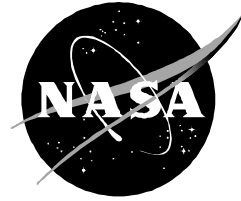


National Aeronautics and  
Space Administration

**Lyndon B. Johnson Space Center**  
2101 NASA Parkway  
Houston, Texas 77058-3696



Reply to Attn of: DS-11-003

April 25, 2011

TO: Distribution

FROM: DS/Chief, Space Transportation Vehicle Division

SUBJECT: STS-134 MOD Space Transportation Vehicle Division Flight  
Readiness Review (FRR) Delta Data Pack/Prelaunch Systems Issues

The enclosed data pack is provided to aid in the preparation for STS-134. The inputs are provided from Space Transportation Vehicle Division Flight Control Team disciplines for STS elements (Orbiter, SSME, SRB, and ET). The focus of this data pack is in-flight operations and the list of items in each section is not necessarily comprehensive.

This publication coincides with the L-1 Week Division Flight Readiness Review for the flight. Changes or issues that require updates after this publication will be provided by the on console team at the L-1 briefing.

*Original signed by:*

Enclosure  
Distribution: See list

## **A. Open Flight Anomalies**

**None**

## B. New Operations

### MMACS:

**APU Operation While Docked** - Analysis is in work to examine the effect that the stack would experience from running a single APU while docked to ISS. The results of this analysis will be used to complete the ULF6\_C10-2 APU Operations While Docked flight rule.

**Hook Requirements for Docked Operations** - Analysis is in work to examine the docking interface loads that would be experienced with multiple hooks out scenarios. The results of this analysis will be used to complete the ULF6\_C10-1 Hook Requirements for Docked Operations flight rule.

**APU Auto Shutdown Inhibit Management** - Management of the auto shutdown function on an APU that has shutdown before 10.5 seconds on a diagnostic restart will change based on newly identified failure modes in the APU. The new philosophy will be documented in the Flight Rule Annex. The CR has been submitted and is making its way through Workflow.

**Hook Failure During Undock** - In an undock scenario where physical separation does not occur, there is a chance that the starred block procedure to close hooks may actually end up damaging the hooks in certain scenarios. A new starred block procedure has been drafted along with a new APDS Contingency Remate Procedure to help get the hooks in a good configuration if this scenario were to occur. MMACS is working with the ODS IPT to get community agreement on the new philosophy.

## **B. New Operations, cont. MMACS, cont.:**

**Docking Procedure Update** - Post STS-133, concerns have been raised regarding the large misalignments that occur during docking, and the amount of time needed for shuttle and ISS to get hard mated (longeron shadowing, vehicle clearances, and docking mechanism damage). The new procedure allows the ring to drive against the fixers during the final ring retraction. This would maintain enough alignment to allow the ring to engage the alignment pins. As a result, large misalignments induced by the gravity gradient are avoided and get hooks closed faster. The procedure change was approved at the GJOP on April 6, 2011 and the crew has been trained on the changes.

## **B. New Operations, cont.**

### **GNC:**

**DAP configurations and constraints** - (Awaiting C. S. Draper Laboratory DAP Modes and Constraints Memo): The current version of the flight rules and crew procedures contain the preliminary data from C. S. Draper Laboratory. Upon receipt of the official memo, GNC will review the document, and update any DAP constraints in the FDF and Flight Rules as required. Final memo expected L-30 days.

**STORRM DTO w/ OBSS not transferred to ISS** – In the event that the OBSS is not transferred to the ISS, a contingency plan is in work to undock and perform the STORRM DTO with the OBSS grappled by the SRMS. Initial evaluation of the DAP based on engineering judgment indicates that no significant issues exist. The funding source for the formal analysis (MPCV or STS) is being negotiated. The results will be documented in the forthcoming C. S. Draper Laboratory DAP Modes and Constraints Memo. (This memo is standard open work.)

## **B. New Operations, cont.**

### **EECOM:**

**In-Suit Light Exercise (ISLE) Prebreathe Protocol** - This new prebreathe protocol is a hybrid of standard campout and exercise prebreathe protocols. In the ISLE protocol, the EV crew would not have an overnight campout in the ISS Airlock. They would execute a 10.2 depress in the Airlock on the morning of the EVA and later perform a very light exercise routine (much less strenuous than traditional exercise protocols). The benefits of the ISLE protocol are crew time/comfort and an O<sub>2</sub> savings of 6 lb/EVA. The ISLE protocol will be used on EVA 3.

**Ingress/Egress Procedures** - Nominal ingress and egress of ISS occurs by working Joint Ops procedures 2.104 (Hatch Opening and Shuttle/ISS Duct Install) and 4.102 (Shuttle/ISS Duct Removal and Hatch Closing). For STS-134, significant additions to these procedures were needed due to the STORRM DTO. New procedures have been created for ingress/egress and have been placed in the flight specific Assembly Operations book, procedures 1.100 and 1.101. Because they reside in the SODF, the procedures are owned by the ECLSS team. However, the EECOM team has thoroughly reviewed the procedures, worked with them on multiple integrated STS-134 sims, and is ready for their implementation on flight.

## **B. New Operations, cont.**

### **PROP:**

**STORRM DTO** - The Sensor Test for Orion Rel-Nav Risk Mitigation (STORRM) DTO will be flown on STS-134. This operation involves a re-rendezvous to within 600 ft of ISS post-undock and flyaround. The orbiter will separate from ISS to a range of ~30,000 ft and then perform an approach on a co-elliptic path similar to what Orion is to fly. The DTO will test out various sensors that will be used by Orion in the RPODU phase.

