

# **Booster Standard Console Procedures**

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**Systems Division  
Mechanical, Booster, Maintenance  
& Crew Systems Branch**

**Final, Rev-G, PCN-1**  
April 19, 2005



National Aeronautics and  
Space Administration

**Lyndon B. Johnson Space Center**  
Houston, Texas



# BOOSTER STANDARD CONSOLE PROCEDURES

FINAL, REV-G

PCN-1

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1.2.1	2.1.3	2.2.4	3.2.1	4.1.9
1.2.3	2.1.4	2.2.5	3.2.2	
1.2.4	2.1.5	2.2.6	3.3.1	
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BOOSTER STANDARD CONSOLE PROCEDURES

FINAL, REV-G

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LYNDON B. JOHNSON SPACE CENTER  
HOUSTON, TEXAS



# SHUTTLE OPS

## BOOSTER STANDARD CONSOLE PROCEDURES

FINAL, REV-G, PCN-1

### PREFACE

This document has been prepared by the Booster Systems Group, Systems Division, NASA Lyndon B. Johnson Space Center, Houston, Texas. Information contained in this document represents the Booster Systems console procedures for STS missions as of August 30, 2006. Revisions to this document will be made as required.

Any questions or comments should be directed to DF55 / Andrew S. Hamilton, Mechanical, Booster, Maintenance & Crew Systems Branch, Booster Systems Group, (281) 244-7197.

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TITLE

NOMINAL SSME OPERATION

PURPOSE

This SCP describes the process used by Main Engine operators to monitor nominally operating engines during powered flight.

DESCRIPTION

- A. SSME ignition occurs at approximately T-6.6 seconds. Initially, the SSMEs throttle up to 100%. At approximately 4 seconds Mission Elapsed Time, the SSMEs throttle up to the mission power level (nominally 104.5%). Next, the SSMEs throttle down to prevent aerodynamic loads from damaging the vehicle. Once the maximum dynamic pressure flight region is complete, the SSMEs throttle up to the mission power level. Nominally, the SSMEs will remain at this power level (104.5%) until the vehicle exceeds 3.0 g's. At this point, the SSMEs throttle down to maintain a 3.0 g's acceleration. Finally, the SSMEs throttle down to the minimum power level (67%) in order to protect the MECO LO2 NPSP requirements. Figure 1.1.1-I shows a nominal SSME power level profile.
- B. The ME operator monitors the following items: ESW, shutdown limits, SSME shutdown pushbuttons, HPOTP and HPFTP discharge pressures and temperatures, HPOTP and HPFTP composite and/or synchronous vibration (depends on what is being downlisted - see Systems Briefs 1.6 and 1.19), HPOTP intermediate seal pressures, LPFTP discharge pressures and temperatures, MCC pressures (Pc), OPOV positions, FPOV positions, SSME delta tags, commanded and actual power levels, FID words, hydraulic supply pressures, SSMEC power sources (ACs), SSMEC electronics (DCUs, IEs, and OEs), SSME command and data paths, EIU MIA ports (1&4), GH2 outlet pressures, and GO2 outlet temperatures.
- C. The majority of the main engine data is found on the ME Ascent display. Other important displays include the DDD Panel, the PASS Header display, the FID display, the SSME Deltas display, and the OFS display (Ref. SCP 3.1.2, ME Console CRT Displays). Figure 1.1.1-II shows the Pass Header, the Main Engine, and the SSME Tags displays. The DDD Panel is shown in Figure 1.1.1-III. Another useful software tool is the RTPlot application.
- D. Off-nominal operation of the SSMEs is monitored using the following data: the main chamber pressures, the high pressure turbopump turbine discharge temperatures, the high pressure turbopump pump discharge pressures, low pressure fuel turbopump turbine discharge temperatures, and the OPOV and FPOV valve positions. These parameters are used to identify off-nominal SSME performance cases (Ref. SCP 2.1.1, SSME Performance Cases; and FR A5-110, SSME Performance Dispersion).

- E. Several redline parameters are available to protect against a catastrophic uncontained SSME shutdown. SSME redline processing consists of the following parameters: HPFTP Turbine Discharge Temperature, HPOTP Turbine Discharge Temperature, HPOTP synchronous vibration (if active), HPFTP synchronous vibration (if active), HPOTP Intermediate Seal Pressure, and MCC Pc. These redline parameters have both qualification limits and shutdown limits. A shutdown limit violation of a redline parameter on all qualified SSME sensors will result in an SSME shutdown (Ref. FR A5-2, Space Shuttle Main Engine Out and SCP 2.1.7, Engine Out With Limits Enabled). The HPOTP DP and the HPFTP DP are also considered redline sensors. However, these two parameters are not used for redline shutdown processing. Table 1.1.1-I shows typical redline parameter nominal values at 104.5%.
- F. Engine performance is mainly reflected through the main chamber pressure (MCC Pc) since it is proportional to SSME thrust. Consequently, the average MCC Pc is used to determine the SSME power level both in Mission Control and by the SSMEC. The SSME power level can also be determined by using the HPOTP discharge pressure. Therefore, two power level indications are available for the ME operator to monitor the SSME performance during a nominal flight. If the HPOTP discharge pressure is not available, an alternate power level is then calculated based on the GH2 Out P and the position that the associated GH2 Flow Control Valve.
- G. The ESW is shown on the Main Engine display (ESW is displayed in hexadecimal). The ESW is decoded on the DDD Panel for operational simplicity - Ref. SB 7.3 Engine Status Word (ESW).
- H. Nominally, the SSME shutdown limits are enabled and the limit shutdown switch is in the AUTO position. The AUTO switch position permits the GPCs to send LIMIT CONTROL INHIBIT commands and LIMIT CONTROL ENABLE commands to all three SSMECs. The limit shutdown switch position is displayed on the DDD panel. The SSME shutdown limit enable/inhibit status is shown on both the DDD panel and the ESW.

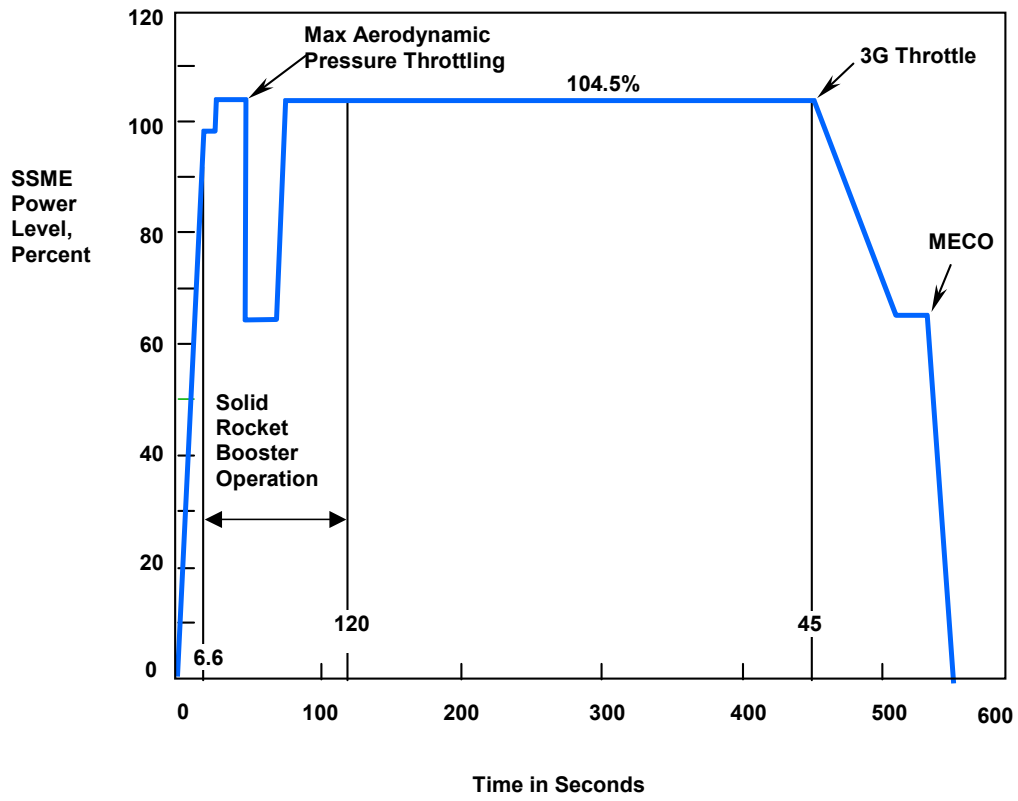


Figure 1.1.1-I. – SSME Typical Mission Power Level Profile



ddd panel				
FF3	FF2	FF4		
E	E	E		
<b>A</b>	<b>A</b>	<b>A</b>		
I	I	I		
<b>L S/D PB</b>		<b>C S/D PB</b>		<b>R S/D PB</b>
(FF 2)		(FF 1)		(FF 3)
(FF 3)		(FF 2)		(FF 4)
<b>LIM SW:</b>	AUTO	AUTO	AUTO	
<b>LIMITS:</b>	Enabled	Enabled	Enabled	
<b>PHASE:</b>	Start Prep	Start Prep	Start Prep	
<b>MODE:</b>	Purge Seq 3	Purge Seq 3	Purge Seq 3	
<b>STATUS:</b>	Engine OK	Engine OK	Engine OK	
<b>DCU A</b>	* L AC 2	* C AC 1	* R AC 3	
<b>DCU B</b>	L AC 3	C AC 2	R AC 1	
<b>EIU</b>	PORT 1	PORT 1	PORT 1	
<b>BYPASS</b>	PORT 4	PORT 4	PORT 4	
	AC BUS MON	AC BUS MON	AC BUS MON	
<b>STRING 1</b>	<b>STRING 2</b>	<b>STRING 3</b>	<b>STRING 4</b>	<b>STRING 5</b>
NBAT=1234				
<b>EPS BUS STATUS:</b>		<b>DSC STATUS:</b>	<b>MDM STATUS:</b>	
<b>SRB SEP</b>	AUTO	<b>PB</b>	<b>SEP</b>	
<b>ET SEP</b>	AUTO			
<b>DUMP</b>	--/--			
<b>WARNINGS/ALERTS:</b>		<b>PWR:</b>		<b>ABORTS:</b>
<b>AUTO TH</b>		<b>MEC 1</b>	ON	
		<b>MEC 2</b>	ON	
ISP data server connection established				

Figure 1.1.1-III. - DDD Panel

Redline Parameter	Nominal Value	Engine
MCC Pc AVG	2870 psi	Block II
HPOTP DP	3804 psi	Block II
HPFTP DP	5664 psi	Block II
HPOTP ISP	214 psi	Block II
HPFTP TDT	1601 R	Block II
HPOTP TDT	1221 R	Block II
HPOTP VIB	<2 G	Block II
HPFTP VIB	<2 G	Block II

Table 1.1.1-I – Predicted SSME Performance at 104.5% Power Level

REFERENCES

1. Space Shuttle Operational Flight Rules, Volume A, All flights, Final, PCN-2, Errata, NSTS-12820, June 25, 2004.
2. Booster Systems Briefs, Final, Rev F, JSC-19041
3. STS-101 NASA SSME Project Flight Readiness Review, February 17, 2000
4. Ascent/Entry Flight Techniques Panel, August 25, 2000
5. ICD-13M15000, SPACE SHUTTLE ORBITER VEHICLE/MAIN ENGINE, Rev AC-40, 4/14/04

TITLE

ME ACTIVITY TIMELINE/POSITION REPORTING

PURPOSE

The purpose of this SCP is to describe the reporting and console operations required at the ME console.

DESCRIPTION

This SCP contains the following ME timelines for nominal, RTLS, and TAL flights:

- TABLE 1.1.2-I. – PRELAUNCH TIMELINE - ME
- TABLE 1.1.2-II. – LAUNCH TIMELINE - ME
- TABLE 1.1.2-III. – POST-MECO TIMELINE - ME
- TABLE 1.1.2-IV. – RTLS TIMELINE - ME
- TABLE 1.1.2-V. – TAL TIMELINE - ME

Time indicated is based on MET. Flight specific times are provided by FDO. ME voice reports to the Booster Systems Engineer (BSE) are shown in quotation marks.

TABLE 1.1.2-I. – PRELAUNCH TIMELINE - ME

Time (min:sec)	Reports/Operations
T <sub>0</sub> – ~20:00	“Three engines in Purge 3” ESW = 4D
T <sub>0</sub> – ~04:30	“Three good SSME hydraulics”
T <sub>0</sub> – ~04:00	“Three engines in Purge 4” ESW = 51 “Limit Switch in Auto” “CCVs open”
T <sub>0</sub> – ~01:30	“Three engines ready” ESW = 59
T <sub>0</sub> – ~00:31	“Counting inside 31”
T <sub>0</sub> – ~00:06.6	“Ignition” ESW = 65 (Start Initiation)
__:__	“Throttle up” 0% < PL < 100%
T <sub>0</sub> – ~00:01.6	“Three at 100” PL = 100% “Mainstage” ESW = 85

TABLE 1.1.2-II. – LAUNCH TIMELINE – ME

Time (min:sec)	Reports/Operations
T <sub>0</sub>	Lift-off
__:__	“Throttle up” 100% < PL < 104%
__:__	“Three at __” (mission power level – nom. 104.5%), “Getting discharge pressures”
__:__	“Throttle down”
__:__	“Three at __” (first half of thrust bucket)
__:__	“Throttle down” (if req’d)
__:__	“Three at __” (second half of thrust bucket, if req’d)
__:__	“Throttle up”
__:__	“Three at __” (mission power level – nom. 104%)
T <sub>0</sub> + ~ 02:06	SRB SEP
__:__	2-Engine TAL. Any suspect engines? (If yes, which engine and why?)
__:__	Negative Return
__:__	Press-to-ATO
__:__	Single Engine Ops Three
__:__	Single Engine TAL
__:__	Press-to-MECO
__:__	Single Engine Press (Manual shutdown calls for loss of TVC, if req’d)
MECO – 2:00	“2 minutes to MECO. Check for underspeed.” (Manual throttle back to 67% at 2% propellant remaining, if req’d)
__:__	“3 g throttling on - all 3”
T <sub>0</sub> + ~08:00	Manual shutdown calls @ 23 K(if req’d)
__:__	“Fine count, good throttles” 3 eng. – “3 at 67” 2 eng. – “2 at 91”
T <sub>0</sub> + ~08:30	“MECO”, “MECO Confirmed”



TABLE 1.1.2-III. – POST MECO TIMELINE – ME

Time (min:sec)	Reports/Operations
Post ET SEP	“Expect dump on __ engines”
__: __	“SSME controller powerdown complete” INCO can be informed that the OPS recorder is no longer needed
T <sub>0</sub> + ~25:00	If SSME controller powerdown is not complete, tell Booster to inform INCO that the OPS recorder is still needed (INCO will stop the OPS recorder at this time unless instructed otherwise by Booster).

TABLE 1.1.2-IV. - RTLS TIMELINE – ME

Time (min:sec)	Reports/Operations
__: __	“C(L,R) engine out” (if req’d)
T <sub>0</sub> + 02:30 or 03:40	RTLS initiation (MM 601) (Report throttle changes and times)
__: __	RTLS powered pitch around (PPA) (Report throttle changes and times)
Prior to T <sub>0</sub> + 08:00	(Cycle Limits Inhibit/Enable/Auto if on 3 eng. RTLS)
__: __	Single-Engine RTLS (2 out red on the Traj display) (Go for Limits Enable/Auto, if req’d)
__: __	RTLS powered pitchdown (PPD) 3 eng. – “3 at 67” 2 eng. – “2 at 91”
__: __	$\alpha = -1$ , Manual shutdown calls (if req’d)
PPD + ~00:20	“MECO”, “MECO Confirmed”
MECO + ~ 00:14	ET SEP
Post ET SEP	“Expect dump on __ engines”
__: __	MOVs (3) – open @ MM 602
__: __	MOVs (3) – close @ Vrel ≤ 3800 ft/s

TABLE 1.1.2-V. – TAL TIMELINE – ME

Time (min:sec)	Reports/Operations
__:__	“C(L,R) engine out” (if req’d) Record the shutdown time
__:__	TAL initiation (Report throttle changes and times)
__:__	Single-Engine Ops Three
__:__	“3g throttling - all 3”
__:__	Manual shutdown calls @ 22.5 K (if req’d)
__:__	“Fine count, good throttles” 3 eng. – “3 at 67” 2 eng. – “2 at 91”
__:__	“MECO”, “MECO Confirmed”
MECO + ~00:21	ET SEP
Post ET SEP	“Expect dump on __ engines”
__:__	MOVs (3) – open @ MM 304 (no insight)
__:__	MOVs (3) – close @ Vrel < 5300 ft/s (no insight)

TITLE

NOMINAL MPS ASCENT OPERATION

PURPOSE

This SCP lists the parameters that the Main Propulsion System (MPS) console operator will monitor and describes typical performance of the associated systems during a nominal ascent.

PROCEDURE

- A. The MPS operator monitors helium supply systems, ET ullage pressurization systems, propellant manifold pressures and propellant low level sensors, SRB parameters, master events controllers (MECs), various valve and switch positions, and event indications including the SRB and ET separation events. The parameters associated with each of these tasks are mostly found on the MPS Ascent display, though some are also found on the PASS header, the Bilevel display, and the DDD Panel. Nominal SRB monitoring, and the associated parameters, are presented in SCP 1.2.2.

In the event that BFS is engaged, insight into each of these systems is reduced. The MPS operator will substitute the BFS Header and BFS MPS Ascent display for the PASS Header and MPS Ascent display.

- B. The helium supply systems for each SSME and the pneumatic system are monitored to ensure that sufficient helium is available to ensure safe SSME and MPS operations. These operations include pneumatic valve actuation during all phases of the mission and the following:
- SSME purge flow during engine start and mainstage
  - SSME purges during SSME cutoff
  - Propellant dumps
  - MPS purge flows for the prevention of contamination and hazardous gas concentration during ascent and entry.

The parameters used for monitoring the helium system include tank pressures, regulator pressures, tank temperatures, and valve positions. The MPS operator also monitors the BFS calculated values for tank pressure change rate (dP/dt) and the helium computation outputs for tank mass flow rate (mdot), interconnect status, leak type, recommended shutdown mode, time of depletion, and minimum tank pressures for each shutdown mode. The outputs of the helium comp are used to determine the necessary actions in the event of a helium leak. The HPOTP intermediate seal pressures give some indication of how well the intermediate seal helium purge is being supported. Off-nominal operations of the helium system during SSME

operation and propellant dump are covered in SCP 2.2.7, Helium Leak Isolation/Evaluation/Interconnection.

At liftoff, the helium supply tank pressures are approximately 4300 psia. The three engine helium supply tank pressures should steadily decline throughout the ascent to support the SSME purges (including the HPOTP intermediate seal purge). The pneumatic helium supply tank pressure should remain steady at a value between 4100 and 4500 psia throughout the ascent. At MECO, helium from the pneumatic tank is used to close the prevalves and usage from the pneumatic tank will be observed.

Interconnect statuses should be neither In Open nor Out Open throughout the ascent. The Left Engine Pneumatic Crossover valve will open immediately post MECO. In addition, if an engine is shutdown at MECO and its tank pressure is less than 2000 psia or is commfaulted by its associated FA MDM, the software will command the interconnect on that engine to In Open. The left engine In Open interconnect and the center and right engine Out Open interconnects will open after ET separation, and all interconnects will close again at MPS dump stop. This configuration of interconnects during the MPS dump allows helium from all tanks to support actuation of MPS valves and pressurized dump of the LO2 manifold. This configuration also provides redundant paths for the helium, one through the pneumatic system and one through the left engine helium system and the left engine crossover.

Prior to lift off (at T - 16 minutes) the crew takes all the helium isolation valve switches from the GPC position to the OPEN position. This prevents the GPCs or an MDM failure from inadvertently allowing the helium isolation valves to close during powered flight. Closing both helium isolation valves closing on a running engine will deprive the HPOTP intermediate seal of purging helium and results in a catastrophic uncontained failure of the HPOTP. The GPCs will stop commanding the isols open at the end of the propellant dump post MECO, but the valves will stay open since the switches are in the OPEN position. The helium isolation valves will close when the crew returns the helium isolation valve switches to the GPC position as part of the MPS PWRDN/ISOL procedure in the Post OMS 1 portion of the Ascent Checklist.

The engine helium regulator pressures will nominally operate at approximately 750 psig. The pressure transducers read absolute pressure, therefore the regulator pressure will be 15 psi higher at liftoff. This is because the regulators control the pressure with reference to ambient pressure (14.7 psia at sea level, 0 psia at orbit altitude). As the ambient pressure decreases during ascent, the indicated regulator pressure will decline to 750 psi. When the crew completes the MPS PWRDN/ISOL procedure in the Post OMS 1 portion of the Ascent Checklist, all the regulator pressures will bleed down, giving multiple expected master alarms.

Nominal HPOTP intermediate seal pressures at an SSME power level of 104% are approximately 205 psia for the Block II main engines. The Main Engine console operator has primary responsibility for the monitoring the intermediate seal pressures, but the MPS

operator will also monitor these parameters. In the event of a helium leak the MPS operator has an acute interest in the health and validity of the HPOTP intermediate seal pressure redline protection.

The BFS down-listed engine helium tank  $dP/dt$  is calculated as the drop in tank pressure over the last three cycles of the BFS helium pressure monitor sequence. The BFS helium pressure monitor sequence cycles at the rate of 1.04 Hz. Thus three cycles is 2.88 seconds and the units of  $dP/dt$  are psi/2.88seconds. The value of the  $dP/dt$  calculation is rounded to the nearest 10, and the nominal value displayed during ascent is 10. There may be momentary values of 0 or 20 due to rounding, but the  $dP/dt$  will return to the nominal value of 10. In informal discussions the units of  $dP/dt$  may be given as psi/3seconds.

The MPS operator monitors the BFS  $dP/dt$  and the helium computation output for the mass flow rate ( $\dot{m}$ ) from each tank. The BFS  $dP/dt$  is used by the crew to work helium leak isolation procedures (Ref. SCP 2.2.7). The  $\dot{m}$  value calculated on the ground by the helium computation has much better resolution than the BFS  $dP/dt$ , giving the mass flow rate from each tank in 0.001 lbm/sec increments. A nominal value of  $\dot{m}$  for each engine is approximately 0.040 lbm/sec. Mass flow rate above 0.045 or below 0.035 is cause for concern. If usage is low, the intermediate seal purge may not be properly supported, and the MPS operator will check the intermediate seal pressures for more information. If usage is high, it may be a helium leak, reference SCP 2.2.7 for more information. A helium leak is defined in the flight rules (Ref 1) as BFS  $dP/dt$  greater than 20 (30 or greater) for 3 seconds or  $\dot{m}$  greater than 0.055 after a mission elapsed time (MET) of 1 minute.

The helium comp outputs for interconnect status, leak type, times of depletion, and shutdown pressures are used in the management of helium leaks. See SCP 2.2.7, Helium Leak Isolation/Evaluation/Interconnection, for more information.

The total helium mass in the three engine tanks and the pneumatic tank is an output of the helium comp and is presented on the MPS Ascent and MPS Entry displays. This total mass will determine the availability of helium for the entry purges and valve actuation (Ref. SCP 2.2.8).

- C. Nominal operation of the external tank (ET) pressurization system is monitored using the following ET LO<sub>2</sub> and LH<sub>2</sub> data: ullage pressures, the 2-inch disconnect pressure, flow control valve power indications, and the ET vent valve positions. Net Positive Suction Pressure (NPSP) is an output of the Booster Operations Support Software (BOSS) Engine Performance Computation. NPSP is critical to the keeping the high pressure propellant pumps from cavitating (Ref. 2.), and the computed real-time value of LH<sub>2</sub> NPSP is used in the management of ET LH<sub>2</sub> ullage pressurization problems (Ref. 3).

There are no procedures for off-nominal performance of the ET LO<sub>2</sub> ullage pressurization system. LO<sub>2</sub> NPSP is much more sensitive to the LO<sub>2</sub> liquid level and vehicle acceleration and is therefore primarily a concern only during SSME shutdown from high power levels due to LOX low-level cutoff. See references 2 and 4 for more information. While the MPS

operator has insight into LO<sub>2</sub> ullage pressures and FCV open power indications no nominal calls or off-nominal actions are taken based on this insight. The LO<sub>2</sub> FCVs are shimmed to a fixed position and no longer actively controlled.

Engine operation is sensitive to ET LH<sub>2</sub> ullage pressurization problems, therefore the MPS operator constantly monitors the status of the ET LH<sub>2</sub> ullage pressurization system. Typical performance of the ET LH<sub>2</sub> ullage pressurization system includes the following:

Three flow control valve (FCV) power indication will cycle on and off in response to their respective ullage pressure transducers to maintain ullage pressure between 32 and 34 psia. A typical signature early in the ascent, with small ullage volume, would be one FCV open and the others opening briefly when the ullage pressures decline to the lower side of the control band. Late in the ascent, as ullage volume gets large, the other flow control valves will open for longer periods or stay open. Which FCV opens first depends on slight biases of the ullage pressure transducer associated with a particular FCV. The FCV associated with the lowest measured pressure will open first, with the FCV associated with the middle valued pressure cycling to control ullage pressure. The last FCV to open will be associated with the pressure transducer giving the highest measured pressure. It may happen that two or more ullage pressure transducers give exactly the same value, in which case the associated FCVs will cycle together.

The primary cue for GH<sub>2</sub> FCV position is the FCV power indication. A verification of FCV position change is the change in the GH<sub>2</sub> outlet pressure from the corresponding engine at the same time that the FCV open indication appears. The GH<sub>2</sub> Out P should drop by 100 to 200 psi when the FCV open indication appears and the valve position changes from closed to open. The console tool RT Plot has two plots that are useful in monitoring the health of the ET LH<sub>2</sub> ullage pressurization system. First, the plot of GH<sub>2</sub> Out Pressure shows a history of FCV actuation. The plot of ullage pressures and NPSP values shows the ullage pressure cycling within the control band in response to FCV actuation and the NPSP trending information is useful during management of an ET LH<sub>2</sub> ullage pressurization problem. For off-nominal performance see SCP 2.2.4, ET LH<sub>2</sub> Ullage Pressurization Failures/NPSP Problem.

- D. The LO<sub>2</sub> and LH<sub>2</sub> manifold pressures along with the LO<sub>2</sub> and LH<sub>2</sub> engine inlet pressures are monitored during powered flight and ET separation for possible line over pressurization or SSME inlet under pressurization conditions. These indications are available on the MPS Ascent display and the Entry display. During ascent, the manifold pressures will change with propellant liquid level and the acceleration of the vehicle.

These manifold and inlet pressures are also monitored during propellant dumps to help determine if the dump was satisfactory. During on orbit and entry, the same pressures are observed for indications of proper vacuum inert and purging. Engine inlet pressures correspond to the manifold pressures when the prevalues are open.

In the event of an engine shutdown prior to MECO, the prevalues on that engine will close and engine inlet pressures are used to determine if the shutdown ruptured any of the propellant lines downstream of the prevalues. Low engine inlet pressures with the prevalues closed indicate ruptured propellant lines and crew will be asked to perform a dump inhibit for the appropriate propellant on that engine prior to MPS dump start (Ref. 5).

ET propellant LO<sub>2</sub> and LH<sub>2</sub> 5 percent, low level cutoff sensors, and the low level arm command are used to monitor the depletion of the propellants. At approximately 30 seconds prior to MECO, the LO<sub>2</sub> 5 percent sensor will indicate dry and the MPS operator will report "LOX at 5". The LH<sub>2</sub> 5 percent sensor will nominally indicate dry about 10 seconds later and the MPS operator will report "Fuel at 5". The timing of these events will change if the main engines are experiencing off-nominal performance. The low-level cutoff protection armed indication nominally appears when the current calculated vehicle mass becomes less than an I-loaded value, referred to as the "Arming Mass". This occurs at approximately MECO -15 seconds and the MPS operator reports "Arm". The low-level cutoff logic will be enabled ("armed"), and the MPS operator will get the ARM indication. The low-level cutoff logic is also armed if two SSMEs have shut down.

At MECO, the MPS operator will watch for propellant low-level sensors indicating dry. If valid low-level sensors indicate dry at MECO, the MPS operator will call "LOX (or fuel) low level cutoff". If the low level sensors indicate dry a second or two after MECO, it is probably due to sloshing of the propellant in the manifold as flow is abruptly stopped. If it is due to sloshing, the low level sensors that indicated dry will alternately indicate dry and wet. The MPS operator must discern the difference between a low level cutoff and sloshing and only make a low level cutoff call when appropriate. A vehicle underspeed called by the Flight Dynamics Officer at MECO is a confirming cue of a low level cutoff.

- E. Various valve positions and event indications are monitored throughout the mission to ensure proper performance of all automatic sequences and manual operations. Refer to SCP 1.2.3, MPS Activity Timeline/Position Reporting for the nominal events, indications, and calls. Some of the valve indications on the MPS Ascent display show that power is applied to the appropriate valve and some show microswitch indications sensing the actual position of the valve. The Bilevel display gives more complete data on these valves including microswitch indications, cockpit switch positions, valve power, and in some cases power from individual Remote Power Controllers (RPC) relaying power to that valve. The Bilevel display is used for failure analysis in the event that a valve does not respond as expected.
- F. The master events controllers (MEC) power switches are in the ON position throughout the ascent. Those events and switch positions associated with SRB and ET separation are monitored to ensure proper separations. The MECs are powered off by the crew at approximately MET 1:30:00 in the Post Insertion checklist. MEC power switch position indications are available on the MPS Ascent display and the DDD panel. Indications for ET separation and SRB separation sequences are available on the MPS Ascent display and the Bilevel display.

- G. The SRB parameters are used to monitor the health of the SRBs during first stage. The SRB chamber pressures (Pc) are used to determine if a delayed SRB SEP will occur (ref. SCP 1.2.2, Nominal SRB Operations, and 2.2.2 SRB Pc Sensor Failure). The SRB fuel supply module (FSM) pressures, SRB HPU turbine speeds, and hydraulic pressures are monitored to determine SRB thrust vector control (TVC) health (ref. SCP 1.2.2, Nominal SRB Operations, and SCP 2.2.2, SRB TVC Redundancy loss).
- H. In the event that BFS is engaged, insight into each system is reduced. The MPS operator will primarily work from the BFS Header display, the BFS MPS Ascent display, and the BFS MPS RT-Plot display, though some indications on the Bilevel display and the DDD panel will still be valid.

Many of the parameters on the MPS displays are fed directly from their Dedicated Signal Conditioners (DSC) to the Pulse Code Master Modulation Unit (PCMMU) for downlisting. The availability of these parameters is dependent upon the Telemetry Format Load (TFL) used in the PCMMU but not directly dependent upon PASS versus BFS control. A rule of thumb is that parameters with MSIDs ending with an A or an E are still available when BFS is engaged. This is true in most cases. Other PASS parameters will not be available when BFS is engaged, however many of these parameters have analogous terms in the BFS. BFS analogs to PASS parameters are substituted as appropriate on the BFS displays.

When BFS is engaged, the MPS operator will lose the following insight: For the helium system, the MPS operator will lose insight into HPOT intermediate seal pressures. For the ET ullage, manifolds, and low level protection system, the MPS operator will have one ullage pressure indication (instead of 3) per propellant, will lose insight into inlet pressures, and will lose insight into the low level sensors. For valve position there will be no pre-vent open microswitch indications and no insight into feedline disconnects and feedline disconnect latches. The only insight into the SRBs is one chamber pressure indication per SRB. The BFS has its own set of parameters for the SRB separation and ET separation sequences that are monitored on the BFS MPS Ascent display or the Bilevel display.

## REFERENCES

1. Space Shuttle Operational Flight Rules, Final PCN-3, January 13, 2005, NSTS-1282
2. Booster Systems Briefs, Rev F, JSC-19041; Section 3.4, MPS Low LO2 and LH2 NPSP.



## TITLE

### NOMINAL SRB OPERATIONS

## PURPOSE

This SCP describes the MPS console operator's procedure for monitoring SRB operations.

## PROCEDURES

- A. The telemetry downlink parameters required for this procedure are listed in Tables 1.2.2-I, 1.2.2-II, and 1.2.2-III. These parameters appear on the MPS Ascent display, Bilevel display, DDD Panel, and BFS MPS Ascent display.
- B. Prelaunch monitoring of SRB operations begins at T -5 minutes, when the Safe and Arm (S&A) device in the igniter moves from the safe position to the arm position. The MPS operator will report to Booster "SRB's are armed" when this is observed on the MPS Ascent display. Refer to Launch Commit Criteria (LCC) SRM-01 and SRM-02 (Ref. 1).

The SRB Thrust Vector Control (TVC) system becomes active at approximately T -26 seconds. At this time the HPU Isolation valves will open, and the primary gas generator control valve will begin to cycle (secondary gas generator control valve will already be open). The MPS operator will report to Booster "HPU Isols open" when he/she observes this complete on the MPS Bilevel display. The four SRB HPU turbine speeds will rise to approximately 72 kRPM (shown on MPS Ascent display) and the MPS operator will report to Booster "Four good SRB turbine speeds". Within seconds, the four SRB HPU hydraulic pressures will rise to approximately 3200 psia accompanied by Primary Pressure OK indications, and the MPS operator will report to Booster "Four good SRB hydraulics". See SRB LCCs BTVC-05, BTVC-07, BTVC-08, BTVC-09, and BTVC-16 (Ref. 1).

- C. Ascent monitoring of SRB operation begins at liftoff. The MPS operator will observe that SRB chamber pressure rises very quickly to approximately 900 psia, indicating that SRB ignition and liftoff have occurred. Throughout first stage the MPS operator will monitor chamber pressures and the health of the HPUs. MPS monitoring of the SRBs ends with the SRB separation sequence.

A graph of typical (actual data from STS-103) chamber pressure ( $P_c$ ) versus mission elapsed time (MET) is plotted in Figure 1.2.2-I. All three chamber pressures on each SRB are displayed on the MPS Ascent display. The BFS selected mid-value  $P_c$  for the left and right SRB's are displayed on the BFS MPS Ascent display.

The MPS operator will monitor the general trending of SRB chamber pressures, but will not try to verify that the chamber pressures are tracking the nominal plot given in Figure

1.2.2-I. They will monitor that the six chamber pressures (three on each SRB) are in reasonable agreement. If the one or more chamber pressure indications varies significantly from the others, then it is a suspected sensor failure and must be evaluated for possible impacts to the SRB Separation sequence. Refer to SCP 2.2.1, SRB Pc Sensor Failure, for more information.

- D. Parameters for monitoring the health of the SRB HPUs include Fuel Supply Module (FSM) pressures, HPU turbine speeds, hydraulic pressures, and primary pressure ok indications. These parameters are displayed on the MPS Ascent display and are listed in Table 1.2.2-I. The nominal FSM pressure decays from 375 psig at HPU startup to above 260 psig at SRB separation. Nominal FSM pressures are plotted as a function of time in Figure 1.2.2-II. Nominal turbine speeds are 72 kRPM +/- 8% (Ref 2). Nominal hydraulic supply pressures are maintained at 3200 +/- 50 psig. In the event that the hydraulic pressure drops below 2050 psig +/- 150 psig, the appropriate SRB switching valve automatically switches to the secondary position (Ref 3). In addition to the low hydraulic pressure, the appropriate primary pressure FAIL indication appears on the MPS Ascent display and provides a second cue that the left or right tilt or rock hydraulic power unit (HPU) has been isolated, and the actuator has been switched to operate on the remaining HPU. In this case, both the tilt and the rock actuators operate on the remaining HPU. Normally, HPU A supplies the rock actuator and HPU B supplies the tilt actuator. A third indication of the isolation is that the remaining HPU turbine will speed up to 79.2 kRPM. See Figure 1.2.2-III for rock and tilt axes orientation. Refer to SCP 2.2.2, SRB TVC Redundancy Loss, for more information.

The MPS operator monitors trending of the FSM pressures, but will not verify that FSM pressure are tracking the nominal plot given in Figure 1.2.2-II. Rather, they will monitor that the four FSM pressures are in reasonable agreement. If one of the FSM pressures diverges from the others, then it is either a sensor failure or an actual failure of the FSM. An actual failure of the FSM such that FSM pressure is less than 80 psig should be accompanied by failure of the associated hydraulic system.

If an HPU fails, the flight director (FLT) and Guidance, Navigation & Control (GNC) Officer should be informed "right (left) SRB hydraulic supply Alpha (Bravo) has failed, redundancy loss only."

- E. The SRB separation sequence begins at an MET of 1:40. SRB separation sequence normally commences when the midvalue select Pc on both SRBs is less than 50 psia. Both SRB's should reach 50 psia within 5.0 seconds (I-load V97U9761C, MAX SRB SEP CUE DIFRNTL) of each other. SRB separation will be delayed if the SRB sep sequence determines that more than five seconds have elapsed between the midvalue Pc of the right and left SRBs reaching 50 psia (Ref. 4,5). The Pc's less than 50 psia and the five second check ensure that the SRB's are burnt out so that a thrust imbalance between the left and right SRB's does not occur, possibly causing loss of vehicle control and/or structural failure. At 50 psia, an SRB may produce approximately 200,000 lbs of thrust, but at SEP command, each SRB's thrust is less than 80,000 pounds. If the 5 second Pc check is not

met, the PASS software will delay separation until the I-loaded backup cue (V97U9751C) is reached. Typically, the value of this I-load is 131.3 seconds, resulting in an 11 second delay and very low thrust is guaranteed. The BFS does not have a maximum time requirement between RH and LH SRB midvalue Pc's < 50 psia and will initiate the separation sequence as soon as the Pc's on both SRBs are less than 50 psi. Refer to SCP 2.2.1, SRB Pc Sensor Failure (Ref. 6), for Pc sensor failures and their impacts on the SRB separation sequence.

Indications appear on the MPS displays when the SRB separation sequence is initiated and SRB separation is commanded. The MPS operator reports these events to the Booster operator with the calls "Pc's < 50" and "SRB sep" respectively. The PASS and BFS SRB SEP events indicated on the MPS Ascent, DDD Panel, and BFS MPS Ascent displays are listed in Tables 1.2.2-II and 1.2.2-III.

- F. SRB monitoring in BFS is limited to the left and right SRB mid value Pc's. The SRB SEP sequence is the same as the PASS except for the absence of the 5.0 second time compare limit for the decay of the mid-value Pc's below 50 psia (Ref. 6, SCP 2.2.1, SRB Pc Sensor Failure).

TABLE 1.2.2-I - SRB PERFORMANCE PARAMETERS

Display *	MSID	Name**	Normal operating range	Units	Remarks
A	B55X1842X	L IGN S&A Armed	1	Discrete	At T-5 minutes
B	B46X1851X	L Isol A Open	1	Discrete	At T-26 seconds
B	B46X1853X	L Isol A Closed	0	Discrete	
B	B46X1852X	L Isol B Open	1	Discrete	
B	B46X1854X	L Isol B Closed	0	Discrete	
B	B46X1862X	L Prim Cntl Vlv A Op	Cycling	Discrete	
B	B46X1864X	L Prim Cntl Vlv B Op	Cycling	Discrete	
B	B46X1861X	L Secd Cntl Vlv A Op	1	Discrete	
B	B46X1863X	L Secd Cntl Vlv B Op	1	Discrete	
A	B47P1300C	L SRB Pc 1	0 - 950	psia	SEP SEQ starts when midvalue of 3 pressures is 50 psia
A	B47P1301C	L SRB Pc 2	0 - 950	psia	
A	B47P1302C	L SRB Pc 3	0 - 950	psia	
C	V98P1740C	L SRB Pc	0 - 950	psia	
A	B46P1305C	L FSM A Press	135 - 400	psia	HPU will fail for FSM P<80 psia
A	B46P1306C	L FSM B Press	135 - 400	psia	
A	B46R1408C	L HPU A TURB SPD	72 +/- 5.8	KRPM	
A	B46R1409C	L HPU B TURB SPD	72 +/- 5.8	KRPM	
A	B58P1303C	L HYD SUP A P	3000 - 3250	psig	
A	B58P1304C	L HYD SUP B P	3000 - 3250	psig	
A	B58X1859X	L TILT PRI P OK	1	Discrete	PASS discrete
A	B58X1860X	L ROCK PRI P OK	1	Discrete	PASS discrete

\* Letters in the Display column indicate where each parameter may be found:

- A MPS Ascent display
- B Bilevel display
- C BFS MPS Ascent display
- D DDD Panel

\*\* The names listed for these parameters are provided for convenience and may or may not agree precisely with the names given in any or all of the following: Master Measurements List, SSSH (Ref. 2), Lockheed Flows (Ref. 4), or FSSR (Ref. 5)

Table continued on next page

TABLE 1.2.2-I - SRB PERFORMANCE PARAMETERS (CONT.)

Display *	MML	Name**	Normal operating range	Units	Remarks
A	B55X2842X	R IGN S&A Armed	1	Discrete	At T-5minutes
B	B46X2851X	R Isol A Open	1	Discrete	At T-26 seconds
B	B46X2853X	R Isol A Closed	0	Discrete	
B	B46X2852X	R Isol B Open	1	Discrete	
B	B46X2854X	R Isol B Closed	0	Discrete	
B	B46X2862X	R Prim Cntl Vlv A Op	Cycling	Discrete	
B	B46X2864X	R Prim Cntl Vlv B Op	Cycling	Discrete	
B	B46X2861X	R Secd Cntl Vlv A Op	1	Discrete	
B	B46X2863X	R Secd Cntl Vlv B Op	1	Discrete	
A	B47P2300C	R SRB Pc 1	0 - 950	psia	SEP SEQ starts when midvalue of 3 pressures is 50 psia
A	B47P2301C	R SRB Pc 2	0 - 950	psia	
A	B47P2302C	R SRB Pc 3	0 - 950	psia	
C	V98P1741C	R SRB Pc	0 - 950	psia	
A	B46P2305C	R FSM A Press	135 - 400	psia	HPU will fail for FSM P<80 psia
A	B46P2306C	R FSM B Press	135 - 400	psia	
A	B46R2408C	R HPU A TURB SPD	72 +/- 5.8	KRPM	
A	B46R2409C	R HPU B TURB SPD	72 +/- 5.8	KRPM	
A	B58P2303C	R HYD SUP A P	3000 - 3250	psig	
A	B58P2304C	R HYD SUP B P	3000 - 3250	psig	
A	B58X2859X	R TILT PRI P OK	1	Discrete	PASS discrete
A	B58X2860X	R ROCK PRI P OK	1	Discrete	PASS discrete

\* Letters in the Display column indicate where each parameter may be found:

- A MPS Ascent display
- B Bilevel display
- C BFS MPS Ascent display
- D DDD Panel

\*\* The names listed for these parameters are provided for convenience and may or may not agree precisely with the names given in any or all of the following: Master Measurements List, SSSH (Ref. 2), Lockheed Flows (Ref. 4), or FSSR (Ref. 5)

TABLE 1.2.2-II - PASS SRB SEPARATION PARAMETERS

Display *	MSID	Name**	Normal value	Units	Remarks
A,B,D	V90X7570X	SRB SEP AUTO ENABLE	1	Discrete	Switch
A,B,D	V90X7571X	SRB SEP MAN/AUTO ENBL	0	Discrete	Switch
A,B,D	V90X7572X	SRB SEP INIT CMD	0	Discrete	Pushbutton
A,B,D	V90X8333X	SRB SEP INIT	1	Discrete	sequence initiated
B	V90X8340X	SRB SEP INHIBIT	0	Discrete	***
A,B,D	V90X8331X	SRB SEP CMD	1	Discrete	sequence complete

\* Letters in the Display column indicate where each parameter may be found:

- A MPS Ascent display
- B Bilevel display
- C BFS MPS Ascent display
- D DDD Panel

\*\* The names listed for these parameters are provided for convenience and may or may not agree precisely with the names given in any or all of the following: Master Measurements List, SSSH (Ref. 2), Lockheed Flows (Ref. 4), or FSSR (Ref. 5)

\*\*\* The SRB Sep inhibit portion of the SRB Sep Sequence compares vehicle rates to I-loaded limit values. If the vehicle rates exceed these values, then SRB separation will be inhibited. These I-loaded limits are set very broad, effectively no-opting this leg of the software.

TABLE 1.2.2-III - BFS SRB SEPARATION PARAMETERS

Display *	MSID	Name**	Normal value	Units	Remarks
B,C	V98X0742X	SRB SEP MAN/AUTO	0	Discrete	Switch
B,C	V98X0743X	SRB SEP INIT CMD	0	Discrete	Pushbutton
B	V98X0744X	SRB SEP ARM CMD	1	Discrete	
B,C	V98X3532X	SRB SEP INIT	1	Discrete	
B,C	V98X3534X	SRB SEP CMD	1	Discrete	

\* Letters in the Display column indicate where each parameter may be found:

- A MPS Ascent display
- B Bilevel display
- C BFS MPS Ascent display
- D DDD Panel

\*\* The names listed for these parameters are provided for convenience and may or may not agree precisely with the names given in any or all of the following: Master Measurements List, SSSH (Ref. 2), Lockheed Flows (Ref. 4), or FSSR (Ref. 5)

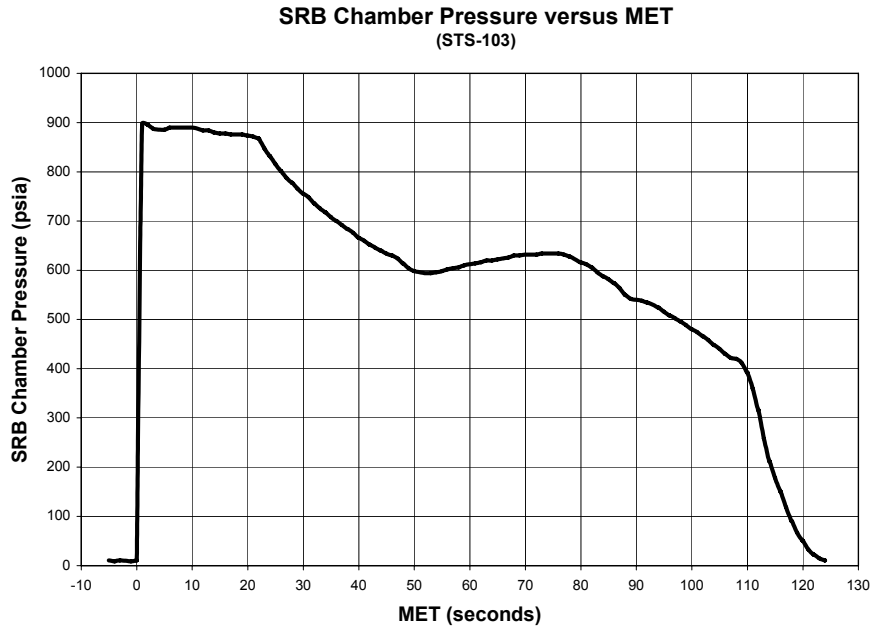


Figure 1.2.2 - I -Chamber Pressure Versus MET

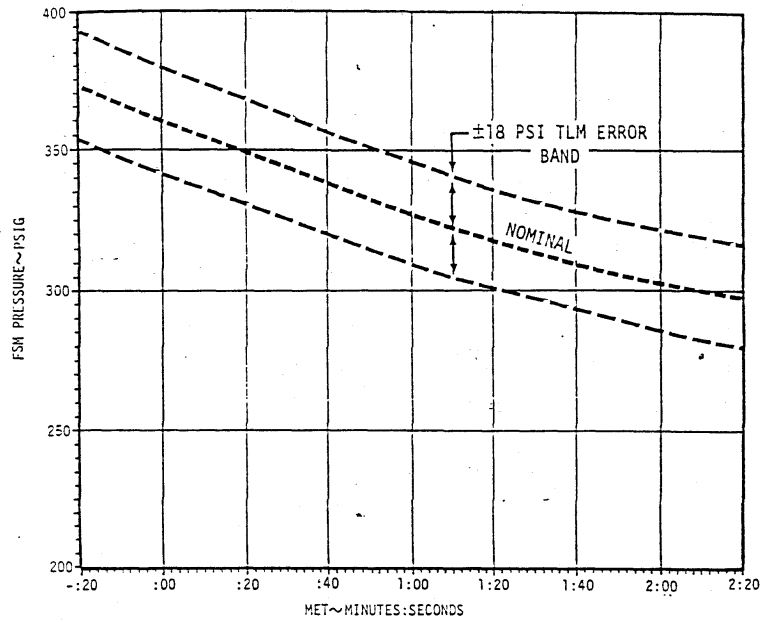


Figure 1.2.2-II - Fuel Supply Module Pressure Versus MET

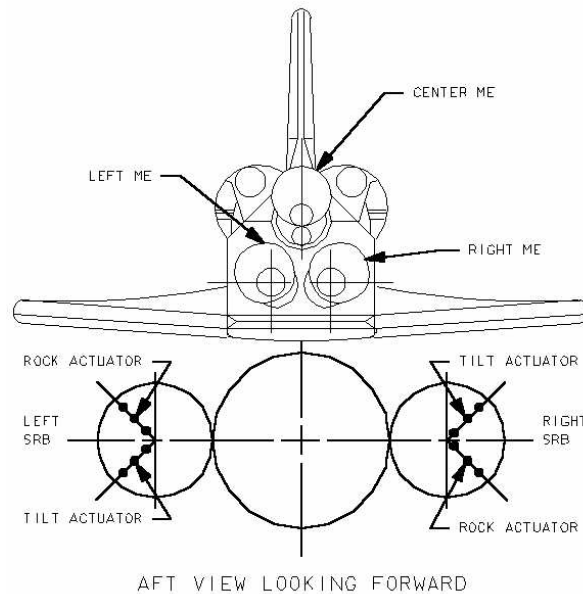


Figure 1.2.2-III - SRB Actuator Orientation (Ref. 7)

REFERENCES

1. Shuttle Launch Commit Criteria and Background Document, Rev G, Chg No 41, NSTS 16007.
2. Space Shuttle Systems Handbook, Rev F; Drawing 10.2, Sheet 1 of 2, Zone A-5, Note 6.
3. Space Shuttle Systems Handbook, Rev F; Drawing 9.14, Sheet 1 of 1, Zone A-4, Note 9.
4. Redundant Computer Set Logic Flow Diagrams Sequencing OI-27; SRB Separation Sequence 4.115.
5. Functional Subsystem Software Requirements (FSSR) GNC, Sequence Requirements, STS 83-0026-27; SRB Separation Sequence 4.115.
6. Booster Systems Standard Console Procedures, Final, Rev. G, JSC-17239; SCP 2.2.1.
7. Space Shuttle Systems Handbook, Rev F, Drawing 9.14, Sheet 1 of 1, Zone N-7.



TITLE

MPS ACTIVITY TIMELINE/POSITION REPORTING

PURPOSE

This SCP contains the timelines for MPS activity that occur from prelaunch to rollout for nominal, RTLS, and TAL flights. MPS voice reports to the Booster position are shown in quotation marks.

DESCRIPTION

The timeline consists of six tables:

- TABLE 1.2.3-I.- PRELAUNCH TIMELINE - MPS ( $T_0$ -16 minutes to  $T_0$ )
- TABLE 1.2.3-II.- LAUNCH TIMELINE - MPS ( $T_0$  through MPS dump)
- TABLE 1.2.3-III.- POST-MECO TIMELINE - MPS (covers first vacuum inert)
- TABLE 1.2.3-IV.- ENTRY TIMELINE - MPS (on-orbit preparation for entry through rollout)
- TABLE 1.2.3-V.- RTLS TIMELINE - MPS (from RTLS call through rollout)
- TABLE 1.2.3-VI.- TAL TIMELINE - MPS (from MECO through rollout)

The timelines include nominal observations, nominal voice reports, and notes giving additional information.

PROCEDURE

During Pre-launch operations, at T - 5 minutes, the MPS valve positions are as follows:

- LO2 Prevalves - open, LH2 Prevalves - closed
- LO2 and LH2 Feedline Disconnects - open and latched
- LO2 and LH2 Outboard Fill/Drain Valves - open
- LO2 Inboard Fill/Drain Valve - open, LH2 Inboard Fill/Drain Valve - closed
- LH2 Topping Valve - open, LH2 Backup Dump Valves - closed
- LO2 and LH2 Feedline Relief Isolation valves - closed
- LO2 Overboard Bleed Valve - open, LO2 POGO Valves - closed

TABLE 1.2.3-I.- PRELAUNCH TIMELINE - MPS

Time (min:sec)	Reports/Operations	Display
T <sub>0</sub> – 16:00	<p><u>Observations:</u> Per the MPS He RECONFIG procedure (Ref. 1a) the crew takes the MPS Helium Isolation valve switches (6) and the Pneumatic Helium Isol switch to the open position.</p> <p><u>Report:</u> “MPS helium reconfiguration complete.”</p>	Bilevel
T <sub>0</sub> – 5:00	<p><u>Observations:</u> Left and Right SRB igniters move to the Arm position.</p> <p><u>Report:</u> “SRB’s Armed.”</p>	MPS Ascent
T <sub>0</sub> – 04:55	<p><u>Observations:</u> LO<sub>2</sub> Replenish Valve (GSE) closes without Booster insight, LO<sub>2</sub> Drainback starts.</p> <p>At T<sub>0</sub> – 04:48, LO<sub>2</sub> inboard fill/drain valve closes.</p> <p><u>Report:</u> “LOX inboard closed, drainback start.”</p>	MPS Ascent
T <sub>0</sub> – 04:15	<p><u>Observations:</u> ET LO<sub>2</sub> vent valve closes</p> <p><u>Report:</u> “LOX vent closed.”</p>	MPS Ascent
T <sub>0</sub> – 02:20	<p><u>Observations:</u> ET LO<sub>2</sub> ullage pressure indications rise to between 19.3 and 22.5 psig (Ref. 2a).</p> <p><u>Report:</u> “LOX tank at flight pressure.”</p>	MPS Ascent
T <sub>0</sub> – 01:55	<p><u>Observations:</u> ET LH<sub>2</sub> vent valve closes.</p> <p>Several seconds later the LH<sub>2</sub> topping valve closes.</p> <p><u>Report:</u> “Fuel vent closed,...topping closed.”</p>	MPS Ascent
T <sub>0</sub> – 01:30	<p><u>Observations:</u> ET Fuel tank pressure rises to between 45.6 and 47.5 psia (Ref. 2b).</p> <p><u>Report:</u> “Fuel tank at flight pressure.”</p>	MPS Ascent

Table continued on next page.

TABLE 1.2.3-I.- PRELAUNCH TIMELINE - MPS, Continued

Time (min:sec)	Reports/Operations	Displays
T <sub>0</sub> – 00:48	<p><u>Observations:</u> LO2 and LH2 outboard fill/drain valves close.</p> <p><u>Report:</u> “Outboards closed.”</p>	MPS Ascent
T <sub>0</sub> – 00:28 Through ~T <sub>0</sub> – 00:28	<p><u>Observation:</u> All four SRB Hydraulic Power Unit (HPU) fuel isolation valves open.</p> <p><u>Report:</u> “HPU isols open”</p> <p><u>Observation:</u> All four HPU turbine speeds increase to between 66.2 and 77.8 kRPM (Ref. 2c).</p> <p><u>Report:</u> “Four good turbine speeds.”</p> <p><u>Observation:</u> All four hydraulic pressures increase to between 2800 and 3486 psia (Ref. 2d). All four Primary Hydraulic Pressure OK indications change from “FAIL” to “OK” (Ref. 2e).</p> <p><u>Report:</u> “Four good SRB hydraulics.”</p>	<p>Bilevel</p> <p>MPS Ascent</p> <p>MPS Ascent</p>
T <sub>0</sub> – 00:12.	<p><u>Observation:</u> Position indicators for both LO2 POGO Recirculation Valves go from closed to open.</p> <p><u>Report:</u> “POGOs open.”</p>	MPS Ascent
T <sub>0</sub> – 00:09	<p><u>Observation:</u> All three fuel prevalues open. The LO2 Overboard Bleed valve closes.</p> <p><u>Report:</u> “Fuel prevalues, overboard bleed.”</p>	MPS Ascent
T <sub>0</sub>	<p><u>Observation:</u> Six SRB chamber pressures rise to approximately 900 psia.</p> <p><u>Report:</u> No Report. The main engine console operator will be giving statuses at this time.</p>	MPS Ascent

TABLE 1.2.3-II.- LAUNCH TIMELINE - MPS

Time (min:sec)	Reports/Operations	Displays
T <sub>0</sub> + 02:00	<p><u>Observations:</u> SRB chamber pressures decline to less than 50 psia and the indication (INIT) appears that the SRB sequence has initiated.</p> <p><u>Report:</u> "PC's less than 50."</p>	MPS Ascent
T <sub>0</sub> + 02:06	<p><u>Observations:</u> SRB separation command indication (CMD) appears.</p> <p><u>Report:</u> "SRB sep."</p>	MPS Ascent
T <sub>0</sub> + ~07:54	<p><u>Observation:</u> The LO2 5 percent liquid level indication appears.</p> <p><u>Report:</u> "LOX at 5."</p>	MPS Ascent
T <sub>0</sub> + ~08:02	<p><u>Observation:</u> The LH2 5 percent liquid level indication appears.</p> <p><u>Report:</u> "Fuel at 5."</p>	MPS Ascent
T <sub>0</sub> + ~ 08:20	<p><u>Observation:</u> The propellant low level cutoff logic armed indication appears.</p> <p><u>Report:</u> "Arm command."</p>	MPS Ascent
MECO	<p><u>Observations:</u> Verify there was no low level cutoff. Indication of a low level cutoff is all qualified sensors indicating dry prior to the MECO CONFIRMED flag being set. The LO2 prevalves close immediately, followed by fuel prevalves closing.</p> <p><u>Report:</u> "Prevalves closed." (report after the ME operator has reported "MECO Confirmed")</p> <p><u>Note:</u> Left Engine Crossover valve opens at this time to help support prevalve actuation, but no report is given until the entire helium system configuration is verified at MECO + 20 seconds.</p> <p><u>Note:</u> In Open interconnect will be powered at this time for any engine that meets the following criteria:            Engine 1(2,3) fail flag = false, and one of the following            1) MDM FA1 (2,3) commfaulted            2) Engine 1(2,3) helium tank P &lt; 2000 psia.            This assures that an engine running to MECO but low on helium has enough helium to pressurize the POGO accumulator during shutdown. No report required.</p>	MPS Ascent

Table continued on next page.

TABLE 1.2.3-II.- LAUNCH TIMELINE – MPS, continued

Time	Reports/Operations	Displays
MECO + 00:08.6	<u>Observations:</u> LO2 and LH2 17 inch disconnects close.	MPS Ascent
	<u>Report:</u> “Disconnects closed.”	
	<u>Observations:</u> LO2 and LH2 relief isolation valves open.	MPS Ascent
	<u>Report:</u> “Relief isols open.”	
MECO + 00:13.4	<u>Observations:</u> The backup dump valves open.	MPS Ascent
	<u>Report:</u> “Back-up dump valves open.”	
MECO + 00:16	<u>Note:</u> SSME fuel bleed valves open, but MPS operator has no insight.	
MECO +00:19.44	<u>Observations:</u> The ET separation command indication (CMD).	MPS Ascent
	<u>Report:</u> “ET sep.”	
MECO +00:22.0	<u>Observations:</u> The left engine crossover valve opened at MECO. Now the Left In Open, Center Out Open and Right Out Open indications appear.	MPS Ascent
	<u>Report:</u> “Good helium config.”	
	<u>Observations:</u> Verify manifold pressures are approximately 70 psia for LOX and 20 psia for Fuel.	MPS Ascent
	<u>Report:</u> “Good manifold pressures.”	

Table continued on next page.

TABLE 1.2.3-II.- LAUNCH TIMELINE – MPS, concluded

Time (min:sec)	Reports/Operations	Displays
Dump Start (MECO + 02:02)	<p><u>Observations:</u> LO2 and LH2 prevalues open, LH2 inboard and outboard fill/drain valves open, LH2 topping valve open, LO2 manifold repress valves powered open. Manifold pressures drop to approximately 20 psia for LOX and 0 psia for Fuel.</p> <p><u>Report:</u> “MPS Dump Start.” “Prevalues open.” “Inboard, outboard, topping open.” “LOX manifold presses on.” “Good dump config.” “Good manifold pressures.” “Dump on 3.”</p> <p><u>Note:</u> SSME Main Oxidizer Valves (MOV) open, but the MPS console operator has no insight. The ME (main engine) console operator will verify for the MPS operator that the LOX dump is occurring on all three engines. The ME operator has direct insight into MOV positions and has additional indication of LOX dump status via the Engine Status Words.</p>	MPS Ascent and Bilevel
Dump + 01:30	<p><u>Observation:</u> LOX manifold repress valve powers removed.</p> <p><u>Report:</u> “LOX manifold presses off, 30 seconds left to dump stop.”</p>	MPS Ascent and Bilevel
Dump Stop, Dump + 02:00	<p><u>Observations:</u> LH2 outboard fill drain and topping valves close. Backup dump valves close. Helium interconnects and Pneumatic crossover valves close. LO2 overboard bleed valve opens. Manifold pressures are approximately 0 psia for LOX and Fuel.</p> <p><u>Report:</u> “MPS Dump Stop.” “Outboard and Topping closed.” “Backup dump valves closed.” “Good Helium config.” “Good manifold pressures.”</p> <p><u>Note:</u> The engine helium isol open commands are removed at this time but the valves remain open because the He Isol valve switches are still in the Open position.</p>	MPS Ascent and Bilevel

TABLE 1.2.3-III.- POST-MECO TIMELINE - MPS

Time (min:sec)	Reports/Operations	Displays
<p>MECO + 5:00 (Approximate)</p>	<p><u>Observations:</u> The crew works the MPS PWRDN/ISOL procedure and MPS GH2 INERTING procedure (Ref. 1b). SSME controller indications on the DDD Panel turn red as a result of taking the six engine controller power switches to Off. All six main engine helium isolation switches taken from the Open position to the GPC position. Pneumatic helium isolation switch taken from Open position to the GPC position. C, L, and R Main Engine Helium regulator pressures bleed down. Multiple expected BFS fault messages for helium regulators appear. Crew verifies all Helium interconnect switches are in GPC.</p> <p><u>Report:</u> “Engine controller powers off.” “Helium Isol switches to GPC.” “Helium messages are expected.” “MPS Powerdown is complete.”</p> <p><u>Note:</u> If AOA, crew works MPS ISOL procedure in the AOA procedures (Ref. 1c) and SSME controllers are not powered OFF. OPS 3 may then be entered before the Vacuum Inerts below, and TAL entry software will initiate at OPS 303.</p> <p><u>Observations:</u> The Press Line Vent switch indications show the switch taken to open, and the valve open power indication appears. One minute later the switch is returned to the GND position and the press line vent valve open power indication disappears.</p> <p><u>Report:</u> “GH2 Inerting steps complete.”</p>	<p>DDD Panel</p> <p>Bilevel</p> <p>MPS Ascent BFS OFS</p> <p>Bilevel</p>

Table continued on next page.

TABLE 1.2.3-III.- POST-MECO TIMELINE - MPS, concluded

Time (min:sec)	Reports/Operations	Displays
Auto Vacuum Inert MECO + 19:02 (Dump + 17:00)	<u>Observations:</u> The LO2 inboard and outboard fill/drain valves open. The LH2 backup dump valves and topping valve open. <u>Report:</u> "First automated vacuum inert start."	MPS Ascent or Bilevel
MECO + 21:02 (Dump + 19:00)	<u>Observations:</u> LO2 outboard fill drain valve closes and the LH2 backup dump valves and topping valve closes. <u>Report:</u> "First automated vacuum inert stop."	MPS Ascent or Bilevel
MECO + 21:42 (Dump + 19:40)	<u>Observations:</u> All fill/drain valve close power removed. <u>Report:</u> "Fill/drain powers removed."	Bilevel
2nd Auto Vac Inert MM106	<u>Observation:</u> The LH2 backup dump valves and topping valve open. <u>Report:</u> "Second automated vacuum inert start."	MPS Ascent Bilevel
MM106 + 2:00	<u>Observation:</u> The LH2 backup dump valves and topping valve close. Center engine He interconnect out open. <u>Report:</u> (as they occur) "LH2 backup dump valves and topping valve closed." "Center He interconnect Out Open."	MPS Ascent Bilevel
MM 106 + 2:10	<u>Observation:</u> LH2 manifold presses open <u>Report:</u> "LH2 manifold presses open. Good manifold pressure"	MPS Ascent Bilevel
MM 106 + 2:20	<u>Observation:</u> LH2 manifold presses close <u>Report:</u> "LH2 manifold presses closed."	MPS Ascent Bilevel
MM 106 + 2:40	<u>Observation:</u> Pneumatic He Isol Closes (open power removed), and Center Engine He Interconnect out open closes. <u>Report:</u> "Pneumatic He Isols closed." "Center He interconnect closed." "Second automated vacuum inert and fuel manifold repress complete."	MPS Ascent Bilevel



TABLE 1.2.3-IV.- ENTRY TIMELINE - MPS

Time (hr:min:sec)	Reports/Operations	Displays
TIG-01:40:00	<p><u>Note:</u> The crew will perform the Caution and Warning Reset procedure (Ref. 3). MPS and Booster console operators have no insight. The procedure inhibits LO<sub>2</sub> and LH<sub>2</sub> manifold pressure C&amp;W (channels 69, 79) and enables C&amp;W on all He REG A's (channels 39, 49, 59).</p>	
TIG-00:30:00	Compute and report helium mass onboard	
TIG- 00:25:00	<p><u>Observations:</u> The crew performs Spec 51, Item 44 Exec (Ref. 4a). Performed prior to MM 302, this closes the left and right vent doors to the aft compartment, and the left vent doors re-open. <u>Report:</u> "Right vent doors closed." <u>Note:</u> If performed after the transition to MM 302, the left vent doors will not re-open. It is important that the left vent doors stay open until after MM 303 transition, because with all vent doors closed a failure during the MM303 helium reconfig could over-pressurize the aft compartment.</p>	SPECS MPS Entry
TIG- 00:00:00	<u>Deorbit burn</u>	
MM303	<p><u>Observation:</u> All helium isols open, allowing regulator pressures and the pneumatic accumulator pressure to rise to approximately 750 psia. <u>Note:</u> The MPS operator must first verify that no anomalous regulator pressures or helium usage occur. Then valve configuration may be verified. <u>Report:</u> "Regulators pressurized and stable." <u>Observations:</u> L, C, and R helium isol valves A and B powered Open PNEU He Isols powered open L He interconnect In Open valve powered open C and R He interconnect Out Open valves powered open PNEU crossover valve powered open LH2 backup dump valves open <u>Report:</u> "All helium isols open" "Good helium config." "Backup dump valves open."</p>	MPS Ascent or MPS Entry  MPS Ascent MPS Bilevel or MPS Entry

Table continued on next page.

TABLE 1.2.3-IV.- ENTRY TIMELINE - MPS, continued

Time	Reports/Operations	Displays
MM 304	<u>Observation:</u> Left vent doors close. <u>Report:</u> "Left vent doors closed."	MPS Entry
V <sub>rel</sub> < 5,300 ft/s	<u>Observations:</u> LO2 prevalues close, Backup dump valves close. LO2 and LH2 manifold repress valves powered open. Blowdowns open. Helium usage starts and stabilizes to approximately 0.087 lb/s. <u>Report:</u> "LOX prevalues closed, back-up dump valves closed." "Represses on, blowdowns open." "Nominal helium usage."  <u>Observations:</u> LO2 and LH2 manifolds pressurized to approximately 20 psia. <u>Report:</u> "Good manifold pressures." <u>Note:</u> Manifold pressure will increase by 15 psia as the orbiter approaches the ground. This is because the repress regulators are referenced to ambient pressure while the manifold pressure transducers measure absolute pressure.	MPS Ascent or MPS Entry           MPS Ascent
V <sub>rel</sub> < 2,400 ft/s	<u>Observations:</u> Vent doors open. <u>Report:</u> "Vent doors open."	MPS Entry
Pre Landing	Report any hazardous condition: High LH <sub>2</sub> manf P or residuals, High LO <sub>2</sub> manf P residuals, required expedited or emergency powerdown	MPS Ascent, MPS Entry
Touchdown		
V <sub>rel</sub> < 5,300 ft/s + 00:10:50	<u>Observations:</u> Blowdown valves close. <u>Report:</u> "Blowdowns closed."	MPS Ascent or MPS Entry

Post landing	<p><u>Observations:</u> The crew performs the POST LANDING MPS RECONFIG procedure (Ref. 4b). All six engine helium isolation switches are taken to Close. The left helium interconnect switch is taken to Out Open. The Pneu left engine crossover switch is taken to Close. Regulator pressures bleed down. Multiple helium messages on the BFS Onboard Fault Summary.</p> <p><u>Report:</u> "Engine helium isols closed." "Left Out Open." "Crossover Closed." "Helium messages are expected." "Post-landing reconfig complete."</p>	MPS Entry or Bilevel and BFS OFS
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TABLE 1.2.3-V.- RTLS TIMELINE – MPS

Time (min:sec)	Reports/Operations	Displays
(From MECO) 00:00	<p><u>Observations:</u> At MECO, the following valves move immediately, but the MPS operator should first verify that there was not a low level cutoff and then watch for the LO2 prevalues: PNEU crossover valve open LH2 recirculation disconnect valve closed. LO2 and LH2 Relief Isolation valves open. (reported later)</p> <p><u>Note:</u> In Open interconnect will be powered at this time for any engine that meets the three following criteria: Engine 1(2,3) fail flag = false, and 1) MDM FA1 (2,3) commfaulted or 2) Engine 1(2,3) helium tank P &lt; 2000 psia. This assures that an engine running to MECO but low on helium has enough helium to pressurize the POGO accumulator during shutdown.</p>	MPS Ascent
00:01.16	<p><u>Observation:</u> LO2 Prevalues close. <u>Report:</u> “LOX prevalues closed.”</p>	MPS Ascent
00:05.6	<p><u>Observation:</u> LH2 Prevalues close. <u>Report:</u> “Fuel prevalues closed.”</p>	MPS Ascent
00:06.6	<p><u>Observation:</u> 17 inch disconnects close. <u>Report:</u> “Disconnects closed.”</p> <p><u>Observation:</u> Relief isolation valves open. <u>Report:</u> “Relief isols open.”</p>	MPS Ascent
00:11.4	<p><u>Observation:</u> LH2 backup dump valves open. <u>Report:</u> “Backup dump valves open.”</p>	MPS Ascent
00:14	<p><u>Observation:</u> ET separation command issued. <u>Report:</u> “ET Sep.”</p>	MPS Ascent, DDD Panel, or Bilevel
00:16	<p><u>Note:</u> SSME fuel bleed valves open, but MPS operator has no insight.</p>	
00:20	<p><u>Observation:</u> Left helium interconnect In Open. Center and right helium interconnects Out Open. <u>Report:</u> “Good helium config.”</p>	MPS Ascent or Bilevel

Table continued on next page.

