FLIGHT READINESS STATEMENT
STS-89/ET-90
EXTERNAL TANK PROJECT
PRE-FLIGHT REVIEW

EXTERNAL TANK ET-90/STS-89, AS IDENTIFIED IN THE EXTERNAL TANK PROJECT PRE-FLIGHT REVIEW DATED OCTOBER 27, 1997, IS CONSIDERED READY TO SUPPORT FLIGHT UPON ACCEPTABLE DISPOSITION OF OPEN/PLANNED WORK AND/OR OPEN ACTIONS.

E. C. SMITH/EB01

M. A. PESSIN/EE31

A. F. WHITAKER/EH01

for A. O. HARRIS/CR01

for G. R. WALLACE/EL01

W. R. HUMPHRIES/ED01

S. P. SAUCIER/EP01

M. D. SMILES/CR70

P. V. COUNTS/SA31, CHAIRMAN

= FRR

COLOR CHART of FAULT TREE

ESCAPE BOX INSUFFICIENT TESTS TO SUPPORT FLEXURAL STRAIN ALLOWABLE

ACTIONS

January 5, 1998

Space Shuttle External Tank

STS-89/ET-90 ΔPre-Flight Review

1) KATNICK/COPSEY REVIEW – Y PANEL FOR ANY UNVIEWED AREA HIGHLIGHT

2) WORK MECHANISM (TWO TONE VS THRUST PANEL) THIS ISSUE IS WITH NEW FOAM – TWO TONE SPRAY HISTORY

3) OUT-of-FAMILY CHART 14
- STATE NO OUT of FAMILY + KSC
- ONE OUT of FAMILY PRIMER @ VENDOR
- LOWEST DENSITY ON ET 89 (STS 87)

4) 18R
STATE ESCAPE
STATE I/T ONLY
- RESULTED IN MOST PROBABLE CRACK FACTOR REDUCED AREA
- CAPTURE LAST BULLET ON PAGE 19

Michoud Space Systems

5) 20 BEEFUP TO TELL THE STORY THAT GOOD RESULTS IN SHEAR BUT WOULD NOT FAIL FOAM.

ET-1

ET90FRR.4250.dd.1/98

6) ADD STS 86/ET 88 DATA TO CHART 22

- MARK H JSC
- RON W KSC
- TERRY/DENNIS LMC
- JIM/GALE MAF

7) GET STS 89 INTO PITCH

8) ET 23 – ADD 75% OR RIGHT % IMPROVEMENT BY MATHINING RIBS

9) ADD MOST PROBABLE CAUSE AT END of FAULT TREE

Overview

- **Changes**
  - Implement thick/thin foam on LO2 tank sidewall
    - Previously discussed at STS-89/ET-90 Pre-Flight Review (10/27/97)
    - Included in Appendix
- **No significant out-of-family processing anomalies**
- **Limited life component status**
  - All items within required life
- **Open work/paper**
  - To be discussed as Special Topic
- **Special Topic**
  - IFA STS-87-I-001, Intertank Thrust Panel Foam Damage
- **Readiness Statement**

October 27, 1997

Space Shuttle
External Tank

STS-89/ET-90
Pre-Flight Review

LOCKHEED MARTIN

Michoud Space Systems

Agenda

• ***Overview***	***Jim Feeley***
• ***Prior Mission Performance Summary***	
• ***Current Mission/External Tank Highlights***	
• ET-90 Mass Properties Status	Mike Simpson
• Changes	Jim Feeley
• Senior Management Review NCDs	Wanda Sigur
• SRM&QA Assessment	Terry McKeough
• KSC Processing	Brian Knipfing
• Verification/Certification	Jim Feeley
• Mission Unique Assessment	
• Readiness Statement	
• Appendices	
- A: Minor Changes	
- B: SRM&QA Assessment	
- C: KSC Processing	
- D: Previously reviewed material	

Overview

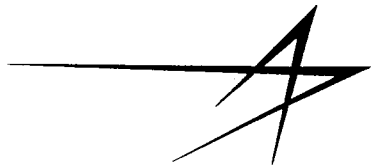
- Review covers changes, differences and "out of family" non-conformances not previously flown and/or reviewed

- This review for STS-89/ET-90 includes:
  - Prior mission performance summary
  - Items specific to mission STS-89
  - Details of previously presented items are included in the Appendix

- **FRR Series**

- Pre-flight Review	10/27/97
- ET/SRB Mate	11/5/97
- Space Shuttle Vehicle FRR	1/5/98
- Mission Management Team (L-2 Day)	1/14/98

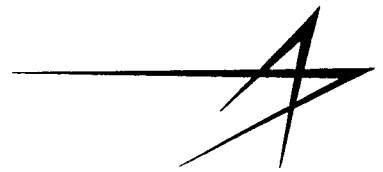
Prior Mission Performance Summary



STS-86/ET-88, 9/25/97

System	Performance
OMRSD	No violations
LCC	Nominal
Instrumentation	Nominal
MPS	Nominal • First ET flown with thick/thin TPS configuration on LH2 tank - Negligible effect on end of replenish LH2 tank ullage pressure • Previous nominal ullage pressure = 0.2 psig • STS-86 ullage pressure - Predicted = 0.232 psig - Actual = 0.19 psig
ET Hazardous Gas	Nominal

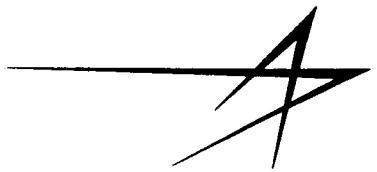
Prior Mission Performance Summary



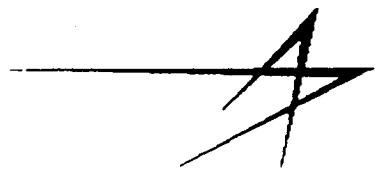
STS-86/ET-88, 9/25/97

System	Performance
First flight of Composite Nose Cone	No issues - Frost formed rapidly around louvers on composite nose cone after vent hood retraction • Frost is acceptable • Update in work to NSTS 08303 Ice/Debris Inspection Criteria to add photograph depicting frost on GO2 vent louvers
TPS	Nominal
ET disposal	Nominal
Orbiter tile damage	Lower surface, above average • Diameter > 1" = 27 • Total = 100
Post flight photo review	Poor visibility - Photos not useful for post flight evaluation

Mission/External Tank Highlights



Mission	**STS-89**
• **Launch**	1/15/98
- Window	0103 - 0113 EDT
- Pad	A
- Orbiter	Endeavour (OV-105)
- Orbital inclination	51.6° - Insertion at 160 NM
- ET photo coverage	• Crew photos from cockpit window
	• Umbilical well cameras
• **Primary payload**	• 8th MIR docking
	• SPACEHAB (double module)
• **Landing**	1/24/98
- Time	0447 EDT
- Location	KSC
External Tank	**ET-90**
• DD250 acceptance	8/28/97
• Shipped to launch site	9/4/97



Mission/External Tank Highlights

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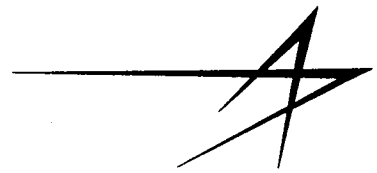
Agenda



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ET-90 Mass Properties Status

Issue: ET-90 weight status (predicted vs. actual delta)

Background:

- The specification weight for ET-90 is 68,805 lbs
- The control weight for LWT is 65,449 +/- 511 lbs
- ET-90 was weighed August 28, 1997

- Actual weight	65,460 lbs
- Predicted weight	64,713 lbs
- Delta	(747) lbs
- Predicted weight adjustment	
• Aluminum density	+472 lbs
• Actual TPS thickness	+274 lbs
- Delta including adjustment	(1 lb)

Rationale for Flight:

- ET-90 actual (scale) weight meets specification and control weight requirements
- Verification weighing will be performed on ET-90 during lift for SRB mate

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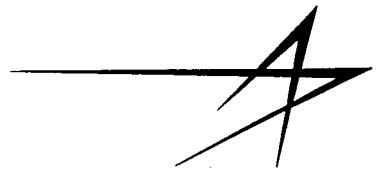
Changes/Senior Management Reviews - List

Description	Presenter
• **Changes**	
- **Requirements**	
• Revise MAF All Systems Test constraints (B02019)	Not presented - Included in Appendix A - Minor Changes
- **Configuration**	
• Implement VPPA welds on LO2 and LH2 tank dome caps (B01887B/B02005)	Not presented - Included in Appendix A - Minor Changes
• Thick/thin foam on LO2 tank ogive/barrel (B01982/B02005)	Jim Feeley
• **Senior Management Review**	
- ET-90 LH2 Tank Extrusion Issue	Wanda Sigur

Thick/Thin TPS on LO2 Tank



Change:

- Implemented new TPS configuration for the LO2 tank ogive and barrel
  - Thickness now varies with circumferential location

Background/ Reason:

- Reduction of TPS average thickness provides a potential 195 lb weight savings for SLWT
- Early incorporation of this change on ET-90 diminishes number of first time configuration changes for SLWT
- Previous LWT spray system applied a constant circumferential foam thickness
- +Z side of LWT has higher ascent heating environments setting the TPS thickness requirements

Thick/Thin TPS on LO2 Tank

Description:

- Hardware
  - TPS reduction encompasses five circumferential thickness bands on LO2 tank
    - Control within each band results in a thick/thin configuration
- Manufacturing
  - Implement use of new delivery system to control foam thickness
    - Tighter tolerance and tailored thicknesses
    - Applies thick/thin foam using variable flow rates

Process Development:

- Validation sprays conducted in production cell
  - Spray #1 was full scale test on GVTA
    - All objectives obtained
      - Tensile strength, density and cryoflex tests were performed
    - One area had out of tolerance thickness
  - Spray #1 repeated with partial spray to adjust thickness
    - Objective obtained
  - Spray #2 performed on ET-90 - All objectives obtained
- Similar process used for ET-88 and 89 LH2 tank barrels

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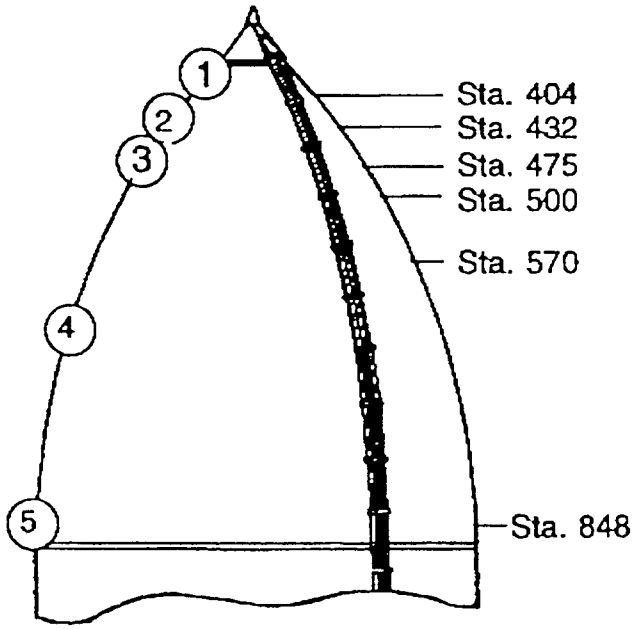
Thick/Thin TPS on LO2 Tank

ET-89 (STS-87)

Station	Thickness (in.)
404 - 439	
• +Z	2.15+0.25"
• -Z	2.15+0.25" -0.53"
454 - 540	2.00±0.38"
570 - 745	1.00+0.38" -0.25"
745 - 852	1.00±0.25"



LO2 Tank (+Z shown)

ET-90 (STS-89)

Station	Thickness (in.)	
	+Z	-Z
404-420	2.15±0.25"	1.85±0.25"
432-460	2.15±0.25"	1.60±0.20"
475-490	2.15±0.25"	1.15±0.15"
500-540	2.15±0.25"	1.00±0.15"
570-848	1.00±0.15"	0.88±0.13"

Plug Pull Values

- Requirement = 30 psi
- ET-90 Actuals

① Lead out	48.0
② Station 400	39.5
③ Station 420	48.0
④ Station 600	54.6
⑤ Lead in	47.9

Thick/Thin TPS on LO2 Tank

ET-89 (STS-87)

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• +Z	2.15+0.25"
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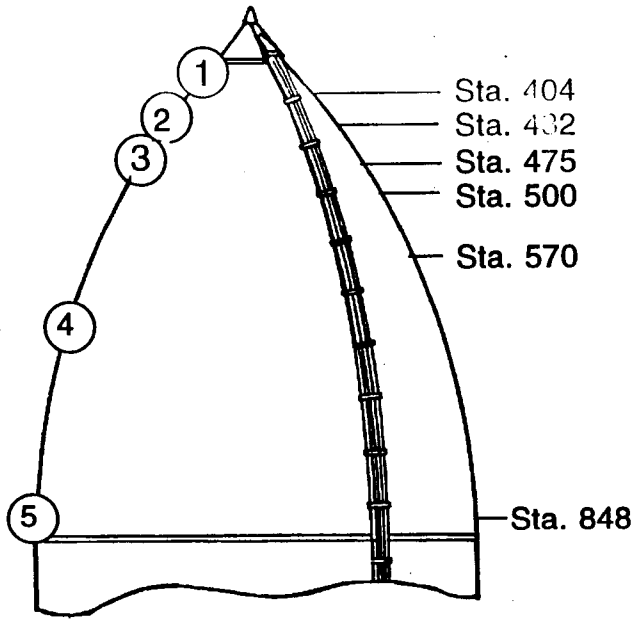

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④ Station 600	65.0
⑤ Lead in	47.9

Thick/Thin TPS on LO2 Tank

Basis for Certification:

- Analysis
  - Stress: New spray configuration meets required FS of 1.10
    - FS unchanged = 1.21 (failure mode: bondline delamination)
  - Thermal
    - LO2 structural temperature unchanged (max. temperature: 300°F at MECO)
    - Minimum TPS thickness maintained
      - No ice/frost formation concern
  - Propulsion: Negligible impact to LO2 propellant inventory (≈ 131 lb reduction)
    - End of replenish ullage pressure
      - Previous nominal = 0.603 psig
      - Predicted STS-89 (ET-90) = 0.635 psig
- Inspection: Plug pulls verify proper application of foam

ET-90 LH2 Tank Extrusion Issue

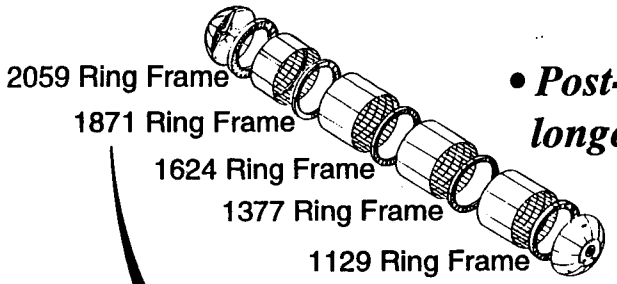
Issue:

