



**SPACE SHUTTLE PROGRAM**  
**Space Shuttle Systems Engineering and Integration Office**  
NASA Johnson Space Center, Houston, Texas



# **STS-129**

## **Agency Flight Readiness Review**

**MS/Donald W. Totton**  
**October 29, 2009**



Pre-decisional. Internal Use Only.





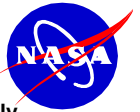
## Topics

Presenter	MS/Don Totton	
Date	10/29/09	Page 2

- **Systems Engineering & Integration**
  - Integrated Debris Risk Summary
  - T-0 Umbilical Ice (External) (IIFA STS-128-002)
  - ET TPS Loss on LH2 IT Flange (IIFA STS-129-004)
    - Will be presented by ET
  - ET LO2 IFR NDE (IIFA STS-127-I-004 for 718 IFR)
    - Will be presented by ET
  - SRB Viton coated Nylon Debris Source (IIFA STS-128-006 Debris Observed on SSME)
    - Will be presented by SRB
  - Main Engine Ignition(MEI) Acoustic & SSME Ignition Overpressure (IOP) Environment Update



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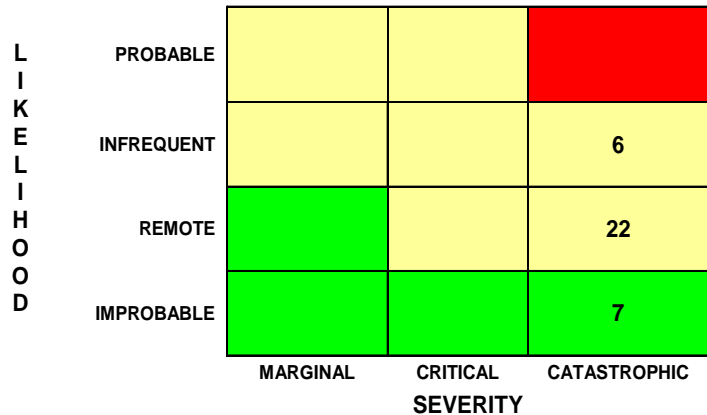
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# Integrated Debris Risk Summary



<b>STS-129 Debris Risk Assessment Summary</b>	Presenter	MS/Don Totton
	Date	10/29/09
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(HAZARD SEVERITY LEVEL AND LIKELIHOOD OF OCCURRENCE WITH CONTROLS IN PLACE)



- 6 Infrequent Causes:**
- Liftoff Debris (AD)
  - ET Umbilical Ice (V)
  - Orbiter Putty Repair (AK)
  - T-0 Umbilical Ice (AO)
  - LO2 IFR (I)
  - Intertank acreage (G)

**Debris Risk Assessment, 10/2009**

**Six IDBR-01 debris risks remain Infrequent/Catastrophic**

- **Liftoff Debris** is expected to remain at this risk level for the life of the Program due to the diversity of potential Debris sources although rigorous controls have been implemented and continuous vigilance is policy.
- **ET Umbilical Ice:** Accepted Risk
- **Putty Repair:** Windows zero impact allowable keeps any impact in the “catastrophic” category, forward work and flight history may be used to reduce the likelihood to “Remote”.
- **T-0 Umbilical Ice:** Closed for Internal Ice, External ice pending closure of IIFA-128-I-002
- **LOX IFR:** Implemented NDE of LO2 IFR ramps thru 553 to screen for large voids
- **ET Intertank Foam Loss:** Changed to Infrequent Catastrophic for STS-128
  - Continued Tensile Testing of ET high risk debris areas



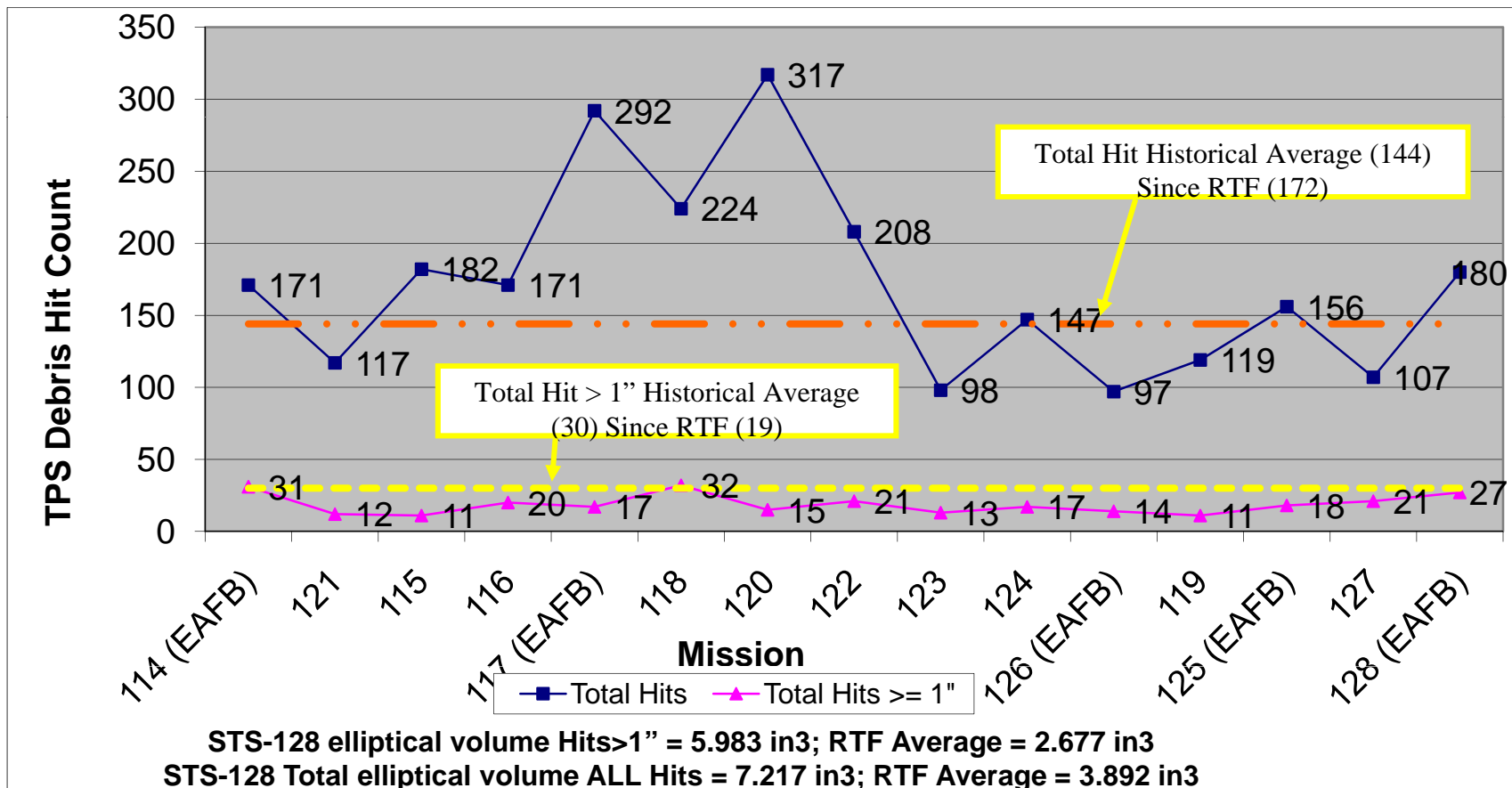
## Orbiter Debris Impact summary STS-128, OV-103

Presenter MS/Don Totton

Date **10/29/09**

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- TPS Hits w/damage > 1" = 27 (23 lower surface, 3 L OMS, 1 R OMS) (Total number of Hits = 180)
- Prior to RTF Average for Lower Surface Hits >1" = 23; Since RTF = 15
- 2 Lost Putty repairs





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# **T-0 Umbilical Ice (External) (IIFA STS-128-002)**



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## STS-128-I-002 T-0 Umbilical External Ice

Presenter	MS/Don Totton	
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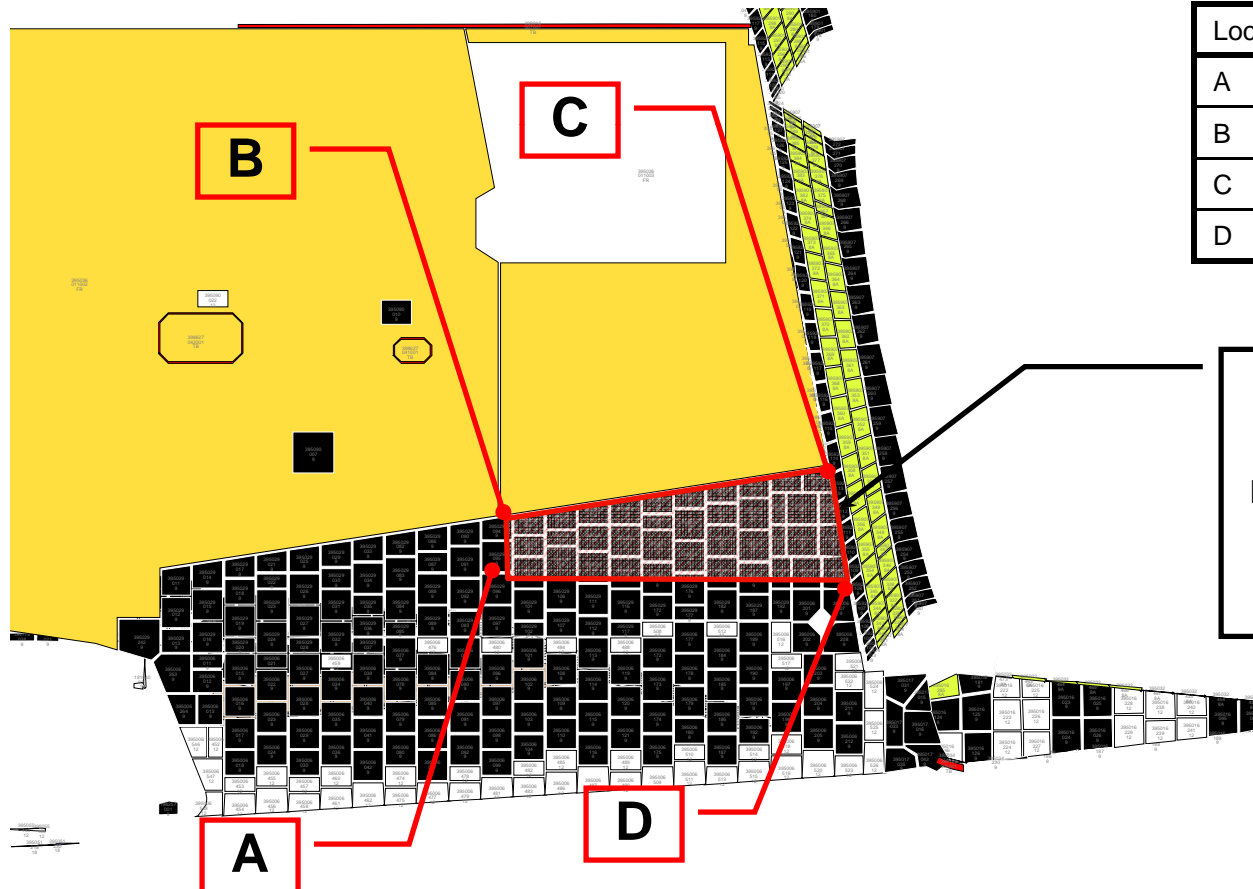
- IIFA for Internal T-0 Umbilical Ice is Closed - through implemented Hardware & Procedure mitigations
- Interim Closure signed for STS-129 on External T-0 Umbilical Ice IIFA
  - Developing Ice Allowables for NSTS 08303
- Waivers have been required for T-0 External ice on the last several flights
- DIG assessed accepting ice up to 0.1 lbm from any location around perimeter of T-0 peripheral seal
  - Technical Review and Concurrence received from ET, SRB, SSME, LOD
  - Orbiter is currently assessing capability for thin tile areas of fuselage
- Risk will be updated to include Orbiter capability results



## Orbiter Identified Area of Concern

Presenter	MS/Don Totton	
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Note that the Xo location is notional and all tile impacts above Zo of 314 are in a thin tile region.



Location	Xo	Zo
A	1445	314
B	1445	325
C	1506	334
D	1510	314

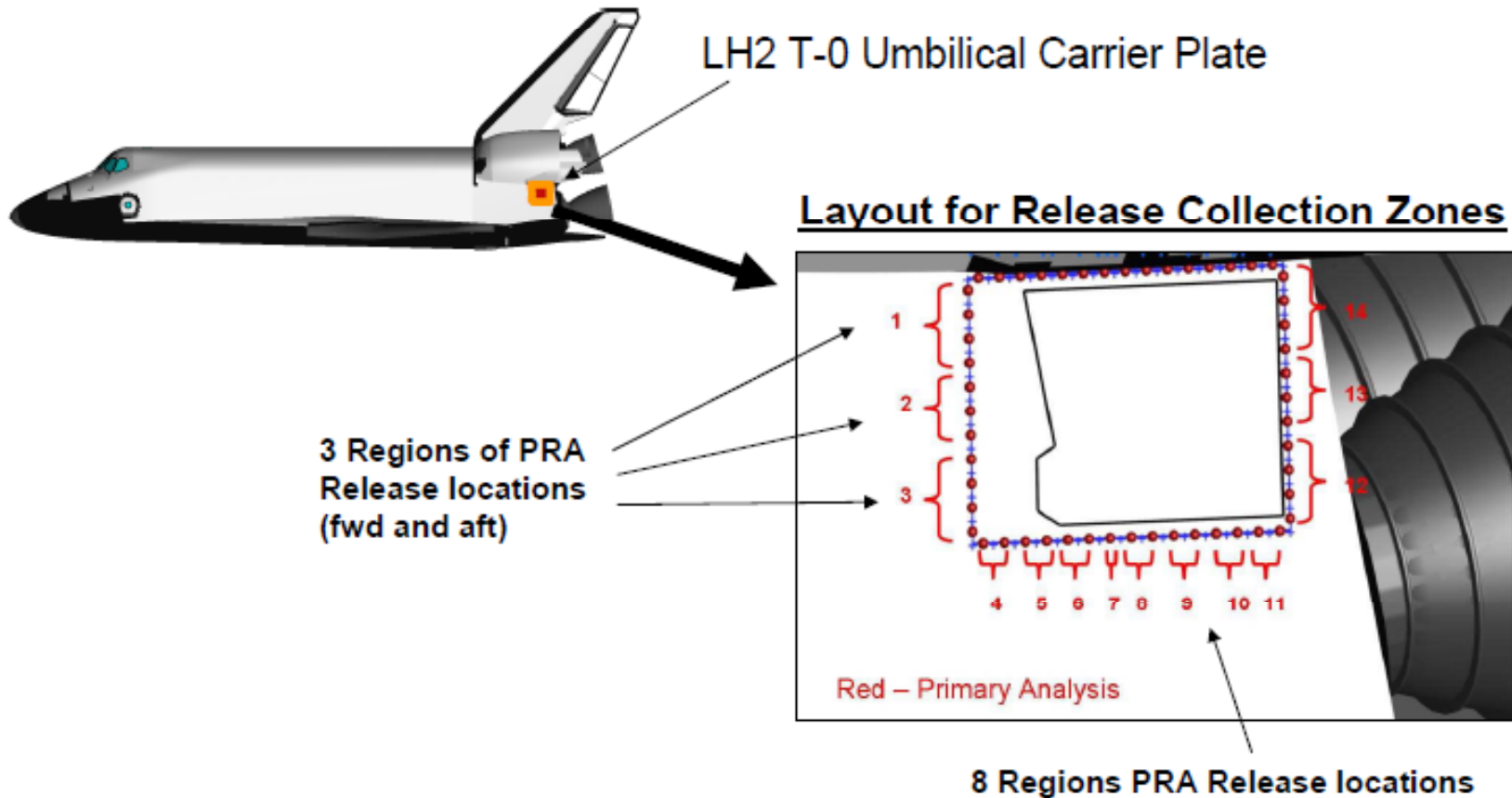
Thin tile region is roughly 30% of total area impacted





# Debris Locations Selected around LH2 T-0 Umbilical Peripheral Seal

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## Risk Assessment for 0.1lbm

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- FIT reports observation
- DIG calculates mass
  - If mass is smaller than allowable - no waiver is required
  - If mass is greater than allowable – a waiver will be processed

Probability of Critical Damage  
(Capability Model Available)

Probability of Impact  
(No Capability Model Developed)

PRA Locations	Probability of Critical Damage (Capability Model Available)				Probability of Impact (No Capability Model Developed)		
	OMS Pod Tile	Side Fuselage Tile*	Aft Blanket Areas <sup>1</sup>	SSME <sup>2</sup>	OMS Stinger	Body Flap	Elevons
FWD 1-3	1/1,200	1/INF	1/INF	1/INF	1/740	1/3,100	1/27M
WING 4-11	1/INF	1/860K	1/INF	1/INF	1/INF	1/1,100	1/8M
AFT 12-14	1/960	1/INF	1/INF	>1/90K	1/5,700	1/INF	1/INF

Note: Table reflects 0.1 lbm DTA assessment - Highest risk location noted / other locations are lower risk  
 Impact / Failure Probability values apply to single piece of ice liberated from single contiguous release location

1 – Based on OMS Pod and side fuselage tile capability

2 – Based on probability of exceeding total KE of 207.9 ft-lbs (capability from ceramic inserts testing)

ET - No Transport Mechanism to External Tank

SRB – Very remote likelihood of impacting SRB

\* Risk Assessment does not reflect Orbiter thin tile update



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# **Main Engine Ignition (MEI) Acoustic & SSME Ignition Overpressure (IOP) Environment Update**



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## Agenda

Presenter MS/M. Miller

Date 10/29/09

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- Environment Update
- Orbiter Assessment

## Presenter

Mark Miller

Mike Dunham

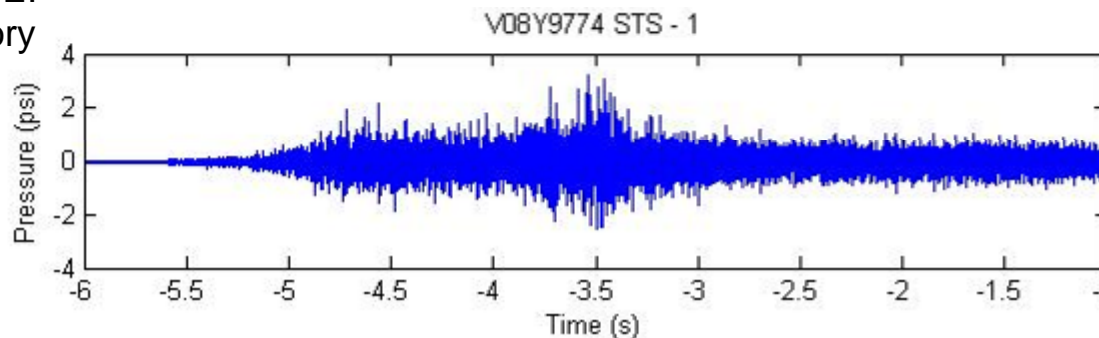


# MEI Acoustic & SSME IOP Environment Issue

Presenter	USA/M. Miller	
Date	10/29/09	Page 13

- **Issue: Updates to MEI Acoustics and SSME IOP**
  - Post-flight analyses of OV-103 microphone measurements indicate MEI Acoustic and SSME IOP levels are above current Acoustics and Shock Data Book design levels for some locations
    - MEI acoustics are fluctuating pressure waves of sound, IOP is fluctuating pressure waves due to SSME thrust ramp-up and free hydrogen ignition
  - SSME IOP environment is currently only defined for Drag Chute Door and incomplete for Orbiter tiles on aft of vehicle
- **Environment update only impacts Orbiter element**

Typical MEI time history





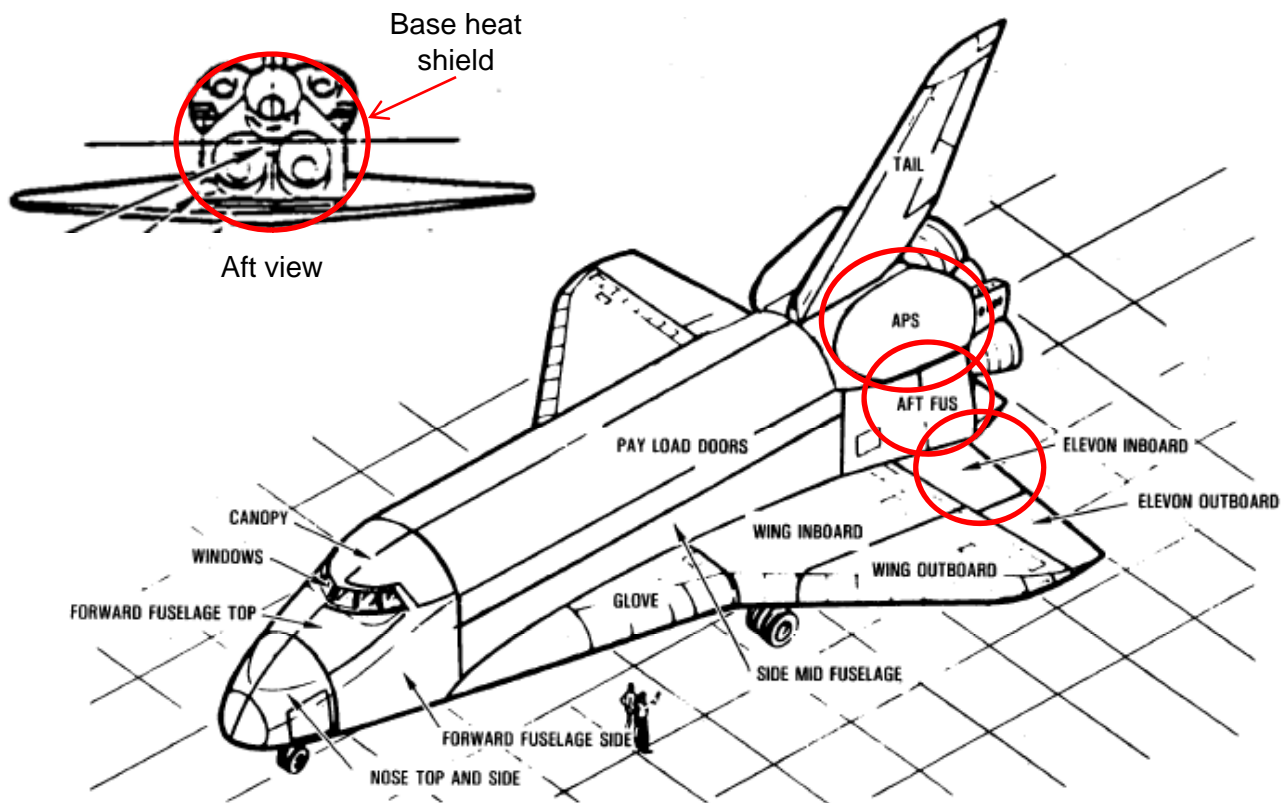
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# Updated MEI Acoustic Zones on Orbiter