TABLE 1.2.3-V.- RTLS TIMELINE - MPS, continued

Time	Reports/Operations	Displays
<p>Dump Start MM602 (≈MECO+00:27)</p>	<p><u>Observations:</u> MM 602 transition. LH2 prevalues open. LH2 inboard and outboard fill/drain valves open. LH2 topping valve opens. <u>Report:</u> “602, Dump start” “LH2 Prevalues open” “LH2 Inboard, outboard, and topping open.”</p>	<p>MPS Ascent, MPS Entry, or Bilevel</p>
<p>MM602 + 00:20 (≈MECO+00:45)</p>	<p><u>Observations:</u> LH2 inboard fill/drain valve close. RTLS repress valves powered open. <u>Report:</u> “Fuel inboard closed, RTLS represses on.”</p>	<p>MPS Ascent</p>
<p>MM602 + mission specific I-Load*</p>	<p><u>Observations:</u> LO2 prevalues open. <u>Report:</u> “LO2 Prevalues open, Dumping on 3.” <u>Note:</u> SSME Main Oxidizer Valves (MOVs) open, but the MPS console operator has no insight. The ME (main engine) console operator will verify for the MPS operator that the LOX dump is occurring on all three engines. The ME operator has direct insight into MOV positions and has additional indication of LOX dump status via the Engine Status Words. <u>*Note:</u> I-load is 53 seconds for missions with forward CG; otherwise, I-load is 0 seconds.</p>	
<p>MM602 + 01:40 (≈MECO+02:05)</p>	<p><u>Observations:</u> RTLS repress valves open power removed. <u>Report:</u> “RTLS represses off.”</p>	<p>MPS Ascent</p>
<p><math>Q \geq 20 \text{ lb/ft}^2</math> &amp; LO2 dump start + 30 sec</p>	<p><u>Observations:</u> LO2 inboard and outboard fill/drain valves open. <u>Report:</u> “LOX inboard and outboard open”</p>	<p>MPS Ascent, MPS Entry, or Bilevel</p>
<p><math>V_{\text{rel}} &lt; 5,300 \text{ ft/s}</math></p>	<p><u>Observations:</u> Helium Blowdown Valves powered open. <u>Report:</u> “Blowdowns open.” <u>Observations:</u> Verify helium usage approximately 0.087 lbm/s. <u>Report:</u> “Good helium usage.”</p>	<p>MPS Ascent, MPS Entry, or Bilevel</p>

Table continued on next page.



TABLE 1.2.3-V.- RTLS TIMELINE - MPS, concluded

<p>Post landing</p>	<p><u>Observations:</u> The crew performs the POST LANDING MPS RECONFIG procedure.                  All six engine helium isolation switches are taken to Close.                  The left helium interconnect switch is taken to Out Open.                  The Pneu left engine crossover switch is taken to Close.                  Regulator pressures bleed down.                  Multiple helium messages on the BFS Onboard Fault Summary.</p> <p><u>Report:</u> “Engine helium isols closed.”                  “Left Out Open.”                  “Crossover Closed.”                  “Helium messages are expected.”                  “Postlanding reconfig complete.”</p>	<p>MPS Entry                  or Bilevel                  and BFS OFS</p>
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TABLE 1.2.3-VI.- TAL TIMELINE - MPS

Time (min:sec)	Reports/Operations	Displays
(From MECO) 00:00	<p><u>Observations:</u> At MECO, the following valves move immediately, but the MPS operator should first verify that there was not a low level cutoff and then verify then watch for the LO2 prevalues: PNEU crossover valve open. LH2 recirculation disconnect valve closes. LO2 and LH2 Relief Isolation valves open. (reported later)</p> <p><u>Note:</u> In Open interconnect will be powered at this time for any engine that meets the three following criteria: Engine 1(2,3) fail flag = false, and 1) MDM FA1 (2,3) commfaulted or 2) Engine 1(2,3) helium tank P &lt; 2000 psia. This assures that an engine running to MECO but low on helium has enough helium to pressurize the POGO accumulator during shutdown.</p>	MPS Ascent
00:01.16	<p><u>Observation:</u> LO2 Prevalues close. <u>Report:</u> "LOX prevalues closed."</p>	MPS Ascent
00:07.6	<p><u>Observation:</u> LH2 Prevalues close. <u>Report:</u> "Fuel prevalues closed."</p>	MPS Ascent
00:08.6	<p><u>Observation:</u> 17 inch disconnects close. <u>Report:</u> "Disconnects closed."</p> <p><u>Observation:</u> Relief isolation valves open. <u>Report:</u> "Relief isols open."</p>	MPS Ascent  MPS Ascent
00:13.4	<p><u>Observation:</u> LH2 backup dump valves open. <u>Report:</u> "Backup dump valves open."</p>	MPS Ascent
00:16	<p><u>Note:</u> SSME fuel bleed valves open, but MPS operator has no insight.</p>	
00:19.44	<p><u>Observation:</u> ET separation command issued. <u>Report:</u> "ET Sep."</p>	MPS Ascent, DDD Panel, or Bilevel
00:22	<p><u>Observation:</u> Left helium interconnect In Open. Center and right helium interconnects Out Open. <u>Report:</u> "Good helium config."</p>	MPS Ascent or Bilevel

Table continued on next page.



TABLE 1.2.3-VI.- TAL TIMELINE - MPS, continued

Time	Reports/Operations	Displays
MM304	<p><u>Observations:</u> MM 304 transition. All prevalves open. LH2 inboard and outboard fill/drain valves open. LH2 topping valve opens. Vent Doors Closed (MPS Entry Display only)</p> <p><u>Report:</u> “304, MPS Dump start” “Prevalves open” “(fuel) inboard, outboard, and topping open.” “Vent doors closed.”</p> <p><u>Note:</u> SSME MOVs open for the LOX dump but the MPS operator has no insight. The main engine console operator also has no insight into MOV positions after the OPS 3 transition (compare to RTLS).</p>	MPS Ascent, MPS Entry, or Bilevel
MM304 + 00:20	<p><u>Observations:</u> LH2 inboard fill/drain valve close. RTLS repress valves powered open.</p> <p><u>Report:</u> “Fuel inboard closed, RTLS represses on.”</p>	MPS Ascent
MM304 + 01:40	<p><u>Observations:</u> RTLS repress valves open power removed.</p> <p><u>Report:</u> “RTLS represses off.”</p>	MPS Ascent
V <sub>rel</sub> < 20 Kft/s	<p><u>Observations:</u> LO2 inboard and outboard fill/drain valves open.</p> <p><u>Report:</u> “LOX inboard and outboard open”</p>	MPS Ascent, MPS Entry, or Bilevel
V <sub>rel</sub> < 19 Kft/s	<p><u>Note:</u> SSME MOVs close, but the MPS operator has no insight.</p>	

Table continued on next page.



TABLE 1.2.3-VI.- TAL TIMELINE - MPS, concluded

<p>Post landing</p>	<p><u>Observations:</u> The crew performs the POST LANDING MPS RECONFIG procedure. All six engine helium isolation switches are taken to Close. The left helium interconnect switch is taken to Out Open. The Pneu left engine crossover switch is taken to Close. Regulator pressures bleed down. Multiple helium messages on the BFS Onboard Fault Summary.</p> <p><u>Report:</u> “Engine helium isols closed.” “Left Out Open.” “Crossover Closed.” “Helium messages are expected.” “Postlanding reconfig complete.”</p>	<p>MPS Entry or Bilevel and BFS OFS</p>
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REFERENCES

1. Flight Data File – Ascent Checklist, JSC-48005, STS-114, Final, PCN-2, 11/24/2003.
  - a. MPS He RECONFIG, page 1-11
  - b. MPS PWRDN/ISOL and MPS GH2 INERTING, page 3-5
  - c. MPS ISOL, page 6-10
2. Shuttle Launch Commit Criteria and Background Document, NSTS 16007, Rev H, PCN-38, 11/7/2003.
  - a. ET-06, ET LO2 Ullage Pressure/Transducer Anomaly, page 17-06.1
  - b. ET-05, ET LH2 Ullage Pressure/Transducer Anomaly, page 17-05.1
  - c. BTVC-08, SRB HPU Turbine Speed Anomaly, page 11-08.1
  - d. BTVC-09, SRB Hydraulic Fluid Supply Pressure Anomaly, page 11-09.1
  - e. BTVC-16, SRB HPU Primary Pressure OK Anomaly, page 11-16.1
3. Flight Data File – Deorbit Prep, JSC-48015, Rev N, 12/15/2003  
Block 18, Reset C/W, page 1-15.
4. Flight Data File - Entry Checklist, JSC-48020, Generic, Rev F, PCN-2, 3/21/2003.
  - a. VENT DOOR CLOSE, page 3-10
  - b. POST LANDING MPS RECONFIG, page 5-9

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TITLE

ON ORBIT AND ENTRY MPS OPERATIONS

PURPOSE

This SCP describes the Main Propulsion System (MPS) and the Mechanical systems (MMACS) console operators' procedures and responsibility for monitoring the MPS during on-orbit and entry phases.

PROCEDURE

Console Configuration

The Ascent MPS must complete a Booster On-Orbit Handover sheet. A sample of the On-Orbit Handover sheet is shown in Figure 1.2.4-I. A copy of this sheet should be given to the MMACS officer, a second copy of this sheet should be placed under the glass in the MPSR, and a third copy should be placed in the log book. This form can be found at:

<S:\Divisions\Df\Private\Df55\FLIGHT ITEMS\Orbit\Handover Sheet.doc>

A. On-Orbit Operations

On the first day following ascent, the Entry Booster or Entry MPS operator should log in to the single head Main Engine workstation (if possible). The workstation will remain logged in as long as it doesn't conflict with simulation activities that will require this machine. When not on console, the Entry operator should "PAUSE" the workstation. The operator may request that FSM "Unpause" the workstation if they were not the one that originally paused it.

The Entry Booster team will need to make sure to follow the sim schedule and log out of the workstation if integrated simulation activities will require this workstation. While the on-orbit configuration of the workstation is up to the individual user, the following displays should be called up at a minimum.

- 1) PASS Header
- 2) MPS Ascent or MPS Entry
- 3) Bi-Level
- 4) DDD Panel
- 5) OFS (displaying PASS messages)
- 6) HTAB (flight configuration)

Either the Entry Booster operator or Entry MPS operator is required to report to console once per day during the mission. Figure 1.2.4-II shows the Orbit Booster Checklist, whose original is located at:

[S:\Divisions\DfPrivate\Df55\FLIGHT ITEMS\Orbit\Orbit Checklist \(Rev B\).doc](S:\Divisions\DfPrivate\Df55\FLIGHT ITEMS\Orbit\Orbit Checklist (Rev B).doc)

There are two primary tasks the on-orbit MPS operator is responsible for. The first is to track the MPS helium pressures and temperatures as well as the LO2 and LH2 manifold pressures. The second is to keep abreast of any other system failures or flight plan changes that affect the MPS system either on-orbit or during entry. All data collected by the MPS operator, as well as any console notes made during the console visit must be kept in the Log Book under "Orbit BSE". At a minimum, the following steps should be performed daily by the Orbit MPS operator.

- 1) Update the Helium History. This is typically kept in running order on console log paper and is kept in the front of the "Orbit BSE" section of the Log Book. The helium history is usually a stand-alone section without other notes or information contained within it. This allows the team to have a single source, running history of the MPS system in a clean, clear, and concise format. The data that must be collected on a daily basis for inclusion in this section are: He tank pressures, He tank temperatures (both mid and aft), and the He masses. Figure 1.2.4-III shows an example Helium History from STS-113. The original Helium History form may be found at:

[S:\Divisions\DfPrivate\Df55\FLIGHT ITEMS\Orbit\Orbit Checklist \(Rev B\).doc](S:\Divisions\DfPrivate\Df55\FLIGHT ITEMS\Orbit\Orbit Checklist (Rev B).doc)

- 2) Review the remainder of the MPS system. A sheet of console log paper is used for this purpose. The goal here is to review the status of the LO2/LH2 systems and ensure they are in a safe configuration. The data that should be reviewed, at a minimum, include: LO2 manifold pressure, LH2 manifold pressure, MPS switch and valve configuration.
- 3) Review the Execute Package, Anomaly and Chit Logs (located under DNAV/Global Apps/MIS), Electronic Flight Notes (EFN), JEDI, and OFS messages for failures affecting the MPS system. Electronic Flight Notes and JEDI are located on the JSC-MAS PC's in the MCC on the web at <http://mod.jsc.nasa.gov/mcc>. Select "REALTIME MISSION" (or "SIM 3" for simulations) / "TOOLS" / "STS-only EFN" (or "ISS/Joint EFN" for ISS flights) or "STS JEDI." At the time of publication, an Operations Interface Procedures (OIP) "Flight Support Products" appendix was under development to describe the operating procedures for Chits, EFN, and JEDI.

All notes made during the review of these resources should be kept on console log sheets and kept in the "Orbit BSE" section of the Log Book. If a condition exists that affects either the future on-orbit or entry operations of the MPS system, ensure that all members of the entry team are informed.

## BOOSTER ON-ORBIT HANDOVER

### Flight Control Team Information

Flight #	
Vehicle	

Personnel	Entry Booster (Prime Contact)	Entry MPS Operator (Secondary Contact)	Booster Group Lead
Name			Jeff Musler
Work Phone			x30720
Home Phone			(281) 286-4608
Cell Phone			832-444-8434
Beeper	(281) 439-3177		(281) 439-3291

### MPS Pressures and Temperatures at Handover from Ascent Team

Date	
MET	
GMT	

The following MPS info is available from the MASTER DNAV at:  
**Shuttle, Booster, ISP Data (on local server-PTM), MPS Ascent**

Helium System	LEFT	CENTER	RIGHT	PNEU	
He Tank P (psia)					
Aft He Tank T (°F)					
Mid He Tank T (°F)					<u>TOTAL</u>
He Mass (lbm)					

MPS	- LO2 -			- LH2 -		
	LEFT	CENTER	RIGHT	LEFT	CENTER	RIGHT
Manifold P (psia)						
Inlet P (psia)						

### Description of Anomalies Affecting Booster Systems:

### Handover Sheet Prepared By:

Name	
Work Phone	
Home Phone	
Cell Phone	

Figure 1.2.4-I: Booster On Orbit Handover Sheet



<p style="text-align: center;"><b>FCR/MPSR Orbit Checklist</b> <b>(Ref. SCP 1.2.4)</b></p> <p style="text-align: center;">STS - _____ OV - _____</p> <ol style="list-style-type: none"><li>1) Check <u>Anomaly</u> Log and file copy in Log Book</li><li>2) Check <u>Chit</u> Logs and file copy in Log Book</li><li>3) Check <u>Execute Package</u><ul style="list-style-type: none"><li>• Use JEDI to ensure most current version</li></ul></li><li>4) Check Flight Notes<ul style="list-style-type: none"><li>• Use MCC-Houston, Tools web page to locate web based EFNs</li></ul></li><li>5) Update “MPS History” and file in Log Book</li><li>6) Fill out Training Roster (file in log book) and complete your timecard</li></ol> <p>S:\\Private\Df55\Flight Items\Orbit\Orbit Checklist.doc <span style="float: right;">Rev B 11/25/02 AJE</span></p>
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Figure 1.2.4-II. Orbit Booster Checklist

**Helium History**

Page No.     

GMT Local / Date MET		Left	Center	Right	Pneu	
	Tank P					
	Aft Tk T					
	Mid Tk T					
	Mass/Total					
LO2 IN P/Manf P						
LH2 IN P/Manf P						
	Tank P					
	Aft Tk T					
	Mid Tk T					
	Mass/Tot					
LO2 IN P/Manf P						
LH2 IN P/Manf P						
	Tank P					
	Aft Tk T					
	Mid Tk T					
	Mass/Tot					
LO2 IN P/Manf P						
LH2 IN P/Manf P						
	Tank P					
	Aft Tk T					
	Mid Tk T					
	Mass/Tot					
LO2 IN P/Manf P						
LH2 IN P/Manf P						
	Tank P					
	Aft Tk T					
	Mid Tk T					
	Mass/Tot					
LO2 IN P/Manf P						
LH2 IN P/Manf P						

Figure 1.2.4-III. Orbit Helium History Sheet

B. Entry Operations (Nominal)

Both the Entry BSE and Entry MPS operators are required to support both the L-1 day briefing and the Deorbit/Entry/Landing for the mission. The MPS has two primary functions during entry. The first is to provide a helium source for the purges that occur during entry. The second is to repress the LO2 and LH2 manifolds for entry. The purges are used to clear the OMS pods, ET umbilical cavity, and aft compartment of any hazardous gasses that might have built up. The manifold repressurization is used to prevent contamination of the LO2 and LH2 manifolds. While the entry configuration of the workstation is up to the individual user, the following displays should be called up at a minimum.

- 1) PASS Header
- 2) MPS Entry
- 3) DDD Panel
- 4) OFS (displaying PASS and BFS messages)
- 5) HTAB (flight configuration)
- 6) CRANS
- 7) RTPLOT (showing He tank and regulator pressures and Tank Temps)
- 8) SPECS (allows the operator to see the crews keystrokes)

There are several events during the de-orbit prep and entry timeframe that are of interest to the MPS and BSE operators. At the OPS 3 transition (DPS entry config, TIG-2:15), the BFS software management (SM) alert caution and warning (C&W) becomes active and monitors the MPS helium and pneumatic regulators. Up to seven MPS helium regulator messages may be annunciated each time the BFS is moded from OPS 0 to OPS 3. This is a result of the C&W noise filter being removed in OI-25. Therefore, the C&W is reset when the GPCs pass through OPS 0 on an OPS transition. Prior to OI-25, the “noise filter” software would “see” the helium regulators bleed below the C&W lower limit when the helium isolation valves were closed in OPS 1. This occurrence would be latched in memory so that warning messages were not reannunciated later. During the DPS entry config, the BFS is moded from OPS 000 to OPS 301 two times. Note that the exact number of messages that will be annunciated in OPS 3 is dependent on downlist limitations.

At 1:40 (hours:minutes) prior to the deorbit burn, TIG-1:40, the MPS hardware C&W is configured to monitor the MPS helium leg regulators.

At MM303, all eight helium isols are commanded open.

At a ground relative velocity of 5300 ft/s, the He blowdown valves open and the vast majority of the entry helium usage begins. These valves remain open for 650 seconds, well after a nominal landing occurs.

Post landing, the helium system will be manually reconfigured as part of the POST LANDING MPS RECONFIG in the Entry checklist. Once the hydraulic systems are shutdown, helium is no longer required as a backup closure method for the main engine valves. In addition, the helium purge of the aft compartment is terminated once the blowdown valves close. In order to preserve the remaining helium for the manifold pressurization, the main engine isolation valves are closed, the left helium interconnect is positioned in the Out/Open position, and the Left engine helium crossover valve is closed. This action isolates the helium supply from the SSMEs to prevent helium venting overboard through the baggy purge and vent mod, and it allows all tanks to feed into the pneumatic system to provide helium for the manifold pressurization until GSE equipment can be attached.

The MPS operator should monitor valve operation during the procedures and should notify the BSE of any anomalies. Malfunction procedures associated with an off-nominal entry purge and manifold re-pressurization are provided in detail in SCP 2.2.8. A detailed description of the numerous valve movements and the times at which they occur can be found on the MPS ENTRY/AOA EVENTS cue card.

#### REFERENCES

1. Flight Data File.
2. Booster Cue Card Book (BCCB), Rev. A, PCN-16.
3. STS Operational Flight Rules, All Flights, Vol. A., PCN-1, November 21, 2002.

TITLE

BOOSTER CONSOLE ACTIVITY TIMELINE/POSITION REPORTING

PURPOSE

The purpose of this SCP is to describe the reporting and console operation required at the Booster console.

DESCRIPTION

The timeline consists of six tables:

- TABLE 1.3.1-I.- PRELAUNCH TIMELINE - BOOSTER (T<sub>0</sub>-20 minutes to T<sub>0</sub>)
- TABLE 1.3.1-II.- LAUNCH TIMELINE - BOOSTER (T<sub>0</sub> through MPS dump)
- TABLE 1.3.1-III.- POST-MECO TIMELINE - BOOSTER (covers first vacuum inert)
- TABLE 1.3.1-IV.- ENTRY TIMELINE - BOOSTER (on-orbit preparation for entry through rollout)
- TABLE 1.3.1-V.- RTLS TIMELINE - BOOSTER (from RTLS call through rollout)
- TABLE 1.3.1-VI.- TAL TIMELINE - BOOSTER (from MECO through rollout)

Each timeline is an integrated timeline of the MPS and ME position reports to the Booster, and the reports made by the Booster to the Flight Director. All voice communications are in quotation marks. All reports from **Booster to the Flight Director are in Bold**.

NOTE: These tables are a high level integration of the MPS and ME timelines. Refer to SCP 1.1.2 for additional information on the ME timelines and SCP 1.2.3 for the MPS timelines.

TABLE 1.3.1-I.- PRELAUNCH TIMELINE - BOOSTER

Time (min: sec)	Reports/operations		
	Booster	ME	MPS
T <sub>0</sub> - 20:00	Transition to MM101	“Three engines in purge 3”	
T <sub>0</sub> - 16:00			“MPS helium reconfig complete”
T <sub>0</sub> - 9:00	GLS start		
T <sub>0</sub> - 5:00	APU start	“Three Good SSME hydraulics”	L&R SRB igniter to ARM position “SRBs armed”
T <sub>0</sub> - 4:48	<b>“LOX drainback start”</b> {note LOX drainback starts at T <sub>0</sub> -4:55 when LO2 Replenish Vlv. (GSE) closes w/o Booster insight}		“LOX inbd F/D-cl. LOX drainback start.”
T <sub>0</sub> - 4:00		“Three engines in purge 4” CCVs open “Limit Switch in Auto”	
T <sub>0</sub> - 2:55	<b>“LOX tank at flight pressure”</b>		“LOX vent valve-cl, LOX tank pressurizing. LOX tank at flight pressure.”
T <sub>0</sub> - 1:55	<b>“FUEL tank at flight pressure”</b>	Monitor engine start conditions	“Fuel vent-closed. Topping valve closed. Fuel tank at flight pressure.”
T <sub>0</sub> - 1:30	<b>“3 engines ready”</b>	“3 engines ready”	
T <sub>0</sub> - 0:48			“Outboards closed”
T <sub>0</sub> - 0:31		“Counting inside 31”	
T <sub>0</sub> - 0:28		Auto seq start	“HPU ISOLs open. 4 good SRB turbine speeds. Four good SRB hydraulics”
T <sub>0</sub> - 0:12.5	“POGOs”		“POGO valves open”
T <sub>0</sub> - 0:09.5	“Fuel prevalves”		“Fuel prevalves open”
T <sub>0</sub> - 0:08	“Overboard bleed”		“Overboard bleed closed”
T <sub>0</sub> - 0:06.6	“Ignition”	“Ignition”	
T <sub>0</sub> - 0:01.6	“Copy mainstage”	“3 at 100”, “Mainstage”	

TABLE 1.3.1-II.- LAUNCH TIMELINE - BOOSTER

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
T <sub>0</sub>	Liftoff	Throttle up	
__:__		“3 at __” (mission power level)	
__:__		“Throttle down”	Monitor He usage
__:__	“Throttle down, 3 at __%”	“3 at __” (thrust bucket)	
T <sub>0</sub> + __:__	“Throttle up, 3 at __%” (mission power level)	“Throttle up”3 at __” (mission power level)	
T <sub>0</sub> + 2:00			“SRB Pc’s < 50”
T <sub>0</sub> + 2:06	“SRB SEP”		“SRB SEP”
__:__	“_____ engine suspect” to TRAJ	2-eng TAL (FDO) “_____ engine suspect”	
__:__		Neg return (FDO)	
__:__		Press-to-ATO (FDO)	
__:__		Single-eng Ops Three (FDO)	

TABLE 1.3.1-II.- Concluded

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
—:—		Press-to-MECO Normal throttles (FDO)	
—:—		Single-eng TAL (FDO)	
—:—		Single-eng press (FDO)	
T <sub>0</sub> + 6:30	“Traj Booster MOCR- Dyn for an underspeed” To TRAJ	“2 minutes to MECO. Check for underspeed.”	
T <sub>0</sub> + ~7:40	<b>“3g throttling - all 3”</b>	“3g throttling - all 3”	
T <sub>0</sub> + ~7:54	“LOX at 5”		“LOX at 5%”
T <sub>0</sub> + ~8:00 (V <sub>1</sub> = 23K)	Man shutdn calls (if req’d)	Man shutdn calls (if req’d)	
T <sub>0</sub> + ~8:02	“FUEL at 5”		“FUEL at 5%”
T <sub>0</sub> + ~8:20	“Arm”		“Arm command”
T <sub>0</sub> + ~8:28	“Fine count”	“Fine count, good throttles”	
T <sub>0</sub> + ~8:33	<b>“MECO, MECO confirmed”</b> “LOX or FUEL low level cutoff” (if req’d)	“MECO” “MECO confirmed”	“LOX or FUEL low level cutoff” (if req’d)



TABLE 1.3.1-III.- POST-MECO TIMELINE - BOOSTER

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
MECO +			
00:08.6	Fdln disc vlv status (auto ET SEP INH if req'd)		“Disconnects closed, relief isols open”
00:13.4			“LH <sub>2</sub> backup dump valves open”
00:16			SSME Bleed Vlvs open (no insight)
00:19.44	<b>“ET SEP”</b>		“ET SEP” Report LO <sub>2</sub> and LH <sub>2</sub> manf pressures, “good manifold pressures”
00:22			“C and R He interconnect out open, L in open, good helium config”
Post ET SEP		“Expect dump on three_ engines”	

TABLE 1.3.1-III.- Continued

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
MECO +  02:02	<b>“MPS dump start”</b>	“Dump on 3”	“MPS dump start” “LH <sub>2</sub> inbd and outbd F/D, topping - op” “LO <sub>2</sub> and LH <sub>2</sub> pv’s - op” “LO <sub>2</sub> manf press - op”
3:32 (Dump+1:30)			“LO <sub>2</sub> manf press - cl, 30 seconds left to dump stop.”
4:02 (Dump+2:00)	<b>“MPS dump complete”</b> Report dump start and stop times to TRAJ	“SSME powerdown complete”	“MPS dump stop” “LH <sub>2</sub> outbd F/D - cl” “LH <sub>2</sub> topping - cl” “LH <sub>2</sub> backup dump - cl” “C and R He intercon out/open - cl” “L He intercon in/open - cl” “Pneu xover - cl” “LO <sub>2</sub> overbd bleed - op”
5:00 (approx)	MPS powerdown/isol Note: If controllers are <b>NOT</b> powered OFF by a MET of 25 minutes. Tell INCO to continue to record SSME data. If this situation occurs, INCO must be told when to stop the recorders.		“He intercons - GPC” “He isols (7) - GPC”
GH2 Inert			H2 press line vent - op
GH2 Inert +1:00	<b>“Steps on Ascent C/L page 3-5 (or 3-6) complete”</b>		H2 press line vent - cl “GH2 inerting steps complete.”

TABLE 1.3.1-III.- Continued

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
MECO + 19:02 (Dump+17:00)	First automated vacuum inert start		“First automated vacuum inert start” LO2 outbd F/D - op LO2 inbd F/D - op LH2 B/U dump - op LH2 topping - op
MECO + 21:02 (Dump+19:00)	First automated vacuum inert stop		“First automated vacuum inert stop” LO2 outbd F/D - cl LH2 B/U dump - cl LH2 topping - cl
MECO + 21:42 (Dump+19:40)			All F/D close power removed
MM 106	Second automated vacuum inert start		“Second automated vacuum inert start” “LH <sub>2</sub> B/U dump - op LH <sub>2</sub> topping - op”
MM 106 + 2:00			“LH <sub>2</sub> B/U dump - cl LH <sub>2</sub> topping - cl” “Center He Interconnect Out Open”
MM 106 + 2:10			“LH <sub>2</sub> manifold presses on. Good manifold pressure”
MM 106 + 2:20			“LH <sub>2</sub> manifold presses closed”
MM 106 + 2:40	Second automated vacuum inert stop		“Pneu He Isol Closed Center He interconnect closed Second automated vacuum inert and fuel manifold repress complete”

TABLE 1.3.1-III - Concluded

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
25:00	SSME OPS recorders turned OFF (unless more time is needed; if so, contact INCO).	SSME OPS recorders turned OFF (unless more time is needed; if so, contact INCO).	

TABLE 1.3.1-IV.- ENTRY TIMELINE - BOOSTER

Time (hr:min:sec)	Reports/operations	
	Booster	MPS
TIG-01:40:00		Caution and warning reset INH LO <sub>2</sub> and LH <sub>2</sub> man p (ch 69, 79) Reset all He Reg A's (ch 39, 49, 59)
TIG-00:30:00	MPS reports helium mass onboard	Compute helium mass onboard
TIG-00:25:00	"Right vent doors closed"	"Right vent doors closed"
__:__	Deorbit burn	Deorbit burn
MM303 (≈ EI-20 min)	Helium config and inert start	Verify L, C, R He isol A and B - op Pneu He isol - op LO <sub>2</sub> and LH <sub>2</sub> outbd F/D - cl C and R He intercons out/open - op L He intercon in/open - op Pneu crossover - op LH <sub>2</sub> backup dump - op
MM304	"Left vent doors closed"	"Left vent doors closed"
Vrel < 5,300 ft/s	Inert stop, repress initiated	LO <sub>2</sub> prevalues - cl. Verify LO <sub>2</sub> and LH <sub>2</sub> man repress op LH <sub>2</sub> backup dump - cl He blowdowns - op Note helium mass
Vrel < 2,400 ft/s		"Vent Doors Open"
Pre Landing	Report LH <sub>2</sub> and LO <sub>2</sub> relief condition. Report any hazardous condition to FDO to relay to ground convoy, and any required expedited or emergency powerdown to Flight and EGIL	Report any hazardous condition: High LH <sub>2</sub> manf P or residuals High LO <sub>2</sub> manf P residuals, required expedited or emergency powerdown
__:__	Touchdown	Touchdown
Vrel < 5,300 ft/s + 00:10:50	He blowdowns closed	"He blowdowns - closed" Note helium mass. Report helium mass used during blowdown.

TABLE 1.3.1-IV.- Concluded

Time (hr:min:sec)	Reports/operations	
	Booster	MPS
Post landing	Helium reconfiguration started	“Helium reconfiguration started” MPS He isols - cl MPS left He interconnect - out open L He crossover - cl

TABLE 1.3.1-V.- RTLS TIMELINE - BOOSTER

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
__: __	<b>“C(L,R) engine out”</b> or other sys reason	“C(L,R) engine out” (if req’d)	
2:30 or 3:40		RTLS initiate (MM 601) 2 eng - “at __ power level” 3 eng - “Throttle down - __%”	
PPA (depends on RTLS select time)	2 eng - “Throttle down - __%” 3 eng - “Throttle up - __%”	2 eng - “Throttle down - __%” 3 eng - “Throttle up - __%”	
Prior to 8:00 MET (3 eng)	<b>“Limits INH-ENA- AUTO”</b> to disable single command channel shutdown logic (if required)	“Limits INH-ENA- AUTO to disable single command channel shutdown logic” (if required)	
PPD		Manual shutdown calls (if required)	
PPD +20 sec		2 eng - “2 at 91” or 3 eng - “3 at 67”	
	<b>“MECO”</b> <b>“MECO confirmed”</b> “LOX or FUEL low level cutoff” (if req’d)	“MECO” “MECO confirmed”	“LOX or FUEL low level cutoff” (if req’d)

TABLE 1.3.1-V.- Continued

Time (min:sec)	Reports/operations		
	Booster	ME	MPS

TABLE 1.3.1-V.- Concluded

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
Q ≥ 20 ft/sec & LO2 dump start + 30 s			“LO <sub>2</sub> F/D vlvs - op”
Vrel < 5300 ft/s			“He blowdowns - op” Note He mass
Vrel < 3800 ft/s		“LOX dump stop” MOVs (3) - cl	“Repress initiated” LO <sub>2</sub> /LH <sub>2</sub> outbd F/D - cl LO <sub>2</sub> pre valves - cl LH <sub>2</sub> backup dump – cl Manifold presses on.”
Vrel < 2400 ft/s			“Vent Doors Open”
Pre Landing	Report LH <sub>2</sub> and LO <sub>2</sub> relief condition. Report any hazardous condition to FDO to relay to ground convoy, and any required expedited or emergency powerdown to Flight and EGIL		Report any hazardous condition: High LH <sub>2</sub> manf P or residuals High LO <sub>2</sub> manf P residuals, required expedited or emergency powerdown
__ : __	Touchdown		Touchdown
Vrel < 5300 ft/s +10:50			“He blowdowns - cl” Note He mass Report He mass used during blowdown
Post Landing	Helium reconfiguration		“Helium reconfiguration



	started		started” MPS He isols - cl MPS left He interconnect - out open L He crossover - cl
--	---------	--	--

TABLE 1.3.1-VI.- TAL TIMELINE - BOOSTER

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
__:__	“C(L,R) engine out” or other sys reason	“C(L,R) eng out” (if req’d)	
__:__	2 eng - “2 at __ power level” 3 eng - “Throttle down - 67%”	TAL initiate 2 eng - “at __ power level” 3 eng - “Throttle down to 67%”	
__:__		Single-eng Ops Three (FDO)	
__:__		Single-eng TAL (FDO)	
__:__	“3g throttling - all 3”	“3g throttling - all 3”	
__:__	“LOX at 5”		“LOX at 5%”
__:__ (V <sub>I</sub> = 22.5K)	Man shutdn calls (if req’d)	Man shutdn calls (if req’d)	
__:__	“FUEL at 5”		“FUEL at 5%”
__:__	“Arm”		“Arm command”
__:__	“Fine count”	“Fine count, good throttles”	
MECO	“MECO” (V <sub>I</sub> = ~23.8K) “MECO confirmed” “LOX or FUEL low level cutoff” (if req’d)	“MECO” (V <sub>I</sub> = ~23.8K) “MECO confirmed”	“LOX or FUEL low level cutoff” (if req’d)

TABLE 1.3.1-VI.- Continued

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
MECO +			
00:01.16			“LO <sub>2</sub> and LH <sub>2</sub> fdln rlf isol vlvs - op” “LO <sub>2</sub> pv’s (3) - cl” “Pneu xover - op”
00:07.6			“LH <sub>2</sub> pv’s (3) - cl”
00:08.6	Fdln disc vlv status		“LO <sub>2</sub> and LH <sub>2</sub> fdln disc - cl”
00:13.4			“LH <sub>2</sub> backup dump valves open”
00:16			SSME bleed valves open (no insight)
00:19.44	<b>“ET SEP”</b>		“ET SEP” Report LO <sub>2</sub> and LH <sub>2</sub> manf pressures
Post ET SEP		“Expect dump on three_engines”	

TABLE 1.3.1-VI.- Continued

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
MM304 + 0:00	MPS dump start	“Dump on three”(but no insight in to MOV positions)	“MPS Dump start” L He intercon in/open C and R He intercon out/open Pneu crossover - op LH <sub>2</sub> inbd and outbd F/D, topping - op LH <sub>2</sub> backup dump - op LO <sub>2</sub> and LH <sub>2</sub> prevalues - op “Vent Doors Closed”
MM304 +0:20			LH <sub>2</sub> RTLS repress - op LH <sub>2</sub> inbd F/D - cl
MM304 +1:40			LH <sub>2</sub> RTLS repress off
Vrel < 20K ft/sec			LO <sub>2</sub> F/Ds - op
Vrel<19K ft/sec			
Vrel < 5300 ft/sec		“Dump stop” (but no insight in to MOV positions)	“He blowdowns - op” LO <sub>2</sub> prevalues - cl LO <sub>2</sub> and LH <sub>2</sub> outbd F/Ds - cl LH <sub>2</sub> backup dump - cl LO <sub>2</sub> and LH <sub>2</sub> manifold repress - op “Good manifold pressures.”
Vrel < 2400 ft/sec			“Vent Doors Open”

TABLE 1.3.1-VI.- Concluded

Time (min:sec)	Reports/operations		
	Booster	ME	MPS
Pre Landing	Report LH <sub>2</sub> and LO <sub>2</sub> relief condition. Report any hazardous condition to FDO to relay to ground convoy, and any required expedited or emergency powerdown to Flight and EGIL		Report any hazardous condition: High LH <sub>2</sub> manf P or residuals High LO <sub>2</sub> manf P residuals, required expedited or emergency powerdown
__:__	Touchdown		Touchdown
Vrel < 5300 ft/sec +10:50			“He blowdowns - cl” Note He mass Report He mass used during blowdown
Post Landing	Helium reconfiguration started		“Helium reconfiguration started” MPS He isols - cl MPS left He interconnect - out open L He crossover - cl

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## TITLE

### BOOSTER PRELAUNCH ACTIVITY/REPORTING

## PURPOSE

The purpose of this SCP is to describe the reporting and console operations required at the Booster FCR console and the MPS MPSR position for the period from prelaunch shift on console to resuming the countdown from the T-9 minute hold.

## DESCRIPTION

The discussion of the Booster prelaunch activities is divided into two sections. The first section provides a general overview of what procedures are being performed, when they are being performed, and what voice loops should be monitored. The second section discusses prelaunch anomaly resolution procedures and coordination with the appropriate KSC engineering team lead (ETL).

### Overview

The prelaunch activities involve monitoring the vehicle and evaluating the effect of any anomalous conditions. The flight director must be kept informed of the status of the propellant loading and any problems that have developed. A listing of the relevant KSC prelaunch procedures, called OMIs, is shown in Table 1.3.2-I. The prelaunch team arrives on console approximately L-14 hours, and the ascent team arrives on shift at approximately L-6 hours.

The prelaunch team will prepare the consoles for launch per SCP 1.3.3. Table 1.3.2-II lists the recommended loops for the Booster Systems Engineer (BSE) to monitor during prelaunch operations (the ME and MPS loops are provided in SCP 1.3.3). Table 1.3.2-III provides a brief description of each of these loops. In both of these tables, the loops shown in **bold** are considered to be a higher priority loop and should be monitored as much as possible. If it becomes necessary to monitor a loop that is not configured on the DVIS panel, the operator should refer to SCP 3.3.2 to reconfigure the panel.

Table 1.3.2-IV identifies the prelaunch events of interest and the reports to be given beginning with the prelaunch team on console to resuming the count from the T-9 minute hold. The OMI sequence, step numbers, and times will vary from flight to flight. Therefore, THIS TABLE SHOULD ONLY SERVE AS A GUIDE TO DETERMINE ROUGHLY WHEN PRELAUNCH EVENTS WILL OCCUR. The applicable voice call is shown in quotation marks, and critical Booster events are shown in **bold**.

Table 1.3.2-I.- Prelaunch OMIs

<b>OMI Number</b>	<b>Description</b>
S0007, Volume 2	Terminal launch countdown
G3151	LO2 system preparation for vehicle loading
G3251	LH2 system preparation for vehicle loading
V9018	SSME/MPS preparation and securing for propellant loading
S1003	MPS LO2 system automatic load and drain operations
S1004	MPS LH2 system automatic load and drain operations

Table 1.3.2-II.- Booster Prelaunch Communication Loops

<b>Voice Loops</b>	<b>Mode</b>
1 A/G 1 (OIS 212)	M
<b>AFD CONF 1</b>	<b>TLM</b>
<b>BOOSTER MPSR 1</b>	<b>TLM</b>
ET HOSC CONF	TLM
<b>FD 1</b>	<b>TLM</b>
<b>MOCR SPEC 1</b>	<b>TLM</b>
<b>MPS HOSC CONF</b>	<b>TLM</b>
OIS 132 OTC	M
OIS 136 TBC	M*
OIS 146 SSME SSMEC	TLM
OIS 156 LO-2	M
OIS 161 PE-1	TLM*
OIS 166 LH2	M
OIS 168 MPS	TLM
OIS 175 R/S&SRB INST	TLM*
OIS 187 HYD ORB&SRB	TLM*
OIS 231 WX TRBL	M*
<b>OIS 232 NTD TD</b>	<b>M</b>
OIS 245 ESA	TLM*
OIS 261 PE 2	TLM*
OPO	M**
SPAN	TLM*
SRB HOSC	TLM
<b>SSME HOSC</b>	<b>TLM</b>
SSPO	M**
<b>SSR 1 CONF</b>	<b>TLM***</b>

**Notes:**

M - Monitor

TLM- Talk/Listen/Monitor

\* - Only need to call up for relevant discussions regarding Booster.

\*\* - Monitor if necessary to understand management rationale for flight.

\*\*\* - MPSR loop only



Table 1.3.2-III.- Prelaunch Loop Descriptions

Loops	Description
1 A/G 1 (OIS 212)	Used in conjunction with OIS 232 and 132; has the capability to talk to the orbiter. Also used to talk to the crew by the FD or CAPCOM.
<b>AFD CONF 1</b>	<b>Used by the Flight Director as a backup to the FD 1 loop, and also to coordinate shift handovers, and to conduct the weather briefings with the crew.</b>
<b>BOOSTER MPSR 1</b>	<b>Used by the BSE, the ME, and the MPS console operators to evaluate and status the SSME and MPS issues between the FCR and the MPSR.</b>
ET HOSC CONF	Used by the ET community to status ET operations, to discuss icing on the ET, and to evaluate any other anomalous ET conditions.
<b>FD 1</b>	<b>Used by the Flight Director to coordinate all systems activity between the Flight Controllers at JSC, the crew, and KSC.</b>
<b>MOCR SPEC 1</b>	<b>Used by other FCR operators to contact the BSE. Also used as a backup to the BOOSTER MPSR 1 loop.</b>
<b>MPS HOSC CONF</b>	<b>Used by the MPS community to coordinate and evaluate MPS related issues. It is also used by KSC MPS personnel (ETL) to contact the JSC Booster for technical discussions. The technical discussions with the ETL will usually take place on OIS 261.</b>
OIS 132 OTC	Used by the Orbiter Test Conductor (OTC) from pickup of test until crew ingress to coordinate and direct orbiter testing. OTC coordination channel is used by the assistant OTC from crew ingress to T-9 minutes to coordinate and direct orbiter subsystem testing. From T-9 minutes through T-O, the assistant OTC continues to monitor OIS 132 to discuss unrelated launch commit criteria problems, as required. This channel is not used to communicate with the orbiter.
OIS 136 TBC	Used to monitor ET OMI processing at KSC.
OIS 146 SSME SSMEC	Prime channel for testing and monitoring of the main engine systems and the SSME controllers.
OIS 156 LO-2	Prime channel for testing and monitoring ground, Orbiter, and ET LO2 systems. The main function will be tanking and detanking (if required).
OIS 161 PE-1 OIS 261 PE 2	Project engineering channels are used to coordinate systems integration and troubleshooting by the engineers in the firing room. OIS 161 is used first. If OIS 161 is busy, then OIS 261 will be used.
OIS 166 LH2	Prime channel for testing and monitoring ground, Orbiter, and ET LH2 systems. The main function will be tanking and detanking (if required).
OIS 168 MPS	Prime channel for main propulsion systems testing, purging, servicing, etc.
OIS 175 R/S&SRB INST	Used by Booster to contact KSC ETL for SRB electrical and instrumentation subsystems.

Table 1.3.2-III.- Prelaunch Loop Descriptions (continued)

Loops	Description
OIS 187 HYD ORB&SRB	Used by Booster to contact KSC ETL for SRB hydraulic system issues.
OIS 231 WX TRBL	Used for communications with KSC meteorologist; may also be used as required for non-weather related hardware/software troubleshooting.
<b>OIS 232 NTD TD</b>	<b>Used by the NASA Test Director (NTD) to integrate all flight hardware and its support equipment. The reporting of flight or ground hardware problems to the NTD is also done on this channel. Also used to monitor and respond to procedure call outs. This channel is not used to communicate with the Orbiter.</b>
OIS 245 ESA	Management loop for KSC Firing Room 2. Used by Booster as backup to OIS 161 to discuss SRM mechanical issues with the KSC ETL.
OPO	Orbiter Project conference loop to coordinate and evaluate orbiter issue; high-level management overview type loop.
SPAN	Used by SPAN Systems and SPAN Manager to coordinate issues with the JSC flight control team and the MER engineering team.
SRB HOSC	Used by the SRB community to status SRB operations and to evaluate anomalous SRB conditions.
<b>SSME HOSC</b>	<b>Used by the Main Engine community to periodically present a main engine status during propellant conditioning. Also a forum to discuss anomalous SSME conditions. It is also used by KSC SSME personnel (ETL) to contact the JSC Booster for technical discussions. The technical discussions with the ETL will usually take place on OIS 146.</b>
SSPO	Mission Management Team (MMT) conference loop to coordinate and evaluate mission critical situations; high-level management overview type loop.
<b>SSR 1 CONF</b>	<b>(MPS and Main Engine Only) Used within the MCC by MPSR operators to communicate with each other; back room equivalent of MOCR SPEC.</b>

Table 1.3.2-IV.- Booster Prelaunch Activity

<b>Time (T- )</b>	<b>Console</b>	<b>Activity/Report</b>	<b>S0007, Vol. 2, Seq. No.</b>
<b>-10H00M</b>		<b>APPROXIMATE TIME FOR ARRIVAL OF ASCENT BOOSTER TEAM</b>	
-10H00M		SRB PIC test	15-0062
-10H00M		SRB aft skirt GN2 purge activation	15-0066
-10H00M		Verify MPS LO2 feed D/V open RPC B on	15-0077
<b>-10H00M</b>		<b>MPS helium tanks to flight pressure</b>	<b>15-0086</b>
-9H00M		SRB powerup. SRB buses A and B power applied and MDM initialized SRB PC1 and PC2 are active	15-0152
	MPS	Report: "SRB Bus A and B powerup"	
-9H00M		SRB field joint heater activation	15-0155
-9H00M		Clear pad for ET loading	15-0164
-9H00M		Air to GN2 changeover	15-0185
<b>-8H15M</b>		<b>Weather update ET tanking preps</b>	<b>15-0217</b>
-7H45M		SRB TVC power up	15-0268
-7H45M		Weather status for SRB retrieval forces	15-0296
<b>-7H00M</b>		<b>LH2 final preps for vehicle loading complete</b>	<b>15-0387</b>
-6H45M		LH2 pre chilldown ops per OMI S1004	15-0390
-6H45M		ET I/T GN2 purge initiation	15-0403
-6H45M		ET I/T haz gas status	15-0406
<b>-6H30M</b>		<b>LO2 final preps for vehicle loading complete</b>	<b>15-0422</b>
	MPS	Report: "Preps for LO2 and LH2 loading complete"	
-6H30M		LO2 loading preliminaries per OMI S1003	15-0426
-6H30M		Initiate SSME purging per OMI S1003	15-0432
	MPS	Report: "SSME GN2 purging initiated"	
<b>-6H10M</b>		<b>MMT/LD weather briefing for ET load</b>	<b>15-0589</b>
-6H05M		LO2/MPS loading preliminaries complete. SSME purge sequence 3 initiated	15-0602
-6H05M		LH2 pre-chilldown operations complete	15-0603
	MPS	Report: "SSME purge sequence 3 initiated"	
<b>-6H05M</b>		<b>LCC verification</b>	<b>15-0646</b>
<b>-6H00M</b>		<b>Verify Go for LO2 &amp; LH2 tanking</b>	<b>15-0655</b>
	MPS/BSE	Report: "Go for tanking"	
-6H00M		T-6 hour hold	15-0656
-6H00M		T-6 hours and counting	15-0664
-6H00M		ET TPS/Frost Ice Team report	16-0002
-6H00M		ET ready for LO2/LH2 loading	16-0005
-6H00M		Begin Haz gas H2 & O2 monitoring	16-0008
-6H00M		Orbiter ready for LO2/LH2 loading	16-0011
<b>-6H00M</b>		<b>Proceed with ET LO2 load per S1003</b>	<b>16-0012</b>

Table 1.3.2-IV.- Booster Prelaunch Activity (continued)

<b>Time (T- )</b>	<b>Console</b>	<b>Activity/Report</b>	<b>S0007, Vol. 2, Seq. No.</b>
-6H00M		Initiate LO2 transfer line chilldown	16-0014
-6H00M		Initiate LH2 facility/orbiter chilldown	16-0016
	MPS/BSE	Report: "LO2 transfer line chilldown initiated" "LH2 facility/orbiter chilldown initiated"	
-6H00M		Verify SRB nozzle temperatures	16-0023
-6H00M		Operate SRB aft skirt low flow rate purge & monitor temp limits	16-0024
-5H50M		LH2 facility/Orbiter chilldown complete; initiate LH2 slow fill to 5% sensor wet	16-0027
	MPS/BSE	Report: "LH2 tank in slow fill to 5%" Record: GMT of LH2 slow fill initiate	
-5H50M		LO2 transfer line chilldown complete; initiate Orbiter MPS (LO2) chilldown Record: GMT of transfer line chilldown	16-0028
-5H20M		Orbiter MPS (LO2) chilldown complete; initiate LO2 slow fill	16-0031
	MPS/BSE	Report: "LO2 tank in slow fill to 5%" Record: GMT of LO2 slow fill initiation	
-5H10M		LH2 ECO sensors wet Record: GMT of LH2 and LO2 ECO sensors wet (LO2 sensors wet following initiation of slow fill NOT during chilldown operations)	16-0032
-5H10M		LO2 slow fill complete; initiate LO2 fast fill to 98%	16-0033
	MPS/BSE	Report: "LO2 tank in fast fill to 98%" Record: GMT of LO2 fast fill initiation	
-5H00M		LH2 slow fill to 5% complete; initiate LH2 fast fill to 98%	16-0037
	MPS/BSE	Report: "LH2 tank in fast fill to 98%" Record: GMT of LH2 fast fill initiation	
-5H00M		Begin LH2 recirculation. LH2 recirc pumps on, recirc valves open, prevalues closed	16-0038
	MPS	Report: "LH2 recirc pumps on"	

Table 1.3.2-IV.- Booster Prelaunch Activity (continued)

<b>Time (T- )</b>	<b>Console</b>	<b>Activity/Report</b>	<b>S0007, Vol. 2, Seq. No.</b>
-4H00M		MPS LH2 ET ullage pressure transducer #4 verification	16-0070
-4H00M	MPS/BSE	Report: "Booster is GO for ET ullage transducer switch out"	
-4H00M		Spare ET ullage transducer switched in	16-0071
	MPS/BSE	Report: "Ullage transducer #4 looks good" "Booster is GO to swap back"	
-4H00M		Standby for ullage transducer #4 switch out	16-0072
-4H00M		Spare ET ullage transducer switched back out.	16-0073
	BSE/MPS	Report: "Transducer swap out looked good; no anomalies" Record: GMT at completion of swap out procedure	
-3H45M		LH2 fast fill to 98% complete; initiating LH2 topping to 100%; close LH2 inboard fill and drain valve	16-0074
	MPS/BSE	Report: "LH2 fast fill to 98% complete" "LH2 topping to 100% initiated" Record: GMT of LH2 topping initiation	
-3H45M		SRB/ET PIC resistance checks	16-0081
-3H45M		MEC preflight BITE test	16-0084
-3H25M		LO2 fast fill to 98% complete; initiating LO2 topping to 100%	16-0122
	MPS/BSE	Report: "LO2 fast fill to 98% complete" "LO2 topping to 100% initiated" Record: GMT of LO2 topping initiation	
-3H05M		LH2 topping to 100% complete; initiating replenish Record: GMT of LH2 replenish initiation	16-0127
-3H05M		LO2 topping to 100% complete; initiating replenish Record: GMT of LO2 replenish initiation	
-3H05M		LO2 in stable replenish	16-0128
	MPS/BSE	Report: "LO2 in stable replenish"	
-3H05M		LH2 in stable replenish	16-0131
	MPS/BSE	Report: "LH2 in stable replenish"	

Table 1.3.2-IV.- Booster Prelaunch Activity (continued)

<b>Time (T- )</b>	<b>Console</b>	<b>Activity/Report</b>	<b>S0007, Vol. 2, Seq. No.</b>
<b>-3H00M</b>		<b>APPROXIMATE TIME FOR ARRIVAL OF ASCENT BOOSTER TEAM</b>	
-3H00M		T-3 hour countdown hold	6-0153
-3H00M		Flight crew wakeup	16-0200
-3H00M		Flight crew weather briefing	16-0282
-3H00M		T-3 hours and counting	16-0421
-3H00M		SRB RGA powerup (SRB bus C is powered up; SRB PC3 active)	16-0436
-3H00M	MPS	Report: "SRB Bus C powerup"	
-2H55M		Flight crew departs O&C building	16-0449
-2H45M		Final Ice/Debris Team report	16-0466
<b>-2H45M</b>		<b>Launch commit criteria verification</b>	<b>16-0469</b>
<b>-2H45M</b>	<b>MPS/ME/ BSE</b>	<b>Report: "No LCC violations"</b>	
-2H30M		ET liquid level sensor checks	16-0510
-2H25M		Flight crew ingress; monitor switch positions during ingress	16-0525
-2H00M		SRB recovery area status	16-0562
-1H30M		SRM chamber pressure verification	16-0578
	MPS	Report: "SRB PC verification in progress"	
-1H20M		Hatch closure	16-0682
<b>-55M00S</b>		<b>Launch window update Record: LO2 drainback hold time</b>	<b>16-0723</b>
	<b>MPS</b>	<b>Report: "Copy, LO2 drainback hold time is XX"</b>	
-40M00S		LD/FD weather briefing	16-0798
<b>-29M00S</b>		<b>MEC preflight BITE</b>	<b>16-0832</b>
-20M00S		T-20 minute countdown hold	16-0865
-20M00S		All KSC personnel switch to 1 A/G 1 (OIS 212) for remainder of count	16-0918
-20M00S		T-20 minute briefing by NTD	16-0933
-20M00S		T-20 minutes and counting	16-0948
-20M00S		PASS to OPS1	16-0949
-18M30S		BFS to OPS1	16-0953
<b>-16M00S</b>		<b>MPS helium reconfiguration</b>	<b>16-0970</b>
	<b>MPS/BSE</b>	<b>Report: "MPS helium reconfig complete"</b>	
-09M00S		T-9 minute countdown hold	16-1010

Table 1.3.2-IV.- Booster Prelaunch Activity (continued)

<b>Time (T- )</b>	<b>Console</b>	<b>Activity/Report</b>	<b>S0007, Vol. 2, Seq. No.</b>
<b>-09M00S</b>		<b>Final determination of launch window Record: LO2 drainback hold time</b>	<b>16-1018</b>
	<b>MPS</b>	<b>Report: “Copy, final LO2 drainback hold time is XX”</b>	
<b>-09M00S</b>		<b>Launch commit criteria verification</b>	<b>16-1047</b>
<b>-09M00S</b>	<b>MPS/ME /BSE</b>	<b>Report: “No LCC violations”</b>	
<b>-09M00S</b>		T-9 minutes and counting	16-1075

Prelaunch Anomaly Resolution

Note: The process used to resolve prelaunch anomalies is identified in an as yet unpublished FCOH procedure. The following description is a summary of the preliminary procedure. Once the FCOH procedure is published, it will take precedence over this portion of the SCP.

LCC violations are identified and resolved by the Launch Control team in the prime Firing Room at KSC. Support in resolving LCC violations is provided to the prime Firing Room by the KSC Engineering team (located in the backup Firing Room), the Mission Evaluation Room (MER), Huntsville Operations Support Center (HOSC), and the JSC Flight Control team. A subsystem ETL, located in the backup Firing Room, coordinates all design center inputs on LCC violations to the Launch Control Team.

The ETLs that Booster interfaces with are defined in the JSC Booster ETL/SSE Matrix contained in the Booster Cue Card book. A sample ETL Matrix is shown in Table 1.3.3-V.

JSC involvement in the resolution of LCC violations prior to providing a “GO” to pick up from the T-9 minute hold will be worked through the KSC Engineering Team in the backup Firing Room. After the T-9 minute hold, all inputs for the KSC Launch Control Team will be passed through the Flight Director. Direct conversations between JSC Flight Control team members and the KSC ETLs after T-9 minutes and counting should only occur at the direction of the Flight Director.

Table 1.3.2-V.- Sample KSC ETL/JSC Flight Control Team Loop Protocol

SYSTEM	SYSTEM Call-Sign	ETL OIS Loop (see notes)	Project Coordination Loop	ETL Phone # (Firing Room 2)
SSME	CSME	146	SSME HOSC	(407) 867-4383 -3541
CCME	CCME	146	SSME HOSC	(407) 867-4367 -4368
MPS/SSME	CM S/CM	261	MPS HOSC	(407) 867-4383 -3541
LOX/LH2	CLC L/CLH	261	MPS HOSC	(407) 867-4383 -3541
SRM MECH		161/245	SRB HOSC	(407) 857-2882 -2883
BOOSTER E&I	CPWR	175	N/A	(407) 867-4371 -3576
SRB APU & HYD	CBHY/CBAP	187	N/A	(407) 867-4382 -3531

**Notes:**

1. SSME/CCME ETLs will call JSC BOOSTER on SSME HOSC. JSC BOOSTER will call SSME/CCME ETLs on OIS 146. ETL discussions will take place on OIS 146.
2. MPS/LOX/LH2 ETLs will call JSC BOOSTER on MPS HOSC. JSC BOOSTER will call MPS/LOX/LH2 ETLs on OIS 261. ETL discussions will take place on OIS 261.
3. SRM MECH ETL will discuss/coordinate any SRM MECH issues on SRB HOSC prior to discussions on OIS 161/245. SRB MECH ETL will be side toning SRB HOSC at all times.

REFERENCES

1. Shuttle Countdown (LPS), OMI S0007, Volume 2, Rev CT, April 4, 2000.



## TITLE

MPS PRELAUNCH OPERATIONS

## PURPOSE

The purpose of this SCP is to describe the responsibilities and actions of the MPS operator during prelaunch activities in the MPSR. This SCP is to be used in conjunction with SCP 1.3.2, Booster Prelaunch Activity/Reporting.

## DESCRIPTION

The following topics are discussed in this SCP:

- Prelaunch checklists and activities
- Problem correction
- Operations And Maintenance Instructions (OMIs)
- Prelaunch cue cards
- S0007 Interim Problem Report (IPR)

## PROCEDURE

### A. PRELAUNCH CHECKLISTS AND ACTIVITIES

The prelaunch team arrives on console at approximately T-10 hours (L-14 hours). Upon arrival, the MPS operator must set up the MPS console (Ref. SCP 3.2.1- MPS Console Location/Configuration) and DVIS communication system (Ref. 3.3.2 – BSE/ME/MPS Communication Panels). In addition, the MPS operator must verify that all the required MPSR documentation is available to support flight operations.

#### 1. CONSOLE SETUP

The prelaunch configuration of the workstation is up to the individual user. However, the following displays should be called up at a minimum:

- PASS Header
- MPS Prelaunch
- MPS Ascent
- ME Ascent
- MPS Bilevel
- DDD Panel
- RTPLOT (MPS)

- RTPLOT (Skin Temp)
- XGOAL
- ELOG
- FID Display
- BOSS Menu Comp
- OFS (PASS/BFS)
- LAUNCH STATUS

## 2. DOCUMENTATION VERIFICATION

The availability of all required documentation should be verified. A listing of the required documentation is found in the “FCR & MPSR Prelaunch Checklist”. A sample copy of the “FCR & MPSR Prelaunch Checklist” is shown in Figure 1.3.3-I. The ascent Booster will provide two copies of the prelaunch checklist (one for the prelaunch Booster and one for the prelaunch MPS operator) to the prelaunch team prior to the prelaunch shift. Any documentation found in the console in-box should also be reviewed for booster systems applicability.

## 3. SYSTEMS MONITORING

The MPS operator should actively listen to the voice loops throughout the shift. SCP 1.3.2, “Booster Prelaunch Activity/Reporting” identifies the prelaunch DVIS communication loops monitored by the prelaunch Booster and prelaunch MPS operators.

Major countdown milestones and any booster systems milestones should be noted. Problem identification and resolution should be followed and noted in both the prelaunch checklist and the console logs (reference FCOH SOP 1.1, “Console Logs” for additional information). Prelaunch anomaly resolution protocol between KSC and JSC is described in SCP 1.3.2, “Booster Prelaunch Activity/Reporting”.

## 4. SOFTWARE FILE TIME TAGS

The MPS operator must verify that the following time tags are correct by using the appropriate checklist (Certification of Flight Readiness Addendum):

- BOSS Software Executable Time Tags
- BOSS Software Data File Time Tags
- MET Software Data File Time Tags
- Global Software Data File Time Tags

The MPS operator must notify the BSE if a discrepancy is found with the time tags.

## B. PROBLEM CORRECTION

Console, workstation, and facility problems should be reported so the responsible persons can begin troubleshooting in order to make the appropriate repairs.

Workstation software problems should be reported to the Booster's Group Administrator (GA). Workstation hardware problems should be reported to WSS on the GC CALL loop. Any facility problem (lighting, temperature, DVIS, etc.) should be reported to GC on the GC CALL loop. For additional information, or in the event that an MCC anomaly report (AR) is required, reference FCOH SOP 1.7, "MCC/SMS Problem Reporting."

If some of the telemetry appears to have poor quality or certain parameters are missing, the user must verify that the correct simulation or flight activity has been selected. If the activity is correct, the GA should be informed as soon as possible.

In the event of a headset malfunction, the user should obtain a replacement at the USA logistics substore located in building 5 (room 1006). Emergency replacement of defective units may be obtained through the Facility Operations Manager (FOM) in the MCC (room 111). Prior to exchanging the headset, the user should try another headset jack and another DVIS panel to make sure the problem is with the headset.

## C. OMI USAGE

The OMI books, located in both the MPSR and the FCR, are followed during the entire prelaunch countdown by both the prelaunch team and the ascent team. They are also used following any launch scrub or pad abort situations.

The OMIs are published by KSC for four basic purposes:

- To provide the sequence of operations required to prepare the shuttle for launch
- To service certain propellants and gases to the shuttle for launch
- To launch the shuttle
- To perform initial pad safing after launch and provide for turnaround operations

There are several OMI volumes. S0007, volumes 1-5, are the primary controlling task documents. Volume 2 of S0007 is the primary OMI used by the MPS operator during prelaunch. Several subtask OMI documents are used in conjunction with the S0007 documents. These subtask OMI documents are mainly used to perform specialized tasks. The subtask OMIs that are applicable to Booster include: G3151, G3251, S1003, S1004, V1009, and V9018. In addition, there is an OMI document for the Terminal Countdown Demonstration Test (TCDT), S0017, and for the Shuttle Final Countdown Phase Simulation, S0044.

The flow of prelaunch activities from S0007 is shown in Figure 1.3.3-II. A listing of the S0007 volumes 1-5 is provided in Table 1.3.3-I. S0007 subtask OMIs are shown in Figure 1.3.3-III.

SCP 1.3.2, “Booster Prelaunch Activity/Reporting”, provides a summary of events and required reporting by both the BOOSTER and MPS operators.

#### D. PRELAUNCH CUE CARDS

Using the prelaunch cue card shown in Figure 1.3.3-IV, the MPS operator can verify that the MPS valve and switch positions have been correctly configured.

#### E. INTERIM PROBLEM REPORT (IPR)

An IPR is any off-nominal condition that affects a shuttle system during prelaunch operations. The Shuttle Processing Engineering web site (<http://www-launchops.ksc.nasa.gov>) lists all the S0007 IPRs for a particular flight. Additional information such as the status of an IPR is provided as well.

#### REFERENCES

1. FCR & MPSR Prelaunch Checklist, Rev. S, 1/19/00.
2. FCOH, Shuttle OPS, Final, Rev. B, CPN-7, JSC-26843, 8/25/99.

**FCR & MPSR Prelaunch Checklist  
Booster and MPS  
Rev S (1/19/00 JDR/JLM)**

STS - \_\_\_\_\_ OV - \_\_\_\_\_ Launch Attempt - \_\_\_\_\_ Date - \_\_\_\_\_

	Prelaunch	Launch	Entry
Booster	_____	_____	_____
MPS Prime	_____	_____	_____
MPS OJT	_____	_____	_____
ME Prime		_____	
ME OJT		_____	

Were any calibration curves updated? \_\_\_\_\_

If calibration curves updated, which ones?  
\_\_\_\_\_  
\_\_\_\_\_

If there are calibration curve changes,  
verify the changes per MPS Operator Instruction: \_\_\_\_\_

Make sure there are enough  
chairs for the Ascent Team  
(at least 2 FCR and 5 MPSR chairs) \_\_\_\_\_

**DVIS**

Voice Loops OK \_\_\_\_\_ Is the ring volume turned down ? \_\_\_\_\_

Figure 1.3.3-I. - MPS Prelaunch Checklist (sample), sheet 1 of 4.

### Workstation Programs

- Verify the time tags of all the files listed in the COFR statement addendum match the time tags of the computer files. OK \_\_\_\_\_
- BOSS Displays OK \_\_\_\_\_
- BOSS Comps OK \_\_\_\_\_
- ISP Channel OK \_\_\_\_\_
- BSE Channel OK \_\_\_\_\_
- BFS Channel OK \_\_\_\_\_
- ISP Limit OK \_\_\_\_\_
- Flight Director Status (IMGO) OK \_\_\_\_\_
- VCR OK \_\_\_\_\_
- CRANS\_RT OK \_\_\_\_\_
- ELOG OK \_\_\_\_\_
- RTPLOT OK \_\_\_\_\_
- OFS (Master, Shuttle, DPS, RTdata from DPS, OFS) OK \_\_\_\_\_
- EDTE MSK 0918 (MOC commanding only) or MRTCs on TELCOM Command Inventory Display (Command Server only) OK \_\_\_\_\_
- MRTCs Safed (MRTCs will show 'U' and all RTCs will show 'S') OK \_\_\_\_\_

Figure 1.3.3-I. - MPS Prelaunch Checklist (sample), sheet 2 of 4.

**FCR / MPSR Library (check mark indicates book/data available)**

	FCR	MPSR	
• OMI's	_____	_____	
• Flight Rules	_____	_____	
• FDF	_____	_____	
• Software OPS notes	_____	_____	
• LCCs	_____	_____	
• SCPs	_____	_____	
• System's Briefs	_____	_____	
• Phone List	_____	_____	
• SSME/NPSP Constants for the BOSS Performance Computation		_____	
• GLS Sequence Document		_____	
• SODB (Vol. I and III)		_____	
• MPS Components Manual		_____	
• ET Books (Blue Books)		_____	
• SSME Controller Spec		_____	
• SRB and RSRM Level III FRR Books		_____	
• Flight Specific Update for RSRM Countdown Data Book (if available)		_____	
• Previous Flight Data (most recent flight data if previous flight data is not available)			
– MSFC Report – SRB Flight Evaluation Report		_____	(1)
– MSFC Report – RSRM Flight Evaluation Report		_____	(1)
– Boeing Integrated MPS Post Flight Final Report (Blue Book)		_____	(2)
– ET-MPS Engineering Evaluation Final Report		_____	(2)
– Console Log Books		_____	(2)
(1) previous STS flight only			
(2) previous STS flight plus previous STS flight of the same Orbiter			

Figure 1.3.3-I. - MPS Prelaunch Checklist (sample), sheet 3 of 4.

**Prelaunch Summary**

STS - \_\_\_\_\_ OV - \_\_\_\_\_ Launch Attempt - \_\_\_\_\_ Date - \_\_\_\_\_

Prelaunch BSE \_\_\_\_\_ on console at \_\_\_\_\_  
 Prelaunch MPS \_\_\_\_\_ on console at \_\_\_\_\_

MPS	LO2	LH2
LO2 transfer Line Chilldown Complete		N/A
LH2 Facility/Orbiter Chilldown Complete, Initiate LH2 Slow Fill	N/A	
Orbiter MPS LO2 Chilldown Complete, Initiate LO2 Slow Fill		N/A
4 Low Level Sensors Wet (Note 1)		
Slow Fill Complete/Initiate Fast Fill (Note 2)		
Fast Fill Complete/Initiate Topping at 98%		
LH2 Ullage Pressure Sensor Swap	N/A	
Topping Complete/Initiate Replenish at 100%		
Haz Gas Concentrations (Note 3) Initial Value/Leveled Out At:		

Note 1: On LO2 side, after Slow Fill Initiation

Note 2: LO2 approx. 11 minutes between slow fill & fast fill; LH2 fast fill starts at 5%

Note 3: Check after recirc pumps are started, approx. 15 minutes after LH2 fast fill starts

Purge Sequence	Initiation Time
PSN-1	
PSN-2	
PSN-3	

Prelaunch To Ascent Team Handover Completed \_\_\_\_\_

Copy of completed Prelaunch Training Roster to log book \_\_\_\_

Figure 1.3.3-I. - MPS Prelaunch Checklist (sample), sheet 4 of 4.



