Substantiation of Bonded Repair (SoBR) Working Group
FAA Aviation Safety – Bonded Repair Initiative

SoBR WG Meeting
August 20, 2015
(abbreviated meeting content)

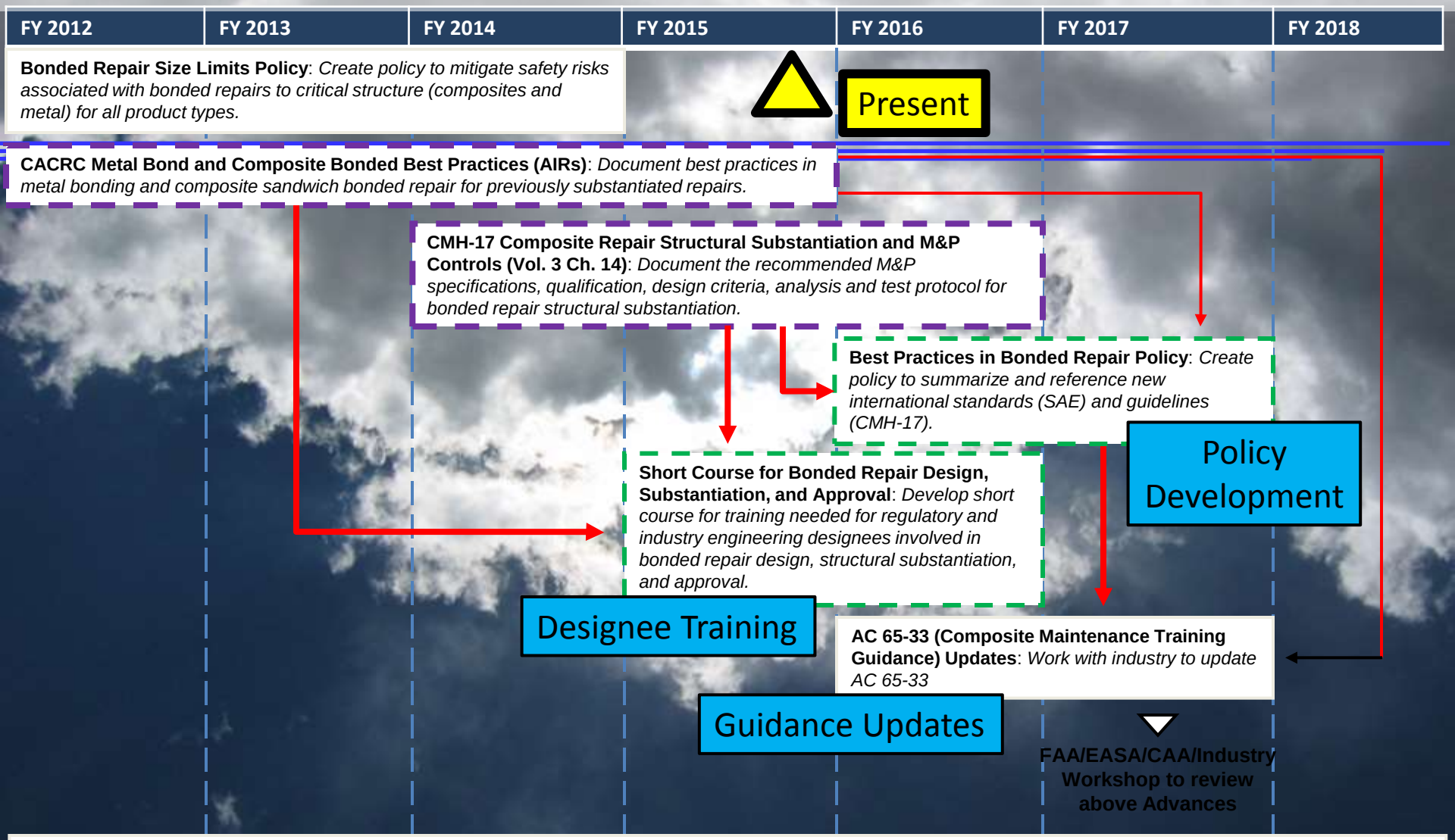
Mike Borgman

Spirit AeroSystems, Inc.

