that helped fill previously identified needs
- Section 17.7 is new content

17.1 Introduction
- 17.1.1 Background
- 17.1.2 Purpose and scope

17.2 Safety risk management overview
- 17.2.1 Definitions
- 17.2.2 Process of safety risk management
- 17.2.3 Hazard identification and initial safety assessment
- 17.2.4 Risk analysis and strategies
- 17.2.5 Risk assessment and mitigation actions

17.3 Structural safety and regulations
- 17.3.1 Sources of information
- 17.3.2 Regulations
- 17.3.3 Guidance documents

17.4 Structural safety assessment considerations
- 17.4.1 Design
- 17.4.2 Manufacturing
- 17.4.3 Maintenance
- 17.4.4 Operations
- 17.4.5 Airworthiness requirements
- 17.4.6 Structural integrity
  - 1.7.4.6.1 Life cycle considerations
- 17.4.7 Illustration
  - 1.7.4.7.1 Flight 261

17.5 Structural safety management procedure
- 17.5.1 Describe structure
- 17.5.2 Identify unsafe conditions and damage threats
- 17.5.3 Analyze risk
- 17.5.4 Assess risk
- 17.5.5 Mitigate risk

17.6 Structural safety management applications
- 17.6.1 Application: implication of less reliance on OEMs for repaired parts
- 17.6.2 Application: nonconforming extensive repair involving metal bonding
- 17.6.3 Application: nonconforming extensive repair involving composite repair

17.7 Structural safety awareness course structure

V3 Section 17.7

- New Section, 17.7 “Structural Safety Awareness Course Structure” provides a standard, including major discussion points by topic, for developing a course in composite structural engineering technology (CSET)
- Parties developing CSET courses should cover the content in Section 17.7, highlighting the key points for each section

17.7 Structural Safety Awareness Course Structure

CSET Subject 1. Introduction and Challenges

17.7.1.1	Composites Overview
17.7.1.2	Challenges
17.7.1.3	Integrated Product Development Teams (IPDT/IPT)

CSET Subject 2. Materials and Processes

17.7.2.1	Material and Process (M&P) Control
17.7.2.2	Defects and Damage
17.7.2.3	Protection of Structure
17.7.2.4	Manufacturing Implementation
17.7.2.5	Maintenance Implementation

CSET Subject 3. Design

17.7.3.1	Structural Design Details
17.7.3.2	Design Considerations for Manufacturing and Maintenance
17.7.3.3	Other Design Considerations
17.7.3.4	Design Requirements, Criteria and Objectives
17.7.3.5	Lamination Theory and Design
17.7.3.6	Composite Analysis Methods
17.7.3.7	Composite Material Allowables, Design Values, and Knockdown Factors
17.7.3.8	Structural Bonding
17.7.3.9	Structural Bolted Joints

CSET Subject 4. Structural Substantiation

17.7.4.1	Regulations and Guidance
17.7.4.2	Certification Approaches and Related Considerations
17.7.4.3	Damage and Defects
17.7.4.4	Building Block Testing and Analysis
17.7.4.5	Large Scale Testing Considerations

CSET Subject 5. Manufacturing Considerations

17.7.5.1	Quality Control
17.7.5.2	Certification Conformity Process
17.7.5.3	Manufacturing Defect Disposition

CSET Subject 6. Maintenance Considerations

17.7.6.1	Inspection and Maintenance
17.7.6.2	Structural Repair Development and Substantiation
17.7.6.3	Teamwork
17.7.6.4	Repair Techniques

CSET Subject 7. Other Subjects

17.7.7.1	Flutter and other aeroelastic instabilities
17.7.7.2	Crashworthiness
17.7.7.3	Fire Safety
17.7.7.4	Lightning Protection

Safety Management Working Group

Other Goals:

- Add guidelines for structural modifications involving composites
  - Moved to SAE Tasking
  - May still require CMH-17 detailed background in the future
- Add guidelines for composite design process (moved to GWG Chapter 7)
- Add guidelines for technology readiness (moved to GWG Chapter 7)

Fall 2023 Yellow Page Review

Section 17.7 Structural Safety Awareness Course Structure

COMPOSITE MATERIALS HANDBOOK

Section 17.7

Section 17.7 is new for Revision H

- Sections 17.7.3.5 – 17.7.7.4 had negative votes in first ballot, was revised, and submitted for votes (Fall 2023 YP1)
- Earlier sections had previously been submitted with all comments resolved

Results of Fall 2023 YP1 Voting and Feedback

TOTAL VOTERS	**36**
Affirmative	12
Affirmative with Comment	3
Negative with Comment	4
Abstain	17

Negative Vote and Suggested Resolution

Those comments not listed were minor and adopted in the final draft (e.g., missing headings in outline, minor word smithing)

17.7.3.7 Composite Material Allowables, Design Values, and Knockdown Factors

- Was: *Specification limits are determined using the data used to compute the material allowables; each batch of material is compared to these specification limits to detect a failure of the M&P controls*
- Comment: Not all spec limits are allowables and not all allowables are spec limits. Often there is minimal overlap when considering test method, configuration, environment, etc. Is the intent for this to be "lamina" material allowables?
- Resolution
  - Replaced text with: *Any changes after allowables creation need to be assessed. The data obtained in the material qualification program such as averages and standard deviations should form the basis for establishing specification limits. Each batch of material is compared to these specification limits to detect a failure of the M&P controls.*
  - Rationale: Borrowing verbiage from existing CSET Module 3.7, Slide 42