The STORRM DTO is a higher priority than the flyaround, so to be go for the flyaround there must be enough propellant for 3-sigma usage of both the flyaround and STORRM DTO. Once the flyaround has begun if a breakout is required then there is very little chance of performing the STORRM DTO.

### **INCO:**

**SSV usage for STORRM DTO** - The STORRM views on the middeck laptop will be viewed on the ground using SSV. These views are utilized during rendezvous tools checkouts, rendezvous, undock, and re-rendezvous. During rendezvous tools checkout, rendezvous, and docked operations after AMS unberth, SSV will be configured to OUTRATE - 2 which provides an image refresh rate of one image every 40 seconds. During the AMS TFL, rendezvous tools checkout, and undocking, SSV will be configured to OUTRATE -3 which provides a image refresh rate of one image every 20 seconds. Lastly, during the re-rendezvous period, SSV will be configured to OUTRATE - 5 which provide an image refresh rate of one image every 10 seconds.

## C. Operational Workarounds

### MMACS:

**Antiskid Switch Guard** - During a generic, stand-alone BFS entry training run in the SMS, the training team accidentally sent a command to power off Antiskid after TAEM which resulted in a Loss of Control (LOC). Software review and SAIL testing showed this is expected behavior by the BFS per requirements. On the BFS, when Antiskid power is cycled from ON to OFF after TAEM the four associated wheel speed sensor outputs switch from “1” to “0” causing Weight on Wheels (WOW) to be set. WOW triggers several changes in the DAP to ensure control in the two-point stance which will cause a LOC while still in flight. Powering off Antiskid prior to TAEM will not trigger WOW since the BFS first pass logic checks for this condition. Subsequently the PASS is not susceptible to this failure since its WOW detection logic is more robust.

To mitigate this risk in flight, an AEFTP Splinter on Jan 20, 2011 decided to place a switch guard over the Antiskid switch prelaunch and keep it in the “ON” position the entire flight. For on-orbit power down, Antiskid power will instead be controlled solely by turning off the upstream Brake Power switches (nominal configuration for orbit). Flight Rule and FDF updates have been completed and flew on STS-133.

### GNC:

**BFS Antiskid Flight Rule** – This flight rule is a duplicate of the STS-133 rule. The rule documents that the BFS is NOGO for engagement if the antiskid power switch is taken from ON to OFF during MM305 or MM603.



## C. Operational Workarounds, cont.

### EGIL:

#### Anomalies that Occurred during last Flight of OV-105 (STS-130)

**Fuel Cell 2 Substack 3 Delta Voltage Self-Test Fail** - On Flight Day 13, the Fuel Cell 2 Substack Delta Voltage reading failed the self-test that it performs every 7.5 minutes on 5 separate occasions. The Cell Performance Monitor (CPM) for Fuel Cell 2 was replaced.

**SSPTS OPCU Converter 1A Fault Isolator Trip** - On Flight Day 11, the OPCU 1A fault isolator tripped during SSPTS reactivation. As a result, SSR-204, OPCU FAULT ISOLATOR TRIP RECOVER (MAL, page 7-314) was worked which recovered all capability within 15 minutes of the trip. An OPCU fault isolator trip (OPCU 2A) also occurred on STS-119 on OV-103 during SSPTS reactivation. There is high confidence that if the OPCU fault isolator trips during SSPTS activation that the OPCU converter will be recovered after troubleshooting. The plan is to fly as-is.

**Fuel Cell 2 H2 Flowmeter Erratic Postlanding** - On Entry Day, the FC2 H2 flowmeter became erratic post-landing for 11 minutes and then returned to a nominal reading. We have flown with failed or unpowered flowmeters on past flights. There is additional instrumentation that will provide insight into fuel cell operation. The plan is to fly as-is.

## C. Operational Workarounds, cont.

### INCO:

**Docked Late Inspection** - Due to leaving the OBSS on ISS for this mission, STS 134 will have a scheduled Docked Late Inspection.

**S Band FM System** - FM System 1 RF Output power experienced fluctuations started on STS-130 FD12 with the lowest level at 12.9 W. The Spec requirement is 10 W. The FM System provided nominal data playbacks during orbit and post landing, as well as good HUD video downlink during entry. KSC testing showed FM System 1 had fluctuations with an unknown origin. Will fly as FM System 2 as prime with system 1 as backup.

**OIU Configuration management** - While AMS is in the payload bay, the OIU will only be used to route AMS data through the shuttle's payload communications system. AMS is scheduled for transfer to ISS on FD4. At this time, INCO will reconfigure the OIU for ISS telemetry.

## D. Anomaly Resolution

### MMACS:

**(AR 4557) Side Hatch Window MMOD Impact** - At an approximate MET of 008/18:20 the crew reported a small MMOD impact on the side hatch window. The window pane was removed and replaced post-flight.

**(AR 4570) Window 2 MMOD Impact** - At approximately MET 10/11:53 the crew reported that they found an MMOD impact on Window 2 (CDR side, middle window). The window pane was removed and replaced post-flight.

**(AR 4574) Window 1 MMOD Impact** - At approximately MET 12/02:05:00 the crew reported that they found an MMOD impact on Window 1 (CDR side, port window). The crew also reported that there was some visual spider webbing (NOT cracks), possibly due to the MMOD impacting the SRB exhaust on the window. The window pane was removed and replaced post-flight.

