



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



STS-128

Agency Flight Readiness Review

MS/Edward M. Burns
August 18, 2009



Pre-decisional. Internal Use Only.





Agenda

Presenter MS/Ed Burns

Date 08/18/09

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- **Systems Engineering & Integration**
 - Integrated In-flight Anomalies (IFAs)
 - Integrated Debris Risk Summary
 - Integrated Hazard Report Summary
 - Flight Software Readiness
 - Non-Standard Open Work Summary
 - Alternate/Dissenting Opinions
 - Certificate of Flight Readiness



Integrated In-flight Anomalies(IFAs) Summary

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- **STS-119-I-004 “Partial F4D Tyvek Release”**
 - Status - Dispositioned
- **STS-127-I-001 “Liftoff Debris”**
 - Status – Dispositioned
- **STS-127-I-002 “Ice Internal and External to the LH2 T-0 Umbilical”**
 - Status – Dispositioned
- **STS-127-I-003 “LH2 Leak at ET Ground Umbilical Carrier Plate (GUCP)”**
 - Status – Dispositioned
- **STS-127-I-004 “ET TPS Loss at LO2 IFR 718”**
 - Status – OPEN
- **STS-127-I-005 “ET Intertank TPS Foam Losses”**
 - Status – OPEN
- **STS-127-I-006 “ET TPS Loss Outboard Section of the –Y Bipod Closeout”**
 - Status – OPEN
- **STS-127-I-007 “Layer of MCC-1 Missing on Aft Skirt Acreage”**
 - Status – Dispositioned



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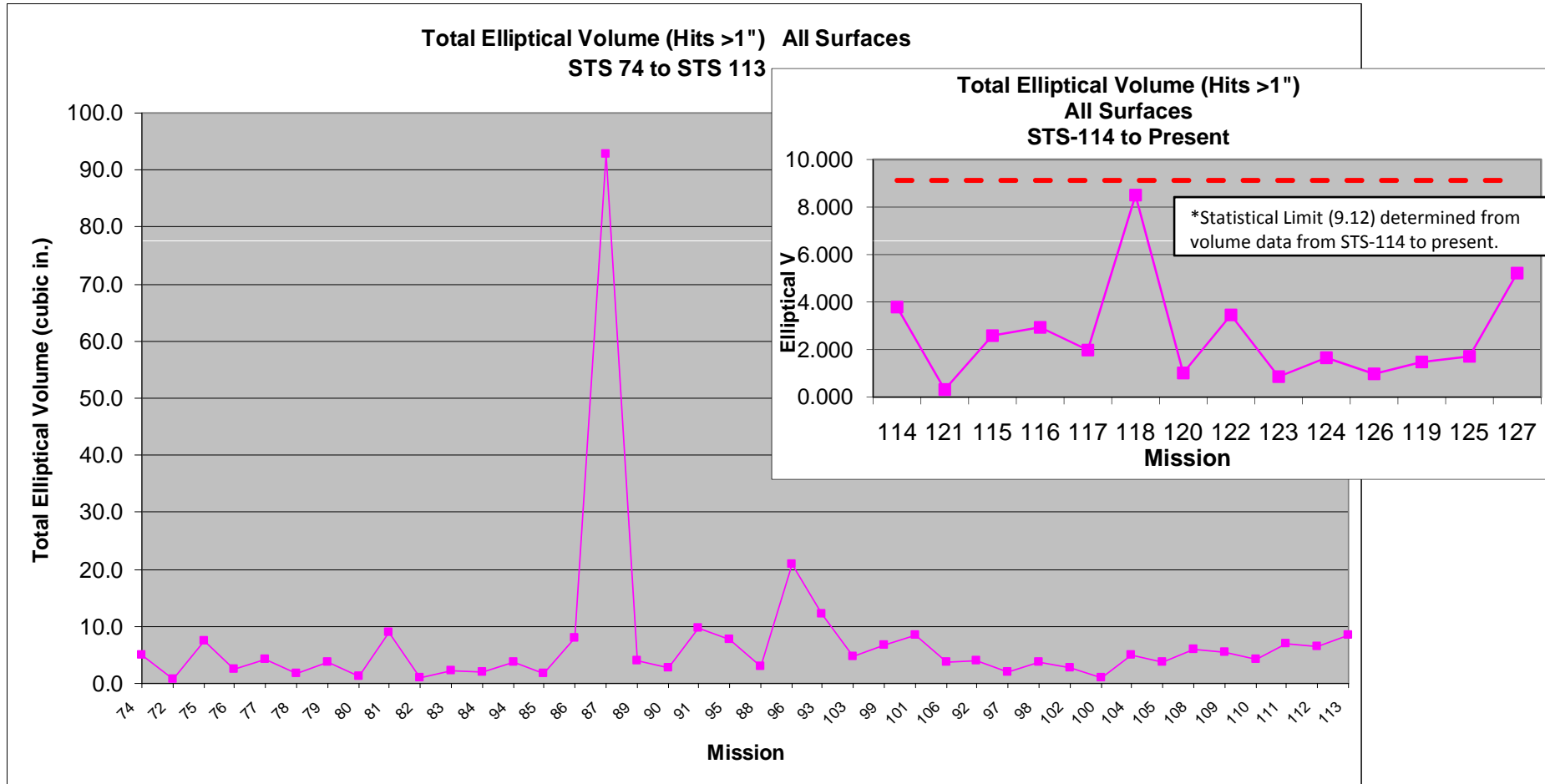
SSP Flight Readiness Review