- A 0.4 inch x-ray indication was detected after initial proof test of the ET-90 LH2 tank
  - Located adjacent to weld in extrusion forward of longerons at Station 1871

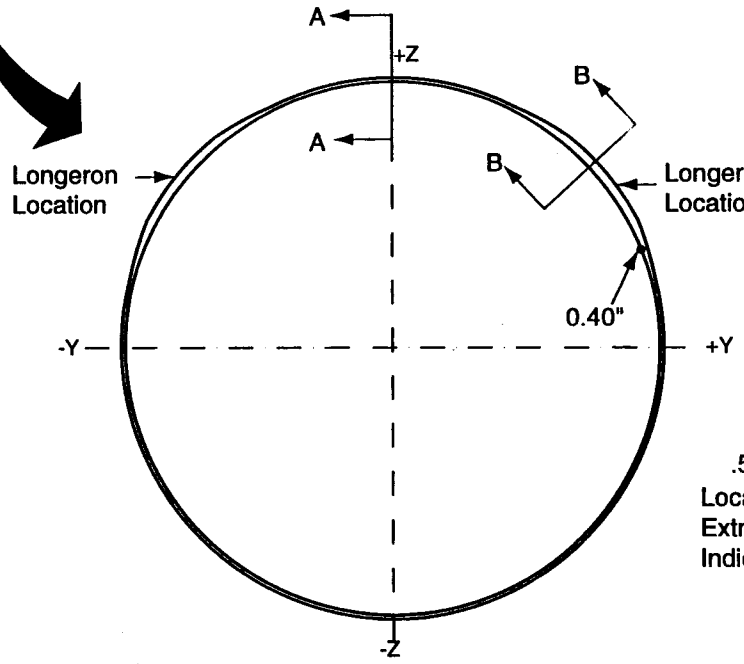
Background:

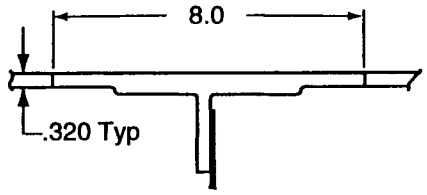
- Similar indications were noted on ET-89 LH2 tank
  - First time occurrence on ET-89
  - Considered to be out of family
- Located in extrusion heat affected zone adjacent to initial weld
- CAPS/SI initiated fault tree - Investigation indicated root cause was low material strength due to re-crystallized grain structure

ET-90 LH2 Tank Extrusion Issue

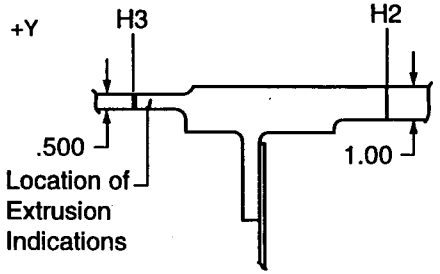


- ***Post-proof indications were located in the longeron areas of the Station 1871 Chord***





Section A-A
(Typical)



Section B-B
(Longeron Area)

Station 1871 Ring Frame Arrangement

ET-90 LH2 Tank Extrusion Issue

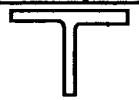
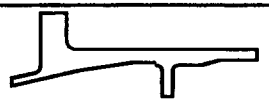
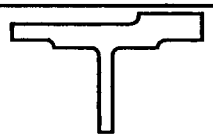
Cause:

- Large re-crystallized grains extended 0.5" to 0.75" from original extruded surface
  - Not completely machined off in manufacture of chord
  - Aggravated by alignment of weld fusion line with natural flow lines of extrusion shape
  - Grains aligned normal to load path
  - Lower toughness, thickened grain boundary precipitation due to large grain size

Disposition:

- Weakened microstructure ground out and replaced with weld wire (including reported x-ray indication)
  - Process fully replaced the extrusion weld heat affected zone
  - Resulting mechanical and fracture properties were typical of allowables established for plate-plate welds
  - Process returned hardware integrity to acceptable levels for proof and flight
- Extensive test program on other extrusions indicated adequate strength at other weld stations
  - Large vertical grain structure not noted
  - Additional post-proof inspections successfully performed to verify integrity

ET-90 LH2 Tank Extrusion Issue

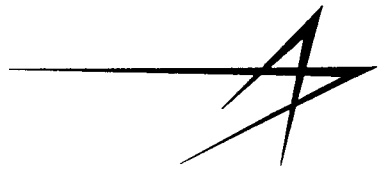
			Ultimate Stress (ksi)			Factor of Safety	
Location	Shape	Weld Code	Flight	Proof	Allowable Stress (ksi)	Required	Actual
744 T-ring		O3 O4	31.96 24.70	23.24 18.15	36.40 36.40	1.32 1.31	1.50 1.93
851 Dome Chord		O5 OAF	21.85 33.40	14.03 31.11	36.40 37.70	1.32 1.35	2.20 1.53
1129 Dome Chord		HFF H8	33.72 23.47	29.53 25.76	38.00 33.70	1.25 1.26	1.41 1.81
1377 & 1624 Frames		H7 H6 H5 H4	29.52 25.38 26.90 35.02	26.77 23.11 23.32 27.89	39.80 39.80 39.80 39.80	1.31 1.30 1.26 1.31	1.77 2.04 1.86 1.49
1871 Frame Chord		H3 H2	19.00 42.30	17.90 30.80	19.10 42.40	1.26 1.26	1.28 1.31
2058 Dome Chord		H1 HAF	33.05 47.20	25.51 35.40	39.80 45.60	1.32 1.31	1.58 1.41

ET-90 LH2 Tank Extrusion Issue

Rationale for Flight:

- Weakened microstructure ground out and replaced with weld wire
- Successful re-proof test of ET-90
  - Post proof x-ray of entire H2 and H3 welds revealed no indications
  - All penetrant indications greater than 0.2" removed by sanding or heat repair
    - Post proof penetrant inspection of enhanced area indicated no changes resulted
- All extrusion welds have positive margins of safety using
  - "As-built" peaking and mismatch
  - Reduced weld strength from recent test program
  - "Enhanced extrusion" weld properties from test program
  - Allowable methodology 99% reliability/95% confidence per Mil-HDBK-5F
- All MRB actions re-reviewed - Positive margins are shown
- All x-rays (pre and post proof test) have been re-reviewed - No indication changes resulted
- All welds are demonstrated to 100% of limit flight loads or greater by proof test
  - Includes effect of reduced cryogenic enhancement of strength
  - Approximately 70% of entire weld length is demonstrated to ultimate design load (limit x SF) by proof test
- Presented/approved at Level II PRCB on 11/22/96 (SR0760)

Agenda



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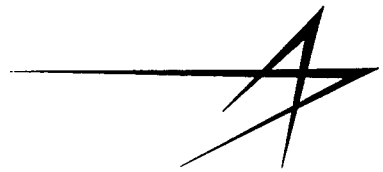
SRM&QA Assessment

as of 10/23/97

Item	Status
• **Alerts**	None open
• **MRB Assessment**	Complete - No issues/no impact to hazard controls
• **Hazard Assessment**	Complete - All hazard reports were re-assessed and hazard controls verified
• **Corrective Action Problem Summaries (CAPS)** - E-163, Temperature transducer failed insulation resistance test during supplier ATP	No issues • All ETs successfully passed ATP - Defect detection assured by testing with component immersed in saline solution • Adequate tests of transducers in place to assure performance • Pending closure at MSFC

Agenda



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KSC Processing - Status

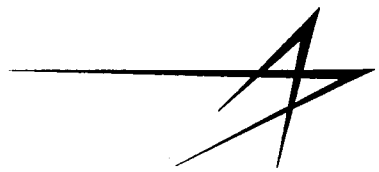
as of 10/23/97

- **Discrepancy Reports (DRs)/Problem Reports (PRs) Review**
  - All PR/MRB * discrepancies/dispositions similar to previously flown vehicles
  - All MRBs have been reviewed by MAF Reliability for potential SMR
- **Limited Life Component/ET Status** *
  - All within required life through scheduled launch date plus 90 days
- **OMRSD Exceptions/Waivers** *
  - GFP LH2 disconnect tip load measurement (WK 03685)
- **Changes**

- ET modifications	None
- OMRSD	None
- Software	None
• SIM Load	12/1/97
• SIM Launch	12/17/97

* Included in Appendix C

Agenda



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Verification/Certification

as of 10/23/97

Item	Status
• **NSTS 07700, Volume X Baseline** - Revision L, Change 236	No constraints
• **Certification documentation** - Hardware Certification Sheets (HCS) • T005H, Implement thick/thin LO2 TPS spray (B01982/A)	To be discussed in separate handout
- Certificates of Qualification (COQ)	Approved - No issues
• **Waivers/Deviations** *	Approved - No issues

* Included in Appendix D

ET-90 PDL Repairs

Issue:

- Concern identified at SLWT DCR for recession of NCFI 24-124 downstream of PDL repairs
  - Possible early ET break-up (> 294,000 ft)
- Open Hardware Certification Sheet (HCS T005H) for ET-90

Background/ Discussion:

- Results of previous test program did not adequately address downstream erosion of NCFI 24-124 aft of PDL repairs
  - PDL repairs $\geq$ 4.0 inches oriented parallel to airflow with heating rate $\geq$ 4.0 btu/ft^2-sec
- ET-90 Clearance based on evaluation of as built hardware
  - Build records reviewed
    - PDL repair locations/sizes identified
  - Vehicle walked-down/photographed to define orientation of repairs $\geq$ 4.0" long
  - Heating environment defined for each repair location
  - One repair (4.0" x 1.6" x 0.9") at station 1950 outboard of -Y longeron had a heating rate = 4.77 btu/ft^2-sec
    - ET-90 actual TPS thickness = 1.5" minimum
  - Remaining repairs were < 4.0 inches or were located in areas with heating rate $\leq$ 4.0 btu/ft^2-sec
- Hot gas facility test program initiated to resolve issue for remaining ETs

ET-90 Rationale for Flight:

- Thermal analysis performed on ET-90 repairs showed that ET breaks up lower than required 294,000 ft
  - Analysis assumed PDL repair to substrate
- Stress analysis: Repaired area meets required FS of 1.10
  - Actual FS = 1.96 (failure mode: bond adhesion)
- Test program to be complete 12/5/97

ET90PFR.4250.10/97.dd

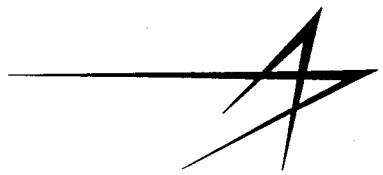
10-27-1997 08:28 5042574405 MAF/MSR P.01

Mission Unique Assessment

as of 10/23/97

Category/Item	STS-89
• **Review of MRB actions using updated loads**	ECD 11/21/97
• **MPS Preflight Prediction Package**	ECD 1/5/98

Readiness Statement



The External Tank, ET-90 is hereby certified and ready for STS-89 flight pending completion/closure of open and planned work

Terry L. Hibbard
Vice President, External Tank Project
Lockheed Martin Michoud Space Systems

Appendices

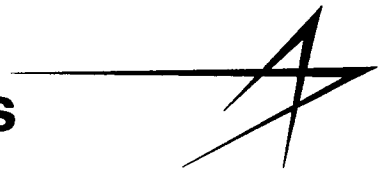
- **A: Minor Changes**

- **B: SRM&QA Assessment**
  - NCD Assessment Criteria
  - Temperature transducer ATP failure (E-163)

- **C: KSC Processing**
  - Limited Life Components
  - Modification Summaries/Status
  - Alternate Blowing Agent Usage at KSC
  - Software Changes: None
  - OMRSD Exceptions/Waivers
  - OMRSD Changes (RCNs): None

- **D: Previously presented items**
  - Level II Waivers
  - Level III Deviations

Revise MAF All Systems Test Constraints



Description:

- Modify TPS closeout constraint in MAF Acceptance Test document (TMO4k-B)
  - Was: Ensure that all MAF TPS closeouts are completed prior to start of All Systems Verification Test
  - Now: Ensure that all TPS closeouts that contact electrical wiring and instrumentation are completed prior to start of All Systems Verification Test

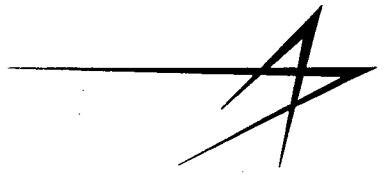
Reason:

- Productivity - Enhance manufacturing process flow

Basis for Certification:

- Similarity - No change in flight hardware

VPPA Welding on LO2/LH2 Tank Domes



Description:

- Replaced TIG weld process with VPPA process on LO2 and LH2 tank domes

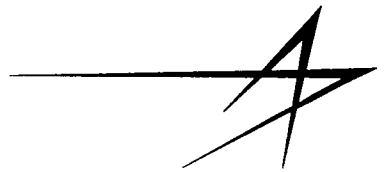
Reason:

- Productivity - Reduce weld preparation, rework activity, cost and schedule

Basis for Certification:

- Test
  - Certification/confidence panels
  - Proof
- Inspection
  - X-ray
  - Penetrant
  - Leak
  - Visual

Class II or JS/DCN Changes



- All Class I/II JS/DCN changes have been reviewed by MSFC Resident Office
- All Class II STP/STM/Standards changes have been reviewed by MSFC M&P Lab
- These changes are acceptable for flight and summarized in this appendix (presentation not required)
  - Presentation criteria - Selection for presentation based on changes affecting:
    - Processes
    - Configuration
    - Material
    - Alternate Hardware
  - Presentation rejection criteria - All changes that do not affect configuration, material or processes
    - Revise Point of Incorporation
    - Drawing Clarification
    - Non-Flight Hardware Installation/Removal
    - Datum Changes
    - Update Usage/List of Materials (L/M)
    - Drawing Incorporation Errors
    - Manufacturing Aid
    - Drawing Errors
    - Fastener Type/Grip
    - Tolerance Change
    - Productivity
    - Minor changes taken care of by initial release of Class I Change (Same categories as above)