Significant Affirmative with Comment Vote and Suggested Resolution

17.7.3.7 Composite Material Allowables, Design Values, and Knockdown Factors

- Was*: Item 1 “Difference between an allowable and a design value” with multiple sub-bullets*
- Comment: Four comments with some conflicting concerns about the definitions and discussions.
- Resolution
  - Replaced all sub-bullets with three new ones:
    - *Regulations refer to "material strength and design values." The term "allowables" is not used in the regulations, but is common vernacular in the aviation industry.*
    - *Material Allowable – A bulk material property derived from the statistical reduction of data from a stable process. The amount of data required to derive these values is governed by the statistical significance (or basis) and methods. Application of material allowables may require additional considerations for use in design.*
    - *Design Value – A material or structural property that is established to represent the finished part property. These numbers are typically based on material allowables and adjusted, using building block tests as necessary to account for the range of part geometric features (e.g., holes, notches, surface finish) and in-service environmental conditions (e.g., temperature, moisture, and fluid). Design values are used in analysis to compute structural design margin (i.e., margin of safety).*
  - Rationale: This version of the definitions of Allowable and Design Value are accepted by the FAA

Negative and Significant Affirmative with Comment Votes and Suggested Resolution

17.7.3.7 Composite Material Allowables, Design Values, and Knockdown Factors

- Was: *Item 5 "Statistical requirements for material allowables" with multiple sub-bullets*
- Comment: Two negative and three affirmative comments with concerns about inconsistency in the terms "values" and "allowables" as well as definitions for them Also requested retitling of the section.
- Resolution
  - Retitled section and replaced all sub-bullets with three new ones:
    5. *Statistical requirements for material strength and design values*
       - *The regulatory requirements do not specify statistical tools, but define the required statistical reliability for material strength and design values to minimize the probability of structural failures due to material variability*
       - *Design values must assure material strength with a reliability of 99 percent probability with 95 percent confidence for single load-carrying members of an assembly or 90 percent probability with 95 percent confidence for redundant structure*
       - *The shape of the statistical distribution of the data affects the final material allowables*
       - *Material allowables must reflect all sources of material and process variability such as deviations from multiple batches of material and multiple production runs*
  - Rationale: The first two bullets use wording directly from the regulations

Open to discussion – does this address all concerns? Do we need another discussion on "allowables" versus material strength and design values, or is the discussion in item 1 sufficient?

Negative and Significant Affirmative with Comment Votes and Suggested Resolution

17.7.3.7 Composite Material Allowables, Design Values, and Knockdown Factors

- Was: *Item 5 "Difference between an allowable and a design value" with two sub-bullets on*
  - *Statistical basis for design values is primarily affected by geometry and location criticality for category 1 defects and damage*
  - *Larger categories 2-4 defects and damage states substantiated typically with larger subcomponents, exhibit wider variability in assumptions*
- Comment: One negative and two affirmative comment regarding implication of these sub-bullets.
- Resolution
  - Deleted bullets
  - Reasoning: Too detailed for this discussion

Negative Vote and Suggested Resolution

17.7.3.7 Composite Material Allowables, Design Values, and Knockdown Factors

- Was*: Item 6 “Shared databases and equivalence” with sub-bullet*
  - *To use a shared database, the end-user must demonstrate equivalence by showing that processing the same material at their location yields the same statistical distributions as the original data*
- Comment: “Same statistical distributions" does not recognize use of judgment as discussed in other parts of the handbook.
- Resolution
  - Reword to: *To use a shared database, the end-user must demonstrate equivalence by showing that processing the same material at their location yields the statistically equivalent properties*
  - Reasoning: Readers can go to the appropriate section in the handbook to find equivalence requirements

Negative Vote and Suggested Resolution

17.7.3.8 Structural Bonding

- Was: *Opening summary paragraph that defined three types of bonding but did not differentiate the difference with co-curing relative to the other two.*
- Comment: Add caveat here to address co-cured joints not always being considered as bondlines.
- Resolution
  - Reword to:
    In theory, there are three types of bonding processes – co-curing, co-bonding, and secondary bonding. Co-curing occurs during initial part fabrication, where two laminates are fabricated as one component and all cured at once. It is not treated as a "bond" in FAA guidance, although it carries many of the attributes and expectations associated with bonded joints. Co-bonding and Secondary Bonding both require at least one surface to be cured (or metallic), such that the surface to be bonded requires activation to generate a new chemical bond with the adhesive.

    Shear load capability is affected by structural design details, such as adhesive thickness and relative magnitude of moduli and thicknesses. The three methods for joining composite or composite-to-metal parts may use a variety of configurations. Design must provide resistance to creep or fatigue of the bond (References 17.7 (d) Section (TBD), 17.7.3.8). All bonded joints can have the same potential manufacturing defects that exist for composite lamination, including porosity, disbonds, delamination and inclusions.
  - Reasoning: Better matches other guidance and handbook content

Negative Vote and Suggested Resolution

17.7.4.1 Regulation and Guidance

- Was: Item 2 “Structural substantiation and proof of structure” bullet:
  - *Any damage that reduces strength below ultimate load must be repaired when found*
- Comment: Revise by adding to the end "before returning the aircraft to service" as the statement conflicts with the practice of using "ferry flights" to return an aircraft to a maintenance base. The statement is also not applicable to military aircraft.
- Resolution
  - Reword to add “*before returning the aircraft to service*” but no modification for military aircraft.