TABLE 1.3.3-I. - S0007 DESCRIPTIONS

S0007 - VOL. 1			
Pre-Operation Setups for GSE, Orbiter, ET, SRB, Payloads			
Sequence		Function	Time Period
Begin	End		
1-XXX	12-XXX	Generic Pre-Operation	N/A

S0007 - VOL. 2			
Operation Timeline for GSE, Orbiter, ET, SRB, Payloads, Launch Timeline, RSLs Abort, RSLs Hold, BFS Engaged Abort, SRB Holdfire, Unplanned Hold Before T-5 minutes, Recycle Control Sequence			
Sequence		Function	Time Period
Begin	End		
13-XXX	16-XXX	Nominal Launch Timeline	T-43 hrs to T-0
17-XXX	24-XXX	Launch Abort or Post Launch	T-0 to Post Launch/Abort Safing
25-XXX	27-XXX	Reserved	N/A
28-XXX	28-XXX	Prelaunch Hold Option 1: Unplanned Long Hold	T-9 minutes to T-5 minutes

S0007 - VOL. 3	
Launch Abort Scrub and Turnaround	
Sequence	Function
29-XXX	Reserved
30-XXX	Initial Launch Scrub
31-XXX	24 Hour Scrub Turnaround
32-XXX	48 Hour or Longer Scrub Turnaround
35-XXX	Launch Scrub & Secure
36-XXX	PRSD Scrub Turnaround Options

TABLE 1.3.3 -I. - S0007 DESCRIPTIONS

S0007 - VOL. 4		
Prelaunch and Postlaunch System & Subsystem Test. Tests Outside Standard Timelines With No Attached Time Tags.		
Sequence		System & Subsystem Tests
Begin	End	Specifics Of Interest:
37-XXX	97-XXX	
Sequence		Function
41		ET level sensor calibration checks
44		MPS helium tank load GSE & LH2/LO2 prepress
48		SRB/ET PIC resistance tests
57		Ice/Frost inspection
60		ET GH2 vent retract system config
61		SRB Ignition S&A Device Verification (contingency)
68		ET IT Entry
72		ET Bipod Heater Verification
76		Shuttle Ascent Switchlist
79		Pre-Ascent Switch Lists

S0007 - VOL. 5		
Preplanned Contingency Actions to Provide Workarounds To Enable A Launch to Continue & Emergency Instructions to Safe & Secure Vehicle, MLP, GSE, and Flight Crew		
Sequence		Function
Begin	End	
98-XXX	134-XXX	Contingency Actions and Safe & Secure Functions

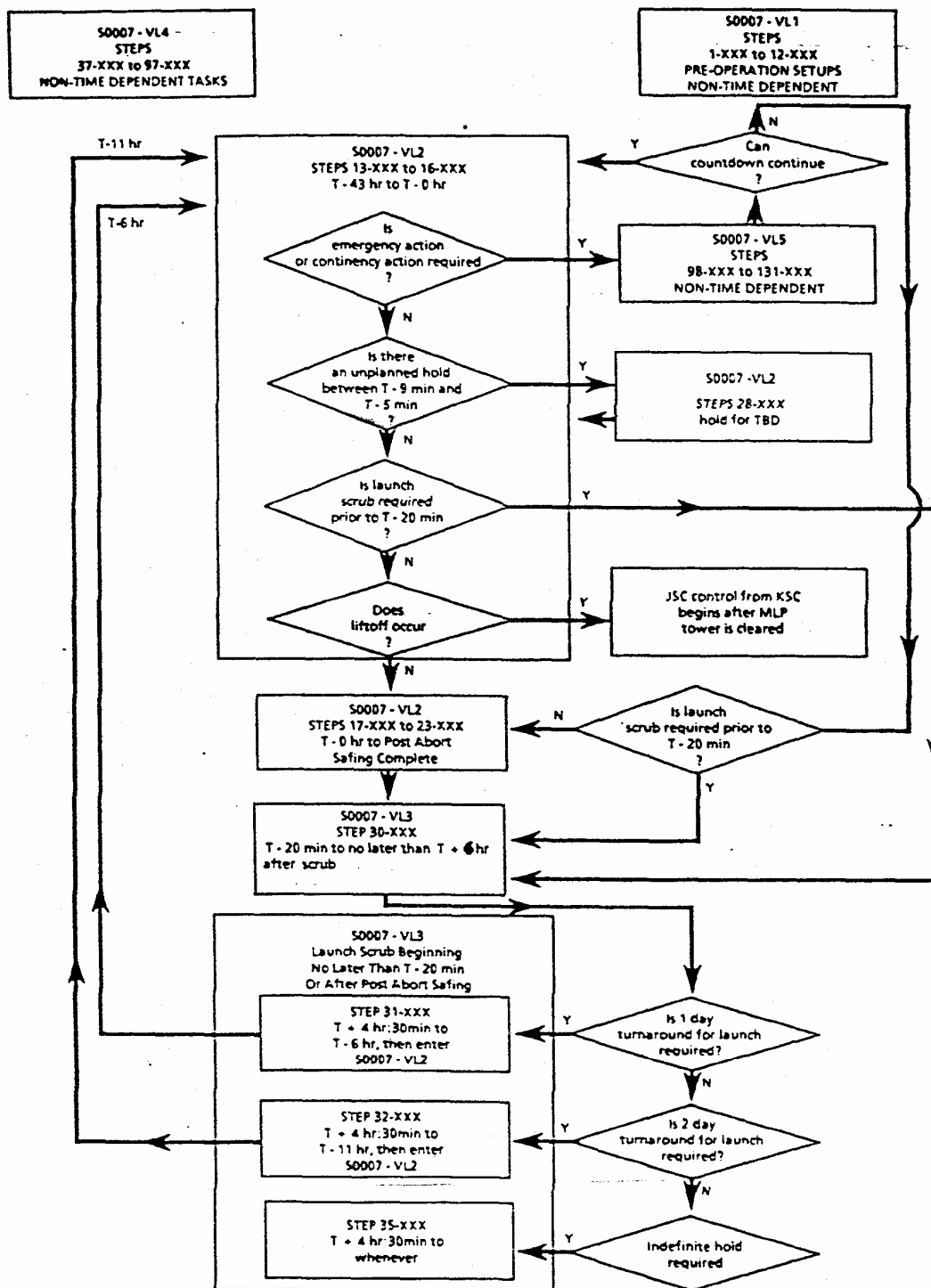


Figure 1.3.3-II. - S0007 Launch Flow

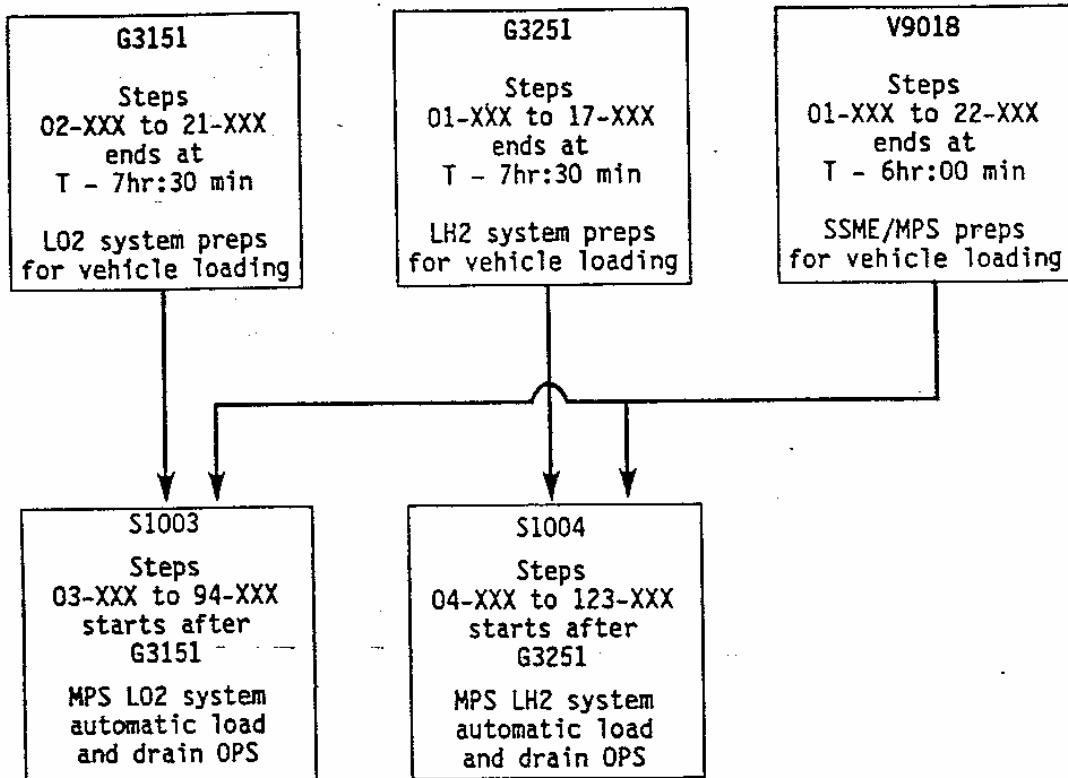


Figure 1.3.3-III. - S0007 Subtask OMI Flows

MPS PRELAUNCH EVENTS

EVENT

PRE-CRYO LOADING

\*\*\*\*\* SEE VALVE CONFIGURATION \*\*\*\*\*

COCKPIT SWITCH LIST  
(PRE-INGRESS)

MANF PRESS (2) - GPC  
F/D VALVES (4) - GND  
PREVALVES (6) - GPC  
FEEDLINE RLF ISOL (2) - GPC  
HE ISOL VALVES (7) - GPC  
PNEU XOVER VALVE - GPC  
HE INTERCONNECT VALVES (3) - GPC

ENG HE BOTTLES @ 1800-2200 PSIA  
ENG HE REG OUT PRESS @ 730-788 PSIA  
PNEU HE REG OUT PRESS @ 716-796 PSIA

SUBSEQUENT TO PURGE SEQ 3  
LO2 P/V - OPEN

LO2 CHILLDOWN  
LO2 OB F/D - OPEN  
LO2 ECO SENSORS WET

LO2 DRAINBACK TO END OF FLUSH  
LO2 ECO SENSORS - WET TO DRY

LH2 CHILLDOWN & SLOW FILL TO 5% SENSOR  
LH2 OB F/D - OPEN  
LH2 TOPPING VALVE - OPEN (PRIOR TO SLOW FILL)

LO2 SLOW FILL - ABOVE 2% (LO2 ULLAGE 2.0-8.0 PSIG)  
LO2 ECO SENSORS - WET

LH2 FAST FILL TO 85% - WHEN 3 OF 4 ECO SENSORS WET  
LH2 ECO SENSORS WET  
LH2 ULLAGE PRESS BAND - (32.9-43.2 PSIA)  
TEMPORARILY SWITCH LH2 ULLAGE PRESS TRANS 3 & 4 DURING FAST FILL

LO2 FAST FILL TO 98% - INITIATED 11 MINUTES AFTER 2%

(15 MIN. AFTER START OF LH2 FAST FILL)  
LH2 RECIRC VALVES - OPEN  
LH2 RECIRC PUMPS (10800-11800 RPM)  
LH2 PREVALVES - CLOSE

FAST FILL PHASE COMPLETE - TRANSITION TO REDUCED FAST-FILL  
LH2 IB F/D - CLOSE

LO2/LH2 TOPPING PHASE  
98% SENSORS WET  
ULLAGE PRESS BAND - (LO2 - 0.0-17.1 PSIG; LH2 - 14.7-35.7 PSIA)

LO2/LH2 STABLE REPLENISH  
100% SENSORS WET

RTLS	V	HELIUM	L	C	R	P	Q	LO2	LH2
IB	O	ISO A	O	O	O	O	FV OP O		OOO
OB	O	ISO B	O	O	O	O	FV CL X	XXX	
		INT IN					FD DISC	OO	OO
P1	O	INT OUT	O				FD LATCH	**	**
P2	O	XVR/BD12	O				FD RIS O		
							IB F/D X		
		MNA ----> APC4 ----> ALC1					OB F/D X	X	X
		MNB ----> APC5 ----> ALC2					MN P1/2O	/	/
		MNC ----> APC6 ----> ALC3					OVB/TOFX		X
							R DSC X		
							P LN V O		
							POG01/2O		

Figure 1.3.3-IV. - MPS Prelaunch Cue Card

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## TITLE

BOOSTER PRE-FLIGHT DUTIES

## PURPOSE

This SCP describes the steps that must be performed by the Booster team prior to each mission.

## DESCRIPTION

The preparation conducted prior to flight is one of the most critical tasks performed by the Booster team. Any errors in the products generated or steps omitted from the process can severely impact the team's ability to make critical calls during the ascent timeframe. To ensure the integrity of the tools being used by the Booster team, a checklist has been developed for use in preparation for flight.

## PROCEDURE

The ascent team is responsible for keeping abreast of issues that may affect the flight. One of the more important pre-flight milestones is the Flight Readiness Review (FRR). This review typically takes place about 30 days prior to flight. The FRR is a review completed before each flight, of pertinent flight and system information. The Booster Group prepares inputs to the FRR, and members of the flight-specific Booster team attend the meetings. The FRR covers system anomalies since the last flight, equipment replacements, significant configuration differences, significant flight data file changes, significant changes in flight rules, unresolved anomalies, system waivers, and other pertinent issues. Additionally, each subsystem conducts its own FRR (SSME, SRB, ET, etc.). It is highly encouraged that members of the flight team support these meetings to remain aware of any issues that are still unresolved.

The Booster flight team prepares inputs for the Systems Division to present. Data is gathered from many sources and it is important to reference where the information is coming from (i.e. Noon Board, PSIG, AEFTP, etc.). The DF Systems Division Work Instructions for generating the FRR data pack, WI-DF-07, Shuttle FRR DataPack Generation, are located on the DF TA Homepage:

<http://mod.jsc.nasa.gov/df/dfdiv/shuttlea/index.html>

or directly at:

<http://mod.jsc.nasa.gov/df/masterlist/df07.doc>

When preparing the FRR inputs, review previous FRR inputs, to ensure consistency, and review anomalies that might show a trend. FRR is draft reviewed by the flight team and submitted to the Systems Division's technical advisor.

After writing the inputs, representatives attend the pre-FRR meetings and the FRR. The representatives note system issues that concern the Booster Group and gather data that is presented. Most of the information is available as handouts. This information is used to assist in planning for the current mission, and to track future issues and problems.

Inside of L-7 a checklist is used to ensure that all necessary steps are completed prior to flight. The checklist used for flight preparation is located at:

[S:/Divisions/Df/Private/Df55/FLIGHT ITEMS/Prelaunch/Flight Prep\(Rev x\).doc](S:/Divisions/Df/Private/Df55/FLIGHT ITEMS/Prelaunch/Flight Prep(Rev x).doc)

In the above address 'x' is the current revision of this document. The checklist located in this directory contains both the pre-launch and post-launch tasks.

#### REFERENCES

1. Booster Pre-Flight Preparations Checklist
2. Booster Cue Card Handbook, Rev. A. PCN-2
3. SSME Flight OPS Handbook, STS-101



TITLE

MAIN ENGINE TABLES

PURPOSE

The purpose of this SCP is to describe to the Booster Main Engine operator (ME) the purpose of the Main Engine Tables (MET) and how they are produced. A serious potential for error exists in the creation of these tables.

**WARNING**

The tools used to create the MET asks for the data for the 3 SSMEs in order of the LEFT, CENTER, and RIGHT SSMEs. The data used for input into the MET are given in order of the CENTER, LEFT, and RIGHT SSMEs. This is due to operational differences between the Booster Flight Control team and the engineering community. It is a simple error, but one that must be avoided, to transpose the LEFT and CENTER SSME data. Guard against this pitfall at all costs.

DESCRIPTION

The Main Engine operator uses the Main Engine Tables (MET) program to create the SSME off-nominal performance case tables used on console by the Booster Team and in the Abort Region Determinator (ARD) by the Flight Dynamics Team. These tables predict off-nominal performance of the Space Shuttle Main Engine (SSME) for predefined failure cases. The tables are based on the Rocketdyne Power Balance Model (PBM) December 2000 version for the Block II SSMEs. At approximately L-7 days, Marshall Space Flight Center (MSFC) (code EE21-SSME Chief Engineers Office) supplies engine specific Tag data in what is commonly called the MSFC Tag Letter (Fig. 1.4.2-I). The Tag data are the predicted values for the operational parameters for each SSME at a mission elapsed time of 194 seconds (engine start + 200 seconds) and at an LO2 inlet pressure of 63 psia.

The off-nominal tables provide deviations to nominal SSME operation. The MET program uses the SSME Tag data as a base and applies the deltas found in the off-nominal tables to create off-nominal SSME performance predictions.

Inputs to the MET program are taken from the L-7 day flight specific Trajectory Design Data Package (TDDP - Fig. 1.4.2-II) and the MSFC Tag Letter (Fig. 1.4.2-I). The TDDP may be found electronically on the Boeing data portal website (using your BPN account). The official MSFC Tags are received as a response to an SODB data request.

The MET output files are created by the flight Main Engine operator. Copies of the tables are then given to the Booster Systems Engineer (BSE) for review. Once the tables are verified as being correct by the BSE, the BSE will provide a paper copy of the “no-delta” tables to the ARD support personnel (TRAJ officer) and will place an electronic version of this document in the following directory: `/users/booster/FOR_FDO_xxx_FLT` (where xxx is the flight number) ensuring permissions on the file and directory allow others to read it but not to write over it (the permissions should already have been set to 555 by the ME). FDO uses the MET output to update the ARD with the most up-to-date engine performance data. Since this data does not change very often, FDO may not need to update the ARD input for the new flight. The process for verifying whether or not the MET data has changed for a given flight is located in the Booster Pre-Flight Preparations Checklist. In addition to updating the ARD, though, FDO uses the “no\_delta” data to double-check Booster’s TDDP input data with their own inputs into the ARD. To facilitate this cross-checking, and to help reduce the chance of other process escapes, the BSE should provide FDO with the “no\_delta” data every flight.

For reference purposes, the *no\_delta* version of the MET output (of Thrust, Mixture Ratio, and Specific Impulse) only changes from flight to flight if the performance case deltas have changed (which only occurs if they are updated by Booster personnel due to a new release or update of the Rocketdyne Power Balance Model) - OR - if the SSME Tag Mixture Ratio has been changed from the previous flight (Specific Impulse in Hydraulic Lockup is a function of Tag Mixture Ratio). If the performance case input files are not updated between flights and the Tag Mixture Ratio has not changed, the MET *no\_delta* output of Thrust, Mixture Ratio, and Specific Impulse will be the same as the previous flight’s data, even though engines’ Tag temperatures, pressures, and valve positions, etc. may have changed. Since FDO only uses the *no\_delta* tables, they do not need to repeat their preflight preparations using the new tables if the data within the tables has not changed.

Procedures for recognizing SSME performance cases and using the MET outputs are documented in SCP 2.1.1.

## PROCEDURE

1. In order to run MET, log on to a workstation and select an activity. Open an X-term window and verify that the `/users/bseds/DATA/MET/MetOut` directory is empty. If it is not, delete the files in this directory. The MetOut directory is where the input and output data files will be stored. It should be empty before MET is run for flight.
2. From the BOOSTER DNAV select “MET” from the BSE TOOLS window. The initial input/output page is displayed. Figure 1.4.2-III shows the input screen at the end of data input. The data used in this example is from STS-101, and the TAGs and TDDP used for the input are shown in Figures 1.4.2-I and 1.4.2-II respectively. On the data input page, input fields appear as recessed blocks and buttons appear as raised blocks.

3. The first item to be completed is the DATA TYPE input block. Position the cursor, on the "DATA TYPE" input button and select "SIM" for simulation or "FLT" for flight. Next, the user selects whether to create "deltas" tables or "no-delta" tables using the "Delta Table" button. The "Deltas" option will allow the user to create tables that provide a delta from nominal for the temperatures, pressures, and valve positions for each of the performance cases. The "Deltas" option zeros out all of the Tag temperatures, pressures, and valve positions.

Note: Since selecting "Deltas" zeros out all of the temperature, pressure, and valve position predictions, it is recommended that the operator run the "No Deltas" first, then the "Deltas" table second.

Note: Make sure to select "Deltas" or "No Deltas" prior to entering the "Flight" number. After the flight number is entered, the user will not be allowed to change the "Delta Table" selection.

4. Next, a three digit flight number must be input. The flight number is used as the extension for the output files. After the flight number is input, the input fields appear as recessed blocks with the active input field highlighted. Modifications and/or inputs can only be made to an active input field. The left and right arrow keys allow cursor motion within the input field, and the backspace/delete key is used to modify and/or correct inputs. To advance to the next input field either the RETURN key or TAB key can be used. The mouse can be used to move within a field or move to another field. Once the data type and flight number are selected, they cannot be changed unless the program is terminated and then restarted.
5. Selection of the vehicle is similar to the data type. Position the mouse on the input button and depress and hold the left mouse button, release the button when the mouse is positioned over the desired vehicle number. The vehicle number is specified in the L-7 TDDP, the Flight Requirements Document (FRD), and the Booster FRR Data Package.
6. Input the date of the **MSFC Tag Letter**
7. Erase and re-input today's date using two digits for the year

NOTE: In order for the MET program to run, the cursor must pass through this cell (otherwise the program will not recognize that it automatically input today's date). The user is asked to re-input today's date to prevent any inadvertent errors while the cursor is in that cell.

8. Select engine type. Click the left mouse button on the engine type button and select the appropriate engine type for each SSME position (Block IIA, Block II, etc.). The engine type is specified in the L-7 TDDP (Figure 1.4.2-II).

Note: If re-entering data using a previous ".dat" file from the MetOut directory, the engine type may not be preserved. Before selecting the "COMPUTE" block, make sure that the proper engine type is selected.

9. Fill in the Engine Number, Thrust, Mission Pc, and Mission Power Level fields. This information is found in the **L-7 TDDP**.
10. Once the fields for main data are filled, the data under DISPLAY TAG TEMPS must be entered. Position the mouse cursor on the block that reads: DISPLAY TAG TEMPS, and depress the left mouse button. After releasing the mouse button, additional input fields are displayed on the screen. Previously entered data will also remain on the screen. Complete these input fields using the **MSFC Tag Letter**. TAGs input here include the HPOTP and HPFTP turbine discharge temperatures, and the HPOTP and HPFTP pump discharge pressures - all for the mission power level.
11. Once this is done, click the left mouse button on the block which reads "DISPLAY FLOWRATE AND VALVE POSITION". Additional data fields will be displayed on the screen. The inlet fuel and LOX flowrate, and GH2/GO2 pressurization flowrates (all for the mission power level) are input from the **L-7 TDDP**.
12. After the flowrates are input, the OPOV and FPOV positions at both the mission power level and at 109% throttles are input from the **MSFC Tag Letter**.
13. When all input fields have been completed (Figure 1.4.2-III), the main engine tables are generated by selecting the COMPUTE button. Selection of the compute button starts the computations and operations required to generate the outputs. When the program operations are complete the computed values will be displayed.

Note: All input fields must have data for the program to operate properly.

14. After the COMPUTE block is selected, the PRINT block will appear. The print block will print out the main engine tables. After the tables have been printed, the MET program will terminate.
15. After the "No Deltas" table has printed, open an X-term window and change to the /users/bseds/DATA/MET/MetOut directory. The MET output will be in the file named "met-flt.Fxxx.no\_delta" ("met-sim.Sxxx.no\_delta" for sim tables) where "xxx" is the three-digit flight number. The MET input will be in the file named "flight.xxx.no\_delta.dat" ("sim.xxx.no\_delta.dat" for sim tables). Change the permissions on the file to 555 (using chmod 555 <filename>), and then copy both of these files into the Main Engine operator's personal directory.

16. Rerun MET as before except select the "Deltas" option.
17. After the input data has been verified, select COMPUTE and print out the deltas version of the MET output.
18. After the deltas table has printed, open an X-term window and change to the /users/bseds/DATA/MET/MetOut directory. The MET output will again be in the file named "met-flt.Fxxx.deltas" ("met-sim.Sxxx.deltas" for sim tables) where "xxx" is the three-digit flight number. The MET input will be in the file named "flight.xxx.deltas.dat." ("sim.xxx.deltas.dat" for sim tables). Change the permissions on the file to 555 (using `chmod 555 <filename>`), and then copy both of these files into the Main Engine operators personal directory.
19. If MET needs to be run again, the operator can copy the appropriate ".dat" file back into the MetOut directory, then run MET. After the flight number is selected, MET should recognize the ".dat" file and input the appropriate data on the input screen.

REFERENCES:

1. STS-113 MSFC SSME Tag Letter.
2. STS-113 L-7 SSME TDDP.



Figure 1.4.2-I SSME Tag letter example (Ref. 1)

DATE: 11/17/02 \*TIME: 13:43  
 PAGE 7  
 TDDP NO: SPLBF113(007)  
 RELEASED

4. SSME TAG DATA

ENGINE NUMBER = 2050 DATA ID : MS246-02H  
 TYPE: BLOCK II TAG DATE: 09/03/2002  
 CONTROLLER M/R = 6.0320

POWER LEVEL	%	100.0	104.5	106.0
LO2 FLOWRATE	(LBM/SEC)	895.73	936.18	949.66
LH2 FLOWRATE	(LBM/SEC)	148.27	154.97	157.21
GO2 FLOWRATE	(LBM/SEC)	1.84	1.91	1.94
GH2 FLOWRATE	(LBM/SEC)	0.66	0.69	0.70
THRUST	(LBF)	470574	491967	499103
CONTROLLER PC	(PSIA)	2747.0	2870.6	2911.8
MIXTURE RATIO		6.0413	6.0409	6.0408
ISP	(SEC)	451.83	451.95	451.99
NOZ. EXIT AREA	(IN2)	6507.5	6507.8	6507.9

---

ENGINE NUMBER = 2044 DATA ID : MS246-02H  
 TYPE: BLOCK II TAG DATE: 09/03/2002  
 CONTROLLER M/R = 6.0320

POWER LEVEL	%	100.0	104.5	106.0
LO2 FLOWRATE	(LBM/SEC)	896.96	937.41	950.90
LH2 FLOWRATE	(LBM/SEC)	148.47	155.18	157.41
GO2 FLOWRATE	(LBM/SEC)	1.84	1.91	1.94
GH2 FLOWRATE	(LBM/SEC)	0.66	0.69	0.70
THRUST	(LBF)	471817	493210	500346
CONTROLLER PC	(PSIA)	2747.0	2870.6	2911.8
MIXTURE RATIO		6.0413	6.0409	6.0408
ISP	(SEC)	452.39	452.49	452.53
NOZ. EXIT AREA	(IN2)	6507.5	6507.8	6507.9

---

ENGINE NUMBER = 2045 DATA ID : MS246-02H  
 TYPE: BLOCK II TAG DATE: 09/03/2002  
 CONTROLLER M/R = 6.0320

POWER LEVEL	%	100.0	104.5	106.0
LO2 FLOWRATE	(LBM/SEC)	896.32	936.77	950.26
LH2 FLOWRATE	(LBM/SEC)	148.36	155.07	157.31
GO2 FLOWRATE	(LBM/SEC)	1.84	1.91	1.94
GH2 FLOWRATE	(LBM/SEC)	0.66	0.69	0.70
THRUST	(LBF)	471279	492672	499808
CONTROLLER PC	(PSIA)	2747.0	2870.6	2911.8
MIXTURE RATIO		6.0413	6.0409	6.0408
ISP	(SEC)	452.21	452.31	452.35
NOZ. EXIT AREA	(IN2)	6507.5	6507.8	6507.9

Figure 1.4.2-II: L-7 SSME TDDP example (Ref. 2)

Main Engine Table Program

**X** MAIN ENGINE TABLE PROGRAM Ver 15.00

DATA TYPE  FLT  Delta Table  No Deltas

Flight  Vehicle

Date of TAG Data  Today's Date

POWER LEVEL - BUCKET  USER:

	LEFT	CENTER	RIGHT
ENGINE TYPE	<input type="checkbox"/> BLOCK II <input type="checkbox"/>	<input type="checkbox"/> BLOCK II <input type="checkbox"/>	<input type="checkbox"/> BLOCK II <input type="checkbox"/>
ENGINE NO.	<input type="text" value="2044"/>	<input type="text" value="2050"/>	<input type="text" value="2045"/>
THRUST	<input type="text" value="493210"/>	<input type="text" value="491967"/>	<input type="text" value="492672"/>
MISSION Pc	<input type="text" value="2870.60"/>	<input type="text" value="2870.60"/>	<input type="text" value="2870.60"/>
MISSION PL	<input type="text" value="104.50"/>	<input type="text" value="104.50"/>	<input type="text" value="104.50"/>
HPOT A/B TEMP	<input type="text" value="1255"/> / <input type="text" value="1262"/>	<input type="text" value="1200"/> / <input type="text" value="1221"/>	<input type="text" value="1146"/> / <input type="text" value="1156"/>
HPFT A/B TEMP	<input type="text" value="1576"/> / <input type="text" value="1544"/>	<input type="text" value="1557"/> / <input type="text" value="1557"/>	<input type="text" value="1565"/> / <input type="text" value="1548"/>
HPOT DISCH PRESS	<input type="text" value="3799"/>	<input type="text" value="3826"/>	<input type="text" value="3809"/>
HPFT DISCH PRESS	<input type="text" value="5690"/>	<input type="text" value="5634"/>	<input type="text" value="5612"/>
INLET FUEL FLOWRATE	<input type="text" value="155.180"/>	<input type="text" value="154.970"/>	<input type="text" value="155.070"/>
INLET LOX FLOWRATE	<input type="text" value="937.410"/>	<input type="text" value="936.180"/>	<input type="text" value="936.770"/>
INLET MIXTURE RATIO			
GH2/GO2 PRESS. FLOW	<input type="text" value="0.690"/> / <input type="text" value="1.910"/>	<input type="text" value="0.690"/> / <input type="text" value="1.910"/>	<input type="text" value="0.690"/> / <input type="text" value="1.910"/>
OVERBOARD FUEL FLOW			
OVERBOARD LOX FLOW			
OVERBOARD MIX. RATIO			
OVERBOARD ISP			
OPOV/FPOV POS - MPL	<input type="text" value="63.6"/> / <input type="text" value="76.3"/>	<input type="text" value="63.3"/> / <input type="text" value="75.8"/>	<input type="text" value="62.7"/> / <input type="text" value="76.0"/>
OPOV/FPOV POS - 109	<input type="text" value="65.6"/> / <input type="text" value="77.5"/>	<input type="text" value="65.3"/> / <input type="text" value="76.9"/>	<input type="text" value="64.6"/> / <input type="text" value="77.1"/>

**COMPUTE**

Figure 1.4.2-III Completed MET input screen example



## TITLE

Calibration Curve Updates

## PURPOSE

The purpose of this SCP is to provide a brief overview of calibration curves and how to update them in the front-end processor (FEP).

## DESCRIPTION

Calibration curves are used to translate the raw PCM counts provided to the FEP by the Orbiter downlink into the appropriate engineering units. The FEP receives the calibration curves through the Shuttle Data Tape (SDT). The SDT contains all of the calibration curves needed to translate the Orbiter's downlink data back into the appropriate engineering units. The final version of the SDT for a given flight is delivered to the MCC months prior to a scheduled flight.

Some calibration curves are unique to a given transducer. For Booster, the MPS helium tank pressure calibration curves and the MPS helium regulator pressure calibration curves are transducer unique. In the event that a transducer with a unique calibration curve is changed out after the SDT has been delivered, the FEP will need to be updated with the new calibration curves prior to flight. Booster is notified of calibration curve changes made after the delivery of the SDT in the Post MCC Build Configuration memo delivered to DF55 a few weeks prior to flight.

## PROCEDURE

Calibration curve changes are made to the FEP using the Telemetry Services Application following the conclusion of the L-1 Day Crew Briefing. The procedure for performing these changes is documented in FCOH 4.7.5, "FEP Temporary/Permanent Calibration Changes."

1. The operator making the changes (usually MPS) will need a copy of the Post MCC Build Configuration Memo.
2. It is **HIGHLY** recommended that two persons perform the update in order to check each other's work. The affected prelaunch operator will also verify the updated calibration curves per the Booster Prelaunch Preparation Checklist.

3. Following the L-1 Day Crew Briefing, inform WSS on WSS CALL that “permanent FEP calibration curves changes are about to be performed to the UDL1 FEP per FCOH 4.7.5.” Ask WSS if “DLRT Prime has been allocated to the flight activity.” DLRT Prime is usually available about 48 hours prior to launch. If DLRT Prime is unavailable, the calibration curve updates cannot be made. If WSS has any questions, direct them to the FCOH procedure.
4. Make sure the Advisory Services application is running and is visible BEFORE starting the Telemetry Services application. While updating the calibration curves, use Advisory Services to confirm that the calibration curve changes have been made.
5. Follow the calibration curve update procedure as described in FCOH 4.7.5. Once the Telemetry Services application is started, make sure the OI/GPC Parameters icon is selected (shuttle icon with doors closed). Once in the “Alter Parameter Calibration Coefficient,” make sure to select “Permanent.”
6. Also, make sure to create hard copies of the updated curves as described in the FCOH procedure. These hard copies should be placed in the Log Book.
7. Once the updates are complete, inform WSS, as described in FCOH 4.7.5, that “the FEP calibration curve updates are complete” and ask that “the changes be moved into the CM server.” According to the FCOH procedure, WSS will need to know the flight number, the activity, and the parameter type. The parameter type for Booster updates will be “OI/GPC/Payload MDM” type parameters. If WSS has any questions, direct them to the FCOH procedure.
8. To verify calibration curve updates, start Telemetry Services as described in Step 5 above. Select “Calibration Change,” then select “View Discipline CAL Report.” Select “ALL” for the discipline (sometimes the calibration curve changes are not associated with Booster, and therefore, will not appear under a Booster only discipline report). Once the report is displayed, select “File,” then “Print” to print out a hard copy of the report.

## REFERENCES

1. FCOH 4.7.5, “FEP Temporary/Permanent Calibration Changes”

## TITLE

Verifying Booster I-Loads

## PURPOSE

The purpose of this SCP is to provide a brief overview of I-Loads and how they are verified for each flight.

## DESCRIPTION

I-Loads are flight specific constants that are loaded into the PASS and BFS flight software before each flight. There are thousands of I-loads, but some Booster I-Loads are so important that they are verified prior to each flight. For example, the SSME power level for the thrust bucket and the RTLS LO2 dump timer.

## PROCEDURE

The entire PASS and BFS flight software load needed for each flight is compiled and stored on a CD-ROM in the Communications and Data Systems branch office. Before each flight, a member of the Booster group will borrow the CD and then copies it to their machine. You can obtain the I-Loads directly from the CD-ROM or by accessing the saved copy. Currently the DF55 electronic librarian copies the I-Loads onto the DF55 GA's PC. You can get to this folder by selecting START, RUN from one of the network PCs. Type in \\Martin-keith\booster data\I-loads\STS-XXX, where XXX is the flight number, and then select OK. In this folder are two folders: *PASS* and *BFS*

1. The information on the CD-ROM is opened using the program Digital Xpress Reports (DXR). DXR can be found at MOD Server Menu\MOD Wide Applications\DXR. In the *PASS* folder, open the file *ildmprpt.dat*.
2. When you open the *.dat* file, you will notice that no information is displayed. Using the toolbar at the top of the DXR window, go to Search/Index Search. This will open an *Index Search* window that will allow you to search for I-loads by MSID. Under *Search Criteria*, the column on the left will already have "Msid:" in it. In the column on the right, enter the MSID number you wish to search for, such as V97U9743C, and then click "OK". Note, the search is not case sensitive. See Figure 1.4.4-I

NOTE: The I-loads that need to be verified are found in the "Booster Pre-Flight Preparations Checklist," located at *S:\Divisions\DF\Private\DF55\*

*Prelaunch\Flight Prep.* Table 1.4.4-I shows an example of the I-Loads page from that checklist.

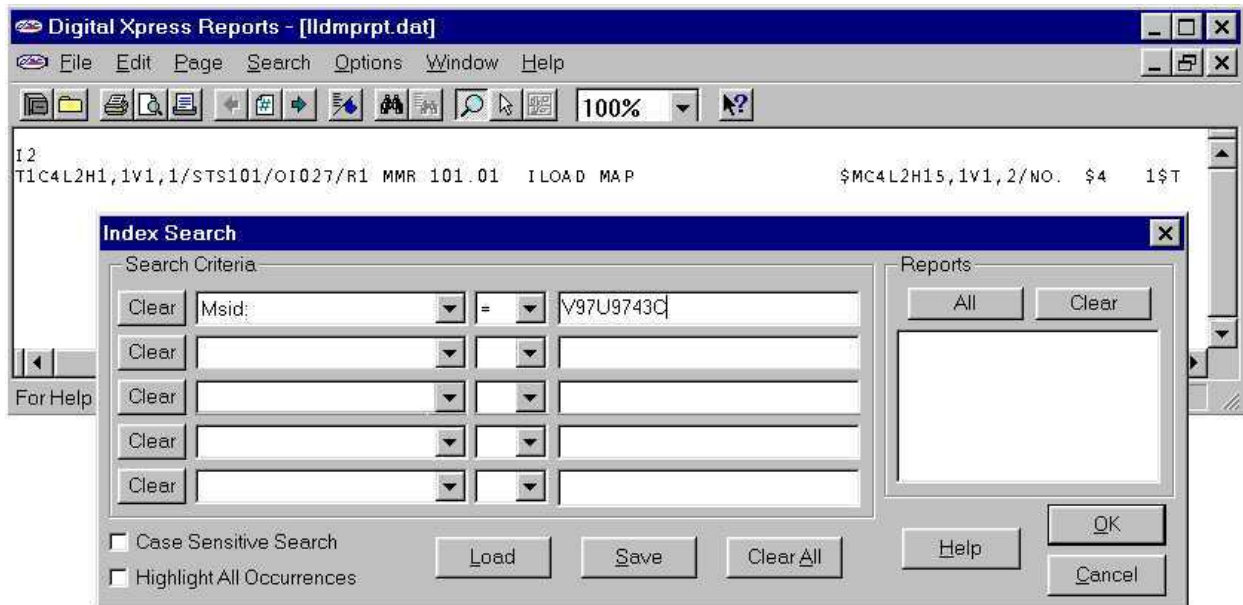


Figure 1.4.4-I DXR Window with Index Search window open

3. A window called *Search Results (1 Record(s) Found)* should appear. The MSID you request should be listed, followed by a page number and the *ildmprpt.dat* file name. Double-click on this entry. This will open the page of the *.dat* file that contains that MSID. If the MSID is at the bottom of the page, you may have to scroll down the window, but the MSID will be highlighted for easy recognition. See Figure 1.4.4-II. Check the MSID and the name to ensure you inputted the correct MSID for the search. Record the value of the MSID, as given in the “VALUE BLOCK” column on the far right, onto the pre-flight checklist.
4. Verify any BFS I-loads (for example, the ET\_LH2ULP\_HI is a BFS I-load). Open the BFS folder and open the *.dat* file as you did for the PASS. Again, use the index search and enter the MSID. When you open the page containing the requested MSID, you’ll notice the format is slightly different. See Figure 1.4.4-III. Unlike the PASS I-load pages that give the MSID and name, the BFS only shows the MSID. However, as with the PASS I-loads, the appropriate value will be highlighted for easy recognition. The value for the MSID is again on the far right side, under “ENG. VALUE.”

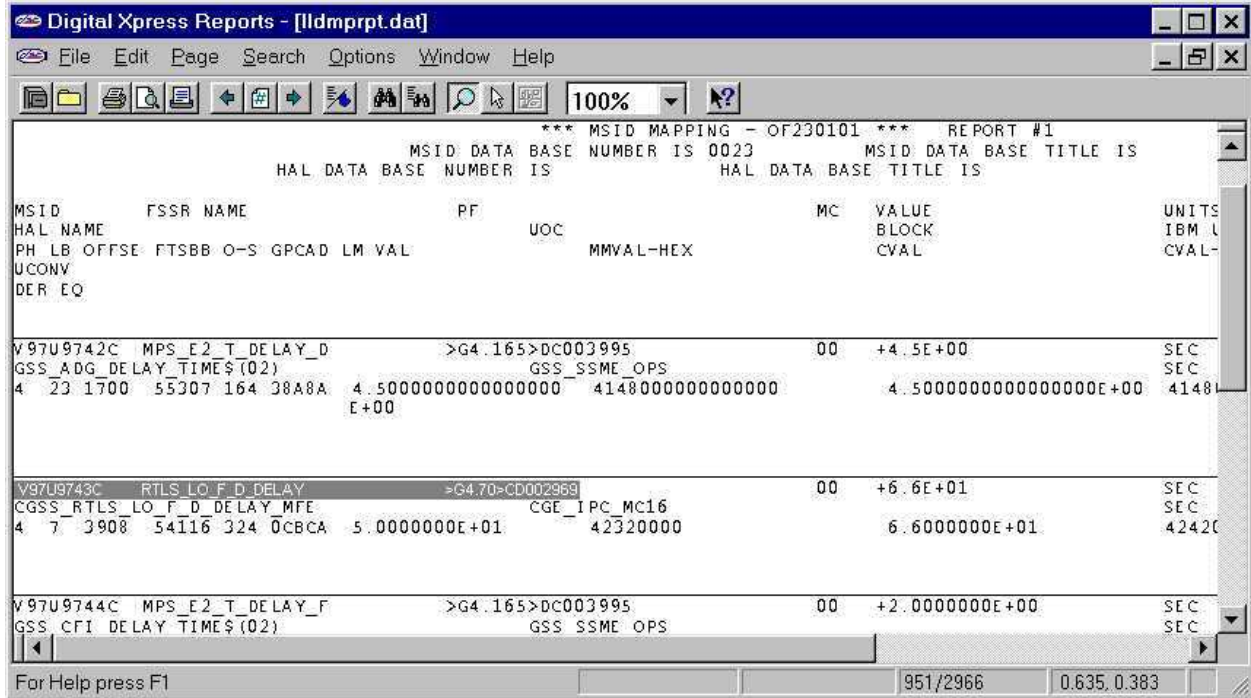


Figure 1.4.4-II PASS I-load page

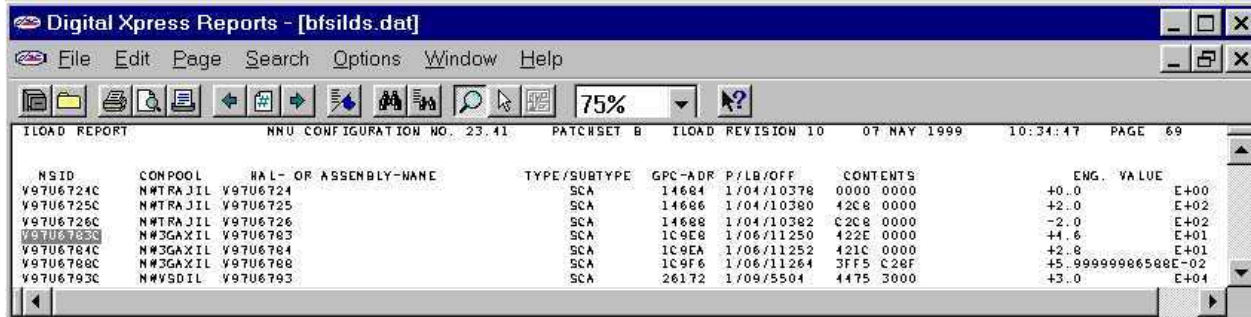


Figure 1.4.4-III BFS I-load page

**MPS I-Loads:**

OI-28 and subs:

V97U9730C (RTLS\_MOV\_DELAY) \_\_\_\_\_ Seconds

V97U6783C (ET\_LH2ULP\_HI) \_\_\_\_\_ psia (1)

**Main Engine I-Loads (Pc Meter scaling):**

		PH-II (2)	BLK-I (2)	BLK-IIA (3)	BLK-II (3)
V97U3979C (CPRESS(1)) _____	PCT/PSIA	3.318e-2	3.318e-2	3.640e-2	3.640e-2
V97U3980C (CPRESS(2)) _____	PCT/PSIA	3.323e-2	3.323e-2	3.640e-2	3.640e-2
V97U3981C (CPRESS(3)) _____	PCT/PSIA	3.322e-2	3.322e-2	3.640e-2	3.640e-2
V97U4425C (KMIN) _____	Percent	(minimum throttles)			
V97U0601C (KMAX_ABORT) _____	Percent	(throttles for SSME out between V_KMAX bounds)			
V97U0602C (KMAX_NOM) _____	Percent	(mission throttles)			
V99U7107C (KMAX_SECONDARY) _____	Percent	(maximum throttles)			
V97U4810C (THROT(3)) _____	Percent	(bucket throttle setting) (4)			
V97U9355C (K_CMD_STG2) _____	Percent	(2 <sup>nd</sup> stage throttles = mission throttles)			
V97U0603C (V_KMAX_DOWN) _____	Percent	(upper boundary) (5)			
V97U0604C (V_KMAX_UP) _____	Percent	(lower boundary) (5)			

**Notes:**

- (1) BFS ONLY I-load. Value should be 48.9 psia for Block II SSME cluster flights and 46 psia for all non-Block II SSME cluster flights. Also, since this is a BFS ONLY I-load, you must search the BFS I-load map report in the BFS\BFSILDS.DAT file.
- (2) Phase-II and Block-I I-load values are the "default" values in the software. The I-load manager (John Craft - 8/4/97) decided that it was not necessary to update these each flight. The "correct" value for Phase-II would be 3.327e-2 and the Block-I would be 3.311e-2. The correct values are determined using the equation  $100 / (\text{PcRef} @ 100\%)$ .
- (3) BLK-IIA and BLK-II values above are based on 6/97 Pc value of 2747 PSIA at 100% RPL.
- (4) The bucket throttle setting is subject to change in real-time based on adaptive first stage guidance.
- (5) For one SSME out, if velocity is <V\_KMAX\_UP or > V\_KMAX\_DOWN, then KMAX=KMAX\_NOM. Otherwise set to KMAX\_ABORT

**Main Engine Controller Software Values:**

Obtain a copy of the Single Channel Engine Shutdown (SCES) Data Change Request (DCR) listing the flight specific SSME Single Command Channel Shutdown Timer value. The Booster Group Lead is on distribution for this DCR. Verify vs. the following:

$$\begin{aligned} \text{SCES} &= \text{MECO command time} - 3 \text{ sigma dispersions} + \text{difference between last engine start and liftoff} \\ &= \text{MECO command time} - 5.5 \text{ seconds} + 6.36 \text{ seconds} \\ &= \text{MECO command time} + 0.86 \text{ seconds} \end{aligned}$$

MECO command time is available from the FDO ascent events summary.

Table 1.4.4-I. - I-Loads Checklist from Booster Pre-Flight Preparations Checklist (example)

## TITLE

ISP LIMIT MANAGER

## PURPOSE

This SCP describes how the Booster flight control team creates the Information Sharing Protocol (ISP) limit manager configuration files required to support simulations and flights. This SCP defines the different limit contexts.

The Limit Manager User's Guide (LOR-TR1944) describes basic limit manager operations. If a copy of the guide is available, users should carefully review the following sections in the user's guide prior to configuring limit manager: Sections 1.1 (Limit Manager), 1.1.2 (Editing Limit Attributes), 1.1.3 (Uploading and Downloading), and 1.1.4 (Checkpoints). If a copy of the guide is not available, the instructions given below may be adequate.

NOTE: This SCP only addresses Booster unique aspects of the ISP limit manager application. It does NOT describe the basic operations of limit manager.

## DESCRIPTION

ISP limit manager performs limit-sensing on ISP parameters before these parameters are published to ISP displays. An ISP parameter may be a direct downlisted MSID, or it may be the output of an ISP computation. When an ISP parameter violates the predefined upper, lower, or equality limit, the appropriate status flag and color are then "associated" with that parameter.

### Booster Limit Configurations

For Booster, ISP limit manager is configured with four limit groups (MPS, Left Engine, Center Engine, and Right Engine). Each group has several contexts that typically define a flight condition or flight phase. The MPS limit contexts are Prelaunch, First Stage, Second Stage, ET SEP, Orbit, and Entry. The Left, Center, and Right Engine limit contexts are Prelaunch, Mission Power Level (MPL), Below MPL, Above MPL, Engine Out, and ET SEP.

Individual limit sensed parameters and their limit values are stored within a particular limit context. Limit manager uses logic rules specified in the user defined *booster.lc* file to determine those groups and contexts to use for limit sensing at a given moment. The *booster.lc* file is stored in the booster *Limits* directory. The relevant limit manager files are located in the limits directory at *users/bseds/DATA/Limits*. A description of how to decode the logic statements used in the *.lc* file can be found in the ISP Limit Manager User's Guide, Section 1.1.1. Table 1.4.5-I provides an overview of the Limit Manager groups and contexts used by Booster.

Table 1.4.5-I. - Limit Groups and Contexts for Booster

Group	Context	Generic Definition of Context	Purpose/Use for Context
MPS	Prelaunch	Prior to SRB ignition	Primarily used to monitor LCC.
	First Stage	First stage	Allows first stage MPS limits to be set to tightly limit sense helium pressures and temperatures.
	Second Stage	NOM: post SRB SEP to MM 104 transition. RTLS: post SRB SEP to MM 602 transition.	Allows second stage MPS limits to be set to tightly limit sense helium pressures and temperatures.
	ET SEP	NOM: MM 104 to OPS 2 transition. RTLS: MM602 through post landing.	Allows termination of MPS limit sensed parameters associated with powered flight.
	Orbit	Post OPS 2 transition to MM 303 transition.	Allows limit sensing of only those MPS parameters associated with orbit operations.
	Entry	NOM: MM 303 transition through post landing. TAL: MM 304 transition through post landing.	Allows limit sensing of only those MPS parameters associated with entry operations.
Engine <sup>①</sup>	Prelaunch	Prior to SRB ignition	Primarily used to monitor LCC.
	Mission Power Level	Powered flight with associated SSME running and GPC power level command between 101% and 106%. <sup>②</sup>	Most limits set to monitor predicted parameters at 104%; this is the nominal limits context for main engine.
	Below MPL	Powered flight with associated SSME on and GPC power level command less than or equal to 100%. <sup>②</sup>	Limit set used when SSME starts to 100% or throttles into the bucket
	Above MPL	Powered flight with associated SSME on and GPC power level command greater than or equal to 106%. <sup>②</sup>	Limit set used when SSME is running at abort or maximum power levels.
	Engine Out	Powered flight with associated SSME out. <sup>②</sup>	Turns all limit sensed parameters red for associated SSME as continuous reminder that SSME is out.
	ET SEP	Post MM 104 or MM 602 transition.	Disables most SSME limit sensing.

Notes:

- ① Left, Center, and Right Engine group contexts are identical. Therefore, the “Engine” group is the only one shown in Table 1.4.5-I.
- ② SSME out indications are provided by the BOSS engine avionics computation.



## PROCEDURES

Two general activities are described in the following section: using limit manager and preparing checkpoint files for flight.

### Using Limit Manager

The two basic steps involved in starting limit manager are starting the application and opening a previously saved checkpoint. All other generic limit manager activities are described in detail in the “Limit Manager User’s Guide”.

NOTE: All servers must have a unique limit manager running in order for the limit sensing to be active. In other words, if the BSE, Main Engine, and MPS operators are all using different servers, three versions of limit manager will be required (one for each server). If all the operators will be sharing data from one server, one (and ONLY ONE) limit manager should be used.

### Starting Limit Manager

1. Limit manager is started automatically when Auto-Pilot is started from DNAV. To start it manually, select *ISP Limit* from the *ISP Tools* pulldown menu on the Booster DNAV. The *Limit Manager* application window will appear (Figure 1.4.5-I).
2. If limit manager has been started using Auto-Pilot, it will automatically select the sim or flight checkpoint associated with the current activity’s flight ID. If you want to use a different checkpoint, limit manager must be deregistered using Autopanel (from the *Global Applications* pulldown menu on the Master DNAV). Once limit manager is deregistered, it will shutdown. It can then be called up manually as described in Step 1.
3. If limit manager has been started manually, choose *File, Open* to open a previously saved checkpoint file. Usually, the appropriate checkpoint file will be named *fltxxx.cp* or *simxxx.cp* depending on whether the activity is a flight or simulation (*xxx* is the flight ID number). The checkpoint files are located under *users/bseds/DATA/Limits*. Looking at the *Limit Manager* window, the limit contexts (Prelaunch, First Stage, etc.) should now be active. Inactive contexts are listed using a light-gray font. If a context is inactive no limit sensing for that context is possible because no limit information has been loaded into that context.
4. Verify that the *ENABLE* and *AUTO* buttons are selected. Also, verify that limit manager is connected to the server by making sure the *CONNECT* selection in the window pulldown menu (select ((-)) symbol in upper left corner) is grayed out. If it is not connected, select *CONNECT*. Finally, verify that limit manager has automatically selected the appropriate limit context (may only be possible once data has begun flowing to the server).

5. Limit manager will automatically switch between limit contexts. If it does not, verify that *AUTO* button is selected. If *AUTO* is selected and the wrong limit context is still in effect, manually select the appropriate limit context.
6. Limit manager will automatically reconnect to the server once the server is restarted prior to each run. If limit manager does not connect, repeat the above procedures at Step 4.

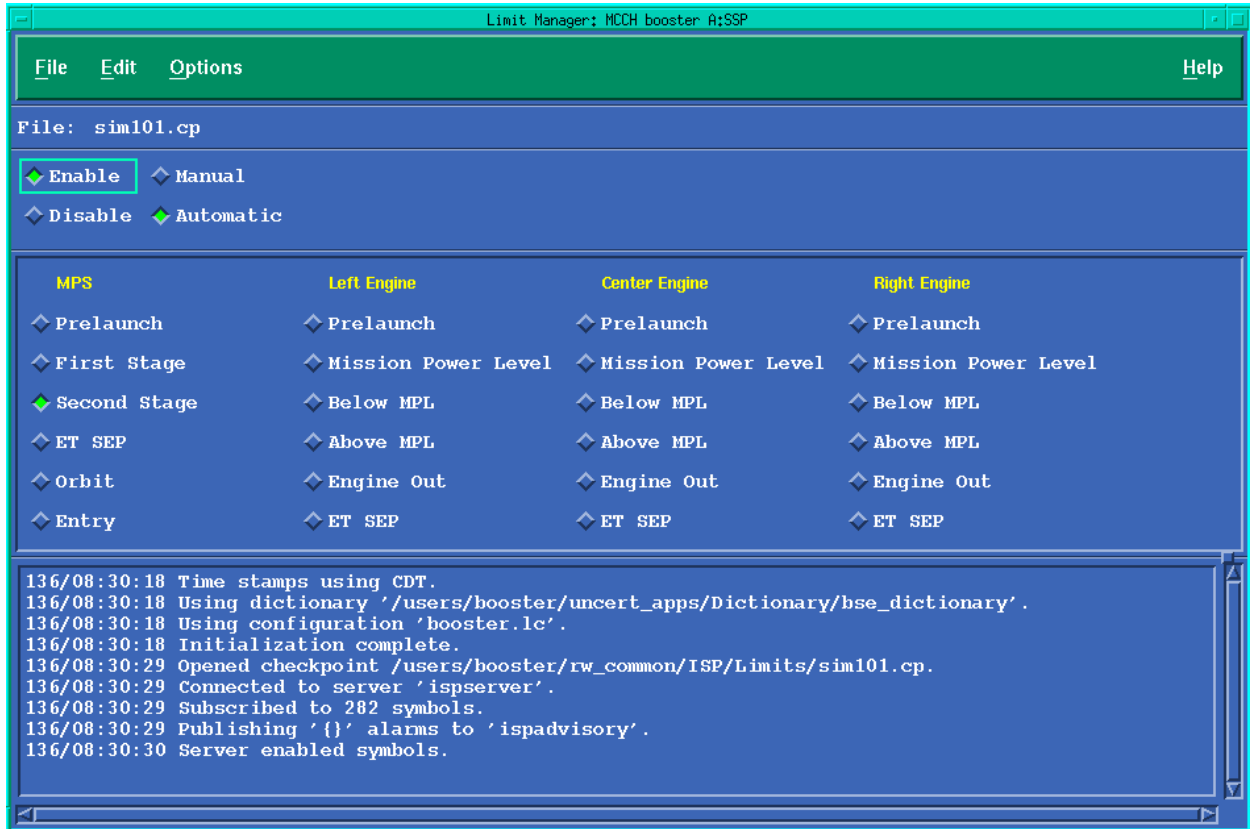


Figure 1.4.5-I. - ISP Limit Manager Application Window

### Preparing Limit Manager for Flight

Limits are prepared for flight per the instructions provided in the following three sections: Preparing MPS Limits, Preparing SSME Limits, and Moving the Checkpoint File.

### Preparing MPS Limits (MPS Operators Only)

1. Copy the flight.cp file limit library to the MPS operator's home directory.
  - a. The flight.cp is located in the */users/bseds/DATA/Limits/LIBRARY* directory.

- b. Create a flight directory in the MPS operators personal directory called *XXX*, where *xxx* is the flight number, using the Unix command “`mkdir XXX.`” After it is created change to that directory using the “`cd XXX`” command. Within the *XXX* directory create another directory called *Limits*.
    - c. From the MPS operator’s *Limits* directory, copy in the MPS directory using the following command: “`cp -p /users/bseds/DATA/Limits/LIBRARY flight.cp.`”
  2. If ME has not created a checkpoint file for this flight, then proceed to Step 3. Otherwise, open the checkpoint file for this flight (refer to previous section, *Starting Limit Manager*), and then proceed to Step 4.
  3. Start *isplimit* by selecting *ISP Limit* from the *ISP Tools* pulldown menu on the Booster DNAV. This will open a window called *Limit Manager*. Notice that all the items are grayed-out, signifying that they have not yet been uploaded. Also notice that File: <none> is displayed in the upper left corner. Select *File*, then *Open* and choose the *flight.cp* file that was placed in the operator’s *XXX/Limits* directory. After you are done making any required changes to the checkpoint, you will save this limit manager checkpoint as a flight specific checkpoint file.
  4. In the *Limit Manager* window select *Edit, List* to open the *List Editor* window (see Figure 1.4.5-II). Update any of the contexts as required, if required. The following describes how to edit the limit checkpoint .

File: center\_above\_b2a.1im

Symbol	Owner	Nomenclature	Value	Color	Description
E41P1008B	booster	ME-1 HPFT COOLANT PRESS CHA D	1800	Yellow	Qual limit
E41P1008B	booster	ME-1 HPFT COOLANT PRESS CHA D	3430	Yellow	100 to 109% rl
E41P1009B	booster	ME-1 HPFT COOLANT PRESS CHB D	1800	Yellow	Qual limit
E41P1009B	booster	ME-1 HPFT COOLANT PRESS CHB D	3430	Yellow	100 to 109% rl
E41P1014B	booster	ME-1 HPOT I-SEAL PGE P CH A DW	169	Yellow	10 to redline
E41P1014B	booster	ME-1 HPOT I-SEAL PGE P CH A DW	227	Yellow	Mean + 3 sigma
E41P1015B	booster	ME-1 HPOT I-SEAL PGE P CH B DW	169	Yellow	10 to redline
E41P1015B	booster	ME-1 HPOT I-SEAL PGE P CH B DW	227	Yellow	Mean + 3 sigma

Sort rows.

Figure 1.4.5-II. - List Editor

- a. Click on the limit group button on the right side of the *List Editor* window (button default is MPS), and select “MPS” from the pull down menu. Click on the limit context button (button default is ALL), and select “Prelaunch” from the pull down menu.
  - b. Next, in the *List Editor* window download the prelaunch context using either Download/Merge or the shortcut key (↓). Make updates as required.
  - c. Select all, either by going under *Edit/Select All* or by using the shortcut key (≡) on the toolbar. Then upload the limits by selecting Upload/Replace. Finally, clear out this *List Editor* window by selecting all and cutting (using *Edit/Cut* or the cut shortcut key, ✂).
  - d. After you are complete, you’ll want to print out a copy of the prelaunch limit file to verify your changes. With the MPS and Prelaunch buttons selected, download the prelaunch file using *Download/Merge* or the shortcut key (↓). Under File/Print select Rewrite/Laser/OK.
  - e. Repeat steps a. – c. for the other limit contexts (i.e. *First Stage* through *Entry*). Before you clear out the window, print out the limit file. Under File/Print select Rewrite/Laser/OK.
5. Once the MPS limits are updated, save this checkpoint (using *File/Save As* on the *Limit Manager* window) in your personal directory under your XXX/Limits directory as fltXXX.cp, where XXX is the flight number. If you are already using a checkpoint file created by ME, then just click *File/Save*.

**WARNING:** Updating limits in the checkpoint MUST be coordinated with the Main Engine operator. Make sure the MPS and Main Engine updates are made to the SAME *fltxxx.cp* file (this file can temporarily be located in either the MPS or Main Engine operators’ home directories). Also, make sure that the MPS and Main Engine operators DO NOT update the checkpoint file AT THE SAME TIME.

6. Once the MPS limits are loaded into the checkpoint, notify the Booster operator that the MPS limits are complete and provide the Booster operator with the checkpoint file name and the path to the checkpoint file.

#### Preparing Main Engine Limits (Main Engine Operators Only)

1. If MPS has created a checkpoint file for this flight, open the checkpoint file for this flight (refer to previous section *Starting Limit Manager*), then proceed to Step 34. Otherwise, if MPS has not yet created a checkpoint file, proceed to Step 2.
2. Start isplimit by selecting *ISP Limit* from the *ISP Tools* pulldown menu on the Booster NAV. This will open a window called *Limit Manager*. Notice that all the Main Engine items are grayed-out, signifying that they have not yet been uploaded. Also notice that File: <none> is displayed in the upper left corner. See step 1 in the MPS section for directions on

moving the flight.cp file to the appropriate directory. Select *File*, then *Open* and choose the flight.cp file that was placed in the operator's *XXX/Limits* directory. After you are done updating the limits files, you will save this limit manager as a flight specific checkpoint file.

3. In the *Limit Manager* window select *Edit, List* to open the *List Editor* window (see Figure 1.4.5-II). Follow the instructions in the preceding *Preparing MPS Limits* section on updating limits, except you'll choose the respective engine for the limits group instead of MPS.
4. Once the Main Engine limits are updated, save this checkpoint (using *File/Save As* on the *Limit Manager* window) in your personal directory under your *XXX/Limits* directory as fltXXX.cp, where XXX is the flight number. If you are already using a checkpoint file created by MPS, then just click *File/Save*.

**WARNING:** Updating limits in the checkpoint MUST be coordinated with the Main Engine operator. Make sure the MPS and Main Engine updates are made to the SAME *fltxxx.cp* file (this file can temporarily be located in either the MPS or Main Engine operators' home directories). Also, make sure that the MPS and Main Engine operators DO NOT update the checkpoint file AT THE SAME TIME.

Once the Main Engine limits are updated in the checkpoint, notify the Booster operator that the Main Engine limits are complete and provide the Booster operator with the checkpoint file name and the path to the checkpoint file.

#### Moving the Checkpoint File (Booster Operators Only)

1. Once BOTH the MPS and Main Engine operators have informed the Booster that the checkpoint file has been configured, the Booster should ask one of the Booster GAs to change permissions on the */users/bseds/DATA/Limits* directory to allow any booster to write to the directory (chmod 777).
2. Under the Booster's personal account, the Booster should copy the flight checkpoint into the */users/bseds/DATA/Limits* directory. The Booster should then change permissions on the checkpoint file to allow only the Booster's personal account to have write permission to the file (chmod 755).
3. The Booster should now ask one of the Booster GAs to change the permissions on the limits directory back to write access for the GAs only (chmod 775).

#### Playing the Checkpoint File

1. To ensure that no errors were made in uploading the limits files, playback the previous flight's VCR file along with this checkpoint and ensure that there is no erroneous limit sensing.

2. Under the Booster *DNAV/Playback/Playback Options*, select the appropriate engine types under *SSME Table*, select “Don’t Run” for ISP Tools and DPS OFS under *Start Options*, and select “Use Flight Meds” under *Med Options*. Under the Booster DNAV select “Set bse\_flight\_id” from the *Server* pull-down menu. Scroll through the list and select the flight number that corresponds to the VCR file. Start the VCR and the Playback Server. Under *ISP Tools/ISP Limit*, open the new flight checkpoint file.

## REFERENCES

1. Information Sharing Protocol (ISP) Release 3.4, Limit Manager User’s Guide, Lockheed Martin, LOR-TR 1944, August 1996.

## TITLE

RECOGNITION AND EVALUATION OF SSME PERFORMANCE CASES

## PURPOSE

This SCP discusses the procedures used to evaluate the space shuttle main engine (SSME) performance dispersions currently covered by the Booster Systems Group. After identification of an SSME performance dispersion, the Booster team will provide the Trajectory Officer (TRAJ) with the SSME, time of occurrence, the mode, and the level of dispersion. The TRAJ officer incorporates the corrected values for mixture ratio, specific impulse, and power level for the performance dispersion into the abort region determinator (ARD). The ARD is used by the Flight Dynamics Officer (FDO) to evaluate vehicle capability, determine abort boundaries, and evaluate second-stage performance. Because an SSME performance dispersion can have a significant impact on vehicle performance, any off nominal SSME operating condition must be quickly and accurately identified during ascent.

NOTE: This SCP assumes the reader as already read SB 1.17, SSME Performance Case Description and SB 7.6, Performance Comp.

## DESCRIPTION

Booster console operators use a number of SSME parameters to monitor nominal/off-nominal SSME performance. The most significant of these parameters are the Main Combustion Chamber Pressure (MCC Pc), the High Pressure Oxidizer Turbopump Pump Discharge Pressure (HPOT DP) and Turbine Discharge Temperature (HPOT TDT), the High Pressure Fuel Turbopump Pump Discharge Pressure (HPFT DP) and Turbine Discharge Temperature (HPFT TDT), the Fuel Preburner Oxidizer Valve (FPOV) position, and Oxidizer Preburner Oxidizer Valve (OPOV) position. SB 1.17, SSME Performance Case Description, discusses how each SSME parameter is impacted by various SSME performance dispersions. The Engine Status Word (ESW), provided by the SSME controller, can also provide an indication of off-nominal SSME performance.

The downlisted SSME parameter values are displayed on the Main Engine display (see SCP 3.1.2). The adjusted SSME tag deltas are the differences between the predicted parameter values at 104.5% power level and 1-G inlet conditions and the actual telemetry values that have been adjusted with the power level gain and the LO2 inlet pressure gains. There are two types of tag deltas, pre-flight and in-flight. The tag deltas, computed by the engine performance computation (perf comp) of Booster Operational Support Software (BOSS), are displayed on the Delta display (ref. SCP 3.1.2).

NOTE: Booster console operators should only use the in-flight tag delta if the operator is certain that the SSME performance dispersion occurred after the perf comp has calculated good in-flight tag predictions.

Booster console operators must have copies of the Main Engine Table (MET) outputs (both the delta tables and non-delta tables) to assist in recognition of the off-nominal performance cases (ref. SCP 1.4.2, Main Engine Tables). The user should be aware that the MET outputs are based on the SSME at 104.5% power level and at 1-G inlet condition. Since the tag deltas are adjusted for the power level gains and the LO2 inlet pressure gains, the BSE and ME operators should compare the tag delta with the delta tables to quantify the SSME performance dispersion if the perf comp is operational. The perf comp attempts to quantify the SSME performance dispersion and display the type of performance dispersion, level, and time of occurrence on the Main Engine display. Due to the fact that sensor biases or tag predication errors can cause errors in the perf comp output, the Booster console operator must always verify the perf comp output using the MET. Table 2.1.1-I shows the one-sigma values for pre-flight tag prediction error based on the flight experience for Block IIA SSME types.

TABLE 2.1.1-I: ONE SIGMA

	<b>One- Sigma Values</b>
<b>HPOT TDT A/B</b>	<b>± 40 / ± 40</b>
<b>HPFT TDT A/B</b>	<b>± 44 / ± 44</b>
<b>OPOV/FPOV</b>	<b>± 0.8 / ± 0.7</b>
<b>HPOT/HPFT DP</b>	<b>± 29 / ± 43</b>

Flight Rule A5-110, SSME Performance Dispersion, details the specific performance dispersions that can be quantified by the Booster console operators. These performance cases are listed in Table 2.1.1-II.

TABLE 2.1.1-II: SSME PERFORMANCE DISPERSION

1	SINGLE MCC PC CHANNEL SHIFT HIGH ACTUAL LOW
2	SINGLE MCC PC CHANNEL SHIFT LOW ACTUAL HIGH
3	DUAL MCC PC CHANNEL SHIFT HIGH ACTUAL LOW
4	DUAL MCC PC CHANNEL SHIFT LOW ACTUAL HIGH
5	LPFT DISCHARGE TEMPERATURE SENSOR SHIFT LOW
6	ELECTRICAL LOCKUP
7	FUEL FLOWMETER SHIFT HIGH ACTUAL LOW
8	FUEL FLOWMETER SHIFT LOW ACTUAL HIGH
9	HYDRAULIC LOCKUP
10	PRE-THRUST LIMITING NOZZLE LEAK
11	POST-THRUST LIMITING NOZZLE LEAK
12	HPOT EFFICIENCY LOSS



Table 2.1.1-III shows the tag deltas for various performance dispersions based on the Block-II SSME power balance model dated December 2000. Table 2.1.1-III also shows the performance parameter trends as the performance case continues to degrade. Parameters used to call these performance dispersions are highlighted in the Table 2.1.1-III. This table is intended to provide a general overview and trend of the performance parameters for various performance cases, and is not to be used as official console cue card. Booster console operators must always use the main engine tables as the official source on console to recognize and evaluate performance dispersions.

TABLE 2.1.1-III: TAG DELTAS AND TRENDS FOR VARIOUS PERFORMANCE DISPERSIONS.

<b>Pc Shift High / Actual Low – Level 1.5</b>			<b>(↓ MR)</b>
HPOT TDT A/B	-61 ↓	/	-61 ↓
HPFT TDT A/B	-6 ↓	/	-6 ↓
HPOT/HPFT DP	-74 ↓	/	-62 ↓
OPOV/FPOV	-1.0 ↓	/	0.4 ↑
<b>Pc Shift Low / Actual High – Level 1.5</b>			<b>(↑ MR)</b>
HPOT TDT A/B	66 ↑	/	66 ↑
HPFT TDT A/B	5 ↑	/	5 ↑
HPOT/HPFT DP	75 ↑	/	63 ↑
OPOV/FPOV	1.2 ↑	/	-0.4 ↓
<b>HPOT Efficiency Loss at Thrust Limiting</b>			<b>(↓ MR)</b>
HPOT TDT A/B	117 ↓	/	117 ↓
HPFT TDT A/B	-28 ↓	/	-28 ↓
HPOT/HPFT DP	-4 ↓	/	27 ↓
OPOV/FPOV	4.2 ↑	/	0.1 ↑
<b>Pre-Thrust Limiting Nozzle Leak – Level 1</b>			<b>(↑ MR)</b>
HPOT TDT A/B	156 ↑	/	156 ↑
HPFT TDT A/B	75 ↑	/	75 ↑
HPOT/HPFT DP	45 ↑	/	-59 ↓
OPOV/FPOV	1.8 ↑	/	-0.6 ↓
<b>FFM Shift High / Actual Low – Level 1</b>			<b>(↑ MR)</b>
HPOT TDT A/B	126 ↑	/	126 ↑
HPFT TDT A/B	-14 ↓	/	-14 ↓
HPOT/HPFT DP	32 ↑	/	-73 ↓
OPOV/FPOV	1.2 ↑	/	-1.9 ↓
<b>FFM Shift Low / Actual High – Level 1</b>			<b>(↓ MR)</b>
HPOT TDT A/B	-104 ↓	/	-104 ↓
HPFT TDT A/B	13 ↑	/	13 ↑
HPOT/HPFT DP	-29 ↓	/	76 ↑
OPOV/FPOV	-0.9 ↓	/	2.1 ↑

PROCEDURE

This section describes the actions required to monitor and report each of the SSME performance dispersions. The cues used to recognize each case are summarized, followed by the main engine operator’s responsibilities to the Booster operator and Booster’s responsibility to the TRAJ Officer and the Flight Director.

*Single MCC Pc Channel Shift*

A single MCC Pc channel shift will cause the average MCC Pc to diverge from the reference MCC Pc value. The SSME controller will rebalance the engine to bring the average MCC Pc to the reference MCC Pc. For example, when a single MCC Pc channel shifts high, the actual engine will power down or low which is defined as single MCC Pc shift high actual low.

The Main Engine and Booster console operators should always compare MCC Pc channel A and channel B to one another. If the delta between the two MCC Pc channels is greater than or equal to 50 psia, it is most likely caused by a single MCC Pc channel shift. Next, the operators must determine the actual direction and the amount of shift in the HPOT TDT, the HPOT DP, and the OPOV position. All three of these parameters will shift in the direction of the actual engine shift and so will the good MCC Pc channel. The actual MCC Pc error is the delta between the MCC Pc average and the good Pc channel, and the level for this performance dispersion is calculated by dividing the actual MCC Pc error by 25 psia. Table 2.1.1-IV shows the HPOT TDT and the HPOT DP tag delta for the level one single MCC Pc channel shift (MCC Pc error equal to 25 psia).