Integrated Debris Risk Summary



STS-127 Debris Impacts > 1" All Surfaces compared to Historical

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Total Elliptical Volume STS-127

Total STS-127 Tile Damages = **107**
 Tile Damages Greater than 1" = **21**

5.752 in³
5.217 in³

Avg Tile Damages since RTF = **172**
 Avg Damages Greater than 1" = **32**





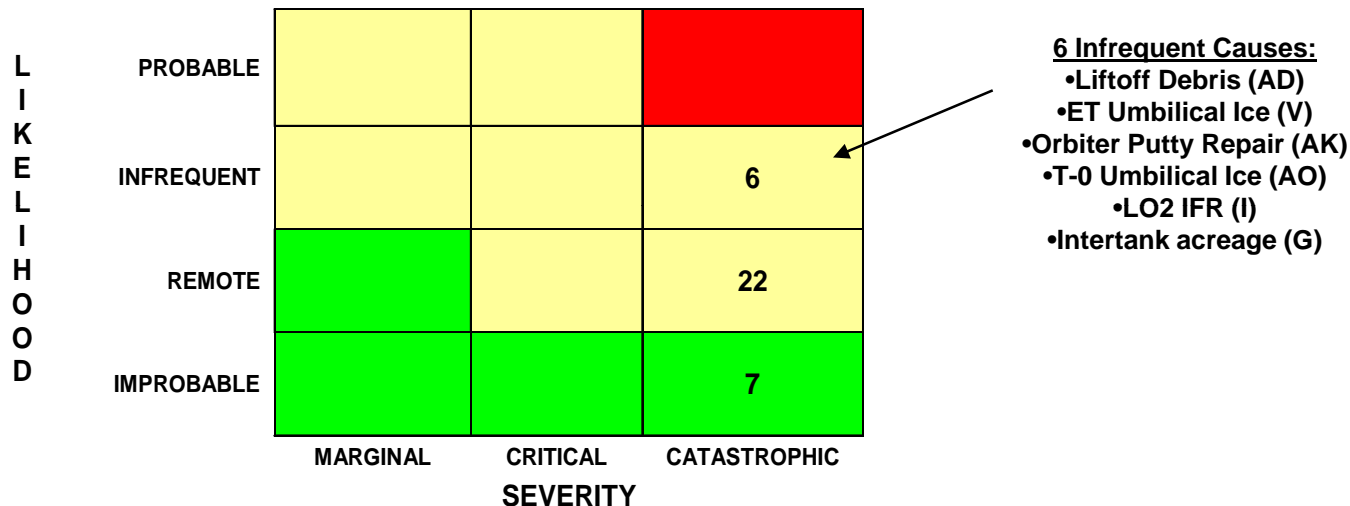
STS-128 Debris Risk Assessment Summary

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(HAZARD SEVERITY LEVEL AND LIKELIHOOD OF OCCURRENCE WITH CONTROLS IN PLACE)