Bonded Repair of PSE and Non-PSE Situation – Target – Proposal (*STP*)

- Situation
  - Insufficient guidance exists for approving bonded repairs
  - Case studies imply risk of deficient repairs in-service
- Target
  - Develop and implement industry norms outlining required approved data and best practices to validate repair airworthiness
- Proposal
  - Leverage CACRC and CMH-17 to document approaches
  - Reference output in new guidance and policy

FAA/AVS Bonded Repair Initiatives Timeline



Research Support to Bonded Structure Initiatives, Including Bonded Repair: *Benchmark industry practices and identify potential safety problems to support the development of regulatory policy, guidance and training that mitigate risks. This research will also include inspection method and other maintenance technology evaluations.*

Formed Working Group: Substantiation of Bonded Repair (SoBR)

- **SoBR Mission**
  - ***Lead and review creation of the bonded repair substantiation norms to be documented in CMH-17 and referred to by new guidance and policy.***
- **SoBR Objective**
  - ***Ensure viable, sufficient, bonded repair substantiation approaches become the documented best practices.***

Roll Call – August 20

1.	Maurizio Molinari	TCCA	**Present**
2.	Simon Waite	EASA	
3.	Larry Ilcewicz	FAA	**Present**
4.	Allen Rauschendorfer	FAA	**Present**
5.	Robert Stegeman	FAA	**Present**
6.	Rusty Jones	FAA	
7.	Ana Rodriguez	Airbus	
8.	Allen J Fawcett	Boeing	
9.	Gary Oakes	Boeing	
10.	David Wilson	Bombardier	**Present**
11.	Geoffrey Walsh	Bombardier	
12.	Rushabh Kothari	Bombardier	**Present**
13.	John Welch	Spirit AeroSystems, Inc.	
14.	Michael Borgman	Spirit AeroSystems, Inc.	**resent**
15.	Peter Smith	Consultant	**Present**
16.	Andries Buitenhuis	Fokker Aerostructures	
17.	Jan Waleson	Fokker Aerostructures	**Present**
18.	Thomas Rood	AV Tech	**Present**
19.	Cyndi Ashforth	FAA	

NOTE on BRSL

- BRSL requires substantiation for two scenarios:
  1. Repair bond intact (“patch on”) = Ultimate capable
  2. Repair failed (“patch off”) = Limit Capable

		BRSL - implied substantiation requirements	
		1) Repair intact	2) Repair failed
Strength & Deformation	Limit	●	●
	Ultimate	●	---
Damage tolerance		●	●
Durability		●	●
Environmental resilience		●	●

X = basis airframe TC requirements

Y = requirements defined during **repair** substantiation and approval process

- **Impossible task for MRO engineer?**
- **What arguments might a DER use to overcome this? Equivalency?**

CASE STUDY #1 –CMH-17 WRITE-UP POINTS

Case Study #1 – Flap Wedge

Recall: Damage and Repair Definitions

- Damage
  - Component: *Outboard flap wedge*
  - Damage necessitated re-skin
- Proposed repair
  - Replace skin and core per SRM except substitute *HFA in lieu of preferred PAA surface preparation*
  - SRM allowance: PAA is primary repair procedure; however, *allowance for substitute surface preparation 'whenever PAA is not convenient'*
- ***Component disintegrated in service***

Case #1 Outcome *(from SoBR discussions)*

- A materials/process substitution which are not *specifically* validated by SRM must be validated by M&P specialist
  - Structural analyst should not assume process OK even if it appears covered by SRM statement
    - Need to include nuances of bonding
    - Most techs would just change the process without looking back
    - Caution needs to be embedded in our CMH-17
    - And back-up with test data
  - The process must be specifically approved instead of relying on *inferred* approval