Class II or JS/DCN Changes

Change No.	Description	Discipline
H34809-992	• Revert back to original method of dimensioning to prevent tool rework of the LH2 dome caps • Add tooling holes to permit dye penetrant inspection and ease packaging/handling	Structures
H35809-054	Revised true position tolerance on 36 hole pattern of the LO2 oxidizer flange to reduce potential rework	Propulsion
H35809-141	Clarified heat shrink tubing installation over locking pin by adding flag note and dimensional requirements to LO2 manhole flange of LO2 dome cap	Structures
H35809-180	Revised drawing to correct dimension of a HGDS tube diameter in the Intertank - Data base load error	Propulsion
H35809-242	Revised LO2 dome weld assembly part number callout to reflect correct dash number of the cap	Structures
H35809-641	Revised LO2 tank foam application drawing to reflect foam thickness transition line from Station 404 to 389. Drawing erroneously changed during previous revision	TPS

Class II or JS/DCN Changes

Change No.	Description	Discipline
H35809-809	Revised STP to specify proof load values for bearing installed with Type II staking	Structures
H35809-825	Added a note to LO2 tank clean and prime drawing to mask around electrical feedthru to preclude primer from blocking any potential leak during bubble leak test	Structures
H35809-827	Revised GUCP swivel housing assembly drawing to use Krytox lubricant in place of Sanstrom 326A	Propulsion
H35809-842	Revised CIL implementation drawing to incorporate miscellaneous comments and corrections	Systems
H35809-854	Relaxed tolerance on flange of LO2 and LH2 electrical umbilical cable tray fairing to allow supplier to use computer machining program to build parts	Structures
H35809-876	Revise requirement of applying N363B lubricant to helium inject line by omitting lubricant under the clamp that attaches the line to the structure, as this area is not accessible. Lubricant was not applied on prior builds	Structures
H50001-791	Eliminated non-essential GX-6300 gelation test because witness panel provides proof adhesive is cured	Materials
J31176	Added ICD flag notes to field of drawing. ET hardware meets all ICD requirements	Systems

Class Changes - STPs/STMs/STDs/AVL

Change No.	Document	Description
H35809-837	AVL 26L6/7	Correct vendor part numbers
H35809-838	Std 34L3-5	Correct dimension on standard

NCD Assessment Criteria

- Assessment of all MRB Items
  - Adequacy of technical dispositions
  - Completeness of required repair/retest
  - First time occurrences/SMR
  - Verification of margin of safety assessment/documented
  - Review of impact to hazards
  - Engineering review for impact to loads
  - Engineering review for reduced extrusion to plate weld allowables

Temperature Transducer ATP Failure (E-163)

Issue:
- A Rosemount temperature transducer failed insulation resistance (IR) segment of the supplier ATP
  - Requirement: IR $\geq$ 50 megohms with 50 volts applied
  - Actual: IR read 10 to 30 megohms
- Low IR could result in undetected false bias output
  - Criticality 1R from lift-off to ET/Orbiter separation

Background:
- Four transducers used per ET
  - 2 each in Intertank
  - 2 each in Nose Cone
- Post visual inspection revealed damage to sensing element

Cause:
- Damaged induced during cleaning operation by metallic tool after brazing

Corrective Action:
- Manufacturing process revised
  - Limited cleaning to rinse operation
  - Visual inspection using 30X magnification

Rationale for Flight:
- All ETs successfully passed ATP
  - Defect detection assured by testing with component immersed in saline solution
- Adequate tests of transducers in place to assure performance
- Pending closure at MSFC

ET-90 DR/PR/OMRSD Waiver/Exceptions

as of 10/23/97

System	Discrepancy	Problem	MRB Items	Exceptions/ Waivers
• Electrical	**0**	**1**	0	**0**
• Propulsion/ Pneumatics	**1**	**3**	0	**1**
• Structures	**3**	**3**	0	**0**
• Thermal (TPS)	**0**	**4**	2	**0**
Total	**4**	**11**	**2**	**1**

ET-90 PR/MRBs - Summary

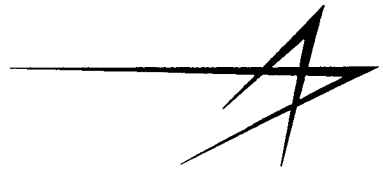
PR No./Status	Title/Description	Disposition
TPS		
PET-90-TS-0002	Three areas of under-sprayed SS-1171 foam on edge of aft third hardpoint closeout	• Use as repaired - Trimmed and filled with PDL - Thermal analysis indicates no ice/frost or debris concern
PET-90-TS-0004	GFP LH2 disconnect aft inboard pyro can closeout exceeds void criteria of 3 acceptable voids within 1 square inch (BNA responsibility)	• Use as is - Foam application within BNA process controls data base - Surface smooth enough for acceptable fire barrier - Accepted by BNA engineering and meets LMMSS acceptance criteria

ET-90 Limited Life Components

Cycle Sensitive

Description	Part No.	Serial No.	Limit	Required	Remaining
LO2 Fwd Ogive Cover Plate	80911001207-029	000416230	100	1	100
LO2 Tank Mechanical Assy	80912002000-019	000388790	100	1	100
LO2 Manhole Cover Assy	80911001205-010	000480820	100	1	100
LH2 Manhole Cover Assy	80914081488-019	000442850	100	1	100
LH2 Tank Mechanical Assy	80914002000-009	000413830	100	1	100
LH2 Manhole Cover Assy (Aft Dome)	80911001444-010	000406650	100	1	100
		000434360	100	1	100

ET-90 Limited Life Components



Age Sensitive

Description	Part No.	Serial No.	Limit	Initiation	Expiration
External Tank	80901000000-270	00000083	6 Yrs	8/7/1997	8/7/2003

Age Sensitive Pyrotechnics - 10 Years Life/Requires Lot Verification Tests After 4 and 7 Years

Description	Part No.	Lot No.	Serial No.	Date of Manufacture	Expiration
Separator Assy GUCP	PD5000020-059	AAG	00001126	12/13/1996	12/13/2000
Cartridge Assy	PD5000020-030	AAG	00001214	11/27/1996	11/27/2000
			00001216	11/27/1996	11/27/2000

ET-90 Alternate Blowing Agent Usage at KSC

as of 10/23/97

Foam	Document	Description	Location	Size
SS-1171	T5141	Aft hardpoint closeout	Sta 1973 - 2076, 180°	4410 sq. in.
PDL-1034	PR-TS-0002	Aft hardpoint closeout	Sta 1973 - 2076, 180°	11 sq. in.

ET-90 File IV OMRSD Waiver

Waiver No.	Description	Acceptance Rationale
WK03685	Measured tip load on GFP LH2 disconnect should be within +/-10 lbs of ATP value or last adjustment value with a minimum value of 55 lbs • ATP value = 82.3 lbs • ET-90 value at KSC = 68.8 lbs	• No hardware problems identified - All other measurements within limits • Measured value is within both flight and water flow test experience • Similar values recorded on 4 other ETs

Level II Waivers

Document/ Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700 Vol. V - Information Management Requirements				
Generic part name, type, common designation, and part manufacturer H4 code are not required for EEE parts status printout	S00127B 6/28/88	Table C.5 Item 2SR-10	6	ETs 49 & up
Data required in limited life status report is supplied in acceptance data package	S00127B 6/28/88	Table C.6 Item 2SR-7	8	ETs 49 & up
Requirement to deliver element pressure vessel historical data to EPO will remain at contractor facility	S00127B 6/28/88	Table C.6 Item 2SR-7	10	ETs 49 & up

Level II Waivers

Document/ Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700 Vol. X - Space Shuttle Flight and Ground System Specification , Book 1 Requirements				
Electrical wiring of redundant systems NSTS 08080-1, 20A/4B	S40732G 6/18/88	Table 2.0	362	ETs 23, 27-29, 31 & up
Electrical bonding per MIL-B-5087B (2)	S040732M 9/9/88	3.6.14	378	ETs 23, 27-29, 31 & up
Soldering, circuit boards & connectors	S040732M 9/9/88	3.6.15.1.1	379	ETs 23, 27-29, 31 & up
PD7400106 circuit boards	S040732M 9/9/88	3.6.15.2.1	382	ETs 23, 27-29, 31 & up
PCM MUX and pressure transducer circuit boards	S040732M 9/9/88	3.6.15.2.1	383	ETs 23, 27-29, 31 & up

Level II Waivers

Document/ Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700 Vol. X - Space Shuttle Flight and Ground System Specification , Book 1 Requirements				
CIL fail safe and redundancy requirements	S040201E 4/3/87	3.5.1.1.1 Thru 3.5.1.1.3	401	ETs 23, 27-29, 31 & up
2058 Frame, Bearing Stress	S40793H, H-R1 11/22/88	3.2.2.1.5.2	452	ETs 23, 27-29, 31 & up
Soldering of electrical connectors	S094779C 2/21/91	3.6.15.1.1	573	ETs 37, 41 & up

Level II Waivers

Document/ Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 08060, Rev. F - System Pyrotechnic Specification				
Use 40M36298 connectors	S040732F 6/24/88	3.4.1	61	ETs 23,27-29, 31 & up
Prevent adverse effects of common mode currents	S040732F 6/24/88	8.2.1	64	ETs 23, 27-29, 31 & up
Fire circuit wiring shall be routed separately	S040732F 6/24/88	8.2.3	65	ETs 23, 27-29, 31 & up
NSTS 07700-10-MVP-01 - Shuttle Master Verification Plan				
Environmental acceptance of ET components	S002130H 3/7/89	3.7.1	13	ETs 23, 27-29, 31 & up
NSTS 08123, Rev. B - Certification of Flexible Hoses and Bellows				
LH2 feedline bellows	S005203G-R1 8/2/91	1.2	3	ETs 42 - 45, 47 & up

Level II Waivers

Document/ Requirement	Authority	Paragraph	Waiver No.	Effectivity
SL-E-0001 - Specification Electromagnetic Compatibility Requirement				
Wire marking is not applicable to the ET	S40732K 9/27/88	3.2.5	3	ETs 23, 27-29, 31 & up
SW-E-0002 - Ground Support Equipment General Design Requirements				
Factor of safety applied to yield for GUCP leg	S87020L 8/17/88	3.4.2.1	21	ETs 23, 27-29, 31 & up
ICD 2-12001 - Orbiter Vehicle/External Tank				
Potential particulate on downstream side of LH2 tank siphon screens could violate cleanliness requirement	S058410 7/24/97	3.3.2	IO-1403	ETs 87-91

Level III Deviations

Document/ Requirement	Authority	Paragraph	Waiver No.	Effectivity
CPTO1M09A, External Tank Contract End Item Specification				
Potential particulate on downstream side of LH2 tank siphon screens could violate cleanliness requirement	CCBD ET3-00-9409 7/31/97	Para 3.3.10 (d)	231 R1 231 R2	ETs 87-91 ETs 96-98
MMC-ET-TMO4k-B, Space Shuttle ET Flight Acceptance Requirements				
LH2 tank proof pressure test exceeded maximum cumulative time requirement	CCBD ET3-00-9311 5/6/96 CCBD ET3-00-9329 8/1/96	Para 2.3.1.2	224 227	ET-90

FLIGHT READINESS STATEMENT
STS-89/ET-90
EXTERNAL TANK PROJECT
Δ PRE-FLIGHT REVIEW

EXTERNAL TANK ET-90/STS-89, AS IDENTIFIED IN THE EXTERNAL TANK PROJECT DELTA PRE-FLIGHT REVIEW DATED JANUARY 5, 1998, IS CONSIDERED READY TO SUPPORT FLIGHT UPON ACCEPTABLE DISPOSITION OF OPEN/PLANNED WORK AND/OR OPEN ACTIONS.

for E. C. SMITH/EB01

for M. A. PESSIN/EE31

for A. F. WHITAKER/EH01

A. O. HARRIS/CR01

G. R. WALLACE/EL01

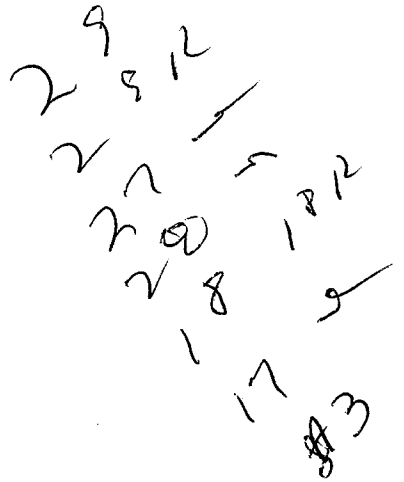
W. R. HUMPHRIES/ED01

S. P. SAUCIER/EP01

M. D. SMILES/CR70

P. V. COUNTS/SA31, CHAIRMAN

Special Topic
IFA STS-87-I-001
Intertank Thrust Panel Foam Loss



IFA STS-87-I-001, Intertank Thrust Panel Foam Loss

Agenda

- Issue
- Background
- Discussion
  - Fault Tree Approach
  - Fault Tree Findings
- ET-90 Flight Clearance
- Conclusions

