Composites Damage Tolerance

MSFC Engineering

Damage Tolerance

Assessment Branch

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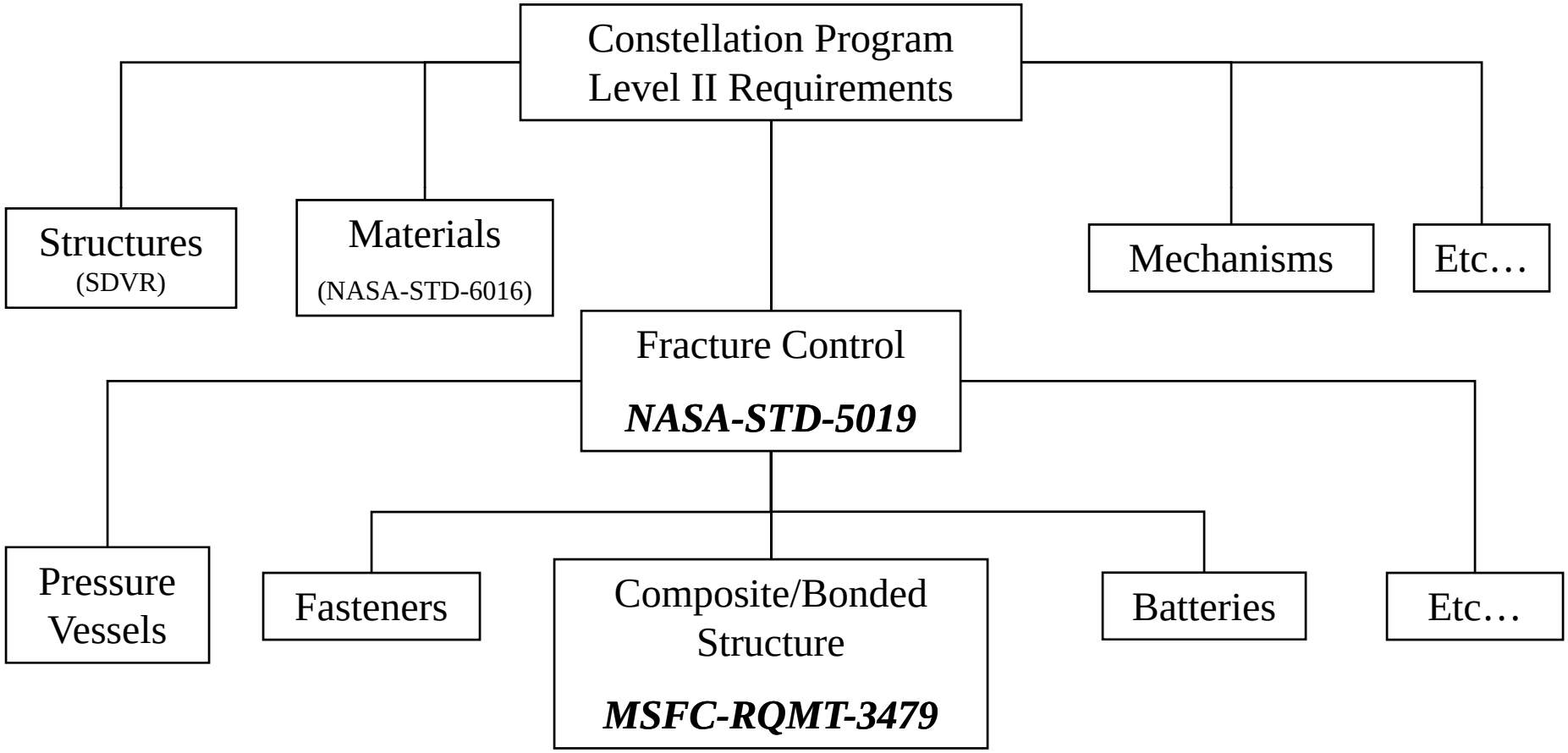
September, 2008

Composites Damage Tolerance

- **Constellation Requirements for Fracture Control**
- **MSFC-RQMT-3479**
  - Background & Development Approach
  - Examples of Criteria & Implementation

Composites Damage Tolerance

How does damage tolerance of composites fit within the framework of Constellation requirements?