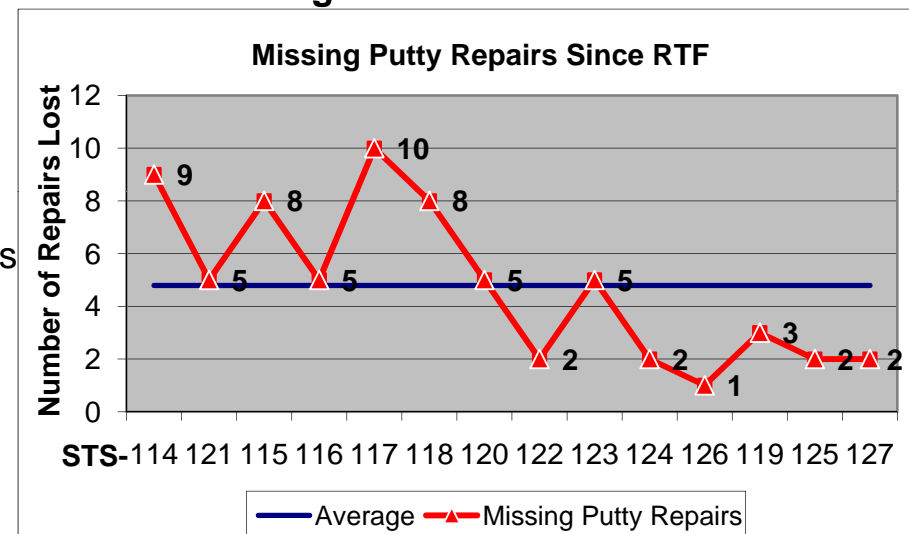
Four IDBR-01 debris risks remain Infrequent/Catastrophic, Intertank & LO2 IFR added for STS-128

- **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**: In progress testing may allow a future reduction to “Remote”.
- **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**: Interim closure for STS-125, STS-127, & STS-128 pending closure of IIFA-125-I-002
- **LOX IFR**: Change based on uncertainties associated with STS-125 & STS-127 718 IFR losses
- **ET Intertank Foam Loss**: Change to Infrequent Catastrophic



Putty Repair Debris Summary

- **TPS putty repairs have been added to the expected debris list & NSTS 60559**
- **Multiple CAR's have been initiated since RTF with the following corrective actions initiated**
 - Acceptance criteria modified
 - Tactile test added
 - Minimum gap inspections performed
 - Multiple vehicle inspections – Eng/QA
 - Process/tooling improved to add robustness
 - Training enhanced
 - Undercut improvement



- **Putty repair release rate is currently trending downward**
 - Masses are within historical distribution but losses still occurring
- **OPO/TPS PRT have taken additional risk reduction steps in critical areas**
 - Repair allowable filler volume has been reduced to limit putty repair masses
- **Tiles with large repairs are being removed in critical areas FWD of the RCC and windows**
- **Inspections continue and Tiles to be removed are ranked by size/location/repair type**
- **CHIT's will be initiated and a subset of tiles removed every flow until EOP**



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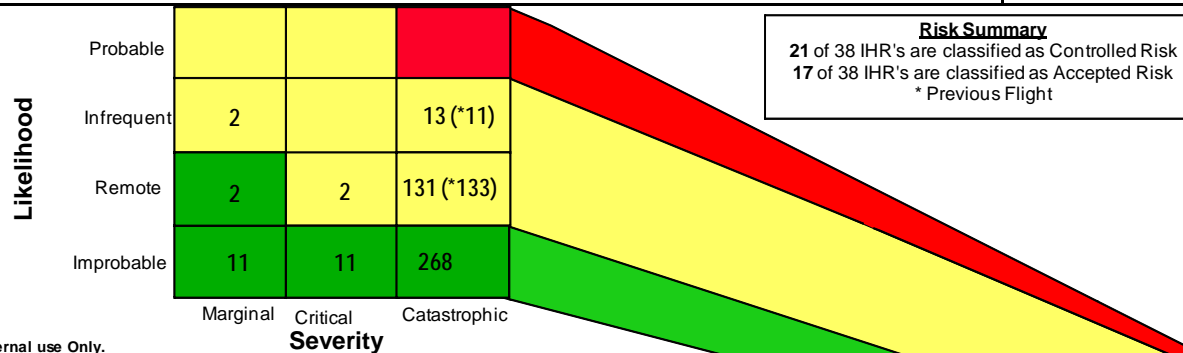
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Integrated Hazard Risk Matrix