TABLE 2.1.1-IV: LEVEL 1 SINGLE MCC PC SHIFT TAG DELTA.

	Single MCC Pc Shift High Actual Low	Single MCC Pc Shift Low Actual High
HPOT TDT	-41	43
HPOT DP	-49	50

The operator should always compare the HPOT TDT and the HPOT DP tag delta to corresponding MCC Pc error in the delta table. If the HPOT TDT and the HPOT DP tag delta are greater than expected, this might be a dual Pc shift case instead of the single Pc shift case. In second stage, the operator should check the thrust factor (see SCP 2.1.14). This is done to verify the direction of the actual shift. For the shift high actual low case, the thrust factor should be less than 1.00. Conversely, for the shift low actual high case, the thrust factor should be greater than 1.00.

For single MCC Pc channel shifts, the flight rules allow for a power cycle of the SSME controller with the bad MCC Pc channel. This will disqualify the bad sensor and remove the

SSME performance dispersion. The effected SSME controller can only be power cycled if all of the following conditions are satisfied: 1) ATO cannot be achieved with the performance case intact, 2) loss of the controller will not cause electric or hydraulic lockup, 3) loss of the controller will not cause the engine to shutdown, and 4) FDO determines that removing the performance dispersion will regain uphill capability. When power is reapplied to the engine controller, the associated command channel should be recovered to transmit commands and data while the associated digital controller unit (DCU) and the electronics will remain disqualified. Flight Rules state that it is acceptable to cause a momentary or permanent SSME command path failure, because the SSME can still rebalance to correct for the performance case.

Flight Rules also state that it is accepted that power cycling will cause loss of the RTVMS Accelerometer Redline function. Power cycling will cause loss of the RTVMS Accelerometer Redline function since RTVMS is only a fail-safe system. Loss of this redline protection on one SSME is accepted to regain ATO capability. The PRCB opted for a fail-safe system on 4/11/99 - reference PRCBD S071886A. This avoided \$8.7M in costs with no predicted change in the probability of an erroneous shutdown.

The Main Engine and the Booster operators' actions for the single MCC Pc shift case are listed in Table 2.1.1-V.

TABLE 2.1.1-V: MAIN ENGINE AND BOOSTER ACTIONS FOR MCC PC SHIFT CASES

Main Engine Operator's Actions
1) Reports to Booster the affected engine with single MCC Pc shift, direction, level, time of occurrence, and the mixture ratio impact.
2) Inform Booster of the bad MCC Pc channel and its associated controller power source that can be power cycled to regain uphill capability.
3) Inform Booster of the good MCC Pc channel and that loss of its associated controller power source will cause the case to double.
4) Check the thrust factor in second stage to verify the direction of the actual shift.

Booster Officer's Actions
1) Verify the Main Engine Operator's calls and report to TRAJ the affected engine with MCC Pc shift, direction, level, and time of occurrence.
2) Inform TRAJ that this performance case can be removed by power cycling the bad engine controller to regain uphill capability.
3) Inform the Flight Director of the affected engine with the performance case, level, type of mixture ratio impact, and the engine controller that can be power cycled to regain uphill capability. Use the nomenclature "Panel R2, Engine Power Left (Center, Right), AC1 (2, 3)".

*Dual MCC Pc Channel Shift*

A dual MCC Pc channel shift will also cause the average MCC Pc to diverge from the reference MCC Pc value. The SSME controller will rebalance the engine to bring the average MCC Pc to the reference MCC Pc. Since the effect on the SSME is the same for single or dual MCC Pc channel shifts, the same Main Engine Tables are use for both of these cases.

The dual Pc channel shift case can be caused by both MCC Pc channels shifting. This can occur with or without a delta between the two MCC Pc channels. In the case where one MCC Pc channel is disqualified while the remaining MCC Pc channel shifts, the dual MCC Pc shift criteria are used to quantify this performance dispersion. The operational parameters used to identify and quantify a dual MCC Pc channel shift case are the HPOT TDT, the HPOT DP, and the HPFT DP. Table 2.1.1-VI shows the minimum tag delta required for a dual MCC Pc channel shift (MCC Pc error 37.5 psia).

TABLE 2.1.1-VI: MINIMUM (LEVEL 1.5) DUAL MCC PC SHIFT TAG DELTA.

	Dual MCC Pc Shift High Actual Low	Dual MCC Pc Shift Low Actual High
HPOT TDT	-60	65
HPOT DP	-74	75
HPFT DP	-61	62

A minimum MCC error of 37.5 ensures the performance case is not called erroneously due to tag prediction errors and ensures the rebalance in the engine was not caused by any other performance cases.

Again for the dual MCC Pc shift case, the thrust factor should be verified in second stage. For the shift high actual low case, the thrust factor should be less than 1.00. For the shift low actual high case, the thrust factor should be greater than 1.00.

The Main Engine and the Booster operators' actions for the dual MCC Pc shift case are listed in Table 2.2.1-VII.

TABLE 2.2.1-VII: MAIN ENGINE AND BOOSTER ACTIONS FOR DUAL MCC PC SHIFT CASE

Main Engine Operator's Actions
1) Reports to Booster the affected engine with dual MCC Pc shift, direction, level, time of occurrence, and the mixture ratio impact.
2) Inform Booster that the SSME controller cannot be power cycled for this case.
3) Check the thrust factor in second stage to verify the direction of the actual shift.

Booster Officer's Actions
1) Verify the Main Engine Operator's calls and report to TRAJ the affected engine with MCC Pc shift, direction, level, and time of occurrence.
2) Inform Flight of the affected engine with the performance case, level, and type of mixture ratio impact.

*Fuel Flowmeter Shifts*

The data from four fuel flowmeter sensors are processed by the SSME controller to calculate and control the SSME mixture ratio. A shift in one or more fuel flowmeter sensors will result in a mixture ratio error. The SSME controller will rebalance the engine to match the commanded mixture ratio.

Only the average of the four fuel flowmeter sensor measurements is available in the Booster team's real time data. As a result, there is not a direct fuel flowmeter measurement that can be used to identify and quantify a flowmeter shift. A group of four operational parameters, the HPOT TDT, the HPOT DP, the HPFT DP, and the FPOV position, are used to identify and quantify this case. Table 2.1.1-VIII shows the minimum tag delta required for a level one fuel flowmeter shift (450 GPM Shift).

TABLE 2.1.1-VIII: LEVEL 1 FUEL FLOWMETER SHIFT TAG DELTA.

	FFM Shift High Actual Low	FFM Shift Low Actual High
HPOT TDT	127	-106
HPOT DP	32	-29
HPFT DP	-75	80
FPOV	-1.8	2.1

The minimum fuel flow error of 450 GPM ensures the performance case is not called erroneously due to tag prediction errors and ensures the rebalance in the engine was not caused by any other performance cases. Each additional level increase is based on additional 150 GPM shift as indicted on the MET outputs. The additional shift will be reflected in the HPOT TDT, the HPOT DP, the HPFT DP, and the FPOV position.

Since all of the parameters used to call the fuel flowmeter shift high actual low case shift in the same direction as the pre-thrust limiting nozzle leak, the Booster console operator must check the HPFT TDT to differentiate between these two cases. For the fuel flowmeter shift high actual low case the HPFT TDT will slightly decrease, while for the pre-thrust limiting nozzle leak case, they will increase significantly.

The Main Engine and the Booster operators' actions for the fuel flowmeter shift case are listed in Table 2.2.1-IX.

TABLE 2.2.1-IX: MAIN ENGINE AND BOOSTER ACTIONS FOR FUEL FLOWMETER SHIFT CASE

Main Engine Operator's Actions
1) Reports to Booster the affected engine with the fuel flowmeter shift, direction, level, time of occurrence, and the mixture ratio impact.
2) For fuel flowmeter shift high actual low, check that HPFT TDT has not shifted high and that all operational tag deltas are proportional for a given GPM error.
Booster Officer's Actions
1) Verify the Main Engine Operator's calls and reports to TRAJ the affected engine with fuel flowmeter shift, direction, level, and time of occurrence.
2) Inform Flight of the affected engine with the performance case, level, and type of mixture ratio impact.

*Electric Lockup*

The SSME controller provides status of some off-nominal operating conditions in the engine status word. The engine status word is a four digit hexadecimal word that is displayed on the Main Engine display. An electric lockup has occurred if the last two characters of the engine status word are 8E or 8F. The decoded engine status word is displayed on the DDD Panel display. The SSME controller enters the electric lockup mode when both of the MCC Pc channel pairs (A & B) or all fuel flowmeter sensors (A1, A2, B1, and B2) have been disqualified.

If SSME is in electric lockup mode, the SSME controller will not accept any new throttle commands from the GPC and will continue to control the SSME valves to their last commanded positions.

If the SSME did rebalance prior to electric lockup, it will be locked at an off-nominal condition. In this case, the electric lockup must be modeled using the MCC Pc shift delta tables or the fuel flowmeter shift delta table. The tables used to model this case depend on what sensor caused the electric lockup. The level will be based on the operational parameter deltas from the respective delta tables. If the SSME did not rebalance prior to electric lockup or is not locked up at the mission power level, the case should be modeled using the backup electric lockup table.

The Main Engine and the Booster operators' actions for the electric lockup case are listed in Table 2.2.1-X.

TABLE 2.2.1-X: MAIN ENGINE AND BOOSTER ACTIONS FOR ELECTRIC LOCKUP CASE

Main Engine Operator's Actions
1) Reports to Booster the affected engine with the electric lockup, power level at which the SSME is locked up at, the appropriate MET that should be used to model the case, level, and the time of occurrence.
2) Check for other actions that might be required for a stuck throttle (SCP 2.1.5, One Stuck Throttle, and SCP 2.1.6, Two Stuck Throttle).

Booster Officer's Actions
1) Verify the Main Engine Operator's calls and report to TRAJ the affected engine with the electric lockup, power level at which the SSME is locked up at, the appropriate MET that should be used to model the case, level, and the time of occurrence.
2) Inform Flight of the affected engine with the electric lockup, power level at which the SSME is locked up at, and type of mixture ratio impact if any.
3) Inform Flight of any other actions that might be required for a stuck throttle (SCP 2.1.5, One Stuck Throttle, and SCP 2.1.6, Two Stuck Throttle).

*Hydraulic Lockup*

There are a number of failures that will cause an SSME hydraulic lockup. These are detailed in Flight Rule A5-3. In addition, the loss of a single orbiter auxiliary power unit (APU) will cause a hydraulic lockup on one SSME.

Just like electric lockup, the SSME controller will announce a hydraulic lockup in the engine status word and will not accept new throttle commands from the GPC. Unlike electric lockup, the SSME can not actively control the SSME valves at their last commanded positions since there are mechanisms on the valves that attempt to lock them in place with hydraulic pressure. Therefore, the SSME valve(s) can drift while the engine is in hydraulic lockup.

A hydraulic lockup is declared when the hydraulic supply pressure drops below 1500 psia or when the last two characters of the engine status word indicate 92 or 93. The Booster console operator must model the instantaneous level when this case is declared and monitor for a possible drift. If the SSME is drifting, FDO/TRAJ must be updated with the drift level. The engine performance computation will calculate the drift level assuming a linear drift with a drift MECO time of 15 minutes. The output from this calculation is displayed on the main engine display. The SSME drift cannot be modeled without the engine performance computation output.

The Main Engine and the Booster operators' actions for the hydraulic lockup case are listed in Table 2.1.1-XI.



TABLE 2.1.1-XI: MAIN ENGINE AND BOOSTER ACTIONS FOR HYDRAULIC LOCKUP CASE

Main Engine Operator's Actions
1) Reports to Booster the affected engine with the hydraulic lockup, instantaneous level, the instantaneous power level, and time of occurrence.
2) Check for a possible drift on the effected SSME. If the SSME is drifting, report the drift level and drift power level at drift MECO of 15 minutes.
3) If the operational parameters are approaching a redline due to the drift, determine and report to Booster the time of the expected redline shut down.
4) Check for other actions that might be required for a stuck throttle (SCP 2.1.5, One Stuck Throttle, and SCP 2.1.6, Two Stuck Throttle).

Booster Officer's Actions
1) Verify the Main Engine Operator's calls and report to TRAJ the affected engine with the hydraulic lockup, instantaneous level, the instantaneous power level, and time of the occurrence.
2) Inform the Flight Director of the affected engine with the hydraulic lockup, power level at which the SSME is locked up at, and type of mixture ratio impact due to the drift if any.
3) If the operational parameters are approaching a redline due to the drift, inform Traj that this engine is suspect and determine and report to Flight the time of the expected redline shut down.
4) Inform Flight of any other actions that might be required for a stuck throttle (SCP 2.1.5, One Stuck Throttle, and SCP 2.1.6, Two Stuck Throttle).

*Pre-Thrust Limiting Nozzle Leaks*

Nozzle leaks are fuel leaks which occur downstream of the fuel flow meter (located between the LPFTP and the HPFTP) and result in decreased fuel flow to the MCC. The mixture ratio control loop is not aware of the fuel loss, but the thrust control loop will observe a decrease in MCC Pc average. The SSME will open the OPOV to compensate for the drop in MCC Pc average. The increase in oxidizer flow and decrease in fuel flow to the MCC and preburners cause an increased mixture ratio in each chamber and consequently causes the SSME to operate at higher than normal temperatures. If the leak rate increases, the OPOV will continue to open until it reaches its maximum OPOV limit (thrust limiting).

The four operational parameters used to identify and quantify a pre-thrust limiting nozzle leak are the HPOT TDT, the HPFT TDT, the HPFP DP, and the OPOV position. Table 2.1.1-XII shows the minimum tag delta required for level one pre-thrust limiting nozzle leak (7 lbm/sec).

TABLE 2.1.1-XII: LEVEL 1 PRE-THRUST LIMITING NOZZLE LEAK TAG DELTA.

	Pre-Thrust Limiting Nozzle Leak
HPOT TDT	155
HPFT TDT	71
HPFT DP	-60
OPOV	1.7

The minimum nozzle leak rate of 7 lbm/sec ensures the performance case is not called erroneously due to tag prediction errors and ensures the rebalance in the engine was not caused by any other performance cases. As mentioned before, the pre-thrust limiting nozzle leak and the fuel flowmeter shift high actual low look similar in a sense that the HPOT TDT, the HPFT DP, and the OPOV position all shift in same direction. The Main Engine and Booster console operators need to make sure the HPFT TDT delta is not caused by bad tag predictions and all operational tag deltas are proportional for a given leak rate.

The Main Engine and the Booster operators' actions for the pre-thrust limiting nozzle leak are listed in Table 2.1.1-XIII.

TABLE 2.1.1-XIII: MAIN ENGINE AND BOOSTER ACTIONS FOR PRE-THRUST LIMITING NOZZLE LEAK CASE

Main Engine Operator's Actions
1) Reports to Booster the affected engine with the pre-thrust limiting nozzle leak, level, time of occurrence, and the associated leak rate.
2) Check that HPFT TDT delta is not caused by bad tag predictions and that all operational tag deltas are proportional for a given leak rate.

Booster Officer's Actions
1) Verify the Main Engine Operator's calls and report to TRAJ the affected engine with nozzle leak, level, and time of occurrence.
2) Inform the Flight Director of the affected engine with the performance case, level, and type of mixture ratio impact.

NOTE: Due to a limitation on number of input tables in the ARD, the pre-thrust limiting and the post-thrust limiting nozzle leak are listed as one input table called the Nozzle Leak. Therefore when modeling this case with TRAJ, simply refer to this case as a nozzle leak.

*Post-Thrust Limiting Nozzle Leaks*

As the nozzle leak rate continues to increase, the OPOV valve will continue to open until it reaches its maximum limit, called OPOV limiting or thrust limiting. The SSME controller will post Failure Identifier (FID) 020-003 “MISC REPORT -“ “THRUST LIMITING” and annunciate thrust limiting in the engine status word displayed on the Main Engine display. Thrust limiting is indicated by the last two characters of the engine status word showing 8A or 8B.

Since thrust limiting can also be caused by an HPOT efficiency loss, the operator needs to be careful in diagnosing a nozzle leak. The HPOT TDT and HPFT TDT deltas are used to differentiate between a post-thrust limiting nozzle leak and an HPOT efficiency case. The HPOT TDT deltas are significantly higher for a nozzle leak when compared to the HPOT efficiency loss case. For Block II SSMEs if the HPOT TDT delta is greater than 193 deg R, the case is most likely a post-thrust limiting nozzle leak. As the leak rate continues to increase, the HPOT TDT delta will continue to increase. The HPOTP TDT delta will increase for a degrading post-thrust limiting nozzle leak case, while it decreases post thrust limiting for a degrading HPOT efficiency case.

As the leak rate increases after thrust limiting, the MCC Pc will decrease due to less fuel entering the MCC. Therefore the level for post-thrust limiting nozzle leak is based on the MCC Pc delta. The leak rate at which the SSME reaches thrust limiting varies from engine to engine, since the maximum OPOV limit is calculated real-time just after engine start.

The Main Engine and the Booster operators’ actions for the post-thrust limiting nozzle leak are listed in Table 2.1.1-XIV.

TABLE 2.1.1-XIV: MAIN ENGINE AND BOOSTER ACTIONS FOR POST-THRUST  
 LIMITING NOZZLE LEAK CASE

Main Engine Operator's Actions
1) Reports to Booster the affected engine with the post-thrust limiting nozzle leak, level, time of occurrence, and the associated leak rate.
2) Check that HPFT TDT delta is not caused by bad tag predictions and that all operational tag deltas are proportional for a given leak rate. Also if the case continues to degrade, the HPOT TDT should continue to increase.

Booster Officer's Actions
1) Verify the Main Engine Operator's calls and report to TRAJ the affected engine with nozzle leak, level, and time of occurrence.
2) Inform the Flight Director of the affected engine with the performance case, level, and type of mixture ratio impact.

*HPOT Efficiency Loss*

For an HPOT efficiency loss, the MCC Pc will decrease due to degraded output from the high pressure oxidizer turbopump. The SSME controller will compensate by opening the OPOV. If the HPOT efficiency continues to degrade, the OPOV will reach its maximum limit and SSME controller will enter thrust limiting. Due to the fact that the main engine controller can correct this case by opening the OPOV, no performance impact is seen until the engine enters thrust limiting. Again the last two characters of the engine status word will indicate 8A or 8B and FID 020-003 is posted. Any additional HPOT efficiency loss after thrust limiting will result in degraded SSME performance.

Since thrust limiting can also be caused by a nozzle leak, the operator needs to be careful in diagnosing an HPOT efficiency loss. The HPOT TDT deltas are used to differentiate between a post-thrust limiting nozzle leak and an HPOT efficiency case. The HPOT TDT delta is not as high for an HPOT efficiency loss as it is for the nozzle leak. For Block II SSMEs if the HPOT TDT delta is less than 193 deg R, the case is most likely an HPOT efficiency loss. As the HPOT efficiency continues to degrade, the HPOT TDT delta will continue to decrease. The HPOT TDT delta will increase for a post-thrust limiting nozzle leak case, while it decreases for an HPOT efficiency case. The level for post-thrust limiting HPOT efficiency loss is based on the MCC Pc delta.

The Main Engine and the Booster operators' actions for the HPOT efficiency loss are listed in Table 2.1.1-XV.

TABLE 2.1.1-XV: MAIN ENGINE AND BOOSTER ACTIONS FOR HPOT EFFICIENCY LOSS CASE

Main Engine Operator's Actions
1) Reports to Booster the affected engine with the HPOT efficiency loss, level, and time of occurrence.
2) Check the HPOT TDT tag delta. If they increase then it might be a nozzle leak.

Booster Officer's Actions
1) Verify the Main Engine Operator's calls and report to TRAJ the affected engine with the HPOT efficiency loss, level, and time of occurrence.
2) Inform the Flight Director of the affected engine with the performance case, level, and type of mixture ratio impact.

*Low Pressure Fuel Turbopump (LPFT) Discharge Temperature Shift*

The low pressure fuel turbopump discharge temperature (LPFT DT) is used in the SSME mixture ratio control loop to calculate LH2 density and subsequently the LH2 mass flow rate. The SSME mixture ratio control loop will attempt to adjust the mixture ratio in response to perceived changes in the LH2 density caused by LPFT DT sensor shift. Total failure of the discharge temperature sensors on an SSME will result in substitution of a fixed density constant into the mixture ratio control loop. This minimizes the performance degradation and no update to the ARD is required. However, a shift low in the LPFT DT sensors, within qualified limits, will result in an SSME performance dispersion.

To recognize this performance dispersion, a comparison of the LPFT DT data of the three SSMEs is made throughout ascent. If one temperature shifts low by one or more degrees from the mid-value of the three SSMEs, the case is present. To confirm the level, the operator should compare the HPOT TDT tag delta with the MET output if possible. Although the case is present when a one-degree shift occurs, the minimum level per the flight rule at which the case can be model into the ARD is level 2 (a two-degree shift). This covers instrumentation accuracy and ensures sufficient change in the engine parameters for failure identification.

The Main Engine and the Booster operators' actions for the LPFT DT shift are listed in Table 2.1.1-XVI.

TABLE 2.1.1-XVI: MAIN ENGINE AND BOOSTER ACTIONS FOR LPFT DT SHIFT CASE

Main Engine Operator's Actions
1) Reports to Booster the affected engine with the LPFT DT shift, level, and time of occurrence.
2) Check the HPOT TDT tag delta to the MET output to confirm the level.

Booster Officer's Actions
1) Verify the Main Engine Operator's calls and report to TRAJ the affected engine with the LPFT DT shift, level, and time of occurrence when case is equal to or greater than level 2.
2) Inform the Flight Director of the affected engine with the performance case, level, and type of mixture ratio impact.

If the sensor degrades and fails qualification limits, the SSME will enter fixed density as indicated by the last two characters an engine status word, 96 or 97 (but no FID is posted). At this point, the LPFT DT shift can be removed from the ARD.

REFERENCES

- 1) Space Shuttle Operational Flight Rules, Volume A, All flights, Final, PCN-2, Errata, NSTS-12820, June 25, 2004.
- 2) Booster Standard Console Procedures, Rev G, JSC-17239.
- 3) Booster Systems Briefs, Basic, Rev F, JSC-19041.
- 4) Rocketdyne's Block II SSME Off-Nominal Power Balance Model Data, December, 2000.
- 5) Booster Main Engine Tables.

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TITLE

SSME CONTROLLER REDUNDANCY LOSS

PURPOSE

Controller redundancy loss is defined as loss of the input electronics (IE), output electronics (OE), digital computer unit (DCU)/computer interface electronics (CIE), or power supply electronics (PSE) in channel A or B of any engine, such that the engine is one failure away from a pneumatic shutdown. See Figure 2.1.2-I for an overview of the SSME Block II Controller with the Advance Health Management System (AHMS) Phase 1 Upgrade and its redundancy management scheme.

DESCRIPTION

A. Loss of PSE Channel A or B

Loss of either channel's power supply electronics will result in the disqualification of all functions on that channel: the DCU, CIE, IE, OE, as well as all four Digital Signal Processors (DSP). Only functions/sensors on the remaining channel will be used for engine control. Disqualification reporting will be under either FID 001-001 or FID 002-001. If either channel's DCU/CIE pair is disqualified due to a non-power related problem and power is subsequently lost on that channel, FID 001-002 or 002-002 will be issued. No FIDs will be reported for loss of other functions/channels/sensors on the failed side of the controller. In the case of a primary data path failure, the 60 kilo-bit EIU downlink source will be switched to the secondary data, but the GPCs will still not have primary data for the 32-word GPC downlist. Since all four DSPs are disqualified for loss of either PSE A or B, the Real Time Vibration Monitoring System (RTVMS) synchronous vibration redline function will be lost on both the HPOTP and HPFTP for either of these failures. The DSPs remain disqualified even if power is recovered. Note that this fact could be used to deactivate the RTVMS redline if it were desired (but no situation has been identified where this is the case) by power cycling DCU B (primary data would be retained). Also note that the SSMEC Part 1 Spec does not list the DSP as a lost component for FID 001-001, 001-002, 002-001, and 002-002 - since the DSP loss (in the case of a DCU power failure) is a secondary failure (due to the IE failing) it is not required to be listed in the FID table. This item was worked as Review Item Discrepancy (RID) 002-RedingJD / PH1\_SW\_CDR\_RID01 at the AHMS Phase 1 Software Critical Design Review.

This failure is read up to the crew as "loss of controller A(B)." The crew uses their cue cards to keep track of command path status.

If the EGIL operator is reporting a short that can impact an AC bus during ascent, the Booster operator should coordinate with the EGIL the impacts of the bus loss on SSME controllers. If SSME controllers are lost due to AC buses, the Booster operator should report to the Flight Director that the SSME Controllers associated with AC Bus 1, 2, or 3 are failed. The EGIL operator should not take AC Bus loss actions, which will drop the entire bus, until after the SSME controllers have failed.

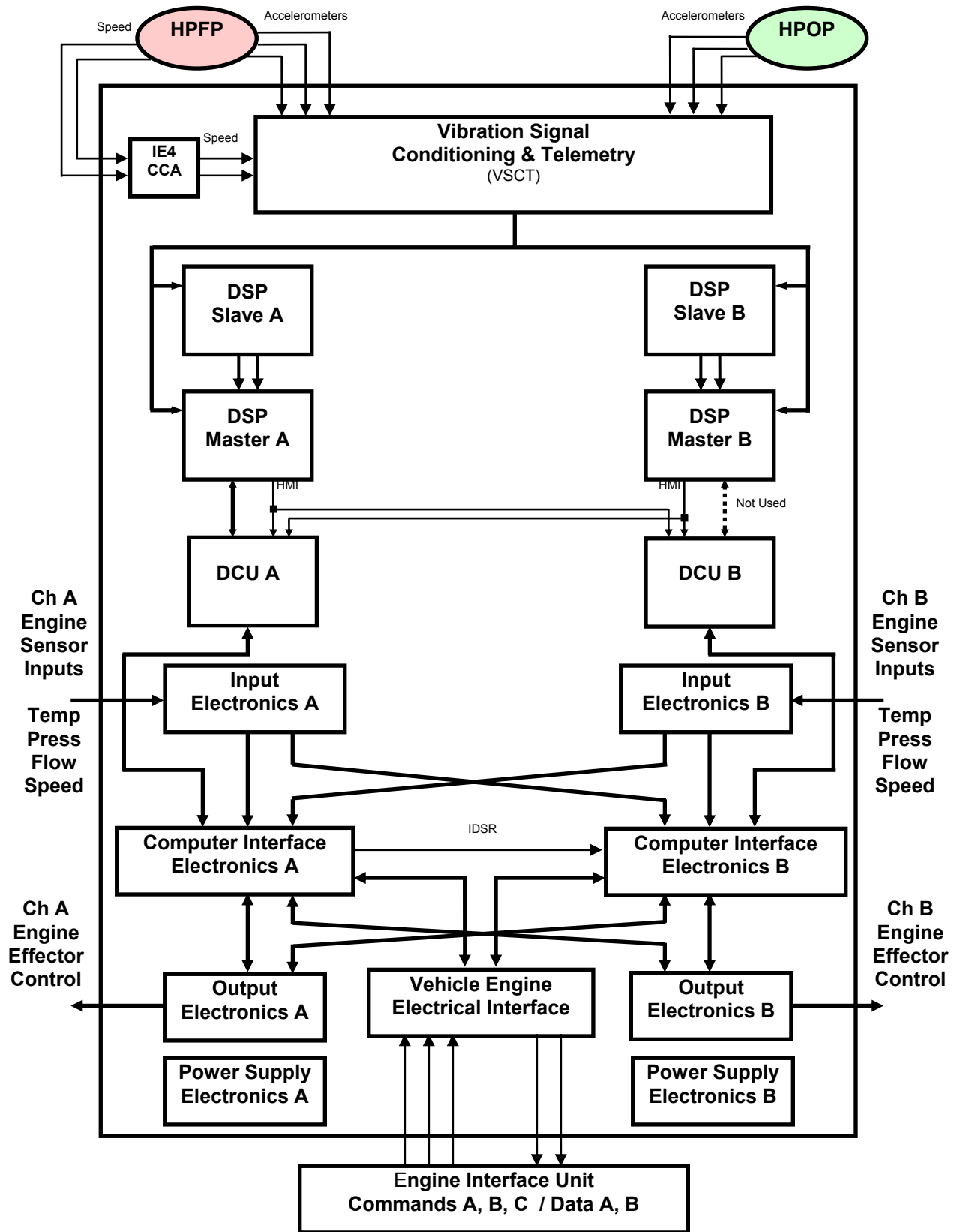


Figure 2.1.2-I – SSME Block II Controller with AHMS Phase 1 Upgrade - Overview

#### B. Loss of DCU/CIE Channel A or B

Loss of either DCU will also result in loss of that channel's CIE. If the DCU and CIE were halted due to loss of power (FID 001-001 or FID 002-001), then that channel's IE and OE, and all four DSPs will also be disqualified (see below for redundancy impacts). If a DCU/CIE pair was disqualified due to a non-power related problem (FID 001-000 or FID 002-000), then the IE and OE on that channel can still be used by the remaining DCU and none of the DSPs will be disqualified. If the non-power related problem was on DCU A, however, the RTVMS synchronous vibration redline function will be lost since only DCU A communicates with the DSPs, processes the Health Management Interrupt, and performs qualification of both pairs of DSPs. If the non-power related problem was on DCU B, the RTVMS synchronous vibration reline will still function properly since DCU B does not interact with the DSPs.

This failure is passed up to the crew as “loss of electronics A(B).”

#### C. Loss of IE Channel A or B

Loss of either IE channel will result in the disqualification of all sensors used in control, ignition confirmation, or engine limit monitoring on that channel (including disqualification of all four of the DSPs and thus the entire RTVMS synchronous vibration redline function on both the HPOTP and HPFTP). If either IE fails its address and data bus self test, the in-charge DCU will also be disqualified. A FID will only report the IE disqualification (FID 003-001, 002, 012, 013 or 004-001, 002, 012, 013). If DCU A was disqualified due to this failure mode, then switchover to DCU B can be detected by monitoring ID word 2. Failure of this test, while DCU B is in charge, will result in a pneumatic shutdown. An IE failure can propagate and cause that channel's OE to be disqualified. In this case, the FID will be reported for the OE with the IE failure encoded in the delimiter (for example, FID 005-010 - see Table 2.1.2-II).

The failure of IE is read up to the crew as “loss of electronics A(B).”

#### D. Loss of OE Channel A or B

Loss of either OE channel will result in commanding the emergency shutdown solenoid power to off and the OE registers to the fail-safe configuration, in the respective OE channel. The fail-safe configuration includes: the deactivation of all ON/OFF valves and igniters, as well as the deactivation of all internal functions. All ON/OFF valves, propellant valve actuators, and LVDT/RVDT excitations on the failed channel will also be disqualified. The remaining OE will maintain actuator control. The FID (005-XXX or 006-XXX) will report the OE failure and the delimiter has encoded information regarding the IE status. If either IE has previously failed, it might be masked by the OE failure report if the information were not in the delimiter. OE failures do not have any impact on the DSPs or the RTVMS synchronous vibration redline function (unless the IE is also lost when the OE fails – like for FID 005-010).

Loss of the OE is read up to the crew as “loss of electronics A(B).”

#### E. Non-disqualifying Failure of OE A or OE B

The controller performs self-tests on the on/off devices by verifying their current state with their last commanded state. Since the OE is used to command and verify these states, these tests can be

considered part of the OE self tests. This is true even though failure of these tests does not necessarily result in loss of the OE. Failure of these tests is reported via FIDs 007-100, 200, 300 and 010-100, 200, 300. There are two notable self-test cases. One is the failure of the emergency shutdown solenoid bit failed on (part of FIDs 007-100 and 010-100). If this failure occurs, then the OE will be disqualified at shutdown and FID 005-101/006-101 will be issued (assuming no previous IE failure, otherwise the FID will be 005-110/006-110 or 005-120/006-120 if IE A or IE B had previously failed). When one OE is disqualified, the other OE will control the emergency shutdown solenoid. The other failure to note is that if any of the fail-safe bits have failed OFF (FID 007-300/010-300), the engine will go into hydraulic lockup if the other channel's fail-safe bit on that actuator fails OFF. These two special cases are documented in Figure 2.1.2-II.

Special Case OE Failures (BLOCK II: OI-6)	
CASE 1:	Emergency Shutdown Solenoid fails on in Mainstage
	SIGNATURE: (during mainstage) FID = 007-100 or 010-100, OE A(B), NOT DQL-REGISTER 1 (during shutdown) FID = 005-101 or 006-101, OE A(B) D/QUAL - & ACTUATORS
	RESPONSE: NONE BY MCC CONTROLLER WILL DISQUALIFY OE DURING S/D
CASE 2:	ALTHOUGH FIDs 007 & 010 ARE NON-DISQUALIFYING, BE AWARE OF THE FOLLOWING FAILURE RESPONSE:
	FID 007-300 or 010-300: 2ND FAILURE RESULTS IN HYDRAULIC LOCKUP
	06/10/94

Figure 2.1.2-II - Special case OE Failures Cue Card.

#### F. Loss of Both SSME Controllers/Electronics

With the loss of both SSME controllers or both SSME electronics, the SSME will shutdown pneumatically behind a data path failure. That is for the loss of both power supplies, or loss of DCU A and DCU B, or loss of IE A and IE B, or loss of OE A and OE B. Flight Rule A5-2 contains a failure matrix for controller failures resulting in shutdown. When both controller channels fail, the SSME fail-safe pneumatic shutdown solenoid valve in the pneumatic control assembly (PCA) is de-energized resulting in a pneumatic shutdown of the SSME. Also when both controller channels fail, the SSME controller stops processing data resulting in a data path failure.

The loss of different electronics channels does not result in an SSME shutdown (i.e. loss of IE A and OE B) because the IEs and OEs are cross-strapped to the CIE. Figure 2.1.2-I depicts the controller interfaces that illustrate this point.

G. Loss of a Portion or All of the Vibration Signal Conditioning and Telemetry (VSCT) card.

Loss of a portion or all of the VSCT card is not loss of controller redundancy. The VSCT is redundantly powered, and if a portion of the power is lost, a portion of the data processed by the VSCT card is lost - see Systems Brief 1.19 for details.

H. Loss of Any or All DSPs

Loss of any or all DSPs is not loss of controller redundancy.

PROCEDURE

A. Associated Flight Rules

1. A5-2, Space Shuttle Main Engine Out
2. A5-3, Stuck Throttle
3. A5-111, AC Bus Sensor Electronics Control

B. Crew Operations

1. Recognition of Failure - None.
2. Crew Procedure - None.
3. Activity - The crew will (1) take the AC BUS SENSORS to OFF (per MCC's call) and (2) mark the failed channels on the MPS cue card (see Figure 2.1.2-III below) and/or knee board pages.

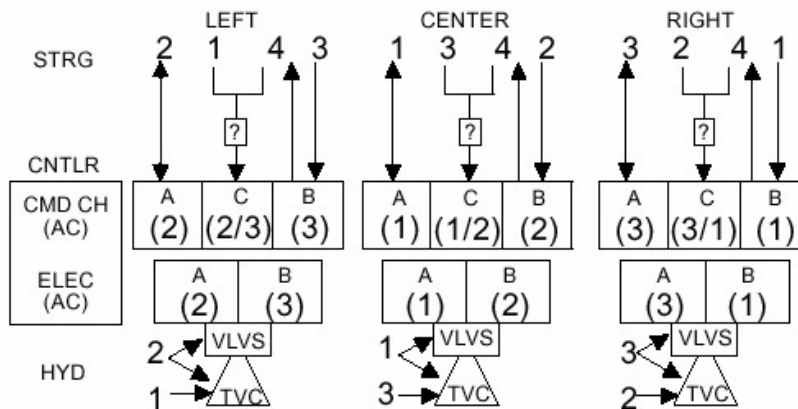


Figure 2.1.2-III – MPS Cue Card from FDF

C. MCC Operations

1. Recognition of Failure – Table 2.1.2-II lists the FIDs associated with controller failures and the engine status word (ESW) indicating major component failure (MCF) as the final entry in the table. All FIDs associated with loss of controller redundancy have been included in Table 2.1.2-II in order to represent the differences between various FIDs (e.g. “OE A D/QUAL-& ACTRS & IE B” versus “OE A D/QUAL-& ACTUATORS”).

TABLE 2.1.2-II - RECOGNITION OF FAILURE (PASS)

PARAMETER NO.	FAILURE VALUE/TREND		DISPLAYED ON
	(FID)	FID-DLM (octal)      Syntax	
(C) E41M1005P	001-000	DCU A D/QUAL-DCU/CIE ONLY	Main Engine & FID Displays
(L) E41M2005P	001-001	DCU A D/QUAL-DUE TO CH PWR	
(R) E41M3005P	001-002	DCU A D/QUAL-SUBS. PWR FAIL	
	002-000	DCU B D/QUAL-DCU/CIE ONLY	
	002-001	DCU B D/QUAL-DUE TO CH PWR	
	002-002	DCU B D/QUAL-SUBS. PWR FAIL	
	003-001	IE A D/QUAL - & SENSORS	
	003-002	IE A D/QUAL - & SENSORS	
	003-012	IE A D/QUAL - & SENSORS	
	003-013	IE A D/QUAL - & SENSORS	
	003-201	IE A D/QUAL - & SENSORS	
	003-202	IE A D/QUAL - & SENSORS	
	003-203	IE A D/QUAL - & SENSORS	
	003-204	IE A D/QUAL - & SENSORS	
	003-205	IE A D/QUAL - & SENSORS	
	003-206	IE A D/QUAL - & SENSORS	
	003-207	IE A D/QUAL - & SENSORS	
	003-210	IE A D/QUAL - & SENSORS	
	003-211	IE A D/QUAL - & SENSORS	
	003-501	IE A D/QUAL - & SENSORS	
	004-001	IE B D/QUAL - & SENSORS	
	004-002	IE B D/QUAL - & SENSORS	
	004-012	IE B D/QUAL - & SENSORS	
	004-013	IE B D/QUAL - & SENSORS	
	004-201	IE B D/QUAL - & SENSORS	
	004-202	IE B D/QUAL - & SENSORS	
	004-203	IE B D/QUAL - & SENSORS	
	004-204	IE B D/QUAL - & SENSORS	
	004-205	IE B D/QUAL - & SENSORS	
	004-206	IE B D/QUAL - & SENSORS	
	004-207	IE B D/QUAL - & SENSORS	
	004-210	IE B D/QUAL - & SENSORS	
	004-211	IE B D/QUAL - & SENSORS	
	004-501	IE B D/QUAL - & SENSORS	

TABLE 2.1.2-II - RECOGNITION OF FAILURE (PASS) (Continued)

PARAMETER NO.	FAILURE VALUE/TREND		DISPLAYED ON
	FID-DLM (octal)	Syntax	
(FID)			
(C) E41M1005P	005-000	OE A D/QUAL-& ACTUATORS	Main Engine & FID Displays
(L) E41M2005P	005-010	OE A D/QUAL-& ACTRS & IE A	
(R) E41M3005P	005-020	OE A D/QUAL-& ACTRS & IE B	
	005-100	OE A D/QUAL-& ACTUATORS	
	005-101	OE A D/QUAL-& ACTUATORS	
	005-102	OE A D/QUAL-& ACTUATORS	
	005-110	OE A D/QUAL-& ACTRS & IE A	
	005-111	OE A D/QUAL-& ACTRS & IE A	
	005-112	OE A D/QUAL-& ACTRS & IE A	
	005-120	OE A D/QUAL-& ACTRS & IE B	
	005-121	OE A D/QUAL-& ACTRS & IE B	
	005-122	OE A D/QUAL-& ACTRS & IE B	
	005-300	OE A D/QUAL-& ACTUATORS	
	005-310	OE A D/QUAL-& ACTRS & IE A	
	005-320	OE A D/QUAL-& ACTRS & IE B	
	005-400	OE A D/QUAL-& ACTUATORS	
	005-401	OE A D/QUAL-& ACTUATORS	
	005-402	OE A D/QUAL-& ACTUATORS	
	005-403	OE A D/QUAL-& ACTUATORS	
	005-404	OE A D/QUAL-& ACTUATORS	
	005-405	OE A D/QUAL-& ACTUATORS	
	005-406	OE A D/QUAL-& ACTUATORS	
	005-407	OE A D/QUAL-& ACTUATORS	
	005-410	OE A D/QUAL-& ACTRS & IE A	
	005-411	OE A D/QUAL-& ACTRS & IE A	
	005-412	OE A D/QUAL-& ACTRS & IE A	
	005-413	OE A D/QUAL-& ACTRS & IE A	
	005-414	OE A D/QUAL-& ACTRS & IE A	
	005-415	OE A D/QUAL-& ACTRS & IE A	
	005-416	OE A D/QUAL-& ACTRS & IE A	
	005-417	OE A D/QUAL-& ACTRS & IE A	
	005-420	OE A D/QUAL-& ACTRS & IE B	
	005-421	OE A D/QUAL-& ACTRS & IE B	
	005-422	OE A D/QUAL-& ACTRS & IE B	
	005-423	OE A D/QUAL-& ACTRS & IE B	
	005-424	OE A D/QUAL-& ACTRS & IE B	
	005-425	OE A D/QUAL-& ACTRS & IE B	
	005-426	OE A D/QUAL-& ACTRS & IE B	
	005-427	OE A D/QUAL-& ACTRS & IE B	
	005-500	OE A D/QUAL-& ACTUATORS	
	005-510	OE A D/QUAL-& ACTRS & IE A	
	005-520	OE A D/QUAL-& ACTRS & IE B	



TABLE 2.1.2-II - RECOGNITION OF FAILURE (PASS) (Concluded)

PARAMETER NO.	FAILURE VALUE/TREND		DISPLAYED ON
	FID-DLM (octal)	Syntax	
(FID)			
(C) E41M1005P	006-000	OE B D/QUAL-& ACTUATORS	Main Engine & FID Displays
(L) E41M2005P	006-010	OE B D/QUAL-& ACTRS & IE A	
(R) E41M3005P	006-020	OE B D/QUAL-& ACTRS & IE B	
	006-100	OE B D/QUAL-& ACTUATORS	
	006-101	OE B D/QUAL-& ACTUATORS	
	006-102	OE B D/QUAL-& ACTUATORS	
	006-110	OE B D/QUAL-& ACTRS & IE A	
	006-111	OE B D/QUAL-& ACTRS & IE A	
	006-112	OE B D/QUAL-& ACTRS & IE A	
	006-120	OE B D/QUAL-& ACTRS & IE B	
	006-121	OE B D/QUAL-& ACTRS & IE B	
	006-122	OE B D/QUAL-& ACTRS & IE B	
	006-200	OE B D/QUAL-& ACTUATORS	
	006-210	OE B D/QUAL-& ACTRS & IE A	
	006-220	OE B D/QUAL-& ACTRS & IE B	
	006-300	OE B D/QUAL-& ACTUATORS	
	006-310	OE B D/QUAL-& ACTRS & IE A	
	006-320	OE B D/QUAL-& ACTRS & IE B	
	006-400	OE B D/QUAL-& ACTUATORS	
	006-401	OE B D/QUAL-& ACTUATORS	
	006-402	OE B D/QUAL-& ACTUATORS	
	006-403	OE B D/QUAL-& ACTUATORS	
	006-404	OE B D/QUAL-& ACTUATORS	
	006-405	OE B D/QUAL-& ACTUATORS	
	006-406	OE B D/QUAL-& ACTUATORS	
	006-407	OE B D/QUAL-& ACTUATORS	
	006-410	OE B D/QUAL-& ACTRS & IE A	
	006-411	OE B D/QUAL-& ACTRS & IE A	
	006-412	OE B D/QUAL-& ACTRS & IE A	
	006-413	OE B D/QUAL-& ACTRS & IE A	
	006-414	OE B D/QUAL-& ACTRS & IE A	
	006-415	OE B D/QUAL-& ACTRS & IE A	
	006-416	OE B D/QUAL-& ACTRS & IE A	
	006-417	OE B D/QUAL-& ACTRS & IE A	
	006-420	OE B D/QUAL-& ACTRS & IE B	
	006-421	OE B D/QUAL-& ACTRS & IE B	
	006-422	OE B D/QUAL-& ACTRS & IE B	
	006-423	OE B D/QUAL-& ACTRS & IE B	
	006-424	OE B D/QUAL-& ACTRS & IE B	
	006-425	OE B D/QUAL-& ACTRS & IE B	
	006-426	OE B D/QUAL-& ACTRS & IE B	
	006-427	OE B D/QUAL-& ACTRS & IE B	
(ESW)			
V98M2200P (C) V98M2220P (L) V98M2240P (R)	HEX ESW, LAST 2 DIGITS	<u>MCF</u> 86	<u>ELE</u> 87
			Main Engine & DDD Panel Displays

MCC recognition of the failure after a BFS engage is limited because the BFS only downlists three SSME parameters (MCC Pc average, ESW, and TREF). SCP 2.1.3 contains a more detailed discussion on primary and secondary data. With no FIDs downlisted after BFS engage, the ESW is used to deduce a problem with the SSME. If the ESW indicates an MCF, the MCC calls for AC BUS SENSORS to OFF as a precautionary measure (see Flight Rule A5-111 AC Bus Sensor Electronics Control). It is understood that the exact failure is not known, but taking the AC BUS SENSORS to OFF is the only action that can be taken. Table 2.1.2-III shows the BFS recognition.

TABLE 2.1.2-III - RECOGNITION OF FAILURE (BFS)

PARAMETER NO.	FAILURE VALUE/TREND			DISPLAYED ON
(ESW) V98M2200P (C) V98M2220P (L) V98M2240P (R)	HEX ESW, LAST 2 DIGITS	<u>MCF</u> 86	<u>ELE</u> 87	BFS Main Engine Display

2. MCC Activity – Table 2.1.2-IV lists the MCC activity for Booster, Main Engine, and Flight Director console positions in response to the loss of controller redundancy on an engine.

TABLE 2.1.2-IV - MCC ACTIVITY

Step	Activity	Position
1	Report "Loss of controller(electronics) A(B) on C(L,R) engine."	ME/BSE/FD
2	"AC BUS SENSORS - OFF" (see note c below) Verify on the DDD Panel display	ME/BSE/FD ME/BSE
3	Report "Critical to AC 1(2,3)."	ME/BSE/FD
4	Review specific redundancy loss and criticality of subsequent failure (as time permits).	ME/BSE/FD

Notes:

- a. Subsequent loss of the redundant equipment will result in a DCU halt, fail-safe pneumatic shutdown, and the fault message "MPS DATA C(L,R)." See SCP 2.1.3, Data Path Fail, for more information.
- b. The ground "FAILURE VALUE/TREND" in Table 2.1.2-II represents a decoded syntax of word 5 from each engine's VDT. The MSIDs for these parameters are decoded by the FID Computation (reference SB 7.2), which generates the syntax and T-Reference time of failure. The syntax is displayed on the workstation SSME and FID displays. The octal values of the FID and delimiter numbers are displayed on the workstation FID Display.
- c. Placing the AC bus sensors switch in the "OFF" position is required to protect for a single point failure in the bus sensor monitor electronics that could inadvertently cause the remaining AC power bus to fail.

D. Supporting Data

Figure 2.1.2-IV shows the SEII Interrupt/RVDT Mismatch Logic Flow as information only in order to show the impact of controller/electronic failures. Refer to SCP 2.1.5 for a detailed description of hydraulic (and electric) lockups as a result of other failures combined with loss of controller redundancy.

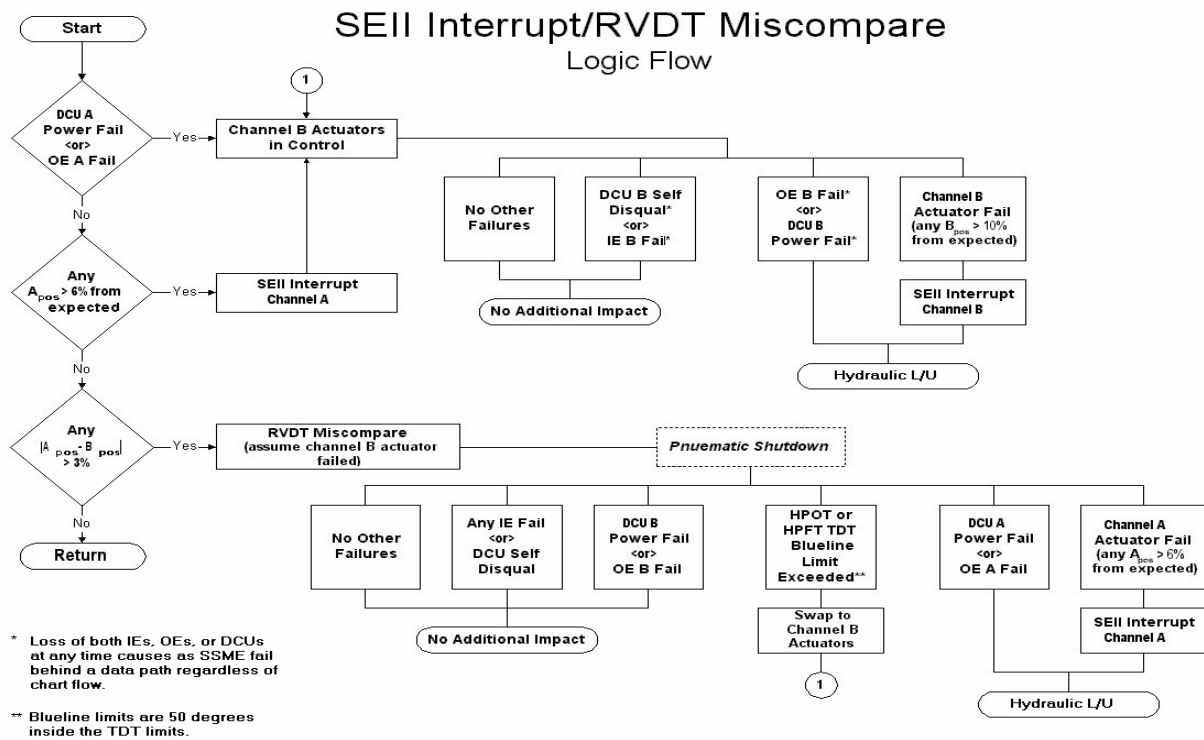


Figure 2.1.2-IV- SEII Interrupt/RVDT Mismatch Logic Flow.

## REFERENCES

1. Space Shuttle Operational Flight Rules, Volume A, All flights, Final, PCN-2, Errata, NSTS-12820, June 25, 2004.
2. Ascent/Entry Systems Procedures, Generic, Rev L, JSC-48001-I, May 15, 2003.
3. CP406R0021 (Initial Release, plus ECP 1432, and RCNs 7316 and 7294), Part I, Computer Program Contract End Item, Block II SSME Operational Program, AHMS Phase 1 Upgrade, July 22, 2004. (SSMEC Part I Spec)

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TITLE

DATA PATH FAILURE

PURPOSE

This SCP describes the avionics and electrical failures that cause an SSME data path failure or an EIU Port Bypass and the necessary actions for both MCC and crew.

DESCRIPTION

The data from the SSME controller are arranged into a vehicle data table (VDT) (reference SB 1.8 for more information on the VDT). The controller transmits the VDT, consisting of 128 words, to the controller interface adapter (CIA) 1 and CIA 2 of the engine interface unit (EIU). Refer to Figure 2.1.3-I for the data flow from the engine to the GPC. In the EIU, the first 32 words are loaded into a status register for transmission by the GPCs. The remaining 96 words are not available to MCC flight controllers real time. The first 32 words are transmitted as the primary data stream on multiplexer interface adapter (MIA) 1. The secondary data stream includes only the first six words transmitted on MIA 4. The secondary data only includes ID word 1, ID word 2, the engine status word, reference time (T-REF), hard failure identification (FID), and the average main chamber combustion pressure (Pc AVG). Figure 2.1.3-I shows the command and data flow for the SSMEs.

A. Definition of data path and how it can occur

A data path failure is the loss of both primary and secondary data streams from the SSMEs to the GPCs. This type of anomaly exists after the occurrence of any of the four following scenarios:

1. The failure of the GPCs (or flight critical busses at the GPC) out of the redundant set associated with MIAs 1 and 4. Refer to Figure 2.1.3-I for the GPC/flight critical MDM combinations for each SSME.
2. The failures of MIAs 1 and 4.
3. The failures of CIAs 1 and 2.
4. Combinations of GPC, MIA, CIA and AC power bus failures that affect the primary and secondary data streams.

Note that the Booster operator should coordinate with the DPS operator on the MOCR DPS/CDMS 1 loop to ensure that any GPC fail-to-synch should be taken

to halt prior to MECO in order to avoid any erroneous commands from the failed GPC during shutdown. Likewise, the Booster should also coordinate with the EGIL on MOCR SYS 1 to not work AC bus loss actions during ascent until the associated SSME controllers have failed (see SCP 2.1.2 for more information).

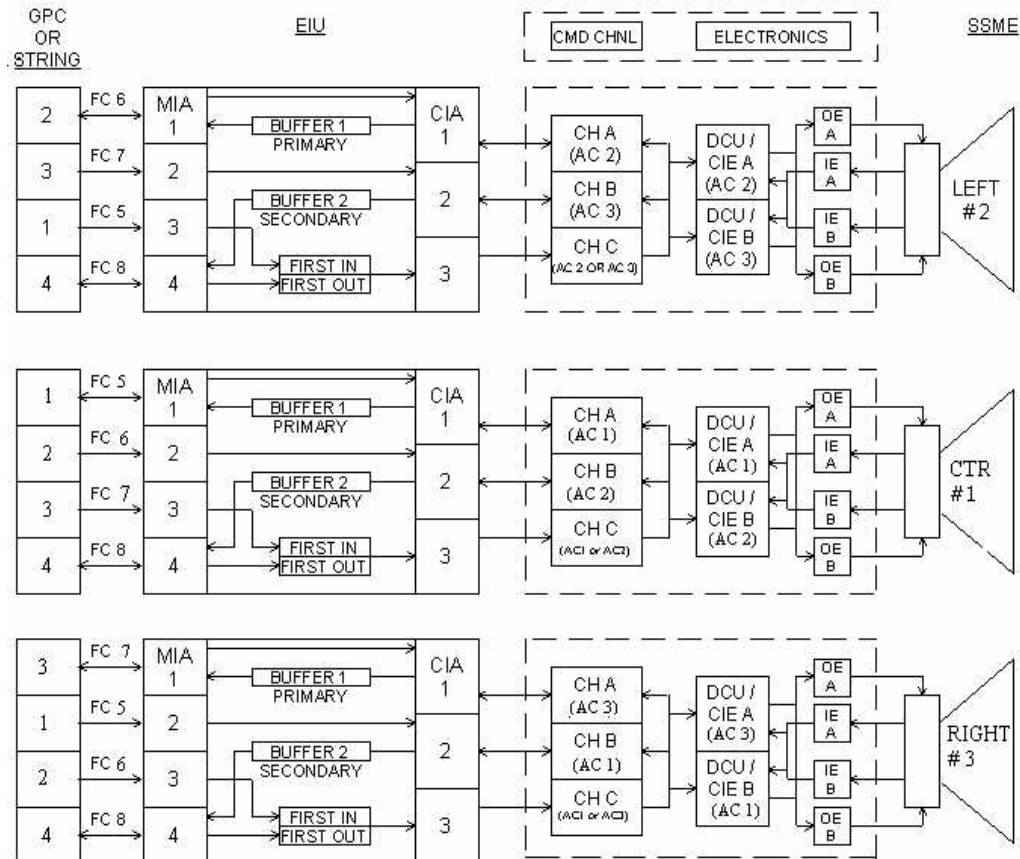


FIGURE 2.1.3-I EIU COMMAND/DATA FLOW

### B. Recognition of the failure

When a data path failure occurs, the crew will get the amber SSME status light, and the Pc meter will show 0% power level. Additionally, the MPS DATA C (L,R) fault message appears on the crew's CRT as well as the MCC main engine. The MCC will see that TREF does not update, and the main engine data on that engine is frozen at its last value. Additionally the words "DATA FAIL" will appear at the top of the affected engine's display and the affected data will be masked – this is driven by the GPC downlisted Primary and Secondary Data Fail flags.

C. Determine if the engine is running

When a data path failure occurs, the Pc meter will indicate zero and the crew may not be able to determine the status of the SSME. There are several parameters the crew and the MCC can use to determine if the engine is running (reference Flight Rule 5\_2, ENGINE OUT).

1. G-level/thrust factor decrease (2<sup>nd</sup> stage only)

If a main engine shuts down, the g-level will decrease. The g-level can be found on the PASS and BFS header displays as well as via RTPLOT. During 2<sup>nd</sup> stage, when one, two, or three engines shutdown, the g-level will decrease by 33, 50 and 100%, respectively. The MCC has an additional acceleration related cue, Thrust Factor. Thrust Factor is calculated by guidance and is the calculated thrust divided by the expected thrust (nominally 1.00). If three engines are running, and then an engine goes out behind a data path, the thrust factor will read 0.67. Once the main engine shutdown pushbutton is pushed on the failed engine the thrust factor will return to 1.00. Thrust factor will not work as a cue for an engine out without a data path because guidance will see the engine out and calculate the thrust factor for the expected thrust of two engines (i.e., it will remain 1.00).

This cue is only valid in second stage since the thrust from the SRBs is so large, it is difficult to tell if an engine is still running or not. Thrust factor is only calculated in second stage.

2. GH2 out pressure < 1050 psia

GH2 outlet pressure is on the main engine display. The crew will also get a BFS C&W message if the pressure drops below 1050 psia.

3. GO2 outlet temperature < 300 deg. F

This parameter can be found on the main engine display. The GO2 outlet temperature and GH2 outlet pressure for each engine are channelized through the same OI MDM and OI DSC. Since one failure can take both of these cues, these parameters only count as one cue in the MCC when determining if an engine is out. These two cues are the easiest cues to use from a console standpoint. However, the GO2 outlet temperature will drop below 300 deg. F while in the bucket. If a data path occurs while in the bucket, the console operator should look for an additional drop in GH2 outlet pressure and GO2 outlet temperature. When an engine failed during STS 51-F, the GO2 outlet temperature dropped below 125 deg. F for about 15 seconds and then began to rise (but stayed below 300 deg. F). The crew will receive a BFS C&W message when the temperature drops below 125 deg. F.



#### 4. Helium cues

As long as there is not already a helium leak on the engine with a data path, the crew will receive a helium dP/dt fault message when the engine initiates the shutdown purges. Once the 16-second purge is complete the helium tank pressure will remain constant. It is the responsibility of the MPS and Booster operators to look for these cues (all other cues up to this point are the responsibility of the Main Engine and Booster operators).

#### 5. Drop in second stage performance

The Abort Region Determinator (ARD) uses downlisted and radar data to determine if the shuttle is performing as expected. With an engine out in second stage, the performance will drop significantly and this trend will be obvious to the Flight Dynamics Officer (FDO). This cue is used as a last resort since it takes more time to coordinate.

The team's response to a data path failure is covered in section 5 of the Flight Rules. Crew actions for a data path are summarized in figure 2.1.3-II.

**MPS DATA**  
 ✓ MCC, accel, He dP/dT,  
   'MPS H2 OUT P',  
   'MPS O2 OUT T'  
 If SSME fail (MCC or 3 cues):  
   Aff MN ENG SHUTDN pb – push  
 If 3 ENG remaining:  
 ◇ MAIN ENGINE LIMIT  
   SHUT DN – ENA,AUTO  
 If no comm: Assume MPS CMD  
 If multi (No MECO Confirm):  
   Post MECO:  
     MN ENG SHUTDN pb (three) –  
     push (simo)

FIGURE 2.1.3-II CREW ACTIONS FOR DATA PATH

#### D. Operational impacts (engine running case)

Once a data path failure has been indicated, the crew and MCC need to determine if the engine is running or has failed behind the data path. If there are three engines running, limits need to be taken to ENABLE then AUTO. This action is required because limits are automatically inhibited when the data path failure occurs. If the BFS is engaged, the switch is taken to the ENABLE position. The BFS limit switch logic is different from the PASS, and ENABLE then AUTO will cause the limits to return to the INHIBIT state.

If the engine is determined to be running, and the limits are re-enabled, the next priority is to determine if the command path is valid. If there is no communication with the MCC, the crew will assume that a data path failure is also a command path failure, and shut down the engine as if it were a command path failure (reference SCP 2.1.4). The ground will verify commands through throttling during 3-g throttling. The throttling commands are verified by seeing a decrease in GH2 outlet pressure and GO2 outlet temperature corresponding to the lower power levels.

If an engine subsequently fails, the required actions depend on which engine fails. To understand the rationale behind the following steps, the MECO CONFIRMED flag needs to be discussed. MECO CONFIRMED is a flag that tells the GNC software that all the SSMEs are out. Embedded within the MECO CONFIRMED routine is a MECO command, so that when MECO CONFIRMED is set, a MECO command is also issued. There are several ways to set MECO CONFIRMED. They are discussed briefly below.

- 1) Three SSME chamber pressures ( $P_c$ ) less than 30%. An SSME cannot sustain combustion with a  $P_c < 30$ , and therefore if a  $P_c < 30$  exists on an engine, the engine is out. If all three  $P_c$ s are less than 30%, then all three engines are out and MECO CONFIRMED is set.
- 2) Two  $P_c$ s less than 30% and a data path failure on the third engine. The SSME OPS software assumes that an engine with a data path failure is out. If one engine has a data path failure and the remaining engine's  $P_c$ s are less than 30%, the logic assumes all three engines are out and MECO CONFIRMED is set.
- 3) GPCs in Major Mode 104 (MM 104). Proceeding to MM104 sets MECO CONFIRMED.
- 4) Pressing all three Main Engine pushbuttons.
- 5) The method of last resort for setting MECO CONFIRMED is an ET FAST SEP. This is a procedure associated with contingency aborts where the separation from the tank is done under very dynamic conditions. The fact that setting MECO CONFIRMED also issues a MECO command is critical here. Once again, if the shuttle has separated from the ET, the SSMEs must be out.

If the engine that fails is the engine with the data path, the limits will remain enabled which is the desired state for two SSMEs running. If the engine that failed was one of the engines without the data path failure, the limits will be automatically inhibited. With the data path on one of the remaining engines, it is desirable to leave limits inhibited. This is due to the fact that if the other engine without the data path failed, the SSME OPS software would see two  $P_c$ s  $< 30$  and a data path failure and MECO CONFIRMED would be set (see paragraph 2 above), and therefore all engines would be commanded to shut down. If there were also a command path on the engine with the data path, then the pre-valves for that engine would be closed and the engine would fail catastrophically. Additional information can be found in section 5 of the Flight Rules.

If multiple data path failures exist, this early MECO concern is eliminated if both of the data path engines are running when the data path failures occur since the last Pc data seen would be greater than 30 at the time the data path condition were created. In this case the limits must be taken to hard ENABLE, instead of the usual ENABLE then AUTO, to ensure the redline shutdown limits are active for all three engines. The limit switch logic for the ENABLE then AUTO sequence will only allow an engine to ENABLE its own limits. If an engine has a data path failure, it will issue limits inhibit commands to the other two engines and will not try to enable its own limits. This case is best explained via example.

Assume all three engines are running and the left and right engines have data path fail flags set. If the limit switch is taken to ENABLE then AUTO, the CSSME will re-enable its limits. The LSSME will issue limits inhibit commands to the center and right SSMEs and the RSSME will issue limits inhibit commands to the center and left SSMEs. When all is said and done, the CSSME will end up with limits enabled and the left and right SSMEs will end up with their limits inhibited. For more information see the SSME OPS SEQ.

In the above case, assume the LSSME had shut down and then experienced a data path failure after the shutdown was complete. The last Pc seen by the software on the LSSME would be less than 30. In this case, all the engine's responses to the limits actions stated in the above example remain the same. However, the early MECO CONFIRMED logic concern still exists even with multiple data path failures since a zero Pc is available for the left SSME. In this case, if the CSSME were to fail, then the SSME OPS software would see zero Pc on the Left and Center SSMEs and a data path on the right, even though there is a data path on the Left SSME. In this case, the booster team must protect against an early MECO being commanded via the MECO CONFIRMED flag by keeping the limits inhibited on the CSSME.

When a data path failure occurs, the controller will send a switch VDT command to switch VDT transmission from DCU A to DCU B. This is done in case the failure is a single point failure, which looks like a data path failure, but can be cleared by a switch VDT command. The rest of this paragraph is a discussion of what can happen if it is not this single point failure mode and a command path failure is not additionally present. If both DCU A and DCU B are functional, and if data is restored through a restring or I/O reset, DCU B will control data transmission and DCU A will control engine operations. If either DCU A or DCU B is disqualified, this does not apply. There may be differences in the VDT when it is being transmitted by the standby DCU. See section 3.2.2:2.2 of the SSME Part 1 Spec. for more information.

While it is possible to recover the SSME data via various methods (I/O reset, restring, and BFS engage) it is important to note that the data path fail flags remain latched (both PASS and BFS). If the BFS is engaged, all data path fail flags are reset and the data flow from the SSMEs to the GPCs is re-evaluated. If the data path is not recovered via the BFS engage, the data path failure will be re-announced. If the data path is recovered, the flag remains cleared.

#### E. Operational cues (engine out case)

If the engine has failed behind a data path, guidance will not recognize the failure until the Main Engine push button is pressed. Getting this step done quickly is important because it sends the safing command which closes the prevalues, and informs the guidance software which engine is failed and how many are remaining.

If a control bus failure or contact failure “zeros” the output from one of the contacts, the push-button is non-operational. To regain the ability to safe the engine and mode guidance, the FF MDM, which corresponds to the failed contact, can be power cycled to create a commfault. This commfault allows the good contact to be used. Once the push-button is pushed, the MDM may be recovered with an I/O reset.

#### F. How BOSS recognizes a data path failure

The “AVIONICS” comp declares a data path failure when the GPC downlist has both Primary and Secondary Data Fail flags set or if T-REF (the downlisted SSMEC clock) is not updating. Additionally, the comp can declare an engine out behind a data path if specific combinations of the cues mentioned above in Section E are satisfied. See the AVIONICS comp documentation for more information. Regardless of the information provided by the comps, it is ultimately the team’s responsibility to determine if a data path failure exists and whether or not the effected engine is running.

#### G. EIU Port Bypass

When a GPC (PASS or BFS) stops receiving communication from an EIU MIA port, it sets a failure flag on the port, also known as a port bypass. When a port bypass occurs, the GPC will no longer listen to data coming from that port, but commands will still be sent to that port as if that port was active. The port can be recovered by the crew via an I/O Reset - EXEC to the PASS or BFS, depending on which system considers the port down. On console, Booster operators have insight into MIA ports 1 and 4, and the operator can see the bypass status in PASS on the DDD panel display by the word "Port 1" or “Port 4” changing from white to red. The BFS bypass status is seen as a red "B" next to the word "Port 1" or “Port 4”.

This failure can manifest itself several ways, such as a power fail in the EIU which takes out two ports, a failure of the port itself, or the failure of a Flight Critical String. A port bypass impacts the SSME operation by prohibiting data flow from the SSME to the GPC on the failed port, essentially acting as one half of a data path failure.

A power failure inside the EIU can be static or transient. A static power failure will cause a port bypass, and no recovery efforts by the crew will be successful. A transient failure will cause a port bypass, but an I/O Reset will recover data flow through the port. Note that following a transient power failure, commands will still be sent through the port to the SSME (with or without an I/O reset from the crew), but the GPC will not listen to the data flowing back from the SSME. If a transient power failure is experienced, the failure could return at any time rendering

the port failed and causing another port bypass. Transient failures may be continually recovered, but could return as a permanent failure, causing data and commands to stop flowing through the port. In this case, the engine is considered to have a "suspect command path failure" and must be shut down pre-MECO because the failure could return close to MECO, causing a late command path failure.

Note that there is no downlist insight into MIA ports 2 and 3. Port 3 shares the same power supply as port 1 and port 2 shares the same power supply as port 4. Since a port bypass can be caused by a power failure, this would make the respective port 2 or 3 suspect. More information is available in Flight Rule A5-107.

Typically, when a port bypass is experienced, the Booster console will request that the crew perform an I/O Reset with concurrence from the DPS officer in an attempt to recover data. If the port is recovered, then the EIU failure was most likely a transient power failure, and Booster will treat the engine as having a suspect command path. If the I/O reset is unsuccessful, then the port is down by a permanent power failure or an internal port failure. In either case, commands and data will no longer pass through the port, and the operator must determine the health of the opposite port (2 or 3) or consider it failed as well.

#### REFERENCES

1. STS Operational Rules, Volume A, Final, PCN-3, January 13, 2005.
2. Ascent/Entry Systems Procedures, Generic Rev K, .
3. Booster Systems Briefs, JSC-19041, Rev F.
4. Avionics comp. Documentation binder.
5. CP406R0008 (Rev H), Part I, Computer Program Contract End Item, Block II SSME Operational Program, March 16, 2001 (SSMEC Part I Spec).
6. Lockheed Flows, OI-29.

TITLE

COMMAND PATH FAILURE

PURPOSE

This SCP describes the avionics and electrical failures that put an SSME into command path failure and the necessary actions for both MCC and crew.

DESCRIPTION

HOW A COMMAND PATH FAILURE OCCURS

A command path failure will result when two of the three controller channel command paths fail. If at least two of the three commands (which reside in the controller channels) are in agreement, the command is considered valid. Otherwise, a command path failure will result. There is one exception to the two of three command requirement. This is called single command channel shutdown. Single command shutdown allows an engine to be shutdown with only one command out of three under certain circumstances. Operationally, this software is not relied upon by the MCC and the engine will be shutdown like a typical command path failure.

Commands are sent from the GPCs (redundant set), through the engine interface unit (EIU), to the SSME controller. Refer to SCP 2.1.3, Data Path Fail, Figure 2.1.3-I for SSME command channels. The commands that pass through the multiplexer interface adapter (MIA) 1 and MIA 2 pass through the EIU and proceed directly to the engine controller channels A and B, respectively. The commands that pass through MIA 3 and MIA 4 of the EIU pass through a first in/first out buffer. Only one of these commands will pass through to controller channel C.

The main engine controller will compare the commands that are present in each channel. If two of the three commands are in agreement, the command will be accepted. A command acceptance bit in the engine status word (ESW) will be set and sent back to the GPCs. If a GPC does not see this acceptance bit from the controller, or if a command reject bit is set, the SSME SOP sequence will set a command path failure discrete. If the GPC that sets the discrete is able to communicate with the GPC that is driving an onboard crew display CRT and engine status light, the GPC will issue a command path fail message and illuminate the appropriate amber status light.