Negative Vote and Suggested Resolution

17.7.4.1 Regulation and Guidance

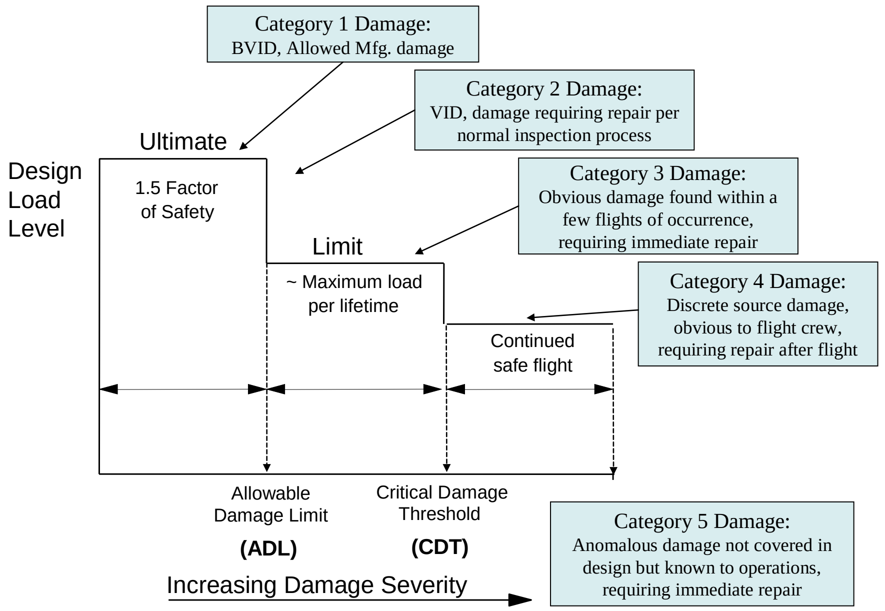
- Was: Item 3 “Static strength” bullet
  - *Fatigue and damage tolerance substantiation begins with a threat assessment and definition of associated damages (References 17.7 (d) and Volume 3 Section 12.3.1)*
- Comment: Affirmative comment to remove reference. Affirmative comment “The third bullet under Static Strength relates to fatigue and damage tolerance substantiation. Should it be deleted or moved into the Fatigue and Damage Tolerance area”

  Resolution
  - Removed reference and moved bullet to Item #4 for F&DT, but the entire static strength section needs to be revisited because it includes more bullets related to F&DT but completely misses the emphasis on the fact that damage tolerance begins during static strength substantiation

Negative Votes and Suggested Resolutions

17.7.4.3

- Was: *Listed Categories of damage with brief descriptions*
- Comment: Suggest simply deleting these sub-bullets since the categories of damage are clearly defined in reference 17.7(a). Trying to accurately define categories of damage in short bullets is not easy….
- Resolution
  - Added figure showing categories 1 through 5 based on detectability and severity (from AC20-107B)
  - Directed reader to AC20-107B for a more complete description of categories
  - Modified cover sentence: *Defects and damage threats are classified into five categories based on the likelihood of occurrence, detectability, and possible severity of event. Further detail available in Reference 17.7 (a)*



Negative Votes and Suggested Resolutions

17.7.4.4 (#2, Fifth Bullet)

- Was: *Evaluating material and process variability for each failure mode can influence design values. For example, coupon and element tests with similar failure modes may have interacting failure modes that can lower strength at a larger scale*
- Comment: I'm still not sure I understand this [second sentence]. We are talking about material and process variability, not interacting failure modes. Either delete this sentence or add clarification. It seems to imply that the results of the coupon and element tests may not be valid since they don't include interacting failure modes that can occur at a larger scale? Normally we think in terms of critical failure modes and evaluate them at various levels of the building block. Critical failure mode interactions at large-scale that are not seen in the rest of the building block would be unusual (and need to be addressed case by case).
- Resolution
  - The bullet in question is deleted.
  - Rationale: The commenter is correct; the effect of competing failure modes is better discussed elsewhere
    - Note: M&P variability can be significant enough to change failure modes, particularly at structural scale where failure modes are competing

Negative Votes and Suggested Resolutions

17.7.5.3 (#1)

- Was: *Damage: A specific type of anomaly originating from an external source*
- Comment: I still find this confusing to call an anomaly damage. Are we talking about impact damage in the factory here? I think this bullet should be deleted since this section isn't really talking about damage. The title of the section is "Manufacturing Defect Disposition". In-factory impact damage is a different discussion.
- Resolution
  - The text does not call an anomaly damage - "Damage is a type of anomaly" was the original wording submitted to YP
  - This content is intended to clarify the common terms of Anomaly, Damage, Flaw, and Defect
  - Added definitions for all the terms to be more comprehensive. A proposed bullet list for item 1 would now say:

1. Definitions

- *The terms Anomalies, Flaws, Damages, and Defects are often used interchangeably, but have specific meanings*
- *An anomaly is an indication seen during any phase of inspection that may or may not be acceptable*
- *A flaw is an unintentional attribute created during composite consolidation; it may or may not be found during inspection; it may or may not be acceptable*
- *A damage is an unintentional attribute created later in the manufacturing process or in service; it may or may not be found during inspection; it may or may not be acceptable*
- *A defect is an anomaly, flaw, or damage that is not allowed in the design; it may or may not be detectable*

Open for wordsmithing

Term	Detected	Acceptable
Anomaly	Yes	Maybe
Flaw	Maybe	Maybe
Damage	Maybe	Maybe
Defect	Maybe	No

Negative Votes and Suggested Resolutions

17.7.5.3 (#4, 5th Bullet)

- Was: *Rework returns a part to its original design configuration, such as an undersized hole that is further drilled to the correct size, or an area of surface porosity that is filled with resin.*
- Comment: Please pickup this previous edit. Rework doesn't always take it back to the original configuration but does need to meet the original requirements, there's a difference. Reviewer says to say: *Rework returns a part to its original design configuration (or equivalent), such as an undersized hole that is further drilled to the correct size, or an area of surface porosity that is filled with resin. In all cases, rework results in a condition that meets the original design requirements.*
- Resolution
  - Replaced sentence with*: Rework returns a part to a conforming configuration, such as an undersized hole that is further drilled to the correct size, or an area of surface porosity that is filled with resin*
  - Reasoning: Rework brings it to a configuration that is allowed under existing type design. Repair changes the configuration of the part to something other than original type design, but that is acceptable through further substantiation to demonstrate compliance.