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Hazard Report #	Integrated Hazard Titles	Controlled					Accepted Risk					probable-catastrophic			
		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
"Accepted Risk" Hazard Reports															
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					
Accepted Risk Distribution Totals		(see next page)					148	0	2	2	131	0	0	13	0

Notes: *: The previous flight risk numbers are in parenthesis to right, if different from upcoming mission





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STS-128

SSP Flight Readiness Review

MS4/Daryl Peltier
August 18,2009



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STS-128 FLIGHT SOFTWARE SUMMARY

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- **First 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 major new capabilities
 - Multiple maintenance and maintainability updates
 - Relieved memory space constraints to support any mandatory changes identified during program fly out
 - Eliminated several FSW user and op note conditions
 - Enhancements made to BFS HUD to make performance more similar to PASS HUD
 - Bodyflap warning message added to HUD
 - Runway overlay uses landing site table data for correct length
 - HUD high g limit (flashing NZ value) added
 - Decel command restored and is usable
 - One new PASS source update was applied to the STS-128 flight system
 - Film ET Camera (SCR 93262A) modified the umbilical well film camera activation to collect photo data at times during first stage
- **Second flight of MAGRS-3S Link 613-9966-008 GPS FSW**
 - No changes from STS-125 software



STS-128 FSW READINESS SUMMARY

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- **Integrated Avionics Verification (IAV) is complete**
 - A total of 53 test cases were performed in the Shuttle Avionics Integration Laboratory (SAIL) and analyzed in support of OI-34
 - A total of 8 cases were executed and analyzed in support of STS-128
 - Included testing of full flight system (PASS/BFS OI-34 and STS-128 changes; 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 07/16/09**
 - No known constraints
- **With the completion of planned open work, FSW will be ready to support STS-128 launch**



STS-128 Non-Standard Open Work Summary

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	Completion Date
System Safety <ul style="list-style-type: none"> - Disposition of STS-127-I-004, ET TPS loss at LO2 IFR 718 - Disposition of STS-127-I-005, ET intertank TPS foam losses - Disposition of STS-127-I-006, ET TPS loss outboard section Y-bipod closeout 	08/21/09 08/21/09 08/21/09
Imagery <ul style="list-style-type: none"> - Disposition of two new NIRD observations 	08/21/09



Alternate/Dissenting Opinions

Presenter **MS/Ed Burns**

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- **Alternate/dissenting opinions were actively solicited. The following dissenting opinions were identified:**

STS-128 Ice Frost Ramp (IFR) Issue

Name	Recommendation
Vince Reyes/SE&I Chief Safety Officer	No go. Flight Rational insufficient. Additional NDE needs to be performed on IFRs forward of the Xt 718 IFR(Xt 593, 634, 676)
Loraine Schafer/Manager, KSC Integration Office	No go. The IFR understanding is low. Good controls are not in place unless we also rely on the possible use of on orbit repair. The NDE has not ensured that a large piece of foam will not be lost.



**Alternate/Dissenting Opinions
 Continued**

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STS-128 Intertank Foam Loss Issue

Name	Recommendation
Vince Reyes/SE&I Chief Safety Officer	No Go. The current flight rationale for the STS-128 Intertank Foam loss issue is insufficient. Opinion is that plug pull data and results are insufficient to rationalize the data review that demonstrates the similarities between ET-131 and ET-132. Additional flight rationale is required or mitigation which could include tank swap.
Loraine Schafer/Manager, KSC Integration Office	No Go. Understanding is low. Plug pulls assume global random contamination if it exists at all, however there could be small isolated spots in areas not tested. In addition, there are lack of controls without acknowledging use of on orbit repair.
Helen McConnaughey/Manager, Propulsion Systems Engineering & Integration Office	No Go.