The following is a discussion on how a command path failure can manifest itself. The center engine will be the focal point for these examples; however, similar arguments can also be made for the other engines (Figure. 2.1.3-1).

GPCs 1 and 2 are associated with EIU ports 1 and 2 (MIAs 1 and 2), so their commands will pass directly through the EIU to command channels A and B, respectively. If these two

computers fail-to-halt (stop operating), they will no longer be able to send commands. When a new command is issued, the controller will only see one command that will be in command channel C. The two of three requirement for the controller to accept the command is not satisfied, so the controller does not set the command accept bit. The remaining GPCs expect to see the command accept bit since they issued a new command. The absence of the command accept bit causes the SSME SOP to declare a command path failure. The remaining GPCs will drive an onboard crew message on any CRT controlled by those GPCs, but the main engine status light will not illuminate because FF MDM 1, which controls the status light, was lost when GPC 1 failed.

The commands pass from the GPCs to the EIU via a flight critical (FC) data bus. The FC 5, 6, 7, and 8 buses also transfer data to FA MDMs 1, 2, 3, and 4, respectively. If an FC bus fails (commonly referred to as a loss of the FA MDM at the GPC), commands cannot pass from the GPC to the EIU. This situation has the same effect on the engine as a GPC failure. Therefore, a command path failure can result not only from multiple GPC failures, but also from multiple flight critical string failures. For example, if FA 1 and FA 2 fail at the GPC, then FCs 5 and 6 are failed, and commands cannot be sent through the flight critical string to the EIU then to the controller. The two of three requirement for the controller to accept the command is not satisfied, so a command path failure will exist.

The previous example dealt with MDMs failing at the GPC. If the FA MDM fails at the MDM, commands can still pass from the GPC to the EIU on the FC data bus because the failure is localized to the MDM and does not impact the ability of the GPC to communicate to the FC data bus or the FC to communicate to the EIU. This type of failure will not yield a command path failure.

A command path failure will also occur if MIAs 1 and 2 of the EIU fail. When a MIA fails, commands are not able to pass through the EIU to the SSME controller. The two of three requirement is not satisfied, and a command path failure will exist. Note that only MIA 1 and 4 statuses are downlisted and displayed on the DDD Panel display.

If a MIA is lost due to a power transient, data from that MIA is lost, but commanding is recovered immediately. Therefore an I/O RESET is all that is required to regain full function of the port. Although direct insight of port status is only available for MIA 1 and MIA 4, the other two MIA ports share common power sources with MIAs 1 and 4. MIA 1 is paired with MIA3, and MIA 4 is paired with MIA2. Therefore, the loss of MIA 1 or 4 could potentially mean the loss of the another MIA, leading to a suspect command path in combination with other failures. The main engine operator should be prepared to treat MIA 2 or 3 as failed until verification of commanding capability is determined.

The EIU interfaces with the SSME controller via controller interface adapters (CIA) that reside in the EIU. Each of the CIAs in the EIU is associated with a controller channel. Commands pass through the CIAs prior to going to the controller. When a CIA fails, the command cannot pass to the controller. If any two CIAs fail, the two of three requirement is not satisfied in the controller, and a command path failure will exist.

A command path failure can also occur due to combinations of GPC, CIA, and MIA failures. The failures of MIA 2 and CIA 3 will yield a command path failure. Alternately, if GPC 2 and MIA 1 fail, the same result will occur. In these cases, the two of three requirement is not satisfied in the controller and a command path failure exists.

A command path failure will also occur if one of these failures is coupled with an AC bus or a main power bus failure. Figure 2.1.3-I shows the power buses associated with each channel and the digital computer unit (DCU) of the SSME controller. When an AC bus fails, two engines are affected. For example, if AC 1 fails, DCU A of the center main engine controller and DCU B of the right main engine controller fail. Also, channel A of the center engine controller and channel B of the right engine controller fail. In the above example, main A powers AC 1 and therefore, if main A fails, AC 1 fails.

The following is an example of a command path failure using an AC bus failure. If AC 2 and center engine EIU MIA 1 fail, channel A and B of the center SSME controller will not be able to receive commands. Therefore, the two of three requirement is not satisfied in the controller, and a command path failure will exist. In this case, a data path failure will also occur. The data path failure will mask the command path failure. For more details, refer to SCP 2.1.3.

If the EGIL operator is reporting a short that can impact an AC bus during ascent, the Booster operator should coordinate with the EGIL the impacts of the bus loss on SSME controllers. If SSME controllers are lost due to AC buses, the Booster operator should report to the Flight Director that the SSME Controllers associated with AC Bus XYZ are failed. The EGIL operator should not take AC Bus loss actions, which will drop the entire bus, until after the SSME controllers have failed.

## OPERATIONAL CUES AND ACTIONS

Operationally, there are several cues which indicate a command path failure. A command path failure generates the MPS CMD C (L,R) fault message. Also, the amber light on panel F7 will illuminate. If a command path failure is present, the Pc, GO2 outlet temperature, and GH2 outlet pressure will not change when new throttle commands are sent (e.g. 3-g throttling).

When a command path failure occurs on an engine, that engine must be manually shut down with the AC power switches and push-button prior to MECO to prevent propellant depletion through an engine. Also, shutdown should occur in a timeframe that will allow sufficient time to mode guidance. Refer to Flight Rule A5-106, MANUAL SHUTDOWN FOR COMMAND/DATA PATH FAILURES, for the appropriate manual SSME shutdown cues.

Sometimes another failure will require the shutdown of another engine prior to shutting down the command path engine. One such case is when one engine has a helium leak and will not support MECO shutdown requirements. An engine with a helium leak is shut down prior to the one with the command path failure. The risk in shutting down the command path first is that the MECO time moves out and the engine with a helium leak may not make it to the second engine



shutdown cue. If the engine with the command path failure is shut down first, limit shutdown will be inhibited when the leaking engine may need to shut down with the limits enabled. Also, the leaking engine is considered more suspect and unpredictable since the leak rate could increase. A safe pre-MECO shutdown of the command path engine is achieved at the appropriate two-engine running boundary (e.g., 24.5K for uphill trajectory).

If the command path failure was caused by data processing system (DPS) failures (GPCs, FCs), command capability may be recovered by GPC reassignment (i.e., restringing). The Booster Systems Engineer (BSE) will contact the DPS Officer and provide the DPS Officer with the desired strings to be recovered. The DPS Officer will determine whether restringing will recover the strings the BSE requires within the DPS Flight Rules (Section 7). If restringing will regain command capability to the engine, the DPS Officer will provide a Nominal Bus Assignment Table (NBAT) for the crew to perform.

Once the restringing is complete, an SSME that had a command path failure while in the bucket may not throttle up automatically. MCC will direct the crew to select manual throttles, issue a new throttle command by moving the Speedbrake Throttle Controller (SBTC) slightly, return the throttles to the mission power level, and then select auto throttles (this is known as “jiggling the throttles”). The SSME should automatically throttle up unless a non-throttle command (such as a limits command) is sent in second stage prior to the restring. This scenario typically occurs when the crew cycles the shutdown limits switch in second stage prior to the restring. This phenomenon is because a new throttle level command is sent on the first guidance cycle after staging. Limits are not currently cycled in this manner but were in the past. The MCC calls and activity required for command path failures are summarized in Table 2.1.4-I.

The controller software requires that two of the three controller channels are in agreement, except for the START and START ENABLE commands that require three out of three channels. Agreement means that the commands are exactly the same. If a command, other than START or START ENABLE, does not achieve a three-of-three vote, it will still be accepted, but the engine status word (ESW) will indicate a major component fail (MCF) and a hard failure identification (FID) (FID 042-DLMs 101, 102, or 103) will be posted (ref. SB 7.2). If either the START ENABLE or START command does not achieve a three-of-three vote, the command will be rejected, an INHIBIT will be set, the ESW will indicate an MCF, and FID 42 will be issued.

TABLE 2.1.4-I - MCC ACTIVITY (Command path failure)

Step	Activity	Position
1	Report: "C(L,R) engine command path failure at ____%" For affected engine: MPS ENG PWR (two) - OFF and Main Engine Shut Down PB – Push at 23K (24.5 with two engines on) (at 22.5K for TAL or $\alpha = -1$ for RTLS)	ME/BSE/ FD/crew
2	If restringing will regain command capability to SSME, report: "Regaining string(s) ____ will restore command capability. Is restringing possible?"  If restringing is possible, report: "Restringing will regain command capability"  If restringing is not possible or restringing will not regain command capability to SSME, report: "Restringing will not regain command capability"	ME/BSE/DPS  BSE/FD  ME/BSE/FD
3	After restringing is complete (if SSME stuck in the bucket does not throttle to the mission power level, report: "Jiggle the throttles then return to auto."  After throttling: If engine responds to manual throttle commands, report: "C(L,R) engine throttled up, three engines at ____% (mission power level) return to auto throttles" "No manual shutdown required" Provide FDO the engine throttle up time: "The C(L,R) engine throttled up at ____ MET."  If engine does not respond to manual throttle commands, report: "C(L,R) engine did not respond to throttle commands," return to step 1.	ME/BSE/ FD/crew  ME/BSE/ FD/crew  BSE/FDO  ME/BSE/ FD/crew

### Erroneous Command/Data Path Failure Indications

If a PASS GPC has failed synchronization (failed-to-sync) with the redundant set, the flight crew and the MCC will receive erroneous indications of data and command path failures. When a GPC has failed-to-sync, the other GPCs stop listening to the failed computer and vice versa. Therefore, the failed GPC does not have any data on the other two engines (the computer can still see data on the SSME that has that GPC on its primary data path). The other PASS GPCs now use the secondary data from the engine whose primary data path has failed. These data are obtained from GPC 4. Note that the GPCs also downlist SSME Primary Data Fail and Secondary Data Fail Flags on the engines.

For example, assume GPC 1 fails to sync. GPC 1 only sees data from the C SSME. It will believe data path failures exist on the L and R SSMEs. In response to this, GPC 1 will issue a "LIMITS INHIBIT" command (see SCP 2.1.3) to all three SSMEs. GPC 1 cannot tell how the L & R engines respond to this command. However, it can see that the command is not accepted by the C SSME (the other two command buffers will not have this limits command). In response to this, GPC 1 will assume a command path failure exists on the C SSME and will annunciate it with the GPC message and the amber status light. If the failed GPC does not drive a CRT, the crew will not see the erroneous messages; however, they will see the amber status light which is also an erroneous indication of engine health. A summary of the erroneous messages and status lights is contained in Table 2.1.4-II.

Another example of erroneous command path messages stems from the asynchronous relationship between the GPC 40 msec read cycle and the SSMEC 40 msec VDT transmission cycle. When the GPC issues a command to the SSMEC, it expects a command reception message in the subsequent VDT cycle. The GPC Time Base Oscillator is not synchronized with the SSMEC's Time Base Oscillator, though, so it is possible for the GPC to occasionally "miss" one VDT cycle. In this instance, if the GPC sends a command and then misses the following VDT cycle, it will not receive the expected command accept message from the SSMEC and will assume that a command path failure has occurred. In reality, the SSMEC processed the command correctly and sent a response, but the GPC did not receive the reply.

When this occurs, all GPC's in the common set will post a command path failure message on the OFS (ex: "MPS CMD C"), and will status the associated Panel F7 SSME Status light amber. Since the command path message is erroneous, the ground and crew should expect the SSMEC to follow GPC commands for the remainder of the flight (since a command path failure did not actually occur). The next time that a command is properly sent/response received, the cabin light will go out. Additionally, the ground and crew can verify good commanding via correct engine throttling using the MCC Pc level or GH2 Outlet pressure (at the throttle bucket, 3-g throttling, or "other"), or by other means such as limit switch actions.

This failure was discovered in the mid eighties and the following DR's were written: PASS DR: 37594 and BFS DR: 106180. This failure has been seen on many "sim" engines, and on the left engine of STS-75 (occurred at T+4 secs).

It should be noted that in addition to timing skew between the GPC's and the SSMEC's, the Engine Interface Unit (EIU) (the MDM through which GPC commands and SSMEC return data flow) can be another source of timing slack. For the purposes of this issue and the associated DR's, though, it is assumed that the data flow through the EIU is synchronous with the device that sent the data.

If the crew sees any indication of an engine problem during 3g throttling (i.e., MPS data/command path or engine status light) and time is not available for the MCC to evaluate and make a recommendation, the engine should be shut down manually. Refer to Flight Rule A5-106, MANUAL SHUTDOWN FOR COMMAND/DATA PATH FAILURES, for shutdown velocities.

Note that the Booster operator should coordinate with the DPS operator on the MOCR DPS/CDMS 1 loop to determine whether or not any GPC fail-to-syncs have been taken to halt prior to MECO in order to avoid any erroneous commands from the failed GPC during shutdown. The Booster team should assume that any failed-to-sync GPC that has not been halted is preventing the first in-first out buffer from working. It is also possible for an unhalted fail-to-sync GPC to tie up the first in-first out buffer or to command an early MECO for MECO times after the single command channel shutdown timer has expired.

TABLE 2.1.4-II - GPC FAIL-TO-SYNC FAULT MESSAGE SUMMARY

GPC fail-to-sync	Erroneous fault summary message
1	MPS DATA L MPS DATA R MPS CMD C C amber light
2	MPS DATA C MPS DATA R MPS CMD L L amber light
3	*MPS DATA C *MPS DATA L *MPS CMD R R amber light
4	No messages

\* These messages are not displayed to the crew because GPC 3 does not nominally drive a CRT. These messages will be displayed on the fault summary page.

## SINGLE COMMAND CHANNEL SHUTDOWN

Single command channel shutdown is designed for an engine with a command path that occurs so close to MECO that the crew cannot take the appropriate action to shut the engine down. After a mission specific timer has expired (see equation below), a shutdown enable command followed by a shutdown command on a single channel can shutdown an engine as long as the following conditions are met: (1) no limits inhibit command has been sent to the engine; (2) the shutdown enable on the single channel is the only channel to change since the last command vote; (3) the shutdown enable must be followed by the shutdown command; and (4) the shutdown enable and shutdown commands must be on the same channel.

Unfortunately, if a GPC fails-to-sync after the timer has expired, the fail-to-sync GPC could shutdown all three engines prior to MECO if the single command channel shutdown logic is enabled. To minimize the exposure to this danger, the limit switch will be toggled to INHIBIT-ENABLE-AUTO anytime the predicted MECO time is much past MET 8:45 minutes and limits have never been inhibited on all running SSMEs. This action is particularly important for an RTLS where MECO can be past 10 minutes MET per Flight Rule A5-103, LIMIT SHUTDOWN CONTROL, paragraph H.

Mission Specific Shutdown Timer = (predicted MECO time in MET) + (6.36 seconds to adjust time from SSME start) - (5.5 seconds, 3 sigma dispersion)

## PREVALVE TIMING ISSUE

The following excerpt from Boeing letter 540-002 describes the prevalve timing issues associated with shutting down the last SSME with the AC power switches on panel R2. Until the release of this letter, it was believed that removing power from the last running SSME (via the AC switches) would result in erroneous prevalve timing and subsequent pump overspeed. However, this letter describes one scenario where the last running SSME can be safely shutdown using the AC switches because MECO confirmed is set simultaneously with the engine shutdown.

It is important to note that the only time this is acceptable is when the last running SSME has a command path failure and MECO confirmed is set due to the data path failure following the AC switches taken to OFF. By that, if one of the failed SSMEs failed behind a data path, the method described in the letter will not work. For all other cases (hydraulic lockup, electric lockup, helium leaks or pushbutton failures), use of the AC switches for shutdown is not acceptable.

“The closure timing of the LO<sub>2</sub> prevalues is critical during MECO because there are no G’s on the vehicle. The prevalues must be closed to prevent HPOT cavitation and/or overspeed. In the specific case in question involving the premature shutdown of 2 engines (Pc < 30 set in the software) and a command path failure on the third engine. The remaining engine with the command path failure may be shutdown safely using the AC power switches AND the Shutdown Push buttons. (Refer to Flight Rule A5-106, Manual Shutdown for Command/ Data Path

Failures). Shutting down the last remaining engine with the AC power switches creates a flight data path failure (refer to section 4.8.2.3.4 Data-Path Failure Processing of STS83-0026). The shutdown pushbutton alerts guidance that an engine is out and sets the “safing” flag for that main engine. The combination of two engines in shutdown phase and a flight data path failure will set the MECO Confirmed and the MECO Command flag. The MECO Command flag is the trigger that the software uses to initiate the prevalve closing process at MECO. In this case, the prevalve timing constraints can be satisfied by shutting down the remaining engine with the AC power switches and the shutdown push buttons.

The following software requirement to support this position may be found in section 4.2.1 SSME Operation Sequence and 4.8.2 SSME SOP of the “Space Shuttle Orbiter Operational Level C Functional Subsystem Software Requirements STS83-0026”:

In the case where there are two engines with Pcs < 30 and a Flight data path failure on the other engine a MECO CONFIRMED FLAG (V90X8561X) will be set at the same time as the MECO COMMAND FLAG (V90X8569X) in step 31. Once MECO command is initiated the shutdown command issued flag is set. (Steps 27, 28, 29 engines 1,2,3 respectively) The combination of a Flight data path failure, MECO command flag, and the shutdown command issued flag or safing flag will result in the LO2 prevalves being commanded closed after the 1.078 seconds time delay has expired. (Steps 2,6,10 engines 1,2,3 respectively)

The flight data path failure processing software is contained in section 4.8.2.3.4”

## MCC SOFTWARE LOGIC

The MCC software (Booster Operational Support Software or BOSS) does some command path processing, but does not cover all potential failure modes. BOSS checks each command channel as follows:

1. Channel 1 is checked in the data path routine and is set bad if its associated flight critical is failed, DCU A is power failed, or EIU port 1 is failed.
2. Channel 2 is failed if its flight critical is failed.
3. Channel 3 is failed if both flight criticals going into the first in, first out buffer are failed, or flight critical input to MIA 3 and EIU port 4 are failed.

Then if two of the three channels are failed, the command path flag is set and a flag will be displayed informing the operator of the failure.

**MPS CMD/HYD/ELEC**

If 2 HYD SYS failed:  
MAIN ENGINE LIMIT SHUT DN – INH  
TRAJ Display – Cue SERC, ITEM 6  
(EXEC if gimbaling eng fails)

If:	When:	Shut down:
2 Pcs stuck > 85% & 3-ENG RTLS	MECO -2:00	1 aff MN ENG: CMD: (AC/pb)** HYD: (pb)
2 HYD SYS failed & Nom/ATO/TAL/ 2-ENG RTLS	Nom/ATO: SE PRESS TAL: SE TAL 2-ENG RTLS: 2 OUT RED	<u>ENG(HYD) SD</u> C(1) & R(3) C L(2) & C(1) L L(2) & R(3) R ELEC: (pb)
He lk S/D reqd		Aff MN ENG (pb)
MPS CMD(s)**	Nom/ATO and: 3 ENG: V > 23K 2 ENG: V > 24.5K	Aff MN ENG (AC/pb)** If 2 CMD: repeat
2 MPS HYD/ELEC & 3-ENG Nom/ATO/TAL	TAL: V > 22.5K RTLS: $\alpha = -1$	1 aff MN ENG: HYD: (pb) ELEC: (pb)
1 MPS HYD/ELEC & 3-ENG Nom/ATO	V > 23K	Aff MN ENG (pb)

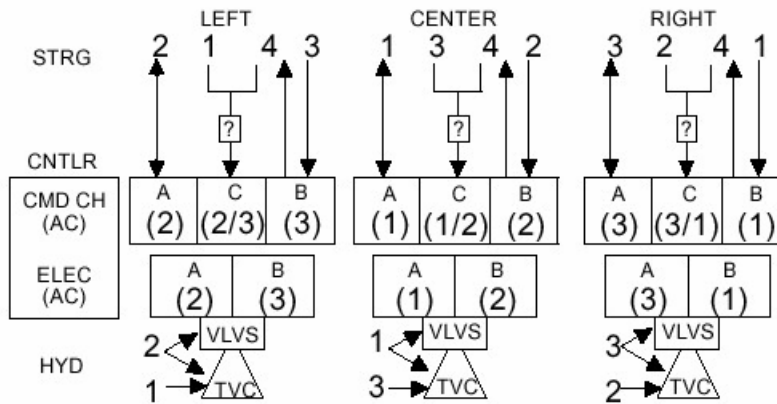


FIGURE 2.1.4-I - CREW ACTIONS FOR COMMAND PATH

REFERENCES

1. STS Operational Rules, All Flights, Final, PCN-3, NSTS-12820, January 13, 2005.
2. Booster Systems Briefs, Basic, Rev F, JSC-19041.
3. Ascent/Entry Systems Procedures, Generic, Rev L, JSC-48001, May 15, 2003.
4. Mission Operations Directorate Note of Interest, DF6/85-112-NOI.
5. Boeing letter 540-002 from Nelva W. Cary to M.F. Machula, March 15, 2000.



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TITLE

ONE STUCK THROTTLE

PURPOSE

This SCP describes the required action(s) for an SSME with a stuck throttle (command path failure, electrical lockup or hydraulic lockup).

DESCRIPTION

An SSME that cannot respond to throttle commands is referred to as having a stuck throttle. A stuck throttle can be caused by any of the following failures: an electrical lockup, a hydraulic lockup, or a command path failure.

In electrical lockup, the engine propellant valves are actively controlled at their last commanded position that existed prior to loss of all four LH<sub>2</sub> flowmeter transducers or both Pc transducer pairs (refer to SCP 2.1.1).

In hydraulic lockup, the engine propellant valve commands shall remain at the values last commanded prior to entering hydraulic lockup (refer to SCP 2.1.1), but valve drift may occur.

In a command path failure, the command capability from the GPC's to an SSME is lost. As a result, the engine controller will actively command the valves to control the thrust and mixture ratio to the last validly commanded power level.

An SSME with a command path failure must be manually shut down prior to MECO due to the loss of command capability (refer to SCP 2.1.4). Sometimes, it is both necessary and possible to regain command capability by restringing and shutdown may no longer be required. One such case is when an engine is stuck in the bucket and uphill capability is not available.

If three SSME's are running and an SSME in hydraulic or electrical lockup at a power level greater than 67 percent is allowed to run until MECO, the engine LO<sub>2</sub> NPSP and LO<sub>2</sub> mass requirements at MECO may be violated. When the LO<sub>2</sub> low-level sensors go dry (i.e. an LO<sub>2</sub> low level cutoff), the GPC logic starts a timer to delay MECO. When this timer expires, MECO command is issued and the SSME's shut down. These timers are designed to ensure maximum allowable consumption of LO<sub>2</sub> during engine shutdown while still preventing LO<sub>2</sub> depletion. The values of the timers are set for specific combinations of engine power levels, however, and if an engine is stuck higher than the intended level an NPSP violation can occur (potentially catastrophic). The timer used for a given flight day is determined real-time via software following the logic flow shown in Figure 2.1.5-I.

At the time of this SCP, the Boeing MPS community is evaluating the performance of the MPS system with the new OI-30 LLCO logic table (Figure 2.1.5-I). One of the problems they are

working on is the three engine running/one stuck throttle case. If the stuck throttle engine is locked below the value of MPS\_STUCK (an I-Load shown on Figure 2.1.5-I), the nominal 0.358 second timer will be used. The current value of MPS\_STUCK was set without proper evaluation, and this value must be recalculated. If the engine is stuck higher than this value, then a 0.0 second timer will be used, but it is unknown at this time how high the stuck engine power level can be without violating MECO NPSP requirements. An additional wrench in this issue is the potential acceleration violation that the orbiter experiences when the stuck throttle engine is allowed to run into MECO. If the acceleration is too high, then the acceleration may limit the maximum stuck throttle power level, rather than the NPSP violation. Boeing/Ascent GN&C is performing this analysis. This SCP and the Flight Rules will be updated when these analyses are complete.

The abort region determinator (ARD) is used during ascent to evaluate the vehicle capability to reach the nominal MECO targets. This capability is expressed in terms of a velocity margin remaining at MECO. Velocity margin is defined as the difference between the delta-V available from the propellant remaining and the delta-V required to execute the mission mode in question. The velocity margin calculations are biased to protect for a 3-sigma bad performance day. If, anytime after SRB separation, the velocity margin is indicating less than zero, then a low-level cutoff is possible. Given the potentially catastrophic nature of the shutdown and given that an LO<sub>2</sub> low level cutoff cannot always be predicted [reference the STS-93 unpredicted LO<sub>2</sub> low level cutoff which was caused by the largest inert weight error in Shuttle Program history and by an SSME nozzle leak which was smaller than the minimum criteria of Rule {A5-110}, SSME PERFORMANCE DISPERSION, and therefore not modeled in the ARD], it was decided to accept the operational impacts of always shutting down a locked up engine when three engines are on as opposed to relying on the ARD to make a real-time performance evaluation (reference Ascent Flight Techniques Panel Meeting #160, August 27, 1999). These impacts include up to 60 feet per second of lost performance and a planar error at MECO of up to 10 feet per second (some planar error is inevitable for these cases even if the stuck engine is not shut down).

By shutting down the stuck engine prior to MECO, the two remaining engines will throttle to 91 percent power level for fine count. The low-level cutoff delay timer for the two-engine on case is zero, thereby maximizing the NPSP and LO<sub>2</sub> residual mass for two engines shutting down from 91 percent.

For the two-engine-on case with stuck throttles at any power level, the technical community determined that the NPSP would not be severely violated and the minimum post shutdown LO<sub>2</sub> mass requirements would be satisfied. Therefore, no action was required (reference the 24th PSIG in November 1983 and Ascent Flight Techniques on May 21, 1984). Table 2.1.5-I and Figure 2.1.5-II summarize the results of the analysis. For an RTLS or TAL abort, the LO<sub>2</sub> residuals should be sufficient enough to prevent an LO<sub>2</sub> low-level cutoff. See Booster Systems Brief 3.4 for more information on NPSP.

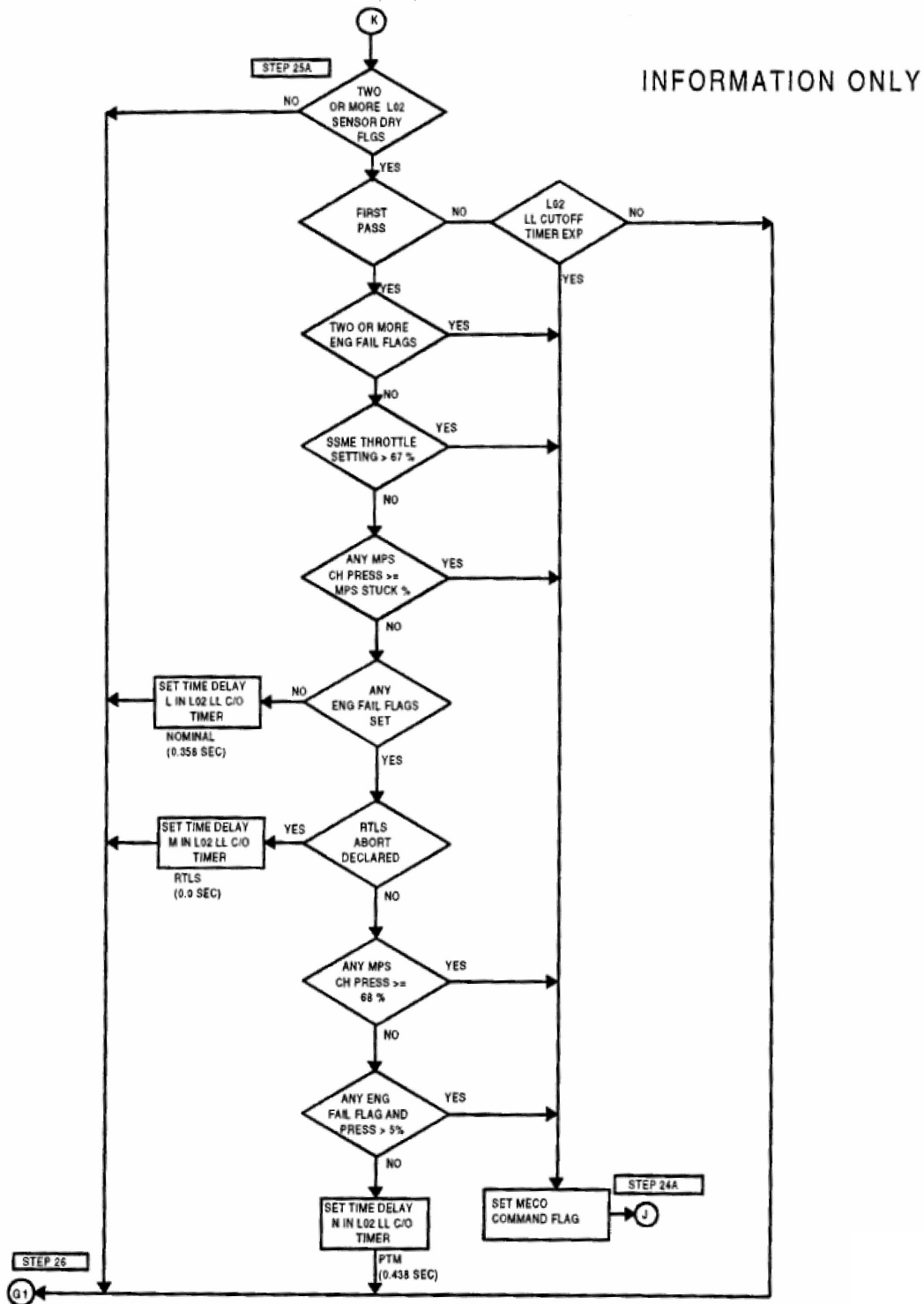


Figure 2.1.5-I. – OI-30 LO2 Low Level Cut Off Timer Logic Flow  
(From CR 92670D, Abort PE)

Figure 2.1.5-II was derived from the ICD minimum LO<sub>2</sub> NPSP curve (reference ICD fig. 4.2.2-1). For Figure 2.1.5-II, the NPSP required at shutdown is the same as the ICD curve independent of the number of SSMEs running because the engine at the higher power level must have its NPSP requirement met. That is, three SSMEs running at 104% have a lower NPSP requirement than one SSME running at 109% because the 109% requirement is greater.

Table 2.1.5-I was presented at the 24th PSIG by Rocketdyne. One change was made to the table after reviewing the low-level cutoff data from STS 51-F and is reflected in the table. After a review of the terminal drain temperatures from 51-F, it was determined that the LO<sub>2</sub> was supercooled and therefore had a NPSP 1.9 psi greater than previously predicted. The required NPSP for each case is driven by the engine at the highest power level and is derived from the ICD curves. The LO<sub>2</sub> mass data at main oxidizer valve (MOV) closure relates to the amount of LO<sub>2</sub> which is found between the closed pre valve and the low-pressure oxidizer pump (LPOP) inlet when the MOV closes. The ICD requirement for this mass is found in paragraph 4.3.8 and is 80 lb for each SSME which shuts down at MECO (i.e. 80 lb required above the low pressure oxidizer turbopump at the completion of SSME shutdown). In the total mass required column, it is assumed that the volume between the pre valve and LPOP inlet is completely filled with LO<sub>2</sub> (having a mass of 540 lb) for any engine which has shut down prematurely (i.e., R/L shutdown, command path manual shutdown, etc.) In the first case where one engine has shut down prematurely, one engine is stuck at 104 percent and the other is at 91 percent, the total mass required is 700 lb including the 80 lb for each running engine and the 540 lb for the engine which shut down prematurely. The minimum mass is not supplied in only one case (one engine shut down with two engines stuck at 109% power level). The negative number for the case where two engines shut down from 109 percent means that the LO<sub>2</sub>/GO<sub>2</sub> interface has already gone through the LPOP inlet by the time the MOV closes.

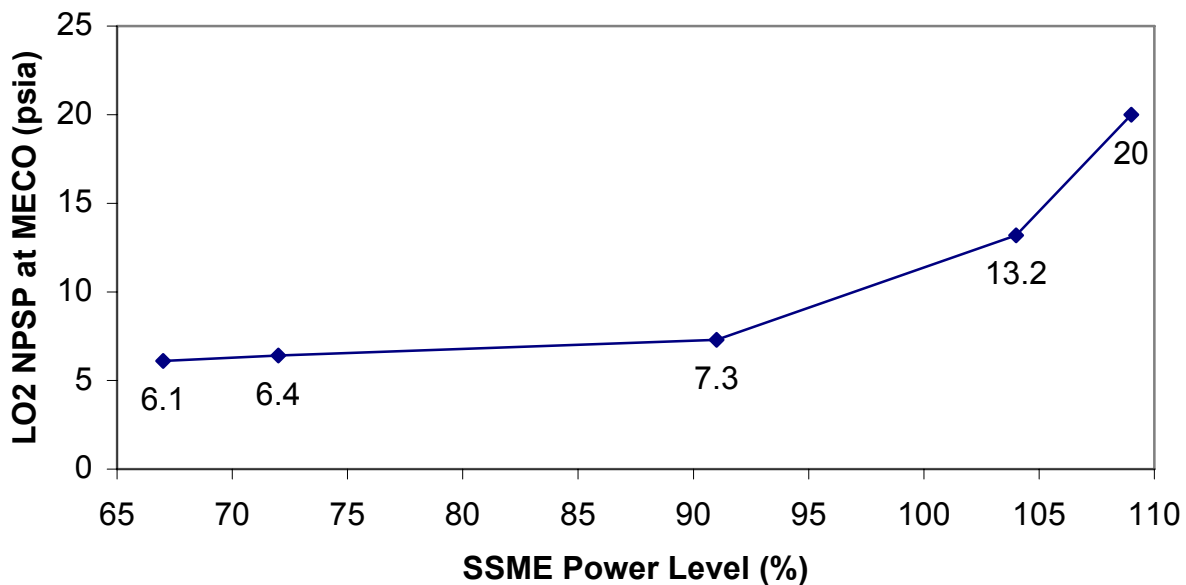


Figure 2.1.5-II. – LO<sub>2</sub> NPSP Required at MECO

TABLE 2.1.5-I.- LO<sub>2</sub> NPSP REQUIREMENTS DURING SHUTDOWN FOR LO<sub>2</sub> LOW LEVEL CUTOFF

SSME Power level at MECO, percent	Delay Timer, (Seconds)	Supplied [Required] NPSP, (PSI)	Supplied [Required] Residual LO2 (LBM)	DURATION OF VIOLATION (SEC)
0,0,67	0	4.2 [6.1]	3090 [1160]	1.3
0,0,91	0	4.0 [7.3]	2707 [1160]	1.2
0,0,104	0	3.1 [13.2]	2503 [1160]	2.1
0,0,109	0	3.0 [20]	2424 [1160]	3.0
<b>91,0,91</b>	0	<b>8.9 [7.3]</b>	<b>1386 [700]</b>	<b>0.00</b>
104,0,104	0	8.1 [13.2]	836 [700]	0.7
<b>109,0,109</b>	<b>0</b>	<b>6.7 [20.0]</b>	<b>469 [700]</b>	<b>1.2</b>
67,0,104	0	6.8 [13.2]	1575 [700]	0.8
67,0,109	0	6.4 [20.0]	1490 [700]	1.3
91,0,104	0	7.8 [13.2]	1140 [700]	0.7
91,0,106	0	7.6 [15.9]	1098 [700]	0.9
91,0,109	0	7.3 [20.0]	1035 [700]	1.1
<b>67,67,67</b>	0.358	<b>8.9 [6.1]</b>	<b>498 [240]</b>	<b>0.00</b>
67,0,67	0	8.7 [6.1]	<b>2167 [700]</b>	<b>0.00</b>
<b>67,67,72</b>	0.358	<b>8.3 [6.4]</b>	<b>366 [240]</b>	<b>0.00</b>

A. Flight Rules - (SSME Systems Management)

1. A5-106, MANUAL SHUTDOWN FOR COMMAND/DATA PATH FAILURES
2. A5-108, MANUAL SHUTDOWN FOR HYDRAULIC OR ELECTRICAL LOCKUP
3. A5-110, SSME PERFORMANCE DISPERSION

B. Crew Procedure - Cue Cards

**MPS CMD/HYD/ELEC**

If 2 HYD SYS failed:

MAIN ENGINE LIMIT SHUT DN – INH

TRAJ Display – Cue SERC, ITEM 6

(EXEC if gimbaling eng fails)

If:	When:	Shut down:
2 Pcs stuck > 85% & 3-ENG RTLS	MECO -2:00	1 aff MN ENG: CMD: (AC/pb)** HYD: (pb)
2 HYD SYS failed & Nom/ATO/TAL/ 2-ENG RTLS	Nom/ATO: SE PRESS TAL: SE TAL 2-ENG RTLS: 2 OUT RED	<u>ENG(HYD)   SD</u> C(1) & R(3)   C L(2) & C(1)   L L(2) & R(3)   R ELEC: (pb)
He Ik S/D reqd		Aff MN ENG (pb)
MPS CMD(s)**	Nom/ATO and: 3 ENG: V > 23K 2 ENG: V > 24.5K	Aff MN ENG (AC/pb)** If 2 CMD: repeat
2 MPS HYD/ELEC & 3-ENG Nom/ATO/TAL	TAL: V > 22.5K RTLS: α = -1	1 aff MN ENG: HYD: (pb) ELEC: (pb)
1 MPS HYD/ELEC & 3-ENG Nom/ATO	V > 23K	Aff MN ENG (pb)





REFERENCES

1. STS Operational Flight Rules, Volume A, All Flights, Final, PCN-1, JSC-12820, November 21, 2002.
2. Space Shuttle Operational, Level C, Functional Subsystems Software Requirements Document, Sequencing, OI-29
3. Flight Data File – Ascent/Entry Systems Procedure, Generic Rev J, PCN-5, August 11, 2000
4. Flight Techniques - April 29, 1988, July 19, 1988 and August 27, 1999
5. 24th PSIG - Nov. 1983 and August 25, 1999
6. SODB, Vol I, Rev F, Amendment 362 (Paragraph 4.3.1.9, Table 4.3.1-20)

TITLE

TWO STUCK THROTTLES

PURPOSE

This SCP describes the Booster flight control team and shuttle crew's responses to two SSMEs with stuck throttles.

DESCRIPTION

An engine that is unable to accept throttle commands is said to have a stuck throttle. This can be caused by any of the following failure conditions: command path failure (See SCP 2.1.4), hydraulic lockup, or electric lockup. The actions for one stuck throttle can be found in SCP 2.1.5. With two stuck throttles, the actions taken depend on the type of lockup, what power level the throttles are stuck at, and what flight trajectory is being performed. These cases are discussed briefly below, for a more detailed description of the actions taken and the rationale behind them, see section A5 and A8 of the Flight Rules (FR). In all the cases discussed below, it is assumed the throttles are stuck at a power level greater than the minimum power level. The types of cases involving two stuck throttles can be divided into two groups. One group is all the combinations of two stuck throttle cases where complete thrust vector control (TVC) is maintained (See FR A5-109). The other is where TVC is lost on an engine due to multiple hydraulic system failures (See FR A8-61). An engine without TVC is also called a non-gimballing engine. These terms are used interchangeably in this document.

A. Two stuck throttles three engine running (not dual APU failures)

The main concern in this case is exceeding the shuttle's structural limit of 3.5 g's. Nominally, the three SSMEs throttle back from the mission power level at about 1 minute to MECO to maintain a maximum vehicle acceleration of 3 g's. If one engine has a stuck throttle, the other two engines can still throttle back and maintain the desired maximum acceleration. If two engine throttles are stuck at a high power level, only one engine can throttle back. This is not sufficient to keep the vehicle from exceeding its 3.5 g maximum acceleration limit. Additionally, depending on where the engines are stuck, a potential exists for violation of LO2 net positive suction pressure (NPSP) limits. The NPSP limit ensures that sufficient head pressure exists on the HPOT at shutdown. This pressure provides resistance to the turbine, as it spins down and allows for a safe shutdown. NPSP is discussed in greater detail in section 3.4 of the Systems Briefs. For these reasons, one of the engines with a stuck throttle will be shutdown pre-MECO. The actions required for this case as well as the rationale behind them are discussed in FR A5-109.

If two engines are running, the concerns listed above do not apply. In this situation, the only time an engine would need to be shut down is if it has a command path failure (See SCP 2.1.4).

B. Two stuck throttles three engines running (dual APU failures)

The main concern in this case is vehicle control. If two hydraulic systems are failed, TVC is lost on one of the SSMEs. If an RTLS is being performed, the SSME limit switch will be taken to inhibit until post powered pitch around (PPA), otherwise the limit switch is taken to inhibit until two engine TAL capability exists. The RTLS PPA is a very demanding maneuver. It can be performed with an engine that has lost TVC if all three engines are running. If an SSME has lost TVC, a loss of vehicle control is likely if the RTLS PPA is attempted on two engines. The rationale behind these actions is explained in detail in SCP 2.1.11 and FR A5-103. The boundaries and conditions where a non-gimballing engine will be shut down are described in detail in FR A8-61 and shown in Figure 2.1.6-I.

C. Procedures

In addition to the limits and shutdown actions required for these cases, there are manual throttle actions that are taken in response to vehicle guidance and targeting concerns. These actions are required when a TAL or RTLS abort is being performed. These actions are described in FR A5-109.

**TAL:** If a TAL abort is declared after two of the engine throttles are stuck, the crew needs to take manual throttles at 104% prior to abort selection. The throttles can be returned AUTO anytime after the TAL flag has been set. During a three engine TAL, the engines will nominally throttle back to provide more time for the TAL dump. If two engines are stuck high, the time gained by throttling one engine back is minimal and the guidance transients that may be introduced outweigh the benefits gained. Taking the manual throttle actions described above will keep the good throttle at the mission power level.

**RTLS:** If an RTLS abort is declared after two of the engine throttles are stuck, the crew needs to take manual throttles to the minimum power level for at least 10 seconds prior to abort selection. The throttles must also be returned to AUTO prior to abort selection. The throttle steps in this case are done to allow guidance to converge on a correct average thrust level. This eliminates the potential of an early powered pitch around. Returning to auto throttles prior to abort selection is important since failure to do so will result in the loss of guidance's fine mass control. This will affect the propellant remaining in the tank at MECO and hence the ET separation conditions.

D. Crew Actions

Figure 2.1.6-I shows the MPS CMD/HYD/ELEC cue card. This card covers all SSME shutdown and limits actions required by the crew for the cases described above.

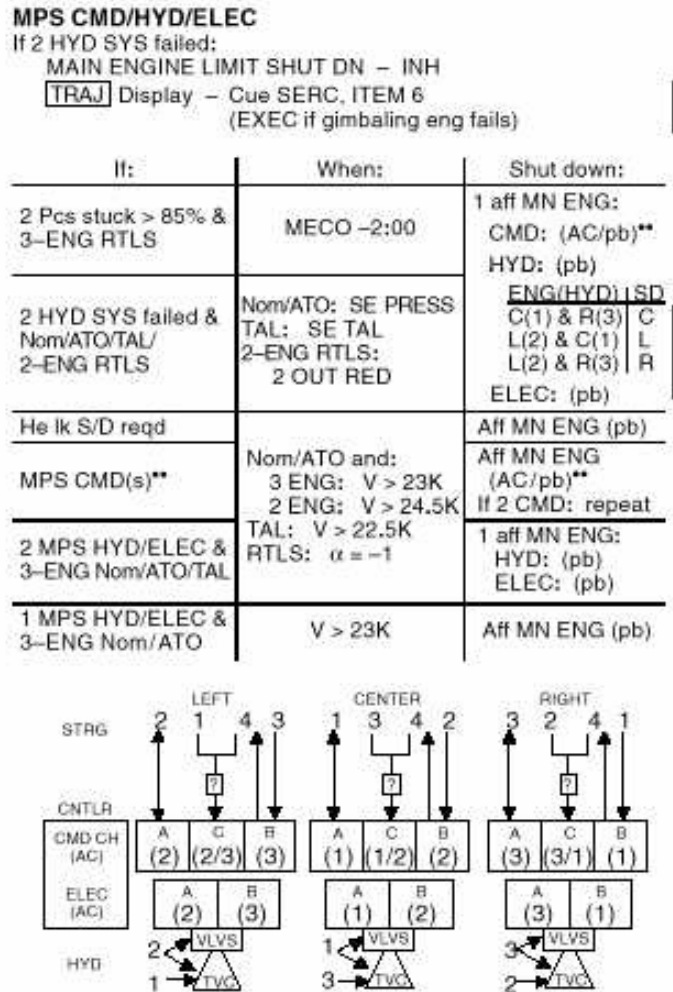


Figure 2.1.6-I. MPS CMD/HYD/ELEC cue card.

REFERENCES

1. STS Operational Flight Rules, All Flights, Final, PCN-3, January 13, 2005.
2. AESP (VOL II, REV K).
3. Booster Systems Briefs, Basic, Rev. F.

TITLE

ENGINE OUT WITH LIMITS ENABLED

PURPOSE

This SCP describes the signature for recognizing an SSME shutdown with limits enabled and the required actions by the ground and crew. For more details on limit switch actions, reference SCP 2.1.11, Main Engine Limit Shut Down switch, and SCP 2.1.12, SSME Switch Failures/Malfunctions Procedures.

DESCRIPTION

During main stage if an SSME exceeds an engine redline shutdown limit on all qualified sensors while limit shutdown capability is enabled, the SSME controller will shut that engine down. The SSME redlines are designed to minimize the risk of catastrophic damage. For information on the rationale behind the SSME redlines refer to Systems Brief 1.7, SSME Auto Shutdown Redlines and Reasonableness Tests and Flight Rule A5-2, Space Shuttle Main Engine Out. An engine may also shut down from a combination of sensor failures and controller electronics failures. Lastly, an engine can also shutdown as a result of de-energizing the pneumatic shutdown solenoid (fail safe shutdown). In the case where an engine shuts down behind a data path failure, guidance is not moded until that engine's shutdown pushbutton is depressed.

Mission Control Center actions/calls for an engine out with limits enabled are summarized in Table 2.1.7-I. Figures 2.1.7-I and 2.1.7-II contain the crew cue cards for an engine out and for inhibiting the MPS dump. The MPS dump will be inhibited for an engine out if the LO2 and LH2 pressures are too low (reference FR A5-201, MPS DUMP INHIBIT and SCP 2.2.9, MPS Dump Inhibit).

Two cues are required for both the crew and the MCC to confirm that an SSME has failed with a valid data path. The crew must have three shutdown cues to confirm that an SSME has failed behind a data path failure, while only two shutdown cues are required for the MCC to confirm that an SSME has failed behind a data path failure. There are multiple cues available to both the MCC and crew to determine if an SSME has shutdown prematurely and they are as follows:

A. SSME Failure Identifier (FID) 013 or 017 (MCC only with valid data)

FID 013 or 017 represents an engine shutdown due to a redline limit violation and can be seen on the main engine display and the FID summary display. The SSME controller will generate a FID 013 or 017 (reference SB 7.1.2, SSME Hard Failure Identification (FID) Processing) for the parameters listed in Table 2.1.7-II if a redline limit is exceeded on all qualified sensors.

Table 2.1.7-I MCC ACTIONS FOR ENGINE OUT

Step	Activity	Position
1	Determine if engine is out using the criteria in Flight Rule A5-2. Report: "C (L,R) engine out" If a data path fail, also ask to push the affected engine pushbutton to mode guidance.	ME/BSE  FD/FDO/CREW
2	Report time of shutdown to FDO in the case of a data path fail since the fail message (what FDO normally uses to determine engine out time) will not have the time the engine went out. Determining the engine-out time is case-specific, and may involve looking at the Data Path time on OFS, the Engine Out time on ME Ascent display, or related FIDs on FID Display.  If the cause is known, report the cause of the engine shut down to FD.	ME/BSE  FD/FDO
3	Confirm limits are inhibited on the remaining engine(s). Recommend to re-enable limits ASAP or at the appropriate boundary (reference Flight Rule A5-103). "Limits Enable/AUTO"	ME/BSE  FD/Crew
4	Confirm AC bus sensors off on the DDD Panel. If the predicted underspeed is greater than 500 ft/s with 2 engines running (reference Flight Rule A5-112), "Throttle back at 2 % remaining"  If there is one engine running " Throttle back at 2 % remaining "  This is per the crew procedure.	ME/BSE  FD/FDO/Crew
5	If pneumatic shutdown, report post-MECO: "LOX dump on two engines only"	ME/BSE
6	If LO2 inlet pressure < 40 psia or LH2 inlet pressure < 30 psia (reference Flight Rule A5-201), report post-MECO: "LO2(LH2) inlet pressures less than required, MPS Dump Inhibit on C(L,R) LO2(LH2) post-MECO"	MPS/BSE  FD/Crew

**SSME FAIL/SHUTDN**

AC BUS SNSR (three) – OFF

If 2 ENG remaining:

◇ MAIN ENGINE LIMIT  
SHUT DN – ENA, AUTO

If 1 ENG remaining:

When MPS PRPLT = 2%:

MAN THROT Pc → 67%,

At CO: Shut dn MN ENG (pb)

FIGURE 2.1.7-I. - ENGINE SHUTDOWN CUE CARD

**MPS DUMP INHIBIT**

Post MECO:

Aff MPS ENG PWR (two) – OFF  
LO2(H2) PRE VLV – CL

FIGURE 2.1.7-II. - MPS DUMP INHIBIT PROCEDURE

TABLE 2.1.7-II. - SSME REDLINE PARAMETERS

PARAMETER	SHUTDOWN LIMIT
HPFTP TURBINE DISCHARGE TEMPERATURE (FID 013)	> 1860 DEG R (1) NO LOWER LIMIT
HPOTP TURBINE DISCHARGE TEMPERATURE	> 1660 DEG R < 720 DEG R
HPOTP INTERMEDIATE SEAL PRESSURE (FID 013)	NO UPPER LIMIT < 159 PSIA
MCC PC AVERAGE (FID 013)	NO UPPER LIMIT PC CHANNEL AVG. < PC REF. - 200 PSI (2)
HPFTP RTVMS PUMP END ACCELEROMETER SYNCHRONOUS (1N) VIBRATION (FID 017)	>8 G (HMII ISSUED BY DSP) (3)
HPOTP RTVMS PUMP END ACCELEROMETER SYNCHRONOUS (1N) VIBRATION (FID 017)	>4 G (HMII ISSUED BY DSP) (3)

NOTE 1: These Channel A redline value can be adjusted by the SSME project to provide the same amount of margin between A and B channels given the predicted temperature for each channel.

NOTE 2: The MCC Pc redline is Pc channel average < (PcREF – 400 PSIA) during throttling or when the Power Level ≤ 75%.

NOTE 3: HMII = Health Management Indications Interrupt, DSP = Digital Signal Processor.

**B. Engine Status Word (ESW) shows Shutdown or Post Shutdown Phase (MCC only with valid data)**

If the ESW is in shutdown or post shutdown phase as shown in Table 2.1.7-III, the engine has failed. The main engine display shows the ESW in HEX and the DDD panel converts the HEX to display the English translation. The ESW will appear as shown in the MCF column if the engine shutdown due to a major component failure. The ELE column indication is only maintained as long as all qualified sensors or channels of a parameter are in a confirmed failure state and no sensor or channel for that parameter is temporarily disqualified (see paragraph 3.3.3:5.3.1 of the SSMEC Part I Spec Volume 1)



TABLE 2.1.7-III. - ENGINE STATUS WORDS FOR SHUTDOWN AND POST SHUTDOWN PHASES

Last Two ESW digits (in HEX) indication engine shutdown

	MCF	ELE
Shutdown Hydraulic	AE	AF
Shutdown Pneumatic	B2	B3
Post Shutdown Standby	C6	C7

C. MCC Pc < 900 psia (30% onboard) (with valid data)

The MCC Pc is displayed on the main engine display in psia while the crew meter reads percent. 30% power level is well below the point where an engine can operate in a stable manner. A power level < 30% is the indication used by the SSME OPS sequence to determine that an engine has shut down - for MECO Confirmed purposes only (reference the Space Shuttle Orbiter Operational, Level C, FSSR, GNC, Sequence Requirements).

D. SSME FAIL Fault Message (with valid data)

For a failed SSME, an SSME FAIL C(L,R) fault message will be generated. This message will be displayed on the Orbiter Fault Summary (OFS) and the crew's fault summary page. The fault message is generated by the GPCs when the SSME fail flag is set by the SSME OPS sequence.

E. Red Main Engine Status Light (onboard only with valid data)

The main engine status light is set red when an engine has exceeded limits or the engine is in shutdown or post shutdown standby phase. For more information on this light, reference Systems Brief 1.11 , SSME Crew Controls.

F. G-Level/Thrust Factor Decrease (2nd stage only)

If a main engine fails, the g-level will decrease. The g-level can be found on both the PASS Header display and RTPLOT. During 2nd stage when one, two, or three engines shutdown in sequence, the g-level decreases by 33, 50, and 100%, respectively. G-level is mostly a crew cue while the MCC uses the acceleration plot and thrust factor. Thrust factor (Tf) is calculated by second stage guidance and is the calculated thrust divided by the tag thrust for the number of SSMEs operating (nominally Tf is 1.00). For two engines on and an engine out behind a data path, thrust factor will read 0.67. Once the main engine pushbutton is pushed on the failed engine, the thrust factor will return to 1.00. Thrust factor is shown on the PASS Header display. Thrust factor will not work as a cue for an engine out with valid data because guidance will see the engine out and calculate the thrust factor for the expected thrust of two engines (i.e., it will remain 1.00). This is why the acceleration plot is also used.

This g-level cue is only valid in second stage since during first stage, the SRB thrust far exceeds the SSME thrust making it difficult to detect an engine shutdown based upon changes in vehicle acceleration. Thrust factor is only calculated by guidance in second stage for the same reason.

#### G. GH2 OUT Pressure < 1050 psia

GH2 outlet pressure is on both the main engine display and the BFS GNC SYS SUMM 1 display (onboard). A Caution & Warning message will be generated if the pressure drops below 1050 psia.

#### H. GO2 OUT Temperature < 300 deg F

This parameter can be found on both the main engine display and the BFS GNC SYS SUMM 1 display (onboard).

The GO2 outlet temperature and the GH2 outlet pressure for each engine are channelized through the same OI MDM and OI DSC; so one failure can take out both of these cues. For this reason these parameters only count as one cue for the MCC when determining if an engine is out. These two cues are the easiest cues to use from a console standpoint. However, the GO2 outlet temperature may drop below 300 deg F while in the bucket. If a data path occurs while in the bucket, the console operator should look for an additional drop in GH2 outlet pressure and GO2 outlet temperature. When an engine failed during STS 51-F the GO2 outlet temperature dropped below 125 deg F for about 15 seconds. The crew will receive a C&W message when the temperature drops below 125 deg F.

#### I. Helium Cues

As long as there is not a non-isolatable helium leak on the engine with a data path failure, the crew will receive a helium dP/dt fault message (“MPS HE P C(L,R)”) when the engine initiates the shutdown purges. Once the shutdown purges are completed by 15.5 seconds after the engine shuts down, the helium tank pressure will remain constant. It is the responsibility of the MPS and Booster operators to look for this cue. All other cues up to this point are the responsibility of the Main Engine and Booster operators.

#### J. Drop In Second Stage Performance

The Abort Region Determinator (ARD) uses downlisted data and tracking data to determine if the shuttle is performing as expected. With an engine out in second stage, the performance will drop significantly and this trend will be obvious to the Flight Dynamics Officer (FDO). This cue is used as a last resort since it takes more time to coordinate.

#### REFERENCES

1. Space Shuttle Operational Flight Rules, Volume A, All Flights, Final PCN-3, January 13, 2005, NSTS-12820.
2. Ascent/Entry Systems Procedures, Generic Rev L, May 15, 2003, JSC-48001.
3. Space Shuttle Orbiter Operational Level C, FSSR, GNC, Sequence Requirements, April 24, 1997, STS 83-0026-27
4. CP406R0021 (Initial Release, plus ECP 1432, and RCNs 7316 and 7294), Part I, Computer Program Contract End Item, Block II SSME Operational Program, AHMS Phase 1 Upgrade, July 22, 2004. (SSMEC Part 1 Spec)

## TITLE

### ENGINE LIMITS EXCEEDED WITH LIMITS INHIBITED

## PURPOSE

There are many situations that can cause main engine limits to be inhibited, and thus the possibility exists for an SSME to operate in an out of limits condition with limits inhibited. This SCP describes the required actions for this situation.

## DESCRIPTION

If a SSME's performance deteriorates during mainstage with shutdown limits inhibited, that engine may continue to run even though it has exceeded an engine redline. With limit shutdown capability inhibited, that engine can shut down safely only if commanded by guidance or manually initiated (shutdown using the push-button or the AC power switches). This case is covered by Flight Rules A5-103, Limit Shutdown Control, and 5-104, Data Path Fail/Engine-On Limit Shutdown Control.

### I. Limits Evaluation

When limits are inhibited on a main engine, the first two digits of the Engine Status Word (ESW) will be 00 (verses 01 for limits enabled) and the DDD panel will indicate "limits inhibited" (in red) as well. In this situation, if the engine violates its redline shutdown limits on all qualified sensors, the last two digits of the ESW will be 87, 8B, 8F, 93 or 97 (refer to the ESW cue card for an explanation of the different ESW codes). On the DDD panel, those last two digits of the ESW will be converted to indicate "Engine limits Exceeded". If the limits were enabled, a 013-XXX (or 017-XXX - for RTVMS) FID (Failure IDentifier) would be posted indicating engine shutdown. However, with limits inhibited, and redlines exceeded, a 113-XXX (or 117-XXX) FID will be posted indicating "exceeding limit" and the crew will have a red main engine status light on board. The FID comp will convert the delimiter (XXX part) of the FID and indicate which redline sensor is voting for shutdown. For example a 113-401 FID will be converted to Exceeding Limit - HPOT IMD SL PA (High pressure oxidizer turbopump intermediate seal pressure sensor A). If for some reason, the redline ceases to violate, the only place the indication will be seen is in the ESW - which will change to major component failure (MCF). One exception to that would be, for example, if a 011-XXX FID was posted indicating all redline sensors have been disqualified (and therefore can't vote for shutdown). Table 2.1.8-1 shows the engine status for each FID and ESW combination mentioned above. Limits inhibited is a serious situation and close attention must be paid to the ESW and FIDs to ensure proper evaluation of engine events.

A major difference between the PASS and BFS software is BFS doesn't downlist FIDs or SSME redline data. This makes it impossible to precisely know which sensor is voting for shutdown. Careful monitoring of the ESW will provide insight into if the engine is exceeding limits or not.

Table 2.1.8-1 Engine Status Evaluation

ESW		FID	Engine Status
0187 Limits enabled Engine limits exceeded		013-XXX or 017-XXX Limit shutdown	Engine shutdown with limits enabled (this ESW is only displayed momentarily - it will then eventually proceed through shutdown to post shutdown standby).
0087 Limits inhibited Engine limits exceeded		113-XXX or 117-XXX Exceeding limit	Engine is violating redline limits but inhibit is preventing shutdown.
Then:	0086 Limits inhibited Major component failure	113-XXX or 117-XXX Exceeding limit	Engine is no longer violating redline limits because at least one of the qualified sensor readings is no longer exceeding redline limits.
Or:	0086 Limits inhibited Major component failure	113-XXX followed by a 011-XXX FID or 117-XXX followed by a 016-XXX FID (Redundant sensor fail)	Engine is no longer violating redline limits because all the violating sensors were disqualified. If this was due to redline sensor failures then the situation is probably OK but if the problem is real, the engine is extremely sick.

## II. Scenarios with limits inhibited

There are several scenarios that can cause limits to be inhibited:

- 1) One engine out, one redline sensor failure (but not RTVMS redline accelerometers), and either of the remaining engines is one redline sensor failure away from an erroneous shutdown on the same type redline sensor.
- 2) One engine out, two or more of the same type (temperature or pressure but not RTVMS redline accelerometer) engine redline sensors have failed and either of the remaining engines is one redline sensor failure away from an erroneous shutdown.
- 3) One engine out and BFS engaged.
- 4) One engine out and one of the remaining engines has a non-isolatable MPS helium leak prior to the single engine limits (TAL abort) or single engine RTLS (RTLS abort) boundary: when the pneumatic helium and/or failed engine's MPS helium tank pressure reaches 1150 psia following the interconnect of the pneumatics system and the previously shutdown engine's helium to the leaking system's helium or when both leaking engine's helium regulator pressures are below 715 (679) psia.
- 5) Loss of TVC control (actuator hard over or loss of two APUs)
- 6) One engine out and a running engine has a data path failure

7) Two engines out

Each of these scenarios is fully discussed in the flight rules. The philosophy of when to reenable the main engine limit shutdown software attempts to balance the risk of an engine failing catastrophically while the limits are inhibited against the risk associated with a two engine-out contingency abort. In the case of multiple sensor failures (scenario #2), the limits are taken to inhibit to prevent an erroneous engine shutdown due to a sensor problem. If the BFS is engaged with an engine shutdown, limits are inhibited because failure of another engine would result in loss of control (BFS does not support single engine roll control). In the non-isolatable MPS helium leak case outlined above, limits are inhibited to allow the engine to make use of redline margin (run below the redline) and gain more run time. For loss of TVC control, limits are inhibited to avoid an RTLS abort and also to prevent an engine shutdown prior to RTLS powered pitch around with a non-gimballing engine (loss of control). Limits are inhibited if one engine is out and a running engine has a data path failure because loss of the other running engine would cause an early main engine cutoff (MECO). With two engines shutdown, limits are inhibited since three engine-out contingency aborts contain “black zones” and are more severe than the two-engine contingency aborts.

REFERENCES

1. Space Shuttle Operational Flight Rules, Volume A, All flights, Final, PCN-2, Errata, NSTS-12820, June 25, 2004.

## TITLE

SUSPECT ENGINE

## PURPOSE

This SCP defines which failures designate an SSME as a suspect engine. This SCP also explains when and why the suspect engine call is made by the ME and BSE operator.

## DESCRIPTION

A suspect engine is an engine that has a failure that makes the continued operation of that engine questionable. A suspect engine results from any one of the following engine failure conditions:

1. All qualified redline sensors on a parameter shift in the same direction, with at least one, but not all, qualified sensors violating the redline limit(s);
2. All qualified sensors exceed the limits for a particular redline after shutdown monitoring is inhibited.
3. Nonisolatable MPS helium leak;
4. Low LH2 net positive suction pressure (NPSP) resulting from an LH2 ullage leak or orbiter GH2 pressurization system anomaly. This failure makes all engines are considered suspect.
5. Drifting performance with all qualified sensors of any given redline parameter approaching their redline limits.

Note: An engine will not be declared suspect based on vibration data if the RTVMS vibration redline system is in monitor mode, if the composite vibration has replaced the synchronous vibration in the downlist (that parameter cannot be used), or if the FASCOS composite vibration data is available in the downlist.

Each of the five failure conditions is briefly described below.

The first failure condition was identified when the turbine discharge temperature redline was developed for the high-pressure fuel pump. The temperature at the two channel A sensors may be cooler than the two channel B sensors since the A and B sensors are at physically different locations and the temperature distribution around the exhaust of the turbine is not homogeneous. Therefore, the channel A and B redline values can be individually set in an attempt to assure that all four temperature measurements exceed their respective limits at the same time. Because of this potential difference, it was decided that it was possible for the four sensors not to exceed the redline limits at the same time when a pump failure occurred. This condition applies to the other



redlines as well because each redline has two, three, or four sensors. Even though the redline limits for each sensor of the other redlines are the same, it may be possible for the sensors not to exceed their limits at the same time due to sensor or hardware problems.

The second failure condition applies to a redline limit violation occurring when the redline shutdown logic is inhibited. If all qualified sensors have exceeded the limits, the pump may have a hardware failure and may not be able to continue to operate.

The third failure condition is a non-isolatable MPS helium leak. MPS helium is required for the intermediate seal purge in the high-pressure oxidizer turbopump. The crew will try to isolate the leak. If the leak cannot be isolated and is small, there may be sufficient helium to support the purge until MECO. However, the leak may get worse, resulting in helium depletion and engine shutdown prior to MECO. For this reason, the engine will be suspect with any non-isolatable MPS helium leak, large or small.

The fourth failure condition is low LH2 NPSP due to orbiter GH2 pressurization system anomaly or due to an LH2 ullage leak (Ref. SCP 2.2.4). Since limits are to be in hard enable for these cases and one or more SSMEs may be approaching their respective HPFTP turbine discharge temperature redline upper limit(s) due to the low LH2 NPSP, multiple engines can shutdown sequentially or simultaneously. Therefore, all three engines are considered suspect. If three flow control valves are failed closed, or if the failure is due to an LH2 ullage leak, the Booster will call for a TAL abort to the TAL or ACLS site achieving the earliest MECO time.

The fifth failure condition is drifting performance with all qualified sensors of any given redline parameter approaching their redline limits. An engine in hydraulic lockup is expected to drift. This performance drift should elevate HPOTP turbine discharge temperatures which may eventually exceed the redline causing the engine to shutdown. Nozzle leaks and HPOTP efficiency loss cases may cause redline exceedance and subsequent shutdown due to violation of one of the turbine discharge temperature redlines or the MCC Pc low redline. MCC Pc shifts and FFM shifts may cause a redline exceedance (probably one of the turbine discharge temperatures) and subsequent shutdown. Electric lockups due to large FFM shifts can cause a redline exceedance (due to turbine discharge temperatures or the MCC Pc redline).

The HPOTP and HPFTP RTVMS redline accelerometers could also indicate that an engine is suspect, but only if the vibration redline is active, and functioning normally. If the RTVMS vibration redline system is in monitor mode it has not been approved by the Shuttle Program for redline use. Due to the inability to discern between a sensor failure and a turbomachinery failure, the FASCOS composite vibration data has never been approved by the Shuttle Program for redline use - this is the reason for the development of the RTVMS system to replace FASCOS. Data that has not been approved by the Shuttle Program for redline use should also not be used to declare an engine suspect. The vibration redline associated with the AHMS Phase 1 system is intended to be a much more reliable vibration monitoring tool once it has been activated by the Shuttle Program. Until this time, however, the data produced by the AHMS system cannot be used to declare an engine suspect. Reference Systems Brief 1.6 for FASCOS and Systems Brief 1.19 for RTVMS. Additionally, only the synchronous vibration data can be

used to declare an engine suspect, not the composite vibration data which replaces the synchronous vibration data when that parameter has been disqualified by the RTVMS system (that parameter can no longer be trusted).

If there is no uphill capability and: an engine is stuck in the throttle bucket, or more than one engine is suspect, or one engine has failed and one of the remaining engines is suspect; and FDO has the option to decide between a TAL versus an RTLS abort, the decision will be to go TAL. This is because the TAL abort profile is more forgiving to multiple engine failures than an RTLS abort (single engine capability is achieved earlier on a TAL and the ET separation conditions are less risky). GNC also needs to know if an engine is suspect on an RTLS in order to make a decision regarding early enabling of single-engine roll control authority (toggling SERC).

## PROCEDURE

### A. Flight Rules

#### 1. Failure Definitions

- a. A5-5, SUSPECT ENGINE
- b. A4-56, PERFORMANCE BOUNDARIES
- c. A5-156, ABORT PREFERENCE FOR SYSTEMS FAILURES
- d. A8-61, SSME SHUTDOWN DUE TO HYDRAULIC SYSTEM FAILURES

### B. Crew Operations

The crew can detect cases involving a non-isolatable helium leak or a redline exceedance when the redline limits are inhibited. However, the application of the suspect-engine rule is an MCC responsibility.

C. MCC Operations

1. Recognition of failure

TABLE 2.1.9-I. – SUSPECT ENGINE DETECTION

CONDITION	ASSESSMENT	DISPLAYED ON
All R/L sensors shift in same direction, one but not all voting for S/D	Ref. SCP 2.1.8 (redline limits exceeded) SBs 7.2 (FID=013 or 017) & 7.3 (ESW=MCF)	main_engine
All R/L sensors exceed limits on a given parameter, with limits inhibited	Ref. SCP 2.1.8 (redline limits exceeded) SBs 7.2 (FID=113 or 117) & 7.3 (ESW=ELE)	main_engine
Non-isolatable He Leak	Ref. SCPs 2.2.6 & 2.2.7 (per MPS)	mps_ascent
Low LH2 NPSP	Ref. SCP 2.2.4 (per MPS)	mps_ascent
Drifting performance with all qualified sensors on a R/L parameter approaching a R/L limit	Ref. SCP 2.1.8 (redline limits) & SBs 7.1.2 (FID if any) & 7.3 (ESW may indicate HL, EL or OPOV limiting)	main_engine

2. Activity

TABLE 2.1.9-II. - MCC ACTIVITY

STEP	ACTIVITY	POSITION
1	When suspect engine condition is detected, report: "C(L,R) engine is suspect" to TRAJ after 2 Eng TAL and before Negative Return, and to GNC after an RTLS abort.	ME/MPS/ BSE/TRAJ/ GNC/FD
2	If there is no uphill capability and: an engine is stuck in the throttle bucket or more than one engine is suspect, or one engine has failed and one of the remaining engines is suspect, FDO will call for TAL abort over an RTLS abort.	ME/BSE/ FDO/FD
3	On an RTLS abort with two engines running and one of which is suspect, GNC will call to toggle SERC.	ME/BSE/ GNC/FD

REFERENCES

- 1) Space Shuttle Operational Flight Rules, Volume A, All flights, Final, PCN-2, Errata, NSTS-12820, June 25, 2004.
- 2) Booster Standard Console Procedures, Rev G, JSC-17239.
- 3) Booster Systems Briefs, Basic, Rev F, JSC-19041, July 7, 2003.

## TITLE

SSME SHUTDOWN CASES

## PURPOSE

This SCP describes system malfunctions that result in PRE-MECO SSME shutdown. It also outlines the cues for SSME shutdown when manual action is required by the crew.

## DESCRIPTION

Booster SSME shutdown cases are covered in section 5 of the Flight Rules.

A matrix that summarizes the manual shutdown cases is shown in figure 2.1.9-I. For each failure case, the matrix lists the shutdown decisions to be made by the MCC. Each flight phase (nominal, ATO, RTLS, and TAL) and the number of SSMEs operating (three or two) are considered in the matrix. This matrix is kept in the Booster Cue Cards Handbook for quick reference. Figure 2.1.9-II shows the crew procedures.

In this SCP, each failure case in the matrix will be briefly discussed.

## PROCEDURE

For nominal/ATO aborts, the shutdown velocity is 23K (three engines running) and 24.5K (two engine running). These inertial velocity ( $V_I$ ) cues correspond to approximately 30 seconds prior to MECO. A velocity that equates to MECO minus 30 seconds gives guidance time to compensate for late engine out and converge to the proper MECO targets. For a TAL abort, the shut down  $V_I$  is 22.5K (MECO - 30 seconds). The only exception is an RTLS where the engine is shut down during powered pitchdown at  $\alpha = -1$  degrees. On a three- or two-engine abort RTLS, if an engine is shut down at  $TGO \leq 60$  seconds, guidance will not mode to the target set corresponding to the remaining number of engines.