Presenter **USA/M. Miller**

Date **10/29/09**

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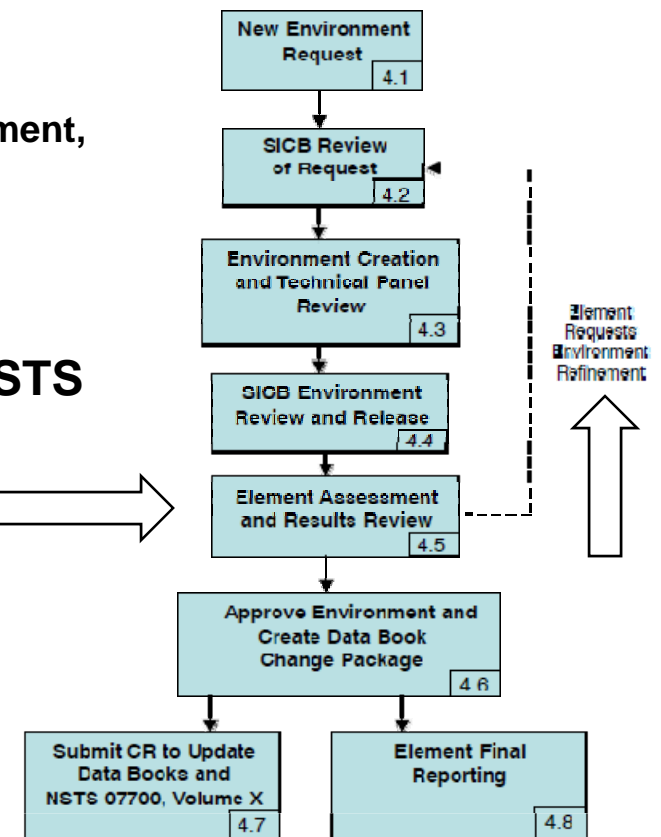
# MEI Acoustic & SSME IOP Environment — Environment Process

Presenter	USA/M. Miller	
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- Many integrated environments are non flight specific and require coordination between elements and SE&I for their development
  - Previous examples: Roll Maneuver Q plane development, Rollout Fatigue Loads
  - Require long term development and flight readiness assessments for those flights in the interim
- An improved process for formalizing assessments has been used since RTF2. (NSTS 07700 Vol. IV, App AB)

Current stage of Process →

FIGURE AB-1  
 ENVIRONMENT TRANSMITTAL PROCESS





## MEI Acoustic & SSME IOP Environment – Background

Presenter USA/M. Miller

Date 10/29/09

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- **MEI Acoustics knowledge has evolved**
  - **Lift-off Acoustics was initially developed primarily based on the 6.4% scale model test but did not include SSME simulation**
  - **STS-1 to -5 flight data then identified a significant higher MEI Acoustic environment than the Lift-off Acoustics**
    - **An improved environment was developed and documented in the Acoustics and Shock Data Book**
  - **Post flight data analysis resumed after STS-26 RTF for OV-102 and OV-103**
  - **STS-95 Drag Chute Door failure during MEI transient caused an evaluation of MEI which resulted in an increase in the Drag Chute Door MEI Acoustic environment.**
    - **Flight instrumentation was added for environment verification**
  - **Around STS-107 RTF various analysis techniques were investigated to better assess this main engine start-up transient and capture the total event duration**
    - **Resolution of many technical issues were required before formal release of updated environment**





## MEI Acoustic & SSME IOP Environment – Background

Presenter USA/M. Miller

Date 10/29/09

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- **SSME IOP Knowledge has evolved as well**
  - **Ignition of free hydrogen effects originally developed in 1980, but has changed with the addition of suppression hardware.**
    - **Pyrotechnic hydrogen burn-off system (ROFI) implemented prior to STS-1 reduced the hydrogen ignition overpressure to a negligible level and was excluded from the current Acoustics and Shock Data Book (SD 74-SH-0082B)**
  - **SRB IOP was dominant for STS-1 but suppressed by SRB Duct water deluge and water bags for STS-2 and subs**
  - **After the STS-95 Drag Chute Door failure, a design SSME IOP environment was baselined for Drag Chute Door only in Section 7.5.8 of the Loads Data Book (Vol. 2)**
  - **During STS-122, a left OMS / RCS Stinger tile loss coincided with a large negative peak**
    - **TPS PRT concluded that KSC handling was the failure root cause (IOP Wave occurred after the tile loss)**
    - **This incident caused review of ASD environment; found that SSME IOP environment was not adequately defined for aft of Orbiter**



## Environment Update

Presenter USA/M. Miller

Date 10/29/09

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- **Ground rules and update criteria were approved by Loads Panel (June 2009) and included some conservatism**
  - The maximum value from all the flight data collected at each frequency was used in the updated environment
  - Frequencies without an update will remain at the current data book levels regardless of whether flight history shows lower values or not
  - Assumes these higher values are applicable for each remaining flight (does not account for a mission mix including startups with lower noise levels)
  - The peaks in this data are applied uniformly to the surfaces they represent
  - Methodology of the Acoustics and Shock Databook was reviewed and considered to remain applicable
- **As elements report issues the process is to remove conservatism at specific locations**



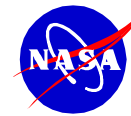
## MEI Acoustic & SSME IOP Environment Development

Presenter USA/M. Miller

Date 10/29/09

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- A broad technical community has studied all aspects of data collection, processing, and analysis methodology
- Environment updates are based on flight experience measurements
  - As many as 27 flights of data are available for some locations
- Flight data is consistent since STS-26 (instrumentation reactivated)
  - No correlation to SSME hardware changes
- Three independent Data Labs (Boeing/Huntington Beach Data Lab, Marshall DROID, KSC Wave Lab) verified the data reductions
  - Resolved concern that some increases might be due to data processing
- By correlating with MSFC analyses including unsteady CFD, the cause of peak MEI Acoustics was determined to come from Lip Restricted Shock Separation (RSS) Oscillation from the SSME nozzle during start transient
- Issues with sampling window were resolved
  - Studies were performed to determine most appropriate sampling window
  - Technical community concluded the shorter 0.5 sec window was best to characterize the environment
- Discrepancies resolved through calibration checks of microphones and removing identified bad data

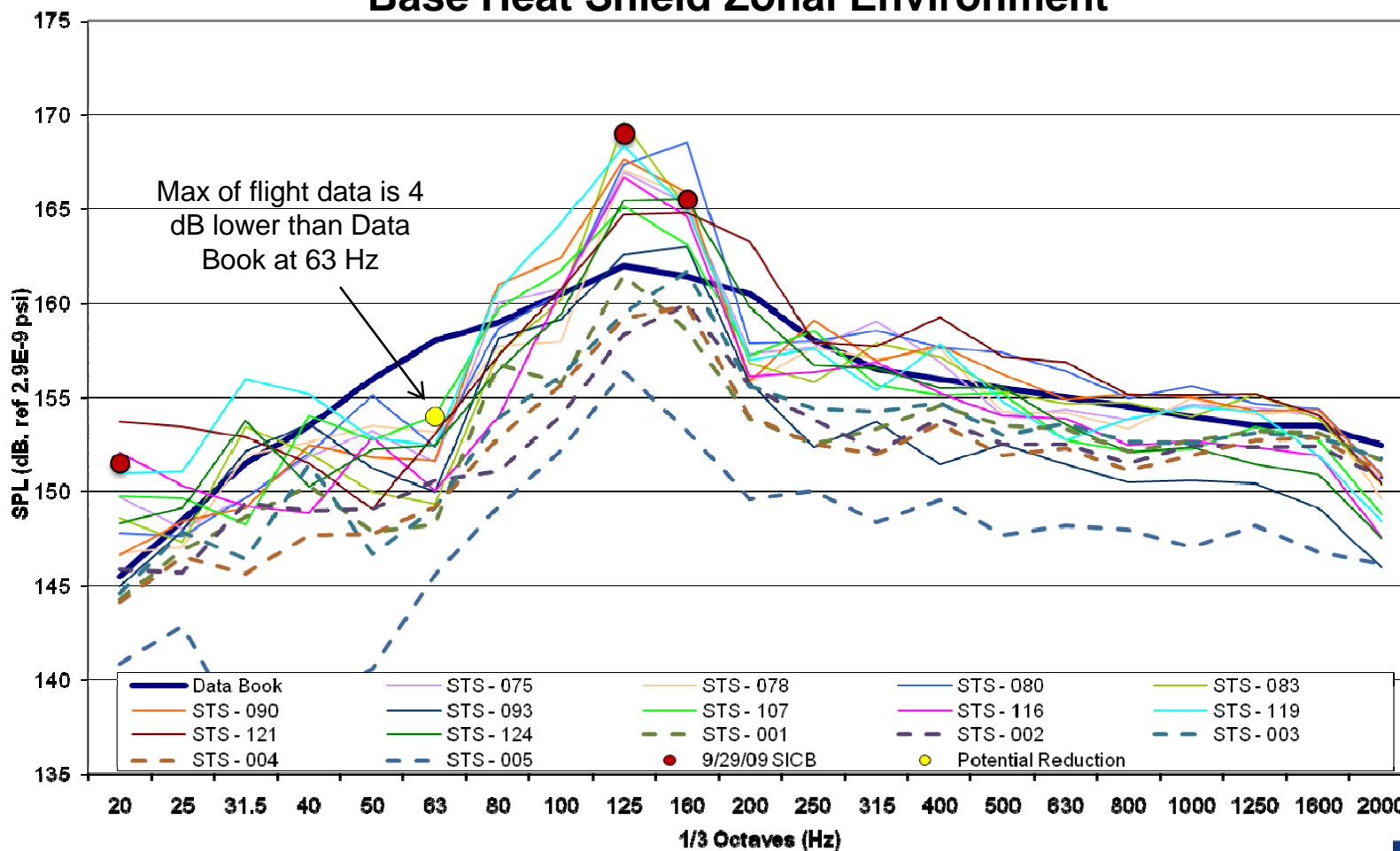


# Flight History and Design Data

Presenter	USA/M. Miller	
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V08Y9686A

## Base Heat Shield Zonal Environment





## Environment Concurrence/Approval

Presenter USA/M. Miller

Date 10/29/09

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- All aspects of the environment development and update have been presented and concurred at Joint Aero/Loads Panels
- 09/29/09 SICB approved proposed environment updates for Orbiter assessment and authorized verification of vertical tail measurements
- Results of MEI and IOP updates formally transmitted to OPO for assessment
  - IOP assessment has not identified any issues
  - MEI assessment has identified parts with life concerns
  - OPO will discuss hardware assessments



## Summary for Released Environments

Presenter USA/M. Miller

Date 10/29/09

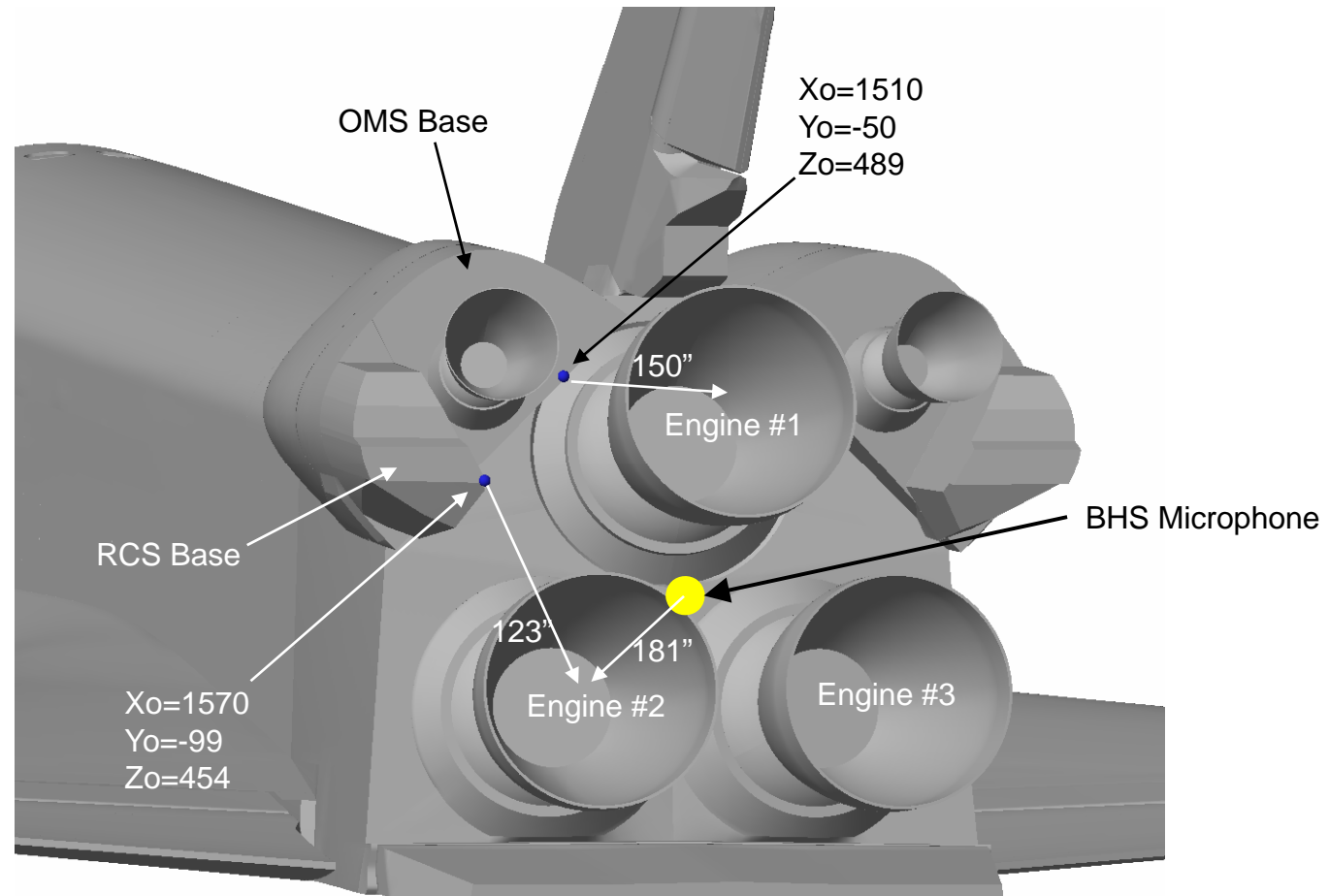
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- **Preliminary Orbiter assessment identified structural mission life concern for the OMS/RCS Base area (10/14/09 Joint Aero/Loads Panel) using the Design Limit**
- **Further review by SE&I of source data for this zone indicates Design Limit can not be reduced, but a fatigue environment can be defined**
- **Since there are missions with significantly lower pressure levels, using a mission mix should provide a more representative lifetime exposure environment**
- **Four MEI Acoustics mission mix options were investigated and presented to 10/21/09 Joint Aero/Loads Panel**
  - **Obtained technical concurrence from Joint Aero/Loads Panel on 10/21/09 to use the 50% mission approach (Option 3) to be consistent with current Data Book approach for Ascent Aero-Acoustics fatigue analysis**
- **Mission mix for fatigue analysis was approved at the Special SICB 10/23/09**



# Orbiter Based Heat Shield Zone Geometry

Presenter	USA/M. Miller	
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Blue dots are the approximate closest points to engines  
Nozzle centers (1 diameter aft) are used as reference sources



# MEI Acoustic & SSME IOP Environment 50% Mission Approach Overview

Presenter	USA/M. Miller	
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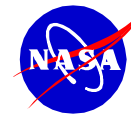
SICB Update RMS P **1.203** psi = 1% of mission mix

Flight	RMS P (psi)	Max RMS P (psi)
STS - 080	1.211	<b>1.211</b>
STS - 119	1.184	<b>1.184</b>
STS - 109	1.183	<b>1.183</b>
STS - 083	1.163	<b>1.163</b>
STS - 090	1.129	<b>1.129</b>
STS - 075	1.056	<b>1.056</b>
STS - 078	1.020	<b>1.020</b>
STS - 121	1.010	<b>1.010</b>
STS - 124	0.971	
STS - 116	0.966	
STS - 107	0.933	
STS - 094	0.887	
STS - 128	0.798	
STS - 093	0.757	

= 49% of mission mix  
 (For 100 missions, each of these 7 RMS pressures will be applied to 7 missions)

= 50% of mission mix  
 (Max. of bottom 50% of missions)



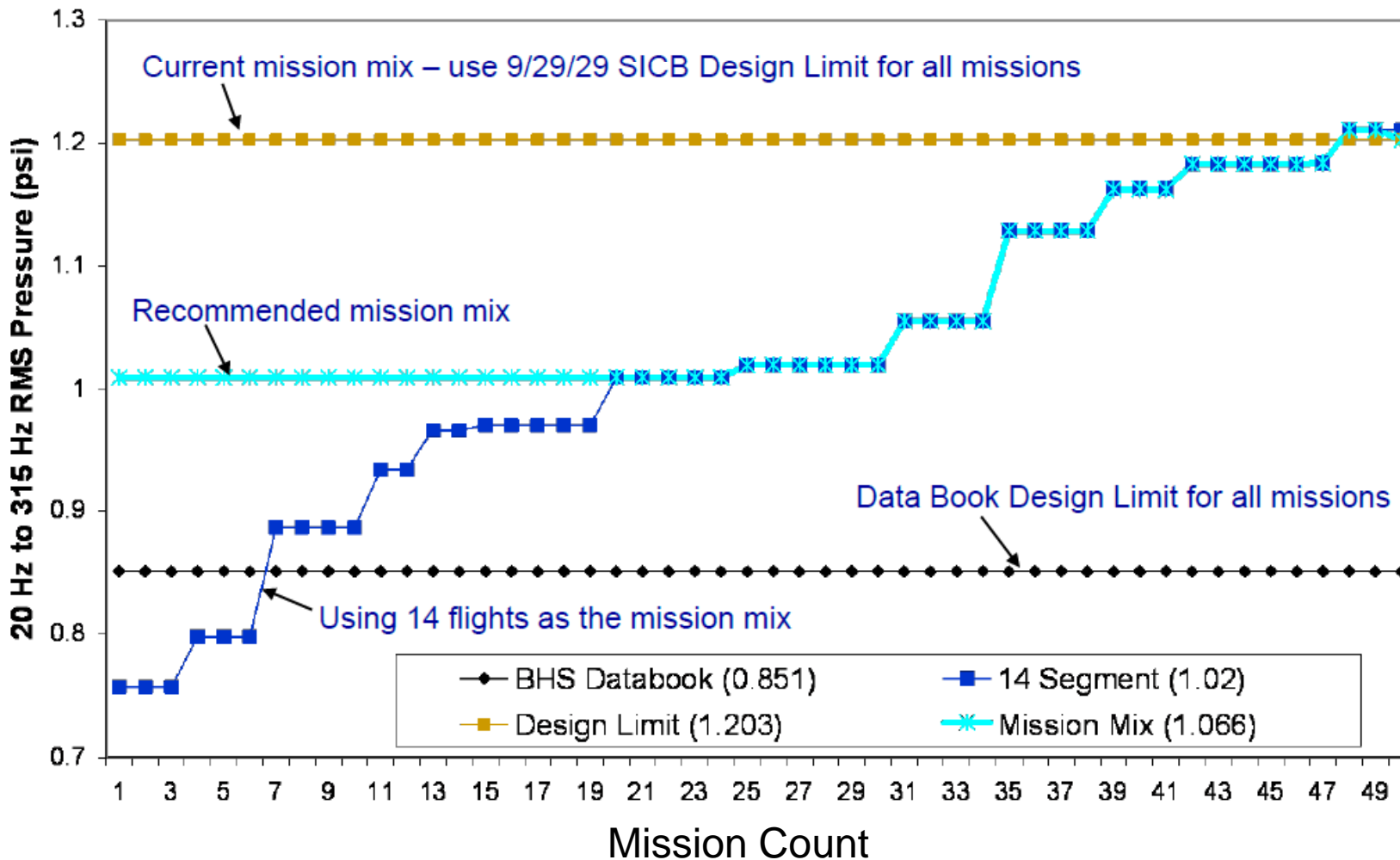


# MEI Acoustic & SSME IOP Environment 50% Mission Approach Overview

Presenter USA/M. Miller

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## MEI Acoustic & SSME IOP Environment Summary

Presenter	USA/M. Miller	
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- **No impacts to other elements**
- **Open work items for released environments**
  - **Documenting analysis and assessments**
  - **Additional instrumentation for OMS base area or on Pad to help verify environment**



# MEI Acoustic & SSME IOP Environment Vertical Tail Open Work

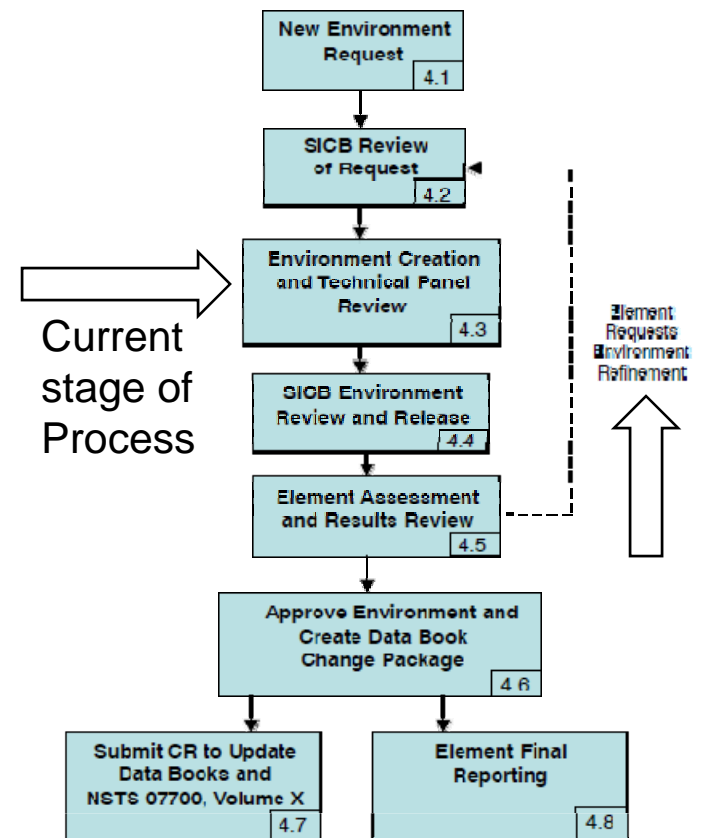
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- The Vertical Tail and Drag Chute environments are still in the development stage and will not be available until after launch
  - One microphone and one pressure transducer was found to require further dynamic calibration for the Vertical Tail and Drag Chute compartment area environment definition
  - Issues were discovered with previous calibrations
  - Multidiscipline team is working to calibrate instruments

### Summary:

- FLT-based environment updates have overlap missions during their development
- The Program has utilized the baselined environment until all the update work is completed by SE&I and the Elements
  - All environments and element assessments have some conservatism built in them for unknowns and bad sensors (as stated earlier)
  - OV -103 is the fleet leader and has flown 37 missions without major issues with STS-129 (OV-104) flying 30 times to date
- Continued FLT operations require SSP acceptance of additional risk due to the environment uncertainty

FIGURE AD-1  
 ENVIRONMENT TRANSMITTAL PROCESS





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# **Main Engine Ignition (MEI) Acoustic & SSME Ignition Overpressure (IOP) Environment Update**

## **Orbiter Assessment**



Pre-decisional. Internal Use Only.