Case #1 Outcome *(from SoBR discussions)*

- CMH-17 should notably mention environmental durability
  - Fundamental level "…everything done as intended then not a problem…"
  - Should gather historic precedents
    - Look at hail damaged repaired spoilers
    - Look at trailing edge wedges
    - Piper has done tons of metal-bond (should consult with them for historic data)
      - Maurizio – thin composite structure more at risk
      - Thick structure behaves less susceptibly – degradation may occur earlier
      - Clearly dependen\t on load spectra and operating environment
  - Where problems have been found there is no record of how repair work performed
    - Records keeping requirements are only 2 years (part of 145 ticket, 121, records generally show it was done right)
    - Bonded repair technology is not sufficiently robust

Case #1 Outcome *(from SoBR discussions)*

- SoBR WG did not come to consensus on tests required to substantiate alternate surface preparation methods
  - At a minimum, CMH-17 should contain statement like: *If such and such a test had been ran then you would have observed "x" which would shown the substitution should not be used.*
  - *More depth required. Need more in depth discussion.*
- Component criticality assessment must be presented along with evidence

Case #1 Outcome *(from SoBR discussions)*

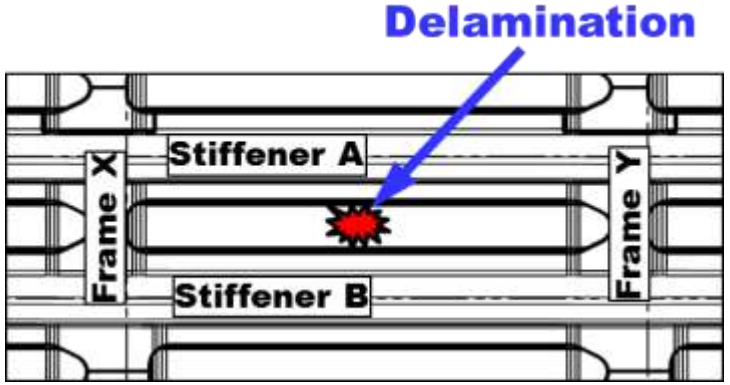
- SoBR should provide guidance for pragmatic evaluation of component criticality
  - Words to categorize major versus minor may be required
  - However, major versus minor is managed at the operator level
  - Secondary effects should be notably mentioned and discussed in our section
  - Thomas Rood will work to gather info to help us fully understand SRM content (examples) and draft relevant statements
  - Stegeman – major repair but minor change
  - Minor change to a major repair (doesn't look like the book but is close to it)
  - Just need to get the topics on the table that must be considered to make major/minor PSE/non-PSE
  - BRSL only applies toe PSE FCS. What about everything else. For example no guidance on honeycomb structure repairs
  - "Reinforcing" required data
  - Total rebuild does not necessarily require approved data (restoring to original configuration)
    - Need to outline the underlying process controls and inspection methods that make this approach acceptable
  - We are setting the bar to filter out the unqualified service provideers
  - Competency measures

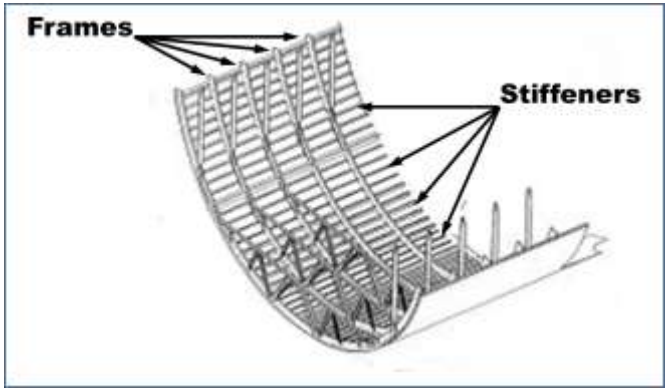
CASE STUDY #2 – CMH-17 WRITE-UP POINTS

FictaCase Study #2 - Fuselage Repair

Description of Damage

- Damage description
  - Component: Fuselage
  - Damage:
    - **VID larger than RDL**
      - Dispersed delaminations at up to 70% depth from OML
      - Centered between stiffeners A and B and frames X and Y
      - Damage to skin only *(no stringer or **interface bond damage?**)*
    - Location visible on walk around