Negative Votes and Suggested Resolution

17.7.6.1

- Was: *Anomalies are categorized from 1 to 5 in AC 20-107B (Reference 17.7(a))*
- Comment: Replace with "Damage and defect types". Not sure why this was changed (from last review). "Anomalies" doesn't work per your definition of it shown earlier. (Second Reviewer): Agree, "anomalies" doesn't work here, especially since it is referring to all categories of damage
- Background
  - Changed in last review from "damage and defect types" to "anomalies", with the comment "Corrected to the term that encompasses everything".
- Resolution
  - Revised to say: *Flaws and damages are categorized from 1 to 5 in AC 20-107B (Reference 17.7(a))*
  - Reasoning:
    - Category 1 flaws or damage are, by definition, not a <u>Defect</u>, because they are allowed in type design without repair.
    - "Anomalies" only apply to those items that are found with inspection.
    - Therefore, the correct comprehensive wording that encompasses everything that exists, whether found in inspection or not, and whether acceptable or rejectable, is "Flaws and Damages."

Negative Votes and Proposed Resolution (similar to prior slide)

17.7.6.1

- Was: *Anomalies up to the level of detectability and/or acceptability are substantiated to carry ultimate load for the life of the aircraft*
- Comment: Same comment as above (prior slide): *"Anomalies" doesn't work per your definition of it shown earlier. (Second Reviewer): Agree, "anomalies" doesn't work here, especially since it is referring to all categories of damage*

- Resolution
  - Reworded bullet to say: *Flaws and damages up to the level of detectability and/or acceptability are substantiated to carry ultimate load for the life of the aircraft*
  - Reasoning: Anomalies isn't a comprehensive-enough term because it only refers to things that are detected in inspection. By definition, Category 1 must include everything you can't find. That is comprehensively both flaws created during consolidation and damages that occur later.

Negative Votes and Suggested Resolutions

17.7.6.4

- Was: *Permanent repairs may require extra inspections and other related maintenance activities depending on part criticality, repair complexity, and probability of exposure to environmental or other threats.*
- Comment: This may need discussion since it contradicts CSET slide 14, which says "Permanent repairs are those that when performed correctly, appropriately sealed with protection system restored, will require no further action (i.e., no inspections at specified intervals)"
- Resolution
  - Reworded the sentence to (change shown in red): *Permanent repairs by third parties may require extra inspections and other related maintenance activities depending on part criticality, repair complexity, and probability of exposure to environmental or other threats.*
  - Reasoning: The CSET statement is specific to OEM repairs.

Negative Votes and Suggested Resolutions

17.7.6.4 (#2, 4th Bullet)

- Was:
  - *Permanent repairs must adhere to substantiated data, materials, and processes and sustain ultimate load throughout the service life of the part and may require inspections specific to the repairs*
- Comment: This is not true, bolted metallic repairs are allowed to follow a typical DT approach and allow cracking if detected before falling below limit load capability. Inspection must allow the approach. Rare but it does happen for repairs. Proposed rewording: *Permanent repairs must adhere to substantiated data, materials, and processes and meet strength and damage tolerance requirements for the service life of the part and may require inspections specific to the repairs*
- Resolution
  - Deleted the 4th bullet and slightly revised the first bullet to include extra point of emphasis. Change to first bullet shown in red: *Bonded or bolted repairs to composite structural components must meet the appropriate airworthiness requirements including those for material and process qualification, static strength, fatigue, damage tolerance, inspections and lightning protection (particularly in the fuel tank)*

Negative Votes and Suggested Resolutions

17.7.6.4 (#2, 10th Bullet)

- Was:
  - *Bolted repairs should be substantiated to limit load with damage substantiated by previous testing (for example one bolt removed) and ultimate load with the damage (e.g., cracks or delaminations of certain size around a subset of bolts as substantiated by previous testing).*
- Comment: Confusing, how about just say; *Bolted repairs with undetectable damage should be good for ultimate load. Bolted repair to PSE structure with metallic plates should be designed damage tolerant, considering starter cracks, crack growth, and maintaining limit load until cracks are found by planned inspection.* (Second Reviewer) Agree, this is very confusing and needs reworking.
- Resolution
  - Replaced bullet with some edits to the sentence suggested in comment (changes shown in red): *Bolted repairs with undetectable or allowed damage should demonstrate ultimate load capability. Bolted repair to primary structure elements (PSE) with metallic plates should be designed to be damage tolerant, considering starter cracks, crack growth, and maintaining limit load until cracks are found by planned inspection.*

Efforts to Complete Content for Rev H

- Negative comment dispositions will be transmitted to the reviewers
  - Will include any updates from today's discussions
  - Goal: May 17, 2024
- Final combined version of the chapter will be reviewed by Larry and Cindy
  - Are there any other volunteers to do a final review?
  - Goal: May 31, 2024
- Final copy will be submitted to the Secretariat for publication
  - Should we email copies or create a forum to post?

Candidate Future Initiatives

1. Review existing content in Sections 17.1-17.6 and see if changes are needed for:
    - CMC
    - AM
    - NAS 9927 “Safety Management Systems and Practices for Design and Manufacturing”
    - FAA’s proposed SMS rule for Design and Manufacturing Organizations https://drs.faa.gov/browse/excelExternalWindow/FR-NPRM-2022-28583-0000000000000.0001

Closure / Actions

- Thanks for attending!
- Actions:
    1. (add)

Safety Management Working Group Notes

1st Joint CMH-17 Meeting
Scottsdale, AZ
April 2024

The safety management working group met April 24 from 3:30-5:30 PM with the following agenda:

- Welcome
- Disposition of Significant 2023 Fall YP1 Comments
- Efforts to Content for Rev H
- Candidate Future Initiatives
- Closure/Actions

The majority of time was spent reviewing significant 2023 Fall Yellow Page 1 Comments on Section 17.7, primarily to disposition negative votes. Due to time, we were not able to review all the comments. The following ones were discussed (see slides):