# Overview

Presenter: <b>M. Dunham</b>	
Date: Oct 27, 2009	Page: 28.1



- **Orbiter has performed assessments of the new SSME IOP and MEI acoustic environments**
- **Increases to the Orbiter acoustic environments can affect structural responses including primary structure fatigue, TPS/panel accelerations, and subsystem vibration requirements**
- **Increases to SSME IOP can affect TPS margins in the aft end of the Orbiter**
- **Agenda**
  - Impacts to TPS tiles
  - Impacts to subsystems
  - Impacts to primary structure life
  - Path to flight rationale

# MEI and IOP Impacts to TPS Margins

Presenter: <b>M. Dunham</b>	
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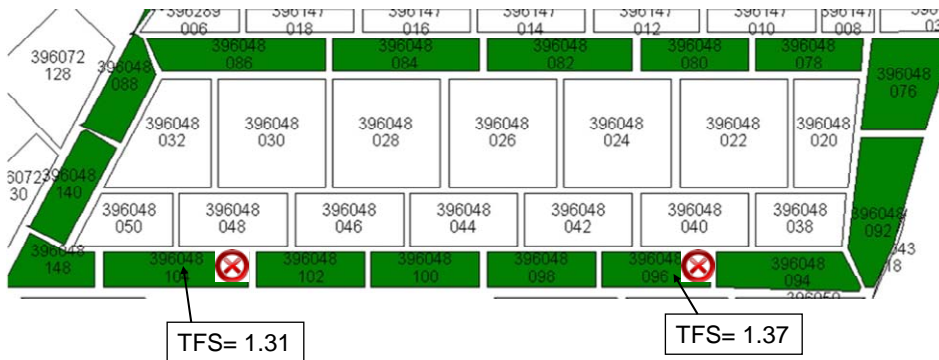
- **MEI acoustic environments must first be converted into accelerations on TPS tiles**
  - Accelerations are greatest at the center of structural panels where acreage tiles are present
- **All design acreage TPS assessed to be good for increase in IOP and MEI**
  - Approximately 9000 tiles were assessed
- **Carrier panel analysis generally shows good margin for new environments**
  - IOP has a large effect
  - Carrier panel tiles on base heat shield, vertical stabilizer (drag chute), and body flap are showing preliminary values of  $FS > 1.4$
  - OMS Pod/RCS have a small number of design tiles where  $FS < 1.4$ 
    - 6 total (3 each pod) on interior side of RCS
    - 4 total (2 each pod) on aft end of RCS on OV-103
      - OV-104 and OV-105 have been changed to AETB8 as attrition mods
  - Pulse Velocity Test (PVT) previously performed on 5 of the 6 tiles on OV-104 provide  $FS \geq 1.4$ 
    - PVT of installed tiles provides demonstrated capability above A Basis material properties
  - Remaining RCS carrier panel will have gap filler modification performed on pad that will result in  $FS > 1.4$

# RCS Carrier Panels with design FS < 1.4

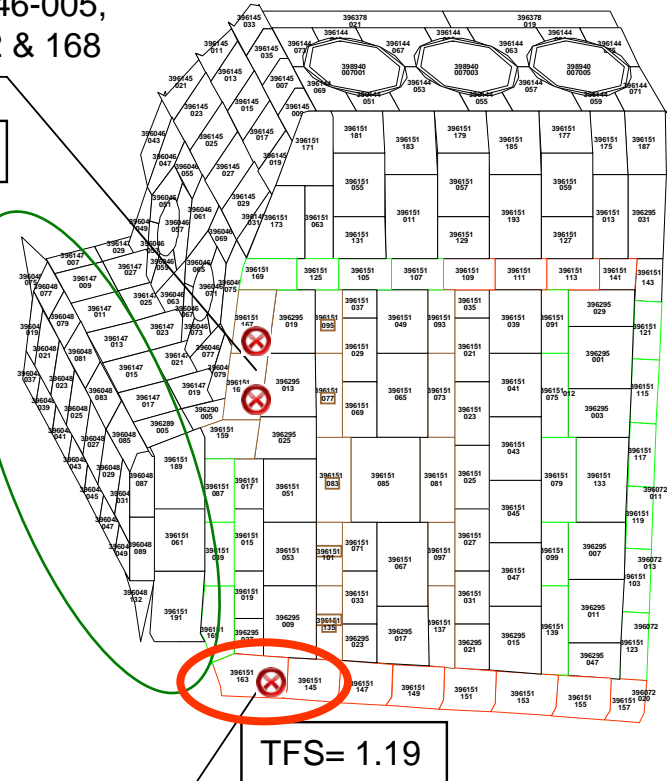


Two tiles on C/P 396246-005, 396151- 161, 167 (162 & 168 on opposite side)

TFS= 1.30, 1.35



OV-103 only; looking fwd



One tile on C/P 396244-003, 396151-163 / 164

View looking outbd on aft RCS stinger



# MEI Acoustic Impact on Subsystems

Presenter: <b>M. Dunham</b>	
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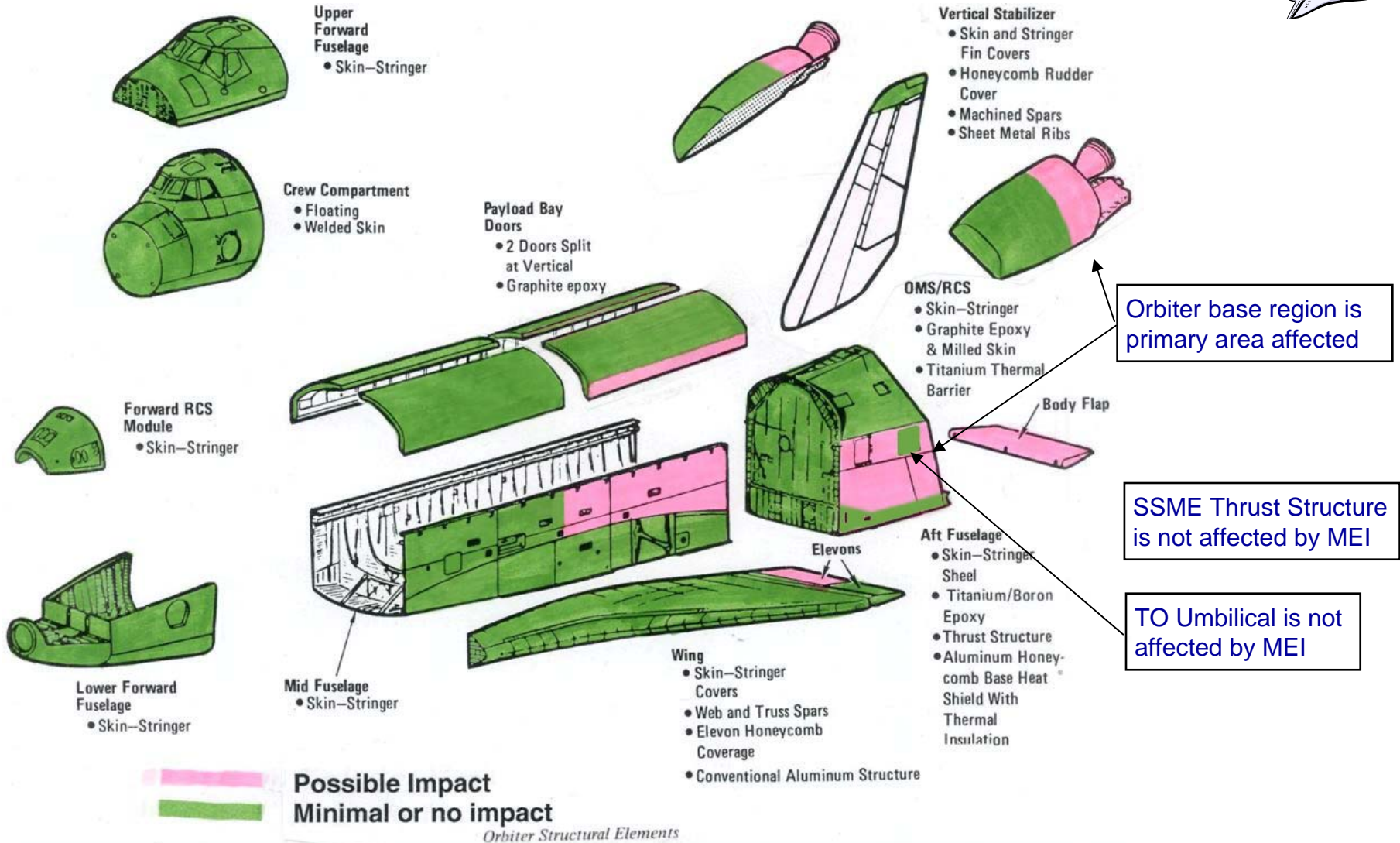


- **Subsystems are items internal to the primary structure including tanks, mechanisms, boxes, valves and plumbing**
- **Most subsystems are demonstrated by vibration testing**
  - Acoustics increase would increase vibration environments
  - Vibration tests are not performed to failure, so actual ability to operate in increased environments is unknown
- **Regions of the Orbiter with increased vibration environments have been identified to the subsystem hardware communities**
  - Evaluation of risk to program is being performed in two phases (e.g., susceptibility to vibration including failure history, any testing conservatism, redundancy, criticality)
    - Phase 1 – identify subsystems that are attached so that they may be affected; evaluate any simple rationale for clearing
    - Phase 2 – detailed review of qual testing and related dynamics items
      - Components that do not have clearance rationale will be evaluated for risk
- **Shuttle Program may have to accept some risk associated with not demonstrating capability at these increased levels**
  - Long term, update may cause significant certification “paper” issues, primarily in aft of Orbiter



# Regions Affected by MEI Increases That Require Subsystem Evaluation

Presenter: M. Dunham	
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# MEI Acoustic Impact on Subsystems

Presenter: <b>M. Dunham</b>	
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- **All Orbiter (CFE and GFE) subsystems were surveyed**
- **11 subsystems identified items that might be in the area of concern**
  - APU, ATCS, ECLSS, GFE, Hydraulics, Landing/Decel, MADS, Mechanisms, MPS, OI, OMS/RCS, PRSD
  - 115 component items were identified (single and group)
- **41 were determined not to be actually in the area of concern**
- **65 were in area of concern, but were cleared by other rationale**
- **8 are still in work**
  - ECD 10/28
- **1 is on “short list” of items that require detailed (“phase 2”) review**
  - ECD 11/3
- **Items on “short list” will be reviewed with hardware owners and dynamics group for additional insights into qual testing and flight history**
  - Items that cannot be cleared by detailed evaluations will have summary risk evaluation, including criticality and redundancy, generated
  - Those items will be brought back to OPO and Program
  - Final resolution will be briefed at L-2

# Primary Structure Life Impacts

Presenter: <b>M. Dunham</b>	
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- **The only structures that did not meet the goal of 50 missions capability were in the OMS base and RCS region**
  - Along with the Base Heat Shield, these have the highest MEI acoustic levels (new = 172.9db OA; databook = 170.4db OA)
    - A 42% increase in load (20 to 315hz)
- **List of Critical components remaining**
  - OMS/RCS access panel
  - RCS stinger attach point

# Previous Access Panel Crack

Presenter: <b>M. Dunham</b>	
Date: <b>Oct 27, 2009</b>	Page: <b>28.8</b>

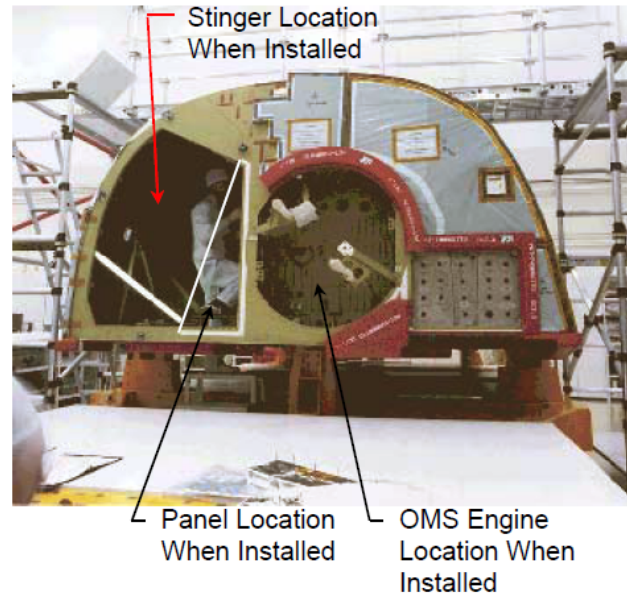


## STS-99 DELTA PRELAUNCH MMT

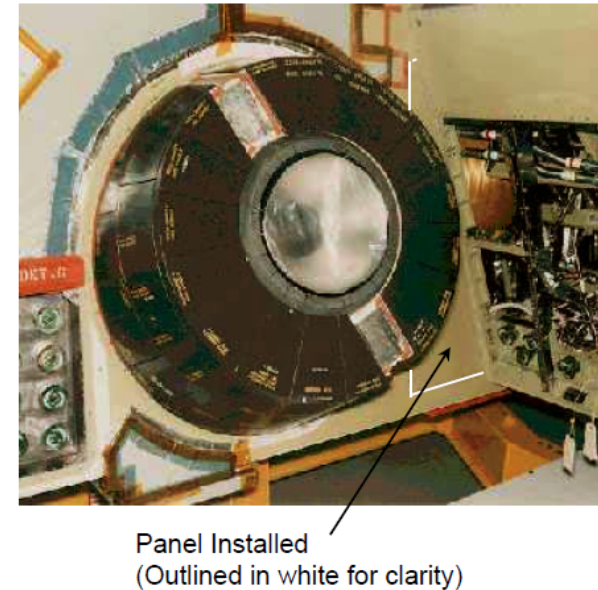
<b>OV-102 LEFT OMS POD (LP05) AFT DECK PANEL CRACK</b>	Presenter: Vic Speed
	Organization/Date: Orbiter/02-09-00

- “During orbiter major modification (OMM) OMRS V30 structural inspection of the OV-102 LH OMS pod (LP05) a structural crack was detected”
- “Finite element model confirms that pressure loading from MEI acoustics would result in local high bending stress at crack location”
- “Other flight loads (lift-off, ascent, descent) have a very small effect on the mission life and are non-critical relative to strength margin at the failure site”

### OMS Pod Helium Tank Access Panel Orientation Views



**View A-A Looking Fwd**  
(During Early Pod Assembly)



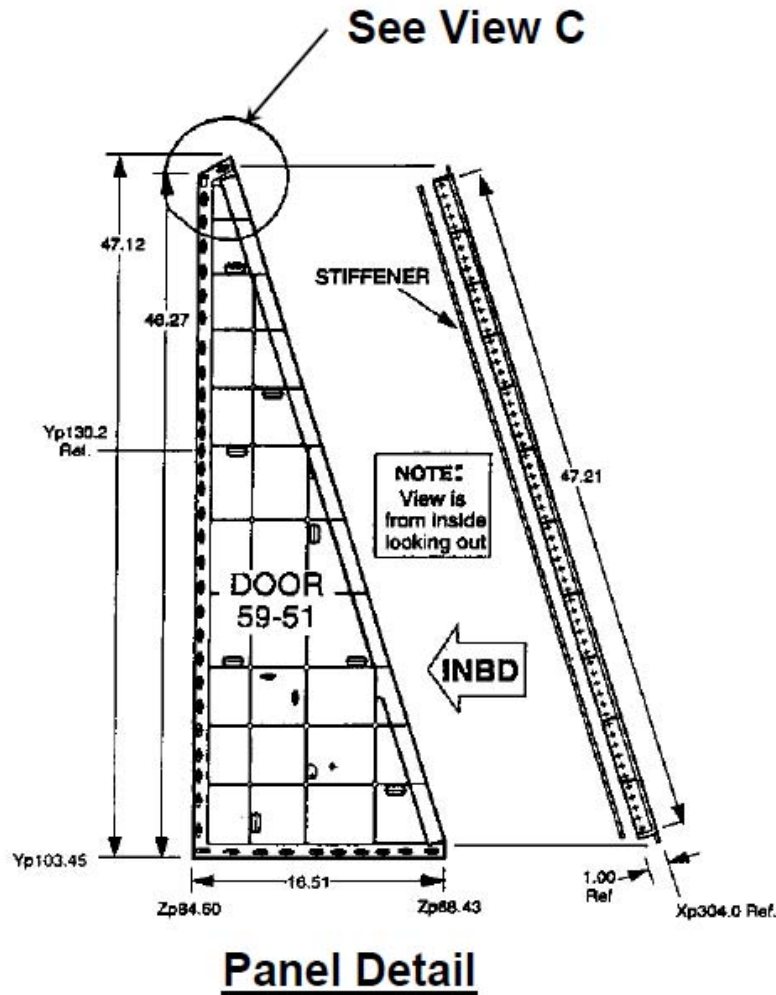
**View A-A Looking Fwd/Inbd**  
(After Panel & Stinger Installation)



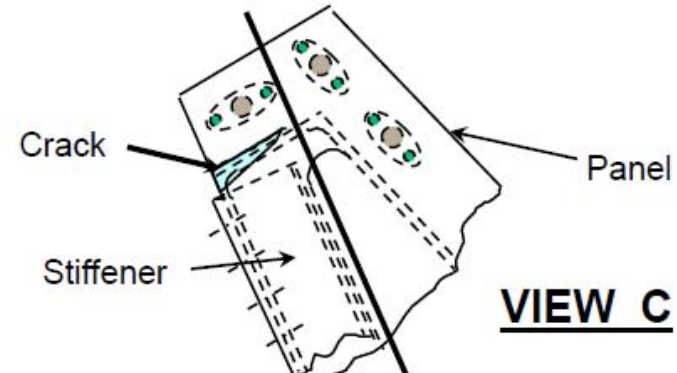


# Previous Access Panel Crack

Presenter: <b>M. Dunham</b>	
Date: <b>Oct 27, 2009</b>	Page: <b>28.9</b>



**Interior Section B-B Looking Inboard**

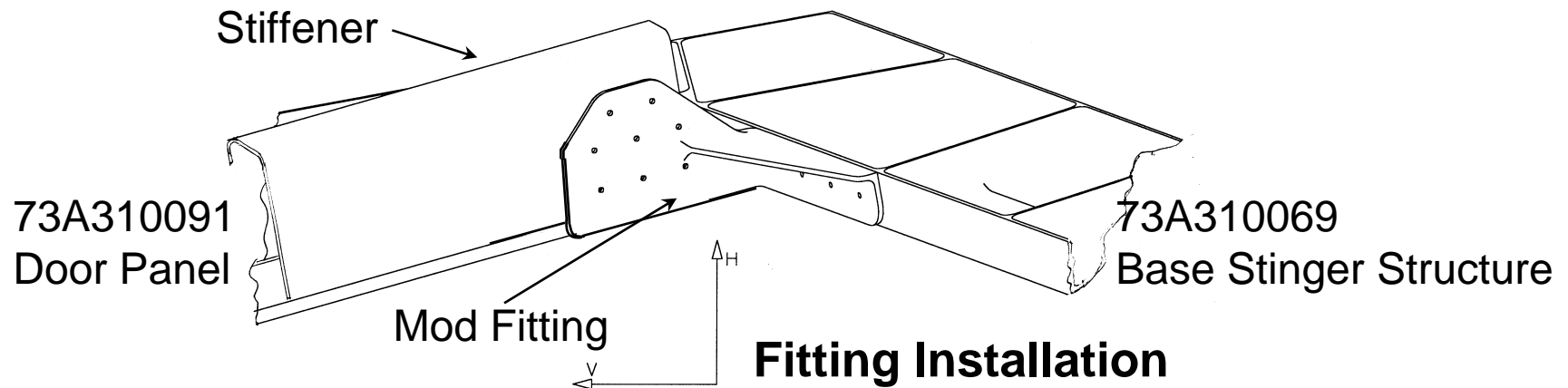


# Access Panel Expected To Clear

Presenter: <b>M. Dunham</b>	
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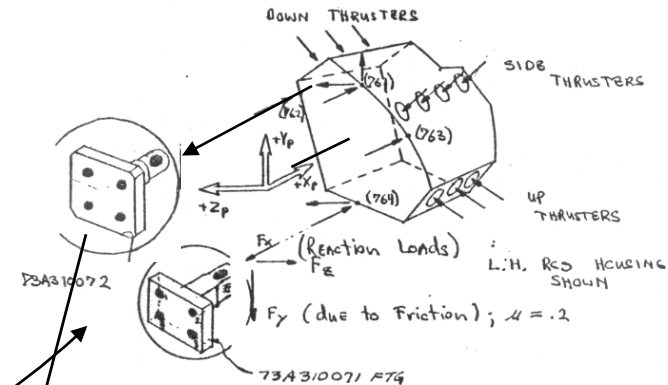
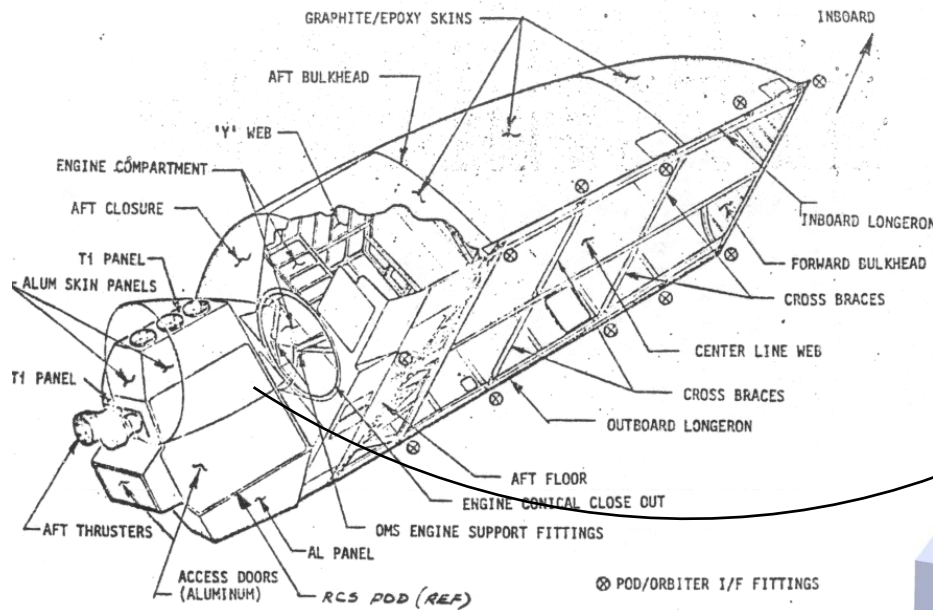