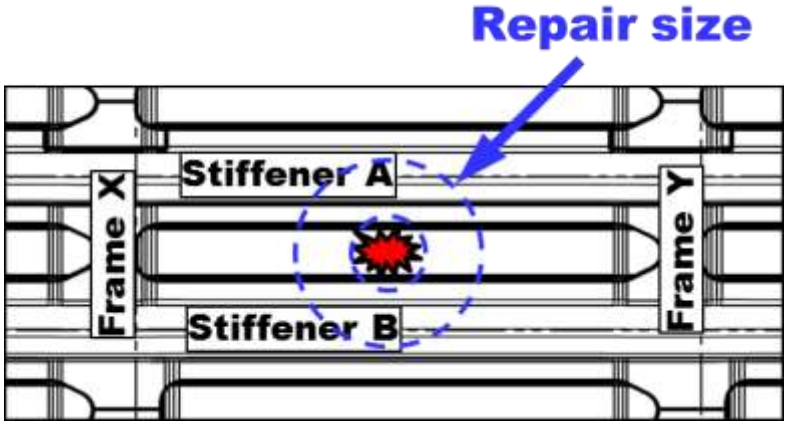




Case Study #2 - Fuselage Repair

Proposed Repair

- Proposed repair definition
  - Remove damage from OML
  - Apply Flush bonded repair
    - Partial-depth taper sand
  - Surface prep per SRM
  - Cure per SRM
  - Repair material per SRM
  - Repair adhesive per SRM
  - Ply for ply replacement per SRM
  - Repair plies defined per SRM
  - Lightning strike restoration per SRM

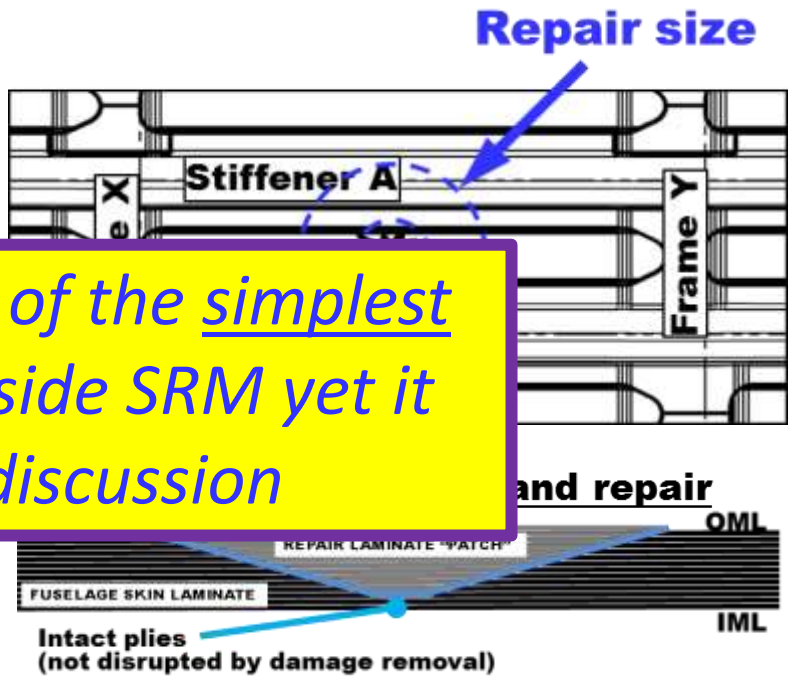


Case Study #2 - Fuselage Repair

Proposed Repair

- Proposed repair definition
  - Remove damage from OML
  - Apply Flush bonded repair
  - Repair material per SRM
  - Repair adhesive per SRM
  - Ply for ply replacement per SRM
  - Lightning strike restoration per SRM