MSFC- RQMT-3479 Background & Development Approach

- **Began development of composite fracture control requirements to address shortcomings of prior requirements**
  - **Prior requirements were limited in scope to proof testing, manufacturing history, and NDE**
- **Developed in conjunction with members of the NASA Fracture Control Methodology Panel during 2004 – 2006**
  - **Significant fracture community involvement (~115 comments addressed) prior to final version publication**
  - **Adopted Agency effort into a MSFC Requirements Document, June 2006**
  - **NASA Fracture Control Methodology Panel agreed in 2006 that NASA-STD-5019 would refer to MSFC-RQMT-3479 for fracture control of composites**
- **Cast requirements in the framework and language of existing NASA fracture control requirements.**
- **Review other requirements in addition to NASA requirements:**
  - **Aircraft – Military – Joint Services Specification Guide (JSSG) 2006**
  - **Aircraft – Civil – FARs/MIL-HDBK-17F**
  - **General literature**
- **Rely on ANSI/AIAA S-081 for COPVs.**
- **Refer to MIL-HDBK-17F (now CMH-17) for specific methodologies.**

- **Further Development**
  - **Efforts to revise NASA-STD-5019(A) are underway to include MSFC-RQMT-3479 requirements and to update with lessons learned from Orion and Ares efforts**

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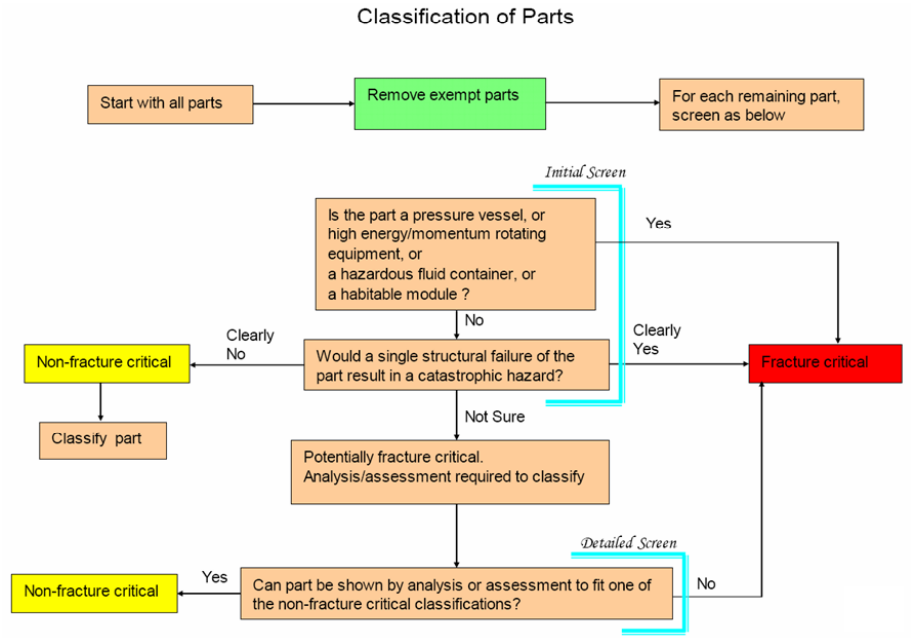

Classification of Composite Parts and Bonds for Fracture Control

A part (or bond) is fracture critical if its failure due to the presence of a flaw would result in a catastrophic hazard. All composite parts and bonds shall be classified according to the following:

Exempt
- Non-structural and no safety critical function

Non-Fracture Critical
- Low released mass
- Fail safe
- Contained
- Low risk
- Non-hazardous leak before burst (NHLBB)

Fracture Critical
- Proofed
- Damage tolerant

Damage Tolerant Approach
- *1. Damage Threat Assessment (DTA)*
- *2. Impact Damage Protection Plan (IDPP)*
- *3. Damage Tolerance Coupon Tests*
- *4. Damage Tolerance Development Tests*
- *5. Analytical Support*
- *6. Damage Tolerance Full-Scale Component Tests*
- *7. Implement IDPP*
- *8. NDE Parts*
- *9. Proof Test to 1.05 Minimum*
- *10. Post-Proof NDE*
- *11. In-Service Inspection*