Intertank Thrust Panel Foam Loss

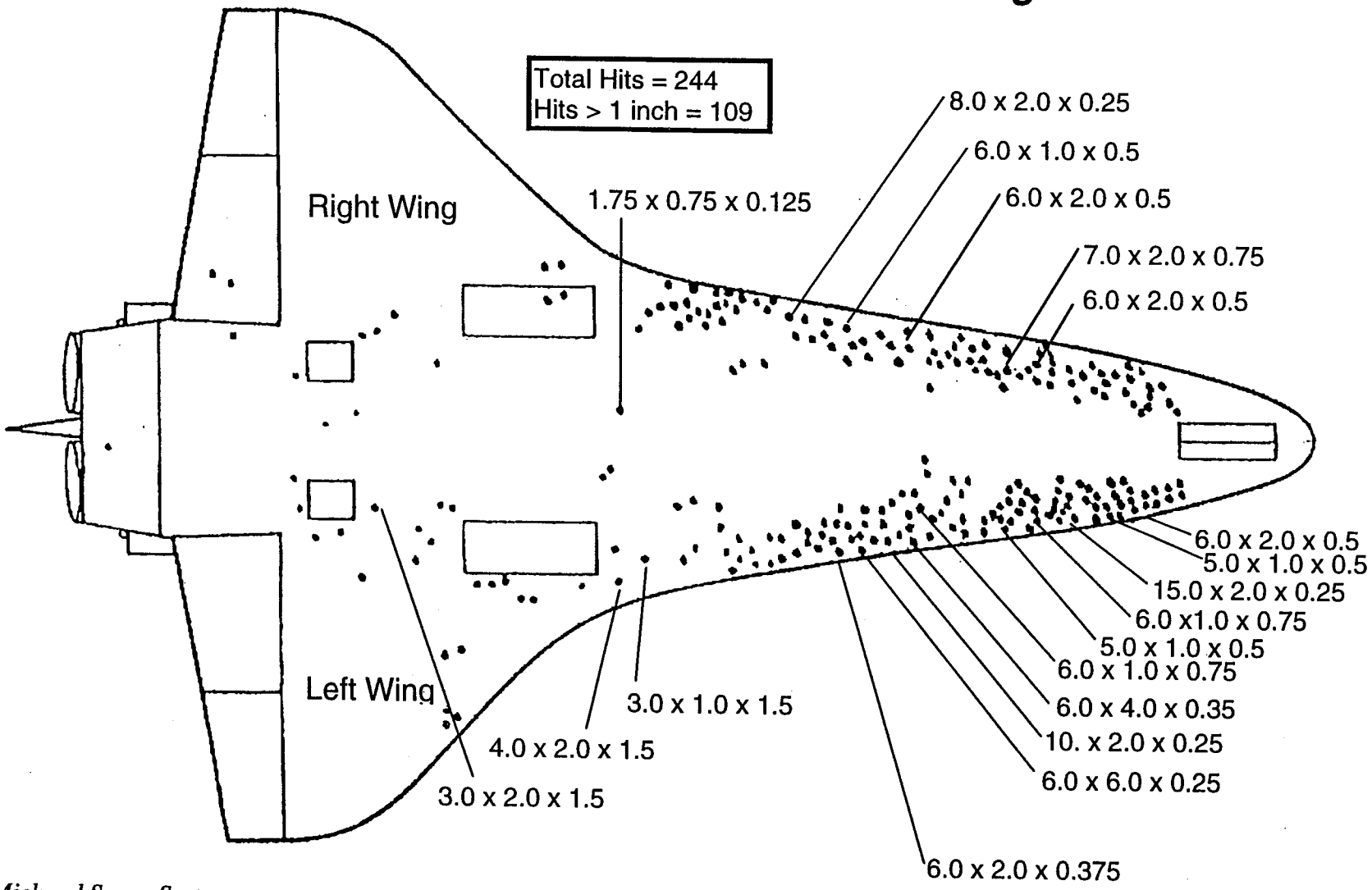
Issue

- STS-87/OV-102 had much greater than average lower surface tile damage (109 hits > 1", average = 14 > 1")
  - Nearly symmetrical damage pattern on Orbiter lower surface from front landing gear to main landing gear door

- Post separation crew photographs showed significant areas of missing foam on the +Y and -Y Intertank thrust panels

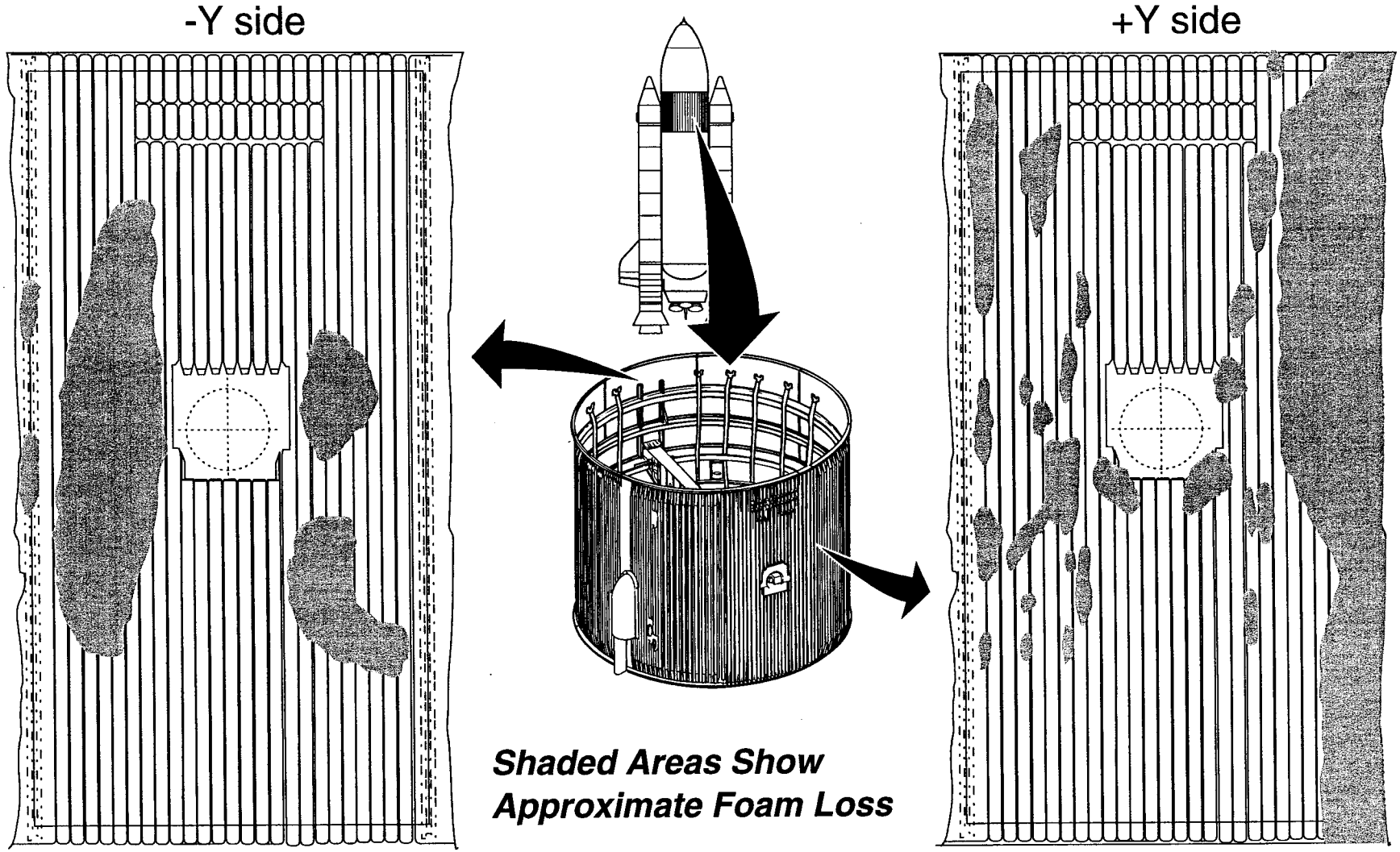
Intertank Thrust Panel Foam Loss

Background - STS-87 Orbiter Lower Surface Tile Damage Locations



Intertank Thrust Panel Foam Loss

Background - ET-89 Intertank Thrust Panels Damaged Foam



Intertank Thrust Panel Foam Loss

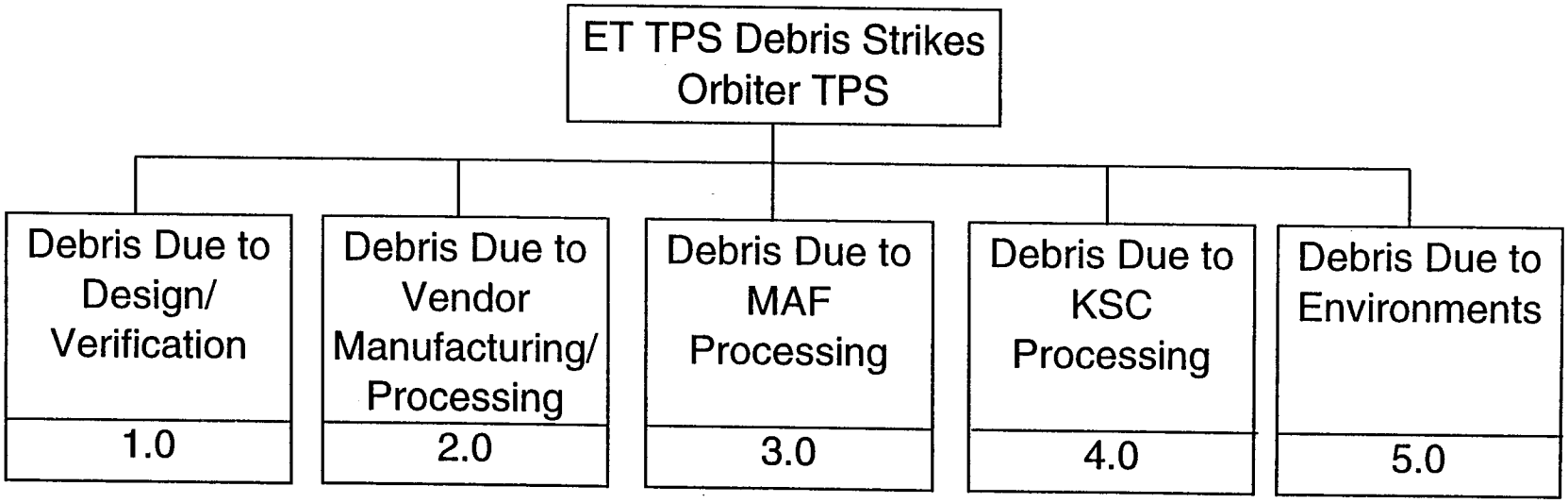
Background

- Integrated Orbiter Tile Damage Assessment Team established to determine cause of significant tile damage on OV-102
  - Fault tree analysis conducted to isolate cause of tile damage
    - Findings indicated that TPS debris from ET thrust panels caused Orbiter tile damage

- Independent External Tank Investigation Team (NASA and Lockheed Martin) established to determine cause of foam loss on ET-89
  - Historical data showed previous incidents of minor/intermittent foam loss with no correlation to Orbiter tile damage
    - ET-89 had significant foam loss and Orbiter had significant tile damage
    - Fault tree approach used to isolate cause

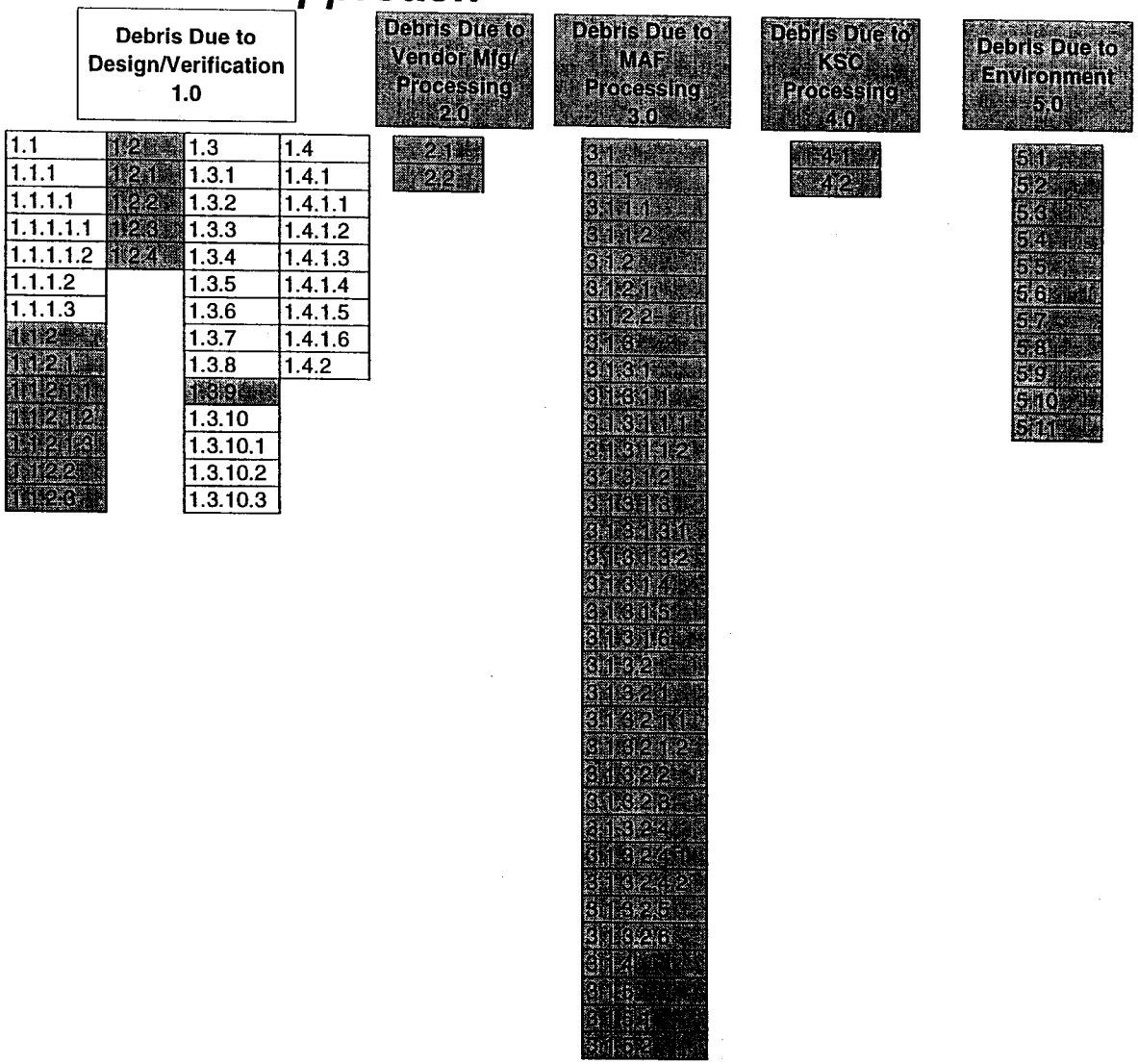
Intertank Thrust Panel Foam Loss

Discussion - Fault Tree Approach



Intertank Thrust Panel Foam Loss

Discussion - Fault Tree Approach



Intertank Thrust Panel Foam Loss

Discussion - Fault Tree Findings

- The following items were assessed and ***determined not to be the cause*** of ET foam loss:
  - Vendor manufacturing/processing (Fault Tree item 2.0)
    - No significant out-of-family processing issues/non-conformances were identified
    - Thrust panel contour and mechanical properties were within engineering requirements
    - Special investigation performed for primer application anomaly on ET-87
      - Retest of ET-89 primer revealed no issues
  - MAF assembly/processing (Fault Tree item 3.0)
    - No significant out-of-family processing issues/non-conformances were identified
    - No engineering design or production build paper anomalies identified
    - Personnel training/certification was adequate
    - No NCFI/primer application anomalies
  - KSC assembly/processing (Fault Tree item 4.0)
    - No significant out-of-family processing issues/non-conformances were identified
    - No changes made to vehicle processing