**(AR 4577) PLBD Centerline Latch Microswitch Failed** - At MET 013/18:00:07 (immediately after TAEM), the PLBD Centerline Latch 13-16 LAT A Microswitch (V98X3409X) toggled between ON and OFF for several seconds. The indication ultimately remained OFF starting at MET 013/18:00:27. Post-flight troubleshooting was unable to recreate the signature which is believed to be attributed to an external factor (thermal or pressure effects). During the troubleshooting, the actuator was noted to make a louder noise than what is typically heard from these types of actuators. Additional troubleshooting was unable to identify a root cause of the louder-than-expected noise. This anomaly was closed as unexplained.

## **D. Anomaly Resolution, cont.**

### **EECOM:**

#### Anomalies occurred during STS-133 (last flight)

**Postlanding NH3 Cntlr B Logic Switchover (AR #005261)**- Following postlanding activation of NH3 Controller B with the Primary (PRI) logic selected, the controller performed an automatic switchover to the Secondary (SEC) logic. The SEC logic performed nominally. Automatic switchovers are designed to occur when the PRI logic detects an undertemp condition. Data analysis has shown that an undertemp condition did not occur and that an issue exists with either the Primary logic or the Primary logic temp sensor. No root cause analysis will be performed. There are no plans to use Primary logic during postlanding on STS-134.

**Hum Sep B H2O Carryover** - On FD2, the crew reported water at the outlet of Hum Sep B. Condensate Collection into a CWC was set up and no further water was reported. Post undocking, when condensate collection was terminated, Hum Sep A was activated and no H2O carryover was reported. H2O carryover on the Hum Seps has been noted on numerous missions. IFMs to collect Hum Sep water are documented in the IFM C/L. No impact to STS-134.

## D. Anomaly Resolution, cont.

### INCO:

#### Anomalies that Occurred during last Flight of OV-105 (STS-130)

**AR# 4527: Loss of Sensor Package 1 ITVC Video during Port Survey** - During Flight Day 2 survey operations there was a temporary loss of the Sensor Package 1 ITVC image. After the crew reselected the automatic gain setting, the image returned. The ITVC performed nominally throughout the rest of the mission and during Late Inspection. This could have been a result of an inadvertent switch bump that closed the iris of the camera.

**AR# 4530: Orbiter Interface Unit / 1553 Bus Interface Errors** - On Flight Day 3 lock between the OIU and the ISS GNC-1 MDM was not established. After ODIN inhibited their FDIR and troubleshooting was performed it was determined that the N2-1 channel B connection is failed while the channel A is still functioning (N2-2 was also testing with both A and B performing nominally). The failure signature points at a possible X4 connector issue (docked audio issues are associated with the same connector).

**AR #4568: DTV MUX FRONT BYPASS Issue** - The DTV MUX did not perform nominally. Two issues were seen with the MUX: (1) 48M OCA did not work due to relays latching within the MUX (2) HD playback downlink did not work due to a channel 2 failure. Workarounds performed due to these failures included using 2M OCA in lieu of 48M OCA, and using channel 1 for HD playbacks in lieu of channel 2. Replacement DTV MUX was installed retested with no issues.

## **D. Anomaly Resolution, cont.**

### **GNC:**

#### Anomalies that Occurred during last Flight of OV-105 (STS-130)

**TCS CW Laser Anomaly (AR 4528)** - During STS-130 (last flight of OV-105) the Trajectory Control Sensor (TCS) transitioned from the pulse laser to the continuous wave laser later than nominally expected. Subsequent operations on the continuous wave laser provided invalid data and processing of the data was inhibited. Post STS-130, the TCS hardware was R&R'ed and no impacts to STS-134 are expected.

### **DPS:**

**MFD 2 1553 Comm. Error During 134 TCDT (IPR 134V-0037)** - During Crew egress following STS-134 TCDT, IDP 1 and IDP 3 reported 2 consecutive 1553 bus errors against MDU MFD2. VM Dump from IDP 1 shows that MFD 2 logged POST results 3 seconds after the 1553 errors. IPR closed as unexplained. If there is a re-occurrence prior to T-11, will replace MDU with pre-tested MDU. LCC effectivity for MDU goes to T-31. If this were to repeat in the launch timeframe, DPS would be go for launch per LCC (1st failure, relies on MEDS redundancy in MDUs).

## D. Anomaly Resolution, cont.

### PROP:

#### Anomalies that Occurred during last Flight of OV-105 (STS-130)

**LOME GN2 Accumulator Leak** - The GN2 accumulator leak rate was the same as seen on previous flights of this vehicle; however, on previous missions the accumulator leak at times appeared as a tank leak due to a leaking pressurization valve between the GN2 tank and the accumulator. That valve was replaced after STS-127 which led to a concern early in the mission that the accumulator caution and warning alarm could annunciate during crew sleep. Therefore, Prop worked with DPS to have a GMEM ready to change the LOME accumulator alarm limit. The GMEM was not used during the flight.

A pre-flight approved GMEM is available for STS-134 should it be necessary to change the limit on either the LOMS Tank Press or Accumulator Press.

## D. Anomaly Resolution, cont. BOOSTER:

**STS-134 External Tank (ET)-138 Transporter Hydraulic Leak** - During transport of ET-138 from the ET Barge to the Vehicle Assembly Building (VAB) on 7/14/2010, a transporter ground support equipment wheel hydraulic supply hose failed when the transporter was about 50 feet south of the VAB south door. A small amount of hydraulic fluid sprayed up from the leak onto the ET near the aft hard point. A total of about 2 quarts of hydraulic fluid was involved in the spill. The spill on the ground was cleaned up by hazardous waste personnel. A replacement hydraulic hose was obtained from another transporter and installed in place of the failed hose and the ET-138 move was completed without further issues. The ET aft hard point has been successfully cleaned and there are no issues with the flight hardware due to the transporter hydraulic leak.