The cue of  $\alpha = -1$  degree (approx MECO-5 sec) was chosen to allow SSME shutdown to begin prior to predicted MECO while the  $LO_2$  is still under G's from the other engine(s). This alleviates  $LO_2$  net positive suction pressure concerns for the high-pressure oxidizer turbopump (HPOTP).  $\alpha = -1$  degree also protects for 1-sigma aerodynamic dispersions. Although sizable transients can be expected subsequent to engine shutdown, flight control has been demonstrated to null these transients prior to ET separation (in some cases ET separation inhibits of approximately 1 second will occur). On a TAL abort, MECO minus 30 seconds occurs at a  $V_I = 22.5$  kfps.

Phase		NOM/ATO (4) (5)		TAL (4) (5)		RTLS (4)	
<b>Case / # Eng ON</b>		<b>3</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>2</b>
2 STUCK (2 APU Fail) or LOSS OF TVC  >>INHIBIT ASAP<< (1) (2) (3)		ENA @ 2E TAL  SE PRESS PB n/gimbal	SERC ON  SE PRESS PB n/gimbal	Man Thr ENA @ 2E TAL  SE TAL PB n/gimbal	SERC ON  SE TAL PB n/gimbal	Man Thr ENA POST PPA Both>85% MECO-2M PB n/gimbal	SERC ON  SE RTLS PB n/gimbal
HELIUM LEAK	No 0-G	Good Hyd PB	23K PB	24.5K PB	22.5K PB	22.5K PB	$\alpha$ - 1 PB
	No Hyd	Min Tk P PB					
	No Redline	Min Tk P PB					
	Limits INH (6) (7) (9)		Leaking IMSL=40 (60 Block I & II) PB		Leaking IMSL=40 (60 Block I & II) PB		Leaking IMSL=40 (60 Block I & II) PB
			Non-Leaking Tk P=1150 PB		Non-Leaking Tk P=1150 PB		Non-Leaking Tk P=1150 PB
CMD PATH or CMD & DATA PATH		23K AC/PB	24.5K AC/PB	22.5K AC/PB	22.5K AC/PB	$\alpha$ - 1 AC/PB	$\alpha$ - 1 AC/PB
2 STUCK (Cmd, Hyd, Elec) (Not 2 APU fail) (2) (8)		23K  C: AC/PB H, E: PB		Man Thr  22.5K C: AC/PB H, E: PB		Man Thr Both>85% MECO-2M C: AC/PB H, E: PB	
1 STUCK (Hydraulic or Electric)		23K  PB					
<b>Case / # Eng ON</b>		<b>3</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>2</b>
<b>Phase</b>		<b>NOM/ATO (4) (5)</b>		<b>TAL (4) (5)</b>		<b>RTLS (4)</b>	

NOTES:

(1)	APU	N/GIMBAL
	2 / L + 1 / C	L
	1 / C + 3 / R	C
	2 / L + 3 / R	R

(2) RTLS: Man Throttles - 67%  
Auto Throttles  
Abort RTLS

TAL: Man Throttles (at 104%)  
Abort TAL  
Auto Throttles

(3) SERC Man Control:  
ASC TRAJ, Item 6

(4) If predicted underspeed > 500 fps for 3 or 2 SSMEs ON:  
Man Throttles to 67% at 2% prop remaining (ASC TRAJ)

(5) If predicted underspeed > 250 fps for 1 SSME ON:  
Man Throttles to 67% at 2% prop remaining (ASC TRAJ)

(6) If failed engine and pneumatic helium tank pressure is 1150 psia after interconnected to leaking engine or leaking engine regulator pressure is below 679 psia (prior to single-engine limits or single-engine RTLS), limits to INHIBIT.

(7) This block assumes failed engine and pneumatic helium are insufficient to sustain the engine with the helium leak through the abort gap - leaking engine will fail before single-engine limits (NOM/ATO/AOA/TAL) or single-engine RTLS (RTLS). If the leak rate is less than 0.310 lbm/sec, interconnect to the running SSME, for only 15 seconds, when leaking tank pressure is 500 psia or the IMSL is 70 psia, whichever comes first.

(8) Shutdown preference is command, hydraulic, then electric

(9) TAL: Man Throttles - 109%  
SE TAL 104 or no IC to running SSME reqd, Auto Throttles - 104%

RTLS: Man Throttles - 109%  
No IC to running SSME reqd, Auto Throttles before PPA  
Otherwise, Auto Throttles after PPA

Figure 2.1.9-I - MCC Console Cue Card - Manual SSME Shutdown Matrix

**MPS CMD/HYD/ELEC**

If 2 HYD SYS failed:

MAIN ENGINE LIMIT SHUT DN – INH

TRAJ Display – Cue SERC, ITEM 6  
 (EXEC if gimbaling eng fails)

If:	When:	Shut down:
2 Pcs stuck > 85% & 3-ENG RTLS	MECO -2:00	1 aff MN ENG: CMD: (AC/pb)** HYD: (pb)
2 HYD SYS failed & Nom/ATO/TAL/ 2-ENG RTLS	Nom/ATO: SE PRESS TAL: SE TAL 2-ENG RTLS: 2 OUT RED	<u>ENG(HYD)   SD</u> C(1) & R(3)   C L(2) & C(1)   L L(2) & R(3)   R ELEC: (pb)
He lk S/D reqd		Aff MN ENG (pb)
MPS CMD(s)**	Nom/ATO and: 3 ENG: V > 23K 2 ENG: V > 24.5K	Aff MN ENG (AC/pb)** If 2 CMD: repeat
2 MPS HYD/ELEC & 3-ENG Nom/ATO/TAL	TAL: V > 22.5K RTLS: $\alpha = -1$	1 aff MN ENG: HYD: (pb) ELEC: (pb)
1 MPS HYD/ELEC & 3-ENG Nom/ATO	V > 23K	Aff MN ENG (pb)

Figure 2.1.9-II - Crew Procedures - Manual SSME Shutdown Matrix



A. Two Stuck Throttles - 2 APUs Failed

If two engines are stuck due to APU failures, one of the engines can no longer gimbal. The crew will shut down the non-gimballing SSME at the single engine press to MECO boundary for uphill cases, the single engine TAL boundary for TAL abort, and MECO-2 minutes for three engine RTLS aborts if both are > 85% power level. For two engine RTLS aborts, the non-gimballing engine is shut down at the single engine RTLS boundary. In most cases the nongimballing engine is shut down to prevent a loss of control should one of the gimballing engines fail (reference SCP 2.1.6).

For the 3 engine RTLS with at least one SSME stuck below 85%, no engines are manually shut down. No action is taken because the pre MECO manual SSME shutdown can result in undesired pitch transients and is not required to protect against excessive g's.

B. MPS Helium Leaks

1. No Zero-G, Good Hydraulics

The engine will run with the helium leak, but the helium supply pressure will not support the zero-g shutdown requirements at MECO (reference SCP 2.2.6 and 2.2.7). For a zero-g shutdown, the LO<sub>2</sub> prevalues are closed, and helium is injected into the POGO accumulator system in order to maintain sufficient pressure at the HPOTP inlet to prevent LO<sub>2</sub> pump overspeed during shutdown. If the affected SSME is (1) predicted to fail earlier than MECO-30 seconds, (2) SSME redline limits are enabled, and (3) the SSME has a functional hydraulic system, then the leaking SSME will shut down automatically when the HPOTP IMSL pressure redline limit is violated. Violation of the HPOTP IMSL pressure redline will cause SSME shutdown even if the engine hydraulic system has failed, however, shutdown requirements will be violated in this case. The SSME redline limit is set to provide sufficient helium pressure and mass for a hydraulic shutdown only.

If the SSME cannot support MECO, but is predicted to violate redline shutdown requirements after MECO-30 seconds, the shutdown pushbutton will be used to shut the SSME down at MECO-30 seconds. By shutting down the engine prior to MECO, safe engine shutdown will occur because the g-load on the vehicle will maintain adequate pressure at the HPOTP inlet. The shutdown cues and rationale are the same as those used for the command path failure case.

Use of the AC power switches is not a preferred option for this case. Using the switches would result in a pneumatic shutdown and a subsequent violation of shutdown helium mass and pressure requirements with catastrophic results.

2. No Zero-G, No Hydraulics

With no hydraulic shutdown capability, the SSME valves will be closed pneumatically when shut down occurs. Although Zero-G helium mass and pressure requirements will

support either a hydraulic or pneumatic shutdown, pre-MECO shutdown requirements are higher for the pneumatic shutdown case. In addition to the requirements for a safe pre-MECO hydraulic shutdown, a pneumatic shutdown also requires helium to close the five hydraulic valves on the engine. Consequently, a pneumatic shutdown requires more helium mass and pressure to support an early SSME out. An SSME with a helium leak and a nonfunctional hydraulic system will be shut down at either the minimum required tank pressure (dependent on the number of helium regulators operating and the helium leak rate) or at MECO-30 seconds ( $\alpha -1$  for RTLS), whichever occurs earlier.

### 3. No Redline, Good SSME Hydraulics

If redline protection has been lost (e.g. HPOT IMSL transducers A and B failed qualification limits), a manual shutdown must be performed at the minimum redline tank pressure requirement.

### 4. Limits Inhibited

If the failure of an SSME with a helium leak will result in loss of the vehicle and crew, the SSME limits will be inhibited for as long as possible. Inhibiting the limits will allow the SSME to continue to operate below the HPOTP IMSL pressure redline limit. Although running an SSME below the limit is not desirable, it is preferred over performing a contingency abort. Furthermore, each SSME redline is set at a value which provides margin against catastrophic failure. Operating the SSME below the redline limit takes advantage of this margin when the only other alternative is loss of the vehicle and crew.

With limits inhibited, SSME shutdown will be performed by the crew as outlined in the flight rules section 5.

## C. Command Path Failure

An SSME with a command path failure can no longer respond to GPC commands, and must be shut down manually by the crew (reference SCP 2.1.4). It is possible to shut down an SSME with command loss as late as MECO when a guided cutoff is expected.

However, if the crew is late in shutting the SSME down or low level cutoff occurs due to propellant depletion, the resulting SSME shutdown is considered catastrophic (reference SB 1.8). The crew will manually shut down the SSME at MECO-30 seconds ( $\alpha -1$  for RTLS), prior to MECO and propellant depletion.

D. Data Path Failure

An SSME with a data path failure is unable to transmit SSME data to the GPC. As a result, the crew and the MCC are unaware of the SSME status. The BSE and ME console operators in the MCC can determine from OI data if the SSME is still operating. The MCC can also verify during 3g throttling that the SSME is responding properly to GPC commands (reference SCP 2.1.3). Without the MCC, the crew cannot detect a command path failure on an SSME with a data path failure. Consequently, the crew will assume a command path failure also exists and will perform SSME shutdown as indicated in section D above.

E. Command/Data Path Failure

An SSME with both a command path and data path failure must be manually shut down prior to MECO as a consequence of the command path failure (paragraph D above).

F. Two Stuck Throttles - Not 2 APUs Failed

For two engines stuck due to non-APU problems, the crew will shut down an engine at 23K for a nominal mission, 22.5K for a TAL abort, and MECO-2 minutes on an RTLS abort (both engines above 85 percent power level). Shutdown of an SSME for these cases will prevent the vehicle from exceeding its 3.5g structural limits (reference SCP 2.1.6). Shutdown priority when two SSMEs are not throttling is: failed command path SSME, hydraulically locked SSME, then electrically locked SSME. If both SSMEs are in hydraulic lockup or electric lockup (with no additional failures), the crew will shut down the appropriate SSME per the 2 HYD SYS FAILED matrix on the MPS CMD/HYD/ELEC cue card (Figure 2.1.9-II).

G. One Hydraulic or Electrical Lockup

An SSME in hydraulic or electrical lockup will be manually shut down in order to protect LO<sub>2</sub> NPSP requirements at shutdown for the three engines running nominal/ATO aborts. A non-throttling engine in combination with a low level cutoff will result in a violation of the engine LO<sub>2</sub> NPSP and/or LO<sub>2</sub> mass requirements at shutdown (reference SCP 2.1.5). The ARD can not predict underspeeds at MECO with enough fidelity to guarantee that a low level cutoff will not occur. For this reason, an SSME in hydraulic or electrical lockup will be shutdown even if no underspeed (i.e. low level cutoff) is predicted.

#### H. Performance Limiting and SSME Hardover Actuator

If the FDO, using the MCC Abort Region Determinator (ARD), predicts early propellant depletion due to off nominal SSME performance, or GNC confirms that an SSME has an ATVC actuator failure, the affected SSME may be shut down prior to MECO. There are currently no flight rules governing when an SSME with a performance dispersion should be shut down. FDO and Booster may work together in real time to make this determination. Shutdown due to ATVC loss is outlined in GNC flight rule, section 8.

REFERENCES

1. STS Operational Rules, All Flights, Final, PCN-1, NSTS-12820, November 21, 2002.
2. Ascent/Entry Systems Procedures, Generic, Rev J, PCN-3, JSC-48001 September 3, 1999.

## TITLE

MAIN ENGINE LIMIT SHUT DOWN SWITCH

## PURPOSE

This SCP discusses the function and use of the main engine limits switch for prelaunch and ascent.

## DESCRIPTION

The main engine limit switch is a three contact, three position switch that controls whether the redline shutdown limits for the main engines are active. The SSME shutdown redlines are discussed in SCP 2.1.7. The positions of the main engine limit switch are: ENABLE, AUTO, and INHIBIT. Each of these functions will be briefly discussed below, for more detailed information including the redundancy management scheme for the switch see Systems Brief 1.16.

**ENABLE:** In this position, all shutdown redlines are active and any engine that has all qualified redline sensors, for a given redline, voting for shutdown, will shutdown. In this position, the General Purpose Computer (GPC) will issue command to the SSME to activate redline shutdown limits without considering the status of the other engines.

**AUTO:** In this position, all shutdown redlines are active and any engine that has all qualified redline sensors, for a given redline, voting for shutdown, will shutdown. Once an engine fails, or suffers a data path failure (see SCP 2.1.3), the GPC will automatically inhibit the redline shutdown limits on the remaining running engines either through MECO or until manual action is taken via the SSME limit switch to re-enable the SSME limits monitoring.

**INHIBIT:** In this position, all shutdown redlines are inhibited and no redline shutdown commands will be issued (see SCP 2.1.8). In this position, the GPC will issue command to the SSME to inhibit redline shutdown limits without considering the status of the other engines.

Nominally, the vehicle is launched with the limit switch in the AUTO position. With no failures, the three engines will run, with all redline limits enabled, until MECO. There are numerous scenarios where the position of this switch and hence the status of the redline limits will need to be managed by the Booster flight control team. These conditions and the rationale behind the required actions, as well as the use of the switch are discussed in Section 5 of the Flight Rules.

Limit switch malfunctions are described in SCP 2.1.12.

REFERENCES

1. STS Operational Rules, All Flights, Final, PCN-1, NSTS-12820, November 21, 2002.

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TITLE

SSME SWITCH FAILURES/MALFUNCTION PROCEDURES

PURPOSE

This SCP describes the SSME switch failures and malfunction procedures.

DESCRIPTION

There are three main groups of switches associated with the SSMEs. The groups are the main engine limit shutdown switch, the main engine shutdown pushbuttons, and the main engine AC power switches.

The limit shutdown switch controls the issuing of limit enable and limits inhibit commands from the GPCs to the three SSME controllers (SSMECs). This switch is on panel C3 (Figure 2.1.12-I) and is a three-position switch (ENABLE, AUTO, and INHIBIT). The ENABLE position causes the GPCs to send enable commands to the SSMEC to apply its internal logic and shut down the engine when redlines are exceeded. The INHIBIT position causes the GPCs to send inhibit commands which disable that portion of the logic that shuts down an engine due to redline violations. The AUTO position permits the GPCs to send INHIBIT commands or ENABLE commands to all three SSMECs. This logic is explained in the SSME OPS sequence and the SCP 2.1.11, SSME Redline Switch Usage.

The left, center, and right main engine shutdown pushbuttons are used to set SHUTDOWN and SAFING flags in the SSME OPS sequence. These three pushbuttons are located on panel C3 (Figure 2.1.12-I). If a pushbutton is depressed for an SSME, the SHUTDOWN and SAFING flags initially set by switch RM, then passed to the SSME OPS sequence where they are latched for the PASS and BFS. The three pushbuttons can also be used to set the MECO Confirmed / MECO Command flags when all three buttons are pushed.

The SSMEC AC power switches are on panel R2. The six switches are arranged in two rows of three switches (Figure 2.1.12-II). Each switch supplies AC power to the SSMEC when in the ON position. The OFF position prevents the selected three-phase AC power from reaching the SSMEC. Although not operationally used, there are also AC power circuit breakers for each of the three phases of AC power used per SSMEC on panel L4 (Figure 2.1.12-III).

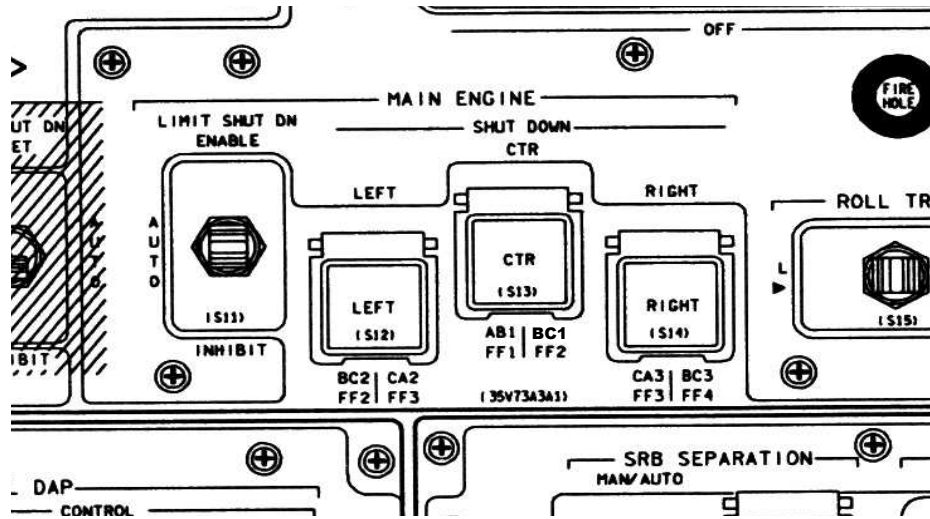


Figure 2.1.12-I. - Panel C3: SSME Pushbuttons and Limit Switch

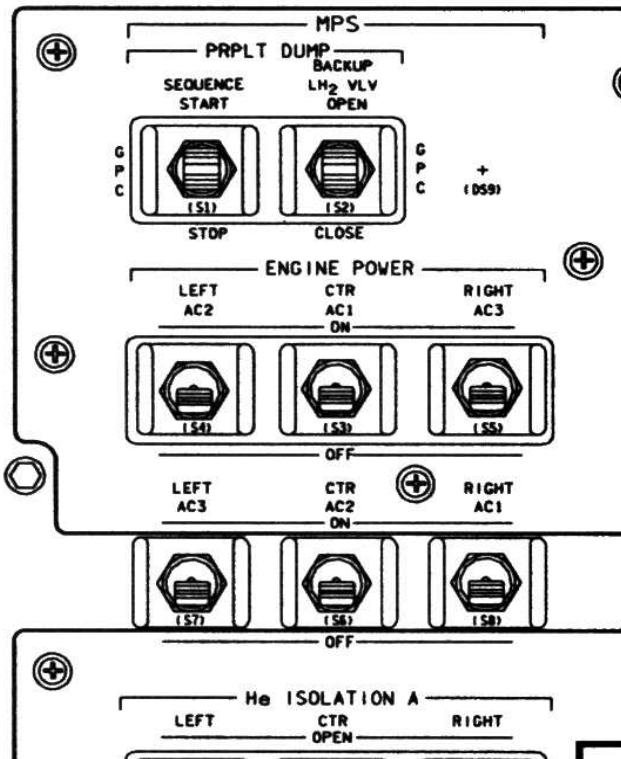


Figure 2.1.12-II. - Panel R2: SSMEC AC power switches

REDUNDANCY MANAGEMENT

Switch RM is outlined in Systems Brief 6.2, Switch Redundancy Management. Recall that switch RM for a three-contact switch is 2 of 3 voting for valid contacts. If a contact is deselected, the switch downmodes to a 2-of-2 AND gate. For a subsequent second contact deselection, the switch is downmoded to a 1-of-1 switch. Two-contact switches start as AND gates and downmode to 1-of-1 switches.

The switch RM logic for the limit shutdown switch will deselect the first failed ON or OFF contact, detected as the losing vote in 2-of-3 voting. For both the limit shutdown switch and shutdown pushbuttons, a failed ON contact may be caused by a contact failure or circuit failure. A failed OFF contact may be caused by a contact failure, circuit failure, or a power supply failure (control bus). Fault Detection, Identification, and Reconfiguration (FDIR) software will also deselect any failed contacts due to commfaulted FF. In the following examples, hot contacts are designated as "1," open contacts are designated as "0," FDIR deselected commfault contacts are designated as "COM," and previous RM deselected contacts are designated as "X."

1. Main Engine Limit Shutdown Switch - switch RM processes each contact position of the limit switch (i.e., ENABLE, AUTO, and INHIBIT). The PASS logic will deselect the first failed contact (contact failed ON or OFF) and downmode to "AND'ing" the remaining two contacts for the particular switch position. Once a contact has been deselected by RM for a particular switch position, it will never be used again for RM and that position will downmode to the next level (i.e. 2 of 2). In the case of a comm faulted position on the switch, it is ignored by RM and FDIR downmodes to the next level of voting to determine switch position. If the comm fault condition clears, then FDIR will upmode and start using the previously comm faulted contact.

- a. Contact Failed ON - RM will detect a voltage output from the contact and will deselect the failed contact (first failure):

	Switch contacts				RM Output
	A	B	C		
ENABLE	1	0	0	= 0	(Hot Contact A deselected)
AUTO	1	1	1	= 1	AUTO
INHIBIT	0	0	0	= 0	

- b. Contact Failed OFF (e.g., control bus failure) - RM will not detect voltage output from one contact and detect voltage from the other two good contacts. The PASS RM logic will deselect the failed contact (first failure):

	Switch contacts				RM Output
	A	B	C		
ENABLE	0	0	0	= 0	
AUTO	1	0	1	= 1	AUTO (Contact B deselected)

INHIBIT	0	0	0	= 0
---------	---	---	---	-----

Note that unlike case a (contacts failed ON), individual failed OFF contacts can not be detected until the limit switch is moved to that position. In the above example, on the AUTO B contact is deselected initially. However, if the limit switch were to be subsequently moved to the ENABLE position:

	Switch contacts				RM Output
	A	B	C		
ENABLE	1	0	1	= 1	ENABLE (Contact B deselected)
AUTO	0	X	0	= 0	(Contact B previously deselected)
INHIBIT	0	0	0	= 0	

- c. Commfault - FF MDMs 2, 3, or 4 failure, or the respective BCE Card B where RM will ignore the commfaulted contacts:

	Switch contacts				RM Output
	A	B	C		
ENABLE	COM	0	0	= 0	(Contact A deselected)
AUTO	COM	1	1	= 1	AUTO (Contact A deselected)
INHIBIT	COM	0	0	= 0	(Contact A deselected)

- d. Commfault then subsequent contact failed off - Because the switch contacts are not polled until the switch is moved into that position, in this two-failure mode case (i.e., commfaulting and failed contact via control bus loss), the switch will be in dilemma for all positions.

For example, starting from the above table with contact A commfaulted, then assuming all of the B contacts are lost due to a control bus loss results in the following:

	Switch contacts				RM Output
	A	B	C		
ENABLE	COM	0	0	= 0	
AUTO	COM	0	1	= 0	AUTO (DEFAULT POSITION)
INHIBIT	COM	0	0	= 0	

In the current configuration, it is not possible to have the RM output for the limit switch read anything but the AUTO position because switch RM will be unable to determine the proper position using the logical AND of contacts B and C for any switch throw. The only way to regain the switch functionality would be to manually commfault the B contacts by power cycling the FF MDM associated with these contacts.

- e. Failed OFF contact then commfault - Unless the limit switch is moved between the first and second failure, and the results from this scenario are the same as those above in case d. After the first failure, AUTO contact B is deselected.

	Switch contacts				<u>RM Output</u>
	A	B	C		
ENABLE	0	0	0	= 0	
AUTO	1	0	1	= 1	AUTO (Contact B deselected)
INHIBIT	0	0	0	= 0	

If the FF MDM (or BCE Card B) associated with the A contacts should subsequently fail, then all of the A contacts will be deselected.

	Switch contacts				<u>RM Output</u>
	A	B	C		
ENABLE	COM	0	0	= 0	
AUTO	COM	X	1	= 1	AUTO (pass through on C only)
INHIBIT	COM	0	0	= 0	

Note that even though the limit switch has been accurately identified to be in the AUTO position (as opposed to the earlier case where no determination was possible and the default AUTO position was selected), subsequent limit switch movements will still result in the switch being determined to be in the AUTO position. For example, if the switch is now moved to the ENABLE position, the RM output will still be AUTO.

	Switch contacts				<u>RM Output</u>
	A	B	C		
ENABLE	COM	0	1	= 0	
AUTO	COM	X	0	= 0	AUTO (DEFAULT POSITION)
INHIBIT	COM	0	0	= 0	

However, if the limit switch is moved to either the enable or inhibit position after the initial contact OFF failure but before the commfault, then the switch will work for the positions to which it was moved. For example, after a control bus fail (Contact fail OFF), if the switch was taken to Auto, the associated contacts will be deselected:

	Switch contacts				<u>RM Output</u>
	A	B	C		
ENABLE	0	X	0	= 0	(B deselected by switch throw)
AUTO	1	X	1	= 0	AUTO
INHIBIT	0	0	0	= 0	

A subsequent commfault would then leave the enable contact functional:

	Switch contacts				<u>RM Output</u>
	A	B	C		
ENABLE	COM	X	1	= 1	ENABLE (by C contact only)
AUTO	COM	X	0	= 0	
INHIBIT	COM	0	0	= 0	

Recall that moving a switch to Inhibit may regain its functionality in this case, but will remove single command channel shutdown logic for an engine if it receives the inhibit command.

2. Main Engine Shutdown Pushbuttons - the purpose of the pushbutton is to set the shutdown command flag and the safing command flag. The shutdown command flag will force the SSME OPS sequence to shutdown an engine, but both contacts of the pushbutton must be operational (no failures). The safing command flag when combined with a data path fail flag will set the SSME fail flag in the SSME OPS sequence. The OPS sequence will then inform guidance that the SSME has failed, and the SSME OPS sequence will close the prevalves on that SSME.

Note the "ME SD SW" fault summary message described in the following section is available in OPS 1, but not in OPS 6. The switch processing is the same in both OPS even though no message is generated.

- a. Contact Failed ON - one contact has a voltage output, one contact does not. This causes a dilemma and the "ME SD SW" fault message is generated in OPS 1. The pushbutton can no longer set the shutdown command flag, but it may still set the safing command flag in many different ways. The safing command flag will be set if the good contact (contact B) is commfaulted (even without pushing the pushbutton). The safing command flag can also be set by pushing the pushbutton after the failed contact (contact A) is commfaulted. Finally, the safing command flag could be set by simply pushing the pushbutton as long as the both the A and B contacts can be energized.

	Switch contacts			<u>RM Output</u>
	A	B		
PB NOT pushed	1	0	= ?	DILEMMA

- b. Contact Failed OFF - one contact does not have a voltage output, one contact does when the pushbutton is pushed. This also causes a dilemma and the "ME SD SW" fault message is generated in OPS 1. The pushbutton can no longer set the shutdown command flag, but it may be used to set the safing command flag by commfaulting the failed OFF contact then pushing the pushbutton again.

	Switch contacts		RM Output
	A	B	
PB pushed	0	1	= ? DILEMMA

- c. Commfault - contact commfaulted due to FF MDM (or Card B) failure. With one contact commfaulted, the pushbutton can no longer set the shutdown command flag, but it may set the safing command flag. No fault message is generated.

	Switch contacts		RM Output
	A	B	
PB pushed	1	COM	= 1 Safing Command

3. Engine Power Switches - three contact switches that provide AC power to the respective DCU. Each contact provides power from a different AC phase.
- Contact Failed ON - if one or two of the AC phase contacts are failed to the ON position, the power switch is “said” to be functional. The AC power to the SSMEC can be terminated using the engine power switch since the SSMEC requires all three phases to operate. If three of the AC phase contacts are failed to the ON position, the engine power switch cannot be used to terminate power to the SSMEC. The AC power to the SSMEC for that bus would have to be removed via the AC circuit breakers on panel L4 (Figure 2.1.12-III) - if all three contacts were failed ON such that the switch could not release the 3-phase power.
  - Contact Failed OFF - if one or more contacts for the AC power switch fail to make contact regardless of the switch position, then the switch is nonfunctional. AC power to the associated SSMEC will cease and the SSMEC will report AC power failure annunciated by FID. The SSME should remain ON with power available via the redundant AC power source. However, redundancy for the engine remaining ON is lost (refer to SCP 2.1.2 for loss of controller redundancy).

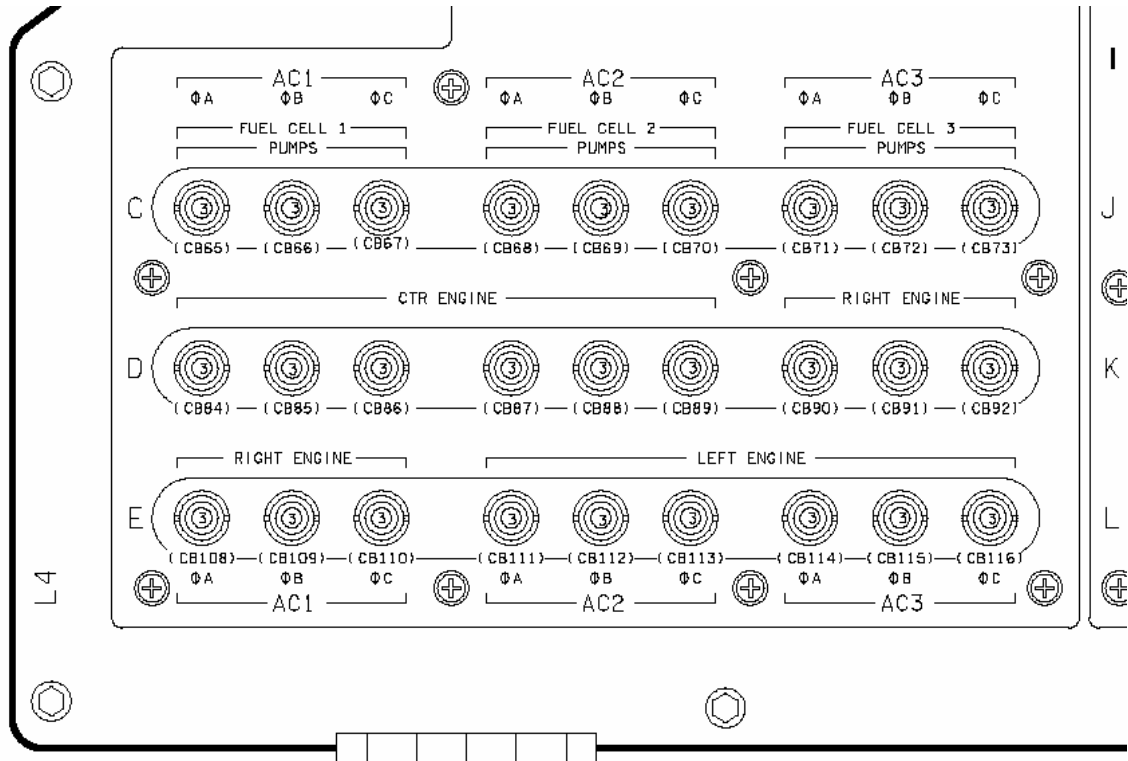


Figure 2.1.12-III. - Panel L4: SSME AC circuit breakers

PROCEDURE

1. It takes two failures to cause a dilemma on a three contact switch (refer to SCP 2.2.3). Dilemmas on the limit shutdown switch can be resolved by commfaulting the appropriate FF MDM. It may also be possible for the crew to reset the protection control device that has tripped off line on the failed control bus. This non-standard practice should only be used if there is no other way to regain the necessary function. In addition, resetting the circuit protection may not regain control bus function, and if it does, it is likely that it will only be for a very short time (a few seconds).

TABLE 2.1.12-I. - LIMIT SD SW / CNTL BUS / MDM MATRIX

Switch Contact	Failed Bus	Commfault MDM
A	BC2	FF2
B	CA3	FF3
C	BC3	FF4

2. If the EGIL operator calls a suspect failure on control buses BC2, CA3, or BC3, the Booster operator may report to EGIL the health of the control buses on Panel C3, where the limit switch is located. Statuses of the three contacts for each position are indicated on the DDD



Panel console display. Other Booster operator cues into control bus health are described in SCP 2.2.15. If the control bus for a switch contact is confirmed as failed, then the Main Engine Limits switch can be toggled to Enable and back to Auto. This forces switch RM to deselect the ENA position contact powered by the failed control bus and downmodes FDIR for that position. This protects for future failures that may preclude the use of the limits switch.

3. An SSME with one commfaulted contact on its main engine shutdown pushbutton can still be shutdown by using the AC power switches. This procedure is indicated by the use of "(AC/pb)" in the checklist. The AC power is turned OFF first to ensure engine shutdown, and the shutdown pushbutton is pushed to set the safing command flag. The combination of the data path failure flag caused by turning off the AC power switches and the safing command flag set by pushing the shutdown pushbutton, sets the SSME fail flag in the SSME OPS sequence. The OPS sequence then informs guidance that the SSME has failed. The OPS sequence also closes the prevalues on the shutdown SSME

Should the safing function of the pushbutton be inoperative due to control bus problems, the appropriate FF MDM may be commfaulted to allow the pushbutton to operate. This is achieved by power cycling the affected FF MDM, pushing the SD PB, and then performing an I/O RESET EXEC to a PASS GNC GPC. Table 2.1.12-II indicates the relationship between the control busses, MDMs, and pushbuttons:

Note: The decision to commfault an MDM is made in real time. IMUs 1, 2, and 3 are on FFs 1, 2, and 3, respectively. If other failures exist, the decision may be to not commfault the MDM for the shutdown pushbuttons.

TABLE 2.1.12-II. - SSME SHUTDOWN PUSHBUTTON / CNTL BUS / MDM MATRIX

S/D PB Contact	Failed Bus	Commfault MDM
CENTER A	AB1	FF1
CENTER B	BC1	FF2
LEFT A	BC2	FF2
LEFT B	CA2	FF3
RIGHT A	CA3	FF3
RIGHT B	BC3	FF4

Note: This procedure was approved by the Ascent/Entry Flight Techniques Panel meeting No. 30 on March 27, 1987 (ref. FR A5-105, Data Path Fail/Engine-Out Action).

Referring to the table above, the failure of GPC 3 and 4 would no-op the right engine pushbutton in addition to creating a data path failure on the right engine. If the right engine fails subsequent to the GPC failures, the only way to regain pushbutton capability is to restring to regain either of the flight criticals associated with FF3 or FF4.

If multiple data paths exist and guidance cannot be moded due to a pushbutton failure, the crew must perform an "OPS 104 PRO" post MECO to set the MECO confirmed flag. This action can only be executed on nominal, ATO, and TAL trajectories. The MECO confirmed flag can also be set by performing an ET FAST SEP. An ET FAST SEP is performed by taking the ET SEP switch to MAN and pressing the ET SEP pushbutton. In PASS, fast sep logic is only supported in major modes 102, 601, or in major mode 103 when the Second SSME Fail Confirm flag had been set. BFS only supports fast sep logic in major mode 102 (ref. FR A5-113, Manual MECO/MECO Confirmed).

4. Circuit breakers can be pulled to remove power if AC power is failed ON. For AC power failed OFF, the SSMEC has lost redundancy and the AC bus sensors are to be turned OFF (ref. SCP 2.1.2).

#### REFERENCES

1. Booster Systems Briefs, Basic, Rev F, JSC-19041
2. Space Shuttle Orbiter Operational, Level C, FSSR, GNC, Part D, Redundancy Management, September 26, 2002, STS 83-0010-27
3. Space Shuttle Systems Handbook, Rev G, DCN-1, November 15, 2002, Drawings. 10.3 and 20.1, JSC-11174
4. Flight Data File
5. Space Shuttle Operational Flight Rules, Volume A, All Flights, Final, PCN-3, January 13, 2005, NSTS-12820.

TITLE

SSME MANUAL THROTTLING/MAXIMUM THROTTLES

PURPOSE

This SCP describes the process for engaging manual or maximum throttles. The scenarios where manual or maximum throttles are required are also discussed.

DESCRIPTION

The SSME throttle commands are normally generated by ascent guidance and sent to the SSME SOP software sequence. The SSME SOP then sends the commanded SSME throttle setting to all three engine's controllers. However, for certain cases, SSME throttling must be performed manually. When manual throttling is engaged, the pilot can throttle the SSMEs by moving the right hand speed brake/throttle controller (SBTC) handle. The SBTC SOP generates the throttle settings in percent. When manual throttles are engaged, the pilot must perform the following (normally automatic) functions:

- a. Throttle up to mission power level after liftoff. (Recall that liftoff is performed at 100 percent power level.)
- b. Throttling for maximum dynamic pressure when three SSMEs are operating
- c. Throttling to limit vehicle acceleration below 3 Gs.
- d. Throttling at fine count to the MECO prep power level.
- e. Main Engine Cutoff (MECO)

The Flight Rules identify several cases that require manual throttling. These cases include:

- a. Failure to initiate or terminate thrust bucket commands for first stage dynamic pressure control.
- b. Failure to achieve fuel dissipation throttle command on initiation of an RTLS.
- c. Initiation of a two-SSME RTLS with one SSME throttle stuck in the thrust bucket. (Return to auto throttle will be initiated during flyback phase on ground call after confirmation of guidance convergence.)
- d. Incorrect throttle command for TAL OMS dump control.

- e. Throttle commands not decreasing to limit acceleration to 3-Gs.
- f. Any time control stick steering (CSS) is selected.
- g. When a large MECO underspeed is predicted. For this case, the throttles will be manually commanded to the minimum power level at 2 percent propellant remaining to protect against a low-level cutoff at a high power level.
- h. For low LH2 NPSP.
- i. When a TAL underspeed is predicted and flying at a lower throttle setting can reduce that underspeed. Throttles will be retarded to minimum power level when the performance gain is maximized.
- j. When there are three engines running and two have stuck throttles prior to TAL or RTLS abort. Auto throttles will be reselected after the abort is executed.
- k. To maintain throttles at 109 percent power level during the flyback phase of an RTLS abort.
- l. If a lower SSME power level is required subsequent to enabling maximum throttles.

The explanation and rationale for selecting manual throttles for these cases are contained in sections 4 and 5 of the Flight Rules document.

Additionally, manual throttles may also be required to throttle an SSME out of the bucket after a command path failure has been recovered with a restring. This case is discussed in more detail in SCP 2.1.14 - Thrust Factor and SSME Throttling Post Restring.

#### PROCEDURE

Manual throttling can only be performed using the pilot's speed brake/throttle controller (SBTC). In addition, manual throttling is only supported by the PASS. There is no manual throttling capability on the BFS. Manual throttling is engaged and disengaged as follows:

- a. The pilot depresses and holds the takeover button located on the right side of the SBTC handle on panel C3. Depressing the SBTC takeover button extinguishes the SBTC pushbutton indicator (PBI) AUTO lights on panels F2 and F4 and freezes the throttle command at its last value before takeover.

- b. The pilot moves the SBTC handle forward or aft, with the takeover button still depressed, until the manual throttle command matches the last auto throttle command within an I-LOADed value (typically 4% V97U9001C EPS\_THROT). If the throttle command is not matched before the takeover button is released, the throttle control will be returned to auto throttling and the SBTC AUTO PBI will be lit.
- c. When the manual throttle setting matches the auto throttle setting within 4%, the MAN lights of the SBTC PBIs will be illuminated. When this occurs, the SBTC takeover button can be released. Subsequent depressing of the takeover button during manual throttling has no affect.
- d. Subsequent movements of the SBTC handle will generate corresponding throttle commands to all three SSMEs. The speed brake/throttle controller position is converted into a throttle command in percent rated power level (RPL). This command is limited to avoid violating the minimum and maximum throttle command range. The minimum and maximum throttle commands are I-loads. Nominally the minimum throttle setting (KMIN) is 67 percent. The maximum throttle setting (KMAX), which corresponds to the SBTC handle being in the full forward position, is set at the nominal flight throttle command (normally 104 percent). If maximum throttles (109 percent) are selected by the crew, KMAX is then set equal to 109 percent and the SBTC is re-scaled. The SBTC full forward position will then be 109 percent.
- e. To return to auto throttling from manual control, either the left or right SBTC PBI (on panels F2 and F4, respectively) is depressed. This engages auto throttling and lights the SBTC AUTO PBI. Throttle matching is not required before returning to auto throttle control. The throttle setting will remain at the power level set during manual throttling until the GPCs command a new throttle level.

#### DESCRIPTION (MAXIMUM THROTTLES)

Normally, the mission power level (usually 104%) is sufficient for all ascent phases. However, during some emergency situations (such as contingency aborts) a higher power level is required. This power level is called maximum throttles and is an I-LOADed value (typically 109%, V97U4424CB KMAX). While selecting maximum throttles increases orbiter performance, it also increases the probability of catastrophic SSME failure.

Flight Rules identify several cases that require maximum throttles. These cases include:

- a. If an engine-out occurs during first stage after throttle up, and one of the remaining SSMEs has a stuck throttle in the thrust bucket, maximum throttles will be enabled if this will regain RTLS capability.
- b. If an engine-out occurs during first stage, maximum throttles will be enabled prior to RTLS selection if a depressed trajectory with low vehicle acceleration exists.
- c. Abort gap closure.

- d. To avoid post TAL selection site redesignation when operating on a single SSME.
- e. To minimize exposure to a contingency abort or crew bailout situation.

The explanation and rationale for selecting maximum throttles for these cases are contained in sections 4 and 5 of the Flight Rules document.

During the flyback phase (i.e., after powered pitcharound) in MM 601, the engines will be commanded between 67 and 109 percent as required to meet RTLS guidance targets, regardless of the number of engines operating. Once maximum throttles have been selected they cannot be deselected. Therefore, if maximum throttles are no longer needed the crew will have to throttle down manually to get to the mission power level.

Recall that when maximum throttles are selected the SBTC is rescaled so that the full-forward position is now equal to 109%. Therefore, if manual throttles are engaged, maximum throttles are subsequently selected, and the SBTC is in the full-forward position the SSMEs will be commanded to 109%. If the SBTC is in less than the full-forward position, the SSME throttles will be adjusted to a new throttle setting determined by the rescaled SBTC.

PROCEDURE (MAXIMUM THROTTLES)

To select maximum throttles in the PASS or BFS, the crew must enter an item 4 on the Override display (SPEC 51). Guidance will set the throttle command equal to the maximum throttle command (i.e. engage maximum throttles for all three engines) according to Table 1.5.1.

Table 1.5.1 - Maximum Throttle Selection

Major Mode	Criteria	Result
MM 102	- Maximum throttles have been selected - Less than three SSMEs are running	GPCs command maximum throttles
MM 103	- Maximum throttles have been selected - Three G throttling is not in progress	GPCs command maximum throttles
MM 601 Pre-PPA	- Maximum throttles have been selected - Less than three SSMEs are running	GPCs command maximum throttles
MM 601 Post-PPA	- Maximum throttles have been selected	GPCs enable maximum throttles but do not command them unless required to achieve RTLS guidance targets

REFERENCES

1. Ascent/RTLS Guidance FSSR (OI-30)
2. Sequencing FSSR (OI-30)
3. Flight Control - Sensor/Controller FSSR (OI-30)
4. Space Shuttle Operational Flight Rules, Vol. A. Final, PCN-3, January 13, 2005, JSC-12820
5. I-LOAD database for STS-114

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TITLE

SSME THRUST FACTOR AND SSME THROTTLING POST RESTRING

PURPOSE

This SCP explains the THRUST FACTOR that is computed by guidance and used in the MCC as a cue for an engine-out behind a data path failure. Additionally, it discusses the GPC I/O commands to the EIU and the SSME throttle response post restrung.

DESCRIPTION (Thrust Factor)

The Acceleration-Mass Update Task (ACC\_MASS UPD TASK) is a part of second stage guidance whose purpose is to provide other guidance and targeting tasks with estimates of the current vehicle mass and a scaling factor (FT\_FACTOR). FT\_FACTOR, commonly referred to as thrust factor, is used to scale the estimated thrust force on the vehicle so that a smoothed value of the thrust acceleration can be calculated. This scaling factor does not directly influence the throttle commands to the engine, but it can be used to determine how many engines are running and what power level they are running at. Thrust factor is displayed on the Main Engine display (see SCP 3.1.2). The following paragraphs explain how FT\_FACTOR is calculated and how it is used on console.

FT\_FACTOR is an average of the four past values of the ratio of two forces, the current vehicle thrust (FT\_S), and the predicted thrust (FT). The current vehicle thrust is simply Newton's equation  $F = ma$  or  $F = mdv/dt$  where  $dv/dt$  is the derivative of the vehicle's velocity with respect to time. This equation is expressed as:

$$FT\_S = M * (DVSMAG / DTGD)$$

In the above equation, DVSMAG is the change in the magnitude of the vehicle's DVS (accumulated velocity) vector. DTGD is the change in TGD (time).

The total thrust force (FT) is calculated in the Thrust Parameters Task (THRST PRM TSK). FT is a function of the current throttle command (K\_CMD), the number of main engines thought to be thrusting (N\_SSME), and an I-loaded estimate of thrust force for a single main engine (FT\_SSME). The corresponding estimates of force for the OMS engines and RCS jets are added.

$$FT = 0.01 * (K\_CMD) * (N\_SSME) * (FT\_SSME) + (N\_OMS) * (FT\_OMS) + (N\_RCS) * (FT\_RCS)$$

Notice that thrust from the solid rocket boosters (SRBs) is not included in the calculation of FT. Accounting for SRB thrust would be difficult since it varies significantly over time. This fact makes FT and hence FT\_FACTOR unavailable in first stage.

The current value of the thrust factor is the ratio of the two forces:

$$X1 = FT\_S / FT$$

The previous values of these ratios are updated as shown:

$$X4 = X3$$

$$X3 = X2$$

$$X2 = X1$$

The thrust factor is calculated as the average of the past four ratios. However, it is temporarily stored as X\_WEIGHT in order to determine if thrust factor may be updated.

$$X\_WEIGHT = (X1 + X2 + X3 + X4) * 0.25$$

X\_WEIGHT is then checked to see how far it differs from the most recent ratio of current vehicle thrust to predicted thrust.

$$\text{If } ABS(X1 - X\_WEIGHT) < EPS\_X \text{ (0.02 units)}$$

Then:

$$FT\_FACTOR = X\_WEIGHT$$

Where:

$$EPS\_X = \text{criterion for rejecting the thrust factor update (0.02 units)}$$

This validity check causes a delay in thrust factor updates of up to four guidance cycles (approximately eight seconds). If the check described above is not satisfied then FT\_FACTOR is not updated (FT\_FACTOR = FT\_FACTOR).

Thrust factor is also updated by the SSME-Out Safing Task (SSME-OUT SAF TSK) on the first cycle after guidance recognizes that a SSME has failed (SSME\_FAIL = ON). Once guidance recognizes the SSME failed:

$$FT\_FACTOR = 1$$

### PROCEDURE (Thrust Factor)

Thrust factor is only available in second stage and has a nominal value of 1.0. If an engine goes out and guidance does not recognize it (because of a data path failure), the predicted thrust will be wrong. This is caused by N\_SSME being incorrect because the engine-out flags could not be set with a data path failure. With three engines on, if an engine fails behind a data path, the

value of THRUST FACTOR will drop by one third of the nominal value and 0.67 will be displayed on main engine display. However, as stated earlier, it will take up to 8 seconds before the thrust factor changes from 1.0 to 0.67.

THRUST FACTOR can be one of the two cues used to determine if an engine is out behind a data path failure. If an engine goes out with no other failures, guidance updates its thrust prediction to account for only two engines running ( $N_{SSME} = 2$ ) and THRUST FACTOR will still have the nominal value of 1.0.

If three engines are running and one is stuck in the bucket (72 percent), the actual thrust will be lower than the predicted thrust, and the value of thrust factor would be approximately 0.90. THRUST FACTOR can be used to determine the power level of an engine with a data path failure. Table 2.1.14-I lists the value of THRUST FACTOR when the commanded power level is 104 percent and one engine is running at an off-nominal power level. The following formula can be used when the commanded power level is not 104 percent.

$$DATA\_PATH\_PWR\_LVL = (3 * CMD\_PWR\_LVL * THRUST\_FAC) - (2 * CMD\_PWR\_LVL)$$

Similar tables can be generated for other combinations of  $N_{SSME}$  with one stuck throttle.

TABLE 2.1.14-I  
CMD PWR LVL = 104 Percent

<u>Data path/stuck throttle PWR LVL</u>	<u>Thrust factor</u>
109	1.016
108	1.013
107	1.010
106	1.006
105	1.003
104	1.000
103	0.997
102	0.994
101	0.990
100	0.987
99	0.984
98	0.981
97	0.978
96	0.974
95	0.971
94	0.968
93	0.965
92	0.962
91	0.958
90	0.955
89	0.952
88	0.949
87	0.946
86	0.942
85	0.939
84	0.936
83	0.933
82	0.929
81	0.926
80	0.923
79	0.920
78	0.917
77	0.913
76	0.910
75	0.907
74	0.904
73	0.901
72	0.897
71	0.894
70	0.891
69	0.888
68	0.885
67	0.881
66	0.878
65	0.875
0	0.667

DESCRIPTION (SSME Throttling post restring)

Following SRB ignition, the SSME SOP sequence sends SSME commands to the GPC output buffer. The GPC I/O profile takes this command from the buffer and continuously sends it to the EIU until a new command is received in the output buffer. However, the commands being sent to the EIU are different for first and second stage.

During first stage, testing showed that although guidance does not issue a new throttle command on each cycle, it does continuously set the 'throttle flag'. The SSME SOP sequence uses this flag to determine when to issue a throttle command. Therefore, during first-stage, the SSME SOP sequence continuously sends the THROTTLE command to the main engine controller every cycle (unless a higher priority command is issued such as shutdown or limit control). During second stage, the SSME SOP will send commands just once to the GPC output buffer, but the GPC I/O profile will continuously send the last command (not necessarily a throttle command) to the EIU until a new command is received.

The above result is particularly important when a main engine suffers a re-stringable command path. How the engine responds to a re-string depends on the phase of flight and the status of the GPC I/O buffer. Although a specific failure scenario is used for demonstration, the following logic holds for any re-stringable command path failure. For the purposes of discussion, assume the center engine has a re-stringable command path failure (SCP 2.1.4) due to GPC 2 failed to HALT in the bucket and a power failure of CIA 3 at liftoff. Also assume the engine is stuck in the bucket (power level 72%), and that good commands to the engine will be recovered with a re-string. Immediately after throttling out of the bucket, the command buffer will be:

CMD A = 104% throttles  
CMD B = 72% throttles (trapped with GPC 2 FTH)  
CMD C = 0 (power failure of CIA 3)

Since two identical commands are not present, a command path failure will be annunciated and the engine will remain at 72%. For more detailed information concerning command path failures see SCP 2.1.4.

If a re-string is performed in first stage, the command buffer for channel B will be updated to 104% throttles (due to the continuous throttle commanding in first stage). Since the center engine now has two identical, valid commands, it will throttle up to 104% and nominal commanding will have been established.

If a re-string is performed in second stage, the results will depend on what has happened between the last guidance cycle in first stage and the restring. If there have been no SSME commands (other than a throttle command) issued, the center SSME will respond the same as in first stage. The command buffer for channel B will be updated with the last throttle command and the engine will throttle up. If the last command was something other than a throttle command (say a limits ENABLE command) the command buffer prior to re-string will be:

CMD A = LIMITS ENA  
CMD B = 72% throttles (trapped with GPC 2 FTH)  
CMD C = 0 (power failure of CIA 3)

Following the restring, the command buffer for channel B will be updated with the LIMITS ENA command (the last command issued). The engine in this case will not throttle up to the 104% power level although good commands have been established. The engine will remain at 72% until a new throttle command is issued. A way to force a new throttle command to be issued is for the crew to take manual throttles, change the throttles slightly, and then go back to auto throttles. The change in throttle setting will cause a new throttle command to be issued and the center SSME will throttle up in response. This procedure is commonly called "jiggling the throttles".

#### PROCEDURE (SSME Throttling post re-string)

In most cases, an engine with a re-stringable command path failure will throttle up following a restring. If the engine fails to throttle up following a restring, the method of next resort is to cause a new throttle command to be issued (jiggle the throttles, max throttles, 3-g throttles, etc.). If the engine still does not respond, it should be assumed that the command path was not re-stringable (possibly due to another failure) and the engine should be shut down at the appropriate cue (see Section 5 of the Flight Rules).

#### REFERENCES

1. Guidance Ascent/RTLS GN&C FSSR (OI-30)
2. Displays and Controls GN&C FSSR (OI-30)
3. Sequence Requirements FSSR (OI-30)
4. Lockheed flows (OI-30)
5. Booster SCP 2.1.4 (Rev. G, PCN-1)
6. Booster SB (Rev. F)

## TITLE

SRB PC SENSOR FAILURE

## PURPOSE

This SCP addresses multiple failures of chamber pressure (Pc) sensors on a given solid rocket booster (SRB) which would cause a delayed separation of the SRBs.

## DESCRIPTION

This SCP first describes the failure modes of individual SRB Pc transducers, then the logic in the SRB separation sequence that is effected by these failures, and finally some failure combinations that result in delayed SRB separation. References 1 and 2 give more information on the SRB separation sequence.

There are many possible failure modes of an individual SRB Pc transducer. The failure of FA MDM 1, 2, or 3 will commfault one Pc sensor on each SRB. A failure of the GPC associated with that MDM or the BCE card D for that MDM will also comm fault the sensor. The transducer itself may fail high or low, be biased high or low, or fail static. A failure within the appropriate OF DSC (Dedicated Signal Conditioner) can effectively fail a Pc transducer. If power is lost to an OF DSC, the corresponding SRB Pc transducer(s) will be effectively failed low. Failure of a single Pc transducer on each SRB will have no impact to the SRB separation sequence, but multiple failures may result in a delayed SRB separation. The three SRB Pc values are monitored on the MPS Ascent display.

The SRB separation sequence begins at MET 1:40, which is an I-loaded time called "SRB separation sequence initiation time". The SRB sep sequence, started by the Primary Avionics Software System (PASS), monitors the mid-value of the three pressure transducers on each SRB. For example, if the left SRB's three Pc transducers read 740, 730 and 720 psia, the mid-value select would be 730. A 5 second timer starts as soon as the selected Pc for either SRB is less than 50 psia.

If the selected Pc on the left and right do not decay below 50 psia within 5 seconds of each other, SRB separation will be delayed until the backup timer expires at MET 2:11.28. This backup separation cue protects for the latest time at which a chamber pressure of 50 psia could occur. Once the SRB chamber pressure requirements are met OR the backup timer expires, the SRB Sep Init flag is set true and the sequence continues.

The disabling of a SRB Pc sensor by a commfaulted FA MDM affects the separation sequence logic in the following manner. If a single transducer is commfaulted, the software will automatically monitor the average of the remaining two sensors for the Pc less than 50 psia cue. If a second sensor is commfaulted, then the remaining sensor is monitored. If a third sensor fails, the software will use the last good value.

When the SRB Sep Init flag is set true, the SRB separation sequence then starts timers for the Moding Time Delay and the Sep Command Time Delay. The Moding Time Delay must be satisfied before evaluating expiration of the Sep Command Time Delay. This assures a minimum delay for the SRB nozzles to reach their null position and the separation PICs (Pyrotechnic Initiator Controllers) to charge. Finally, the SRB Sep Command Time Delay must expire and the separation command is sent.

Failure to meet the five second requirement, and thus delayed SRB separation, may be caused by the following failure combinations:

- A. Two Pc sensors failed high or failed static above 50 psia

The failure of two-out-of-three Pc sensors on one SRB to the high state or static above 50 psia causes the mid-value sensor to be failed above 50 psia, thus preventing the software from passing the Pc less than 50 psia time comparison.

- B. One Pc sensor commfaulted and one Pc sensor failed high or failed static above ~80 psia

The commfault of FA MDM 1, 2, or 3 forces the software to look at the average of the two remaining sensors on each SRB. If one of the remaining Pc sensors is failed high, the average value will never drop below 50 psia and the 5 second check will not be passed. If one of the remaining Pc sensors is failed static above ~80 psia, the average value may not drop below 50 psia within 5 seconds either.

- C. Two Pc sensors failed low

This failure will result in delayed separation unless it occurs within 5 seconds of the other SRB mid-value Pc dropping below 50 psia.

- D. One Pc sensor commfaulted and one Pc sensor failed low

With one Pc sensor commfaulted and another Pc sensor failed low, the software will be evaluating chamber pressure for that SRB based on the average of one good sensor and one sensor failed low. Assuming zero psia from the failed transducer, the average will reach 50 psia when the good transducer reads 100 psia. Actual chamber pressure drops rapidly enough during tail-off that 100 psia is reached 2 or 3 seconds before 50 psia. Therefore, if the performance of the two SRB's are properly matched, then the average of the two remaining sensors drops below 50 psia within 5 seconds of the other SRB's average value and nominal separation will occur. This scenario compounded by slightly mismatched performance of the two SRBs or other Pc sensors slightly biased could result in delayed separation.

In addition to separation delay due to Pc sensors, separation may be further delayed by one or two engines out in first stage. The SRB separation sequence uses longer times for the Command



Time Delay for one or two SSMEs failed during first stage to ensure very low SRB thrust at separation. This reduces the possibility of re-contact for RTLS and contingency abort scenarios. Nominal values for all I-Loaded timing parameters associated with the SRB separation sequence are summarized in Table 2.2.1-I. All SRB separation I-loads can be found in the Flight Software CD published for each flight and available in the DF2 Branch Office.

Nominal time for each SRB chamber pressure to drop below 50 psia is approximately MET 2:00. If the Pc less than 50 psia time comparison is properly met, SRB separation will occur at approximately MET 2:06. The actual separation time will vary slightly based on the temperature of the SRB propellant (cold solid propellants burn slightly longer than warm propellants) and the separation command delay I-loads chosen for a specific flight. Worst case separation time (multiple Pc sensor failures and two engines out) is MET 2:25.28.

Except for the absence of the 5-second time constraint for Pc decay comparison, and evaluation for commfaulted sensors, the backup flight system (BFS) processing is the same as the PASS (Ref. 3). The mid-value select Pc for each SRB is monitored by the BFS and separation is commanded when the mid-value Pc's decay below 50 psia, or until expiration of the SRB separation backup cue timer when this comparison is not met. The absence of the time comparison in the BFS creates a significant difference in the failure cases. If two Pc's on one SRB fail high (off-scale or static) or are commfaulted, the mid-value select will be high and separation will be delayed, just as in the PASS. However, if two Pc's fail low, the mid-value select will be low and the Pc less than 50 psia comparison with the other SRB will be met so normal separation will occur. This situation is not true for the PASS since the 5-second time constraint would be violated.

Pc values 1, 2, and 3 for each SRB are displayed on the MPS Ascent display when in the PASS. When BFS is engaged, only the BFS mid value select Pc for each SRB is available. This is found on the BFS MPS Ascent display.

The crew has no insight into SRB chamber pressures through first stage except for the "Pc<50" indication on the PASS ASCENT TRAJ and BFS ASCENT TRAJ 1 displays that appears when Pc mid-values on both SRBs are less than 50 psia and the 5-second limit was not violated. The "Pc<50" indication does not appear if the sequence proceeds due to the backup timer. Crew cues for SRB separation are obvious: noise and flashes of the separation bolts and booster separation motors (BSMs) firing and changes in acceleration. Crew procedures (Ref. 4) have the crew verify that SRB separation occurs about 5 seconds after the "Pc<50" indication or via the backup timer by MET 2:21. The Backup timer MET given in the crew procedure is based on the separation time that would occur with multiple Pc sensor failures and one SSME failed (i.e. backup cue time of 131.28 seconds plus command delay time with one engine out (10 seconds).

A delayed SRB separation will result in a depressed trajectory and a reduced MPS flight performance reserve of approximately 1500 lbs. Although no corrective action is possible, a dual SRB Pc failure on either SRB is passed to the flight director and crew as information that may effect later flight malfunction decisions (e.g., abort gap tolerances). Table 2.2.1-II gives typical calls made for SRB Pc transducer failures.



TABLE 2.2.1-I. - SRB SEPARATION I LOAD SUMMARY

NAME	MSID (typical value)	RATIONALE
SRB SEP sequence initiation time ( $t_{init}$ )	V97U9750C (100 sec)	Adequate time to allow detection of multiple Pc transducer failures to the new state less than minimum time for fastest SRB to achieve $P_c = 59.4$ minus $\Delta t_{dif}$ including 9.4 psia transducer error.
SRB SEP backup cue time ( $t_{b/u}$ )	V97U9751C (131.28 sec)	Protects against multiple Pc transducer failures on same SRB. Latest time that slowest SRB reaches the max allowable thrust at separation for steel case SRB minus $\Delta t_{cmd}$ .
SRB Sep Moding Time Delay ( $\Delta t_{fm}$ )	V97U9752C (2.71 sec)	Time for SRB nozzles to reach null position from full thrust angle ( $5^\circ$ ) when driven at minimum rate ( $3^\circ/sec$ ). Also allows sufficient time for PICs to charge (1 sec)
SRB SEP command time delay, nominal ( $\Delta t_{cmd}$ )	V97U9753C (4.42 sec)	Ensures SRB thrust < maximum allowable at separation.
SRB SEP command time delay, abort ( $\Delta t_{cmd-abort}$ )	V99U7589C (10 sec)	Ensures very low SRB thrust at separation. Used for 1 SSME out. Reduces probability of re-contact for RTLS abort scenarios.
SRB SEP command time delay, contingency abort ( $\Delta t_{cmd-cont}$ )	V99U7676C (14 sec)	Ensures very low SRB thrust at separation. Used for 2 SSME's out. Reduces probability of re-contact for contingency abort scenarios.
Maximum SRB SEP cue differential time ( $\Delta t_{dif}$ )	V97U9761C (5 sec)	Maximum expected $\Delta t$ between a fast burning SRB achieving 59.4 psia and a slow SRB achieving 40.6 psia.

TABLE 2.2.1-II. - MCC ACTIVITY

Activity	Position
When first SRB Pc fails high or low, report: "L (R) SRB Pc 1 (2,3) fail high (low): one failure away from delayed SRB Sep"	MPS/BSE
When second SRB Pc fails in the same direction (high or low), report: "L (R) SRB Pc 1 (2,3) fail high (low): Expect delayed SRB SEP"	MPS/BSE/ FD/crew
If BFS is engaged and L (R) SRB Pc fails high, report: "Expect delayed SRB SEP"	MPS/BSE/ FD/crew

REFERENCES

1. Level C Functional Subsystem Software Requirements (PASS FSSR), STS 83-0026-27 May 30,2003, SRB Separation Sequence, page 158.
2. Redundant Computer Set Logic Flow Diagrams (Lockheed Flows), SSD96D0460, PCN-1, March 14, 2003, SRB Separation Sequence, page 3-10.
3. Backup Flight System (BFS) Sequencing Program Requirements Document (PRD), MG 038120-27, February 28, 1997, SRB Separation Sequence Scheduler, page 9 and SRB Separation Sequence, page 13.
4. Flight Data File – Ascent Checklist, JSC-48005-114, Final, Rev A, 01/25/2005, page 2-5

TITLE

SRB TVC REDUNDANCY LOSS

PURPOSE

This SCP describes the failure of the hydraulic power unit (HPU) or its associated fuel supply module (FSM). The main propulsion system (MPS) console operator's procedures and responsibilities for monitoring the SRB TVC system are described.

DESCRIPTION

The rock and tilt actuators, which provide thrust vector control (TVC) for the solid rocket boosters (SRBs), receive hydraulic power from two HPUs. Each actuator has redundant power. The rock actuator receives primary power from HPU A and secondary power from HPU B. The tilt actuator receives primary power from HPU B and secondary power from HPU A. Each HPU receives propellant from its own fuel supply module (FSM). If a FSM leak occurs and the FSM pressure decays below 80 psig, then the associated HPU will not be able to maintain proper hydraulic pressure. FSM pressure normally decays from 375 psig at HPU startup to above 260 psig at SRB separation.

The TVC system is designed to withstand the loss of one HPU. If hydraulic pressure from an actuator's primary HPU drops below  $2050 \pm 150$  psia, a pressure switch (Ref. 1) does two things. One, it signals the speed control circuit of the secondary HPU to control to 110%. This allows the good HPU to supply sufficient power as the secondary source for one actuator and the primary source for the other actuator. Two, it directs high pressure hydraulic flow from the secondary HPU in place of hydraulic flow from the primary HPU. Thus, a single HPU provides sufficient power to both actuators. Should the failed primary HPU recover to 2600 psig or within 700 psig below the secondary pressure, the pressure switch will redirect flow from the primary HPU to support the actuator.

When the actuator has switched to secondary supply, MPS Ascent display will show "FAILED" on the row labeled "PRI P RCK/TLT" in the space corresponding to that actuator. This should be accompanied by a rise in turbine speed for the other HPU from the 100% value of 72000 RPM to the 110% value of approximately 79200 RPM. Also, unless it is only a failure of the pressure switch, the corresponding hydraulic pressure on the MPS Ascent display should read less than  $2050 \pm 150$  psia. See Reference 2 for a schematic of the TVC system.

A failure of an HPU, with the other HPU powering up to 110% results in reduced gimbal rates for the nozzle. Two operating HPUs, each at 100%, provide a gimbal rate of 5 degrees per second for both actuators. A single HPU operating at 110% can power both actuators to gimbal rates of 3 degrees per second and should not adversely affect TVC performance. The guidance, navigation and control (GNC) officer should be immediately informed of the failure and that the

SRB gimbal rates will be affected. If both HPUs on one SRB fail, the TVC system will attempt to lock up both rock and tilt actuators in the last commanded position. This may result in loss of vehicle control, depending on the nozzle position at failure and time of failure (Refs. 3 and 4). The TVC system will lockup when both hydraulic pressures drop below 1000 psia. Between 1000 psia and 2800 psia gimbal control is available, but at a greatly reduced gimbal rate.

Each HPU has two gas generator control valves (primary and secondary) and two Magnetic Pickup Units (MPUs) monitoring turbine speed. The primary control valve (normally open) and secondary control valve (normally closed, powered open) are in series, thus both control valves must be open to allow fuel enter the gas generator and power the turbine. Open control valves allow continuous flow of fuel to the APU and cause turbine speed to increase.

The primary control valve is used to control the turbines to either 100% or 110% if required. The 100% and 110% control circuits sense turbine speed from MPU1 and control the (normally open) primary gas generator control valve. The 112% control circuit senses turbine speed from MPU2 and controls the (normally closed, powered open) secondary control valve. The 100% or 110% control circuit will intermittently power the primary control valve closed to limit HPU power. Although the 100% or 110% circuit normally limits turbine HPU power, the 112% circuit is always active during powered flight, and continually powers the secondary control valve open because turbine speed is below 112%. Should the primary valve fail open, the secondary control valve will be used to control the turbine speeds to 112%

There are three commonly envisioned failure scenarios that lead to HPU power being limited by the 112% circuit. First, MPU1 can fail, causing the 100% or 110% circuit to believe that the turbine speed has dropped, thus the primary control valve will never be powered closed and turbine speed will rise. Second, the 100% or 110% (which ever is controlling) control circuit may fail so that the primary control valve is never powered closed. Third, the primary control valve may fail open so that closed power is ineffective. In any case, when the turbine speed reaches 112%, the 112% control circuit will control power to the (normally closed, powered open) secondary control valve. The HPU will thereafter be controlled by the 112% circuit intermittently powering the secondary control valve.

Powers to the primary and secondary control valves of each HPU are indicated on the Bilevel display. The control valve that limits flow (primary if at 100% or 110%, secondary if at 112%) will cycle at the rate of approximately 1 Hz. The primary and secondary control valve position indications are used during nominal performance to verify that the primary control valve is limiting HPU power, and during failure scenarios to determine if the 112% circuit is controlling.

#### A. Flight Rules

Flight Rule 5-1 (Ref. 2a), Loss of SRB Thrust Vector Control (TVC), defines failure of an HPU as hydraulic pressure of 1000 psig or less (Ref. 3).

Flight Rule 5.-51 (Ref. 2b), Loss of SRB Thrust Vector Control (TVC), states that for loss of two HPUs on the same SRB, flight will continue until loss of control (Ref. 4).

#### B. Crew Operations

The crew has no capability for monitoring SRB performance. They have no procedures to follow and can make no response to a ground call. In the event of lost TVC redundancy, a ground call may be passed to the crew as information because loss of the second HPU on the same actuator may result in loss of vehicle control.

#### C. MCC Operations

Table 2.2.2-I summarizes the PASS parameters associated with the SRB TVC system. Included in Table 2.2.3-I are expected values for each parameter and values associated with degraded performance. Table 2.2.2-II summarizes the expected indications of various failure scenarios and Table 2.2.2-III summarizes MCC response to SRB TVC failures.

No insight into the health of the TVC system is available in BFS.