Examples of MSFC-RQMT-3479 Criteria & Implementation

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Summary Sheet - Composite Fracture Control Classifications and Requirements

	Non-Fracture Critical						Fracture Critical	
			Contained					
Requirements	Low Released Mass	Fail Safe	Metallic Enclosure	Composite Enclosure	Low Risk	NHLBB	Proof Tested	Damage Tolerant
Reference Section	5.2.1	5.2.2	5.2.3.A	5.2.3.B	5.2.4	5.2.5	5.3.1	5.3.2
No catastrophic hazard/loss of SCF	x	x	x	x		x		
Part must be larger than open holes			x	x				
Enclosure/container not FC				x		x		
Not a pressure vessel					x	x		
No hazardous fluid					x	x		
FOS on containment			1.0 Fty, analysis or test	1.15 p'tratn test, or 1.15 p'tratn anlys s/b test				
DUL capability	NFC impacted parts - verf by test			w/impact damage > NDE, from loose part, DTA, or imposed - verf by test	w/impact damage > NDE, DTA, or imposed - verf by test	at Ult FOS x MDP w/impact damage > NDE, DTA, or imposed - verf by test		Per Fig. 5
Inspections								
1. Visual								
a. Walkaround								between each flight
b. Special Visual		pre and post proof, and between flights		pre and post proof, and between flights	pre and post proof, and between flights	pre and post proof, and between flights	pre and post proof, and between flights	pre and post proof, and after every 3rd flight
2. NDE		pre and post proof		pre and post proof	pre and post proof	pre and post proof	pre and post proof	pre and post proof
Proof tested (< 80% Ult) [1]	Foot Note 1	Foot Note 1	Foot Note 1	Foot Note 1	Foot Note 1	Foot Note 1	1.2 x limit, initially and between flights	Initially,1.05 min x limit
DTA Task 1		x		x	x	x	x	x
DTA Task 2				x^{2}	$x^{2,3}$	x^{2}		x
DTA Task 3					x^{3}			x
IDPP		x		x	x	x	x	x

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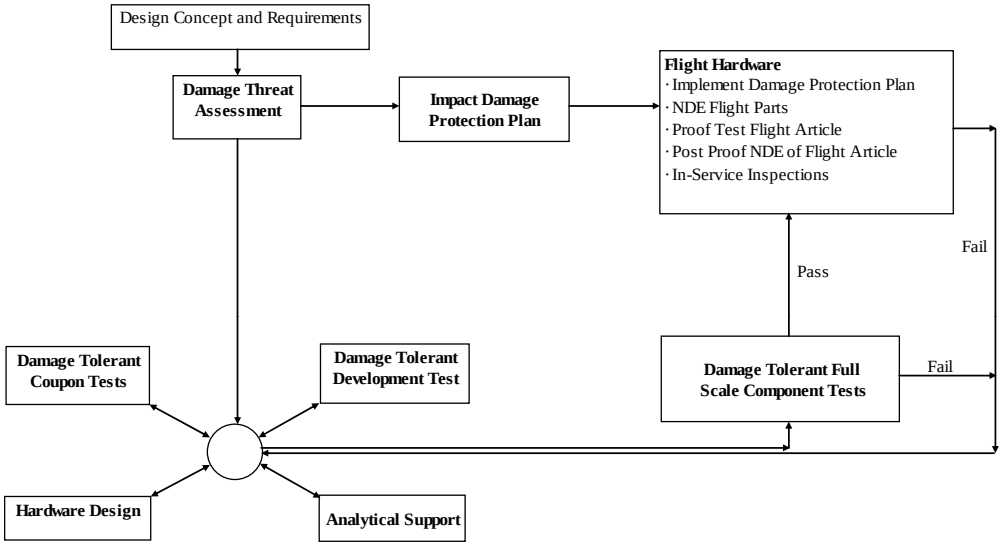
Reference Section	5.2.1	5.2.2	5.2.3.A	5.2.3.B	5.2.4	5.2.5	5.3.1	5.3.2
Damage tolerant coupon tests					x[3]			x
Damage tolerant development tests								x
Damage tolerant full-scale component tests	FC impacted parts	FC impacted parts						Per Fig. 5
Traceability (Section 6.4)		x		x	x	x	x	x
Unique Requirements								
Pressurized enclosures shall have the characteristic of being NHLBB				x				
Walls shall leak ≤ MDP, Verf. by test						for TTF 10 t or 1 inch		
Wall shall not burst @ Ult x MDP, Verf. By test						for TTF 10 t or 1 inch		
Flaw shall not grow @ Ult x MDP, Verf. By test						for TTF 10 t or 1 inch		
No repressurization as pressure leaks down						x		
Generally limited to payloads							x	
Internal to payload,vehicle, module	x		implied	implied				
Debris shall meet low mass		x						
Below no-growth threshold strain					x			
Remaining struc analytically assessed at 1.15 x redistributed dyn load		x - analytical meth verified by test						
Remaining impacted struc must support 1.15 x redistributed limit load		x - NFC parts - verf by test						
See also 5003 for Shuttle payload	x							
No HERM, HMRM, hab mod, SPF bond					x			