**STS-134 External Tank (ET)-138 Ground Umbilical Carrier Plate (GUCP) Seal Defect** - On 7/19/2010, during GUCP installation at KSC on ET-138, a visual defect was found at the 2 o'clock position on the GUCP engagement hydrogen seal primary sealing surface. Reference PR ET-138-ST-0005. Hydrogen leaks in this area caused launch scrubs on STS-27R, 44, 52, 65, 80, 119, 127, and 133. The defective seal was successfully removed and replaced.

**STS-134 Gaseous Hydrogen (GH2) Flow Control Valve Out Of Specification** - On 7/20/2010, during installation of the GH2 Flow Control Valves on OV-105 for STS-134, the Right GH2 FCV was found to have an unacceptable condition of no gap between the solenoid flange and the housing flange. Reference PR MPS-5-25-0958. The discrepant valve was removed and replaced with a spare.



## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

**Loose Washer Found In STS-134 External Tank (ET)-138** - On 8/4/2010, during 17 inch disconnect angle and tip load checks on ET-138 in the vertical orientation in the Vehicle Assembly Building at KSC, a loose 11/16 inch Cadmium plated Stainless Steel washer was found in the Liquid Oxygen 17 inch feedline at the 90 degree bend just before the 17 inch ET/Orbiter disconnect. Reference PR ET-138-FP-0001. The washer found in the Liquid Oxygen 17 inch feedline corresponds to washers used externally to assemble the feedline. Several hundred washers are used in the assembly. Testing has shown that this type of washer can be retained in the feedline bellows or in the Ball Strut Tie Rod Assemblies internal to the feedline. The Orbiter Main Propulsion System has screens located downstream of the prevalves on both the Liquid Oxygen and Liquid Hydrogen systems, upstream of the Main Engine inlets. The pre valve screens are intended to capture debris of this nature. The Propulsion Systems Integration Group evaluated potential consequences of an undetected washer in the feedline. Impact ignition and pre valve screen flow blockage were determined to not be an issue. The Shuttle Program decided to perform X-ray inspections of all five bellows assemblies in the Liquid Oxygen 17 inch feed line on each of the External Tanks currently scheduled to be flown: ET-122, ET-137, and ET-138. Similar X-ray inspections were performed on ET-129 (STS-126) as part of an investigation into a noise heard when ET-129 was rotated to the vertical at KSC. The X-rays revealed no foreign material in the feedlines. Additionally, it was decided to use ET-122 for STS-134, rather than ET-138. ET-122 is the tank that was damaged while at the Michoud Assembly Facility during Hurricane Katrina.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

**Repairs to STS-134 External Tank (ET)-122** - ET-122 was damaged while in the Vertical Assembly Building at the Michoud Assembly Facility during Hurricane Katrina in August of 2005. Roof damage (not directly over ET-122) allowed rain water exposure to the tank outer surface - due to this, both the LH2 and LH2 17 inch disconnects were removed and replaced. Concrete debris and chips from the roof also caused minor foam damage on the Intertank and LO2 tank - primarily on the portion of the tank away from the Orbiter side. Inspections confirmed no structural damage to the LO2 tank. A doubler was installed on one intertank stringer that was dented. Unique foam repairs and inspections were implemented to verify that the hardware meets engineering requirements. Substantially fewer foam repairs were performed on ET-122 than were performed on the hail damaged ET-124 on STS-117. Delayed ET-122 tank completion resulted in Thermal Protection System age-life beyond the 6 year certification requirement. Test and analysis resulted in the Shuttle Program accepting a waiver to NSTS 07700 and the ET Contract End Item Specification for this condition. Delayed tank completion also resulted in returning to several previously flown designs that have been changed on more recent tanks (for example: ET-122 originally had a Protuberance Air Loads (PAL) Ramp installed but this was then removed to conform to STS-114 return to flight configuration - more recent tanks never had a PAL Ramp installed; and ET-122 has aluminum LO2 feedline brackets - more recent tanks have titanium feedline brackets). This required updates to Hazard Reports and Critical Items List retention rationale.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

**133V-0058 - Right Space Shuttle Main Engine (SSME) Controller B Power-up Anomaly On 11/2/2010** - This IPR was taken when the STS-133 Right SSME Controller AC1 Phase B power supply was slow to activate. This scrubbed the STS-133 11/2/2010 launch attempt. The accepted fix for this previously seen failure mode associated with shuttle circuit breakers is to cycle (“scrub”) the circuit breaker five times to clear suspected debris. This was performed. Once the circuit breaker is closed and electrical connection is established, the debris is considered cleared and no further power degradation is expected. The failure signatures and fault tree of this anomaly, failure history of shuttle circuit breakers, and potential mission impacts were reviewed at the Mission Management Team on 11/3/2010. All organizations agreed to proceed to the 11/5/2010 launch attempt assuming the Right SSMEC and power supply were performing normally. Since vehicle repairs due to other IPRs taken on 11/5/2010 (see below) and subsequent launch window constraints delayed the launch until no earlier than 11/30/2010, it was decided to remove and replace all 18 SSME AC circuit breakers on Panel L4. Prior to removal, troubleshooting was performed on the discrepant circuit breaker while it was still installed on Panel L4, with no major discoveries noted. After removal, the circuit breaker was disassembled and the source of the problem was found to be non-conductive debris build-up on the “fixed” ‘B’ contact (as suspected). Troubleshooting was also performed on the Panel R2 Right SSME Controller AC1 Power switch with no anomalies found. Reinstallation of Panel L4 with the new circuit breakers was completed on 11/16/2010 and all functions have been successfully retested. Closure of the anomaly was approved by Space Shuttle Program management at the 11/18/2010 Program Requirements Control Board.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