Note: Case study #2 is one of the simplest fuselage repairs falling outside SRM yet it provoked significant SoBR discussion



Case Study #2 – Summary of SoBR

Points to include in CMH-17 revisions

- *RDL* = Repairable Damage Limit
  - *Only* means approved data exists showing the repair can come off, or propagate to arrestment, and still have limit capability
  - Fact is the max repair size may actually be just the limits of available data
  - ADL and RDL may be defined such that they conform with basis inspection requirements
    - Residual strength alone does not always define ADL & RDL
  - ADL and RDL definition not harmonized across OEM's
    - Should be based on a residual strength and durability requirements
    - Notionally QCR addresses residual strength w/o repair > 90% ultimate
  - Generally BRSL = RDL but analysis methods frequently very conservative
  - BRSL implies: 1) fail safe limit respected, 2) database supporting *everything CAT1 and CAT2*
  - *BRSL "patch off" addresses weak bond only. Doesn't address other damages/defects or fatigue*
  - *Inspection standards are required to find all manufacturing defects in "patch intact" condition*
  - *Older SRM's sometimes specify no size limits. How does that relate to BRSL?*
    - *At times "No size limit" is preferred. Reskin may be structurally preferred over local, finite, repair*
- Data must show repair *damage tolerant*
  - SRM "Allowed" repairs have DT provisioning/considerations baked in
- Repair has to be good with *Cat 1 damage*
  - Consider BVID if high likelihood of impact exists
  - …otherwise consider only standard manufacturing flaws
  - Only consider BVID if repairs are large enough to contain BVID

Note: Case study #2 probably represents the simplest fuselage repair falling outside SRM yet it drove extensive SoBR discussion and cautions

Case Study #2 – Summary of SoBR

Points to include in CMH-17 revisions (cont'd)

- *Full F&DT evaluation* of *intact repair* must be performed
- Repairs susceptible to *CAT2* damage require *intermediate inspections* or evidence not required
  - Standard means of assessing intermediate inspections requirements not established
  - Inspection intervals should be set based on damages likely to occur and corresponding residual strength and durability
  - It is never OK to fly around in below-ultimate condition
  - Inspection intervals should always be justified for repairs beyond SRM limits
  - Growth approaches must be validated by test […representative of aircraft operating environment]
- SoBR discussion should be limited to repairs "way beyond" ADL
- Regulatory states "*engineering judgment*" sometimes necessary. How is this practically used? Seems to conflict with current trends.
- 25.605: ***In***sufficient to point to SRM for process substantiations for repairs beyond SRM limit
- 25.619 should be mentioned
  - Some products may still have need for special factors to cover process variability
  - GA aircraft may be certified primarily by test and resulting factors
  - Some special design criteria invoke special factors to cover uncertainty

Note: Case study #2 probably represents the simplest fuselage repair falling outside SRM yet it drove extensive SoBR discussion and cautions

Case Study #2 – Summary of SoBR

Points to include in CMH-17 revisions (cont'd)

- Must document example of "mountain" that must be climbed to substantiation repairs beyond SRM limit
  - SoBR mission not to "enable" repairs but rather to ensure they are not approved without ample data
- Paragraph required describing complexity and scope of generating adequate substantiating data
  - Mechanical performance data
    - Addressing temperature and moisture effects
    - Determining representative fatigue spectra
    - Assessing durability requirements (damage provisioning based on databases accumulated over time)
  - Process robustness/repeatability data (qualification)
    - Even if you "built it to the drawing" you are not qualified
- Sizing for limit residual strength not possible for non-OEM entities
- Cannot use un-configured test components as basis for demonstrating equivalency

Note: Case study #2 probably represents the simplest fuselage repair falling outside SRM yet it drove extensive SoBR discussion and cautions

Case Study #2 – Summary of SoBR

Points to include in CMH-17 revisions (cont'd)

- Even if you build the database to substantiate repairs beyond SRM limits… *in the end only the OEM has sufficient data to validate residual strength in "patch off" condition*
  - Need to include case studies showing "some path to a solution"
    - May include "stop here if you aren't the OEM"
- *However,* Sooner or later OEM stops maintaining products. Then who is in acceptance mode? Unrealistic to think operator will throw away A/C no longer supported by OEM.