Foot Notes:
1. NASA-STD-5001 requires proof test of all composite parts/structures to 1.05/1.20.
2. Required to the extent needed to establish impact damage size for DUL capability test (Line 11).
3. Required to the extent needed to determine no-growth threshold strain (Line 35).

Composites Damage Tolerance

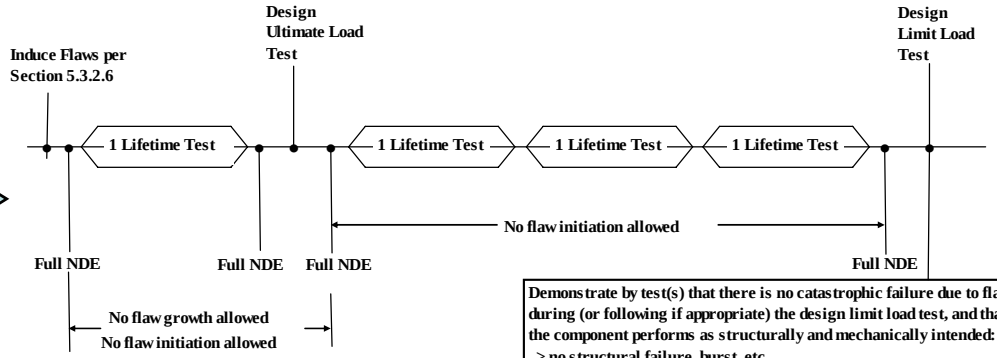
Steps in Establishing Damage Tolerance



Damage Tolerant Approach

- *1. Damage Threat Assessment (DTA)*
- *2. Impact Damage Protection Plan (IDPP)*
- *3. Damage Tolerance Coupon Tests*
- *4. Damage Tolerance Development Tests*
- *5. Analytical Support*
- *6. Damage Tolerance Full-Scale Component Tests*
- *7. Implement IDPP*
- *8. NDE Parts*
- *9. Proof Test to 1.05 Minimum*
- *10. Post-Proof NDE*
- *11. In-Service Inspection*

Damage Tolerant Full-Scale Component Test



Demonstrate by test(s) that there is no catastrophic failure due to flaws during (or following if appropriate) the design limit load test, and that the component performs as structurally and mechanically intended:

- > no structural failure, burst, etc.
- > no catastrophic leak due to flaws
- > no catastrophic mechanical malfunction
- > structurally and mechanically peforms design function

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- **Certification Examples:**
  Fatigue & Strength Tests with Damage

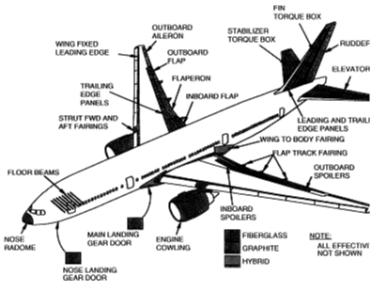
Application/ Examples -MIL-HDBK-17-3F – Section 7.9.2