CoFR Endorsement

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The Space Shuttle Program, Systems Engineering and Integration Office's Flight Preparation Process Plan, documented in NSTS 08117, Requirements and Procedures for Certification of Flight Readiness have been satisfied. Required products and other responsibilities identified in NSTS 08117, paragraph 8.5.12 and Appendix M, have been or will be scheduled for completion. All technical functions and responsibilities are ready and the Systems Engineering and Integration Office is prepared to sign the Certificate of Flight Readiness for STS-128, pending completion of open work.

/s/Donald S. Noah

Donald S. Noah
Manager Systems Engineering and Integration Office



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Back-up charts



Integrated In-flight Anomalies(IFAs)

<p><u>IFA Number: Title</u> Description</p>	<p><i>STS-128 Status and Rationale</i></p>
<ul style="list-style-type: none"> ▪ <u>STS-127-I-001: Unexpected Debris/Expected Debris Exceeding Mass Allowable Prior to Pad Clearance (Liftoff Debris)</u> ▪ 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. 	<ul style="list-style-type: none"> ▪ Risk assessment indicates that given the proposed mitigations, observed debris poses no appreciable increase in risk. ▪ Liftoff debris risk is currently characterized as infrequent, catastrophic due to significant uncertainties in controls and significant limitations in analysis. ▪ 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 abandoned GN2 purge line, relocation of 95' light fixture, and inspection of electrical cabinet handles). Ongoing mitigations include FOD awareness, attrition-based hardware removal, routine inspections and monitoring for facility corrosion. ▪ Recommend updating NSTS 60559 to include Risk Assessment Masses for Expected Debris from Protective Blanket for 24' LH2 Vent Flex Hose. ▪ Disposition rationale presented at 8/07/09 SICB ▪ Status – Dispositioned



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Integrated In-flight Anomalies(IFAs)

IFA Number: <i>Title</i> Description	<i>STS-128 Status and Rationale</i>
<ul style="list-style-type: none"> ▪ <u>STS-127-I-002: Ice Internal and External to the LH2 T-0 Umbilical</u> ▪ During multiple launch attempts of STS-127 on 7/12/09, Final Inspection Team photos indicated slush build-up at one location along the outside edge of the peripheral seal on the lower aft side of the LH2 T-0 umbilical +Z side. The slush formation was estimated to be 4" long forward to aft, 2" wide and ¾" thick. ▪ A LCC waiver to ICE-01 was approved by the MMT prior to launch and the LCC violation was cleared. ▪ Other recent missions where ice has been observed is STS-126 and STS-125. 	<ul style="list-style-type: none"> ▪ As part of the IIFA investigation, the umbilical peripheral seal inspected and tested to verify integrity. ▪ The following inspections/improvements were added to assist in detecting ice near the umbilical or any damage caused by an ice liberation from the umbilical at launch: <ul style="list-style-type: none"> ▪ KSC Final Inspection Team (FIT) has enhanced umbilical plate inspection for ice formation ▪ KSC IAT to expedite T-0 imagery review to reduce review time by ~1 day ▪ JSC MOD implemented on-orbit inspections of aft fuselage and OMS pod area. ▪ STS-128/MLP-2 internal can seals will be inspected prior to T-0 mate and verified free of defects. ▪ Install an RTV "Water Diverter" ▪ Inspections have been performed to verify the FRSI is free of contaminants ▪ RTV sealant or a Teflon seal will be installed at the peripheral seal top splice plate, with KSC ERB approval, same as on STS-127, where a water leak path was discovered. ▪ Status – Dispositioned



IIFA STS-127-I-002 T-0 Umbilical Ice

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- **During STS-127 Launch countdown, the Final Inspection Team observed ice/frost on the outside LH2 T-0 Umbilical plate seal**
 - Possible violation of NSTS 08303 (No issue with Frost)
 - Waiver disposition presented by SE&I to support flight rationale
 - IIFA STS-126-I-002 (Internal Ice STS-126) was CLOSED and combined with T-0 external ice seen on STS-125 into IIFA STS-127-I-002
 - Post-launch inspection confirmed a Freon leak that may have contributed to ice formation
- **Orbiter is developing capability models for the aft region (OMS Pod sidewall, aft fuselage sidewall, upper body flap, etc)**
- **Debris team is working with Orbiter to develop T-0 Umbilical Allowables for external ice to support future mission Day-of-Launch (DOL) decisions**
- **Future plan to update NSTS 08303 with T-0 Ice allowable**
- **Interim closure signed for STS-128 using mitigations of enhanced inspections and sealant added to leak paths**