Intertank Thrust Panel Foam Loss

Discussion - Fault Tree Findings

- Mission Environments (Fault Tree item 5.0) were coordinated with the Level II Integrated Orbiter Tile Damage Assessment Team as part of the investigation
  - Basic vehicle loads - FTB5, FTB6 introduce majority of substrate strains
    - STS-87 load @ 92% design
  - Aerodynamic loads - STS-87 Max Q @ 84% design
    - Airloads act across tops of stringers for cross-flow
    - Shock impingement creates significant ΔPs (7.2 psid)
  - Vacuum - Closed cell foam contains gas at 14.7 psi
  - Heating - STS-87 approximately 50% design heating
  - No thrust oscillations or thrust spikes reported
  - No unusual atmospheric events were observed
  - Roll to heads up and ET venting occurred after most probable time for ET foam loss
  - No unusual debris sources (i.e. from other elements or space debris) were identified

Intertank Thrust Panel Foam Loss

Discussion - Fault Tree Findings

- Design/Verification (Fault Tree item 1.0) were thoroughly reassessed with the following conclusions

  - Suspicion of insufficient tests to support flexural strain allowable

  - Comparison through analysis with room temperature mono-strain test data showed a significant disparity
    - Lower flexure strain capability was indicated
    - Two potential causes were postulated
      - Inadequate number of specimens to accommodate the many process variables
      - Failure to include effects of ribs and two-gun spray in flexure testing
        - Ribs affect spraying process and therefore foam properties
        - Two-gun spray affects properties
        - Stiffness and concentrations from presence of ribs may effect flexure strain-at-failure

Intertank Thrust Panel Foam Loss

Test Results

- Panels were sprayed with two-gun spray process over ribs with rind remaining and machined off
- Four point bend test data with rind remaining confirmed lower flexural strain capability
  - Intial flat panel one-gun spray with rind 0.0326
  - Rib panel two-gun spray with rind 0.0210
  - Rib panel two-gun spray with rind removal 0.0297
- Using above test results, analysis would predict a crack formation for rib panel with rind
  - Initial flat panel on-gun spray with rind FS = 1.26
  - Rib panel two-gun spray with rind FS = 0.81
  - Rib panel two-gun spray with rind removal FS = 1.14

Intertank Thrust Panel Foam Loss

CPR-488 vs NCFI 24-124

Requirement	Spec Requirement		Ultimate Flight Requirement		Typical Property		Performance
	CPR	NCFI	CPR	NCFI	CPR	NCFI	
• Density (pcf)	2.1-2.8	2.0-2.8	Not applicable		2.4	2.2	Not applicable
• Tensile RT (psi)	35 min	30 min	16.2 min	16.2 min	54	44	**NCFI has lower strength, FS min = 2.04 (bond adhesion)**
• Tensile -320°F (psi)	Not applicable		16.2 min	16.2 min	41	41	Same
• Compression (psi)	24 min	25 min	Not applicable		40	33	**NCFI is less damage tolerant**
• Recession rate (in/sec)@ 7 BTU/ft^2-sec	Not applicable		Not applicable		0.0168	0.0094	NCFI has improved recession rate
• Thermal conductivity (BTU/hr-ft-°F) @RT	0.025	0.025	Not applicable		0.0164	0.0164	Same
• Cryo strain (ksi)	Not applicable		22@ -250°F	22@ -250°F	65@ -423°F	89@ -423°F	Both demonstrated to required stress levels

Intertank Thrust Panel Foam Loss

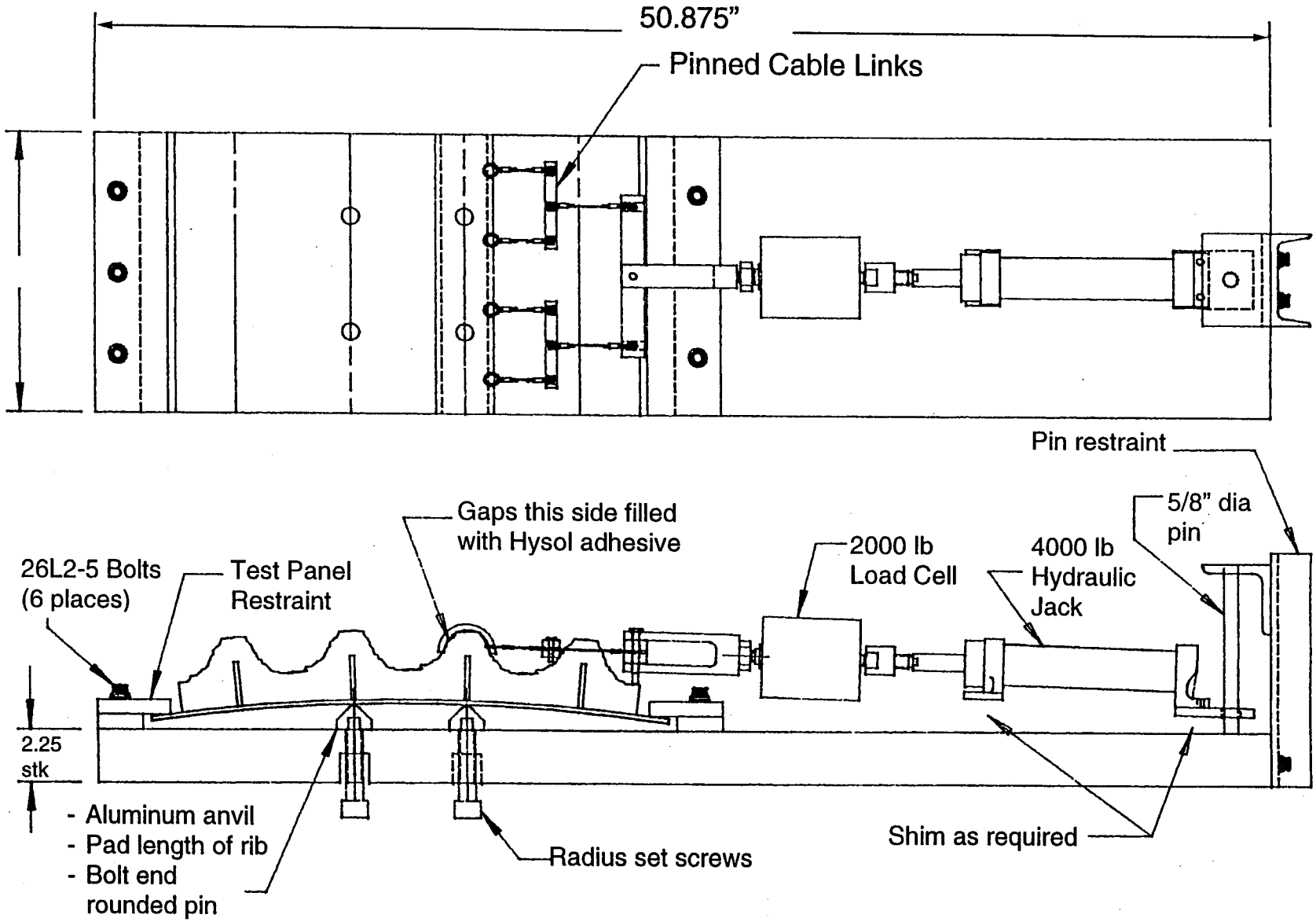
Discussion - Fault Tree Findings

- Additional testing of flexure strain capability of NCFI with rind showed allowable previously used was too high
  - Was: 0.0326
  - Now: 0.0210

- Factor of Safety for cracking of foam in the valleys between ribs become:
  - Was: 1.26
  - Now: 0.81

- Reduced strain capability and strength of the recently implemented "as-sprayed" NCFI 24-124 is the probable source of foam cracking
  - Mechanism for foam loss not identified

Intertank Thrust Panel Foam Loss



Intertank Thrust Panel Foam Loss

Discussion - Fault Tree Findings

- Three phase test
  - Apply flexure, then vacuum, and finally statically simulated airloads
- Success criteria for Intertank ribbed panels
  - Panel with rind must carry reconstructed ET-89 flexure
  - Panel without rind must carry design flexure
  - Both panels must also carry airloads in a vacuum
- Results
  - Panel with rind developed longitudinal TPS crack with flexure only at less than design requirement
  - Panel without rind did not develop TPS crack with flexure only, prior to achieving design requirement
  - Panel subsequently flexed to create cracking
  - Subsequently applied vacuum and airload and successfully completed with no interaction identified for both panels

ADD PASSED

Specimen	Strain (in./in.)	Shear (psi)
– NCFI with rind	0.0210	18.7
– NCFI without rind	0.0297	52.4

Intertank Thrust Panel Foam Loss

ET-90 Flight Clearance

- Re-verified as-built material tensile strength
  - Six plug pulls performed on thrust panel areas and three plug pulls performed on -Z Intertank skin stringer area to verify material strength
    - All values exceeded 30 psi minimum requirement

	Spec Requirement		Actual Property		
Characteristic	**CPR**	**NCFI**	**STS-85/ET-87 CPR**	**STS-87/ET-89 NCFI**	**STS-89/ET-90 NCFI**
Density (pcf) (as-built property)	2.1-2.8	2.0-2.8	2.34-2.32 2.40 avg	2.09-2.46 2.20 avg	2.56-2.50 2.53 avg
Tensile @ RT (psi)	35 min.	30 min.	37.0 - 54.6 46.8 avg	30.1 - 53.3 40.2 avg	31.9 - 52.7 40.2 avg
Compression (psi) (as-accepted property)	24 min.	25 min.	42.5	26	38

Intertank Thrust Panel Foam Loss

ET-90 Flight Clearance

- Actions taken to enhance capability
  - ET-90 foam rind was removed from each thrust panel
    - Removing rind from Intertank TPS provides better strain capability (approximately 30-40% increase)
    - Reduced foam height reduces airload on the foam from cross flow
    - Removal of rind eliminates denser material layer
      - Material less likely to come off in large pieces
      - Material less damaging if impact occurs
    - Reduced foam height reduces bending stresses from meridional flexure

- NCFI 24-124 material comparison
  - Flexural strain at failure (in./in.)

~~STS-85 (ET-87)~~ CPR with rind	~~STS-87 (ET-89)~~ NCFI with rind	~~STS-89 (ET-90)~~ NCFI with rind removed
0.0283	0.0210	0.0297

Intertank Thrust Panel Foam Loss

ET-90 Flight Clearance - Intertank Thrust Panel Foam Factors of Safety

Characteristic	~~STS-85/ET-87~~ CPR (with rind)	~~STS-87/ET-89~~ NCFI (with rind)	~~STS-89/ET-90~~ NCFI (without rind)
• Bondline delamination	1.38	1.65	1.65
• Substrate strain	1.80	2.90	2.90
• Bond adhesion	2.29	1.96	1.96
• Shear	1.68	1.21	2.05
• Flexure (crack initiation)	1.11	0.81	1.14

AIR LOCKING
PLUG OF PANEL

Intertank Thrust Panel Foam Loss

ET-90 Flight Clearance

- STS-89 environments similar to those seen on STS-87 - No added risk
  - Inclination 51.6°
  - STS-86 same inclination (Last Mir rendezvous)
  - Based on the STS-86 BET data trajectory parameters were well within historical flight limits
    - Dynamic pressure
    - Angle of attack
    - Angle of sideslip
    - Mach number
    - Altitude

Intertank Thrust Panel Foam Loss

ET-90 Flight Clearance

- ET-90 Intertank thrust panel as machined foam has higher flexural strain capability than prior flights with unmachined NCFI 24-124
- ET-90 Intertank thrust panel as machined foam has equivalent flexural strain capability as prior flown tanks with unmachined CPR-488
- Machined foam meets all Factor of Safety requirements

STS-89/ET-90
Ready for Flight

Intertank Thrust Panel Foam Loss

ET-90 Flight Clearance - Foam Loss from Combined Environments

- A mechanism for removal of the foam following the now predicted cracking in the valleys has not been identified
- Many interacting environmental factors are applied to the foam in this volatile region during flight
- Ground testing to combine simultaneously all interacting environments of this region can not be performed
- Many partial combinations have been performed over the years
- The impracticality (impossibility) of combining all environments was recognized from the program outset
- The best available verification is to utilize flight combined environments experience and correct for foam differences

Intertank Thrust Panel Foam Loss

ET-90 Flight Clearance

- Most probable causes for foam loss are:
  - Transverse shear of stringer top foam or
  - Flexure of thrust panel valleys between ribs and subsequent undetermined loss mechanism

- Sanding of foam improves FS for each characteristic

Intertank Thrust Panel Foam Loss

ET-90 Flight Clearance

- ET-90 Intertank thrust panel foam is superior to prior successfully flown tanks with CPR

- Positive margins of safety are provided by machined foam
  - Sanded foam results in 30% - 40% increase in both strain-at-failure and tensile strength

- ET can withstand design limit loads and heating without Intertank foam

STS-89 ET-90
ready for flight

Readiness Statement

The External Tank, ET-90, is hereby certified and ready for STS-89 flight pending completion/closure of open and planned work

Terry L. Hibbard
Vice President, External Tank Project
Lockheed Martin Michoud Space Systems

Thick/Thin TPS on LO2 Tank

Change:

- Implemented new TPS configuration for the LO2 tank ogive and barrel
  - Thickness now varies with circumferential location

Background/ Reason:

- Reduction of TPS average thickness provides a potential 195 lb weight savings for SLWT
- Early incorporation of this change on ET-90 diminishes number of first time configuration changes for SLWT
- Previous LWT spray system applied a constant circumferential foam thickness
- +Z side of LWT has higher ascent heating environments setting the TPS thickness requirements

Thick/Thin TPS on LO2 Tank

Description:

- Hardware
  - TPS reduction encompasses five circumferential thickness bands on LO2 tank
    - Control within each band results in a thick/thin configuration
- Manufacturing
  - Implement use of new delivery system to control foam thickness
    - Tighter tolerance and tailored thicknesses
    - Applies thick/thin foam using variable flow rates

Process Development:

- Validation sprays conducted in production cell
  - Spray #1 was full scale test on GVTA
    - All objectives obtained
      - Tensile strength, density and cryoflex tests were performed
    - One area had out of tolerance thickness
  - Spray #1 repeated with partial spray to adjust thickness
    - Objective obtained
  - Spray #2 performed on ET-90 - All objectives obtained
- Similar process used for ET-88 and 89 LH2 tank barrels