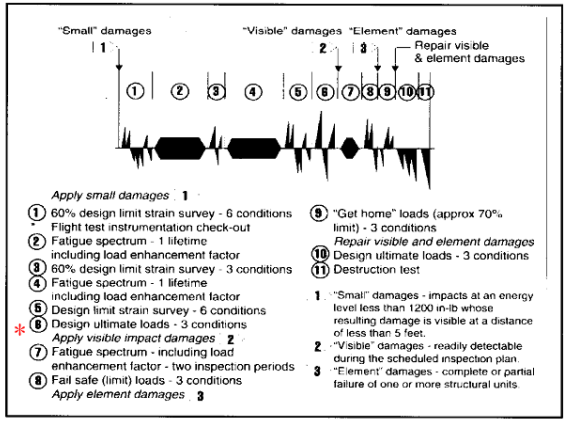
Commercial Aircraft – Boeing 777 Empennage Torque Boxes

Preproduction Horizontal Stabilizer Test Sequence – Demonstrate "No Growth"

Boeing 777 – Composite Usage

- Empennage Torque Boxes
- Passenger Floor Beams
- Aero Fairings and Other Secondary Structures

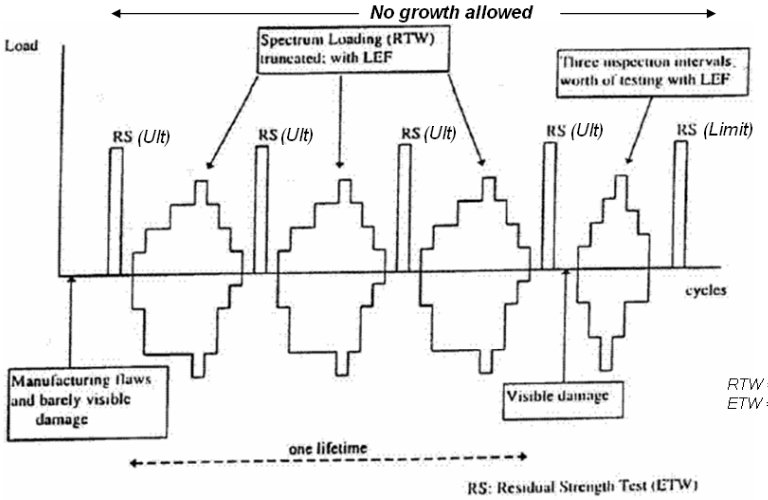




Application/ Examples -MIL-HDBK-17-3F – Figure 7.9.1.6

Rotocraft (Sikorsky)

Damage Tolerant Certification Procedure Schematic



RTW = Room Temp - Wet
ETW = Elevated Temp - Wet

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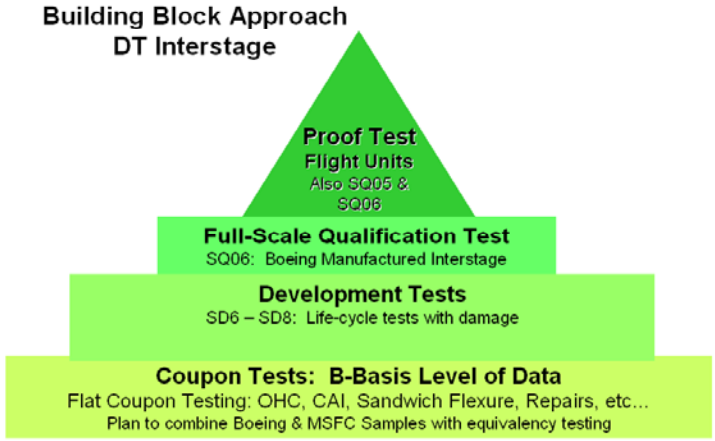
Implementation Example: Ares I Upper Stage Composites Interstage

- **Carbon Fiber Facesheets, Aluminum Honeycomb Core**
  - IM7/8552-1 Carbon/Epoxy Facesheets
  - Al 5052 1/8 inch cell – 3.1 #/ft^3 Core
  - FM300K Adhesive Bondline