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Integrated In-flight Anomalies(IFAs)

<u>IFA Number: Title</u> Description	<i>STS-128 Status and Rationale</i>
<ul style="list-style-type: none"> ▪ <u>STS-127-I-003: LH2 Leak at ET Ground Umbilical Carrier Plate (GUCP)</u> ▪ During the first two launch attempts of ET-131/STS-127, hydrogen leak detectors 23 and 25 located at the ET/GUCP interface observed leakage exceeding the Launch Commit Criteria (LCC) Haz-09 limit of 40,000 ppm. In both cases the launch was scrubbed. 	<ul style="list-style-type: none"> ▪ Following the second scrub, an Investigation Team, developed a working theory that leakage occurred between the flight and ground sides of the quick disconnect assembly as a result of various factors including ET-131 carrier plate clocking, ET-131 hinge brackets clocked and offset, and potential for GUCP movement during assembly that combined to exceed the capability of the seal hardware. ▪ Hardware modifications and procedural changes after the second scrub resulted in a hardware assembly that minimized initial misalignment and reduced potential for movement during assembly. ▪ There were four ET cryo loadings after the changes (one tanking test and three launch attempts) during which no indications of hydrogen leakage were detected at the ET/GUCP interface. ▪ Status – Dispositioned



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Integrated In-flight Anomalies(IFAs)

IFA Number: <i>Title</i> Description	<i>STS-128 Status and Rationale</i>
<ul style="list-style-type: none"> ▪ <u>STS-127-I-004: ET TPS Loss at LO2 IFR 718</u> ▪ From umbilical well imagery, divot seen on the LO2 Ice/Frost ramp (IFR) @ XT718 aft inboard corner. Based on CATIA model representation the estimated mass is ~ 0.044 lbm. Time of release being investigated, however available imagery shows potential release forward of LO2 flange at ~ 126 seconds as most likely candidate. ▪ TPS debris was also observed from same ramp station on STS-125. 	<ul style="list-style-type: none"> ▪ An increase in liberated TPS mass and frequency from the LO2 IFR poses an increased risk for Orbiter damage. ▪ This debris source is documented in Hazard Report IDBR-01, Cause I <ul style="list-style-type: none"> ▪ SE&I recommends changing the risk classification from “Remote, Catastrophic” to “Infrequent, Catastrophic” ▪ LO2 IFR TIM conducted to assess foam application process and debris cloud attributes, as well as possible means to reduce likelihood of releases. ▪ TIM recommendations were: <ul style="list-style-type: none"> ▪ Increase level of NDE to include all horizontally poured LO2 IFRs ▪ Pursue design/process improvements to reduce debris potential ▪ SE&I performing integrated debris risk assessment to accept increase in divoting frequency and potential for larger divots occurring earlier in ASTT ▪ Discussed at 8/07/09 SICB ▪ Status – OPEN



Integrated In-flight Anomalies(IFAs)