**133V-0068 Ground Umbilical Carrier Panel (GUCP) Hydrogen Leak On 11/5/2010** - This IPR was taken when the hydrogen concentration in the GUCP helium purge area exceeded the HAZ-09 LCC value of 40,000 Parts Per Million. This scrubbed the STS-133 11/5/2010 launch attempt. GUCP leaks have previously occurred on STS-27R, 44, 52, 65, 80, 119, and 127. The fix for STS-127 and subsequent flights was to replace the one-part flight seal with a two-part flight seal which is thought to have a greater misalignment capability. This GUCP leak is the largest seen to date, with a calculated value of 26 scfm (~50% larger than the next largest GUCP leak, seen on STS-119). The likely cause for the leak was a combination of two factors. The first was an out-of-family concentric offset between the GUCP and the ET-side Flight Seal - at 0.049", this was just below the maximum allowable of 0.050". The second was the resultant shift of the GUCP / External Tank Carrier Assembly due to uneven loading when the Hydrogen Vent Arm is attached. During disassembly after the launch scrub, the concentricity offset had increased to .061". Work was performed to minimize the concentric offset between the GUCP, the 7" Quick Disconnect, and the ET-side Flight Seal. A new flight side seal was used, as well as a different ground side disconnect. No leaks were detected at the GUCP during the STS-133 Tanking Test on 12/17/2010. During preparation for roll-back after the STS-133 tanking test, the de-mate of the GH2 vent line was reported to be off-nominal. Post-rollout, a small, but in-spec leak was observed during ambient helium leak checks performed on the GUCP. As a result, the STS-133 ET-137 GUCP 7" QD seal was removed and replaced again.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

**STS-134 External Tank (ET)-122 Ground Umbilical Carrier Plate (GUCP) Seal Replaced** - The investigation into the 11/5/2010 STS-133 scrub for a hydrogen leak at the GUCP found concentricity and assembly issues with the GUCP. It was decided to remove and perform concentricity measurements on the STS-134 ET-122 GUCP which requires the flight seal to be replaced as well. No significant issues were found and the GUCP was reinstalled using lessons learned from STS-133. Mate of the GH2 vent line at the pad will also be performed using lessons learned from STS-133.

**133V-0070 PV13 Incorrectly Opened During Drain On 11/5/2010** - This IPR was taken to document an incorrect configuration of the liquid hydrogen (LH2) topping valve (PV13) which was erroneously opened for ~7.5 minutes during STS-133 hydrogen drain operations on 11/5/2010. The two concerns for this IPR are: 1) the potential for flow induced vibration damage of the topping line, and 2) the potential for contamination to migrate from the vehicle LH2 tank through the unfiltered topping line instead of the normal drain path with an associated 400 µm screen. Upon a subsequent tanking and launch, this contamination could then be ingested by the Main Engines during ascent. The KSC Engineering Review Board decided to remove and replace the 70 micron filter on the Mobile Launcher, since this is where any contamination would have settled. The Propulsion Systems Integration Group, and the Systems Integration Control Board both reviewed the matter and concluded that there is no structural concern for the reverse flow through the topping line, and that the increase in risk for potential contamination is small and acceptable. The 11/18/2010 Program Requirements Control Board concurred with this assessment. An update to the integrated hazard report IMPS-01 and a waiver to the associated interface control document was processed to document this issue.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

**133V-0072 Foam Crack at External Tank (ET) Liquid Oxygen (LO2)/Intertank (IT) Interface Flange On 11/5/2010** - A large crack in the ET Thermal Protection System Foam at the LO2/IT flange closeout was observed during the Post Drain walkdown following the first STS-133 launch attempt on 11/5/2010. The launch scrub was due to the hydrogen leak at the Ground Umbilical Carrier Panel (GUCP), but this foam anomaly would have also scrubbed the launch attempt due to violation of the Ice/Debris Inspection Criteria documented in NSTS 08303. Video analysis showed this crack occurred during LO2 tanking, when the LO2 level was near the LO2/IT flange. During foam dissection/removal at the pad on 11/10/2010, the underlying stringer (S7-2 on panel 2 - on the orbiter side, adjacent to the Left SRB thrust panel) was found to have 9" cracks along both feet of the stringer. Further foam removal identified 3.5" cracks along both feet of an adjacent stringer (S6-2 on panel 2). These stringer cracks did not result in cracks in the overlying foam. Both of these stringers are in an area with skin doublers. The damaged segments of stringers S6-2 & S7-2 were removed and replaced with new stringer segments and connected to the existing stringers using z-doublers and radius blocks. Backscatter X-ray and Computed Radiography X-ray examinations were performed at the pad on accessible areas for the +Z (orbiter side) LO2 and LH2 flanges and did not find any additional cracks. Computed Radiography X-ray of the LO2 Tank flange on the remaining two flight tanks for STS-134 (ET-122) and STS-135 (ET-138) has been completed with no anomalies found.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

### **133V-0072 Foam Crack cont.**

Fractography of the panel 2 S6-2 and S7-2 stringer crack surfaces revealed no indication of pre-existing flaws that may have been introduced during assembly or transport. Testing of the failed stringer's material properties revealed a lower fracture toughness when compared to control samples. It was later determined stringers from either of two "suspect" lots also show a low fracture toughness. All cracked stringers were either proven or thought to be from those two lots, which were heat treated by Aerochem between 5/2002 and 8/2002 and used on the majority of ET-137 stringers. The low values for fracture toughness may indicate out of specification heating conditions at some point during the manufacturing process.