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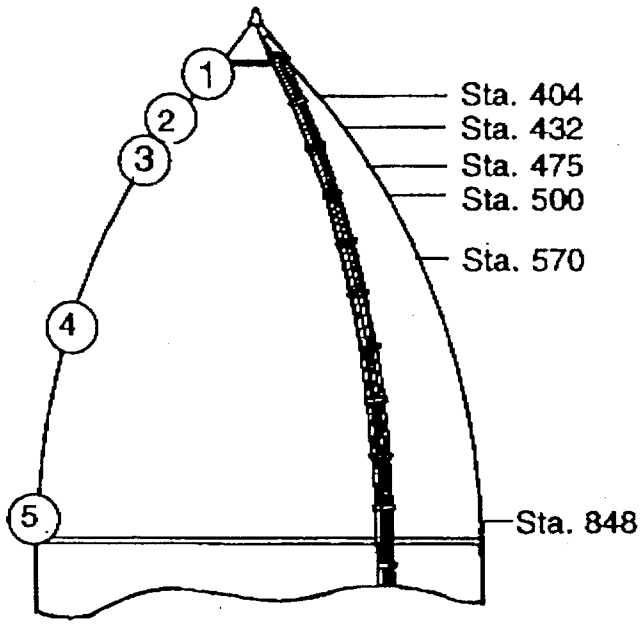
Thick/Thin TPS on LO2 Tank

ET-89 (STS-87)

Station	Thickness (in.)
404 - 439	
• +Z	2.15+0.25"
• -Z	2.15+0.25" -0.53"
454 - 540	2.00±0.38"
570 - 745	1.00+0.38" -0.25"
745 - 852	1.00±0.25"



LO2 Tank (+Z shown)

ET-90 (STS-89)

Station	Thickness (in.)	
	+Z	-Z
404-420	2.15±0.25"	1.85±0.25"
432-460	2.15±0.25"	1.60±0.20"
475-490	2.15±0.25"	1.15±0.15"
500-540	2.15±0.25"	1.00±0.15"
570-848	1.00±0.15"	0.88±0.13"

Plug Pull Values

- Requirement = 30 psi
- ET-90 Actuals

① Lead out	48.0
② Station 400	39.5
③ Station 420	48.0
④ Station 600	54.6
⑤ Lead in	47.9

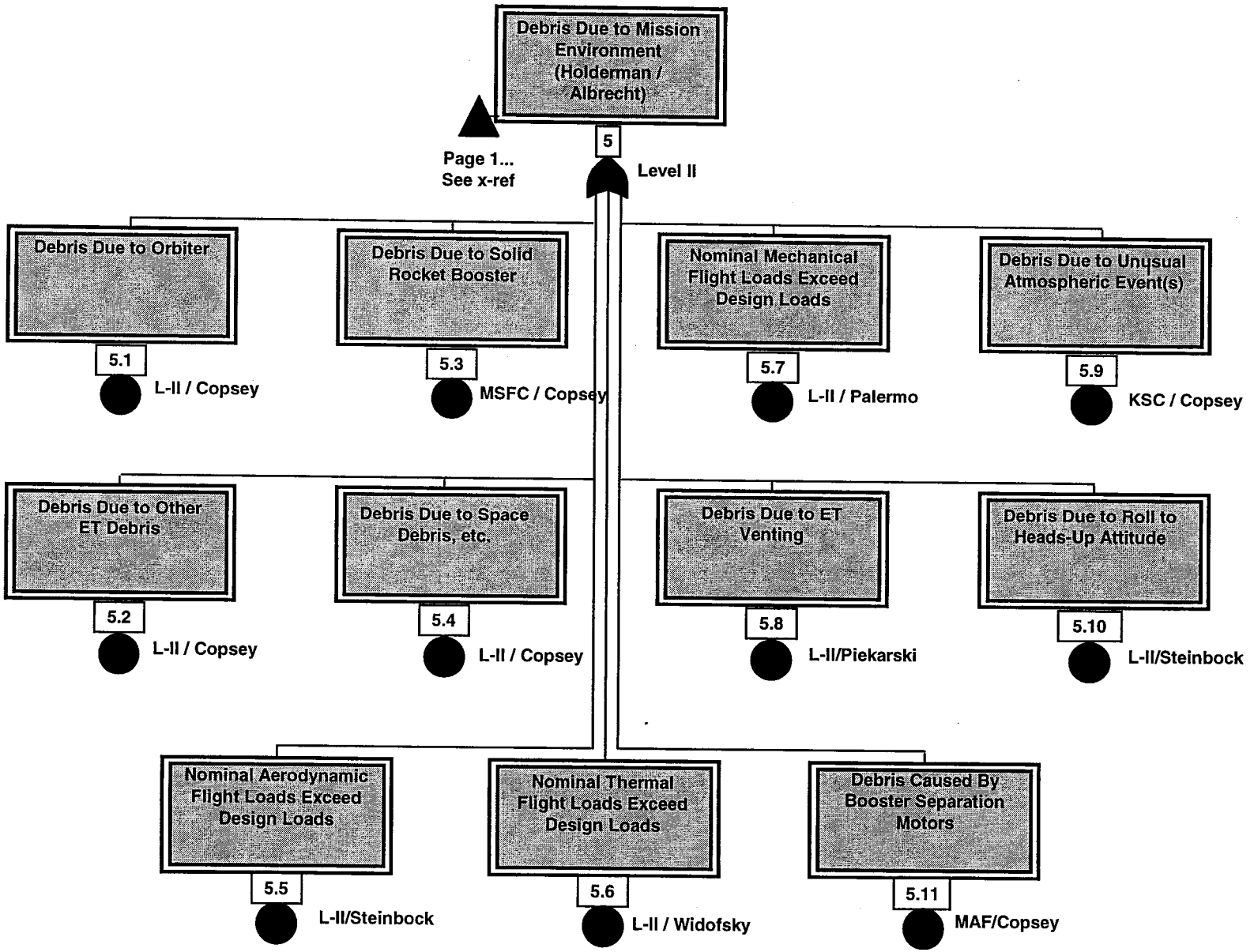
Thick/Thin TPS on LO2 Tank

Basis for Certification:

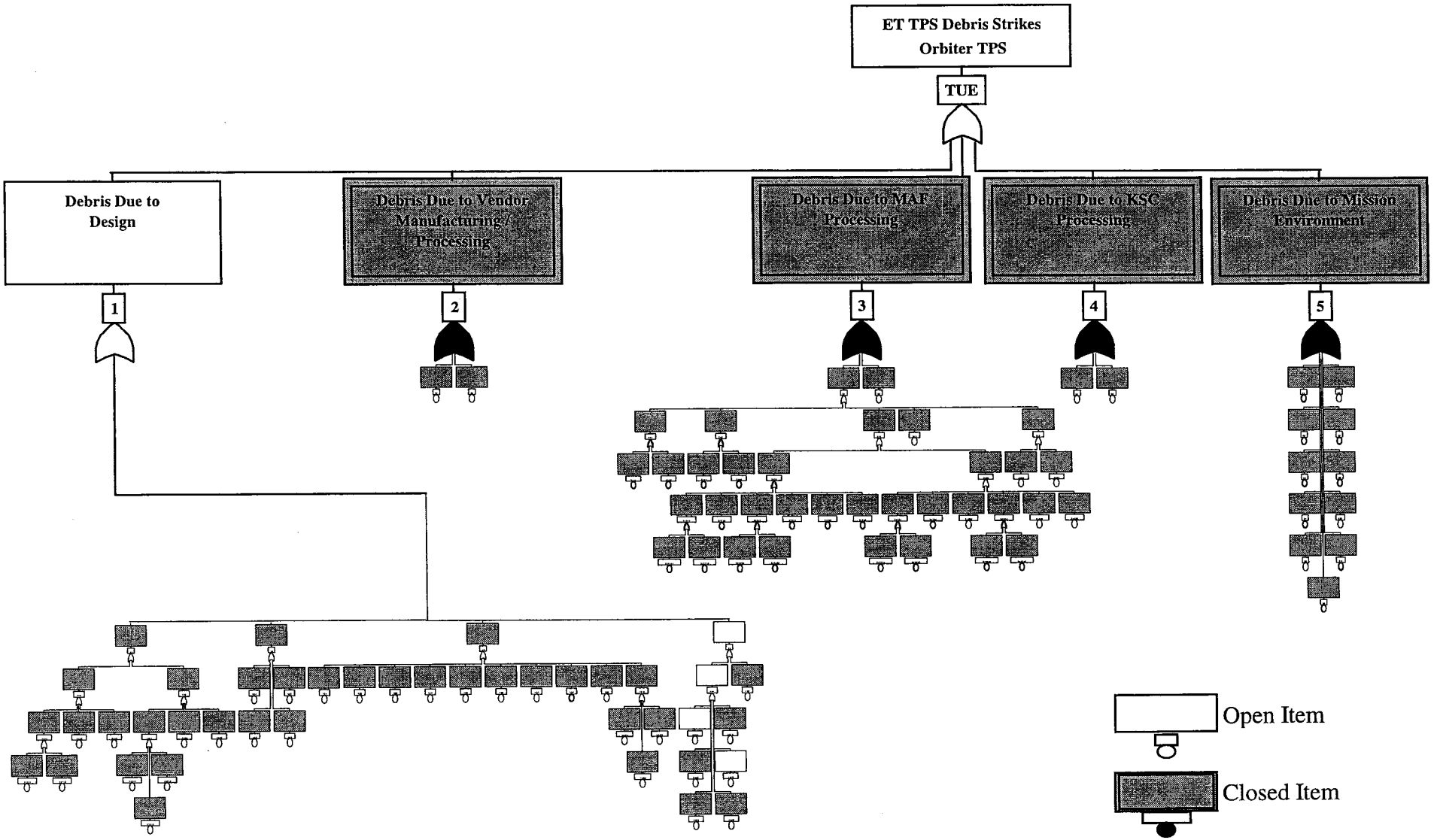
- Analysis
  - Stress: New spray configuration meets required FS of 1.10
    - FS unchanged = 1.21 (failure mode: bondline delamination)
  - Thermal
    - LO2 structural temperature unchanged (max. temperature: 300°F at MECO)
    - Minimum TPS thickness maintained
      - No ice/frost formation concern
  - Propulsion: Negligible impact to LO2 propellant inventory (≈ 131 lb reduction)
    - End of replenish ullage pressure
      - Previous nominal = 0.603 psig
      - Predicted STS-89 (ET-90) = 0.635 psig

- Inspection: Plug pulls verify proper application of foam

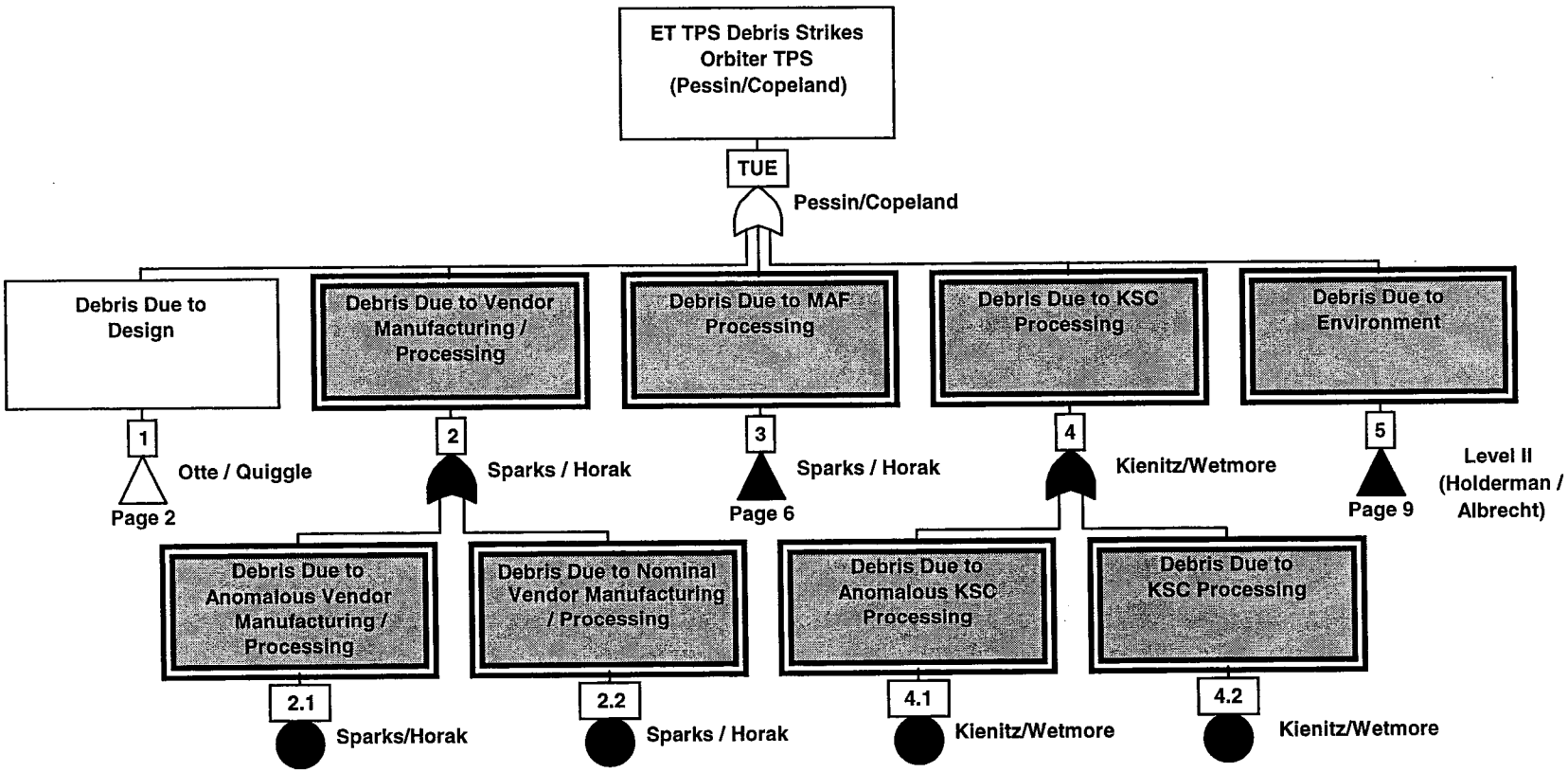
STS-87 Orbiter TPS Damage -- ET Intertank TPS Debris Closure Tree



STS-87 Orbiter TPS Damage -- ET Intertank TPS Debris Closure Tree (Full Page View)