- **All Pods were modified after the crack on OV-102 was found**
  - Inspections of other pods did not detect any cracks in this region
  - Stronger alternate load path for taking loads around the corner
  - Preliminary analysis shows that margin and life are maintained
    - Analysis assumes no load is taken through original load path, although it does still exist
  - A local FEM is being developed to provide better insight

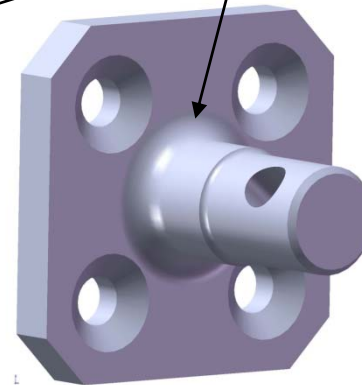


# RCS Stinger Attach Point

Presenter: <b>M. Dunham</b>	
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RCS stinger is attached to OMS Pod at 4 discrete fittings



- Nom Dia = 0.75in
- Titanium 6Al-4V
- Fitting unique in that it carries all three reaction components

RCS Stinger Attach Fitting  
(P/N 73A310072)  
Was 101 missions



# Primary Structure Life Impacts

Presenter: <b>M. Dunham</b>	
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- **Loads Panel review of environments**
  - Design Limit (DL) was reviewed; no change for STS-129
    - Addition of microphones in OMS/RCS base area is desired for near term flight
  - A “DL/50%” Mission Mix was selected
    - Modeled on method used for Aero acoustics
    - RCS stinger attach life increased from 10 missions to 22 missions (scatter factor, SF = 4)
  - Compared to 41 effective missions on STS-129 Pod (RP01)

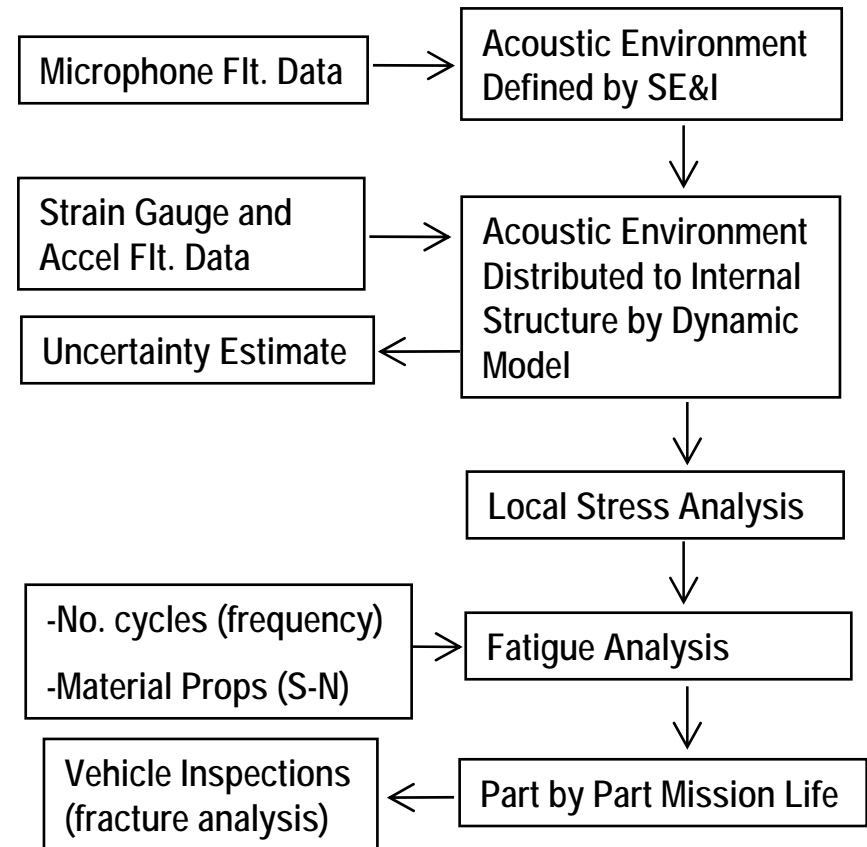


# Acoustic Fatigue Analysis Process

Presenter: <b>M. Dunham</b>	
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- **Acoustic environments are specified by 1/3 octave band SPLs**
- **These environments are applied to the external surfaces of a dynamic model**
  - This produces local loads on internal structure
  - Response frequencies are obtained at critical locations
  - Accelerations can also be extracted and compared to flight accelerometers; Strain data can be compared to flight strain gages
    - Provides verification of model response to acoustic environments
    - Uncertainty can be estimated also
- **Local stress analysis is performed on local loads at critical locations**
  - Much of the analysis scrubbing that has removed parts from the critical list occurred at this stage
- **Material S-N (stress vs cycle) fatigue curves have been reformatted to RMS stress**
- **Mission life is calculated using Minor's Rule**
  - Damage equals the number of cycles applied divided by the number of cycles the material can withstand at a given stress level



# Evaluation of Uncertainty and Conservatism (Engineering Directorate)

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- **Uncertainty #1: Analysis assumes that acoustic environment near stinger is identical to the environment measured at the center of the base heat shield**
  - Actual environment at stinger panels could be more or less severe
  - A dynamic model will attempt to more accurately measure the response of that environment, which corresponds to loading of the RCS upper outboard attach fitting
- **Uncertainty #2: Loads environment was created using a mission mix environment which captures peaks from 14 flights**
  - Though not representative of all shuttle flights, there is precedent for using this approach
  - MEI acoustics account for 99% of the estimated fatigue life for the RCS upper outboard attach fitting
- **Fatigue Analysis Characteristic #1: Scatter factor**
  - Material fatigue curves are developed by subjecting same-lot coupons to constant cyclic stress until failure
  - The scatter factor creates a boundary to cover the expected variation in number of cycles to failures at each stress level
- **Fatigue Analysis Characteristic #2: Life prediction is exponentially related to input cyclic stress level**
  - Small changes to stress level can lead to large changes in life prediction
  - New dynamic and stress models in development will attempt to determine if scaling stress level results from original certification analysis is over/under predicting life prediction



# Dynamics Model

Presenter: <b>M. Dunham</b>	
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- **There is a “missing piece” in the analysis chain that predicts mission life**
  - A dynamic model is required to convert acoustic environments into detailed internal loads (RMS stresses and forces)
  - A model was developed 25 years ago to perform this work
    - This model is not recoverable
    - The current assessment is based on the results found in the acoustic fatigue report
  - Boeing is modifying an existing transient dynamic model to acoustic analysis
    - A fully verified model takes months to develop/complete
    - Objective is to provide an “engineering” level model prior to STS-129 to evaluate any inherent conservatism in the original report
      - Allows comparison of model results to flight data (principally STS-1 thru STS-5)
        - May provide relief on internal loads and stresses
        - Can provide estimate of uncertainties in environment/structural response
      - Allows direct application of new environments
  - Schedule (success oriented):
    - First run 10/28
    - Comparison of limited set of flight (STS 1 thru 5) data to model runs (11/4)
    - Complete assessment of OMS/RCS critical components (11/11)



# Borescope Inspections

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## **Provides visual inspection at part base where fracture expected to occur**

- May not detect needed flaw size (0.150" w X 0.068" d) but could detect gross anomaly
- No known Probability of Detection data for 30X magnification borescope
- Two potential access points for inspection were considered
  - Access through Stinger Door
    - OV-103/LP01: Completed: Approx. 180 degrees of circumference accessible - Minor scratches, machine marks, and possible dent seen; No cracks visible
    - OV-103/RP03: Completed; Approx. 270 degrees of circumference accessible; dry film lube displacement (from installation), but no substrate defects of note. No crack indications noted.
    - OV-104/LP04 & RP01 & OV-105/LP03 & RP04 : In work
  - Access through OML – If unable to get 360 degree part base inspection
    - Considered non-standard; Requires scalloping structural flange to provide access port and potential environmental seal damage
- Existing OMRSD inspections last performed in STS-115 (RTF) Flow are general and not directed towards this area
- Borescope inspection of RCS upper outboard attach fitting on the pad will not yield conclusive results from a fatigue/fracture perspective – should only be used to assess gross anomalies

# Borescope of OV-103 RCS Fitting

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# Other Options Examined

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- Structural Beef-up Feasibility
  - Design would require X,Y, Z load carrying capability and would likely result in stiffness changes and load redistributions that would need to be assessed and could cause problems in other areas
  - Implementation is very difficult due to limited access in the stinger area and would likely result in significant flow impact
  - PRT will perform a feasibility study when access becomes available on LP01
- Disassembly for NDE inspection
  - Provides highest confidence crack detection
  - Requires stinger removal
    - Estimated 12+ month impact based on recent COPV assessment for removal of Helium tank and confirmed by USA GO
      - NDE could occur approx. 2-3 months into this timeline

# Path to Flight Rationale – RCS Stinger

Presenter: <b>M. Dunham</b>	
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- **Primary approach to flight rationale is based on analysis refinement**
  - Engineering dynamics model:
    - Provides potential for relief on RCS attachment load by identifying conservatism in original acoustic fatigue report
      - But possible that scatter factor of 4 may not be met
    - Provides opportunity to evaluate uncertainty in acoustic environment and structural response
  - Borescope inspections of all OMS pod critical attachment will provide verification that gross failure has not occurred
    - Cannot provide definitive verification of capability
    - No failures noted in flight history
- **Results of updated analysis will be presented at L-2**
- **Additional microphone data is highly desirable to help reduce uncertainty in environment for future flights**



# Summary

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- **TPS – OV-104 is cleared pending completion of mod at pad**
- **Subsystems**
  - First phase “in work” will be completed 10/28
  - All detailed evaluations for few remaining items in phase 2 have ECD of 11/3
  - Provide clearance rationale or summary of risk acceptance
- **Access panel**
  - Preliminary analysis of design modification indicates adequate life
    - Refined FEM in work to provide better definition
- **RCS Stinger Attach is being worked at several levels**
  - Inspection options being investigated
    - Near term inspections provide evidence of gross failure only
    - Full NDE inspections require disassembly and long schedules
  - Risk acceptance rationale was examined for scatter factor below requirement of 4 and was determined to be not appropriate
  - Dynamic model is in work to provide addition environment/loads insight into potential conservatism
    - Represents best path to meeting fatigue life requirements on RCS stinger



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# Back-up charts



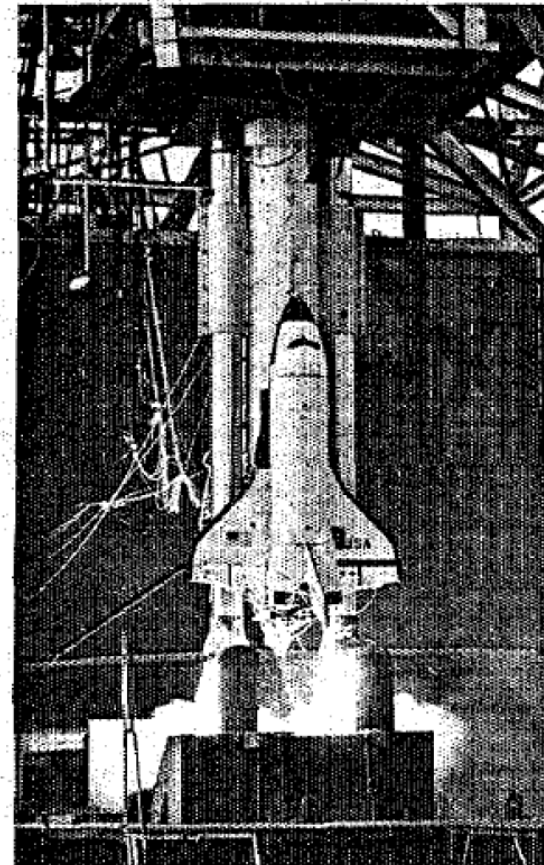
## No Ground Test Data Available for MEI Acoustics

Presenter USA/M. Miller

Date 10/29/09

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- 6.4% model attempted to simulate the SRBs for stable thrust lift-off acoustics predictions
- SSMEs were not simulated



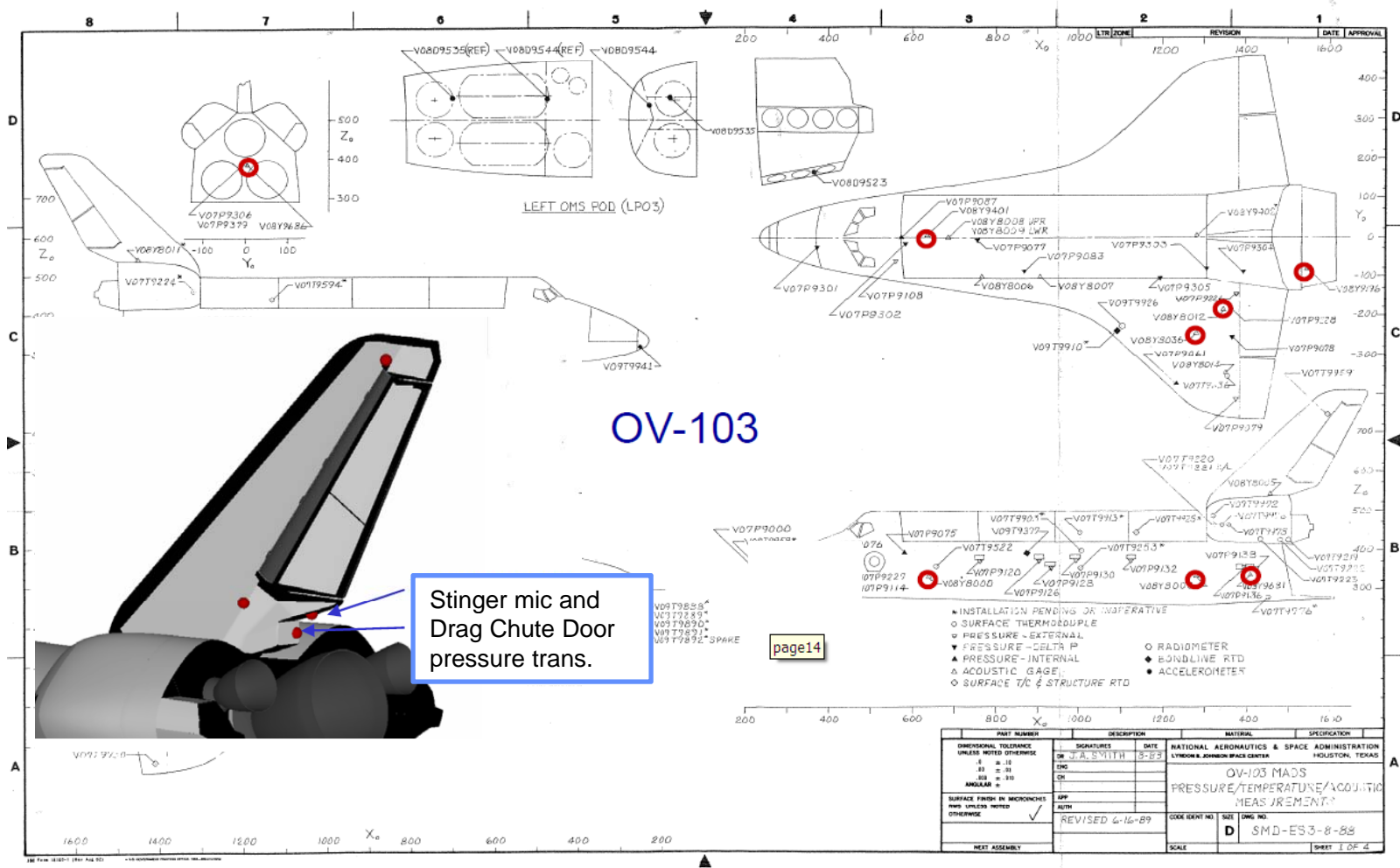
*Fig 1 Liftoff acoustic model*



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# Sensor locations (OV-103)

Presenter	USA/M. Miller
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## Hazard Report Impacts

Presenter USA/M. Miller

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- **Hazard report affected is IVLD-01 Rev E: Exposure to Induced Environment Exceed Structural Capability of SSV.**
  - Cause AD: “Actual Loads Do Not Conform To Design Shock & Acoustics Environment, Frequency and Exposure Period During SSME Build-Up/Shutdown on Launch Pad, Lift-off, or Ascent”
  - Accepted Risk – Remote/Catastrophic
  - Impact to HR: This is a revision to a control document which is already referenced (Acoustics and Shock Data Book). No actual changes to the hazard report.
  - A VTL item will be added to identify increased risk because the lower vertical tail acoustic environment in the Acoustics & Shock Databook may be understated. Open work is to define the appropriate lower vertical tail acoustic environment updates.



## Integrated In-flight Anomalies(IFAs) Summary

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- **STS-128-I-001 “LH2 PV-12 Inboard Fill and Drain Valve did not Indicate Closed when Commanded”**
  - Status – Dispositioned
- **STS-128-I-002 “Ice External to the LH2 T-0 Umbilical”**
  - Status – Dispositioned
- **STS-128-I-003 “Liftoff Debris”**
  - Status – Dispositioned
- **STS-128-I-004 “ET TPS Loss on LH2 Intertank Flange near Starboard Bipod at ~Xt 1123”**
  - Status – Dispositioned
- **STS-128-I-005 “Debris Observed Near RH SRB Aft Skirt HDP #4 Foot”**
  - Status – OPEN
- **STS-128-I-006 “Debris Observed on SSME Hatband”**
  - Status – OPEN



# SPACE SHUTTLE PROGRAM

## Space Shuttle Systems Engineering and Integration Office

NASA Johnson Space Center, Houston, Texas



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Presenter MS/Don Totton

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## Integrated Hazard Risk Matrix

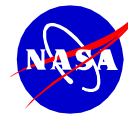
Likelihood	Probable			
	Infrequent	2		13
	Remote	2	2	131
	Improbable	11	11	268
		Marginal	Critical	Catastrophic
		<b>Severity</b>		

**Risk Summary**  
 21 of 38 IHR's are classified as Controlled Risk  
 17 of 38 IHR's are classified as Accepted Risk  
 \* Previous Flight

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Hazard Report #	Integrated Hazard Titles	Controlled					Accepted Risk									
		Controlled Risk	remote-marginal	improbable-marginal	improbable-critical	improbable-catastrophic	Accepted Risk	probable-marginal	infrequent-marginal	remote-critical	remote-catastrophic	probable-critical	infrequent-critical	infrequent-catastrophic	probable-catastrophic	
																
	<b>"Accepted Risk" Hazard Reports</b>															
IDBR-01	Ascent Debris Impact to SSV	7				7	28					22			6	
ICOM-01	Adverse Effects due to Intentional RF Environment	2				2	1					1				
IEME-01	Adverse Electromagnetic Effects (EME)	0					18					18				
IGNC-01	Ascent Trajectory Event Anomaly	13				13	1								1	
IMEO-01	Hazardous Environment in the Aft Compartment	0					4					1			3	
IMPS-01	Contamination in the Integrated MPS H2 System	0					2					1			1	
IMPS-02	Contamination in the Integrated MPS O2 System	0					1					1				
IMPS-03	Improper IMPS configuration during SSME Operation	11				11	3					3				
IMPS-04	Off-Nominal Purges	11				11	1					1				
IMPS-05	Over pressurization of the Integrated MPS H2 System	7				7	1					1				
IMPS-09	Hazardous Environment due to H2 External to SSV	4				4	6					5			1	
INEV-01	Exposure to Natural Environment Exceeds Capability of the Space Shuttle SSV Elements	17	1	1		15	45		1	1		42			1	
ISPR-04	SRB Hold Down Post (HDP) System Malfunction	1				1	1					1				
ISPR-05	SRB Umbilical System Malfunction	3				3	1					1				
ITHM-01	Exposure to Thermal Environment Exceed Capability of SSV	15	1	5	2	7	3		1	1		1				
IVLD-01	Exposure to Induced Environments Exceed Structural Capability of SSV	22				22	26					26				
ILIT-01	Adverse Effects of Lightning	0					6					6				
	<b>Accepted Risk Distribution Totals</b>						(see next page)	148	0	2	2	131	0	0	13	0





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Presenter **MS/Don Totton**

Date **10/29/09**

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## Integrated Hazard Risk Matrix

		<b>"Controlled Risk" Hazard Reports</b>																																												
IARO-01	Aerodynamics Environment not per Specified Design	1			1	0																																								
IEPD-01	Inability to Power Critical Functions	8			3	5																																								
IFSI-01	ET/SRB System Interface Failure	6				6	0																																							
IFSI-02	ET/Orbiter System Interface Failure	10				10	0																																							
IFSI-03	SSME/Orbiter System Interface Failure	14				14	0																																							
IFSI-04	Outer Mold Line Configuration Error	3				3	0																																							
IFSW-01	Flight Software Generic Problems can cause loss of vehicle command and control	1				1	0																																							
IFSW-02	Erroneous Inputs to Flight Software can cause loss of vehicle command and control	9				9	0																																							
IMEO-02	Malfunction of Integrated Hydraulic System (Systems 1, 2 and 3)	4				4	0																																							
IMEO-03	SSME Nozzle/OMS Pod/ Body Flap Interference	2				2	0																																							
IMPS-06	Under pressurization of the Integrated MPS H2 System	7				7	0																																							
IMPS-07	Over pressurization of the Integrated MPS O2 System	7				7	0																																							
IMPS-08	Under pressurization of the Integrated MPS O2 System	7				7	0																																							
IMPS-12	Excessive O2 from ET/Orbiter/SSME External to SSV	7				7	0																																							
IMPS-15	LO2 Geyser Event during Cryo Loading	8				8	0																																							
IMPS-16	Loss of MPS He System	4				4	0																																							
IMPS-17	Inadvertent SSME Shutdown	3				3	0																																							
IPYR-01	Pyrotechnic System Malfunction	11				11	0																																							
ISPR-02	ET Vent Arm System (ETVAS) Umbilical System Malfunction	14				14	0																																							
ISPR-03	Tail Service Mast (TSM) T-0 Umbilical System Malfunction	40			5	6	29	0																																						
IVLD-02	System Instability Results In Structural Failure of SSV	13				13	0																																							
<b>Controlled Risk Distribution Totals</b>		<b>292</b>	<b>2</b>	<b>11</b>	<b>11</b>	<b>268</b>	<b>148</b>	<b>0</b>	<b>2</b>	<b>2</b>	<b>131</b>	<b>0</b>	<b>0</b>	<b>13</b>	<b>0</b>																															