Since analytical models indicated the nominal IT stringer design provides a factor of safety greater than 2 for the maximum flight limit load, and additional margin for the maximum prelaunch limit load - an instrumented tanking test was performed on 12/17/2010 to obtain data to verify the analytical models. Strain gauges and thermocouples were mounted to the ET IT skin and stringers on panels 2 and 3. Photogrammetry methods were used on panels 2 and 6 to determine the displacement of the LO2/IT flange under cryogenic conditions (the LO2/IT flange diameter shrinks by about 1 inch, the LH2/IT flange diameter by about 1.5 inches). Tanking test data verified the structural integrity of the ET-137 intertank stringers and repairs, verified the ET IT structural analytical models and their calculated design margins, and additionally verified the GUCP alignment process was successful (the GUCP had no hydrogen leaks).

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

### **133V-0072 Foam Crack cont.**

A review of the ET IT assembly process revealed multiple opportunities for undetected structural alignment issues within the areas which use skin doublers (adjacent to the SRB thrust panels). These alignment issues can reduce load limit margins by inducing residual stress in the stringers. ET-137 inspections showed potential fit-up issues existed at both stringers S6-2 and S7-2 on panel 2. Open and lifted crack surfaces indicate that residual stresses were present. Burrs on the underside of stringer S6-2 indicates a gapping condition existed. Foam intrusion observed under the stringer foot indicates the foot was not flush with the skin doubler. X-ray data shows the gap between chord and taper shim was larger than typical. Visual inspections show the S6-2 and S7-2 stringers extended over the skin doubler panel by a slight amount.

On 12/30/2010 when the vehicle was rolled back to the Vehicle Assembly Building for further inspections, three more cracked stringers were found at the LO2/IT flange where there was not access for X-ray inspections at the pad (stringers S6-6, S7-6, and S11-6 on panel 6 - on the side opposite the orbiter, adjacent to the Left SRB thrust panel). These stringer cracks also did not result in cracks in the overlying foam. Panel 6 stringer S11-6 is also on a skin doubler, however panel 6 stringers S6-6 and S7-6 are not on a skin doubler. These stringers have been repaired in a similar manner as stringers S6-2 and S7-2 on panel 2.

A structural modification was developed for the stringer ends at the LO2 flange area to mitigate the potential contributors to stringer cracks. This modification adds reinforcing radius blocks over the 2nd to 7th fastener location to increase the local bending stiffness of the stringer feet. This modification was performed for 32 of the stringers on the skin doublers adjacent to each SRB thrust panel in the VAB beginning on 1/3/2011. On 1/10/2011 it was decided to implement the radius block modifications on all of the accessible stringer tops at the LO2 flange. All work associated with this task has been completed satisfactorily and ET-137 was ready for rollout on 1/31/2011.



## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

### **133V-0072 Foam Crack cont.**

Flight rationale for ET-137 was presented at the STS-133 Delta Space Shuttle Program Flight Readiness Review (SSP FRR), held on 2/11/2011 and was approved at the Agency FRR on 2/18/2011. The high contributors to the failures seen at the LO2 stringer ends were traced to a combination of reduced fracture toughness, reduced thickness, and high induced assembly stresses in the stringers - all three are required to generate cracks (although the mix has not been completely replicated). The LO2 side flight rationale relies on engineering tests and analysis showing the radius block modification increases stringer capability (Factor Of Safety for prelaunch = 1.71 and flight = 3.14) and “does no harm”. It also states the modification is local to the structure and does not affect integrated stiffness or loads. Additionally, the repairs to the failed stringers using a similar modification have been verified with results from the 12/17/2010 tanking test.

Flight rationale for the LH2 side includes no cracks were found after Non-Destructive Evaluation (NDE) of the accessible 66 of the 79 suspect stringer LH2 flanges (and also LO2 flanges with similar configurations). Analysis has shown the LH2 stringer ends have a Factor Of Safety for prelaunch = 1.28 and flight = 1.28. Additionally, it was demonstrated the LH2 stringer ends are not prone to the same assembly induced stresses which can reduce their capability when exposed to the prelaunch loading.

Further flight rationale is that the Final Inspection Team imagery will determine if there are no existing cracks in LO2 and LH2/IT foam prior to flight (although only one of the five cracked stringers caused the overlying foam to crack).

There is no issue with the mid-section of the stringers as they are not subject to bending loads as the ends are.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

### **133V-0072 Foam Crack cont.**

Actions were given to MSFC Engineering and the NASA Engineering Safety Council at the Delta SSP FRR to validate the work Lockheed Martin has done to clear ET-137. These actions were brought to and closed by the Shuttle Program on 2/16/2011 before being presented at the Level 1 Agency FRR on 2/18/2011. Booster has no open work associated with this issue.