Note: Case study #2 probably represents the simplest fuselage repair falling outside SRM yet it drove extensive SoBR discussion and cautions

Case Study #2 – Summary of SoBR

Points to include in CMH-17 revisions (cont'd)

- Size of repair is key to need, or not, for allowables development
  - Must show with a limited number of tests that the size limit increase did not violate the assumptions in allowables development
  - Requires structural test articles representing the actual repair performed

Note: Case study #2 probably represents the simplest fuselage repair falling outside SRM yet it drove extensive SoBR discussion and cautions

Case Study #2 – Summary of SoBR

Points to include in CMH-17 revisions (cont'd)

- Concern BRSL will provide a path
  - Might be argued, BRSL allows LL capability with zero margin; therefore, the arrestment features will be spaced such that they meet the original BVID and fatigue requirements, and only driving document is BRSL.
- Outside BRSL allowance.
  - Let's say that OEM developed SRM size limit but knew, based on reliability, trying to get to this larger dimension is not compatible with the materials and processes in the SRM.
  - Repair approver might assume SRM repair sized by limit load capability when in reality it is sized by process or material limitations unrelated to structural analysis
  - All other factors must be met.
    - Have you proved that closely spaced arrestment features meet all other requirements.
  - Limit load allowance is limited to coverage of one manufacturing defect. All other defect coverages must still be considered.
  - Disbond arrestment features may effect other things in a negative way.

Note: Case study #2 probably represents the simplest fuselage repair falling outside SRM yet it drove extensive SoBR discussion and cautions

Case Study #2 – Summary of SoBR

Points to include in CMH-17 revisions (cont'd)

- Need notable mention of Large Damage Containment provisioning
  - Not harmonized across industry so cannot be treated as a norm that can be leveraged for larger repairs
- Case studies for CMH-17 should incrementally progress through range of damages
  - Skin only
  - Skin + stiffener (severed stiffening element)
  - Skin

Note: Case study #2 probably represents the simplest fuselage repair falling outside SRM yet it drove extensive SoBR discussion and cautions

Case Study #2 - Fuselage Repair

Summary against "regulations checklist"

Lengthy discussion was pursued on this slide. Notes on following page.

SUBSTANTIATION CHECKLIST **CS 25.XXX Requirement**		**Repair Bond**	
		Intact (Ultimate Load Capable)	**Failed** (Limit Load Capable)
25.305	**STRENGTH AND DEFORMATION**		
	Safe Operation at ***Limit*** *Load* (deformations okay)	**Validation by mechanical test**	
	Ultimate *Load* capability		
25.307	**PROOF OF STRUCTURE**		
	Each critical load case considered	**Covered by considering critical failure modes and validation by mechanical test**	
	Analysis methods proven to be valid		
25.571	**DAMAGE TOLERANCE AND FATIGUE EVALUATION**		
	No catastrophic failure due to fatigue (progressive damage)	**Test evidence required**	**Detectable + Limit**
	No catastrophic failure due to corrosion	**N/A**	**N/A**
	Manufacturing defects considered	*	*
	Accidental damage considered	~~*Covered by "patch off" design condition~~	
	Load and environment spectra considered	**Test evidence required**	
25.603	**MATERIALS**		
	Process performed in accord with approved documented specifications	**SRM provides coverage**	
25.605	**FABRICATION METHODS**		
	Process proven to yield strength/stiffness assumed in design	~~SRM provides coverage~~ **(validative data required)**	
25.613	**MATERIAL DESIGN VALUES**		
	Strength assessments based on design values with statistical basis	**Test evidence required**	
25.619	**SPECIAL FACTORS**		
	Basis exists for special factors applied	**Not required**	