- Section 17.7.3.7 Slides 9-13 accepted proposed revisions
- Section 17.7.3.8 Slide 14 accepted proposed revision
- Section 17.7.4.1 Slide 15 accepted proposed revision
- Section 17.7.4.1 Slide 16 agreed in concept to the proposal, but significant rewording required in this section
- Section 17.7.4.3 Slide 17 accepted proposed revision
- Section 17.7.4.4 Slide 18 the proposal on the slide was rejected, alternative wording proposed to better explain the intent
- Section 17.7.5.3 Slide 19 rejected proposed revised test to define the terms anomalies, flaws, damages, and defects. Decided to replace bullets with a single statement that says something to the effect of "The terms anomalies, flaws, damages and defects are often used interchangeably but have specific meanings."
- Section 17.7.5.3 Slide 20 accepted proposed revision
- Section 17.7.6.1 Slides 21 and 22 proposed revision agreed to in concept, but attendees wanted to see the exact wording before concurrence
- Section 17.7.6.4 Slide 23 was discussed, but no resolution reached during the meeting
- Section 17.7.6.4 Slide 24 proposed revision agreed to in concept, but attendees wanted to see the exact wording before concurrence
- Section 17.7.6.4 Slide 25 accepted proposed revision

Future actions were discussed from Slide 26. The following actions were identified (different from that proposed on the slide):

1. Revise section 17.7 to incorporate all edits
2. Disposition all comments
3. Send dispositions to the negative commenters, along with the revised document, and request the negative vote be rescinded

4. After negative votes are accepted, post the section on the Safety Management and Guidelines forums for further review
5. Incorporate all final comments and edits into the section and send to the secretariat by the end of July
6. There were no negative comments to the other sections of chapter 17 that were in Fall YP1. Some edits will be made and submitted to the secretariat by the end of July.

Post-Rev H activities were discussed, with no firm plans to propose new taskings in Chapter 17. There seemed to be consensus that providing composite-unique guidelines to satisfy the FAA's new SMS rule for design and production approval holders would be the highest priority for future work in the chapter.

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CMH-17 Supportability Face-to-Face Meeting Scottsdale, AZ

4/24/2024

Larry Gintert

Proposed Agenda

• Introductions and Overview	5 min
• YP Comments/Ch 14 Status	75 min
• 14.7.3 Bonded Repair Analysis	
• 14.12.10 CS #9	
• CS#2 Volunteers and Plan	20 min
• Other Post Rev H plans	15 min
• Planning/Wrap-up	5 min

Ch 14 Sections Recently Sent to YP

- 14.7.3 Bonded Repair Analysis – all comments have been addressed; most recent iterations worked independently with team members (updated Word document)

  (TEAM REVIEW)

- 14.12.10 Case Study #9 –Addressing negative votes and comments; awaiting graphics updates (partially updated Word document)

  (TEAM REVIEW)

Case Study #9 Status Update

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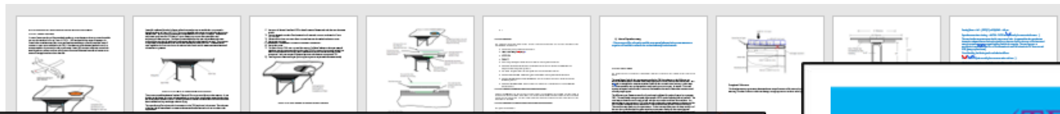
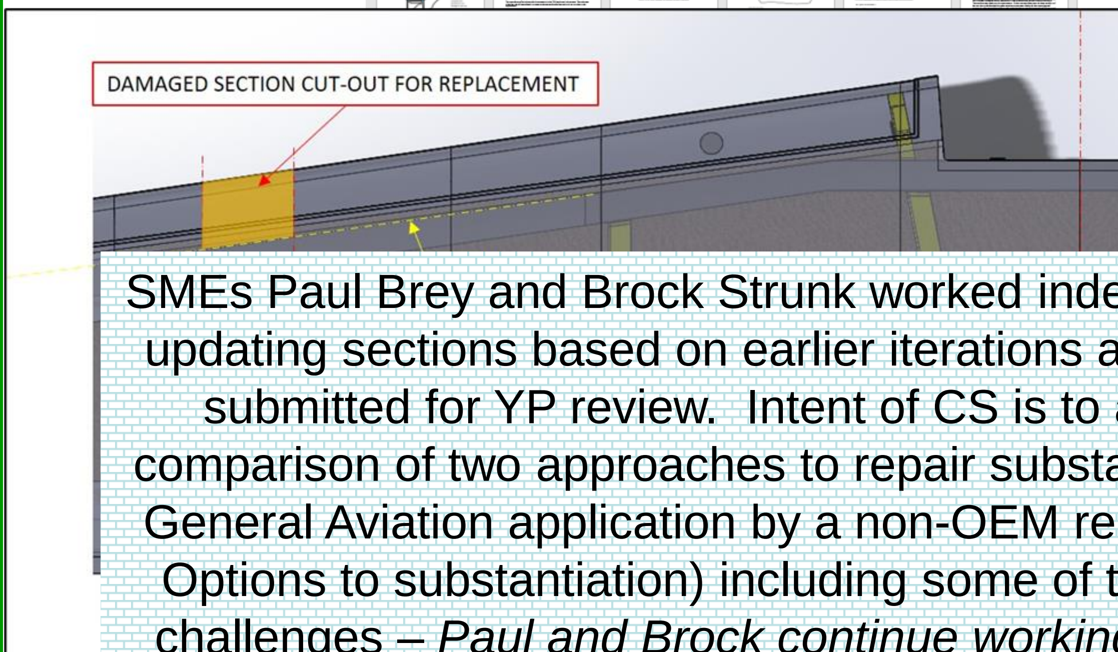
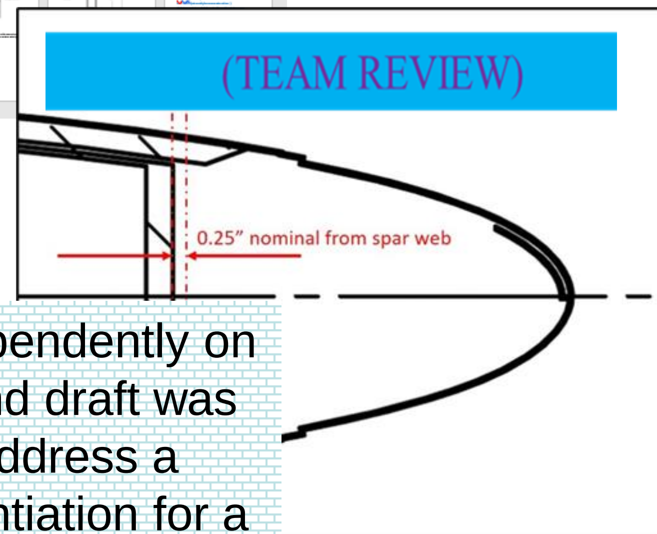
Case Study #9 General Aviation Bonded Wing Skin/Spar Damage