Although it was widely believed that due to a much earlier build date ET-122 for STS-134 had no stringers from the two suspect lots, in January 2011 there was no conclusive evidence to prove this. Rather than trying to prove ET-122 safe to fly as-is, on 1/27/2011 the Shuttle Program decided that it would be better to make the same modifications to ET-122 for STS-134 as were made to ET-137 for STS-133. The modifications to ET-122 were completed on 2/23/2011. ET-138 for STS-135 (which does have stringers from the suspect lots) will also be modified in the same way. This plan allowed the workforce to remain focused on one activity as well as keeping the flight rationale identical for all three remaining Shuttle missions. The 4/19/2011 launch date for STS-134 allows for a tanking test on 3/22/2011 and NDE activities afterwards at the pad.

On 3/7/2011 the Space Shuttle Program decided that a tanking test for ET-122 / STS-134 would not be required. It was shown that none of the four lots of stringers used on ET-122 are the two suspect lots used on ET-137 and ET-138. Additionally, the four ET-122 lots are also not from the same material manufacturing time frame as the two suspect lots. Borescope inspection of ET-122 stringers through vent holes confirmed that the "mottled" appearance of the two suspect lots was not present. Analysis of drill shavings obtained from the ET-122 radius block modification (samples from three of the four ET-122 lots) confirmed that the micro-structural condition compares well with the non-suspect stringer S2-7 from ET-139 and that no significant sub grain boundary or inter-granular precipitation was observed.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

**STS-133 Reduced Margin to Main Engine Thrust Limiting During Ascent** - During STS-133 ascent, Center Space Shuttle Main Engine (SSME) 2044 came very close to its Oxidizer Preburner Oxidizer Valve (OPOV) Thrust Limiting Command Limit just before Main Engine Cutoff. Had the limit been reached, Thrust Limiting Mode would have been activated resulting in a nearly negligible performance impact - the Engine Status Word would have indicated Thrust Limiting, and a Failure Identifier (FID) would have been posted in the Vehicle Data Table. It has been determined that there is adequate margin to thrust limiting for all three STS-134 SSMEs and the Left and Right STS-135 SSMEs. The STS-135 Center SSME 2047 has reduced margin to thrust limiting and was reviewed for a possible update to flight software adaptation data constants to increase the margin. The SSME Project decided to not make any changes. There are no impacts to STS-134 or STS-135.

**Items Dropped In Aft Compartment** - During Aft platform installations on 3/2/2011, two incidents occurred. PR V070-0284 (PVD-5-25-0676): a small filler platform fell and dented a Purge Vent Duct (PVD). The PVD was changed out. PR V070-0283: an Emergency Life Support Apparatus (ELSA) fell from the sidewall shelf to the base heat shield area near the Left SSME. The only damage found was a dent on the base heatshield closeout for the Left SSME, and dent in an MPS GN2 purge line (MPS-5-25-0961). Neither required a repair. Due to concerns with possible ELSA impact to the SSME Controller, wire wiggle tests were performed and no problems were found.

## **D. Anomaly Resolution, cont. BOOSTER, cont.:**

**PD13 And PD17 Removed and Replaced** - During V1149 T-0 Umbilicals and Orbiter/ET Interface Leak Checks on 3/6/2011, PD13 and PD17 Quick Disconnects (QDs) were found to be leaking outside of specification. PD13 is the LO2 Overboard Bleed valve QD (Orbiter half of the Orbiter/Ground disconnect) and PD17 is the LH2 High Point Bleed valve QD (Orbiter half of the Orbiter/Ground disconnect). PD13: MPS-5-25-0962 leaking 316 scim, 115 scim is maximum allowable. PD17: MPS-5-25-0963 leaking 23.8 scim, 10 scim is maximum allowable. Both QDs were removed, replaced, and successfully retested.

**KSC Weather Event on 3/30/2011** - Severe weather occurred at KSC on 3/30/2011 with high winds and hail. ET foam damage due to hail is minor. There are nearly 300 total indentations, mostly on the machined foam just below the composite nosecap. All areas are approximately 0.1 inches deep or less. All areas were determined acceptable for icing, heating, and foam release with no repairs required. The winds exceeded the nominal 60 Knot limit on the ET GH2 Vent Umbilical Arm for approximately one minute, however analysis shows that a safety factor of greater than 5 was maintained at the 7 inch Quick Disconnect to Ground Umbilical Carrier Plate - well within the tested system limits. Additionally, the estimated maximum excursion of the Vent Arm is within the tested and certified excursions of that hardware.

## **E. Miscellaneous (i.e. catch all category)**

### **MMACS:**

**Landing Gear Support Bracket Crack** - Prior to STS-130 two cracks were found on the main landing gear support bracket on OV-105. The bracket holds hydraulic lines, brake heater lines, and telemetry lines, allowing rotation with the gear strut during gear deployment. Analysis showed that the crack was not expected to propagate and that sufficient margin for the bracket existed. A MR accepted the crack for one flight (STS-130). Post- STS-130, the crack was measured again and there were no changes. A MR was accepted to fly-as-is.

**Left Inboard Main Landing Gear Tire Pressure** - On 2/11/11 the left inboard main landing gear tire was being topped off between 408 and 410 psig when the temperature unexpectedly increased. The temperature corrected pressure ended up being 410.8 psig which is 0.8 psig higher than the maximum allowable value. Approximately 7 hours later, the toff sequence was reperformed to bleed off some of the pressure. The temperature corrected pressure was then 409.0 psig and good for flight; however, between the first and second toff sequence on that day, a decay rate of -8.63 psig/day was noted and this violates the maximum allowable decay rate (-0.3 psig/day). It is well known and documented that excessive decay rates will be seen on pressure checks for short intervals of time (in this case ~7 hours). Since the initial toff performed on 5/26/10 showed a -0.09 psig/day decay rate, an MR is being worked to accept this condition as-is. A final verification of the decay rate will be checked again post VAB powerup.