Case Study #2 - Fuselage Repair

Summary against "regulations checklist"

SUBSTANTIATION CHECKLIST CS 25.XXX Requirement		Repair Bond	
		Intact (Ultimate Load Capable)	Failed (Limit Load Capable)
25.305	STRENGTH AND DEFORMATION		
	Safe Operation at ***Limit*** *Load* (deformations okay)	Validation by mechanical test	
	Ultimate *Load* capability		
25.307	PROOF OF STRUCTURE		
	Each critical load case considered	Covered by considering critical failure modes and validation by mechanical test	
	Analysis methods proven to be valid		
25.571	DAMAGE TOLERANCE AND FATIGUE EVALUATION		

WG comments:

- Stop carrying separate column for "failed repair"
- Add row for damage tolerance for inspection interval coverage
- Fail safe "patch off"
- 25.609 should still be listed and identify why significant substantiation is not required for corrosion, and paint must also be considered
- 25.605 since we are outside the SRM envelop it may or not be adequate to point to SRM as the validating document (Gary and Anna)
  - Don't want cowboys making that decision
- The SRM may be size limited based on location and heat sinks etc may degrade the process rigor
- Should keep 25.619 for a check point (to ensure it is considered)
  - Certain products or applications may still have a need for special factors for process variability (GA aircraft many be certified primarily by test)
  - Some specific design criteria also invoke special factors to cover for uncertainty

Case Study #2 - Fuselage Repair

Summary against "guidance checklist"

Lengthy discussion was pursued on this slide. Notes on following page.

Guidance	**Intact** (Ultimate Load Capable)	**Failed** (Limit Load Capable)
CS-25 Book 2 AMC 25.307		
Proof of structure by analysis supported by existing test evidence, or	**Test Data Required**	
Proof of structure by analysis supported by new test evidence, or		
Proof of structure by Test Only		
Limitations of stress analysis method understood	**Test Data Required**	
Conservative stress analysis assumptions used to compensate for limited test evidence	**Assumed CAI sets compression ultimate strain**	
CS-25 Book 2 AMC 25.571		
If repair bond fails residual structure can withstand reasonable loads until failure detected	***TEST EVIDENCE REQ'D***	
Part is *Principal Structural Element*	**YES**	
Bond failure detection strategy and corresponding *special inspections* and intervals defined	**Failure readily detectable (on walk-around)**	
CS-25 Book 2 AMC 25.613		
Repair M&P aligns with M&P used in design value development (*or equivalency established*)	**SRM provides coverage**	
Mechanical test specimens conform to universally accepted standard	**Design Values = YES, Proof of Structure = NO**	
Effects of temperature and moisture taken into account in design values development	**Test Data Required**	
AC 21-26A		
"Quality System" employed in repair materials and processes controls	**Not feasible**	
Inspection standards exist for NDI acceptance tests	**SRM provides coverage**	
Inspection standards exist for DI acceptance tests	**SRM provides coverage**	
inspection standards exist for visual inspections	**SRM provides coverage**	
Geometric inspection performed to confirm compliance with engineering requirements	**Not feasible**	
AMC 20-29		
All Materials & Processes qualified by manufacturing trials and appropriate testing	**SRM provides coverage**	
Surface preparation performed in accord with process qualification or approved data	**SRM provides coverage**	
Mechanical tests for proof of structure performed at appropriate levels of building block	**Required**	
Bond failure detection strategy and corresponding *special inspection* intervals and protocol defined	**Failure readily detectable**	
Bonded Repair Size Limits Policy Memo		
Repair size no larger than size allowing LIMIT LOAD residual strength with repair failed within constraints of arresting design features	***TEST EVIDENCE REQ'D***	

END

Thanks for you attention