# Integrated In Flight Anomalies (IIFAs)

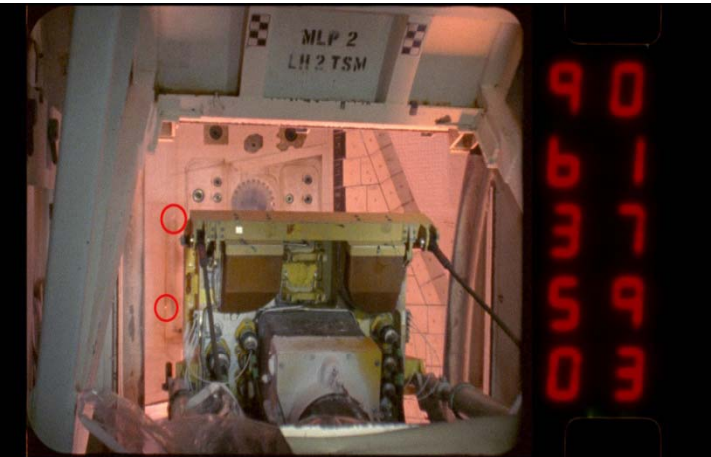
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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-128-I-001: LH2 PV-12 Inboard Fill and Drain valve did not indicate closed when commanded</u></b></p> <ul style="list-style-type: none"> <li>• On 8/26 launch attempt, during transition to reduced fast fill, LH2 inboard fill &amp; drain valve (PV12) position indicator did not indicate closed when valve was commanded closed. Violation of LCC MPS-04</li> <li>• After ET de-tank, valve was cycled in ambient temperature conditions &amp; closed indications were received</li> <li>• On 08/28/09 launch attempt, valve-closed indication was received</li> </ul>	<ul style="list-style-type: none"> <li>▪ Failure investigation to date shows no evidence of a systemic issue.</li> <li>▪ Of all the possible failure causes, system contamination is the only integrated cause that has been identified.</li> <li>▪ Root cause determination in work.</li> <li>▪ Retaining the current LCC protection ensures the Fill and Drain valves are closed (in the appropriate configuration) for launch, which mitigates the hazard risks associated with this IIFA.</li> <li>▪ <b>Status - Dispositioned</b></li> </ul>



# Integrated In Flight Anomalies (IIFAs)

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<p><u>IFA Number : Title</u></p> <p>Description</p>	<p>STS-129 Status and Rationale</p>
<p>▪ <b><u>STS-128-I-002: Ice External to the LH2 T-0 Umbilical</u></b></p> <ul style="list-style-type: none"> <li>• On 8/25 launch attempt, ice buildup was observed on –Z side of LH2 T-0 Umbilical, bridging over to Orbiter TPS. LCC ICE-01 waiver LW-114 approved.</li> <li>• On 8/28 launch attempt, ice observed bridging from the T-0 plate to Orbiter. LCC ICE-01 waiver LW-116 approved.</li> </ul> 	<ul style="list-style-type: none"> <li>• Ice/frost build-up outside peripheral seal on LH2 T-0 Umbilical seen on 3 flights since STS-126</li> <li>• NSTS 08303 has no acceptable definition of Ice/frost buildup on Orbiter at this interface</li> <li>• Umbilical seals inspected &amp; verified integrity</li> <li>• The DTA results indicate credible transport to aft locations of orbiter downstream of T-0 umbilicals</li> <li>▪ Previous improvements to assist in detecting ice near umbilical or damage caused by ice liberation:             <ul style="list-style-type: none"> <li>▪ KSC Final Inspection Team (FIT) to use telescopic camera &amp; heightened awareness during inspections</li> <li>▪ KSC IAT to expedite T-0 imagery review to reduce review time by ~1 day</li> <li>▪ JSC MOD implemented on-orbit inspections of aft fuselage and OMS pod area</li> </ul> </li> <li>▪ STS-129 improvements include increased seal inspections and mitigations to reduce water intrusion</li> <li>▪ <b>Status – Dispositioned</b></li> </ul>



# Integrated In Flight Anomalies (IIFAs)

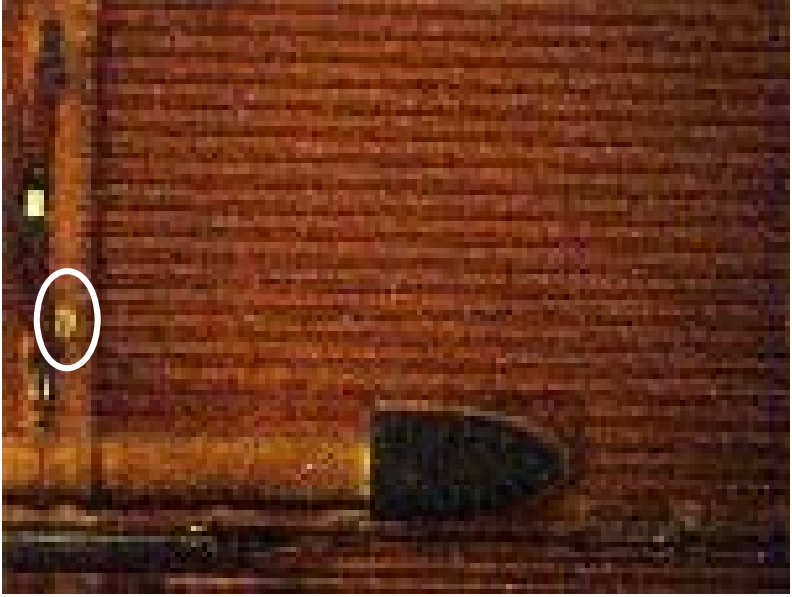
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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-128-I-003: Unexpected Debris/Expected Debris Exceeding Mass Allowable Prior to Pad Clearance (Liftoff Debris)</u></b></p> <p>▪ Multiple pieces of debris were found on pad post-launch that include corrosion, liberated pad hardware, and foreign object debris or were captured in imagery observations</p>	<ul style="list-style-type: none"> <li>• Risk Assessment indicates that given the proposed mitigations, observed debris poses no appreciable increase in risk.</li> <li>• Liftoff debris risk is currently characterized as infrequent, catastrophic due to significant uncertainties in controls and significant limitations in analysis.</li> <li>• Debris release mitigated for identified potential sources of critical debris by removal of abandoned hardware, performing repairs, and adding inspections for system level components (e.g. removal of 95' light fixture, and all bulk head plate handles; replacing all GVA hood access door hinge bolts; and added inspection of light fixtures and bolts for gauge face bezels). Ongoing mitigations include FOD awareness, attrition-based hardware removal, routine inspections and monitoring for facility corrosion.</li> </ul> <p>• <b>Status - Dispositioned</b></p>



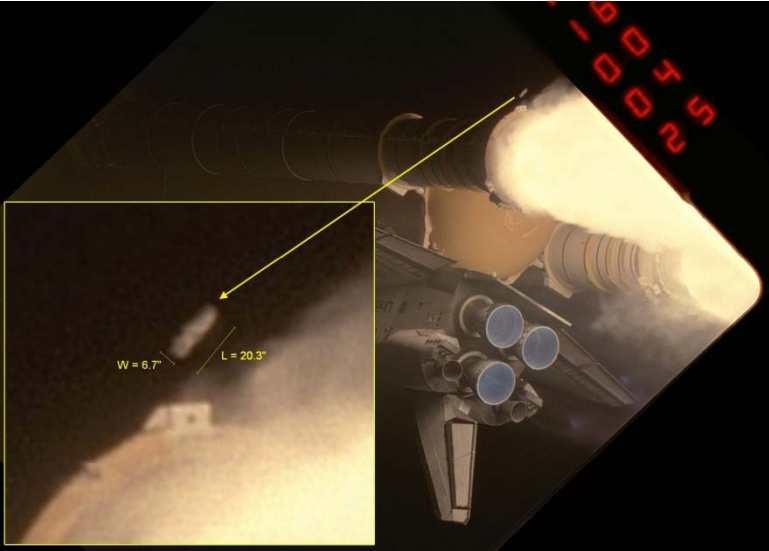
# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<ul style="list-style-type: none"> <li>▪ <b><u>STS-128-I-004: ET TPS Loss On LH2 Intertank Flange Near Starboard Bipod at ~Xt 1123</u></b></li> <li>▪ Missing TPS Divot on the intertank flange, near starboard jackpad at ~Xt 1123. Missing TPS is larger than risk baseline mass</li> </ul> 	<ul style="list-style-type: none"> <li>▪ Mass of TPS loss is .04 lbm, which exceeds NSTS-60559 allowable of .025 lbm for cryo-ingestion</li> <li>▪ It is likely that this loss released late in ASTT since a loss from this area was not observed in the LO2 feedline camera prior to SRB sep when lighting was favorable.</li> <li>▪ Testing, flight DFI data, and analysis demonstrate that ascent structural temperatures in the flange region do not support cryopumping/cryoingestion losses during ASTT.</li> <li>▪ The hazard report IDBR-01 risk classification of remote already captures the risk as a result of a 0.040 lbm loss.</li> <li>▪ The updated PRA based on flight history, which included the STS-128 loss, resulted in an overall risk calculation of 1 in 1,300. As a result of the PRA and existing hazard controls, the risk classification did not change, remaining at remote.</li> <li>▪ <b>Status - Dispositioned</b></li> </ul>



## Integrated In Flight Anomalies (IIFAs)

<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-128-I-005: Debris Observed Near RH SRB Aft Skirt HDP #4 Foot</u></b></p> <ul style="list-style-type: none"> <li>▪ Debris appears to be flexible fabric-like material, 68"x11", max of 2.29 lb</li> <li>▪ Origination point not observed in videos</li> </ul> 	<ul style="list-style-type: none"> <li>▪ SRB aft skirt viton coated nylon assemblies are the only credible source for this debris.</li> <li>▪ Viton is an expected debris source, but this debris exceeds the 0.3 lbm allowable.</li> <li>▪ Initial Debris Transport Analysis (DTA) indicates potential for Viton to impact to other elements.             <ul style="list-style-type: none"> <li>▪ Working to determine credible size and mass</li> </ul> </li> <li>▪ Imagery labs and SRB reviewing flight history to determine release frequency (one-time/common)</li> <li>▪ SRB assessing the maximum debris mass that could be liberated. This maximum debris mass will be used for DTA to determine impact locations and conditions for further Element assessment.</li> <li>▪ Potential FRR exception</li> <li>▪ <b>Status – Open</b></li> </ul>





# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-128-I-006: Debris Observed on SSME Hatband</u></b></p> <ul style="list-style-type: none"> <li>▪ Debris found on SSME #2 and #3 nozzles</li> <li>▪ No damage to nozzle</li> <li>▪ Not present pre-launch, observed in RPM imagery</li> </ul>	<ul style="list-style-type: none"> <li>▪ Debris on SSME #3 was evaluated by each Element to determine the potential source.</li> <li>▪ SRB is the only Element with a potential source of the SRB Viton coated Nylon thermal curtain barrier which is consistent with material lab findings.</li> <li>▪ Unknown source of contamination on SSME #2.</li> <li>▪ <b>Status - Open</b></li> </ul>





# Integrated In Flight Anomalies (IIFAs)

Presenter MS/Don Totton

Date 10/29/09

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<p align="center"><u>IFA Number : Title</u> Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<ul style="list-style-type: none"> <li>▪ <b><u>STS-127-I-002: Ice Internal and External to the LH2 T-0 Umbilical</u></b></li> <li>• Ice/Frost noted on the aft side of the LH2 T-0 umbilical during multiple launch attempts</li> </ul>	<ul style="list-style-type: none"> <li>• Ice/frost inside &amp; outside peripheral seal on LH2 T-0 Umbilical seen on 2 flights since STS-126</li> <li>• NSTS 08303 has no acceptable definition of Ice/frost buildup on Orbiter at this interface</li> <li>• Umbilical seals inspected &amp; verified integrity</li> <li>• The DTA results indicate credible transport to aft locations of orbiter downstream of T-0 umbilicals</li> <li>▪ Improvements to assist in detecting ice near umbilical or damage caused by ice liberation:             <ul style="list-style-type: none"> <li>▪ KSC Final Inspection Team (FIT) to use telescopic camera and heightened awareness during inspections</li> <li>▪ KSC IAT to expedite T-0 imagery review to reduce review time by ~1 day</li> <li>▪ JSC MOD implemented on-orbit inspections of aft fuselage and OMS pod area</li> </ul> </li> <li>▪ Ice internal to the T-0 umbilical classified as an unexplained anomaly (UA). External ice to be tracked through STS-128-I-002</li> <li>▪ <b>Status – Dispositioned</b></li> </ul>



# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<ul style="list-style-type: none"> <li>▪ <b><u>STS-127-I-003: LH2 Leak at ET Ground Umbilical Carrier Plate (GUCP)</u></b></li> <li>▪ During first two launch attempts of ET-131/STS-127, hydrogen leak detectors 23 and 25 located at the ET/GUCP interface observed leakage exceeding Launch Commit Criteria (LCC) Haz-09 limit of 40,000 ppm, resulting in launch scrubs</li> </ul>	<ul style="list-style-type: none"> <li>▪ Failure also seen on STS-119</li> <li>▪ Changes implemented as a result of STS-119 and STS-127 failures               <ul style="list-style-type: none"> <li>▪ Consistent method of flight seal inspection developed &amp; put into place at MAF &amp; KSC to ensure damaged seal could not be utilized</li> <li>▪ Concentricity tool &amp; tighter tolerance guide pins were developed to aid installation of the GUCP</li> <li>▪ Two design changes implemented: washers added to GUCP feet to prevent movement during external loading of hardware; and a 2-piece flight seal is to be used, which has greater resiliency &amp; provides additional capability to compensate for misalignment</li> </ul> </li> <li>▪ Safety risk is mitigated through Leak Detectors 23 and 25 that monitor this interface for any hydrogen leaks</li> <li>▪ Investigation team working to identify all credible failure scenarios and ET performing testing to assist in determining most probable cause</li> <li>▪ <b>Status - Dispositioned</b></li> </ul>



# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-127-I-004: ET TPS Loss at LO2 IFR 718</u></b></p> <ul style="list-style-type: none"> <li>• Divot seen on the LO2 Ice/Frost ramp (IFR) @ XT718 aft inboard corner. Estimated ~ 0.044 lbm</li> <li>• TPS debris was also observed from same ramp station on STS-125</li> </ul>	<p>After STS-127, SE&amp;I changed the risk classification from “Remote, Catastrophic” to “Infrequent, Catastrophic” due to uncertainties in physics modeling of release mechanisms</p> <ul style="list-style-type: none"> <li>• Based on the results of a TIM held on this topic, the following improvements were implemented             <ul style="list-style-type: none"> <li>• Increase level of NDE to include all horizontally poured LO2 IFRs</li> <li>• Audit design/process for improvements to reduce debris potential</li> </ul> </li> <li>• ET Project performed NDE of all STS-129/ET-133 horizontally poured IFRs with acceptable results</li> </ul> <p>▪ <b>Status - Dispositioned</b></p>



# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-127-I-005: ET Intertank TPS Foam Losses</u></b></p> <p>▪ At least 37 TPS losses from Intertank observed ~104 seconds MET. TPS losses occurred on +Z and -Z sides, many go to substrate. Largest mass is ~0.255 lbm, exceeding NSTS-60559 risk.</p>	<ul style="list-style-type: none"> <li>• ET-132/STS-128 TPS performed nominally</li> <li>• Adhesion testing complete for ET-133, with 48 in critical debris area. No suspect bond adhesions conditions identified</li> <li>• Uncertainties in PRA calculation, root cause of failure, and risk of damage to Orbiter resulted in increase in risk from remote to infrequent, remaining an accepted risk</li> <li>• Remainder of fleet to each receive 48 bond tests</li> <li>• <b>Status - Dispositioned</b></li> </ul>



# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u> Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-127-I-006: ET TPS Loss Outboard Section of the -Y Bipod Closeout</u></b></p> <p>• TPS liberated from outboard section of -Y bipod closeout observed ~126 seconds MET. Mass estimate is ~0.068 lbm. This exceeds the NSTS-60559 risk assessment mass of 0.025 lbm</p>	<ul style="list-style-type: none"> <li>• After STS-127, SE&amp;I performed integrated debris risk assessment to accept increase in divot mass potential</li> <li>• Closure of this IIFA is based on the following             <ul style="list-style-type: none"> <li>• The loss mechanism is known and well understood for this location. The release time is consistent with cryo-ingestion failure mechanism</li> <li>• Losses of this nature tend to release later in ASTT, reducing risk for significant damage to orbiter</li> <li>• Risk classification of remote did not change. The risk assessment performed with the 0.1 lbm maximum debris mass resulted in a change of overall risk to 1 in 1,250 for the -Y Bipod and 1 in 3,350 for the +Y Bipod.</li> </ul> </li> <li>• <b>Status - Dispositioned</b></li> </ul>



# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-127-I-007: Layer of MCC-1 Missing on Aft Skirt Acreage</u></b></p> <p>• During STS-127 Post-flight assessment of SRB hardware, one incident of Marshall Convergent Coating (MCC-1) loss on LH Aft Skirt and two incidences of MCC-1 loss on RH Aft Skirt) were discovered</p>	<ul style="list-style-type: none"> <li>• MCC-1 is not expected to liberate during ascent or post SRB Separation. It is classified as unexpected debris</li> <li>• All three liberations occurred in a recovery error overlap area, where spray application was interrupted and re-initiated.</li> <li>• Spray process interruptions due to mechanical problems or controlled parameter tolerance violations is most likely cause</li> <li>• For STS-129 through STS-131, the hardware does not have any overlap recovery areas and are not prone to the same failures as occurred on STS-127</li> <li>• <b>Status - Dispositioned</b></li> </ul>



# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪<b><u>STS-119-I-002: LH2 Leak at ET Ground Umbilical Carrier Plate (GUCP)</u></b></p> <p>▪On first launch attempt, during LH2 ET tank transition from fast fill to topping, leak detectors at the ET/GUCP indicated a leak exceeding 60,000ppm (LCC Haz-09 limit is 40,000ppm). This resulted in launch scrub</p>	<ul style="list-style-type: none"> <li>•There were three main corrective actions taken to minimize any opportunities to develop leaks           <ul style="list-style-type: none"> <li>•GUCP installation was enhanced by the use of higher tolerance guide pins and a newly developed concentricity tool to ensure proper alignment of the GUCP to the ETCA</li> <li>•A new two piece flight seal replaces the one piece seal. This new seal has greater resiliency and provides additional capability to compensate for misalignment and track any hardware movements</li> <li>•The GUCP pivot assemblies will now be centered on the pivot pins and then held in place by shims to preclude any lateral movement and side loading of the GUCP and damage to the flight seal</li> </ul> </li> <li>▪Investigation team working to identify all credible failure scenarios and ET performing testing to assist in determining most probable cause. This will be tracked through STS-127-I-003</li> <li>▪<b>Status - Dispositioned</b></li> </ul>





# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><u>IFA Number : Title</u></p> <p align="center">Description</p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<ul style="list-style-type: none"> <li>▪ <b><u>STS-119-I-004: Partial F4D Tyvek Release</u></b></li> <li>▪ F4D Tyvek cover did not release as designed. Parachute pocket appeared to tear off from rest of cover at ~5.3 sec MET, leaving majority of tyvek cover in place. Cover remnant confirmed to release at ~17.3 sec</li> </ul>	<ul style="list-style-type: none"> <li>▪ Remnants of ~10% of the Tyvek cover have been noted on previous flights, with mass up to ~5grams. This is the first occurrence of a large remnant, which did release early, at ~17.3 sec</li> <li>▪ The primary Orbiter areas of concern for Tyvek remnant impacts are: Windows, OMS Pod tiles, wing chine area tile &amp; the wing RCC leading edge. Debris Transport Analysis indicates a very low risk for Orbiter critical damage</li> <li>▪ Orbiter testing of 10g remnants was performed at impact speeds up to 1200 fps and Non-destructive evaluation (NDE) did not detect any damage to RCC from 10-gram Tyvek impacts</li> <li>▪ Closure of IIFA based on low likelihood that a Tyvek remnant can cause critical SSV damage. Complete Tyvek covers are expected to release very early during ascent and flight history supports that even large fragments release well below velocities required to cause SSV damage</li> <li>▪ <b>Status - Dispositioned</b></li> </ul>



# Integrated In Flight Anomalies (IIFAs)

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<p align="center"><b><u>IFA Number : Title</u></b></p> <p align="center"><b>Description</b></p>	<p align="center"><b>STS-129 Status and Rationale</b></p>
<p>▪ <b><u>STS-126-I-004: MPS GH2 Pressure Flow Control Valve open with no command</u></b></p> <p>▪ During 2nd stage, there was uncommanded drop in SSME #2 hydrogen outlet pressure. Data was indicative of flow control valve (FCV) #2 not fully cycling to high flow position. Valves #1 &amp; 3 compensated, no performance impact</p> <p>▪ Post-flight inspection revealed an FCV hardware failure, with approximately 1/4 of the engine #2 FCV's poppet head missing. This resulted in the pressure drop seen in flight data</p>	<p>▪ Poppet failures could cause ET venting causing a flammable atmosphere outside the ET, or poppet debris could puncture a line causing an explosive atmosphere in the aft compartment. The increase in risk due to these hazards has been documented in previous IIFA closures on this topic and accepted by the SSP</p> <p>▪ Improved eddy current techniques and acceptance criteria have enhanced the ability to recognize &amp; track growth in crack indications. This reduces the risk of a poppet piece liberating in one flight</p> <p>▪ STS-129 poppets inspected to ensure no indications present, using improved inspection capabilities which exceed allowable</p> <p>▪ Orbiter Project has open work in the Hazard Report to implement design controls to reduce likelihood for flow control valve (FCV) poppet failures</p> <p>▪ <b>Status - Dispositioned</b></p>



**Impact Probability Varies by Location around Perimeter of T-0 Umbilical Peripheral Seal**

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**Impact Probability (Components without Capability Models)**

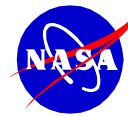
PRA Locations	OMS Stinger	Body Flap	Elevons
1	1/740	No Imp	No Imp
2	1/3,000	1/560K	No Imp
3	1/120K	1/3,100	1/27M
4	No Imp	1/1,200	1/9M
5	No Imp	1/1,100	1/8M
6	No Imp	1/3,300	No Imp
7	No Imp	1/12K	No Imp
8	No Imp	1/47K	No Imp
9	No Imp	1/460K	No Imp
10	No Imp	1/11M	No Imp
11	No Imp	No Imp	No Imp
12	No Imp	No Imp	No Imp
13	No Imp	No Imp	No Imp
14	1/5,700	No Imp	No Imp