## **E. Miscellaneous (i.e. catch all category), cont. MMACS, cont.:**

**Drag Chute Life Limit** - The drag parachute canopy has a reuse life limit of 20 years. For STS-134, the life limit will expire on May 1, 2011. This canopy (s/n 005) has been previously used 5 times. Testing was performed on another canopy (s/n 006) which is from the same lot and has been used 6 times. Material testing has shown that all material strength was significantly above the design minimum. An exception is being written and is planned to go to the OCCB in March for approval. The drag chutes for STS-133 and STS-135 are from a new lot so their reuse life limit does not expire until 2012.

## **EECOM:**

**Waste Water/Supply Water/Pressure Plans** - These items are standard open work.

**CO2 Concerns During PAO Events** - In a debrief of STS-132, the crew mentioned some “stuffy” air and mild CO2 symptoms during a ~40 min PAO event involving the entire combined crew in the JEM. At the time, ventilation in the JEM was degraded, and that issue has since been resolved. While no future problems are expected, ECLSS and EECOM will discuss the item at a future JOP to make sure the entire team is aware of the issue. FAO will be scheduling future PAO events in the Lab or Node 2.

## **E. Miscellaneous (i.e. catch all category), cont.**

### **INCO:**

**LCS Radiation Restrictions** - Due to engineering analysis modifications are in work for Flight Rule C11-13 LCS RADIATION RESTRICTIONS. These updates are in work for STS 133 and subs. The modifications are for the S Band antennas during LCS scans in both High and Low Frequency. The distance from LCS scans and the shuttle S band antennas has increased slightly in range for both frequencies.

### **GNC:**

**IMU Slip Ring Issue**: A flaw exists in the design of the IMU tape cables used to transmit data to and from its inertial components (gyros, accelerometers, etc.) and the clamp used to hold the wires in place. The current design can create a small amount of flexure in some of the wires. This condition can, and has, led to breakage of slip ring wires during ground calibrations and flight operations. A modification to the IMU hardware has been designed and successfully implemented on S/N 214 and S/N 202; these IMU has been installed in OV-105 in slot 1 and slot 3, respectively. The remaining IMU (S/N 203) on OV-105 has not had the modification performed and is susceptible to this failure mode. The modified IMUs eliminate the susceptibility of all three IMUs to the generic failure mode, and thus the need for early mission termination under the generic failure mode section of the flight rules.

**E. Miscellaneous (i.e. catch all category), cont.**

**EGIL:**

**Consumables Status** - The following consumables status is based upon the Final2 analysis cycle dated 04/18/2011 for a 14+2+2 day mission with the following assumptions:

- The 2 additional days are both docked days with 4 SSPTS converters active.
- 65 lbm of O2 offloaded evenly from tanks 1-5.
- 2-2-2 (KSC-KSC-EDW, respectively) deorbit opportunities
- 24 lbm of O2 protected for 4 scheduled EVAs, 1 unscheduled EVA, and PMA/ODS repress
- 30 lbm of ISS O2 transfer
- Analysis protects for 3 hrs of extended postlanding power for middeck payloads (GLACIER and CGBA-2).
- Extra margin allows for Flight Day 4 rendezvous and allows for additional O2 transfer to ISS.

Consumable	Number of Tanks	L/O Quantity (lbm)	Min L/O Rqmt (lbm)	Margin (lbm)	Launch Hold Capability (hours)
Cryogenic H2	5	454.5	388.3	66.1	183.7
Cryogenic O2	5	3817.6	3511.0	306.6	296.2



**E. Miscellaneous (i.e. catch all category), cont.  
EGIL, cont.:**

**Fuel Cell 1 Hydrogen Flowmeter Erratic Readings IFA-126-V-07 /MER 11 (OV-105)** - FC1 H2 Flowmeter failed off-scale high with periods of erratic operation during STS-126. The flowmeter was flown in the de-pinned configuration during STS-127, STS-130, and will be flown the same way on STS-134. This is not an impact to flight operations. There is additional instrumentation that will provide insight into fuel cell operation.

## E. Miscellaneous (i.e. catch all category), cont.

### Equipment Replacements/Additions

STS-134 is the 25th flight of OV-105  
 Inclination: 51.6 degrees  
 Launch PAD: 39A/MLP 2  
 External Tank: S/N 122 (Super Light Weight Tank)  
 RSRM Set: RSRM-113: Left Side (A), Right Side (B)  
 SRB Assembly: BI-145  
 Orbiter Software: OI-34

### SSME Hardware<sup>1</sup>

Position Number	1(C)	2(L)	3(R)
Engine Number	2059	2061	2057
Engine Type	Block II	Block II	Block II
Last Hotfire	STS-130	STS-130	STS-130
Powerhead	6024	6026	6011
Main Injector	6025	6026	6009
MCC	6028	6031	6025
Nozzle	5012	5014	2033
Controller	AF45	AF57	(AF59)
HPFTP	8032R1	8218	8029R1
HPFTP R/L Deg. R	1860	1860	1860
LPFTP	6003	6104	2129
HPOTP	8322	(8221)	8214
HPOTP R/L Deg. R	1660	1660	1660
LPOTP	2329	6204	2430

NOTE: Items in parentheses have been changed out since the last hot-fire of the SSME.

SPACE TRANSPORTATION VEHICLE DIVISION FLIGHT READINESS REVIEW  
FRR DATA PACK  
STS-134 (OV-105)  
April 25, 2011