Coupon Tests

DAMAGE TOLERANCE								
Acreage Core Sandwich								
Test #	Description	Priority	Layup	Specification	Purpose	Test Requestor	Sizes	Quantities
61	Environmental Effects (DT03)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Validate environmental knockdown factors	A. Nettles	6" X 4"	6
62	Residual Strength (DT04)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Develop residual strength curve	A. Nettles	6" X 4"	39
63	No-Growth Threshold (DT05)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Wohler curve generation (no growth threshold)	A. Nettles	6" X 4"	8
64	Fatigue at Hot/Wet (DT06)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Validate environmental knockdown factors	A. Nettles	6" X 4"	2
65	Validation of Repair (DT09)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Validate repair techniques	A. Nettles	6" X 4"	3
Medium Density Core Sandwich								
67	Environmental Effects (DT03)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Validate environmental knockdown factors	A. Nettles	6" X 4"	3
68	Residual Strength (DT04)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Develop residual strength curve	A. Nettles	6" X 4"	39
69	No-Growth Threshold (DT05)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Wohler curve generation (no growth threshold)	A. Nettles	6" X 4"	4
70	Fatigue at Hot/Wet (DT06)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Validate environmental knockdown factors	A. Nettles	6" X 4"	2
71	Validation of Repair (DT09)	1	[45,0,-45,0,90,0,0,90,0]s	N/A	Validate repair techniques	A. Nettles	6" X 4"	3

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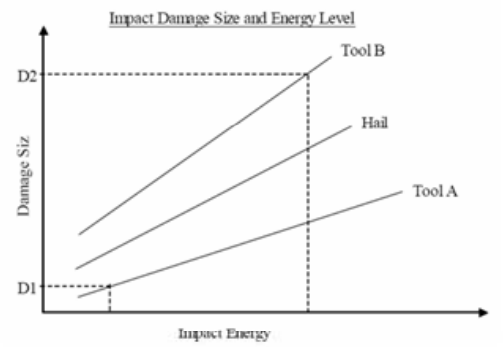
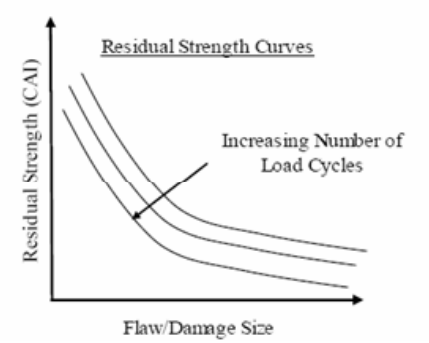
Implementation Example: Ares I Upper Stage Composites Interstage

- **Test Based Approach**

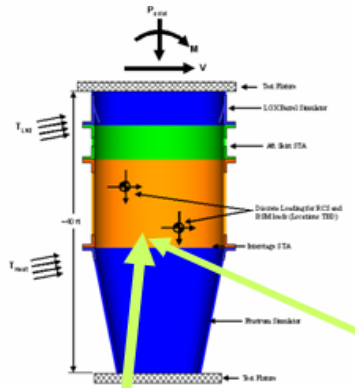
Determine NDE Sizes vs.
Impact Energy (or defect size)



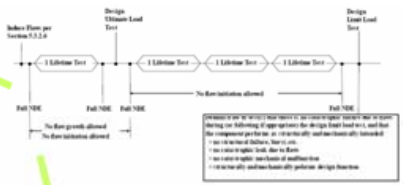
Coupon Tests
Residual Strength vs. NDE (or defect) size



Full-Scale Qualification Test

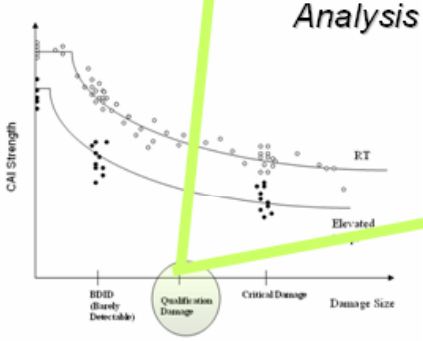


MSFC-RQMT-3479
Figure 5 with Qualification Damage

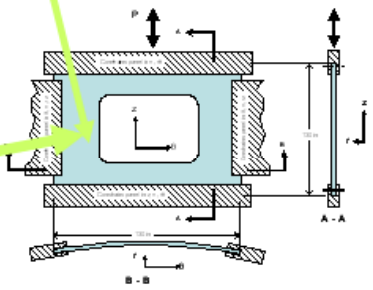


All damage threats larger than the qualification size must be mitigated by a protection plan

Analysis Support



Development Tests



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