**Worst Case Conditional Impact Probability is Isolated to Certain Release Locations**

**Most Locations Result in Low Impact Probability**

Range of Masses 0.02 to 0.1 (discretely selected at ~0.02 increment), Density 47 pcf  
 Masses released for all locations around perimeter of the LH2 T-0 Umbilical peripheral seal  
 1 Release per flight over the Mach range of MET 15-160 seconds (5 second intervals) randomly chosen from the release points inside each release group (simulation of 1000 flights)



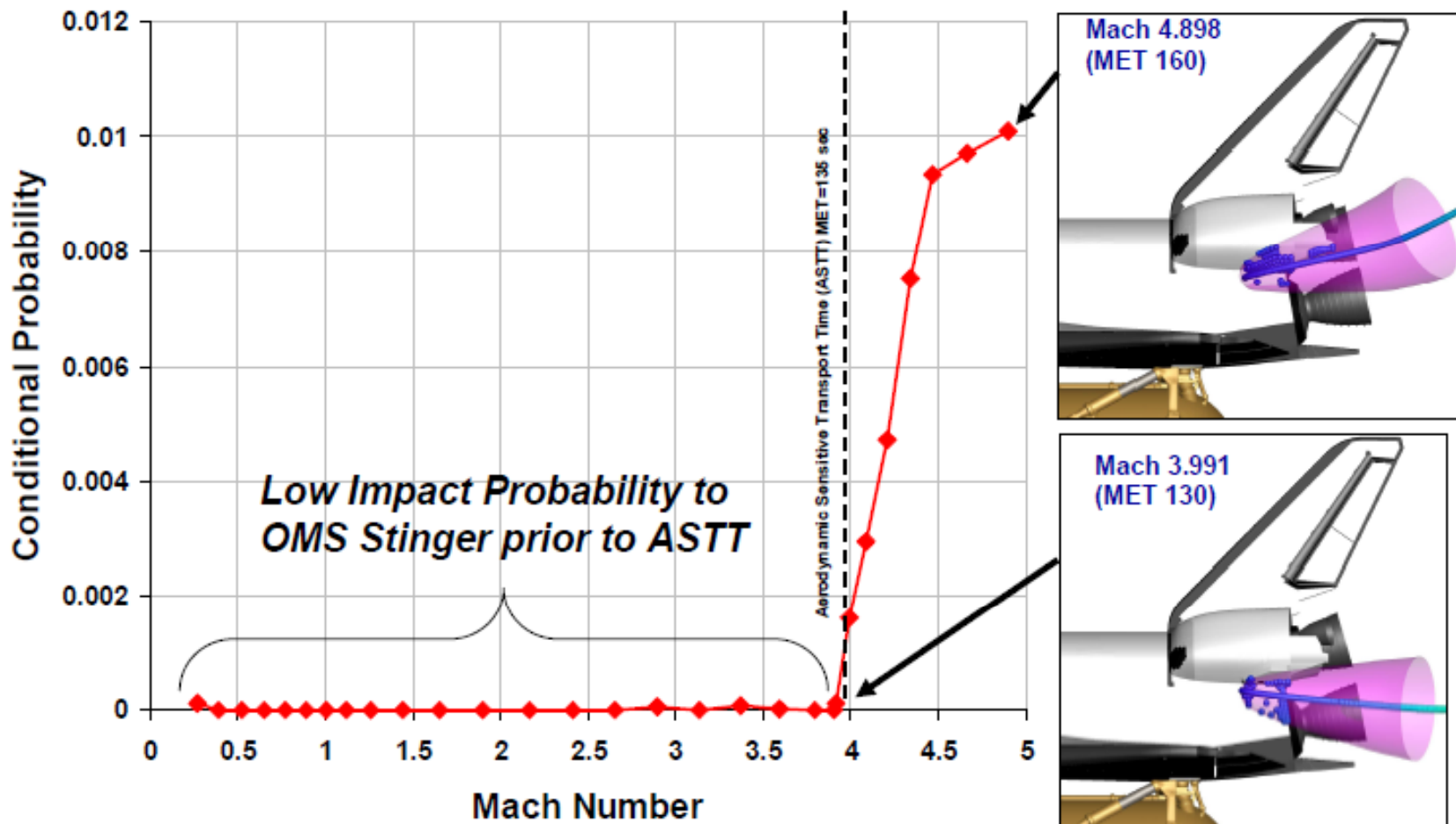


**T-0 Impact Probability of 1/740 to OMS Stinger is Driven by LOW Energy Impacts after ASTT**

Presenter MS/Don Totton

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*Low Impact Probability to OMS Stinger prior to ASTT*

Location 1, Mass = 0.01 lbm, thickness=0.75 in, 4-sigma cone





## ET LO2 IFR NDE ET-133 Summary

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- LO2 IFR NDE data was collected at both MAF and KSC for ET-133
- NDE at MAF resulted in 1 indication of a potential divot assessed with a mass > 0.01 lbm
  - Xt 760 Max total divot mass = 0.011 lbm
  - This potential divoter is a collection of several small void-like indications (spaced < 0.4 ") in the forward toe of the ramp, grouped together and characterized as one shallow slot-type void 2.2" x 0.4"
  - The ET position is this collection of voids would most likely release in multiple small divots and therefore should not be considered as one large divot.
- Two 0.008 lbm potential divots identified at the DPRCB 9/15/09 were from NDE performed at KSC
- DIG Recommendation to Fly as Is:
  - Potential 0.008 divots are below NDE Screening Mass; Repair to forward thin area of ramp could present a higher debris risk
  - Accept ET position on multiple small releases for identified 0.011 potential divot; conservative grouping of smaller voids
  - All Indications are within Process Control
  - Flight history of predicted divots vs losses is very conservative
    - NO losses to date from NDE indicated voids (I/T, LH2, LO2)
  - Maximum risk is well below but bounded by the 0.044 lbm divot previously assessed (PRA 1/480)
- ET-134 (LON Tank) had no (0) NDE indications > 0.01lbm



**ET TPS Loss LH2 IT Flange (STS-128-I-004)**

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- The calculated mass of the STS-128 loss was 0.040 lbm,
  - Exceeds the NSTS60559 Vol. 1 Risk Assessment Mass of 0.025 lbm
  - 0.025 lbm RAM selected as conservative trigger for IFA
- The NSTS60559 Vol. 2 debris cloud includes masses up to 0.041 lbm
- The 0.040 STS-128 loss is enveloped by the accepted risk documented in IDBR-01
- Plan to update NSTS 60559 to increase the Risk Assessment Mass to 0.041 lbm to be consistent with the IDBR-01 risk assessment
- Aerospace ran an updated flight history based analysis for the LH2 flange to include the STS-128 event
  - Frequency of release has dropped since we have only had one release in the half dozen or so flights since the original analysis
  - Including the STS-128 loss increases the risk from Overall PRA 1/1470 to 1/1300
- No change in current risk accepted in IDBR-01

Source	Basis	Tile	Special Tile	Tile Shear	RCC	Overall (1-P <sub>F</sub> )
LH <sub>2</sub> Tank-to-Intertank Flange-Cryogenic Failure Mode	Flight History Filtered to Limit Releases to 0.041 lbm, (0.5 Losses / Flight)	0.9998 1/5K	>0.9999 1/10K	>0.9999 1/10K	0.9994 1/1667	0.9992 1 / 1300





## Viton coated Nylon Debris Source

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- Two STS-128 debris events
  - IIFA STS-128-I-006 Debris Observed on SSME Hatband
  - NIRD 128-005 Debris Observed Near RH SRB Aft Skirt HDP #4 Foot
- DIG asked to assess increasing the SRB Risk Assessment Mass from 0.3 lbm to 2.29 lbm (Attempt to bound STS-128 observed loss by assuming full Viton coated panel)
- Preliminary DTA shows that transport may be possible through baseflow recirculation
  - Viton-coated nylon debris impacts were predicted to the SRB, RSRM, ET base and Orbiter Body Flap. (Recirculation threat exists from ~40 sec to 115 sec)
  - Only the most inboard SRB thermal curtain release locations (Panels 2 thru 5) result in Element impacts
  - Preliminary results indicate release velocities of  $\geq 50$  ft/sec required to impact elements and even higher release velocities to reach SSMEs.
  - Recirculation impact velocities are generally very low
- Discovered Elements never assessed the SRB Risk Assessment Mass (0.3 lbm) since it was previously believed there was no transport forward of the SRB skirt





## Viton coated Nylon Debris Source - Status

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- SRB has determined that the large debris seen on STS-128 was from Panels 19-22 and does not have transport to other elements
- Flight History Review (since RTF) by Imagery Labs have shown no indications of large SRB debris in recirculation area or moving toward the vehicle
  - Imagery noted Small pieces of debris which represent no threat to the vehicle but could account for SSME #3 debris deposit
- SRB preliminary analysis shows that the majority of Viton coated Nylon from the critical transport areas (Panels 2-5) is visibly consumed before 40 sec MET
  - Some remnants likely
  - DTA indicates No transport threat prior to 40 sec MET

### Current Status:

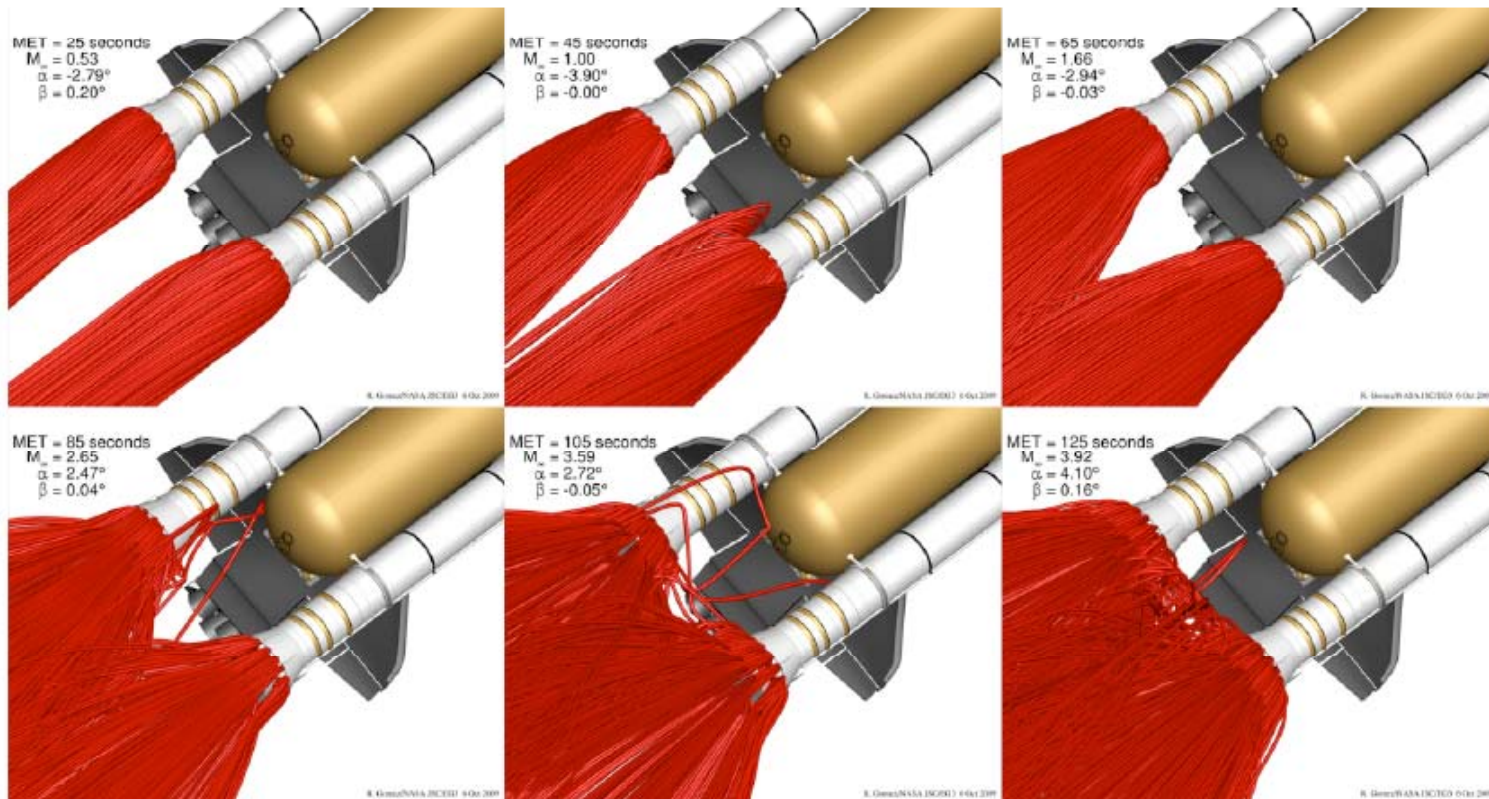
- Credible PRA is not possible since all data is based on conservative assumptions
  - Small debris deposit on SSME #3 remains only actual evidence
- Qualitative Assessment: SRB Debris transport to Orbiter/ET is possible but Highly Unlikely
  - ET & Orbiter have been provided impact angles and velocities and tasked to assess 0.1 lbm Viton/Nylon potential impacts as bounding case (largest credible debris from external thermal curtain ring)
  - RSRM assessing 0.1 lbm impacts from external and 0.6 lbm from inner ring
- Report to SICB 11-2-2009



## Viton Debris Transport to SSME Hatband

$15 \leq \text{MET} < 40$  follows the plume shape.  $40 \leq \text{MET} \leq 45$  debris is entrained in wake.  $75 \leq \text{MET}$  debris enters the recirculating base flow region.

(Results from 1296 traces shown)





## STS-129 Flight Software Summary

Presented USA/John Magley

Date 10/29/09

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- **Second flight of PASS and BFS Operational Increment 34 (OI-34) and MEDS Integrated Display Processor (IDP) / Multifunction Display Unit Function (MDUF) combination (VI 7.00/6.00)**
  - No logic changes from the STS-128 software system
  - PASS I-Load selection has activated the previously unused variable delay function for on-orbit Alt Mode flight control
    - Improves flight control performance when using Alt Mode for Shuttle control of the mated stack
- **Third flight of MAGRS-3S Link 613-9966-008 GPS Flight Software**
  - No changes from STS-128 software



## FSW Readiness Summary

Presented	USA/John Magley	
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- **Integrated Avionics Verification (IAV) is complete**
  - **A total of 14 cases were executed and analyzed in support of STS-129**
    - Included testing of full flight system (PASS/BFS STS-129/OI-34 with flight-specific I-Loads; MEDS VI 7.00/6.00 (IDP/MDUF); MAGRS-3S Link 8; and SSME AD08/DA05 software)
- **SAIL facility will be in a condition of readiness for mission support**
- **Formal Software Readiness Review (SRR) was conducted on 10/08/09**
  - **No known constraints**
- **With the completion of standard open work, FSW will be ready to support STS-129**



## Launch On Need (LON) Status

Presented USA/John Magley

Date 10/29/09

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- **In the event of call-up, the STS-130 flight software products would be flown on OV-105**
  - OI-34 STS-130 Base Load and associated products
  - Flight specific I-Load patches for STS-130 (full payload bay)
  - OI-34 compatible MEDS IDP and MDUF software (VI 7.01/6.00)
  - MAGRS-3S Link 8
- **Completion of the development and verification of flight-specific FSW products for STS-130 will be performed in time to support the 02/04/10 target launch date**
- **Formal Software Readiness Review to be conducted after call-up**



## Payload and General Support Computer Readiness – STS-129

Presenter	MS/Don Totton	
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- **Hardware and Software Summary**

- **STS-129 will be the sixteenth flight of the IBM ThinkPad A31p PGSC**
  - Six PGSC units (None currently planned for ISS transfer)
  - New software
    - No New Software
  - Tenth flight of the A31p Docking Station (OCA and WinDecom)
  - Eighth flight of Netgear Wireless Access Point.
    - Note: No network issues observed during STS-128
- **OCA 48 Mbs High Data Rate impaired during STS-128**
  - Problem due to DTV-MUX switch misconfig that will be highlighted in training

- **PGSC Milestones**







**SPACE SHUTTLE PROGRAM**  
**Space Shuttle Systems Engineering and Integration (SE&I)**  
NASA Johnson Space Center, Houston, Texas



Pre-decisional. Internal Use Only.

**STS-129 Non Standard Open Work**

Presenter **MS/Don Totton**

Date **10/29/09**

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	<b>ECD</b>
<b>Systems Safety</b>	
-Approval of CR S050425JN, IDBR-01, external debris impact to SSV	<b>10/28/09</b>
-Approval of CR S050425JP, IMPS-01, contamination in MPS H2 system and IMPS-05, Overpressurization of the Integrated MPS Hydrogen System	<b>10/28/09</b>
-STS-128-I-005, debris observed near RH SRB aft skirt HDP #4 foot	<b>11/03/09</b>



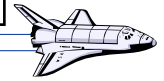


## Alternate/Dissenting Opinions

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- **Alternate/dissenting opinions were actively solicited at the SE&I STS-129 Pre-FRR.**
  - No dissenting opinions were identified.

Presenter: <b>M. Dunham</b>	
Date: <b>Oct 27, 2009</b>	Page: <b>64</b>



## BACKUP



# MEI Acoustic Impact on Subsystems

Presenter: <b>M. Dunham</b>	
Date: <b>Oct 27, 2009</b>	Page: <b>65</b>



## Component items that require DETAILED EVALUATION

<b>Component Name</b>	<b>Subsystem</b>
RCS Stinger - General	OMS/RCS

## Component items still IN WORK

<b>Component Name</b>	<b>Subsystem</b>
Hydraulic Lines - Generic	Hydraulics
Radiator Jumper Hose between Panels 3 & 4	ATCS
Radiator Jumper Hose between Panels 2 & 3 (Panel 3 to U-tube)	ATCS
Radiator Jumper Hose between Panels 2 & 3 (U-tube to panel 2)	ATCS
V070-415413 - LH2 Prepressurization System	MPS
V070-415101 - MPS GN2 SSME Purge Port	MPS
V070-415706 - LO2 Fill and Drain System	MPS
MC282-0082-0010 Helium (He) Supply Tank TK11	MPS



# STR Inspection History

Presenter: M. Dunham	
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- V30JD0.050, V30JH0.050 OMRS – LARCS/RARCS Fwd Blkhd Detailed Int. Insp. (Attach Fittings)
  - Performed at OMDP, prior to RTF, on all pods (2003-2005)
  - OV-103: 7 flights since RTF
  - OV-104: 4 flights since RTF
  - OV-105: 4 flights since RTF
- Helium Tank Access Door Modification completed on all Pods prior to or during OMDP:
  - Crack found in helium tank access door/panel upper corner
  - Conclusion from analysis was that pre-existing flaw had to exist
  - Risk acceptance: Based on adequate mission life remaining for cracks below the “field detectable” crack size of 0.50” in length
  - Inspections with higher sensitivity for crack formation

# Sequence of Disassembly Events

Presenter: M. Dunham	
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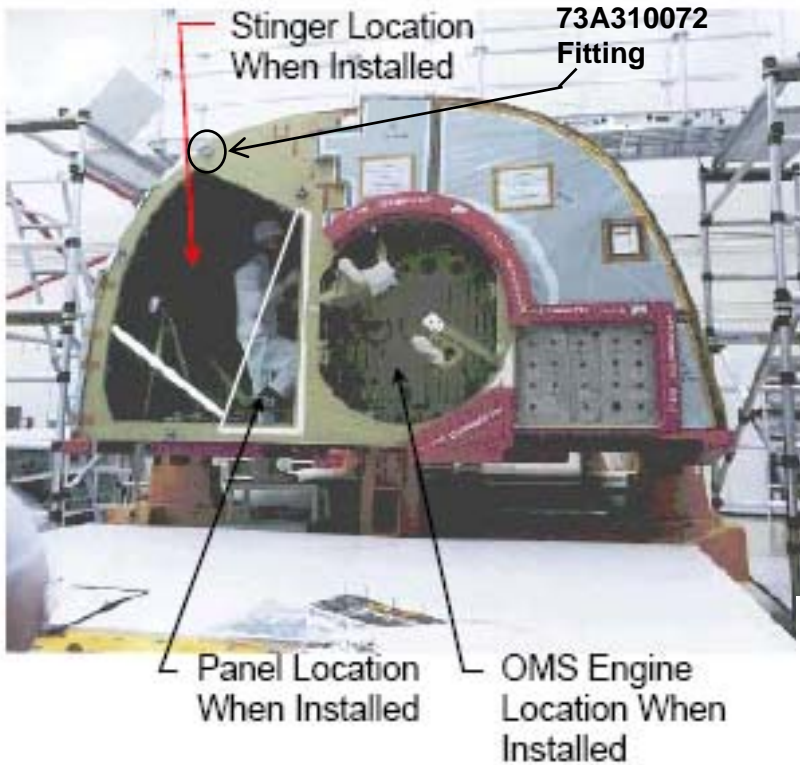
Tasks to Remove and Re-install RCS Stinger (Top-level): Approx. 12 months total

1. Drain crossfeed line
2. Disconnect prop lines and electrical connections
3. Remove pod and send to HMF
4. Drain all 5 RCS manifolds
5. Remove all RCS thrusters (preventative maintenance flushing then required)
6. Cut 10 prop lines between pod and RCS stinger. Removal of some RCS stinger structural braces most likely required.
7. Cut purge line between pod and RCS stinger.
8. Disconnect electrical connectors at stinger/pod interface panel
9. Remove 4 attach pins, then remove RCS stinger (possible TPS impacts?) -Stinger holding fixture/cradle required.
- 10. Perform NDE inspections on attach fitting (At ~2-3 months into timeline)**
11. Install RCS stinger onto pod (TPS impacts?)
12. Re-align/weld 10 prop lines (design/fab of alignment tool required)
13. Perform inspection/leak test of welds
14. Connect purge line and electrical connections
15. Install RCS thrusters (spares or flushed ones)
16. Perform TVCs and other retests (thruster/heater electrical checks)
17. Send pod to OPF and install on orbiter
18. Connect crossfeed and electrical connections
19. Perform pod installation retests
20. Reinstall TPS components