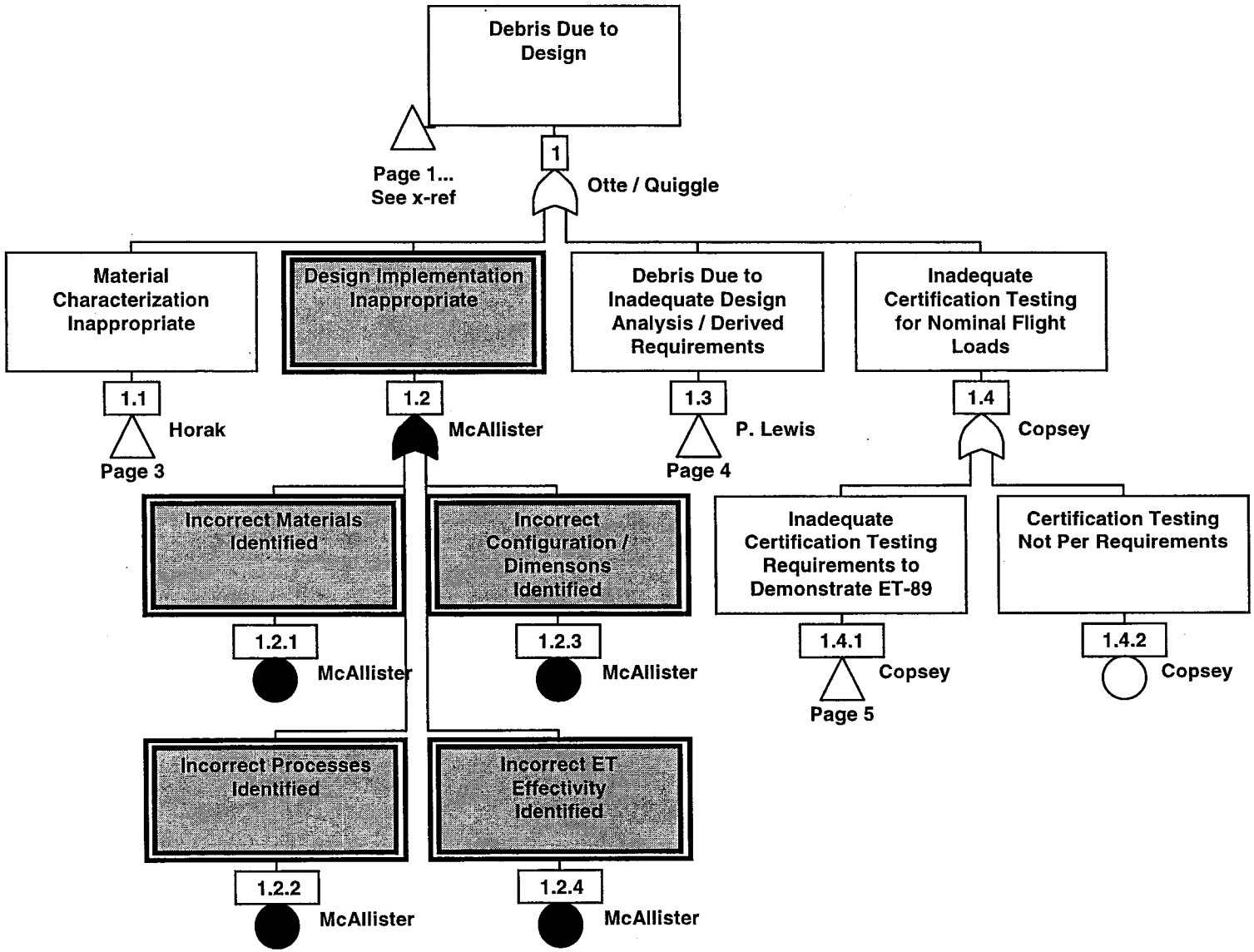
STS-87 Orbiter TPS Damage -- ET Intertank TPS Debris Closure Tree

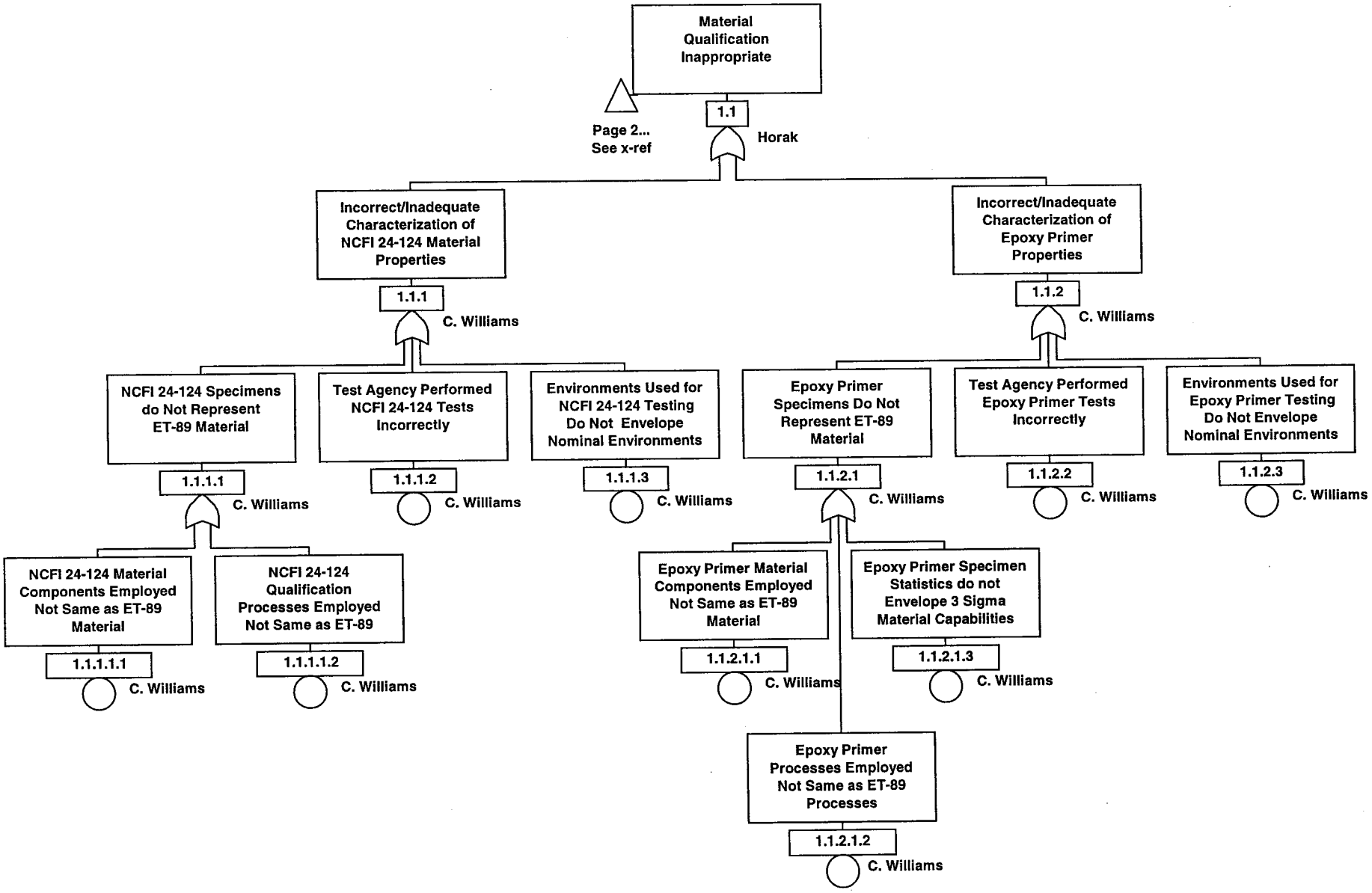


Open Item

Closed Item

STS-87 Orbiter TPS Damage -- ET Intertank TPS Debris Closure Tree




Material Qualification Inappropriate
Page 2... See x-ref
1.1
Horak
Incorrect/Inadequate Characterization of NCFI 24-124 Material Properties
1.1.1
C. Williams
Incorrect/Inadequate Characterization of Epoxy Primer Properties
1.1.2
C. Williams
NCFI 24-124 Specimens do Not Represent ET-89 Material
1.1.1.1
C. Williams
Test Agency Performed NCFI 24-124 Tests Incorrectly
1.1.1.2
C. Williams
Environments Used for NCFI 24-124 Testing Do Not Envelope Nominal Environments
1.1.1.3
C. Williams
Epoxy Primer Specimens Do Not Represent ET-89 Material
1.1.2.1
C. Williams
Test Agency Performed Epoxy Primer Tests Incorrectly
1.1.2.2
C. Williams
Environments Used for Epoxy Primer Testing Do Not Envelope Nominal Environments
1.1.2.3
C. Williams
NCFI 24-124 Material Components Employed Not Same as ET-89 Material
1.1.1.1.1
C. Williams
NCFI 24-124 Qualification Processes Employed Not Same as ET-89
1.1.1.1.2
C. Williams
Epoxy Primer Material Components Employed Not Same as ET-89 Material
1.1.2.1.1
C. Williams
Epoxy Primer Specimen Statistics do not Envelope 3 Sigma Material Capabilities
1.1.2.1.3
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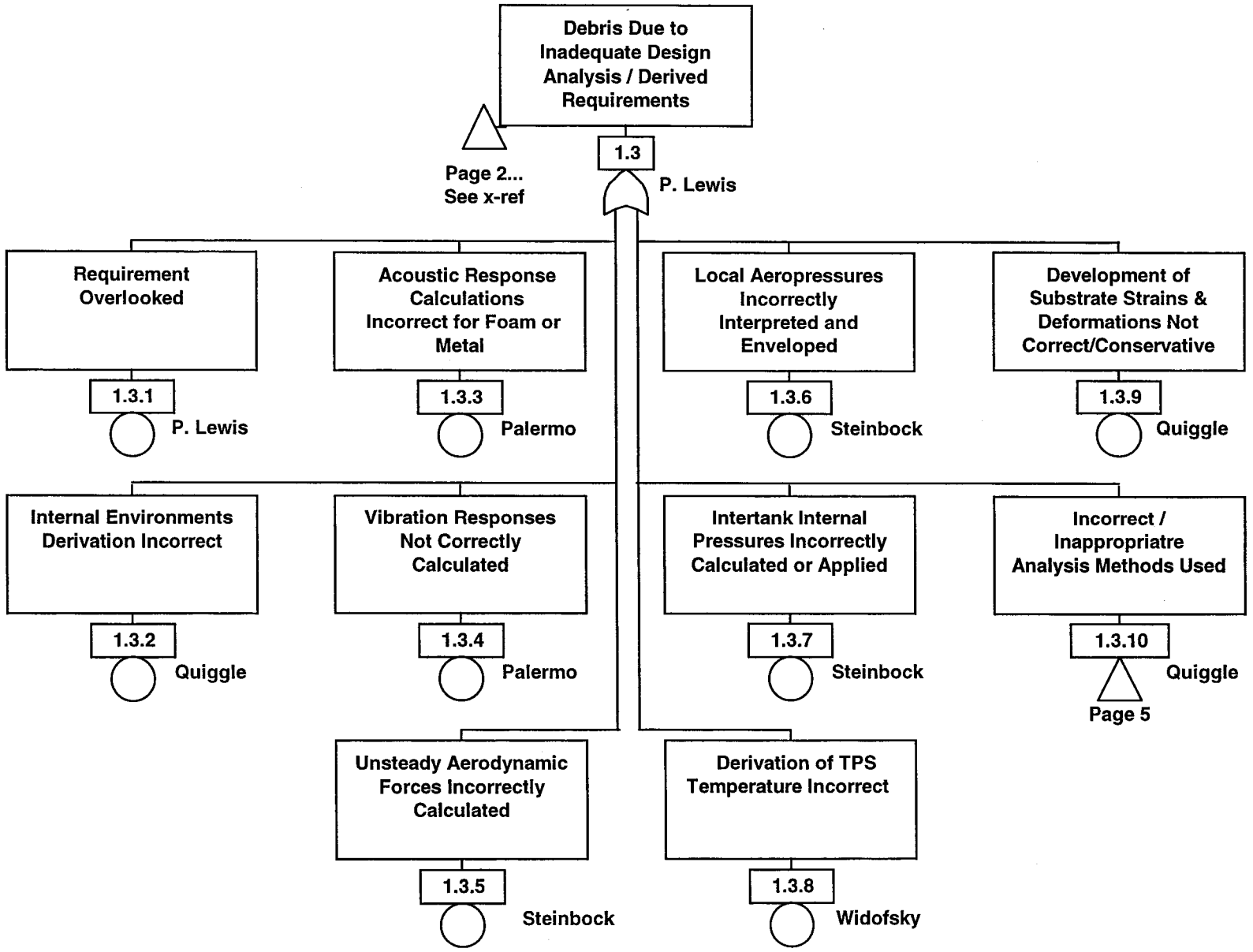
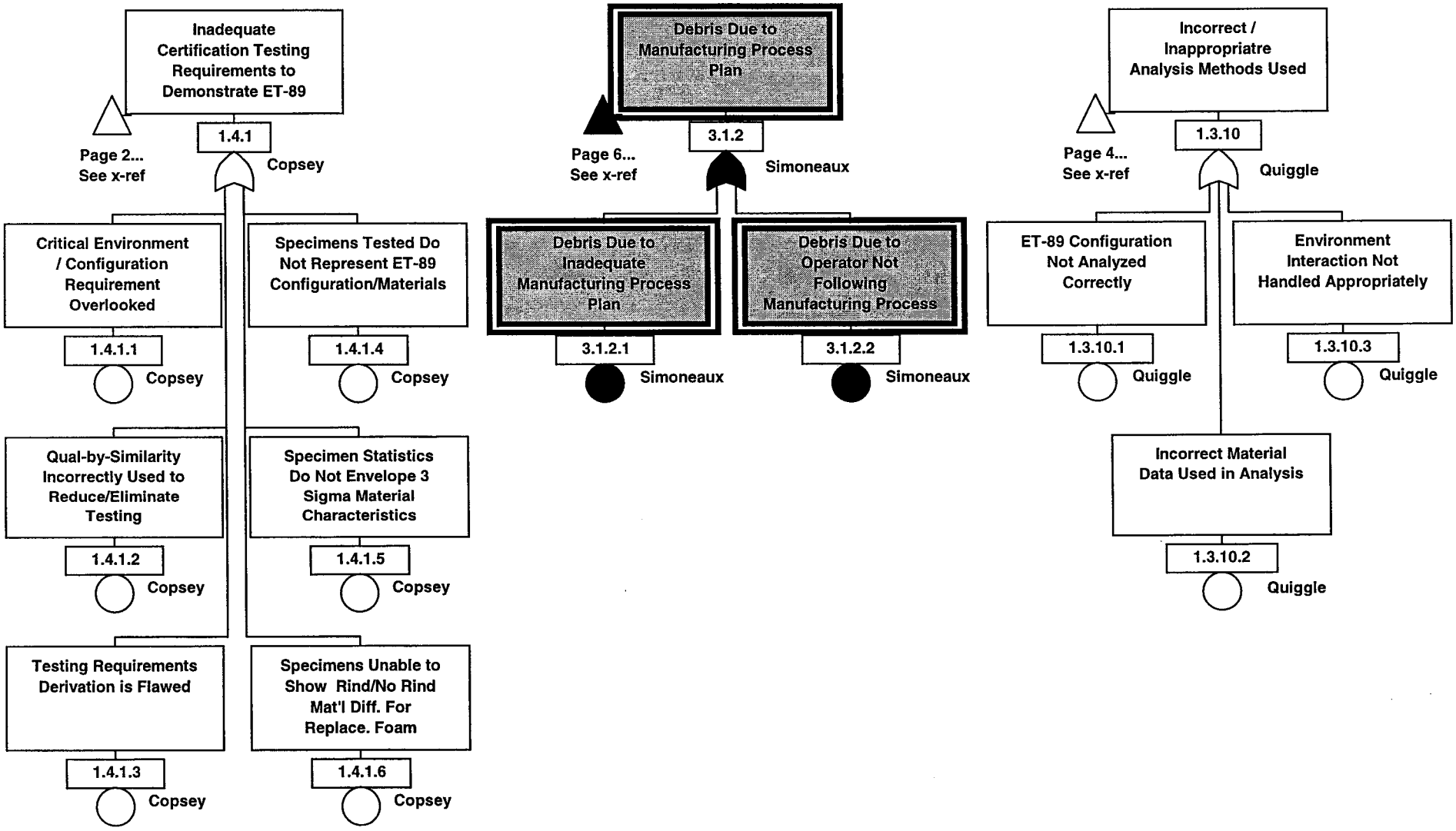
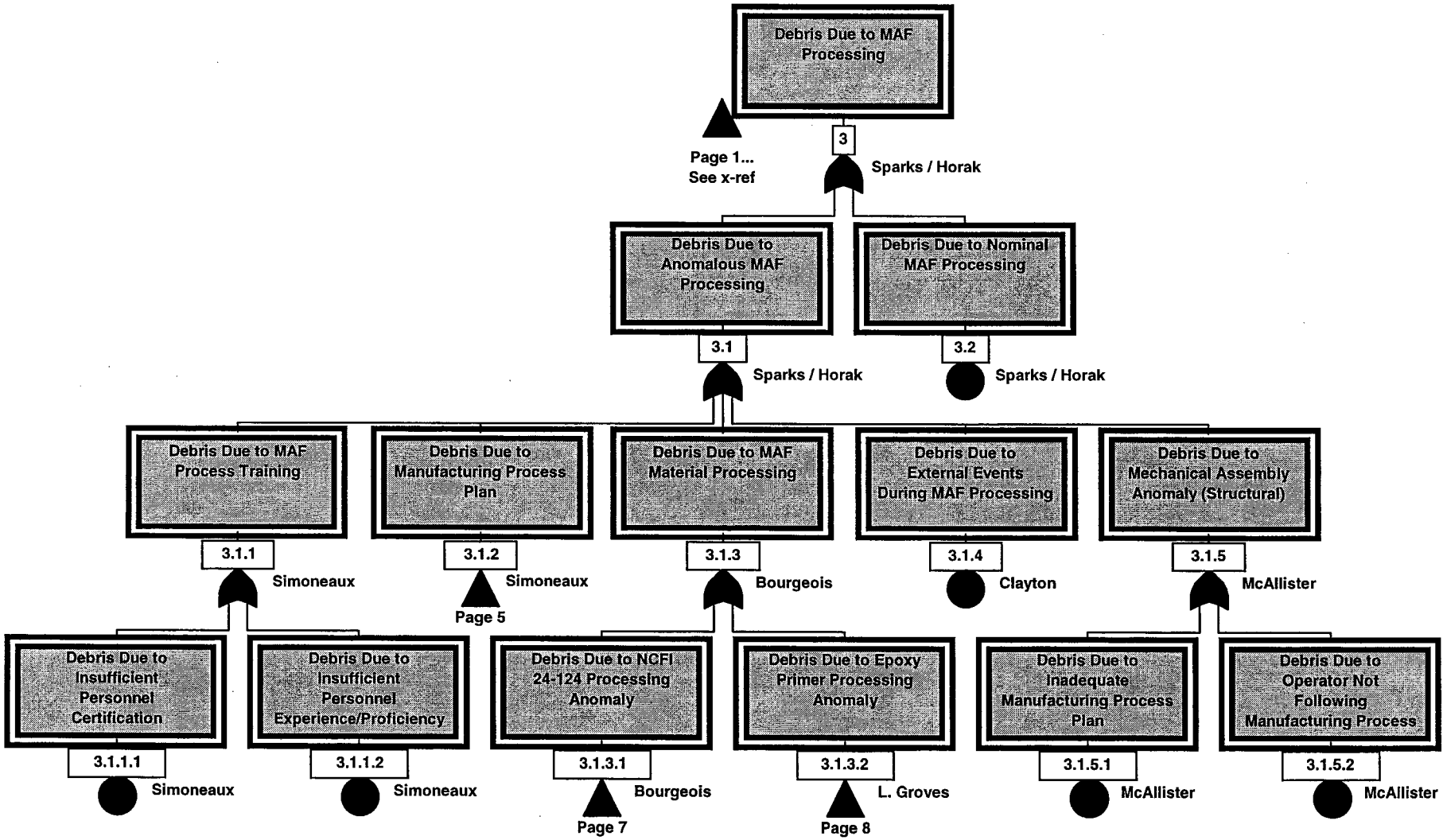
Epoxy Primer Processes Employed Not Same as ET-89 Processes
1.1.2.1.2
C. Williams