TABLE 2.2.2-I.- PASS TVC PARAMETERS

Parameter and MSID	Failure value/trend	Displays
FSM A Pressures (R) B46P2305C (L) B46P1305C  FSM B Pressures (R) B46P2306C (L) B46P1306C	Normally decays from 375 psig at HPU startup to above 260 psig at SRB separation. HPUs cannot maintain hydraulic pressure with less than 80 psig FSM pressure.  Loss of FSM pressure will result in: - drop in turbine speed in associated HPU - loss of associated hydraulic pressure - primary pressure "FAIL" indication - other HPU turbine speed increase to 110%.	MPS Ascent
Turbine A Speeds (R) B46R2406C (L) B46R1406C  Turbine B Speeds (R) B46R2407C (L) B46R1407C	Nominal turbine speed (controlled to 100%) is 72000 RPM.  Secondary HPU turbine speed with primary failed (controlled to 110%) is 79200 RPM.  Turbine speed with primary control valve failure or primary MPU failure (controlled to 112%) is 80640 RPM.	MPS Ascent
HYD SUP A PRESS (R) B58P2303C (L) B58P1303C  HYD SUP B PRESS (R) B58P2304C (L) B58P1304C	Nominal hydraulic supply pressure is 3000 –3250 psig.  Hydraulic pressure < 2050±150 psia results in the corresponding actuator switching to the secondary HPU.  Hydraulic pressure < 1000 psia causes the actuators to lock-up in the last commanded position.	MPS Ascent
ROCK ACTR PRI P OK (R) B58X2860X (L) B58X1860X  TILT ACTR PRI P OK (R) B58X2859X (L) B58X1859X	Nominal indication, "OK", corresponds to each actuator drawing pressure from its primary HPU.  Off-nominal indication, "FAIL", for a given actuator should be accompanied by hydraulic pressure < 2050±150 psia on corresponding HPU and turbine speed on secondary HPU increased to approximately 79200 RPM.	MPS Ascent



TABLE 2.2.2-II.- SRB HPU/TVC FAILURE RECOGNITION MATRIX

FSM Pressure (PSIA)	Turbine speed (RPM)	Hydraulic Pressure (PSIA)	Primary Actr P Status	Problem
P > 240	72,000 ± 6000	P > 2800	OK	Nominal ops
		2200-2800	OK	Sick HPU, TVC, or hydraulic leak
		P < 2050±150	FAIL	Sick HPU, TVC, or hydraulic leak. Actuator switched to secondary Hydraulic supply
	RPM < 66,000	2200-2800	OK	Sick HPU, turbine, or low hydrazine supply rate
		P < 2050±150	FAIL	Sick HPU, turbine, or low hydrazine supply rate Actuator switched to secondary Hydraulic supply
	80,640 ± 6000 (112% PWR) B/U (MPU) in control of rpm	P > 2800	OK	Primary HPU control circuit failed, or primary control valve failed open, or primary magnetic pickup unit (MPU) failed
79,200 ± 6000 (110% PWR)	P > 2800 (P < 2050±150 on other HPU)	OK (FAIL on other actuator)	One failed HPU, on remaining HPU for both actuators.	
P < 240	72,000 ± 6000	P > 2800	OK	FSM leak, either hydrazine or nitrogen
P < 80	RPM < 66,000	2200-2800	OK	Failed primary HPU as a result of FSM leak.
		P < 2050±150	FAIL	Failed primary HPU as a result of FSM leak. Actuator switched to secondary Hydraulic supply
Any value	Any value	P < 1000 on both HPUs	FAIL on both actuators	Both HPUs failed. TVC will attempt lockup at last commanded position

TABLE 2.2.2-III.- MCC FAILURE RESPONSE

Step	Activity	Position
1	Monitor FSM, HYD SUP, and PRI PWR indications onMPS Ascent Display	MPS
2	For right (left): FSM A (B) PRESS < 240 psia HYD SUP A (B) PRESS < 2050±150 psia ROCK (TILT) PRI P “FAIL” indication. Report: “Loss of redundancy on right (left) SRB TVC due to FSM A (B) failure. Expect reduced gimbal rates.” Notify: KSC that the FSM failure creates possible presence of hydrazine on R (L) SRB. This information is vital to the SRB recovery team	MPS/BSE/ FD/crew/ KSC
3	For right (left): HYD SUP A (B) PRESS < 2800 psia ROCK (TILT) PRI P “FAIL” indication. Report: “Loss of redundancy of right (left) SRB TVC due to HPU A (B) failure. Expect reduced gimbal rates.”	MPS/BSE/ FD/crew

REFERENCES

1. Space Shuttle Systems Handbook, Rev F, Dwg 9.14, Sheet 1 of 1, Zone K4.
2. Space Shuttle Systems Handbook, Rev F, Dwg 10.2, Sheet 1 of 2.
3. Space Shuttle Operational Flight Rules, Final PCN-1, NSTS-1282, A5-1, Loss of SRB Thrust Vector Control (TVC).
4. Space Shuttle Operational Flight Rules, Final PCN-91 NSTS-1282; A5-51, Loss of SRB Thrust Vector Control (TVC).

## TITLE

### SRB SEP SEQUENCE SWITCH RM AND SRB JETTISON CAPABILITY

## PURPOSE

This SCP describes the switch redundancy management (RM) and manual SRB jettison capability associated with the SRB separation sequence.

## PROCEDURES

The SRB separation sequence is used during ascent phase to separate the SRB's from the Orbiter/ET vehicle. Separation should always occur automatically; however, the crew has the capability to manually initiate the separation via SEP push-buttons if the SRB SEPARATION mode switch is in the MAN/AUTO position. The separation process begins once either the chamber pressure ( $P_c$ ) is less than 50 psi or the backup timer (typically 131.28 sec) has been reached. See Ref. 1 for details on separation delays. Pyrotechnic Initiator Controller (PIC) arm and GNC moding indicators are then issued at appropriate times, following delays to allow time for the solid rocket motor (SRM) nozzle actuators to null and SRB thrust to decay to an acceptable level (see Ref. 2 for further information).

The reason for the manual SRB separation capability was due to initial concerns of recontact of the SRBs at separation if the vehicle Q bar or vehicle rates were high. For these cases the separation was inhibited until rates were within limits. However, further analysis in the early 1990's proved that delaying SRB separation did not significantly improve separation margins for those cases. Therefore, the decision was made to no-op the inhibit logic by changing the inhibit I-loads to large values (1995; effective STS-73 and subs) such that a separation inhibit will never occur.

The ability to display a "SEP INH" indication on the crew's Ascent TRAJ and TRAJ 1 displays still exists, but the crew's procedure (Ref. 3) now directs the crew to expect AUTO SRB SEP at a backup cue of 2:21 MET if separation doesn't occur by  $P_c < 50 + 5$  seconds. The "SEP INH" indication can be found on the Booster operator's Bi-Level display.

The SRB SEPARATION switch and push-button are located on panel C3 (Figure 2.2.3-I). Switch S1 selects the AUTO or MAN/AUTO separation mode. Push-button S2 initiates the SRB separation sequence when the switch is in MAN/AUTO mode. Automatic separation will occur in both the AUTO and MAN/AUTO positions.

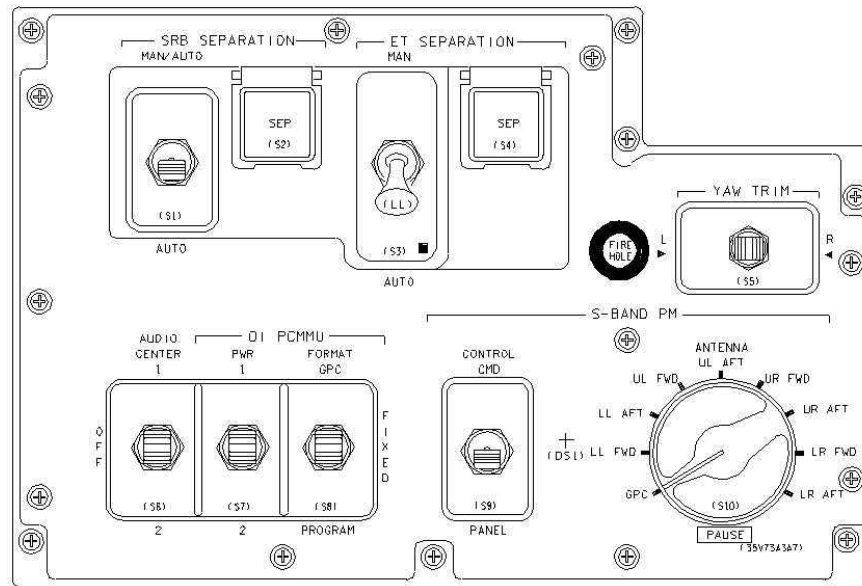


Figure 2.2.3-I.- SRB Separation Switches, Panel C3

### SWITCH RM

Due to the criticality of the SRB separation sequence, triple-pole switches are used for the SRB SEPARATION mode switch and push-button. As shown in Figure 2.2.3-II, the mode switch employs three contacts, each powered from a separate 5-volt source (dedicated signal conditioner ((DSC)) OM1, OF1, or OF2). When the mode switch is in the AUTO position, each 5-volt signal is routed to its own separate flight critical MDM (FF1, 3 or 4) where it is passed to the GNC switch RM (where “two of three” voting occurs for PASS) and to the GNC switch Hardware Interface Program (HIP) (“two of three” voting for BFS). In the MAN/AUTO position, the mode switch also supplies the 5 VDC signals to the SEP push-button. This push-button switch also goes through the same “two of three” voting logic. See reference 5 for further information on PASS switch redundancy management.

The BFS version of RM does not run unless the BFS is engaged in MM 102 and Mission Elapsed Timer (MET) is greater than 100 seconds. The BFS treats the mode switch as a simple “two of three” majority voting. See reference 6 for further information on BFS switch redundancy management.

Since an automatic SRB separation will occur even if the switch defaults to the MAN/AUTO, Booster operators are not required to carefully monitor the position of the SRB Separation switch. The switch position (AUTO or MAN/AUTO) is displayed on the following BOSS software displays: Bi-Level, MPS Ascent, BFS MPS Ascent, and DDD panel.

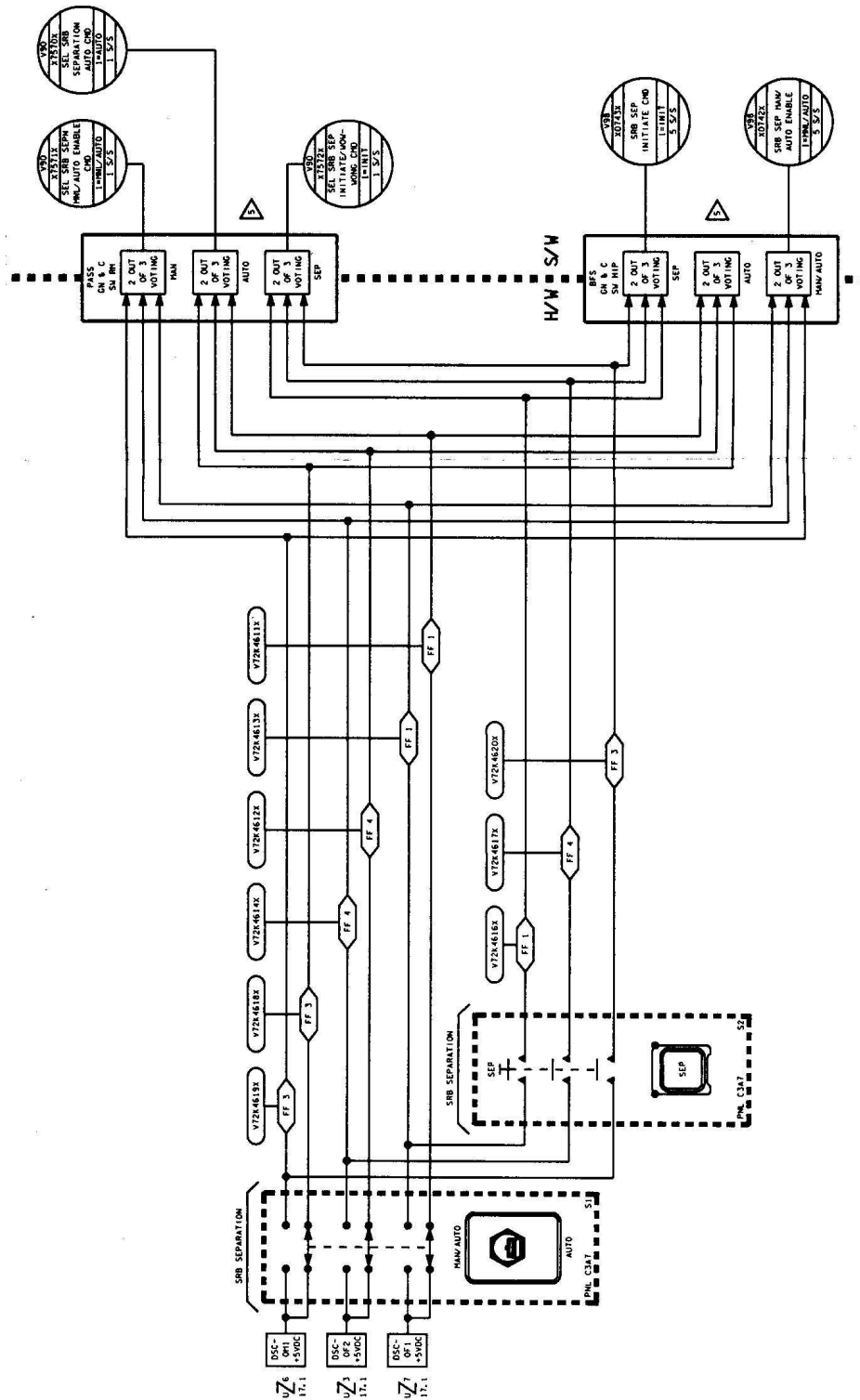


Figure 2.2.3-II – SRB Separation Sequence Switch Wiring (Ref. 4)

REFERENCES

1. Booster Systems Standard Console Procedures, Final, Rev. G, PCN-1JSC-17239; SCP 2.2.1, "SRB PC Sensor Failure."
2. Functional Subsystems Software Requirements (FSSR) GNC, Sequence Requirements; Section 4.115, SRB Separation Sequence.
3. Flight Data File (FDF) - Ascent Checklist, pg. 2-5.
4. SSSH, Vol. II, Rev. F; Dwg. 10.1 Master Events Controller, Sheet 2 of 4.
5. FSSR GNC Part D, Redundancy Management.
6. Backup Flight Software (BFS) Program Requirements Document (PRD), Hardware Interface Program (HIP), Section 3.2.5.6.1 GN&C Switch Processing.

## TITLE

ET LH<sub>2</sub> ULLAGE PRESSURIZATION FAILURES/NPSP PROBLEMS

## PURPOSE

This SCP describes the External Tank (ET) LH<sub>2</sub> ullage pressurization system and the problems associated with low LH<sub>2</sub> NPSP. It also describes the MCC response and crew action taken for failures.

## DESCRIPTION

The LH<sub>2</sub> ullage pressure is controlled by three flow control valves (FCV). These FCVs control flow of high pressure gaseous hydrogen (GH<sub>2</sub>) from each SSME to the LH<sub>2</sub> tank. Each FCV is wired to an ullage pressure transducer and signal conditioner, thus allowing for each FCV to control the ullage pressure in the tank based on the value of its respective sensor. The set point for the GH<sub>2</sub> FCV signal conditioners is 33.0 psia. A 0.4 psi signal conditioner deadband encompassing the set point results in actual activation values as low as 32.6 psia or as high as 33.4 psia (32.2 psia and 33.8 psia indicated when a 0.4 psi worst case transducer bias is included). The GH<sub>2</sub> pressurization system includes the electronics for the analog/digital converter, signal conditioner and LH<sub>2</sub> pressure transducer. The FCV is commanded closed (valve powered closed) when the sensed ullage pressure is above the upper control level and is commanded open (unpowered) when the sensed ullage pressure is below the lower control level. The FCVs are actually shimmed for 70% open / 31% closed (Ref. 1, FR A5-9). This shimming reduces wear on the valves due to cycling, since when open, they are only 70% open, and when closed, they are still providing 31% flow. These are referred to as the high and low flow settings.

The nominal LH<sub>2</sub> ullage pressure is maintained in this region for two reasons. First, it is the nominal operating range for the ullage pressure in the tank. If the pressure rises above this control band, there is a possibility the tank will vent (fire hazard) or rupture (LH<sub>2</sub> vent valve failed closed). The LH<sub>2</sub> vent and relief valve cracks at 36 psig to avoid over pressurizing the tank. If the ullage pressure drops too far below the operating band, the tank may collapse. It should be noted that neither the Light-Weight Tank (LWT) nor Super Light-Weight Tank (SLWT) Interface Control Document (ICD) define the range of structural capability for pressurization system failures. Secondly, this ullage pressure band represents the pressure required to provide proper net positive suction pressure (NPSP) to support engine operation. As ullage pressure decreases so does the inlet pressure to the turbopumps. Since NPSP is a function of inlet pressure, a decrease in ullage pressure could cause NPSP to decrease to levels where cavitation of the low-pressure fuel turbopump is likely (discussed later).

A plot of a nominal ullage pressure profile for a SLWT with three Block II SSMEs is shown in Figure 2.2.4-I. Note that the ullage pressure is maintained between the 33.4 psia and 32.6 psia bands until just before MECO.

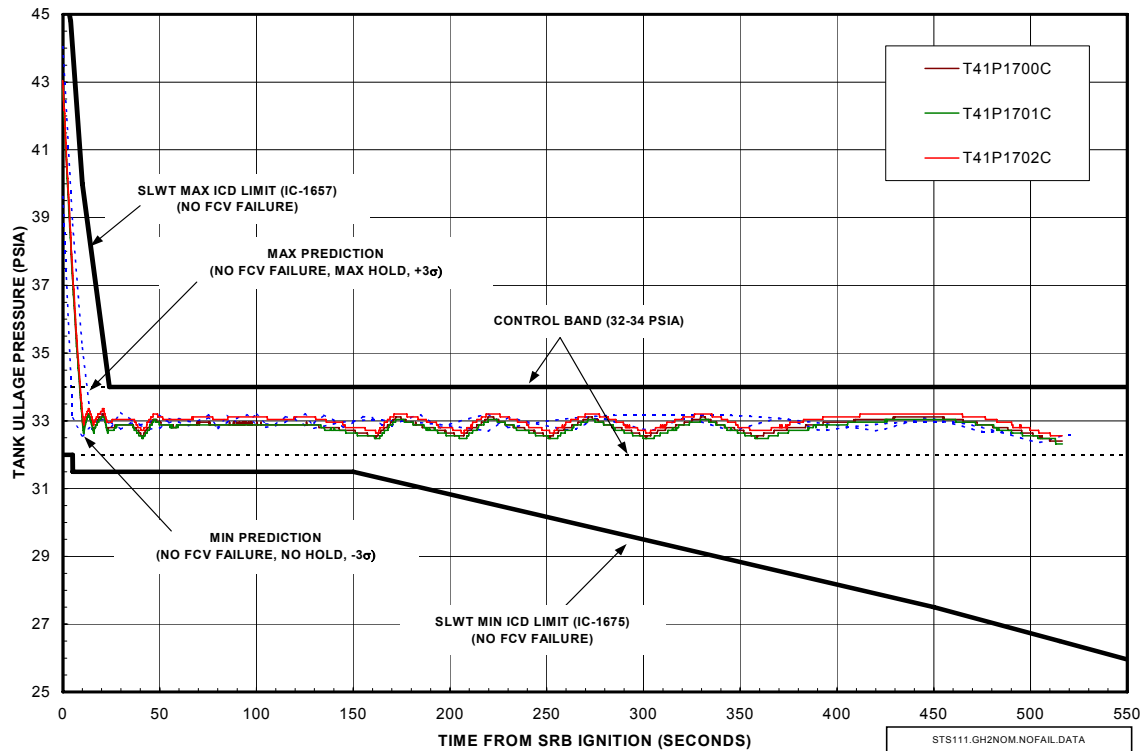


Figure 2.2.4-I - STS-111 (Blk II SSME/SLWT) LH<sub>2</sub> Ullage Pressure (Ref. 2)

The crew can monitor the LH<sub>2</sub> ullage pressure on their SYS SUM display. The MCC monitors both the ullage pressure and the NPSP on the MPS Ascent display. Caution and Warning (C&W) on the ullage pressure exists to alert the crew of off-nominal conditions. A BFS driven SM Alert will be annunciated if the LH<sub>2</sub> ullage pressure reaches 48.9 psia (for Block II SSME clusters). This alert is based on LCC ET-05 that ensures all transducers are functioning properly prelaunch when the vent valve is closed and the tank is pressurized to greater than 45.6 psia.

To alert the crew of low ullage pressure, an SM Alert was set at 28.0 psia. The lower level for the LH<sub>2</sub> ullage pressure SM Alert was developed from the Rockwell charts presented to the 12/12/96 Propulsion Systems Integration Group (PSIG). For any single failure case it is desirable not to have an SM Alert annunciation or crew action required. These operational goals were maintained for the -1301 FCV (70%/31% shim settings). Chart 1-18 of the Rockwell presentation shows a Block II SSME mission with a single flow control valve failed closed. The lowest ullage pressure during this profile is 28.3 psia and the ullage pressure required to maintain an NPSP of 3.5 psi at that time is 27.7 psi. Thus, 28.0 psia was chosen as the value for the SM Alert because it is the median of 27.7 and 28.3. When the ullage pressure reaches 28.0



psia, and the SM Alert is annunciated, the crew will perform their LH2 Ullage procedure (Figure 2.2.4-II) to prevent the ullage pressure from decaying below 28.0 psia.

#### **MPS LH2 ULL**

- ◇ If 2 (3) Ps < 28.0 or > 34.0:  
MPS LH2 ULL PRESS – OP
- When all Ps > 33.0:  
MPS LH2 ULL PRESS – AUTO

Figure 2.2.4-II – Crew Procedure for Ullage Problems (Ref. 3)

During prelaunch, the LH<sub>2</sub> ullage pressure transducers may indicate off-scale low intermittently while at ambient pressure. The operation of the signal conditioner is verified by briefly switching in the spare. After tank prepress at T-1:43 sec., the transducer should work properly. The cause of this phenomenon is probably excessive wear on the windings due to the extended time spent at ambient pressure. Another possible reason is the contamination at the location, which causes the wiper to raise up off the winding, producing an off-scale low reading.

#### Derivation of Instrumentation Error

Flight Rule A5-154, LH<sub>2</sub> Tank Pressurization (Ref. 1), states that the LH<sub>2</sub> ullage pressure will be maintained between 27.7 (28.0) and 35 (33.0) psia. The pressures in the parenthesis include instrumentation errors and represent the limit at which manual action is taken (refer to crew's procedure, Figure 2.2.4-II). The actual instrumentation error was calculated using a one-sigma stack up of the dispersions of the analog/digital converter, signal conditioner, and pressure transducer. The analog/digital converter has a 40 unit range (8 bit word, 40 units/256 = 0.16). The signal conditioner accuracy is 1/4 % of the full-scale range (0 to 52 psia range yielding 0.13 psia). The pressure transducer accuracy is +/- 0.4 psia. Both the pressure transducer and the signal conditioner protect 3-sigma accuracy in their specifications, therefore those values are divided by 3 (0.4 / 3 = 0.13 and 0.13 / 3 = 0.04). The RSS of 0.16, 0.13, and 0.04, is 0.21 psia. This value of 0.21 psia is less than the margin of 0.3 psia between the lowest ullage pressure (28.3) for the Block II SSME ullage pressure profile and the SM Alert (28.0). Therefore in Flight Rule A5-154, the upper limit protects the LH<sub>2</sub> vent crack setting (34.3 +/- 1 psig) and the lower limit provides a cue for manual action protecting the SSME NPSP ICD and the ET structural limit.

#### Ullage Pressurization Problems:

##### A. Failed Open Flow Control Valves

High ullage pressure may be caused by two or three GH<sub>2</sub> flow control valves failed open. A valve may fail open if its associated ullage pressure transducer fails low, the sensor electronics fail, or there is a physical valve failure. Since the MCC monitors both FCV

position and ullage pressure, they will be able to determine the cause of the high ullage pressure condition. If one flow control valve fails open, the remaining two control valves will be able to maintain the ullage pressure within the control band. If two flow control valves are both failed open, the actual ullage pressure will go above the control band. If two or three GH<sub>2</sub> flow control valves fail open during the first two minutes of flight (first stage), the LH<sub>2</sub> ullage pressure may rise to the relief setting (36 psig) and vent GH<sub>2</sub> through the relief valve, creating a potentially flammable environment. GH<sub>2</sub> burning may occur at low altitudes (below 110,000 feet) resulting in burning of the Thermal Protection System (TPS). For small fires (e.g., not causing explosion of the tank), the loss of TPS may result in higher heat transfer, which would increase the LH<sub>2</sub> bulk temperature. This temperature rise causes an increase in the liquid vapor pressure, resulting in a decrease in the NPSP. Recall that NPSP is the total pump inlet pressure minus the liquid vapor pressure. Since there is no method for closing FCVs, for this case there is no action. Additionally, if the crew were to perform their LH<sub>2</sub> Ullage procedure, the situation may worsen by open the remaining FCV.

Often, at least one valve is always open with the other two cycling, making it difficult to detect a single FCV failed open. However, if two valves are shown open (using GH<sub>2</sub> outlet pressure) and three sensors show the ullage pressure as being greater than 34 psia, followed by one of those two valves indicating closed (i.e., trying to reduce the ullage pressure), but GH<sub>2</sub> outlet pressure remains unchanged, then the one FCV remaining open is likely failed open.

#### B. Failed Closed Flow Control Valves or GH<sub>2</sub> Pressurization System Anomaly

If one flow control valve fails closed, the remaining two control valves will be able to maintain the ullage pressure within the control band until close to MECO when normally all three flow control valves are required. However, the decrease is not significant enough (will not reach 28.0 psi C&W limit) to warrant any action. Low ullage pressure may be caused by two or three GH<sub>2</sub> flow control valves failed closed, or a GH<sub>2</sub> pressurization system anomaly (e.g. plugged GH<sub>2</sub> filter). The flow control valves can fail closed if their respective LH<sub>2</sub> ullage pressure sensors fail high, the sensor electronics fail, or if there is a physical valve failure. In addition, if two LH<sub>2</sub> ullage pressure sensors go static between 32 and 34 psia (due to transducer stiction) while their control valves are closed, the true ullage pressure may fall below the control band. Low LH<sub>2</sub> ullage tank pressure (below 32 psia) may result in a low NPSP. NPSP is defined as the total pump inlet pressure minus the liquid vapor pressure (a function of propellant inlet temperature) and frictional losses. NPSP can be degraded due to an abnormally low ullage pressure or an abnormally high pump inlet temperature. Low NPSP during powered flight could result in cavitation of the low-pressure fuel turbopump, elevated high-pressure fuel turbopump (HPFT) turbine discharge temperature (TDT), and redline shutdown of the SSMEs. These characteristics of low LH<sub>2</sub> NPSP were noted in SSME test 904-317. During failure scenarios where NPSP is critical, it is possible that one or multiple engines will violate an SSME redline and shutdown. It is not possible to predict which engine will shutdown first because the regions where NPSP is low are very unstable. Also, the

variations in engine pumps between engines plays a significant role in determining which engine may shutdown first.

Note: After STS-40, the LH<sub>2</sub> inlet temperature transducers were removed from the vehicle. Therefore, NPSP is computed using a constant for the inlet temperature. The computation is accurate because the LH<sub>2</sub> bulk temperature remains relatively constant through powered flight, thus maintaining a fairly constant propellant inlet temperature. However, in the case where the propellant temperature begins to rise (e.g., substantial TPS loss) the computation will not be able to accurately account for this change. During missions where NPSP is critical and the SSMEs have been throttled down, the guided MECO time will be extended. For these cases, the LH<sub>2</sub> inlet temperature begins to rise due to stratification of the propellant at approximately 12000 lbm remaining. A second NPSP computation, Aero NPSP was created for the BRTS software (the prototype version of the BOSS software) to attempt to account for this change in fuel temperature. The Aero NPSP computation was similar to the NPSP computation except it used the manifold temperature instead of the inlet temperatures. However, due to lack of confidence in the Aero NPSP comp it was never officially endorsed for flight operations and has subsequently been deleted from the BOSS MPS Ascent display (2000 release). The constant inlet temperature chosen for the NPSP comp is warmer than that predicted by the Boeing stratification model; consequently, throttle steps (Ref. Flight Rule A5-155) taken at the computed NPSP of 3.5 are slightly prior to when the actual NPSP is 3.5.

If two valves fail closed for a Block II SSME cluster, the ullage pressure will decay below 28.0 psia (if failures occur early in ascent). If the LH<sub>2</sub> ullage pressure drops below 28.0 psia, the SM Alert will annunciate and the crew will work the MPS LH<sub>2</sub> ULL procedure and manually take the ullage pressure switch on panel R2 to the open position (reference Flight Rule A5-154). This action is taken to attempt to open valves that may be closed due to a transducer or electronics failure. If the MCC determines that multiple FCVs are closed, they will direct the crew to perform the procedure once the ullage pressure drops below the control band. However, this action may be ineffective because there is an actual FCV failure rather than a transducer failure. If actual valve failures are the cause, the MCC will inform the crew of which valves are failed and alert them that manual throttling steps per Flight Rule A5-155 will be required once certain cues are met. Upon recognition of the case, the main engine limits will be manually enabled to allow multiple SSMEs to safely shutdown if the NPSP problem causes a SSME redline violation. If the ullage pressure drops low enough to cause the NPSP to drop below 3.5 psi, or the high pressure fuel turbopump turbine discharge temperature (HPFT TDT) to rise to within 75° of the redline, the engines will be manually throttled to 95 percent Rated Power Level (RPL). If one of these two cues is violated again or if the vehicle is approaching 3 g's, the engines will be throttled to 80 percent RPL and subsequently to 67 percent RPL if one of the three cues is violated a third time. No abort will be performed for two flow control valves failed closed.

If three flow control valves fail closed, the ullage pressure cannot be sustained and will drop below 28.0 psia. As with the 2 failure case, the ullage pressure switch will be manually taken to the open position when either the MCC recognizes the case or the crew receives the SM Alert. Analysis indicates that during first stage, with three flow control valves failed closed, ET structural limits and NPSP limits will be violated. Due to the smaller ullage volume in the tank during first stage, opening all three FCVs could result in venting through the tank relief valve. If venting occurs while the vehicle is low in atmosphere, a fire could propagate along the side of the ET. Venting during first stage will be risked in order to protect ET structural requirements. Venting during second stage of flight is not considered to be hazardous since there is not enough oxygen in the upper atmosphere to support combustion. If the steps taken to correct the low ullage pressure problem were ineffective, then limits will manually enabled to allow for safe redline shutdown of multiple engines. Throttling procedures will be accomplished in the same manner as for the 2 FCV failed case. In addition, an abort to the nearest TAL or Augmented Contingency Landing Site (ACLS) will be performed if three FCVs are failed closed per Flight Rules A5-155 and A5-156, Abort Preference for Systems Failures.

In the event of a BFS engage with flow control valves failed closed, the crew cannot manually throttle to maintain acceptable NPSP. In this case, it is possible to shutdown one SSME with a failed FCV to avoid shutdown due to low NPSP. However, there is not an NPSP value that is displayed on the BFS MPS ASCENT display, so the backup NPSP charts in the Booster Cue Cards can be used to approximate the NPSP.

### C. Ullage Leak

Low ullage pressure may also be caused by problems in the external tank. A leak in the pressurization line, the tank, ullage gas cooling due to LH<sub>2</sub> slosh, or a LH<sub>2</sub> tank vent relief valve failed open are all considered “tank leaks,” because there is no way to correct the problem. Flight Rule A5-9, LH<sub>2</sub> Ullage Leak, defines the cues used to determine if ullage problems are the result of a tank leak. If the GH<sub>2</sub> 2-inch disconnect pressure is greater than the lowest expected number for three FCVs open and the ullage pressure is still dropping, the orbiter repressurization system (i.e. FCVs) is considered functional and the failure is considered to be an ullage leak. To ensure that the problem is not due to FCV problems, the LH<sub>2</sub> ullage switch is opened when the MCC sees the case or when the ullage pressure drops below 28.0 psia. This action ensures that all three flow control valves are open and will stay in that position. Once the ullage problem has been confirmed to be an ullage leak, SSME limits must be manually enabled to allow all the engines to safely shutdown on the redlines if required (Ref. Flight Rule A5-155). The crew will select manual throttles at 104% and then perform an abort to the nearest TAL or ACLS. Manual throttles are taken before aborting TAL to prevent the software from throttling back the engines; therefore, the vehicle will be down range as quickly as possible under the power of three SSMEs. Once TAL has been selected, the throttles will be returned to auto to allow for 3-g throttling. It is undesirable to throttle down because the leak rate could increase and throttling down will cause a decrease in GH<sub>2</sub> mass flow

to the ET resulting in a reduced ullage pressure and a corresponding drop in NPSP. Pressurization flow rate is directly associated with power level. The ullage pressure will drop during throttling when an ullage leak is present because the flow of GH<sub>2</sub> into the tank is reduced while the flow of GH<sub>2</sub> out of the tank due to the ullage leak remains constant. Although NPSP margin is gained by throttling down (due to reduced propellant line friction loss), a drop in ullage pressure has been shown to negate any NPSP margin gained by throttling down. Three-g throttling is allowed because the risk of an engine shutting down is less than that of exceeding 3-g's.

Note

For the ullage leak case or multiple flow control valves failed closed it should be noted that a BFS engage should be avoided if possible. As discussed previously, manual throttling is unavailable in the BFS. If the crew were already throttling prior to the engage, the BFS will throttle up immediately after the engage which could lead to engine failures earlier than expected. Similarly, on a TAL, the BFS may throttle back too early.

D. How to Determine if a LH<sub>2</sub> Flow Control Valve is Open or Closed

The primary cue for determining the individual position of the flow control valves is the closed power discrete [open (un-powered) or closed (powered)] being sent from the GH<sub>2</sub> FCV solenoid. No position indications exist on the flow control valves. The backup cues to determine if a valve is open or not is to use the GH<sub>2</sub> outlet pressure and 2" GH<sub>2</sub> disconnect pressure along with the closed power discrete. When the valve is open, the GH<sub>2</sub> outlet pressure will decrease approximately 200 psi from the closed position pressure. The actual outlet pressure varies with power level and engine location. The engine location is considered when evaluating the GH<sub>2</sub> outlet pressure because the pressure drop due to the system frictional losses are different for each engine location. The OMRSD Volume 2, File IX requirements for the GH<sub>2</sub> outlet pressure are shown in Table 2.2.4-I.

TABLE 2.2.4-I - OMRSD GH<sub>2</sub> OUTLET PRESSURE REQUIREMENTS (Ref. 4)

	<b>MSID</b>	<b>Acceptable PSID Change per FCV Cycle</b>
<b>67% SSME Power Level</b>		
MPS ENG 1 GH <sub>2</sub> OUT P	V41P1160A	100 - 180
MPS ENG 2 GH <sub>2</sub> OUT P	V41P1260A	140 - 220
MPS ENG 3 GH <sub>2</sub> OUT P	V41P1360A	100 - 180
<b>104% SSME Power Level</b>		

MPS ENG 1 GH2 OUT P	V41P1160A	180 - 260
MPS ENG 2 GH2 OUT P	V41P1260A	260 - 340
MPS ENG 3 GH2 OUT P	V41P1360A	200 - 280

The 2” GH<sub>2</sub> disconnect pressure increases with the number of flow control valves open. The disconnect pressure will increase approximately 80 to 90 psia for each valve that is open. The actual 2” GH<sub>2</sub> disconnect pressures from the first six missions with Block IIA SSME clusters at 104.5% RPL are shown in Table 2.2.4-II. After the first five flights of Block II clusters, the tables for 2” disconnect pressures will be reported to the Propulsion Systems Integration Group, PSIG action item 010518-01, and the ullage leak definition flight rule will be re-evaluated as needed. Data from the first four flights of a Block II cluster / SLWT configuration, STS-110, STS-111, STS-112, and STS-113 are presented in Table 2.2.4-II.

TABLE 2.2.4-II - 2" GH2 DISCONNECT PRESSURES FOR FCV, BLOCK II SSMES  
(REF. 5, 6)

<b>No. FCVs Open</b>	<b>2" Disc. P (Block II, SLWT)</b>
3 FCVs Open	448-456*
2 FCVs Open	368-384*
1 FCV Open	296-304*

\* - First four flights of Blk II/ SLWT, STS-110, STS-111, STS-112, and STS-113, including 8 psi inst. error (Ref. 6)

E. A summary of all ullage problems is provided in the LH2 Ullage cue card in Figure 2.2.4-III.

**MPS LH<sub>2</sub> ULLAGE PRESSURE PROBLEMS**

DISPLAY STATUS					FAILURE DESCRIPTION	ACTION			
NPSP	FCV POSIT	ULLAGE PRESSURES	INLET TEMPS	TANK VENT		FCV SW OPEN	MAN THROT	ABORT	COMMENTS
-	-	-	-	NOT CL	RELIEF VLV FAILS OPEN	YES	NO	YES	MONITOR ULLAGE PRESSURE & FCV'S. WHEN ULL PRESS < 28.0, ULL PRESS SW TO OPEN. MONITOR NPSP FOR ABORT CUES.
-	2 OP 1 CL	2 < 32 1 > 34 *NOTE 1*	-	-	TWO ULLAGE PRESSURE FAIL LOW	-	-	-	MONITOR LH2 RELIEF VALVE FOR VENTING. IF VENTING, MONITOR LH2 INLET TEMPS FOR RISE AND POSSIBLE LOW NPSP.
-	2 OP 1 CL	3 > 34	-	-	TWO FCV'S FAIL OPEN	-	-	-	
-	3 OP	3 > 34	-	-	THREE FCV'S FAIL OPEN	-	-	-	
-	2 OP 1 CL	1 < 32 2 > 34	-	-	1 FCV FAIL OPEN & 1 ULL PRESS FAIL LOW	-	-	-	
-	2 CL 1 OP	2 > 34 1 < 32 *NOTE 1*	-	CL	TWO ULLAGE PRESSURE FAIL HIGH	YES	NO	NO	WHEN ULL PRESS < 28.0, ULL PRESS SW TO OPEN; WHEN ULL PRESS > 34.5, ULL PRESS SW TO AUTO
-	2 CL 1 OP	3 < 32	-	CL	TWO FCV'S FAIL CLOSE	YES	YES	NO	WHEN ULL PRESS < 28.0, ULL PRESS SW TO OPEN; WHEN ULL PRESS > 34.5, ULL PRESS SW TO AUTO. MONITOR NPSP FOR MAN THROTTLE/ABORT CUES.
-	3 CL	3 < 32	-	-	3 FCV'S FAIL CLOSE	YES	YES	YES	WHEN ULL PRESS < 28.0, ULL PRESS SW TO OPEN; MONITOR NPSP FOR MAN THROTTLE/ABORT CUES.
-	3 OP	3 < 32	-	CL	LOW ULLAGE PRESS DUE TO LEAK OR SLOSH	YES	NO	YES	WHEN ULL PRESS < 28.0, ULL PRESS SW TO OPEN; MONITOR NPSP FOR ABORT CUES.
-	2 CL 1 OP	2 < 32 1 > 34	-	-	ONE FCV FAIL CLOSED & ONE ULL PRESS HIGH	YES	NO	NO	WHEN ULL PRESS < 28.0, ULL PRESS SW TO OPEN; WHEN ULL PRESS > 34.5, SW TO AUTO.
-	-	-	3 > PRED	-	TANK HEATING >PRED'D (REF FIG 2.2.1 - III)	-	-	-	MONITOR FOR LOW NPSP.
< 3.5	-	-	-	-	NPSP < REQ'D *NOTE 2*	-	POSS	YES	USE CASE OF LOW NPSP TO TAKE ACTION
NOT VALID	-	3 < REQ'D	-	-	ULL PRESS < REQ'D (REF FIG 2.2.1 - I)	YES	POSS	POSS	WHEN ULL PRESS < 28.0 ULL PRESS SW TO OPEN. POSS ABORT AND/OR MAN THROT

NOTES:

- OR 2 STATIC BETWEEN 32 AND 34.
- FOR 1 OR 2 ENGINES OUT, SEE NPSP CUE CARD.

FCV POSITION AS A FUNCTION OF GH <sub>2</sub> OUT P (104.5% RPL ONLY)		
	FCV POSITION	Block II
FLIGHT	OPEN	2926
FLIGHT	CLOSED	3159
SIM	OPEN	2930
SIM	CLOSED	3180

AESP FDF Procedure:  
**MPS LH<sub>2</sub> ULL**  
◆ If two or three Ps < 28.0 or > 34.0:  
MPS LH<sub>2</sub> ULL PRESS – OP  
When all Ps > 33.0:  
MPS LH<sub>2</sub> ULL PRESS – AUTO

Figure 2.2.4-III. - LH2 Ullage Pressure Problems Cue Card (Ref. 3, 7, 8)



REFERENCES

1. STS Operational Flight Rules, All Flights, Final PCN-3, January 13, 2005.
2. "STS-111 (OV-105) GH2 Pressurization System Performance Reconstruction," Mai Nguyen, Boeing MPS Analysis, Artemis Action Item 4TM-TBD2, PSIG Telecon, 9/11/02.
3. Flight Data File - Ascent Entry Systems Procedures (AESP), Vol. I, Gen Rev N, PCN-1.
4. OMRSD File IX, Volume 2, Inflight Checkout and Data Requirements, 2/26/02.
5. MEWS output, STS-110, STS-111, STS-112, STS-113, August 4, 2003.
6. Propulsion Systems Integration Group (PSIG) 5/18/01, Action Item 010509-D01, BNA/J. Gallardo.
7. Propulsion Systems Integration Group (PSIG) 5/30/01, Action Item 010518-03, BNA/J. Gallardo.
8. Booster Cue Card Book (BCCB), Basic Rev A, PCN-16.
9. JSC Memo, Fuel NPSP Real-Time Computation for Flight Operations, J. G. Thibodaux, Jr. (EP) to M. R. Frank (CF), Aug. 6, 1979.
10. Shuttle Operational Data Book, JSC-08934, January 1988.
11. PSIG walk on presentation, January 21, 2005.

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TITLE

ET SEPARATION FAILURES

PURPOSE

This SCP describes the external tank (ET) separation sequence and its failure conditions. Included is a discussion of the switch redundancy management (RM), 17-in. disconnect failures, and software override capability.

DESCRIPTION

The ET separation sequence is used during the ascent phase to separate the orbiter from the external propellant tank. Separation normally occurs automatically, but the crew has the capability to manually inhibit the separation sequence at any point (switch S3 to MAN) and to manually initiate the separation (via SEP pushbutton if S3 is in MAN) if required. The ET SEP switches are located on panel C3 as shown below (Figure 2.2.5-I).

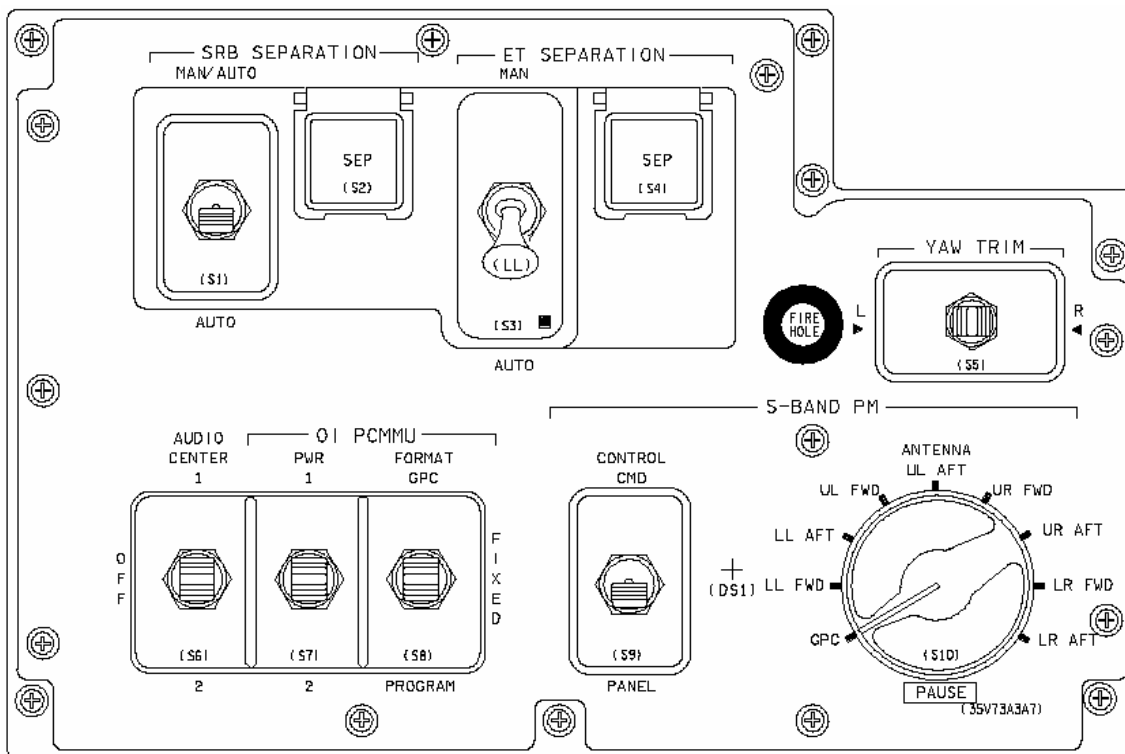


Figure 2.2.5-I - ET SEP Switches on Panel C3 (Ref. 1).

Switch S3 selects the auto or manual separation mode, and pushbutton S4 initiates the sequence when in the manual mode, bypassing all inhibits in the software.

In the automatic mode of the primary avionics software system (PASS) or Backup Flight System (BFS), the ET SEP sequence is initiated when the SSME OPS software sets the MECO CONFIRMED flag. As the sequence progresses, it tests for LO<sub>2</sub> and LH<sub>2</sub> feedline disconnect valve closure and checks that Orbiter body rates are within limits. If any of the tests are not satisfied, the separation is inhibited and an "ET SEP INH" fault message is generated. The sequence can proceed only if the out-of-tolerance parameter comes back within tolerance or if the crew performs a manual separation. When the inhibits are satisfied or bypassed, the structural separation pyrotechnic initiator controllers (PIC) are armed and fired. In the RTLS and TAL abort modes, the ET SEP sequence automatically performs the ET umbilical door closure function which is normally performed as a manual procedure by the crew. If any inhibits are present during the RTLS and the TAL modes, the sequence is delayed up to 6 seconds (RTLS) and 15 seconds (TAL), then the inhibits are automatically overridden and separation occurs. In Major Mode (MM) 103, nominal auto separation occurs 21.2 seconds after MECO CMD, while the RTLS (MM 601) requires only 15.1 seconds (due to reduction of ET umbilical retract fire command time delay within the sequence).

If the manual mode is enabled in MM 103 with PASS operating, the separation sequence is started when the SEP pushbutton is depressed (with the MECO CONFIRMED flag set). If PASS initiates a manual ET SEP via the pushbutton and the backup flight system (BFS) becomes engaged before the separation, the separation will not occur unless the pushbutton is depressed again after BFS is engaged. The sequence proceeds almost identically to the auto mode except the inhibits are overridden. In both cases, manual separation time can be as short as the auto sequence and is dependent on the time the crew depresses the SEP pushbutton.

For some contingency aborts in MM 102 and MM 601, a fast separation mode is available in PASS (MM 102 only for BFS engage). This sequence requires only 4.82 seconds (maximum) to complete and is executed during some contingency aborts or when manual separation is selected and the SEP pb is depressed. The fast separation mode bypasses delays for PIC arm and fire times, feedline disconnect close times, and ET umbilical door retract times. For this case, the SRBs remain attached to the tank and the ET doors are closed automatically.

An example of when to use a fast sep is to manually set MECO confirmed on an RTLS trajectory. If multiple avionics or pushbutton failures cause the loss of pushbutton capability on uphill or TAL trajectories, OPS 104 PRO can be used to set MECO Confirmed. However, OPS 104 PRO is not an allowable entry to set MECO Confirmed on an RTLS, and a fast sep would be required to set MECO confirmed (Ref. 2).

A PASS-only software capability for fast separation initiation in MM 103 is also available. If two SSMEs have failed and manual ET SEP is initiated in MM 103, a fast separation will occur (in 3.6 seconds maximum), and the ET doors will be commanded closed automatically. The BFS does not support fast separation capability in MM 103.

The ET SEP sequence software in the PASS and BFS are as similar as possible. However, the BFS must monitor the PASS sequence to determine where to pickup in the SEP sequence if the BFS is engaged. PASS and BFS sequence execution times are the same and are as follows:

- Nominal auto separation - 21.2 seconds after MECO CMD
- RTLS auto separation - 15.1 seconds after MECO CMD
- Manual separation - crew dependent
- Fast separation MM102 and MM601 - 4.82 seconds after ET SEP MAN INIT
- Fast separation MM103 and 2nd SSME Failed - 3.6 seconds after ET SEP MAN INIT

The various failure modes that can cause the automatic separation of the ET to be delayed are:

1. No MECO CONFIRMED flag
2. Automatic ET separation inhibit
3. Failure of the ET SEP switch, resulting in switch RM defaulting to the MAN position (i.e. "ET SEP MAN" fault message from software in OPS 1 only)
4. Switch taken to the manual position by crew

These failure modes are described in the console cue card in Table 2.2.5-I. The following section provides a more in-depth discussion of the failure modes.

TABLE 2.2.5-I- ET SEP FAILURES

Indication	Action	Rationale
NO MECO CONFIRMED	<ul style="list-style-type: none"> <li>After SSME's have shutdown (per crew/Booster console) crew should depress all three SSME shutdown pushbuttons simultaneously for 1 second on panel C3 or perform OPS 104 PRO</li> </ul>	<ul style="list-style-type: none"> <li>Forces MECO CONFIRMED and then AUTO ET SEP sequence should proceed</li> </ul>
"ET SEP INH" fault summ msg (also on crew display OPS 103 ASCENT TRAJ)	<ul style="list-style-type: none"> <li>Per Ascent C/L, crew takes the ET SEP S/W to MAN, performs the OPS 104 PRO, and checks body rates</li> <li>If rates &gt; 0.7, 0.7, 0.7, null rates then perform manual ET SEP</li> <li>If rates ≤ 0.7, 0.7, 0.7 assume feedline valve failure → initiate ET SEP at MECO + 6 minutes (unless there is an OMS-1 burn, SEP will be performed at MECO + 6 minutes or TIG-1:30, whichever comes first)</li> </ul>	<ul style="list-style-type: none"> <li>AUTO sequence should proceed when body rates are ≤ 0.7, 0.7, 0.7</li> <li>If LO<sub>2</sub> or LH<sub>2</sub> disconnect valve not closed, must delay SEP 6 min for LO<sub>2</sub>/LH<sub>2</sub> to bleed overboard, otherwise ET may contact vehicle after SEP</li> </ul>
"ET SEP MAN" fault msg (indicates sequence has defaulted to MANUAL mode, OPS 1 only)	<ul style="list-style-type: none"> <li>Per cue card, post-MECO: SPEC 51 item 38 entry (item 28 in BFS); to override INHIBITS use item 39 entry (item 29 in BFS) to SEP</li> </ul>	<ul style="list-style-type: none"> <li>Overrides switch failure back to AUTO;</li> <li>Need to verify rates and LO<sub>2</sub>/LH<sub>2</sub> valves closure</li> </ul>
"ET SEP AUTO" fault msg (indicates sequence has defaulted to AUTO mode, RTLS and TAL)	<ul style="list-style-type: none"> <li>No action required</li> </ul>	<ul style="list-style-type: none"> <li>On RTLS and TAL aborts, inhibits are automatically overridden after 6 sec.</li> </ul>
ET SEP does not occur after MECO + 21 sec	<ul style="list-style-type: none"> <li>Check rates and feedline valves: if unsure of valve state, initiate manual ET SEP at MECO +6 minutes</li> <li>If rates OK and feedline valves are closed, select MANUAL mode and initiate ET SEP (pb)</li> </ul>	<ul style="list-style-type: none"> <li>Delays ET SEP for 6 min for LO<sub>2</sub>/LH<sub>2</sub> to bleed overboard</li> <li>Overrides inhibits</li> </ul>
RCS leak (See RCS cue cards)	<ul style="list-style-type: none"> <li>Pre-MECO: ET SEP - MAN (N/A RTLS) and MPS PRPLT DUMP SEQ - STOP (N/A RTLS)</li> <li>Post Isol Proc.: ET SEP - AUTO Post ET SEP - Z translation: MPS PRPLT DUMP SEQ - GPC</li> </ul>	<ul style="list-style-type: none"> <li>Prevents ET SEP from occurring until RCS leak is secured (RCS malfunction may not allow proper vehicle maneuver to avoid ET contact after separation)</li> <li>Prevents MPS dump from starting until ET SEP has occurred</li> </ul>

## FAILURE CASES

### I. NO MECO CONFIRMED FLAG

It is important to set the MECO confirmed flag because it allows the ET SEP sequence to begin. The MECO CONFIRMED flag tells the computers that all engines have shut down (this is important to verify in order to avoid propellant depletion while the SSMEs are running). Without the flag being set the software will never start the separation process. The flag is set when the three SSME chamber pressures (PC) are less than 30 percent or two SSME PC's are less than 30 percent with the third SSME indicating a data path failure. After MECO, the crew will check the cues that the MECO confirmed flag has been set by verifying that the three SSME status lights on Panel F7 are lit with red lights and that the DAP (digital auto pilot) lights on panel C3 are lit. If both cues do not indicate MECO CONFIRMED, the crew will push the three SSME shutdown pushbuttons (panel C3) simultaneously or type OPS 104 PRO to the GNC software. This forces the MECO CONFIRMED flag to be set. The software should then proceed with the automatic ET SEP sequence.

### II. AUTOMATIC ET SEPARATION INHIBIT

An "ET SEP INH" fault message indicates that a problem has occurred and the software has stopped processing the nominal automatic ET separation sequence. This fault message may be caused by either excessive vehicle rates or the lack of verification of closure of the 17-in. disconnect valves. If either of these conditions are met, the software will issue the "ET SEP INH" fault message as well as other cues as discussed in section B.

The crew procedure for an ET separation inhibit is found in the Flight Data File (FDF) Ascent Checklist on the Ascent Procedures page (shown in Figure 2.2.5-II). If the "ET SEP INH" fault message is displayed on the fault message line, the crew will first take the ET SEP switch to the MAN position to enable the crew to control ET separation while they perform the troubleshooting steps. For NOM/ATO/AOA trajectories, the crew will also take the MPS Dump Switch to Stop until after separation to avoid performing the MPS dump while separating from the tank. . They will then check the attitude rates of the vehicle. For NOM/ATO/AOA/TAL, if the rates are larger than 0.7 deg/sec, the crew will null the rates with the reaction control system (RCS) thrusters. When the rates are under the required 0.7 deg/sec, the crew will push the ET SEP pushbutton and jettison the tank.

If the rates are already within limits, the crew will assume a feedline failure if the 17 inch disconnect valve. The crew will then then transition to MM 104 via an OPS 104 PRO in order to set-up OMS burn targets. A disconnect failure can be caused by an actual valve failure or failure to receive closed indications from the valve. ET separation is inhibited for a disconnect failure because if the valves are failed open and ET separation is attempted, the thrust created by the propellants escaping from the ET may cause the ET and Orbiter to collide during the separation sequence.

The Shuttle has redundant ways of closing the disconnects. First, in the closure sequence, the software commands the disconnect latch unlocked. The software will check for 3 of 4 lock and

unlock position indications from each of the latches (both LO<sub>2</sub> and LH<sub>2</sub>). If these checks are passed, the software pneumatically closes the disconnects (both ET and Orbiter halves) and retracts the umbilical. If the latch checks are not passed, the umbilical is retracted and the disconnect valves (both ET and Orbiter halves) are closed by the backup mechanical device. After umbilical retraction, the software checks that at least one of the two closed indications is present (both LO<sub>2</sub> and LH<sub>2</sub>). If a disconnect closed indication is present at the start of the ET SEP sequence, it is disqualified for use during the disconnect check. The disconnect checks are only done on the Orbiter half of each valve because no instrumentation exists on the ET half of the valve after umbilical retract. If the disconnect valve closed indication check fails on either the LO<sub>2</sub> or LH<sub>2</sub> valve, it is assumed failed open and the separation sequence is inhibited. One of two indicators must be verified closed to pass the position check on both the LO<sub>2</sub> and LH<sub>2</sub> disconnects.

The following failure combination cases may cause the loss of GPC commanding to the disconnect valves, but the valves should still close with the backup mechanical retract:

1. MDM FA2 and MDM FA4
2. MDM FA2 and MDM FA3
3. MDM FA3 and MDM FA4
4. MN C (APC 3) and MN B (APC 2)
5. MN B (APC 2) and MDM FA3
6. MN C (APC 3) and MDM FA2
7. MN C (APC 3) and MDM FA4
8. MN C (APC 3) and MN A (via power fail of MDM FA4)
8. ESS 3AB (AP&LC3) and MN C (APC 3)
9. ESS 3AB (AP&LC3) and MDM FA2
10. ESS 3AB (AP&LC3) and MDM FA 3

The separation sequence will be inhibited for loss of telemetry from the 17 in. disconnects. The following combinations of failures will cause the separation sequence to be inhibited because they cause both closed indications on either valve to fail:

Failure of the LO<sub>2</sub> disconnect indications:

1. MDM FA2 or BCE STRING 2 D, and MDM FA3 or BCE STRING 3 D
2. Control bus BC1 and control bus CA1

Failure of LH<sub>2</sub> disconnect indications:

1. MDM FA2 or BCE STRING 2 D, and MDM FA4 or BCE STRING 4 D
2. Control bus BC1 and control bus CA1

The valves themselves may be closed but these combinations of failures mask the closed indication. Since no insight is available, the software will assume that the valve in question is



failed open and ET separation will be delayed. If disconnect indications are recovered and indicating closed, then at the Booster's discretion, the crew can be called and given a go for ET separation.

Note that Control Bus CA1, CA3, BC1, or BC3 failures may be identified via missing feedline disconnect microswitch indicators on the Bilevel MPS console display. In these cases, the Booster operator should inform the EGIL operator of the status of the bus at the 17 in. disconnect location.

For a failed open disconnect, ET separation will be delayed for 6 minutes on a nominal/ATO mission (reference Flight Rule A5-202, Ref. 2), shown in Figure 2.2.5-II. This time period will allow the ET to vent to an ullage pressure which equates to less than 1800 lb thrust out of the failed open disconnect valve. The automatic MPS dump will be performed during the 6 minute delay unless an OMS-1 burn occurs within the six minute time period. In this case, the MPS dump switch will be placed in the STOP position until after ET SEP because propulsive forces generated by the MPS dump could cause ET/Orbiter recontact. ET SEP will be manually commanded 1 minute and 30 seconds prior to the OMS-1 burn or at MECO + 6 minutes, whichever ever comes first (reference Flight Rule A5-202, Ref. 2). For the case of the LO<sub>2</sub> disconnect failure, the MPS LO<sub>2</sub> manifold repress, that nominally occurs at dump start, will be automatically skipped to prevent the overboard loss of helium through the failed 17-in. disconnect. This helium may be necessary later in flight for entry purges.

Note that per Flight Rule A5-202 and A10-243, a bottom-sun orientation will be required for thermal conditioning in the cases when ET Sep is delayed to MECO + 6 minutes. The Booster operator should coordinate the requirement with the MMACS operator.

For RTLS and TAL missions, time criticality requires that the ET separate as soon as possible. The ET is automatically separated for RTLS missions after a 6-second delay and for TAL missions after a 15 sec delay.

#### A. Flight Rules

1. A5-202, ET SEPARATION INHIBIT FOR 17-INCH DISCONNECT FAILURE
2. A5-204, MANUAL MPS DUMP
3. A10-243, ET UMBILICAL DOOR CLOSURE DELAY FOR DISCONNECT VALVE FAILURE

From **ASCENT PROCEDURES**, pg. FB 2-5

MECO	$\sqrt{V_I} = \boxed{25819}$	
MECO+20 s	$\sqrt{ET\ SEP}$	

```

* If 'SEP INH':
*   ET SEP – MAN
*   If Rates > .7,.7,.7:
*     MPS PRPLT DUMP SEQ – STOP
*     Null rates
*     ET SEP – SEP
*     Post ET Sep -Z xlation:
*       MPS PRPLT DUMP SEQ – GPC
*   If Rates < .7,.7,.7:
*     Assume Feedline Fail
*     If VI <  $\boxed{25760}$  or BFS Engaged:
*       OPS 104 – PRO ( $\sqrt{BFS\ 104}$ )
*     NOTE: Expect – 'Illegal Entry' (PASS)
*           'Illegal TIG' (BFS)

```

From **OMS 1 BURN**, pg. FB 2-8

```

* IF TIG LATER THAN MECO + 6 min:
*   MECO + 4 min:  $\sqrt{BDY\ FLP\ pb}$  – It off (MPS dump complete)
*                  $\sqrt{MCC}$  for APU shutdn (if time permits)
* FEEDLINE FAIL:
*   Expect 'Illegal Entry' (PASS)/'Illegal TIG' (BFS) @ tgt select
*   pre ET Sep; input TIG manually & LOAD tgt
*   If TIG > MECO + 6 min:
*     TIG-1:30 or MECO + 6 min (whichever comes first):
*     ET SEP – SEP >>
*   If TIG < MECO + 6 min:
*     MPS PRPLT DUMP SEQ – STOP
*     TIG-1:30: ET SEP – SEP
*     Post ET SEP -Z xlation:
*     MPS PRPLT DUMP SEQ – GPC
* 1 OMS ENG FAIL and  $\Delta VTOT > 500$ :
*   Burn good OMS + l'cnct both OMS to RCS, THC +X at TIG

```

From **POST OMS 1 PROCEDURES**, pg. 3-2

P	<b>MPS DUMP complete</b>
F4	$\sqrt{BDY\ FLP\ pb}$ – It off (MECO + 4 min) (12:24 Nom)

```

* C   If no pitch rate,
*     P – DISC
*     Pitch up at 2°/sec until ET
*     in O/H window (P ~100°)

```

Figure 2.2.5-II – Crew Procedures for ET SEP Failures from Ascent Checklist (Ref. 3)

B. Crew Operations

The fault messages generated for ET SEP failures that are displays on the cockpit CRTs are shown in Table 2.2.5-II, and a matrix of the failure indications and procedures is listed in Table 2.2.5-I.

TABLE 2.2.5-II – CRT FAULT MESSAGES GENERATED FOR ET SEP FAILURES

<b>Message</b>	<b>Type</b>	<b>Displayed on</b>
SEP INH	FLASHING	BFS ASCENT TRAJ 2
SEP INH	STATIC	PASS ASCENT TRAJ
ET SEP INH	STATIC	PASS/BFS FAULT MSG LINE

C. Crew Procedures

The crew procedures from the Ascent Checklist (Ref. 3) for handling ET SEP failures are shown in Figure 2.2.5-II.

III. FAILURE OF THE ET SEP SWITCH, RESULTING IN SWITCH RM DEFAULTING TO THE MAN POSITION (I.E. “ET SEP MAN” FAULT MESSAGE FROM SOFTWARE IN OPS 1 ONLY)

The ET SEP switch position is polled by RM and performs two out of three voting for the switch position. If the RM does not have at least 2 votes available, the switch will be in dilemma. If this happens, the RM will inhibit processing on the ET SEP sequence for nominal/ATO missions and issue the “ET SEP MAN” fault message. For RTLS and TAL aborts , the RM logic defaults to auto (giving “ET SEP AUTO” fault message) to allow for quick separation of the ET during a time critical abort phase. If the dilemma occurs before RTLS or TAL is declared, the sequence will default to manual until the abort is declared and then the software will default to auto with an annunciation of the “ET SEP AUTO” fault message.

A triple pole switch is used for the ET mode switch and the ET SEP pushbutton. As shown in Figure 2.2.5-III, the mode switch employs three contacts, each one powered from a separate 5 V source: Dedicated Signal Conditioners (DSC) OF1, OF2, or OF3. In the MAN position, the mode switch supplies the 5V DC signals to the SEP pushbutton, which also goes through two-out-of-three voting logic.

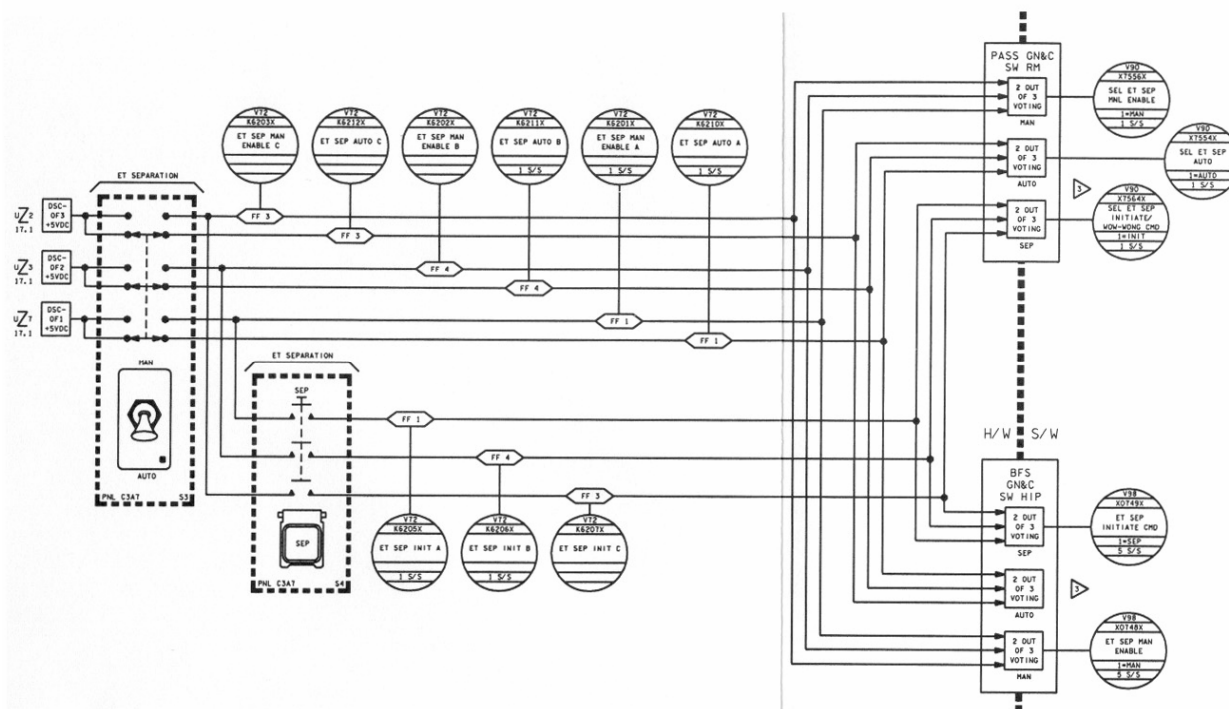


Figure 2.2.5-III - ET SEP Switch Hardware/Software Diagram (Ref. 1)

Operationally, the way to tell if the switch failed RM and defaulted to man (verses the crew moving the switch) is to notice both the ET SEP MAN indication on the DDD panel and the “ET SEP MAN” fault message on OFS (Orbiter Fault Summary). If the crew intentionally took the switch to manual then no fault message would occur. It is important to watch out for DSC failures. Certain DSC failures will cause a number of erroneous RCS leak fault messages to occur and scroll the “ET SEP MAN” fault message off the OFS screen as well as the crew display.

When the switch defaults to MAN, the pushbutton is more than likely bad as well, therefore an alternate method of initiating ET separation is required and is located in the AESP “ET SEP MAN” procedure (see Figure 2.2.5-IV). Software override capability the ET SEP switch is provided on SPEC 51 in both the PASS and BFS (refer to Figure 2.2.5-V). Per Step 1 of the procedure, entering item 38 (PASS) (item 28 BFS) will start the automatic ET SEP sequence, and the ET separation will occur immediately. This item entry is routed directly to the GNC Switch RM, forcing its output to AUTO.

The ET SEP switch AUTO position is not monitored by the BFS. If the PASS detects a pre-BFS engage switch dilemma, it will default the switch to MAN and display the "ET SEP MAN" fault message. If the BFS is subsequently engaged, the manual position can be overridden by item 28 on SPEC 51.



The following two cases are situations where the crew will intentionally move the ET SEP switch to MAN. First, the crew checks for ET SEP at MECO +21 seconds. If an ET SEP INHIBIT occurs, the software will inhibit the ET SEP sequence and the crew will take the ET SEP switch to MAN as part of their procedure used to get off the tank. The crew will not perform the ET SEP switch to MAN on an RTLS or TAL because the software will automatically command ET SEP after a 6 second (RTLS) or 15-second (TAL) delay timer expires. If an ET SEP INHIBIT occurs, the crew will check if rates are out of limits. If rates are out of limits, the crew will take the ET SEP switch to MAN, null the rates, and then manually separate from the tank after the MPS dump is complete. If rates are in limits, the crew will “assume feedline fail” and work the FEEDLINE FAIL procedure.

Second, the crew will take the ET SEP switch to MAN if an RCS leak occurs pre-MECO as part of their forward and aft RCS leak procedures in the AESP (Ref. 5). Post-MECO and after the RCS leak has been secured, the crew will return the switch to the AUTO position to allow the software to proceed with the ET SEP procedure. These actions will not be done for the RCS leak case for the RTLS due to time criticality.

Note that while working an aft or forward RCS leak procedure in the AESP, in addition to the ET SEP MAN switch throw, the crew will also take the MPS PRPLT DUMP SEQUENCE switch to STOP. The crew will move the switch back to GPC to complete the RCS leak procedure after ET Separation. During these switch throws the Booster team should coordinate with the PROP team to track the procedure’s progress.

## REFERENCES

1. Space Shuttle Systems Handbook, JSC-11174, Revision G, DCN-1.
2. STS Operational Flight Rules, Volume A, All Flights, Final, PCN-3, JSC-12820, January 13, 2003.
3. Flight Data File - Ascent Checklist, STS-114, Final, Rev A, January 25, 2005.
4. SODB, Vol I, Paragraph 3.4.3.1, Figures 3.4.3.1-8 and 3.4.3.1-9.
5. Flight Data File – Ascent/Entry Systems Procedure, Generic, Rev L, May 15, 2003.
6. Data Processing System Dictionary, Generic, Rev. K, June 14, 2004.

## TITLE

### SSME SHUTDOWN MODE AND HELIUM PRESSURE REQUIREMENTS

## PURPOSE

This SCP discusses SSME shutdown modes, shutdown helium pressure requirements, and helium time-of-depletion (TOD) numbers and shutdown pressures output by the Helium computation of the Booster Operational Support Software (BOSS). For the purposes of this document, shutdown mode refers to how an SSME will shutdown (e.g. pneumatically or hydraulically), not the method by which the crew or engine controller commands the engine to shutdown (e.g. AC/PB or redline). The procedure for SSME helium leak recognition, isolation, interconnects, and shutdown is addressed in SCP 2.2.7.

Because knowledge of engine shutdown mode and shutdown pressure requirement is required in the helium leak isolation and interconnect procedures, awareness of the shutdown mode and shutdown pressure requirements of each of the three main engines should be maintained at all times. It is not necessary that there be a helium leak to determine shutdown mode and pressure requirement.

## Source of helium at SSME shutdown

Unless interconnected to the pneumatic system or another engine helium system, each SSME will shutdown using only the helium stored in its own helium system. Do not confuse the helium stored in the pneumatic accumulator with the helium stored in the engine bottles. Helium in the pneumatic accumulator only functions to close the prevalues at MECO, and can never be used to shutdown the SSMEs.