View of Extent of Damage

SMEs Paul Brey and Brock Strunk worked independently on updating sections based on earlier iterations and draft was submitted for YP review. Intent of CS is to address a comparison of two approaches to repair substantiation for a General Aviation application by a non-OEM repair shop (2-Options to substantiation) including some of the potential challenges – *Paul and Brock continue working to address the comments and negative votes.*

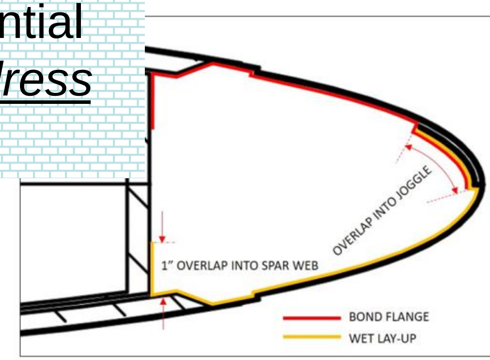


Figure 6 : Lower Skin Wet Lay-up Section View

SoBR Case Studies Status Summary

- Case Study #9 (YP comments/approval)
- Case Study #2 – Synopsis submitted to YP – *volunteers needed to complete the draft partially completed by Mike Borgman*

Case Study #2 completion plus planned revisions to Case Studies #5 and #6 to address "business case analyses" (R. Kaiser) represent the balance of this remaining effort

Case Study #2 Overview

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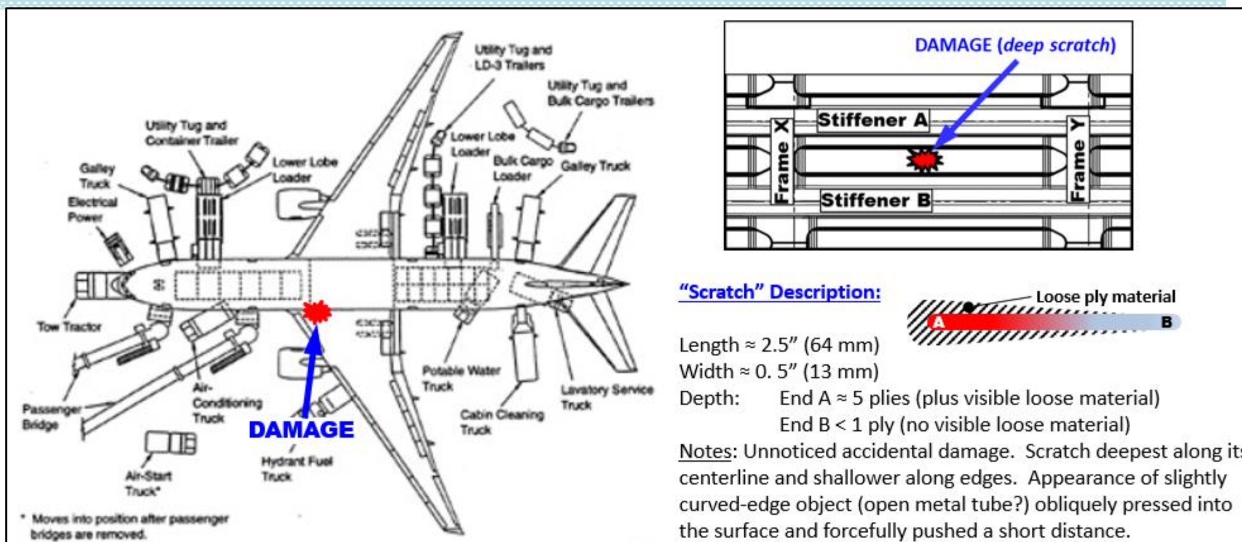
Case Study #2 Fuselage Bonded Repair

DRAFT WIP - meeting identified <u>plan for emphasizing prerequisites and various facilities and training related aspects as more difficult than design, substantiation and completion of the repair as the focus of this Case Study – Synopsis documented for Rev H; **Plans are to populate this Case Study as a priority post-Rev H**</u>

Review conducted <u>with author Mike Borgman</u> during the FTF meeting in October 2023



Case Study #2 Team Identification

- Volunteers identified previously to complete the repair analysis portions of CS#2 (Eric and Nihar)
- Volunteers needed to help populate the "prerequisites" aspects of CS#2 building upon the Mike B. presentation and notes from Oct WSU meeting - (Spirit Leadership? Others?)

Administrative support for virtual working meetings is available to teams – Initiate plans now!