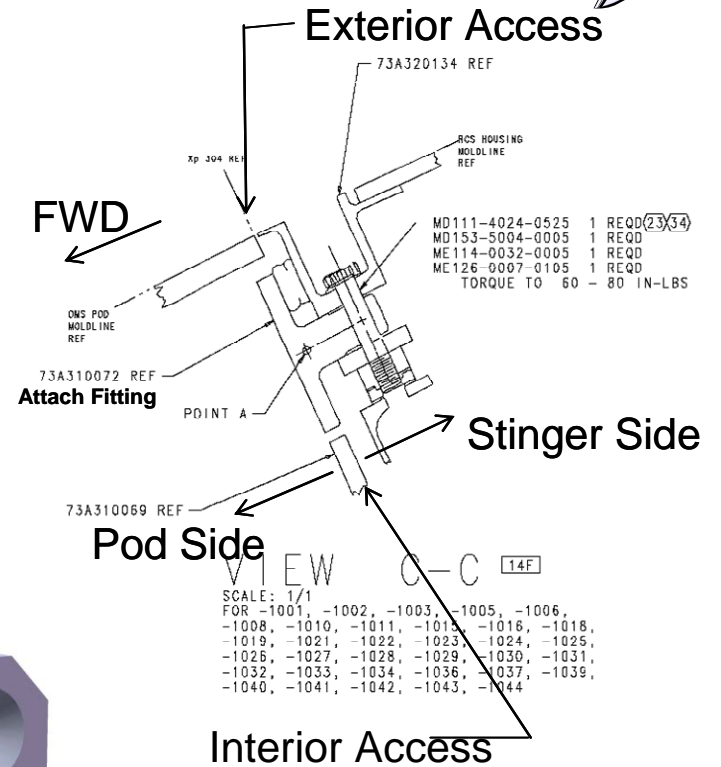


# Attach Point Location & Access

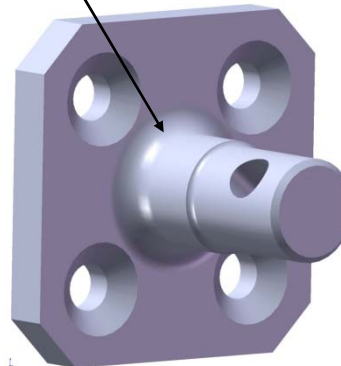
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View looking Forward



Crack initiation expected at part base



P/N 73A310072 Detail, Titanium 6AL-4V



# Pod Effective Flights

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- OMS Pod effective flights (Including Pad Aborts and FRFs):
  - LP01 (OV-103) - 44 (40 missions + 2 FRFs + 2 Pad Aborts) – **Fleet Leader**
  - LP03 (OV-105) - 38 (34 missions + 3 FRFs + 1 Pad Abort)
  - LP04 (OV-104) - 32 (30 missions + 1 FRF + 1 Pad Abort)
  - RP01 (OV-104) - 41 (37 missions + 3 FRFs + 1 Pad Abort)
  - RP03 (OV-103) - 42 (38 missions + 2 FRFs + 2 Pad Aborts)
  - RP04 (OV-105) - 32 (30 missions + 1 FRF + 1 Pad Abort)

- Borescope tools available:

<u>Borescope</u>	<u>Arc</u>	<u>Area for the articulation</u>
2.4 mm	90	¾ inch
4 mm	135	1.5 inches
6 mm	90	2.0 inches



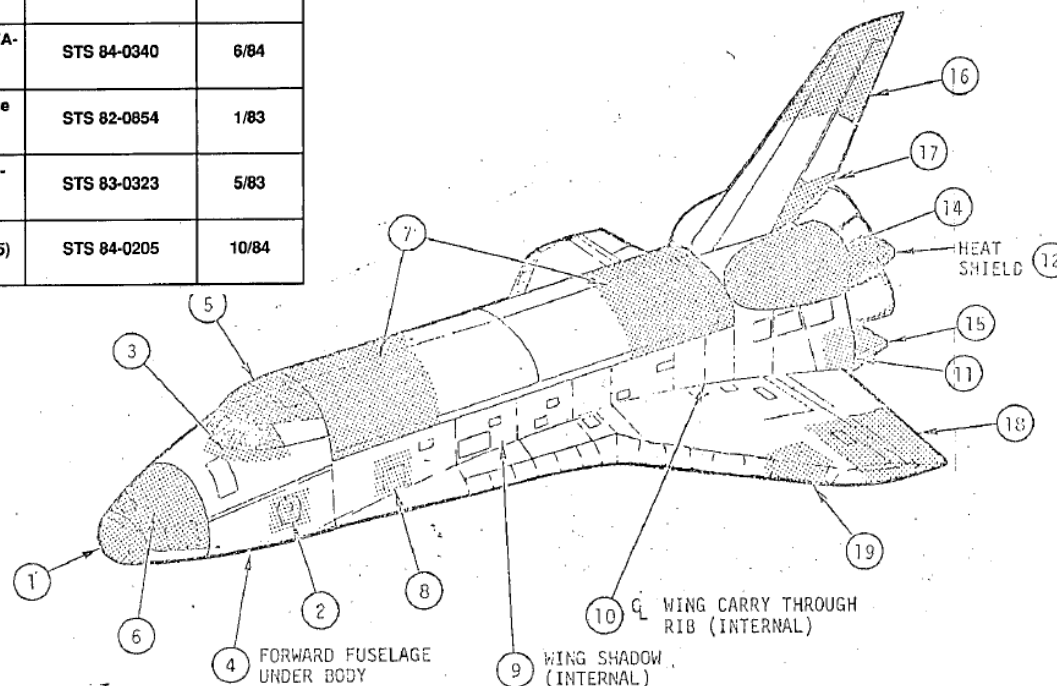


# Primary Structure Impacts of MEI Updates



## Acoustic Tests Performed on Orbiter Vehicle

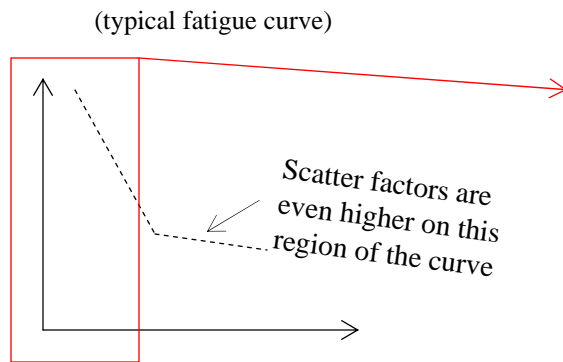
Acoustic Test Article	EAR Number	Cover Date	Acoustic Test Article	EAR Number	Cover Date
Nose Cap (FFA-01 and T5)	SOD 80-0284 (A)	9/80 (12/81)	Base Heat Shield (AFA-12)	STS 9000114	2/90
Wing Leading Edge (WA-19)	SOD 80-0348	9/80	Wing/Elevon (WA-18)	STS 81-0250 (A)	1/81 (8/82)
Mid Fuselage Sidewall (MFA-08)	SOD 80-0400	9/80	Base Heat Shield (Engine Seal)	STS 81-0116	1/81
Aft RCS Pod (AFA-25)	SOD 80-0427	10/80	Crew Hatch (FFA-25)	SOD 80-0485	11/81
Forward RCS (FFA-06)	SOD 80-0434	11/80	Mid Fuselage Bottom (DA-11A)	STS 81-0239 (A)	1/81 (10/82)
Wing Interior Panels (MFA-09 and -10)	SOD 80-0475	11/80	Fwd Fuselage Bottom (DI-19)	STS 81-0280 (-0542)	2/81 (8/81)
Half-span Body Flap (AFA-15)	SOD 80-0458 (A)	11/80 (6/84)	Aft Fuselage Sidewall (AFA-11)	STS 82-0662	10/82
Vertical Stabilizer - Top Half (VSA-16)	SOD 80-0466 (A)	11/80 (12/81)	Lower Aft Fuselage Panel (DA-10)	SSP/V&A-75-61	---
Aft PLBD (PBA 07-02)	SOD 80-0465	11/80	Fwd Fuselage Window/Seal (FFA-03)	STS 84-0340	6/84
Forward PLBD (PBA 07-1)	SOD 80-0476	12/80	Vertical Stabilizer Trailing Edge (VSA-17)	STS 82-0854	1/83
OMS Pod (AFA-26)	STS 81-0251 (A)	1/81 (5/82)	Wing Leading Edge-RCC (WA-19, T35)	STS 83-0323	5/83
Forward Fuselage Underbody (FFA-04)	SOD 80-0496 (A)	12/80 (2/83)	Forward Fuselage Top (FFA-05)	STS 84-0205	10/84



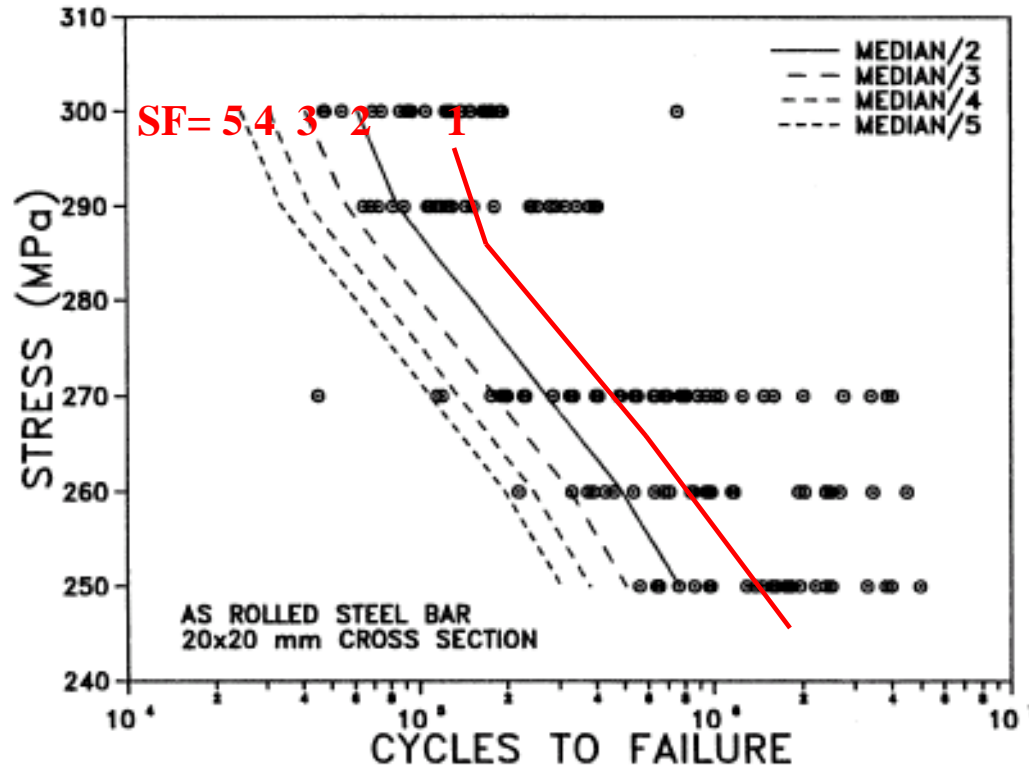
# Fatigue life scatter factor



- Scatter factor accounts for material variations only
- Fatigue analysis starts with assuming the “median” fatigue curve for a given material and applies a scatter factor (SF) to bound lower extreme from the median
- The data below represent a controlled test environment with minimal variation between coupons



**Key Risk:**  
Reducing SF means moving the fatigue curve rightward into the dataset for which failures are increasingly expected



Note: each specimen above is from the same material lot

# Primary Structure Impacts of MEI Updates

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- **MEI acoustics impacts to structure are limited to life, not margin**
- **Acoustic fatigue capability was determined by a series of tests combined with fatigue analysis and flight data**
- **Besides MEI, there are acoustics during liftoff (T+0 to T+6 sec) and during ascent HighQ**
  - These events have much longer duration than MEI
  - In the forward portion of the vehicle, HighQ acoustics have higher magnitude than MEI
    - MEI increases for PBD and fuselage forward of Xo940 are good by comparison to their HighQ acoustic environments
- **Reduction of life requirement to 50 missions will provide some relief**
- **Critical parts will be assessed against increased stress levels**
  - Stress from RMS pressure increase over 20hz to 300hz (range of primary structure strain response) will be used
  - Fatigue analysis will be assessed against the RMS stress increase



# MEI Acoustic Life Analysis Screening

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- Magnitude of RMS stress increases is proportional to increase in RMS pressure between 20hz and 300hz
- Lower magnitude increases (<40%) can be assessed by “inverse power law”
  - Ref section 7.1.1, NASA-HDBK-7005, “Dynamic Environmental Criteria”
  - $n_{eq} = n_o (\sigma_{update}/\sigma_o)^4$

## Comparison of RMS Pressures Across All Acoustic Regimes Including MEI Update

Location	MEI (adj)	MEI	LO	Aero (Nom)	Aero (DL)	MEI Ratio
Table1.1-15 Orbiter Cargo Door - Forward Xo 580-760, Zo > 440	0.10	0.08	0.08	0.30	0.38	121%
Table1.1-18 Mid Fuselage - Side X 580-940, Wing to Zo 440	0.12	0.12	0.15	0.16	0.28	107%
Table1.1-19 Mid Fuselage - Side Xo 940-1307, Wing to Zo 440	0.33	0.19	0.15	0.12	0.23	176%
Table1.1-24 Rear Fuselage - Side Xo 1307-1540	0.35	0.28	0.20	0.13	0.20	126%
Table1.1-32 Orbiter Heat Shield	1.16	0.80	0.24	0.17	0.21	146%
Table1.1-33 Orbiter Tail Lower Section Zo 500-580, 250 Hz	0.88	0.21	0.12	0.09	0.26	421%
Table1.1-34 Orbiter Tail Mid Section Zo 580 - 780, 316 Hz	0.67	0.38	0.19	0.12	0.16	177%
Table1.1-36 Orbiter Body Flap - Top	0.56	0.51	0.20	0.17	0.21	110%
Table1.1-41 Orbiter Wing Inboard - Top Xo 900-1390	0.21	0.21	0.16	0.12	0.12	101%

## Estimated Life Reduction (from 100missions) Using Inverse Power Law

Fatigue Parameter b=4	Duration (sec per 100 mission)				RMS Pressure (Integrated 20 to 200hz)						Equivalent Damage*				Total Damage		Life (Missions)
	MEI	LO	Aero (Nom)	Aero (DL)	MEI (adj)	MEI	LO	Aero (Nom)	Aero (DL)	MEI (adj)	MEI	LO	Aero (Nom)	Aero (DL)	Original	Adjusted	
Table1.1-15 Orbiter Cargo Door - Forward Xo 580-760, Zo > 440	50	450	100	100	0.10	0.08	0.08	0.30	0.38	108	50	450	16673	44594	61767	61825	100
Table1.1-18 Mid Fuselage - Side X 580-940, Wing to Zo 440	50	450	100	86	0.12	0.12	0.15	0.16	0.28	65	50	1193	397	2875	4515	4530	100
Table1.1-19 Mid Fuselage - Side Xo 940-1307, Wing to Zo 440	50	450	600	140	0.33	0.19	0.15	0.12	0.23	481	50	173	86	316	625	1056	59*
Table1.1-24 Rear Fuselage - Side Xo 1307-1540	50	450	600	308	0.35	0.28	0.20	0.13	0.20	128	50	120	32	85	287	365	79
Table1.1-32 Orbiter Heat Shield	50	450	400	296	1.16	0.80	0.24	0.17	0.21	229	50	4	1	1	56	235	24
Table1.1-33 Orbiter Tail Lower Section Zo 500-580, 250 Hz	50	450	550	42	0.88	0.21	0.12	0.09	0.26	15732	50	50	17	105	222	15905	1* <sup>*</sup>
Table1.1-33 Orbiter Tail Lower Section Zo 500-580, 800 Hz	50	450	550	42	0.88	0.21	0.12	0.09	0.26	15732	50	50	17	105	222	15905	2*
Table1.1-34 Orbiter Tail Mid Section Zo 580 - 780, 316 Hz	50	450	525	200	0.67	0.38	0.19	0.12	0.16	488	50	27	6	6	89	526	17*
Table1.1-36 Orbiter Body Flap - Top	50	450	400	344	0.56	0.51	0.20	0.17	0.21	72	50	10	4	10	74	97	77
Table1.1-41 Orbiter Wing Inboard - Top Xo 900-1390	50	450	450	450	0.21	0.21	0.16	0.12	0.12	51	50	169	49	52	320	322	100

\* Life estimate not valid for load increase above 40%



# Primary Structure Impacts of MEI Updates – OMS/RCS Pods

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- **Max OMS/RCS Pod MEI acoustics increases proportional to 46% stress increase**
  - Pods split up into three zones – (1) fwd of aft bulkhead, (2) aft of aft bulkhead and outbd shell of RCS, and (3) aft closure and inbd shell of RCS
  - Zones 1 and 2 use aft fuselage sidewall environment – 25% increase for MEI
  - Zone 3 uses base heat shield environment – 42 % increase for MEI
- **Acoustic test article consisted of partial and full OMS/RCS pod structure**
- **Three parts exhibit life less than 50 missions for MEI increase**
  - All in zone 3 and primarily related to RCS-to-OMS interface components

Structure and Acoustic Fatigue Report(s)	Zone	Part #	Description	Matl & Kt	original analysis										1.25X stress zones 1&2		1.46X stress zone 3		notes	
					mean stress	rms stress	freq	MEI sion including SF=4 damage	LO damage	Aero (j) damage	Mech damage	Total damage	Mission Life	adjusted MEI stress	adjusted MEI cycles to fail	adjusted MEI damage	MEI adjusted mission life (D)			
OMS Pod and aft RCS (1) STS83-0473 & (2) STS84-0612 & (3) SSD93D0295	1	MD111-4020-06	I/F attach bolt @ joint 1	MP35 Kt=3	123.3	9.24	71.8	143.6	0.00079776	0.00128	0.00026	0.00001772	0.0023515	425	11.6	60000	0.00239333	253		
	1	V070-350200	I/F fitting rod end @ joint 12	A286 Kt=3	0	11.22	9.3	18.6	0.0002656	4.7E-05	1.85E-05	0.00E+00	9.24E-05	10818	14.0	3.00E+05	0.000062	7820		
	1	73A310152	I/F fitting @ joint 1	6Al4V Kt=1.92	0	8.97	61.9	123.8	0.0000024	1.2E-07	8E-08	0.00E+00	2.60E-06	384615	11.2	9.00E+06	1.3756E-05	71656		
	1	73A310153	I/F fitting @ joint 2	6Al4V Kt=1	0	12.16	42.2	84.4	0.00000008	0	0	0.00E+00	8.00E-08	12500000	15.2	5.00E+07	1.688E-06	592417		
	1	73A310155	I/F fitting @ joint 6	PH138MO Kt=1.98	0	13.56	81.7	163.4	0.00001256	0	0	0.00E+00	1.26E-05	79618	17.0	1.70E+06	9.6118E-05	10404		
	1	73A310160	I/F fitting @ joint 11	Inco718 Kt=1.5	0	8.25	83	166	0.00000008	0	0	0.00E+00	8.00E-08	12500000	10.3	1.00E+08	0.00000166	602410		
	1	73A310102	skin, graphite epoxy	GrEp Kt=1	0	2.5	47.5	95	0	0	0	0.00E+00	0.00E+00	infinite	3.1	infinite	0	infinite		
	1	73A310142	inbd longeron	2124T851 Kt=1	0	6.06	9.29	18.58	0.00000016	0	0	0.00E+00	1.60E-07	6250000	7.6	2.00E+07	9.29E-07	1076426		
	1	73A310145	outbd longeron	2124T851 Kt=1	0	7.5	71.8	143.6	0.00001596	1E-06	1.76E-07	8.80E-07	1.81E-05	55383	9.4	5.00E+06	0.00002872	32451		
	1	73A310297	splice, graphite epoxy frame to longeron	2124T851 Kt=2.45	0	9.49	71.8	143.6	0.00130544	0.00166	0.001696	1.29E-04	4.79E-03	209	11.9	3.50E+04	0.00410286	132		
	1	73A310107	trunnion bolt, rcs oxidizer tank	6Al4V Kt=2.33	0	2.75	70.8	141.6	0	0	0	0.00E+00	0.00E+00	infinite	3.4	infinite	0	infinite		
	1	73A310258	pin, cone fitting, rcs oxidizer tank	A286 Kt=1	0	1.72	70.8	141.6	0	0	0	0.00E+00	0.00E+00	infinite	2.2	infinite	0	infinite		
	1	73A310109	strut, rcs oxidizer tank	2124T851 Kt=3.2	0	4.09	57.1	114.2	0.00004964	1.7E-06	3.52E-07	0.00E+00	5.17E-05	19338	5.1	8.00E+05	0.00014275	6905		
	1	73A310116	support fitting, oms oxidizer tank (link2)	2124T851 Kt=4.75	0	2.64	38.7	77.4	0.00000086	1.8E-05	1.25E-05	0.00E+00	3.95E-05	25286	3.3	1.50E+06	0.0000516	12114	(k)	
	1	73A310116	support fitting pin, oms oxidizer tank (link1)(ref 3)	A286 Kt=1	0	48.18	29.8	59.54	0.00270728	0.00159	0.001571	2.94E-04	6.16E-03	162	60.2	4.00E+03	0.014885	55		
	2	73A310119	aft bkhd inbd corner (I/F 4)	2124T851 Kt=1.85	0	3.7	44.8	89.6	0.00000092	0	0	1.00E-06	1.92E-06	520833	4.6	6.00E+07	1.4933E-06	401700		
	2	73A310122	beam support oms oxidizer tank	2124T851 Kt=1	0	9.61	16	32.072	0.00001236	5.9E-06	6.93E-06	0.00E+00	2.52E-05	39668	12.0	5.50E+05	5.8313E-05	14053		
	2	73A310424	lower support fitting, oms helium tank	2124T851 Kt=3.2	0	8.22	64.8	129.5	0.0012952	0	0	0.00E+00	1.30E-03	772	10.3	4.50E+04	0.00287778	347		
	2	73A310213	yoke, rcs helium tank 1 (upper)	2124T851 Kt=1.8	9.16	9.16	47.7	95.3	0.00079432	5.4E-06	1.17E-07	0.00E+00	8.00E-04	1250	11.5	1.80E+04	0.00529444	189	(l)	
	2	73A320068	skin, graphite epoxy	GrEp Kt=1	0	3.8	203	406	0	0	0	0	0	infinite	4.8	6.00E+07	6.7667E-06	147783		
	OMS Pod and aft RCS (1) STS83-0473 & (2) STS84-0612 & (3) SSD93D0295	3	73A310162	I/F fitting @ joint 4	2124T851 Kt=2.47	0	1.6	44.9	89.8	0	0	0.00E+00	0.00E+00	infinite	2.3	infinite	0	infinite		
		3	73A310166	web, beam, aft floor truss	2124T851 Kt=1	0	1.48	74	148	0	0	0	0.00E+00	0.00E+00	infinite	2.2	infinite	0	infinite	
		3	73A310069	web, frame, aft closure	2124T851 Kt=1	0	1.14	109	217.4	0	0	0	0.00E+00	0.00E+00	infinite	1.7	infinite	0	infinite	
		3	73A310069	frame, aft closure (ref 3)	2124T851 Kt=1	0	7.87	59.8	119.64	0.000006	0	8.22E-08	0.00E+00	6.08E-06	164414	11.5	1.30E+06	9.2031E-05	10856	
		3	73A310070*	I/F fitting (762)	6Al4V Kt=1	0	28.98	95.1	190.2	0.00057636	1.4E-06	4.23E-06	0	0.000582	1718.238	42.3	1.10E+04	0.01729091	58	(n)
3		73A310071*	I/F fitting pin(764) (ref 3)	MP35 Kt=1	17	42.96	134	268.8	0.000168	7.3E-07	9.94E-08	0.0000165	0.0001853	5396	62.7	8.00E+03	0.0336	30	(o)	
3		73A310072	I/F fitting (761) (ref 3)	6Al4V Kt=2	0	28.49	102	204.6	0.00087064	0.00087	0.000312	2.67E-05	9.92E-03	101	41.6	2.00E+03	0.1023	10		
3		73A310345	I/F fitting (763)(ref 3)	Inco718 Kt=1	0	23.45	74.9	149.8	0.0001498	8.9E-06	0.000173	0.00E+00	3.32E-04	3011	34.2	1.20E+05	0.00124833	699	(m)	
3		73A310217	yoke, rcs helium tank 2 (lower)(ref 3)	2124T851 Kt=1.75	12.15	12.15	74.9	149.85	0.00535144	0.00031	1.76E-07	1.29E-04	5.79E-03	173	17.7	2.00E+03	0.074927	13	(l)	
3		73A320091	pitch up thruster skin	2124T851 Kt=1	0	1.432	300	600	0	0	0	0	0	infinite	2.1	infinite	0	infinite		
3	73A320099	channel, inbd pitch up deck	6Al4V Kt=1	0	0.333	364	728	0	0	0	0	0	infinite	0.5	infinite	0	infinite			
3	73A320134*	fwd bkhd frame, fitting 4 (761)	2124T851 Kt=1	0	6.5	95.1	190.2	2.38E-06	4.2E-05	0	0	4.478E-05	22333	9.5	3.00E+06	0.0000634	9452	(p)		