<p><u>IFA Number: Title</u> Description</p>	<p><i>STS-128 Status and Rationale</i></p>
<ul style="list-style-type: none"> ▪ <u>STS-127-I-005: ET Intertank TPS Foam Losses</u> ▪ At least 37 TPS losses from the Intertank were observed in imagery from the feed line camera around 104 seconds MET. TPS losses occurred on both the +Z and -Z sides with many appearing to go to substrate. Mass of the largest piece is ~0.255 lbm, which exceeds the NSTS-60559 risk. Acreage losses from the Intertank are not common, since this TPS is not susceptible to large voids. However, the STS-127 TPS losses are much larger than expected. 	<ul style="list-style-type: none"> ▪ An increase in liberated intertank TPS poses an increased risk for Orbiter damage. ▪ This foam loss mechanism is documented in Hazard Report IDBR-01, Cause G <ul style="list-style-type: none"> ▪ SE&I recommends changing the risk classification from “Remote, Catastrophic” to “Infrequent, Catastrophic” ▪ Investigation in progress to determine root cause <ul style="list-style-type: none"> ▪ Likely cause determined by the team is “contamination prior to foam application” ▪ No strong discriminators between the processing of ET-131 (STS-127) and ET-132 (STS-128) ▪ Adhesion tests provide only some confidence in the bond strength of the ET-132 Intertank TPS <ul style="list-style-type: none"> ▪ TPS adhesion testing complete with 168 of 170 successful tests ▪ (2 adhesive failures with high pull strength values) ▪ Discussed at 8/07/09 SICB ▪ Status – OPEN





Integrated In-flight Anomalies(IFAs)

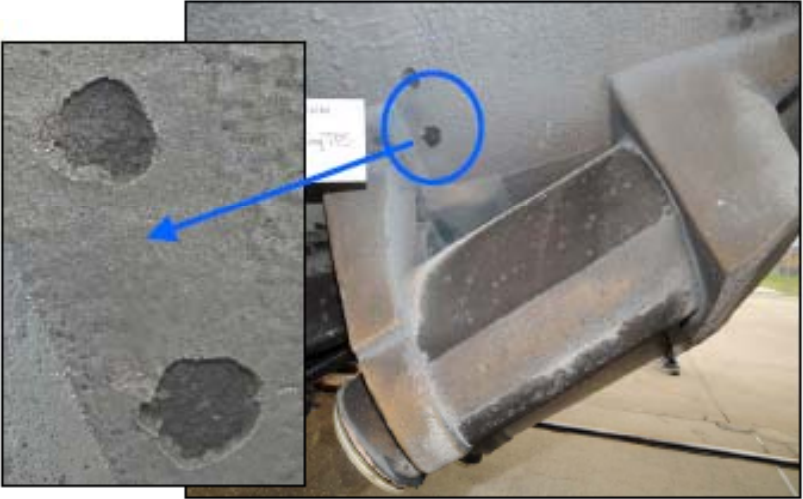
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IFA Number: <i>Title</i> Description	<i>STS-128 Status and Rationale</i>
<ul style="list-style-type: none"> ▪ <u>STS-127-I-006: ET TPS Loss Outboard Section of the -Y Bipod Closeout</u> ▪ TPS liberated from the outboard section of the -Y bipod closeout was observed in imagery from the feed line camera around 126 seconds MET. Mass estimate is ~0.068 lbm based on CATIA model representation from umbilical well imagery. This exceeds the NSTS-60559 risk assessment mass of 0.025 lbm. 	<ul style="list-style-type: none"> ▪ The time of release is consistent with physics-based understanding of cryo-ingestion failure mechanism ▪ Cryo-ingestion of LN2 into a void or subsurface crack(s) near or around the bipod heater wire routed from the Intertank (known LN2 reservoir) ▪ Increase in mass likely related to additional subsurface cracking or gaps between wires caused by multiple cryo cycles ▪ Terahertz NDE performed on ET-132 (STS-128) at KSC <ul style="list-style-type: none"> ▪ Results consistent with cryo-ingestion expectations - no anomalies identified ▪ SE&I performing integrated debris risk assessment to accept increase in divot mass potential <ul style="list-style-type: none"> ▪ Similar risk assessment performed and accepted for LH2 tank IFRs ▪ Discussed at 8/07/09 SICB ▪ Status – OPEN



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Integrated In-flight Anomalies(IFAs)