Post-Rev H Content for CH14

Topics identified at the Wichita F-T-F meeting:

Post Rev H plans for Chapter 14 were discussed. These included:

- Section 14.3 Service Experience update
- FAA/Boeing BRSL information
- CBD method information – Greg Kress
- Case study # 2; whatever sections don't make it into Rev H – (Volunteers)
- Add business cases for Case studies 5 & 6 – Ray Kaiser
- Radome repair case study
- New Case study on large bonded repair of nacelle
- Address Carl Rousseau comments that chapter is too long and detailed
- Add additional bonded design repair examples for GA and rotorcraft
- Include non-aerospace industry (wind turbines, automotive, maritime) into chapter
- Rotor blade repair
- EVTOL rotor repairs

Planning and Wrap-up

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- Monthly SoBR meetings continue near term
- New Task Groups for specific tasking – coordination within PMC and beyond…
- Other?

Summary and Wrap -up

THANK YOU!!!

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COMPOSITE MATERIALS HANDBOOK

- Backup Slides follow

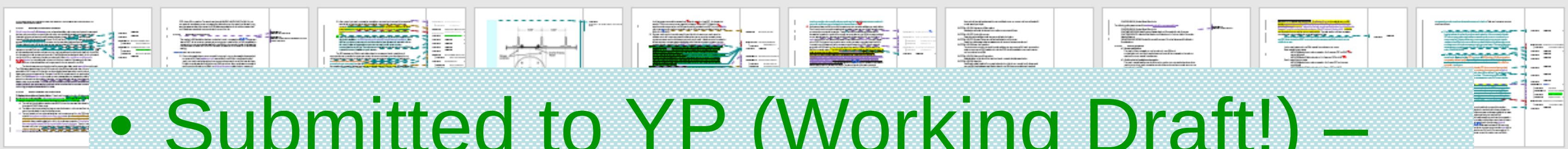
Updates to Rev G of Chapter 14

- Section 14.1 Introduction
- Section 14.2 Important Considerations
- Section 14.3 Service Experience
- Section 14.4 Quality Assurance and Inspection
- Section 14.5 Damage Assessment
- Section 14.6 Repair
- Section 14.7 Repair Analysis
- Section 14.8 Composite Repair of Metallic Structure
- Section 14.9 Maintenance Documentation
- Section 14.10 Design for Supportability
- Section 14.11 Logistics Requirements
- Section 14.12 Repair Case Studies

Outline updated according to Chapter 14 Working Draft

Case Study #6 Overview

Case Study #6 Horizontal Stabilizer Skin and Stringers - Bonded/Bolted Repair

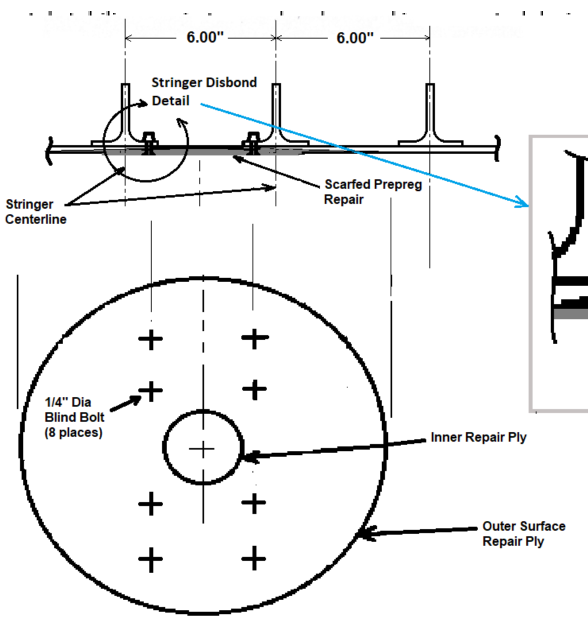


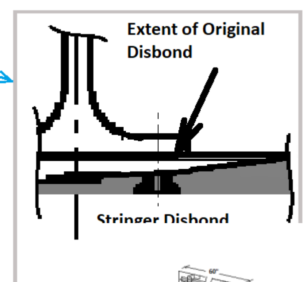
- Submitted to YP (Working Draft!) – Also, adding business case analysis

14.12.7.1 Description and Assessment of Damage

Visible impact damage (VID) to the hori[…] walk-around of a commercial aircraft, a[…] lower surfaces of the tail between eleva[…] showed broken fibers, PE-UT and PA-UT […] delaminations affecting the 12-outer pli[…] inches in diameter. The damage was ap[…] damage size was found to be larger tha[…] this area of the main torque box lower s[…] the skin is 2.00-inch maximum dimensio[…] bondline damage, for a bonded repair u[…] bondlines of the horizontal stabilizer ma[…]

The aircraft was taken out of se[…] OEM was contacted to ask if the 2.00-in[…] 3.00 inches by 12 plies with the disbond[…] appropriate spacing. They asked the OE[…] informed the repairer that to substantia[…] disbonded stringers is a not-inconsidera[…] schedule. The repairer's DER considers […] revenue caused by the aircraft being ou[…] substantiation in-house.





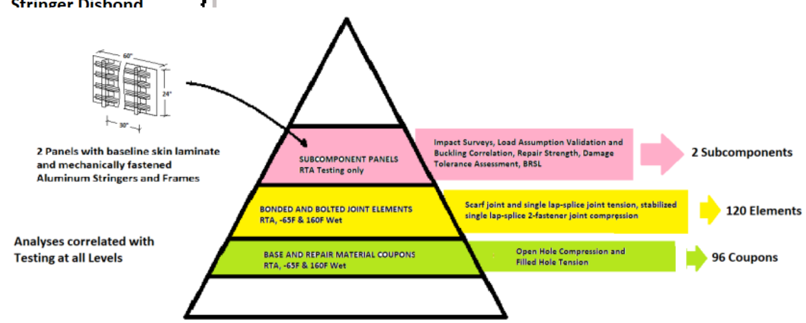


Table 14.12.1 Proposed Update

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TABLE 14.12.1. Repair Case Studies