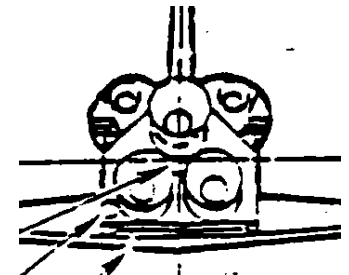


# Description of SSME IOP Environment

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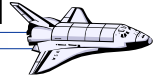
- **SSME IOP is a short duration, low frequency (<50hz) pressure spike**
  - Originating behind the exit plane of the SSMEs, it rapidly reduces as it moves forward, so it is a concern primarily of the Orbiter base region
    - Tail, Aft fuselage sidewall, OMS Pod and Inbd Elevon have smaller impacts
  - The update does NOT affect the primary structure margin or life
    - The SRB IOP has much greater effect on the overall Shuttle vehicle responses
      - Ref section 6.0 of SD74-SH-0082B, "Space Shuttle Systems Acoustic and Shock Data Book"
    - Orbiter Base Heat Shield (BHS) is the most sensitive primary structure to the local effects of IOP
      - Capability has been validated using strain gages on the two BHS support struts
      - BHS was analyzed to 2.2psi static pressure load which exceeds both original and updated values
- **The SSME IOP update affects TPS margins**
  - Pressures are low frequency transients that are analyzed as static
  - New environments in base region are approximately twice original design values
    - Original design environments are based on SD73-SH-0069-9, "Shuttle Design Loads Data Book, Volume 9 – Orbiter Thermal Protection System Loads" (aka "old Volume 9")



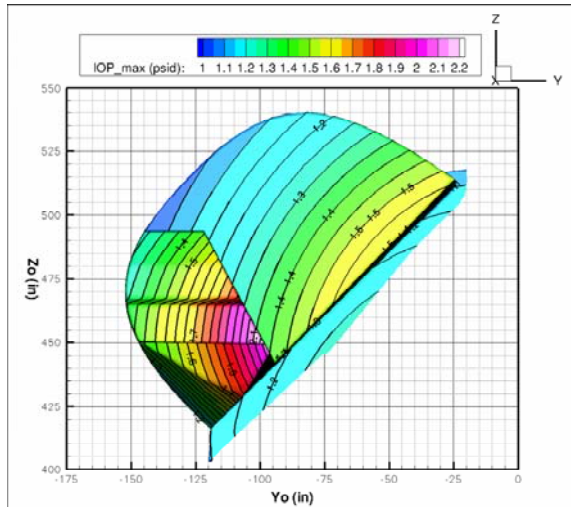


# SSME IOP Environment Update

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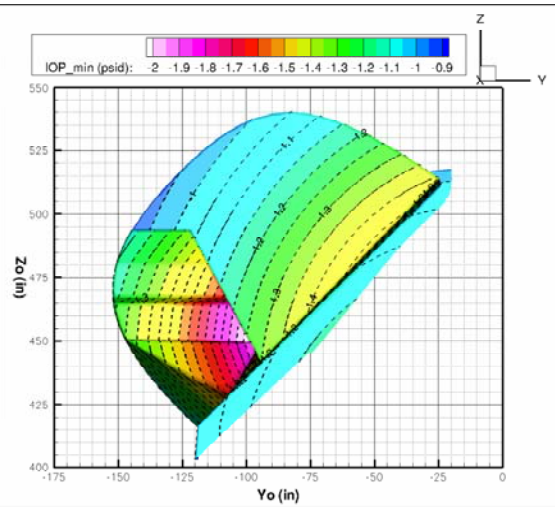


**Max Over-Pressure Peaks (Design)**



**Max Over-Pressure Peaks (Design)**

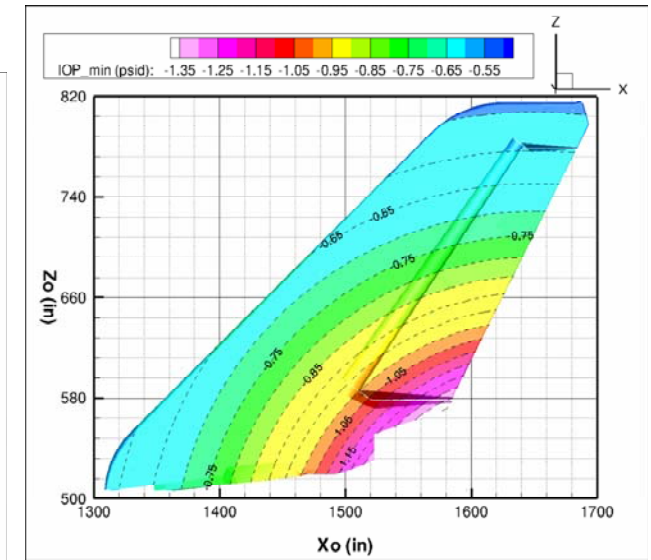
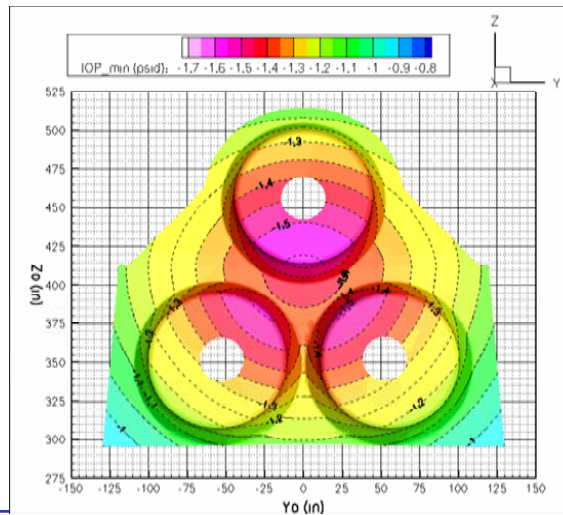
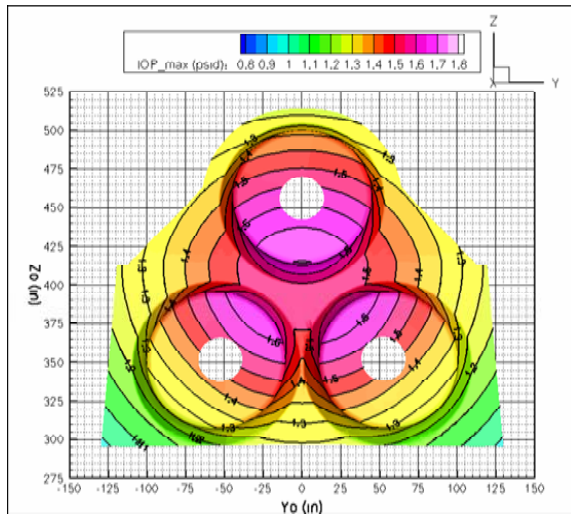
**Max Under-Pressure Peaks (Design)**



**Max Under-Pressure Peaks (Design)**

- **Base region values shown; other regions have lower values**
- **Current TPS design IOP values are less than 1psi**
- **Carrier panel tiles are much more sensitive to these pressure loads than acreage tiles**

**Max Under-Pressure Peaks (Design)**





# Description of MEI Acoustic Environment

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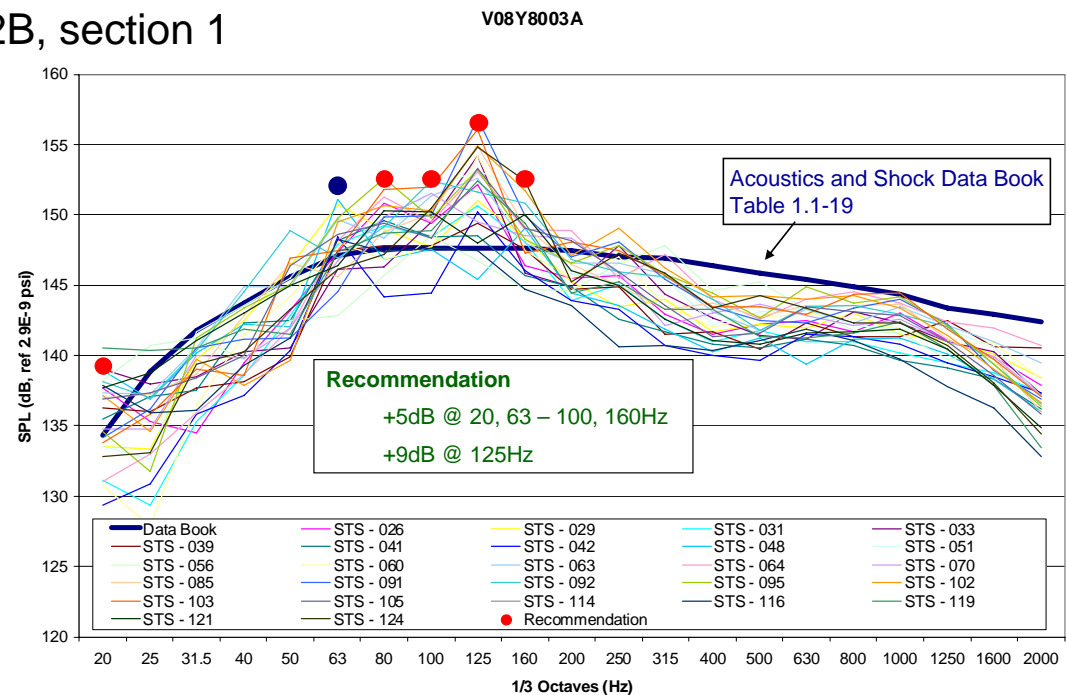
- **MEI acoustics is a short duration (0.5 sec) high frequency (20 – 2000hz) fluctuating pressure**
  - It is maximum in the base region, but does not attenuate as rapidly as SSME IOP
  - Described in 1/3 octave band sound pressure level (SPL) in terms of decibels (dB)
    - dB are log scale; +6dB is twice pressure magnitude; +12dB is four times, etc
    - Applied over zones or regions of Orbiter (e.g., Table 1.1-19 is the side fuselage region from Xo900 to Xo1307)
    - Specified in SD74-SH-0082B, section 1

- **Updates affect:**

- BHS
- OMS Pod/ARCS
- Tail
- Inbd Elevon
- Body Flap
- Upper fuselage aft of Xo940

- **Updates do not affect:**

- Wing & Outbd Elevon
- Upper fuselage fwd of Xo940
- Lower Fuselage



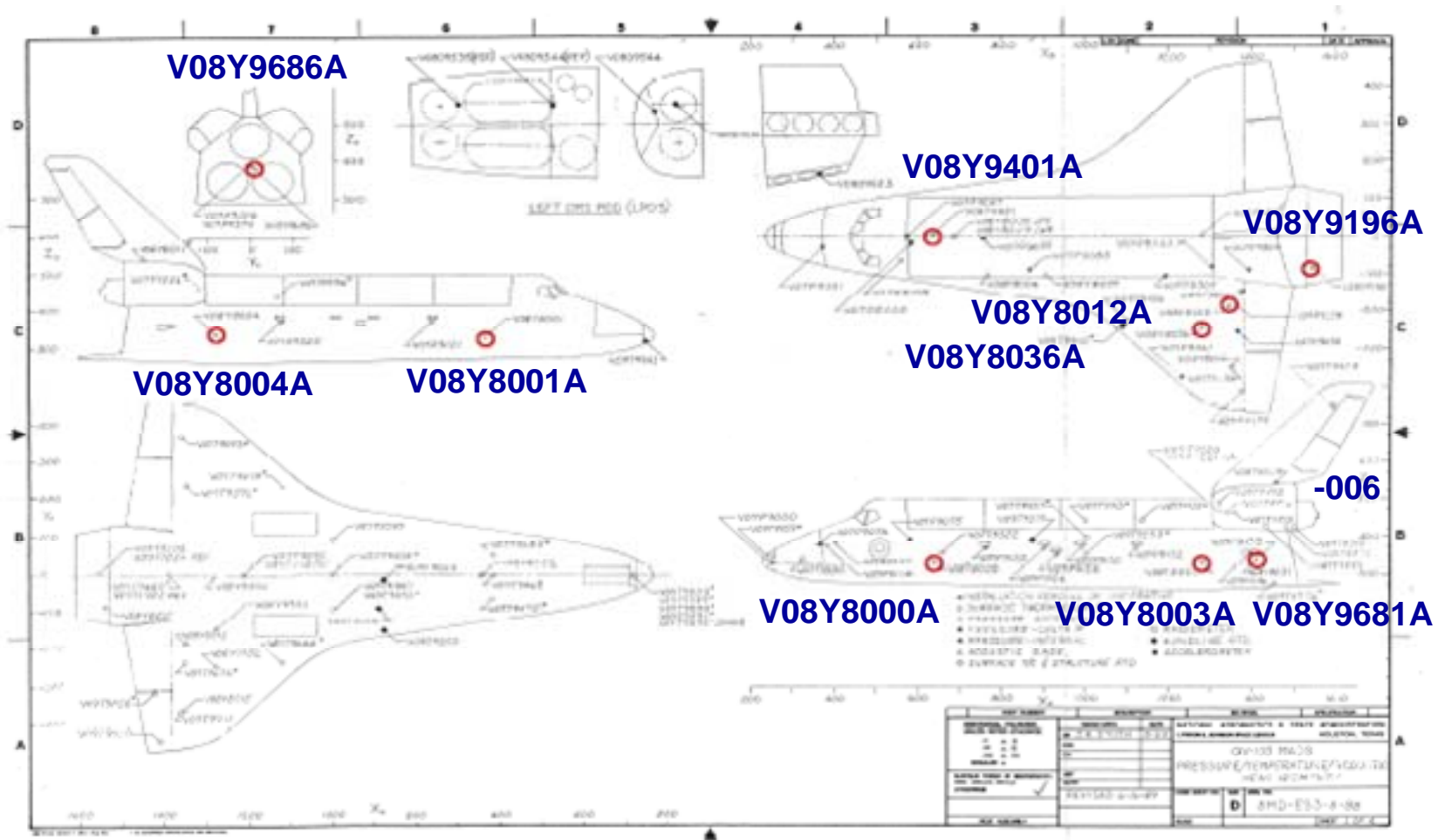
# Location of OV-103 Microphones Used to Develop MEI and IOP Environments

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## 11 Acoustic Sensors

8000A, 8001A, 8003A, 8004A, 8012A, 8036A, 9196A, 9401A, 9681A, 9686A, -006



# Mission Mix - 50% Mission Approach Option

from " OMS/RCS Base MEI Acoustics Mission Mix  
for Structural Mission Life Analysis" JALP 10/22/2009

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- **Approach similar to the Data Book's 50% mission approach for Ascent Aero-Acoustics may be developed for MEI Acoustics**
- **First, need to establish ground rule for maxi-max Design Limit**
  1. Maxi-max of all 14 flights produces 20-315 Hz RMS P = 1.474 psi
  2. Max of 12 flights produces 20-315 Hz RMS P = 1.211 psi
  3. 9/29/09 SICB Update Design Limit produces 20-315 Hz RMS P = 1.203 psi
- **Since #3 is the SICB approved update Design Limit, use 1.203 psi**
- **The approach translates into:**

SICB Update RMS P    **1.203**    psi    = 1% of mission mix

Flight	RMS P (psi)	Max RMS P (psi)
--------	-------------	-----------------

STS - 080	1.211	<b>1.211</b>
STS - 119	1.184	<b>1.184</b>
STS - 109	1.183	<b>1.183</b>
STS - 083	1.163	<b>1.163</b>
STS - 090	1.129	<b>1.129</b>
STS - 075	1.056	<b>1.056</b>
STS - 078	1.020	<b>1.020</b>
STS - 121	1.010	<b>1.010</b>
STS - 124	0.971	
STS - 116	0.966	
STS - 107	0.933	
STS - 094	0.887	
STS - 128	0.798	
STS - 093	0.757	

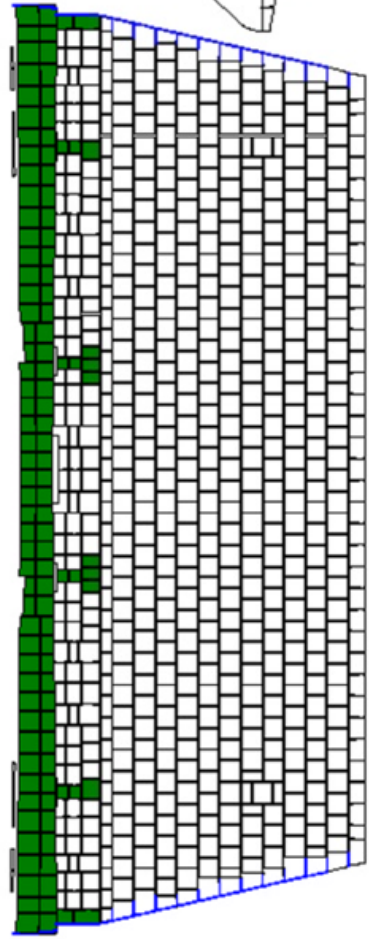
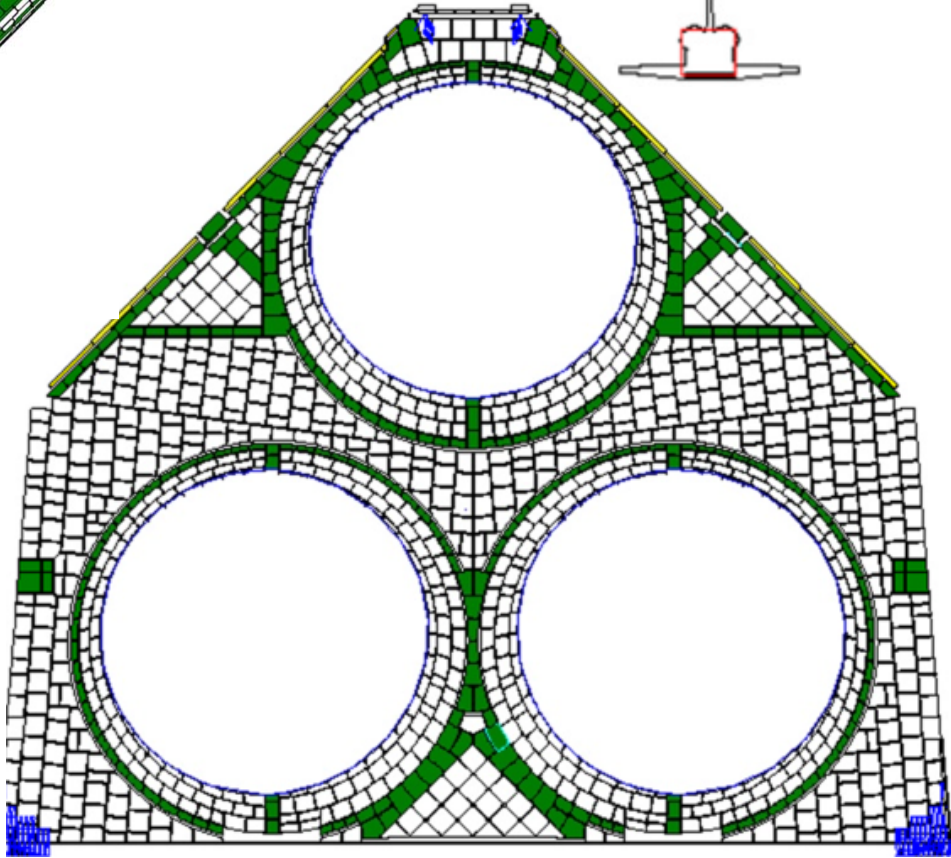
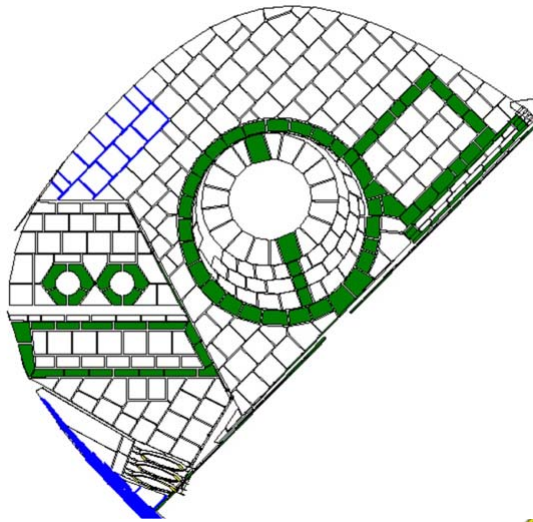
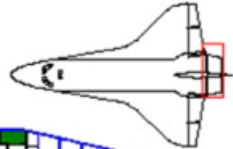
= 49% of mission mix  
(For 100 missions, each of these 7 RMS pressures will be applied to 7 missions)

= 50% of mission mix  
(Max. of bottom 50% of missions)



# Carrier Panel Locations

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There are additional critical RCS stinger tiles on the inbd and lower sides?