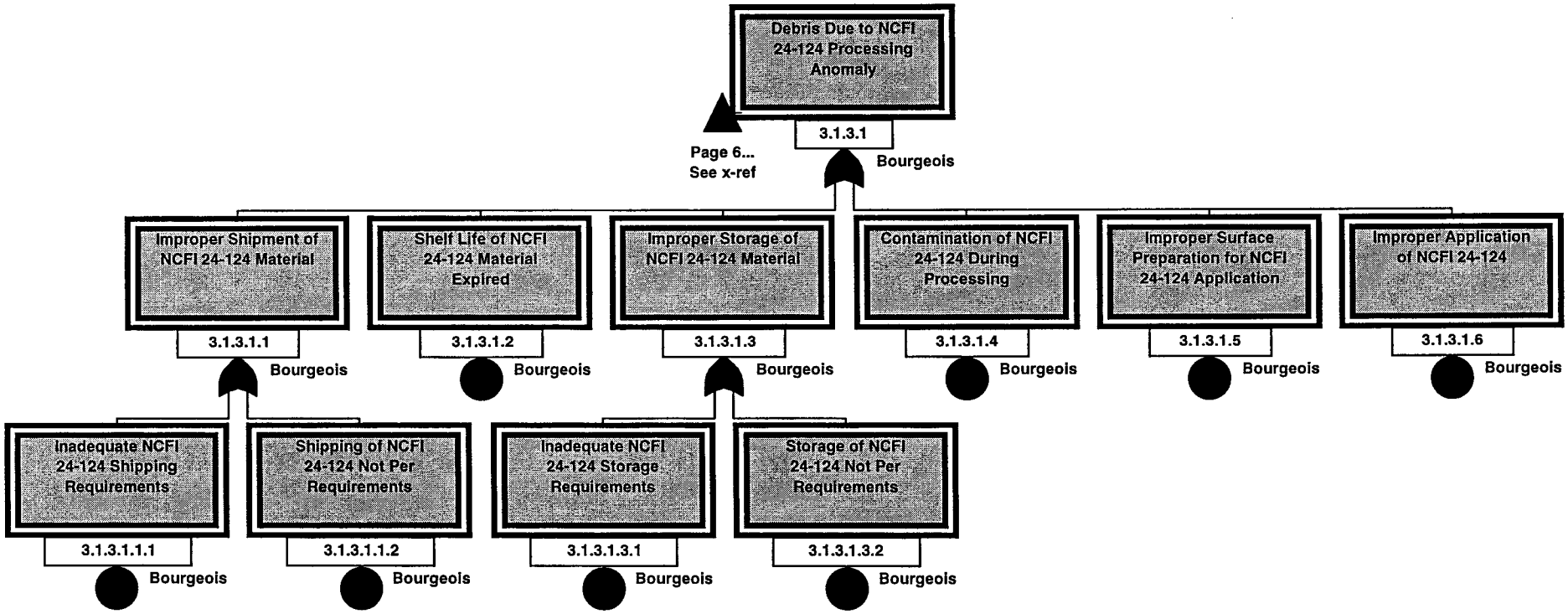

Debris Due to Inadequate Design Analysis / Derived Requirements
1.3
P. Lewis
Page 2... See x-ref
Requirement Overlooked
1.3.1
P. Lewis
Acoustic Response Calculations Incorrect for Foam or Metal
1.3.3
Palermo
Local Aeropressures Incorrectly Interpreted and Enveloped
1.3.6
Steinbock
Development of Substrate Strains & Deformations Not Correct/Conservative
1.3.9
Quiggle
Internal Environments Derivation Incorrect
1.3.2
Quiggle
Vibration Responses Not Correctly Calculated
1.3.4
Palermo
Intertank Internal Pressures Incorrectly Calculated or Applied
1.3.7
Steinbock
Incorrect / Inappropriatre Analysis Methods Used
1.3.10
Quiggle
Page 5
Unsteady Aerodynamic Forces Incorrectly Calculated
1.3.5
Steinbock
Derivation of TPS Temperature Incorrect
1.3.8
Widofsky

STS-87 Orbiter TPS Damage -- ET Intertank TPS Debris Closure Tree



STS-87 Orbiter TPS Damage -- ET Intertank TPS Debris Closure Tree




Debris Due to NCFI 24-124 Processing Anomaly
3.1.3.1
Bourgeois
Page 6... See x-ref
Improper Shipment of NCFI 24-124 Material
3.1.3.1.1
Bourgeois
Shelf Life of NCFI 24-124 Material Expired
3.1.3.1.2
Bourgeois
Improper Storage of NCFI 24-124 Material
3.1.3.1.3
Bourgeois
Contamination of NCFI 24-124 During Processing
3.1.3.1.4
Bourgeois
Improper Surface Preparation for NCFI 24-124 Application
3.1.3.1.5
Bourgeois
Improper Application of NCFI 24-124
3.1.3.1.6
Bourgeois
Inadequate NCFI 24-124 Shipping Requirements
3.1.3.1.1.1
Bourgeois
Shipping of NCFI 24-124 Not Per Requirements
3.1.3.1.1.2
Bourgeois
Inadequate NCFI 24-124 Storage Requirements
3.1.3.1.3.1
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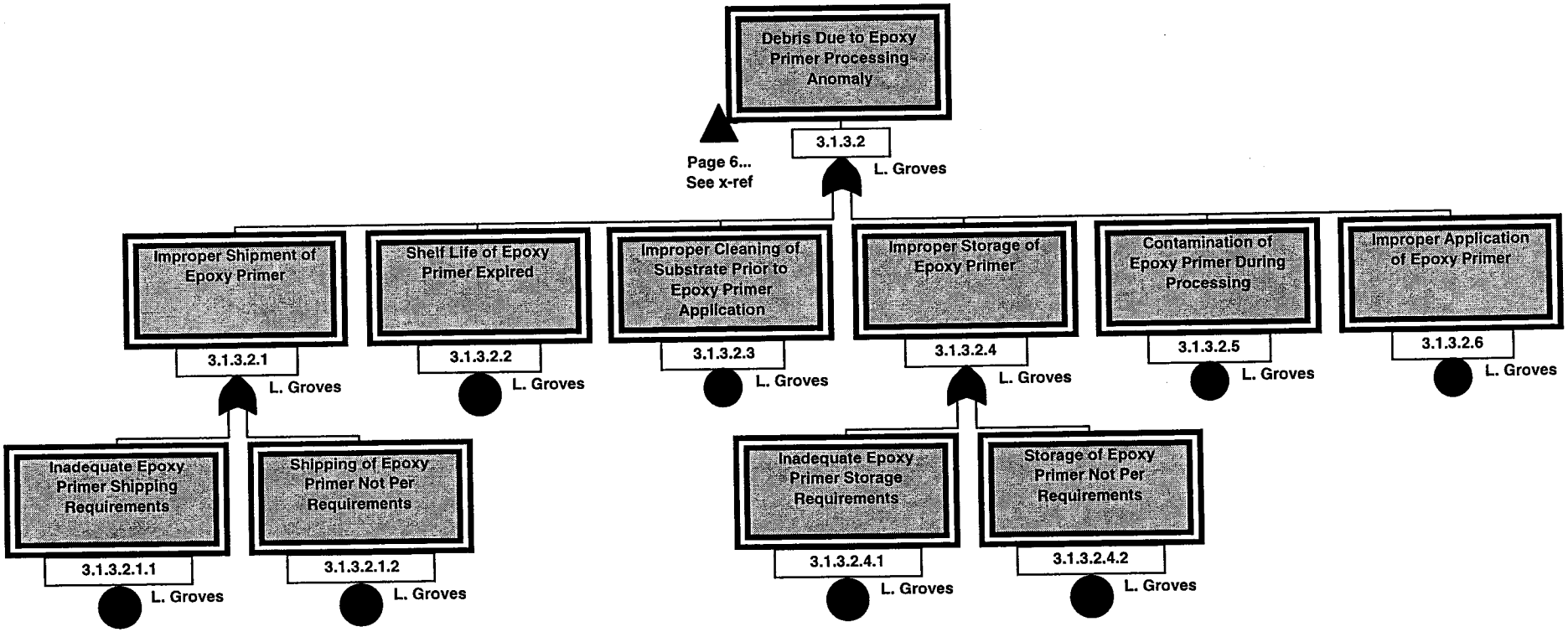
Storage of NCFI 24-124 Not Per Requirements
3.1.3.1.3.2
Bourgeois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3.1.3.2
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Page 6... See x-ref
Improper Shipment of Epoxy Primer
3.1.3.2.1
L. Groves
Shelf Life of Epoxy Primer Expired
3.1.3.2.2
L. Groves
Improper Cleaning of Substrate Prior to Epoxy Primer Application
3.1.3.2.3
L. Groves
Improper Storage of Epoxy Primer
3.1.3.2.4
L. Groves
Contamination of Epoxy Primer During Processing
3.1.3.2.5
L. Groves
Improper Application of Epoxy Primer
3.1.3.2.6
L. Groves
Inadequate Epoxy Primer Shipping Requirements
3.1.3.2.1.1
L. Groves
Shipping of Epoxy Primer Not Per Requirements
3.1.3.2.1.2
L. Groves
Inadequate Epoxy Primer Storage Requirements
3.1.3.2.4.1
L. Groves
Storage of Epoxy Primer Not Per Requirements
3.1.3.2.4.2
L. Groves