Case Study (Section)	Topic	Details	Focus of Study
Case Study No. 1** (14.12.2)	Flap Wedge - Alternate Surface Prep for Metal Bond	Attempted bonded repair of metalbond skin-to-spar aluminum alloy substrates resulted in premature adhesion failure due to improper surface preparation.	Metalbond alternative process
Case Study No. 2 (14.12.3)	Fuselage Skin - Bonded Repair	Deep scratch in the skin laminate is roughly 2.5-inches long and 0.5-inches wide. Visual inspection noted a somewhat concave, rounded, bottom and maximum depth around 5 plies	Focus on prerequisites for a repair shop/team
Case Study No. 3 (14.12.4)	Fuselage Skin - Bolted Repair	VID beyond ADL of solid laminate (3/16-inch diameter hole or 1-inch dent/delamination) – justifies loads assumed for repair based on analyses and engineering judgement	Focus on design load assumptions - non-OEM
Case Study No. 4 (14.12.5)	Horizontal Stabilizer - Family of Wet Layup Repairs	Through-hole damage 2.32-inch diameter in solid laminate areas between stringers and 1.44-inch diameter in foam supported stringer areas.	Focus on building block use for family of repairs by OEM
Case Study No. 5 (14.12.6)	Horizontal Stabilizer - Bonded Repair	Impact damage in 12 outer plies of a constant gage area of the lower skin of a commercial transport aircraft composite horizontal stabilizer main torque-box	Focus on assumed loads - non-OEM + operator business case
Case Study No. 6 (14.12.7)	Horizontal Stabilizer - Bonded/Bolted Repair	Impact damage through full thickness of 20 plies of a constant gage area of the lower skin plus disbonded stringer of horizontal stabilizer main torque-box	Focus on assumed loads - non-OEM + operator business case
Case Study No. 7 (14.12.8)	Fan Cowl - VID Sandwich - Bonded Repair	12-inch diameter visible damage (partial puncture, delamination, fiber fractures in plies, partial depth core damage) to an area of constant thickness sandwich panel face sheet on an outer surface of an engine fan cowl	Secondary structure - non-OEM
Case Study No. 8 (14.12.9)	Wing Box - Fueled - Bonded Repair	Lightning damage consists of discoloration, burn marks, tufting and missing material extends several layers into the thickness of the skin	Focus on substantiation for complex repair - non-OEM; assistance required
Case Study No. 9 (14.12.10)	GA Wing Spar/Skin - Bonded/Wet Layup Repair	Impact damage to the upper wing skin and the spar cap edge limited to the immediate area of the impact, and clearly beyond the limits of cosmetic or minor repair as defined in the SRM	Substantiation using two different approaches - non-OEM

**Note that Case Study #1 can also be found in Volume 3, Section 17.6.2

(TEAM REVIEW)

Sections Previously Sent to YP

- 14.1 - 14.6.5 Repair Process
  - Working draft updated and reviewed during the January meeting
  - Sent to Secretariat on 2/16

CMH-17 Supportability meeting minutes 4/24/24

Larry Gintert opened the meeting with a general overview of the meeting agenda.

Dave Stone presented an opportunity to help revise and update sections of ASM vol 21. He needs volunteers within the next week, and they will have several months to complete the update process.

Larry provided an overview of the latest Yellow Page sections (14.7.3) and case study 9 (14.12.10).

14.7.3 Bonded Repair Analysis The latest update to 14.7.3 (bonded repair analysis) was presented. These included updates to the narrative. It was determined that fatigue is already addressed under the durability and damage tolerance documents and content, so fatigue was removed from the section title. The formatting of many of the equations in the section were messed up in the .pdf copy but are correct in the word.
-“interim” repair needs to be replaced with “permanent” repair throughout this section. Nihar will update this.
Section 14.7.3.4.2.2 was discussed in detail. It was determined that fatigue is already addressed under the durability and damage tolerance documents and content, so fatigue was removed from the section title.

- In paragraph 1, the term “allowable defect” needs to be updated to align with latest language from vol 3-chapter 12 content. Nihar and Eric will address this.
- in paragraph 2, 2^{nd} sentence delete “fatigue analysis.

A discussion was had about why only Category 4 damage was called out regarding PSE. Al Fawcett explained that this is only applicable to large repairs, so lower categories wouldn’t apply. Some additional discussion regarding if “large” should be better defined occurred but was decided that this is an area that would require engineering judgement so no additional explanation was warranted.
-Eric will check regulations on exact language regarding sentence “another aspect to take consideration is increased reliability.” Does this need some word smithing to include “a need for” or is this taken directly from regulations?
-Last paragraph, replace “should be adequate” to “is adequate”.

BRSL section
-Paragraph after figure 14.7.3.4.3(a) add back in the caution that is deleted in the draft, and word smith to include that this content is still awaiting test results for final determination.

Section 14.7.3.4.1 (other factors section):
-Last bullet, on discrete source damage, clarify this is only applicable to large repairs.

14.12.10 Case Study #9 Brock Strunk presented the latest revision of Case Study #9.
This update primarily focused on addressing detailed comments from Steve Ward. Extensive updates have been made throughout the case study. Many of the comments from others echoed the comments from Steve.
-However, Brock and Paul still need to ensure that these additional comments have been addressed too.
-Several figures still need to be updated, but Brock has left comments on exactly what to do and will provide updated CAD images of these.
Once these updates are complete, the updated draft will be placed in the forum for comments.

Post-Rev H Initiatives Larry presented on post Rev H items.

- Case study 2 needs volunteers to help finish this case study. (Nihar and Eric are on board)
- Ray Kaiser had previously indicated that he will develop business cases for the repairs presented in case studies 4 and 5.
- Section 14.3 service experience needs additional content.
- Additional case studies on radomes, rotor blade, GA, rotorcraft, eVTOL and other industries (wind) should be considered for development.
- The ongoing BRSL research should be included.
- Other areas such as CBD method from Greg Kress and potential nacelle repair case study from Spirit should be monitored for inclusion.