IFA Number: <i>Title</i> Description	<i>STS-128 Status and Rationale</i>
<ul style="list-style-type: none"> ▪ <u>STS-127-I-007: Layer of MCC-1 Missing on Aft Skirt Acreage</u> ▪ 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 and reported as post-flight SQUAWKS. <p>RH</p> 	<ul style="list-style-type: none"> ▪ MCC-1 is not expected to liberate during ascent or post SRB Separation. It is classified as unexpected debris. ▪ SRB elevated these losses to an element IFA (127-B-001) and formed Anomaly Resolution Team (ART)-270 on 7/24/2009 to address the three locations of cohesive loss of MCC-1 on BI-138 Aft Skirts. ▪ All three liberations occurred in a recovery error overlap area <ul style="list-style-type: none"> ▪ Spray process interruptions due to mechanical problems or controlled parameter tolerance violations is most likely cause ▪ For STS-128/BI-139, RH forward skirt is the only hardware that has a recovery error overlap area similar to STS-127 <ul style="list-style-type: none"> ▪ All seven BI-139 RH Forward Skirt porta pulls of recovery overlap revealed nominal, in family bond strengths ▪ Disposition rationale presented at 8/07/09 SICB ▪ Status – Dispositioned



LAUNCH ON NEED STATUS

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- In the event of call-up, the STS-129 flight software products would be flown on OV-104
 - OI-34 STS-129 Base Load and associated products
 - Flight specific I-Load patches for STS-129 (full payload bay)
 - OI-34 compatible MEDS IDP and MDUF software (VI 7.00/6.00)
 - MAGRS-3S Link 8
- Completion of the development and verification of flight-specific FSW products for STS-129 will be performed in time to support the 11/12/09 target launch date
- Formal Software Readiness Review to be conducted after call-up



SIGNIFICANT FSW CHANGES BETWEEN OI-33 AND OI-34

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Increase Available GPC Code Space

- **SCR92816D (PASS) – Remove Software Related to FICS**
 - Removed software related to the Forward RCS Interconnect System (FICS) hardware
 - Also freed 38 channelization discretetes
- **SCR93192 (PASS) – Change Effectivity of SCR93179B (Move GNC Utility Routines to MFB)**
 - Utilized an architectural capability introduced on OI-33 to move additional GNC utility functions to Major Function Base protected/code load blocks in the upper 128K of GPC memory (freeing GNC OPS overlay memory in the lower 128K)
- **SCR93172B (PASS, MEDS) – Move Horizontal Situation Display Background and Pseudo Backgrounds to MEDS**
- **SCR93220A (PASS, MEDS) – Move DPS Utility Display Background to MEDS**



SIGNIFICANT FSW CHANGES BETWEEN OI-33 AND OI-34

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Miscellaneous User/Op Note Elimination

- **SCR93194A (BFS) – BFS HUD Additions**
- **SCR93226A (PASS), SCR 93251 (PASS) – Stop Blinking Phugoid Symbol**
- **SCR93227A (PASS) – HUD Position and Altitude Limits**
- **SCR93228A (PASS) – No RNDZ Target Tracking with RNDZ Nav Disabled**
- **SCR93233 (BFS) – BFS RCS Activity Light Processing**
- **SCR93234B (PASS) – IMU RM Undesirable Behavior Correction**
- **SCR93241C (PASS) – Requirements Update to Fix DR 126157 (Horizontal Sit HAC position)**
- **SCR 93242A (PASS) – Correct Orbit GN&C Switch Dilemma Processing**
- **SCR 93250A (PASS) – Enhance Star Tracker Power On/Off Requirements**



STS-128 SYSTEM LEVEL WAIVERS

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- No changes or waivers to NSTS 07700 Vol X impacting software for STS-128
- No new software-induced waivers to NSTS 07700 Vol X



FLIGHT SOFTWARE SUMMARY OF OPEN WORK

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Open Work	Standard Open Work	Completion Date	
FSW - Complementary Load Processing - Dump and Compare Processing	Y Y	L-10 L-5	MS4/Peltier MS4/Peltier



Payload and General Support Computer Readiness – STS-128

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- Hardware and Software Summary**

- STS-128 will be the fifteenth flight of the IBM ThinkPad A31p PGSC**

- Six PGSC units (One planned for ISS transfer)
 - New software
 - TRIDAR DTO software
 - MS Office (2007) Compatibility Pack
 - ISS hard drive manifested for IP Phone & DVD Player

- Ninth flight of the A31p Docking Station (OCA and WinDecom)
 - Seventh flight of Netgear Wireless Access Point.
 - Note: No network issues observed during STS-125, STS-127

- PGSC Milestones**