## Shutdown Modes

There are two shutdown modes available: (a) hydraulic shutdown, and (b) pneumatic shutdown. In the hydraulic shutdown mode, hydraulic pressure from the orbiter hydraulic system is used to close the appropriate SSME valves at shutdown. In a pneumatic shutdown mode, helium from the engine bottles is used to close the appropriate SSME valves at shutdown. The SSME engine controller determines the appropriate shutdown mode and configures the SSME pneumatic control assembly (PCA) appropriately so that the appropriate shutdown is executed.

Helium is also used to pressurize the pogo accumulator during any shutdown. This assists the shutdown by supplying artificial pump head pressure on the HPOTP to prevent cavitation. A final use of helium during any shutdown is to support various engine purges.

### Helium Pressure Requirements To Support Shutdown

Associated with each of the shutdown modes are helium system pressure requirements. These requirements are influenced by the type of shutdown and the conditions under which that shutdown occurs.

(1) Type of shutdown

A higher helium supply pressure is required to support a pneumatic shutdown than a hydraulic shutdown because hydraulic fluid pressure is not used to move the SSME valves during the pneumatic shutdown. The absence of hydraulic pressure is compensated for by increased helium usage. Since the helium system is a blowdown system, this higher usage equates to a higher initial pressure requirement in the engine helium bottles.

(2) Conditions of shutdown

Helium system pressure requirements to support a shutdown are not only influenced by the shutdown mode but also by when an engine is shutdown — either pre-MECO or at MECO. More helium is required to support engine shutdown when the shutdown occurs as vehicle acceleration is dropping to zero (as at MECO) than is required for a shutdown occurring when one or more other engines are operating (pre-MECO shutdown). This requirement is independent of the controller selected shutdown mode (pneumatic or hydraulic). Because helium is used to prevent HPOTP cavitation, more helium is required to supply artificial head to the pump as acceleration is dropping to zero at MECO than is required if the vehicle is under acceleration. Thus helium pressure requirements are higher for a shutdown occurring at MECO. A shutdown at MECO as vehicle acceleration is dropping to zero is called a “zero-G shutdown”.

Given the above discussion, four combinations of shutdown conditions and shutdown modes are possible. These are: (1) Zero-G, pneumatic shutdown; (2) Zero-G, hydraulic shutdown; (3) Pre-MECO Hydraulic Shutdown; and (4) Pre-MECO Pneumatic Shutdown. Of these, the zero-G, hydraulic shutdown is not treated in console operations because this shutdown mode has not been formally treated in analysis of the helium system as documented in the MPS Helium Letters. Instead, the zero-G, pneumatic shutdown (which has almost the same requirement as the zero-G hydraulic shutdown) is treated and is commonly referred to as simply a “zero-G” shutdown. Since a zero-G pneumatic shutdown requires more helium pressure than a zero-G hydraulic shutdown, all booster computations assume that a shutdown at zero-G will occur pneumatically, but if the shutdown occurs hydraulically at zero-G, there will still be enough helium to support.

Note that in commonly used terminology, the term “pre-MECO” is dropped when referring to the pre-MECO hydraulic and pre-MECO pneumatic shutdowns. These shutdown types are simply referred to as a “hydraulic” or “pneumatic” shutdown.



A zero-G shutdown is the nominal shutdown mode of all three SSMEs at MECO and requires the most helium of each of the modes. A pneumatic shutdown requires more helium than the hydraulic shutdown but less helium than the zero-G shutdown.

The interface pressure requirements are shown in Table 2.2.6-I and must be protected to support zero-G, pneumatic, and hydraulic shutdown requirements for the case of nominal helium system operation (two regulators and no helium leaks). The interface pressure is the pressure measured at the SSME helium inlet upstream of the PCA. These requirements are protected by protecting an appropriate helium supply tank pressure upstream of the interface. The supply bottle pressures needed to protect the interface pressure requirements are greater than the interface requirements due to pressure drops in the system, and are also shown in Table 2.2.6-I.

Table 2.2.6-I. Nominal Helium Interface Pressure Requirements for Block II SSME with two Regulators. (Does not include instrumentation error) (Ref. 2)

<b>Shutdown Mode and Condition</b>	<b>Interface Pressure Requirement at Shutdown</b>	<b>Equivalent Bottle Pressure Requirement at Shutdown</b>
Zero-G (pneumatic)	630 psia*	1290 psia
Pneumatic	529 psia*	1080 psia
Hydraulic –Block II SSME	576 psia	639 psia

\* - Shutdown requirement defined at Shutdown Command + 7 sec

Note that equivalent bottle pressure requirements at shutdown listed in Table 2.2.6-I do not account for any effects of interconnecting additional helium tanks. As described in detail in SCP 2.2.7, an engine helium system with a leak may be interconnected to the pneumatic helium system or another engine’s helium system (see Figure 2.2.6-I). In this case of interconnected systems, the equivalent bottle pressure requirement at shutdown would actually be decreased because of the additional volume of helium supply provided for shutdown. The actual amount of conservatism inherent for the interconnected case is unknown. The increased requirements of the “pneumatic-only” numbers in Table 2.2.6-II are a good example of how smaller available helium volumes require greater pressure for safe shutdown.

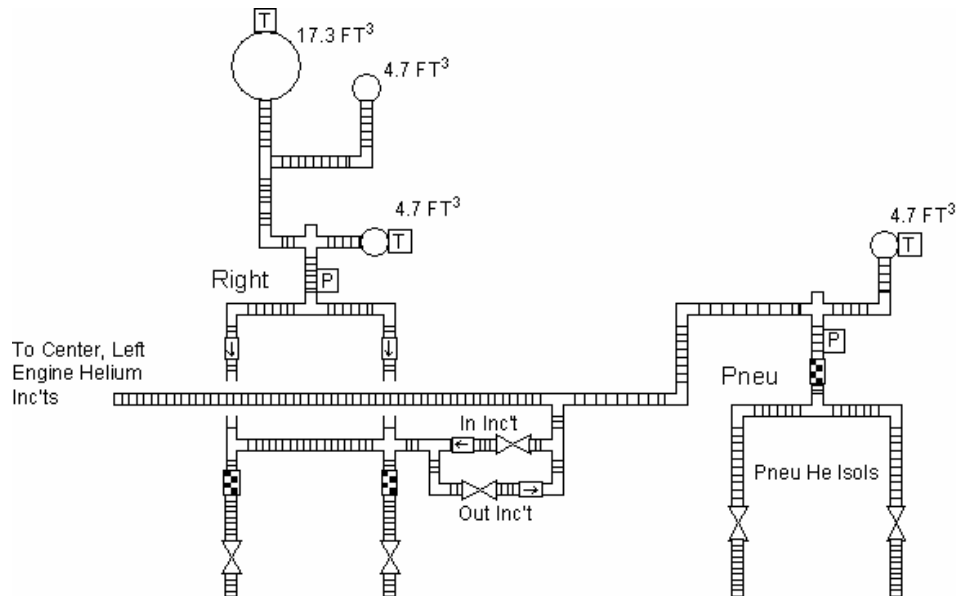


Figure 2.2.6-I: Right Engine and Pneumatic Helium System Interconnects

For the cases of lower system leaks and non-tank upper system leaks (reference SCP 2.2.6), the required pressures are given in Figures 2.2.6-II and 2.2.6-III. The required pressure is a function of total helium usage rate (leak rate + nominal usage rate). If a leaking helium system has a tank leak and helium from the pneumatic system or engine system is interconnected to this system, usage from the interconnected system will equal the nominal engine helium system usage (about 0.040 lbm/sec). Check valves in the helium system will prevent helium from the interconnected system from entering the leaking tank, effectively cutting off the leak.

For the case of a tank leak in which the pneumatic system alone is used to support engine operation, the required pneumatic tank pressures are given in Table 2.2.6-II. The “3 engines to shutdown” number is based on the pneumatic system being interconnected to all three SSMEs, with one engine requiring a pneumatic only shutdown. This number would be used when the pneumatic helium system has been either manually interconnected to multiple engines, or will be automatically interconnected at MECO because those engines have a tank pressure that is below 2000 psia or is commfaulted. The “1 engine to shutdown” number is based on the pneumatic system being interconnected only to the engine requiring a pneumatic shutdown (the more likely situation). See Reference 3 for more details.

For the case of single regulator operations, the required engine tank pressures are provided in Table 2.2.6-III. No requirements have been developed for the case of a closed helium system isolation valve with a leak because this case is considered too remote (single regulator + leak case).

NOTE: All of the shutdown requirements shown in the table and figures below do not include the instrumentation error. If manual shutdown is required to protect the minimum shutdown pressure requirement, the MPS and BSE operators must also protect for an instrumentation error

on top of the shutdown pressure requirement for the given shutdown mode. The current instrumentation error for the helium tank pressure sensor is 20 psia.

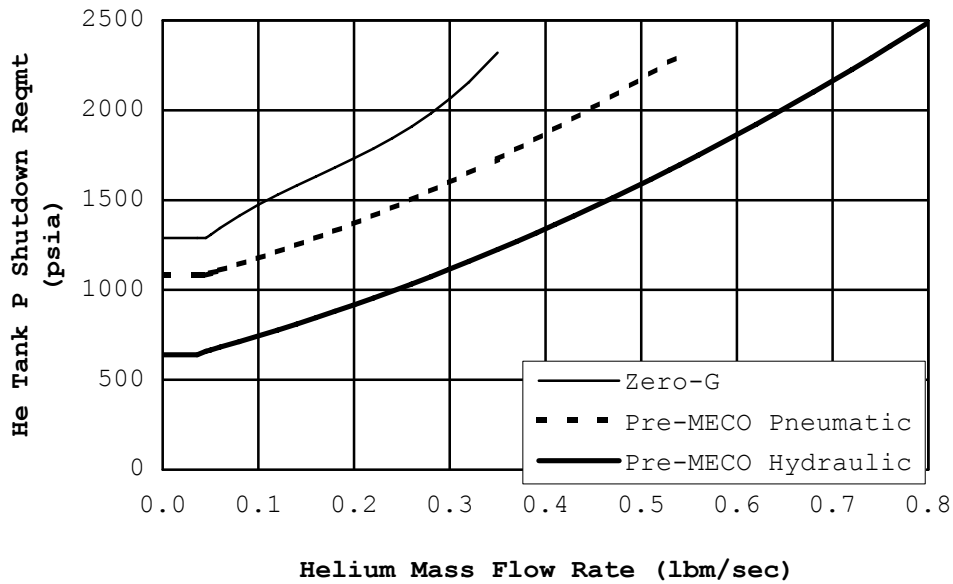


Figure 2.2.6-II. - Minimum helium bottle pressure for SSME shutdown with lower system leak. (Does not include instrumentation error.)

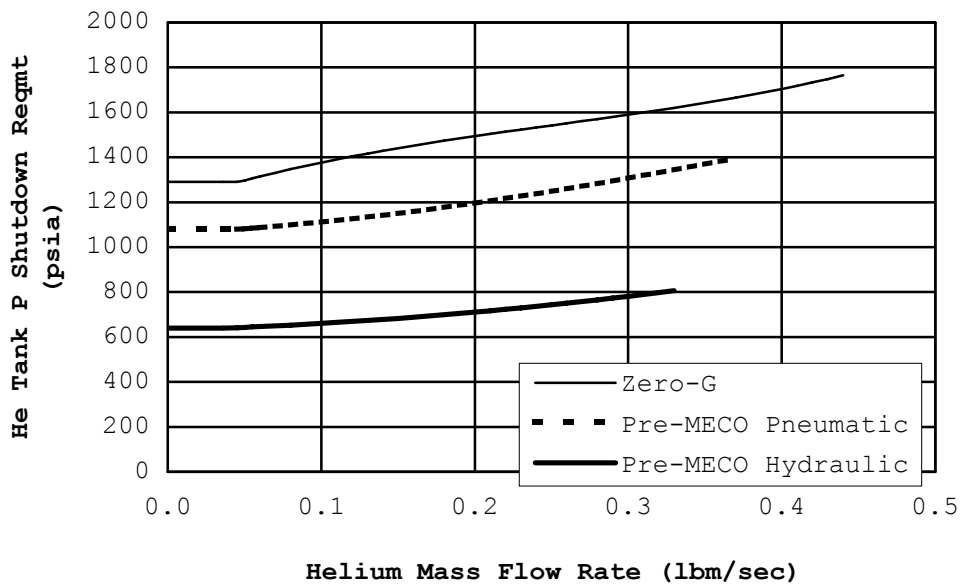


Figure 2.2.6-III. - Minimum helium bottle pressure for SSME shutdown with upper system leak. (Does not include instrumentation error.)

Table 2.2.6-II. Required pneumatic tank pressures to shutdown an engine with a tank leak.  
 (Does not include instrumentation error.)

<b>Shutdown Mode and Condition</b>	<b>Pneumatic Tank Pressure Requirement</b>
Zero-G (pneumatic)	2800 psia (3 engines to shutdown) 2357 psia (1 engine to shutdown)
Pneumatic	2036 psia
Hydraulic - Block II SSME	639 psia

Table 2.2.6-III. Required engine tank pressure to shutdown an engine operating on a single regulator with no helium leak. (Does not include instrumentation error)

<b>Shutdown Mode and Condition</b>	<b>Engine Tank Pressure Requirement</b>
Zero-G (pneumatic)	1963 psia
Pneumatic	1457 psia
Hydraulic - Block II SSME	679 psia

BOSS Output of Shutdown Pressure Requirements and Helium Time-of-Depletion

The Helium computation, part of BOSS, produces several outputs that are used to determine if a SSME helium system will support a particular shutdown mode and are displayed on the mps\_ascent display. The Helium computation outputs the helium shutdown pressure requirements (in units of psia) for zero-G, pneumatic, and hydraulic shutdowns based on the helium usage. The derivation of the Helium computation software and necessary constants are outlined in reference 4. The software always displays the corresponding time-of-depletion (TOD) times for each engine system. The first of the TODs gives the projected time-of-depletion in mission elapsed time (MET) assuming a zero-G (zero-G, pneumatic) shutdown; the second, a pneumatic shutdown; and the third, a hydraulic shutdown.

Nominally, these TODs are computed assuming no leak, but in the event of high-usage the Helium computation selects a leak type (upper system or lower system) and adjusts the TODs to account for the leak. The leak type can also be selected manually using the MENU display. If a leak is isolated to the A or B leg, or if the A or B isolation valve closes for any reason (e.g. a power bus failure), the software will compute and display TODs assuming single regulator operation of the engine (single regulator mode) as long as the helium usage is less than 0.055 lbm/sec. The shutdown TODs represent the MET at which the shutdown pressure requirement for a particular time of shutdown will be violated. The shutdown TODs are obtained by calculating the time it will take to reach the shutdown pressure requirements given in Figures 2.2.6-II and 2.2.6-III and adding the time to the present MET. As a backup to the Helium TOD computation, the minimum shutdown pressures can be determined from the mass flow rate and Figures 2.2.6-II and 2.2.6-III.

Tank leak TOD information is displayed below the pressure measurements for the pneumatic tank and pneumatic accumulator. These TOD's give the pneumatic tank depletion time for zero-G, pneumatic and hydraulic shutdowns. The Helium computation does not determine if the leak is a tank leak or an upper system; therefore, it is up to the operator to choose the correct TOD's. In the tank leak case, the TOD's under the pneumatic tank will give the correct information whereas the TOD under the leaking tank will give you the TOD for the tank to deplete out to space (obviously incorrect - reference SCP 2.2.7). The TOD's under the pneumatic tank are not valid for any leak case other than a tank leak. As a general rule after interconnecting the pneumatic system to an engine helium system with a tank leak, approximately 1 minute of engine run time remains until zero-G requirement violation, 2 minutes until pneumatic requirement violation and 3 minutes until hydraulic limit violation.

As an example, Figure 2.2.6-IV shows the mps\_ascent display and Figure 2.2.6-V shows the menu display for the case of a lower system leak. The total helium usage rate on the center engine is 0.114 lbm/sec . For this type and rate of leak, the figure shows the helium shutdown pressure requirements are 1514 psi for a zero-G shutdown, 1201 psi for a pneumatic shutdown, and 767 psi for a hydraulic shutdown. The mps\_ascent display shows that these shutdown pressure requirements result in helium TODs (in MET) of 8:23 for a zero-G shutdown, 9:14 for a pneumatic shutdown, and 10:34 for a hydraulic shutdown. The software shows "LOWER" on the menu display selection bar for Leak Type to indicate that the leak type is a lower system leak. In addition, a letter "L" is placed on the mps\_ascent display for "LKType". Since the menu display selection bar for Interconnect shows "Pneu", the TOD's assume interconnection of the leaking system to the pneumatic as indicated by the letter "P" on the mps\_ascent display next to the leak type.

It is important to configure the leak type and interconnects properly on the menu display because the shutdown pressure and TOD computations rely on the configuration being accurate. For example, interconnecting additional helium will increase the TOD. Leak types, interconnection and shutdown methods procedures are discussed in SCP 2.2.7.

mps_ascent.new									
HE TANK P		L 4296		C 4303		R 4300		P 4404	
INTERCONNECTS									
ISO A/B OP PWR 0/- 0/- 0/- 0/- 0/- 0/- 0/- 0/-									
REG A/B P 751 739 756 749 751 747 766									
HPOT IMSL P 186 186 179 179 187 188 Accum P 759									
BFS DP/DT		9984		9984		9984		0.002	
COMP Mdot		0.000		0.000		0.000			
LkType/Intcnct / / / /									
Recomnded SHDN									
ZG TOD/SHDN P		00:00 0		00:00 0		00:00 0		00:00 2800	
PN TOD/SHDN P		00:00 0		00:00 0		00:00 0		00:00 2036	
HYD TOD/SHDN P		00:00 0		00:00 0		00:00 0		00:00 639	
MID/AFT TK T		80 / 23		80 / 23		80 / 20		-/ 33 TOT HE M	
HE MASS		70.86		70.97		70.99		13.62 226.44	
PWR LVL 100		D		D		D		LO2 LH2	
FCV		-LO2- VENT X		HIFL -		-LH2- VENT -/X		PV OP O 000 ---	
GH2 OUT P		0 0 0		-		-		PV CL X --- XXX	
DISCONNECT P		40		40		40		FD DSC 00-- 00--	
ULLAGE P		20.4 20.1 20.3		41.8		41.8 41.9		FD LTCH LL-- LL--	
NPSP				D		D D		RLF ISO -X -X	
MANIFOLD P		94		43				IB F/D -X -X	
INLET P		107 103 104		46		48 50		OB F/D 0- 0-	
IN T/LPFT P		-283.3 -283.8 -283.5		51		52 52		OVV/TOP 0- -X	
PROP REM		D 5 CO WWWW		D 5 CO WWWW				R DSC X -	
-SRB-		LEFT RIGHT		M M				P LN V O -	
IGN S&A		ARM/ M ARM/ M		M M				POGO1/2 --XX	
PC 1		9 7		M M				BU DMP IB/OB -X/-X	
PC 2		11 7		M				MN P120 - -	
PC 3		7 9		M				RTLS RPRSS12 - -	
FSM P RCK/TLT		388 / 384 391 / 387		SWITCH PB CMD				BLOWDOWNS - -	
TRBSPD RCK/TLT		0.2 / 0.2 0.2 / 0.2		-SRB- AUTO/---		---		---	
HYD P RCK/TLT		21 / 21 L/ 21		-ET- AUTO/---		---		---	
PRI P RCK/TLT		FAIL/ FAIL FAIL/ FAIL		THROT AUTO/---		MEC1/2 ON /ON		>-	
ISP data server connection established									

Figure 2.2.6-IV. - BOSS processing of a helium system leak on the mps\_ascent display.

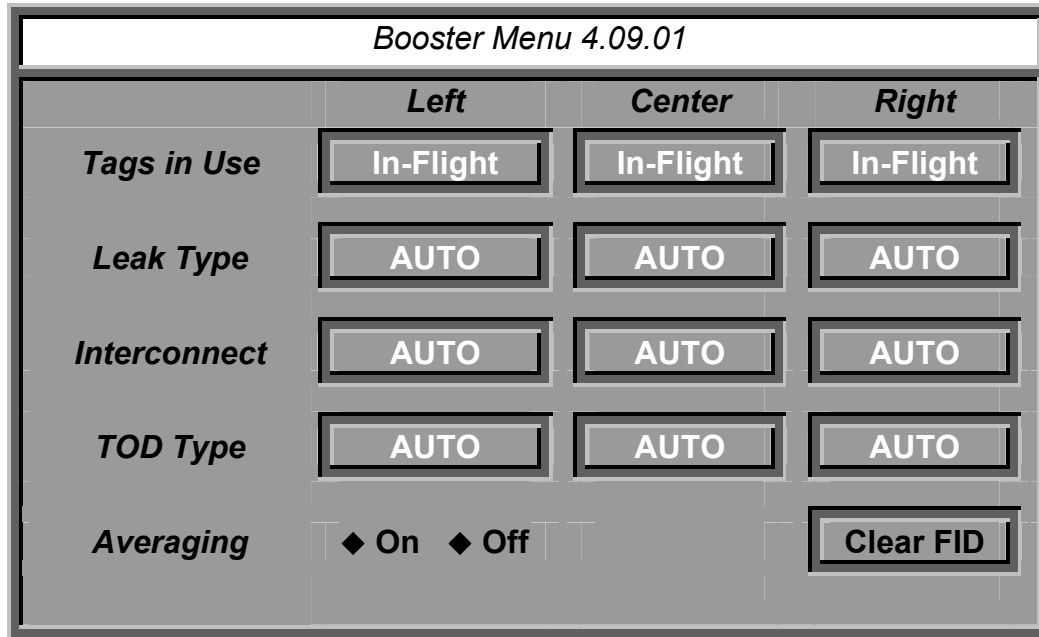


Figure 2.2.6-V. - BOSS processing of a helium system leak on the MENU Selection display.

REFERENCES

1. STS Operational Flight Rules, Volume A - All Flights, November 21, 2002, PNC-1, JSC-12820
2. Rockwell International Internal Letter 287-100-95-179, "Response to SODB Request R1-1640 "MPS He Tank Pressure vs Flowrate for Safe SSME Block I Shutdown", 11/30/95 from Charles J. Sosa to R. C. Hsu.
3. Rockwell International Internal Letter 287-104-89-035, "MPS Helium Leakage Curves to Support Flight Rule 5-28, STS-28," 8/28/89 from M. C. Ventura/M Hagen to S. Cavanaugh.
4. Derivation of BOSS Input Constants, Rev. D, May 4, 2002.

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## TITLE

HELIUM LEAK ISOLATION/EVALUATION/INTERCONNECTION

## PURPOSE

This SCP describes the MCC actions and procedures for recognition and isolation of MPS helium leaks. Additional covered topics include the evaluation of leak types, the assessment of interconnect options to gain additional engine run time, and the determination of the appropriate shutdown method. For purposes of this document, the shutdown method refers to the method by which the crew or the SSME engine controller will shut an engine down (nominal, AC/PB, redline, etc.). The shutdown mode refers to how the SSME will shutdown (pneumatically or hydraulically). SCP 2.2.6 provides an in-depth discussion of shutdown modes and helium requirements. This SCP assumes the reader has a thorough understanding of that material.

## DESCRIPTION

### Isolating leaks

The nominal helium usage per SSME during mainstage is 240 SCFM (0.042 lb/sec). This equates to an approximate helium tank decay rate (dP/dt) of 10 PSI per 3 seconds. The MCC monitors these rates along with the tank pressures and temperatures, the downstream regulated (helium regulator) pressures, helium system valve positions, and the helium time of depletion (TOD) for each engine to ensure normal usage. The crew has the ability to monitor the tank and regulator pressures and the dP/dt, but relies on the Caution and Warning (C&W) system to alert them to off-nominal helium usage. SCP 3.7 provides further information on the C&W alerts that are provided for the SSME tank and regulator pressures and dP/dt.

Above normal helium usage is most readily detectable by an increase in dP/dt (above 20 psia per 3 sec) and the computed mass flowrate (above 0.055 lb/sec after 1 minute MET). Flight Rules A5-10, Significant Engine Helium System Leak, and A5-11, Significant Pneumatic System Helium Leak, define the criteria for calling engine and pneumatic system helium leaks (Ref. 1). A rapid decrease in helium temperature also indicates a leak; however, small leaks may not be detected as quickly. Therefore the tank temperature is only used to monitor system health in the event of the loss of the helium tank pressure transducer.

If a helium leak is detected, the ground will instruct the crew to begin working their helium leak procedure to attempt to isolate the leak. If dP/dt is available and the C&W is annunciated, the crew will begin working the procedure without waiting for the ground call. The crew will use the cue card in their Ascent Entry Systems Procedures (AESP) Flight Data File (FDF) as shown in Figure 2.2.7-I to attempt leak isolation. After first confirming that there is off-nominal helium usage ( $\sqrt{\text{dP/dt}}$ ), the crew needs to determine if there is sufficient time to work the isolation procedure. Per Flight Rule A5-153, Pre-MECO Shut Down of Engines Due to MPS Helium

Leaks, if a helium leak occurs within 60 seconds of MECO, there is insufficient time to work the isolation procedure and properly configure the system for a zero-g shutdown. Therefore, the affected engine must be shutdown pre-MECO.

<b>MPS He P (Pre MECO)</b>
1. $\sqrt{dP/dT}$
If after MECO -60
2. Shut dn MN ENG per MPS CMD/HYD/ELEC >>
If He REG P $\uparrow$ or $\downarrow$ :
3. Aff He ISOL - CL
Otherwise:
4. Aff He ISOL A - CL
If no decr in dP/dT:
5. Aff He ISOL A - OP B - CL
If no decr in dP/dT:
6. Aff He ISOL B - OP
If any ENG failed:
7. Failed ENG He I'CNCT - OUT OP
If nonisolatable:
8. Shut dn MN ENG per MPS CMD/HYD/ELEC
If/when TK P < 1150 or REG P < 679:
9. Aff He I'CNCT - IN OP
If isolated:
10. Aff He I'CNCT - IN OP
If TK P < 2200 @ MECO -60:
11. Shut dn MN ENG per MPS CMD/HYD/ELEC
Post ET Sep:
12. He I'CNCT(s) - GPC
<b>MPS PNEU TK(REG) P</b>
If after MECO -60:
At MECO-30:
1. L ENG He XOVER - OP >>
2. PNEU He ISOL - CL
If PNEU ACUM P decr:
At MECO -30:
3. PNEU He ISOL - OP, Wait 5 sec, then:
4. L ENG He XOVER - OP >>
If PNEU TK P decr:
5. PNEU He ISOL - OP

Figure 2.2.7-I -AESP Crew Procedure for MPS Helium Leaks (Ref. 2)

If there is sufficient time to work the isolation procedure, the crew will proceed to Step 3 where they check the helium regulator pressures to determine if the off-nominal usage is due to a

regulator shift requiring them to close the proper isolation valve. A pressure reading below 679 psia (↓ arrow on crew's BFS GNC SYS SUMM 1 display) would indicate a possible failed open relief valve, and greater than 810 psia (↑ arrow on crew's display) indicates a possible failed open regulator (Ref. 3). Either of these failures would result in helium being dumped into the aft compartment through the relief valve downstream of the regulator. With the vent doors open the aft compartment will not over-pressurize, but the loss of helium will eventually cause the engine to exceed the Intermediate Seal redline limit and shutdown.

If the crew determines that the high helium usage is not due to a regulator or relief valve failure, they will begin working the helium system leak isolation part of the procedure. Isolation valve A will be closed first (Step 4) and the crew will monitor the  $dP/dt$  to determine if the leak has stopped (i.e. leak isolated). If isolated, the leaking leg's regulator pressure will drop to zero since all of the helium supply to leak has been removed, and the mass flow of the system will return to nominal usage. For the specific case where the leak is upstream of the regulator and downstream the isolation valve, the regulator may not backflow, and the isolated leg may maintain pressure. In this case, the mass flow of the system will be the correct cue to determine if the leak is isolated to that leg.

If the leak cannot be isolated to the leg associated with isolation valve A, then the valve is opened and isolation valve B is closed. When an isolation valve is closed, both regulator pressures should decrease approximately 10-15 psi and increase by the same amount when opened. The crew and ground watch for this during the execution of this procedure to ensure that the A valve reopened before closing the B valve. Closing both isolation valves at the same time will deprive the engine Intermediate Seal purge of helium and force a redline shutdown that may be catastrophic since no helium would be available for the pogo post charge. If the helium leak isolation attempt fails, both isolation valves will be opened to ensure redundant helium paths. The crew will then contact the MCC to determine the interconnect and shutdown plan for the affected engine. If the crew does not have communication with the MCC, they will perform Steps 8 and 9 to perform an interconnect and shutdown.

It is important to note that helium isolation will not be performed if the main or sub-bus powering isolation valve A on the leaking engine fails. The A isolation valve has a single power source, and loss of main or sub-bus power results in the A isolation valve closing. Subsequent closure of isolation valve B during the isolation procedure would result in catastrophic shutdown of the engine. The crew's EPS procedures in the AESP FDF (Figure 2.2.7-II ) for main bus and sub bus failures remind them to not isolate MPS helium leaks on the associated helium system (Ref. 2). This reminder is also called out in the sub bus procedure at the bottom of the figure. Flight Rule A5-151, Pre-MECO MPS Helium System Leak Isolation, instructs the ground to not call for the isolation procedure. The sub-buses powering the A isolation valves are as follows: MN A ALC 1, MN B ALC 2, and MN C ALC 3 for the center, left, and right SSMEs respectively. Note that the ALC 1(2,3) buses are sub buses of APC 4(5,6) respectively, therefore loss of the parent APC bus will also result in the A isolation valve closing.

**MNA or AC1 Multi  $\Phi$** 

1. Do not isolate MPS He C
2. MSTR MADS PWR – OFF
3. AC BUS SNSR (three) – OFF
4. Perform FC SHUTDN (within 9 min), then:

Post MECO:

5. L OMS – sel SEC  $\Rightarrow$

**MNB or AC2 Multi  $\Phi$** 

1. Do not isolate MPS He L
2. MSTR MADS PWR – OFF
3. AC BUS SNSR (three) – OFF
4. Perform FC SHUTDN (within 9 min), then:  $\Rightarrow$

FAILED: S-BD PM 1 (NO PNL, CMD)

**MNC or AC3 Multi  $\Phi$** 

1. Do not isolate MPS He R
2. S-BD PM CNTL – PNL, CMD
3. MSTR MADS PWR – OFF
4. AC BUS SNSR (three) – OFF
5. Perform FC SHUTDN (within 9 min), then:

Post MECO:

6. R OMS – sel SEC  $\Rightarrow$

**AC SINGLE  $\Phi$   $\Rightarrow$** **SUBBUS [APC4(5,6) or ALC1(2,3)]**Do not isolate MPS He C(L,R)  $\Rightarrow$ 

Figure 2.2.7-II – AESP FDF Procedures for Main Bus and Sub-bus loss (Ref. 2)

The helium isolation B switches have dual contacts, while the isolation A switches have one contact each. Therefore, the loss of a single control bus can affect the ability to manually control the A isolation valve. Loss of switch contact power (control bus) on the A isolation valve will not result in the isolation valve closing, but will result in loss of manual control of the valve. An isolation valve open command, applied during launch by the GPCs, prevents loss of control bus switch power from closing isolation valves during main engine operation. This command is removed at the end of the MPS dump. For the B isolation valve, loss of a single control bus will prevent the crew from manually closing the isolation valve, but the valve can still be commanded open.

Note that if a Control Bus is verified failed at the helium isolation switch, the Booster operator should report to the EGIL operator the status of the control bus on panel R2. See SCP 2.2.15 for more details.

Summary of leak isolation procedures:

- A. Use one of the following two cues to confirm engine helium leak:
1. Rapid tank pressure decrease and one of the following:
    - a.  $dP/dt > 20$  PSI/3 seconds
    - b.  $\dot{m} > 0.055$  (after 1 minute MET)
  2. Rapid tank temperature decrease in both the mid and aft body tank bottles
- B. Attempt isolation procedure and identify if the leak is isolatable using the following:  
If MPS He Reg P fail high or low; close affected isolation valve, otherwise:
1. Have crew close A isolation valve and monitor  $dP/dt$  and decay rate
  2. If not isolated to the A leg, open the A isolation valve and close the B isolation valve
  3. If not isolated to the B leg, open the B isolation valve (leak is non-isolatable)

MPS Helium Leak Type Assessment

Once the leak procedure is performed, either the leak will be non-isolatable or isolated to a single regulator. Non-isolatable helium leaks render an engine “suspect” per Flight Rule A5-5 (Ref. 1) and will also require assessment of the leak type. Leaks isolated to a single regulator are a special leak type (even though they aren’t leaking) and are defined as “single reg”. To understand the leak types, one must first understand the different subsystems in the MPS helium system.

The helium system can be divided into four separate subsystems: tank system, upper system, regulator system, and lower system (refer to Figure 2.2.7-III). The upper system starts at the tank and ends at the inlet to the regulator. The tank system is a subsystem of the upper system, and includes only the tanks down to the check valves on the A and B legs. An upper system leak is isolatable only between the isolation valve and the regulator. The lower system starts at the regulator outlet and ends at the engine interface. The regulator system is a subsystem of the lower system, and begins at the regulator and ends at the downstream set of check valves. Lower system leaks are only isolatable in the regulator subsystem.

There are four possible leak types: Single regulator, lower system, upper system (non-tank) and upper system (tank). The single regulator leak type is the easiest to recognize because all that is required is to notice one of the isolation valves is closed (either via the He isolation procedure or electrical bus failure). For a leak isolated to a single regulator, the  $\dot{m}$  and  $dP/dt$  will be nominal. A lower system leak is a leak downstream of the regulators and therefore feeds the leak at a constant pressure. Assuming the leak rate does not change, this results in a constant  $dP/dt$  and mass flow rate, but at higher than normal values. The tank temperatures will also decrease more rapidly (at a constant rate) resulting in temperatures diverging from the other non-leaking tanks. Upper system leaks (non-tank and tank) are defined as any leak above a regulator. Since  $dP/dt$  and mass flowrate are proportional to the unregulated tank pressure, this type of leak results in a decaying  $dP/dt$  and mass flow rate. Lower and upper system leak signatures are

easily recognized on console by viewing the mass flow rate plot and looking for a constant rate (lower leak) or a decreasing mass flow rate (upper system).

Because the two types of upper system leaks (tank or non-tank leak) have the same signature, differentiating between the two is not possible prior to interconnecting to another source of helium. If the leak is in tank system, after interconnecting no helium will be supplied from the leaking system tank to the engine until the pressures from all systems feeding the affected engine equalize. Thus the helium in the tank will eventually be lost. This occurs because the high helium pressure from the other interconnected system(s) will close the check valves located at the downstream portion of the affected tank system, effectively isolating that tank from the rest of the MPS system. Once interconnected, a tank leak will have the signature of the leaking system's tank continuing to bleed down (helium lost) and the interconnected system(s) will have a nominal mass flow rate. If only the pneumatic system is interconnected, then the helium system is now effectively pneumatic tank only, and therefore the pneumatic-tank-only computation TOD should be used. In this case, erroneous shutdown pressure and time cues will result if the console operator reads values from the leaking system's TOD comp instead of the pneumatic-tank-only TOD comp. This results from the calculation being based on the leaking tank decay rate which is leaking out to space instead of being used by the engine.

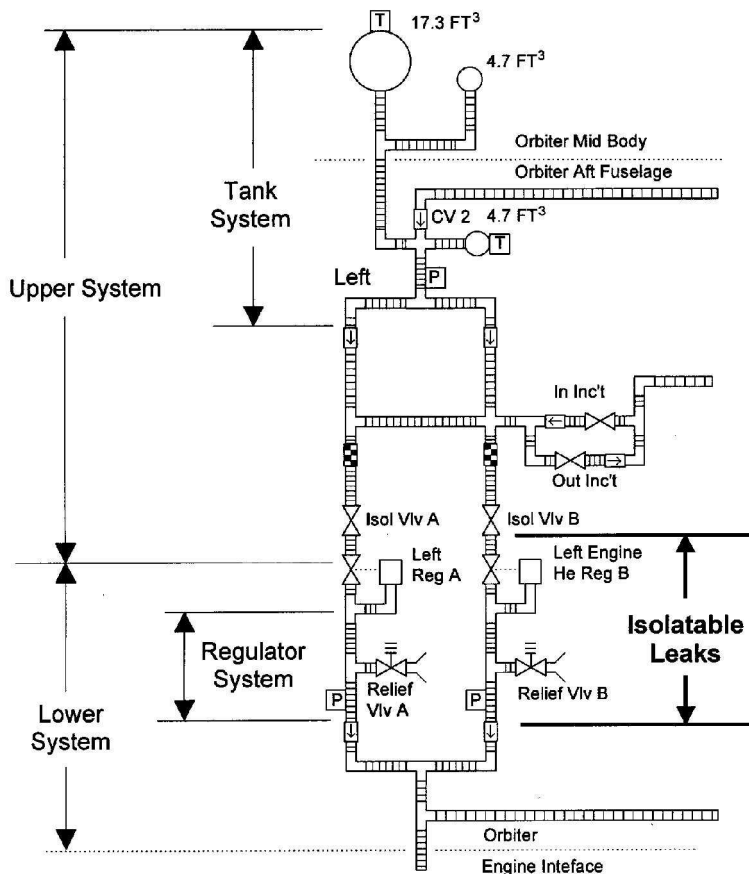


Figure 2.2.7-III - MPS Helium System Leak Types

The signature for an upper system, non-tank leak, is slightly different. After performing the interconnect to an upper system, non-tank leak, the leaking system's tank will stop losing pressure for a short time after the interconnect, and the interconnected systems will indicate higher than normal helium usage due to feeding the affected engine and leak. After the interconnected system's helium pressure equalizes with the leaking system's tank pressure, the check valves in the affected system's tank will open and allow helium from the tank to flow again (feed leak and engine along with interconnected system). Both the leaking system and interconnected system tank pressures will drop off as both tanks feed the leak and engine. Summary of leak type characteristics:

1. Single regulator characteristics
  - a. One isolation valve closed
  - b. Constant mdot and  $dP/dt$  at normal values
2. Lower system leak characteristics
  - a. Constant mdot and  $dP/dt$  at higher than normal values
  - b. Divergence in tank temperature and decreasing at a constant rate.
3. Upper system leak characteristics (before interconnecting)
  - a.  $\text{mdot} > 0.055$  (after 1 minute MET), but decreasing
  - b.  $dP/dt > 20$  for more than 3 seconds, but decreases over time
  - c. Tank temperature diverging, but rate of divergence decreases over time.

Tank leak characteristics (after interconnect):

- a. Tank continues to leak
- b. Nominal helium usage (leak cut off) from interconnected system

Upper System leak characteristics (after interconnect):

- a. Tank pressure constant on affected system until interconnected system(s) equalize
- b. Tank pressure starts again to drop off once interconnected system(s) equalize

### Interconnect Assessment

Engines operating on a single regulator, or engines that have a non-isolatable leak, may require interconnecting to the pneumatic helium supply to satisfy zero-G engine shutdown pressure requirements. A zero-G shutdown will be supported if the zero-G TOD is greater than MECO+30 seconds (additional 30 seconds allows for error in the computations). Interconnects will be performed per Flight Rule A5-152, Pre MECO MPS Helium System Interconnects. In general, engines with lower system leaks or operating on a single regulator may have interconnects performed as soon as practical. To avoid wasting helium in the case of a tank leak, interconnects to a system with an upper system leak are generally performed as late as practical since the leaking tank will be isolated above the check valves, rendering its helium unavailable.

Regardless of the status of the system, interconnects are always performed before the minimum tank pressure or regulator pressure that will satisfy normal engine operation (refer to Flight Rule A5-152). The interconnects in the Flight Rule are based on the minimum shutdown pressures required (refer to SCP 2.2.6). These minimum shutdown pressures were chosen to ensure adequate shutdown purges, maximize helium usage prior to interconnecting and prevent the SSME HPOT intermediate seal (IMSL) purge pressure from decaying below 159 PSIA, the Block II SSME shutdown redline.

The following is a summary of the interconnect plan as described in Flight Rule A5-152. Refer to the Flight Rule for more information.

#### Single regulator interconnect plan (isolated leak)

The interconnect will be performed as soon as practical but above the minimum tank pressure required to perform the shutdown mode. In this scenario, since the leak was isolated, there is no risk of an additional loss of helium.

#### Non-isolatable lower system leak interconnect plan

The pneumatic helium system and any helium from a previously shutdown engine should be interconnected to the leaking system. The interconnect will be performed as soon as practical but above the minimum tank pressure required to perform the shutdown mode. There is no harm in performing the interconnect early in this case since the leak rate is not a function of the feeding source's pressure (i.e. regulated leak hence constant mdot). Hence no helium will be wasted.

#### Non-isolatable upper system leak interconnect plan

Before interconnecting, there is no way to know if the upper system leak is a tank leak or an upper system leak. As previously discussed, since the leak rate associated with an upper system leak is a function of pressure, there is a risk of wasting helium if the leak is in the tank. Therefore, the interconnect will be performed as late as practical but above the minimum tank pressure required to perform the shutdown mode.

The interconnect plan for an upper system leak is different if there are less than three engines on. In this case, it is acceptable to interconnect as soon as practical and accept the risk of a tank leak (described in paragraph A1, b of Flight Rule A5-152). The reasoning in this special case is that by interconnecting early, if it is a tank leak, there will be nominal flow rate from the failed engine's tank and the "leaking" engine will be able to support a nominal MECO. If the leak is an upper system (non-tank) leak, no helium will be wasted so there is no harm in interconnecting early.



### Shutdown plan

SSME shutdown methods can be one of three types: zero-G, redline, and manual. The ideal situation is to allow the engines to shutdown automatically at MECO as long as they can safely perform a zero-G shutdown. If the zero-G requirements cannot be satisfied, the engine will be manually shutdown at either a velocity or vehicle attitude cue as determined by Flight Rule A5-153. If the TOD's cannot support the aforementioned manual shutdown cues, then the shutdown will be either a controller initiated redline shutdown or manual shutdown based on the shutdown mode pressure requirements.

#### Zero-G Shutdown

A zero-G shutdown will be performed if the zero-g shutdown pressure requirements can be satisfied. To meet these requirements, the zero-G TOD must be greater than an MET of MECO + 30 seconds (to allow for error in the computations). No action is required for the shutdown (computer initiated).

#### Redline Shutdown

A redline shutdown will occur if the engine HPOT IMSL redlines are violated. A redline shutdown is automatic and requires no crew action. This shutdown mode assumes the engine can shutdown hydraulically. If limits are inhibited or the HPOT IMSL sensors are disqualified, the engine cannot shut down when the limits are violated. In this case, the appropriate hydraulic shutdown pressure requirement must be manually protected.

#### Manual Shutdown

If zero-G helium requirements cannot be met, the redline shutdown is expected to occur after MECO - 30 seconds, and the hydraulic/pneumatic requirements are satisfied within the MECO  $\pm$  30 time frame, the engine will be shutdown manually on a velocity cue. The velocity cues are as shown in Table 2.2.7-I and further explanation is given in Flight Rule A5-153. A manual shutdown at the velocity cue will be performed using the pushbutton only, unless the engine has a command path failure or the pushbutton is inoperative. In these cases, the engine will be shutdown using the engine controller AC power switches followed by the shutdown push button (AC/PB). An AC/PB shutdown causes the engine to shutdown pneumatically; therefore, the pneumatic pressure requirements must be protected.

Table 2.2.7-I - Velocity Shutdown Cues

Trajectory	Shutdown inertial velocity (VI) in feet/second	
	3 engines running	2 engines running
Nominal/ATO	23K	24.5K
TAL	22.5K	22.5K
RTLS	$\alpha = -1$	$\alpha = -1$

A pneumatic shutdown will also be performed if the engine hydraulic system has been compromised (hydraulic lockup or RVDT miscompare). The pneumatic TOD should be used to predict the shutdown time. When the shutdown pushbutton is depressed, the engine will default to a pneumatic shutdown. If the pneumatic requirement will not be met at MECO (i.e. zero-G shutdown), then the engine should be manually shutdown at the velocity cue or above the minimum pneumatic pressure requirements, whichever cue comes first.

#### Loss of Helium tank Pressure data

The loss of the Helium tank pressure sensor, due to either sensor failures or channelization failures, causes the loss of the crew's dP/dt computation and the loss of the BOSS Mdot computation. Without these tools, the aft and mid helium tank temperatures are the only insight into helium usage. If the rate of change of these temperatures begins to significantly diverge from the other systems, it is likely that a helium leak is present. Isolation steps may be performed, however, unless the operators can positively confirm the helium is adequate to support a zero g shutdown, the affected engine must shutdown pre-MECO.

#### Overview of MCC Software Used in Leak Evaluation and Interconnection

MCC software computes three TOD times for each engine system. The first of these TODs gives the projected time-of-depletion assuming a zero-G shutdown, the second, a pneumatic shutdown, and the third, a hydraulic shutdown. Nominally, these TODs are computed assuming no leak, but in the event of high-usage, the MCC software selects a leak type (upper system, lower system, or single regulator) and adjusts the TODs to account for the leak. These TODs are displayed on the MPS Ascent Display along with the associated tank pressure (refer to Figure 2.2.7-IV).

The MCC software detects upper system leaks prior to interconnecting by a decaying mass flowrate. Once detected, a letter "U" is displayed on the MPS Ascent Display on the line entitled "LkType/Intcnct," in the column of the respective engine. MCC software detects lower system leaks by a constant, but above normal, mass flowrate. The letter "L" is displayed on the display once the software identifies that leak type. MCC software selects single regulator mode anytime one of the helium isolation valves is closed and displays the letter "S." Figure 2.2.7-IV shows an example of the MPS Ascent display with a leak on the Center engine. The dashed box outlines the helium parameters of the display. The software has detected the leak to be a lower



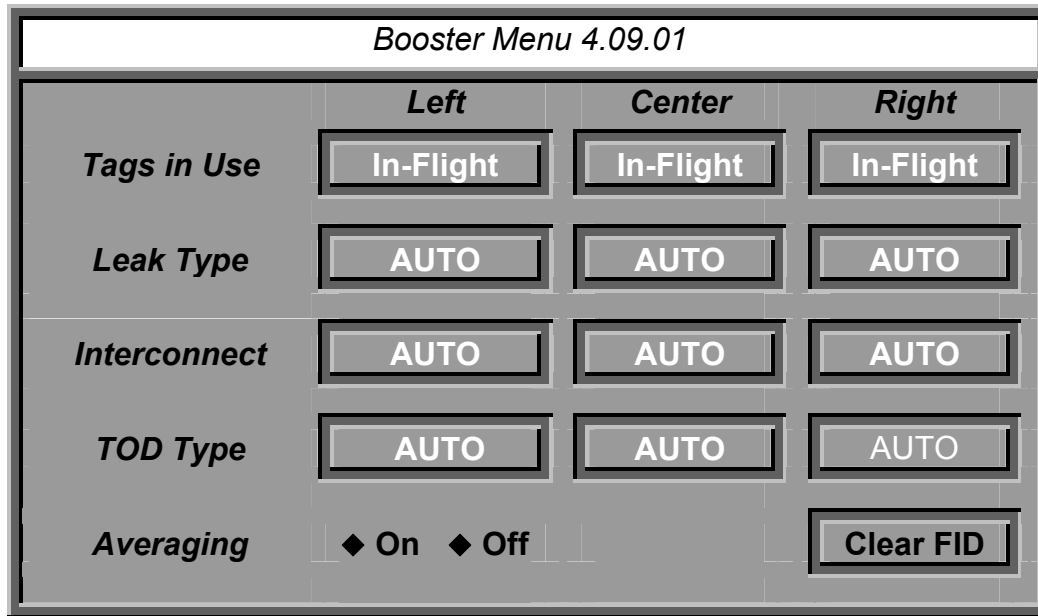


Figure 2.2.7-V – Booster Menu Selection window (Menu Comp)

Nominally, the helium TODs and shutdown pressures calculated for each engine system assume only the engine bottles located in the aft and mid-fuselage of the Orbiter will support engine operation to MECO. However, the MCC software can display the helium TODs assuming additional sources helium will be interconnected into a leaking tank system. The MCC software can display TODs based on the assumption that a leaking engine will be supported by either the pneumatic helium supply or both the pneumatic system and the helium from any engine that has shutdown or has an interconnect out-open. If the MCC software sees any interconnection, it will automatically configure the system to show TOD times based on the interconnect (as long as the menu display’s interconnect button is in the AUTO position). In addition, the operator can override the automatic system by choosing between these modes using the ‘*Interconnect*’ selector button on the Menu window and choosing either AUTO, Pneu, ALL, or None. Once manually configured, automatic configuration is disabled until AUTO is selected from the *Interconnect* menu. It is important to note that the MCC software will only allow the selection of ALL if either an engine has shutdown or another engine’s interconnect is in the OUT OPEN position. Otherwise, the MCC software will change the ALL selection back to \*PNEU\*.

In Figure 2.2.7-IV, the pneumatic system has been interconnected, and the TODs shown for the center engine reflect the additional run-time gained by using the pneumatic system. The interconnect is displayed as ‘INOP’ on the “INTERCONNECTS” line of the Ascent display and the letter “P” on the right hand side of the LkType/Intcnct line. If TODs with an interconnect to a running engine or shutdown engine were desired, the user could click on the “*Interconnect*” button on the Menu display for the center engine and change the interconnect to “ALL”. The letter “P” on the MPS Ascent display would change to an “A” to indicate ‘interconnect all’ has been selected. In this case, the TODs would change to reflect any added run-time gained by

interconnecting to a shutdown engine or an engine with the interconnect switch in the out-open position.

The MPS operator can force single regulator computations by selecting Single Reg from the TOD type option. This allows the operator to evaluate the TOD while both regs are open, or in the case where the isolation valve power status is bad and the comp cannot automatically select single reg. In any case, the comp can only evaluate the single reg TOD if the mdot is less than 0.05 lbm/sec. If the Helium Comp has been manually configured to evaluate as Single Reg and mdot exceeds 0.05 lbm/s, the comp will stop evaluating as Single Reg, the *Leak Type* button on menu comp will be displayed as \*AUTO\*, and the comp will output leak evaluation based on the AUTO setting. If mdot returns to less than 0.05 lbm/s the menu button returns to the selected mode of "Single Reg". If the helium comp automatically enters Single Reg mode for a failure the Isolation Valve Power indication and the user determines that the engine is actually being supplied by both Regulators, dual reg mode can be forced by taking the *Leak Type* button to Upper or Lower.

### Pneumatic Helium Leaks

A pneumatic system helium leak is any leak that causes usage from the pneumatic system, whose primary function is to close the LO<sub>2</sub> and LH<sub>2</sub> prevalues at MECO. Recall that during nominal ascent, without any engine helium systems interconnected, pneumatic helium is not used and its tank pressure should remain constant.

As shown in Figure 2.2.7-IV, MCC monitors pneumatic helium tank pressure and temperature, regulator pressure, and accumulator pressure telemetry. Flight Rules define a significant pneumatic helium system leak as any leak in the tank or accumulator which annunciates the crew system management (SM) alert, PNEU TK P < 3800 psia, before MECO – 30 seconds, or drops the pneumatic accumulator pressure less than 700 psia (Flight Rules A5-11 and 12, Ref. 1). Action is only taken for these two cases. If insight into the pneumatic tank pressure sensor is lost, the pneumatic tank temperature transducer can be used as a back-up cue. Note that if an engine is shut down pre-MECO and the pneumatic tank was previously depleted, as in the case of a large engine helium system leak, the pneumatic accumulator pressure will drop to approximately 708 psia (Ref. 4).

If the pneumatic tank pressure drops below 3800 psia, the crew will be alerted by the SM alert light and tone, and an MPS PNEU TK fault message and down arrow next to MPS PNEU HE TK P on BFS SYS SUMM 1 (CRT). If the pneumatic Regulator or Accumulator pressure falls below 700 psia, the crew will be alerted by the SM alert light and tone, and an MPS PNEU REG (ACCUM) fault message and down arrow next to MPS PNEU HE REG (ACCUM) P on BFS SYS SUMM 1 (CRT).

Any leak in the pneumatic He system will first appear as decreasing pneumatic tank pressure. There are three possible leak locations in the pneumatic system: tank leak, accumulator leak, or regulator system leak. These three leak locations are shown schematically in Figure 2.2.7-VI.

The crew follows the procedure labeled MPS PNEU TK(REG) P from the AESP (Ref. 2) in Figure 2.2.7-I. The primary focus is to ensure that the accumulator is fully charged at MECO. This procedure is broken into several steps. The first step concerns late leaks, within MECO – 1 minute. For this case, there is not enough time to evaluate the leak - the Left Engine Helium Crossover valve is opened, via a switch on Panel R2, to help support the accumulator at MECO.

For pneumatic system leaks that occur before MECO – 1 minute, the AESP procedure begins with closing the Pneumatic Helium Isolation valves on Panel R2. If the pressure continues to drop, the leak is in the pneumatic helium tank. If only the regulator pressure continues to drop, the leak is in the regulator system. If the accumulator and regulator pressure both continue to drop, the leak is in the accumulator.

In the case of a pneumatic tank leak, the crew then proceeds with Step 5 of the AESP procedure (Figure 2.2.7-I) and re-opens the helium isolation valves. The tank leak is non-isolatable, therefore the tank is allowed to supply pressure to the accumulator as long as it has pressure. In the case of an accumulator leak, the crew waits until MECO - 30 seconds and then re-opens the Pneumatic Helium Isolation Valves and Left Engine Helium Crossover Valve on Panel R2. This procedure saves helium in the pneumatic helium tank until it is needed at MECO, and the Left Engine Crossover provides additional support to the accumulator.

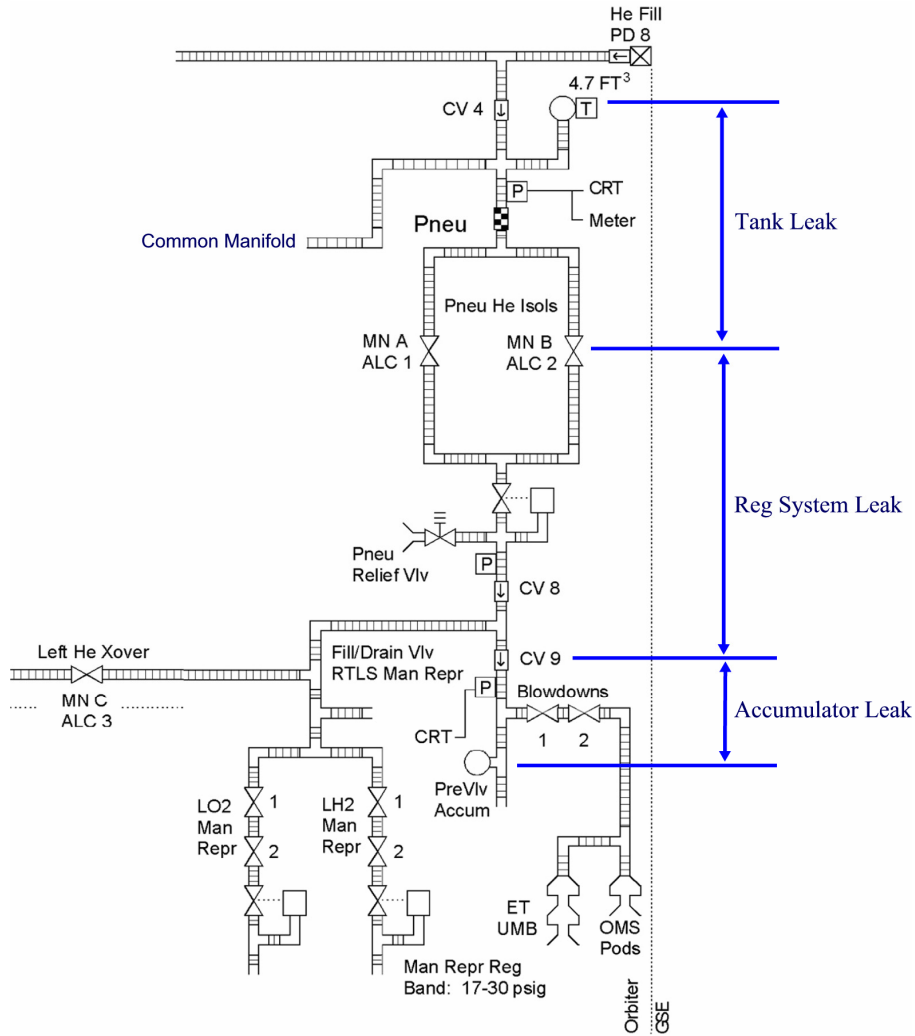


Figure 2.2.7-VI – Pneumatic Helium System Leak Type Schematic

Note that for a pneumatic helium regulator system leak, there is no further action taken in the AESP procedure after closing the pneumatic isols. In this situation, the accumulator holds its pressure for use at MECO, and helium is saved in the pneumatic helium tank in case additional helium is needed for an interconnect.

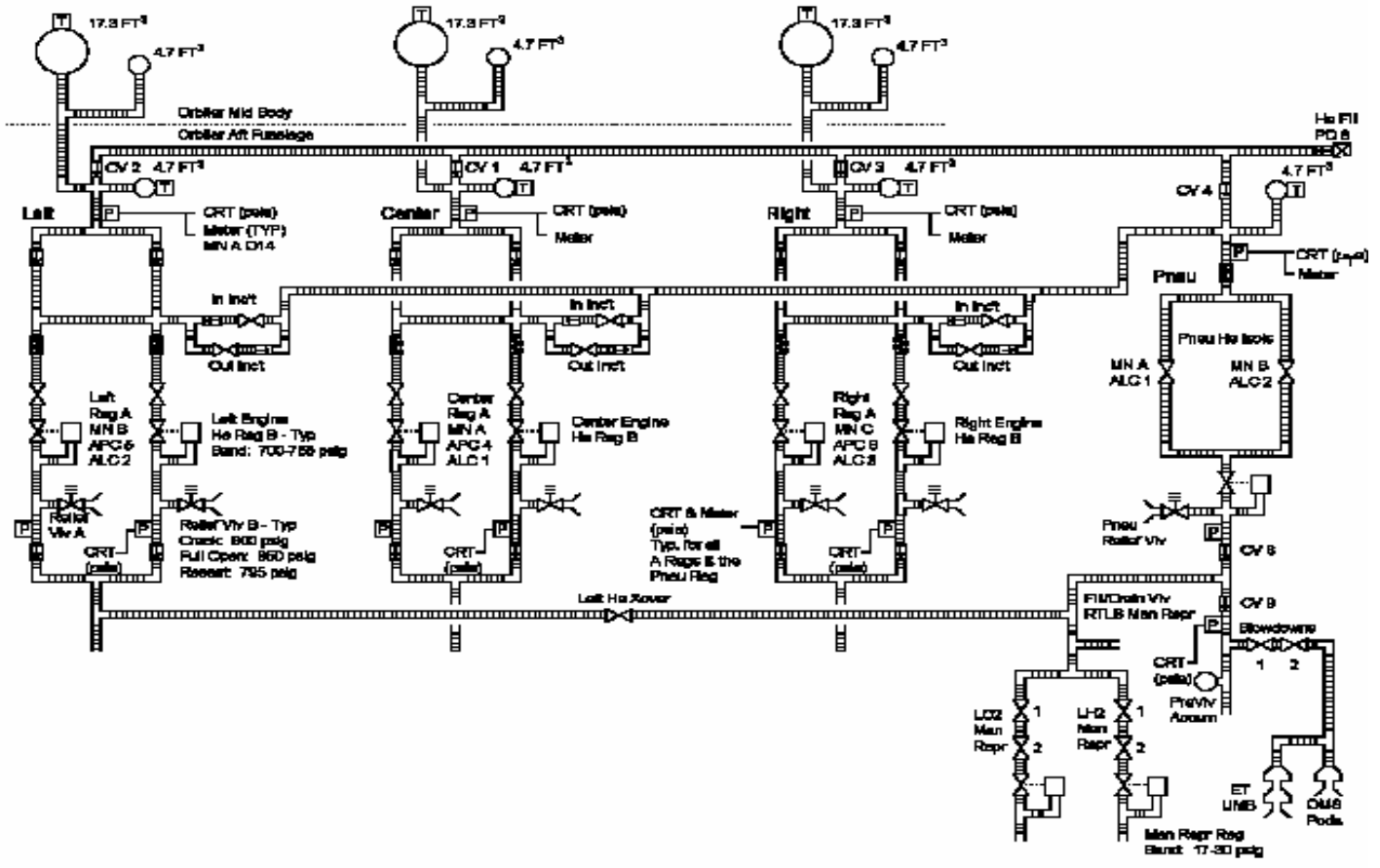


Figure 2.2.7-VII – Orbiter Helium Subsystem Schematic



### Dual Helium Leaks

A dual helium system leak can result from one of two scenarios. The first scenario is the result of two independent helium leaks. The signature of this failure would be two helium systems indicating high helium usage (increased  $dP/dt$  and diverging pressures and temperatures). It is unlikely that both leaks would be the same size and occur simultaneously. Hence the leak signatures for the two systems should be dissimilar. In the event of two, independent helium system leaks, the isolation, interconnect, and shutdown procedures described above should be followed.

The second scenario involves a single helium system leak along with a helium fill check valve failure. Referring to Figure 2.2.7-VII, these check valves are labeled CV1, CV2, and CV3 and are used to isolate the individual helium systems from the common manifold used to transfer helium from the ground storage system to the orbiter. If one of these check valves failed, helium from the failed check valve's system would be able to backflow through the valve, and into the helium systems of the other systems through the helium fill manifold. In the scenario where a check valve is failed and another helium system is leaking, both the leaking system and the system with the failed check valve would feed the leak. The signature for this failure is distinct: a simultaneous leak on two helium systems, similar helium tank pressures and temperatures for both systems, and similar  $dP/dt$  and  $\dot{m}$  values for both systems. A specific MCC procedure exists for troubleshooting this failure mode. There is no corresponding FDF procedure for this failure scenario.

#### Dual He leak procedure summary

- 1) Work the leak isolation procedure described in MPS He P (Figure 2.2.7-I) for both systems simultaneously. If the leak is isolated, analyze the required interconnects and shutdown requirements for the two systems. Based on the size of the leak and the length of time required to isolate the leak, it is possible that one, both, or neither of the affected systems will be able to satisfy zero-G shutdown requirements.
- 2) If the leak is non-isolatable, the next step is to interconnect the Pneumatic Helium system to one of the leaking systems for 15 seconds. The purpose of this step is to attempt to determine which system has the leak and which system has the check valve failure. This is done by observing the leak rate on the intereconnected system.

Refer to Figure 2.2.7-VII while reading the following example:

Assume the Left and Center Helium systems are leaking, and the isolation attempted in step 1 was unsuccessful. Interconnecting to one of these two systems will provide additional insight into which one is the leaking system and which one has the check valve failure. Since both systems exhibit the same leak

indication it does not matter which system is attempted. For this example, the Center SSME will be the target system.

If the center helium tank “stops leaking” (i.e. no helium usage while interconnected) it means that the leak is in the center system and the left system has the failed check valve (CV2). Additionally, the left helium system would show nominal usage during the interconnect since it is no longer feeding the leak. After breaking the interconnect, the left engine will be interconnected to the pneumatic system per the upper system leak cues because the failed check valve effectively creates a tank leak on the non-leaking system regardless of the actual leak type on the leaking system.

If the center helium tank “continues leaking” (i.e. still has helium usage even while interconnected) the only assumption that can be made is that the leak is not below the check valves associated with each leg of the center helium system. Since the center system has demonstrated that the leak is not at or below the interconnects, the proper action is break the interconnect and reinterconnect the pneumatic helium to the center engine per the upper system leak cues. If this occurs.

For discussion purposes, the case described above has two possible explanations for the leak location.

Case 1: A center helium tank leak and a check valve failure on the left system has occurred. In this case the pneumatic system will be feeding the center engine, the center tank is feeding the leak, and the left system is feeding the left engine and the leak (three different  $\dot{m}$  values will result).

Case 2: The left system is leaking and the center check valve has failed. In this case, the pneumatic system will be feeding the center engine, and the left and center tanks will be feeding the left engine and the leak (left and center  $\dot{m}$  values similar).

- 3) After re-establishing the interconnect, the shutdown cues and methods for both systems should be evaluated per the previous sections.

The dual helium leak is a very difficult case to both analyze and correct. Based on the size of the leak and the length of time required to isolate the leak, it is possible that one, both, or neither of the affected systems will be able to satisfy zero-G shutdown requirements. It is highly recommended that the reader, walk through various leak and interconnect scenarios to become familiar with the procedure and the various signatures.

REFERENCES

1. STS Operational Flight Rules, Volume A - All Flights, Final PNC-3, JSC-12820, January 13, 2005.
2. Flight Data File – Ascent/Entry Systems Procedures (AESP), Vol. I, Gen Rev L, May 15, 2003.
3. Flight Data File – DPS Dictionary, Gen Rev K, June 14, 2004.
4. Kavanaugh, Pat (Boeing), e-mail “RE: SMS MPS Helium ARs” to Eyre, A. (DF55), June 10, 2002.

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## TITLE

MPS ENTRY HELIUM MALFUNCTION

## PURPOSE

This SCP describes the crew and main propulsion system (MPS) console operator's procedures and responsibilities for helium malfunctions during entry.

## DESCRIPTION

During entry, the OMS pods, the LH<sub>2</sub> orbiter umbilical cavity, and the aft compartment are purged of hazardous fluid concentrations (e.g. LH<sub>2</sub>, LO<sub>2</sub>, N<sub>2</sub>H<sub>4</sub>, NH<sub>3</sub>, or hydraulic oil) that might have built up in these areas. Failure to purge these areas might result in fire from excessive flammable vapor concentration and possible loss of the vehicle. In addition to the purge, the MPS/SSME lines and manifolds are pressurized to prevent atmospheric contamination during entry. Such contamination would require disassembly and decontamination of the MPS/SSME components prior to subsequent flight. In addition, atmospheric contamination combined with any LH<sub>2</sub> residuals could also pose a flammable concentration concern. One other reason helium is required for entry is to keep the engine valves closed so that when the thrust vector control (TVC) isolation valves are opened, the engine valves don't drift open. If the engine valves were to drift open, contamination could be ingested during entry.

The MPS entry purge configuration is basically the same for nominal, AOA, RTLS and TAL entries. Simply put, during entry the helium system is configured to support an aft compartment purge and pressurization of the LO<sub>2</sub> and LH<sub>2</sub> manifolds. For a precise event timeline of the entry purges refer to the appropriate MPS Dump Events cue card (Ref. 1). The purge consists of: a 145-SCFM average helium purge to the OMS pods, a 339-SCFM average helium purge to LH<sub>2</sub> orbiter umbilical cavity, a 12-SCFM (4 SCFM per engine) helium purge through the LO<sub>2</sub> Bleed check valve orifice into the Pogo and HPOTP, a 6 SCFM (2 SCFM per engine) pneumatic vent mod purge (dumps into the aft), and a 6 SCFM (2 SCFM per engine) Baggy Purge on the LH<sub>2</sub> duct between the LPFTP and HPFTP. The pneumatic vent mod purge is an SSME function that relieves trapped helium pressure in the exit port of the OPOV, FPOV, and CCV into the Orbiter aft compartment via a continuous vent. The vent mod purge prevents actuator drift during hydraulic lockup and prevents problems with pneumatic shutdowns and purges. Note, 1000 standard cubic feet per minute (SCFM) equates to 0.1723 lbm/sec.

The total flow rate averages about 5.25 lb/min (0.0873 lb/sec) starting at  $V_{REL} = 5300$  ft/sec (3800 ft/sec if RTLS) and continuing for 650 seconds, approximately touchdown plus three minutes. Approximately 59 lbs of helium are required to complete the 650-second purges, but 69 lbs total are required to support the aft compartment purge, vent mod purges, baggy purges, and manifold represses (see Table 2.2.8-I). The Booster Operational Systems Software (BOSS)

helium computation calculates the amount of helium available and this information is displayed on the MPS Ascent and Entry displays.

Table 2.2.8-I. Helium Mass Usage During Entry

Description	Start Point	Total Mass Used (lbm)
Vent Mod/Baggy Purge	MM303	6.9
Aft Compartments Purge and LO <sub>2</sub> Bleed CV Leakage	$V_{rel} = 5300$ ft/sec (650 sec duration purge)	59
LO <sub>2</sub> /LH <sub>2</sub> Manifold Repress	$V_{rel} = 5300$ ft/sec	3
Total	MM303 - Aft Purge Stop	~69

The flow is supplied through the pneumatic regulator and the left helium regulators (passing through the crossover valve). For nominal, AOA and TAL entries, the helium system is configured post deorbit burn (i.e. MM 303) so that entry software can start the helium flow at the  $V_{REL} = 5300$  ft/s point. At this point in the descent, the software sequence will command the LO<sub>2</sub> and LH<sub>2</sub> manifold repress valves and helium blowdown valves to open. The LH<sub>2</sub> backup dump valves and LO<sub>2</sub> prevalues are closed at this time so that the system may be pressurized. For an RTLS trajectory, the helium system is configured at MM602 and only the purge starts at  $V_{REL} = 5300$  ft/s. Later at  $V_{REL} 3800$  ft/s, the backup dump valves and LO<sub>2</sub> prevalues are closed and the manifold repress valves are opened to pressurize the manifolds. The reason for the delay in closing the backup dump valves is to allow for the maximum amount of time to vacuum inert the fuel manifold during the short time period of an RTLS entry.

#### MPS Entry Purge / Manifold Pressurization Anomalies

Although, for Nominal/AOA entries there is more time to remove residuals, the aft compartment is purged during all entries for simplification of the entry sequencing software. However, the entry purge is modified in the event that the BFS fails or a vehicle power down is required. For a BFS failure, the crew's BFS GPC Fail procedure in the Entry Pocket Checklist and Ascent/Entry Systems Procedures FDF has them manually close the pneumatic and the three B isolation valves because there is no C&W on the B regulators or the pneumatic regulator without the BFS (Ref. 2).

Since the effectiveness of the purge has never been quantified, critical capability in other systems will not be traded off to complete the purge (Ref. 3). Crew procedure changes to the helium purge also exist to cover vehicle power down for the loss of two fuel cells, two freon loops or two H<sub>2</sub>O loops (Reference the appropriate FDF procedure depending on the trajectory). MPS valves that are normally powered opened during entry, will be positioned closed (unpowered) to save power, approximately 218 W (Ref. 3). No LO<sub>2</sub> or LH<sub>2</sub> manifold repress

will be attempted. Without the manifold repress, MPS line contamination may occur which will require a more thorough cleaning procedure post-landing and could pose a flammability hazard due to the ingestion of atmospheric contamination ( $O_2$ ) into the  $LH_2$  manifold. The other function served by the manifold repress is to dilute the propellant residuals (specifically the  $LH_2$ ) to reduce the flammability concern at landing as the contents of the  $LH_2$  manifold vent through the manifold relief valve and escape through the seals around the 17" disconnect valve, fill/drain valve, etc. due to allowable spec leakage of these components.

Figure 2.2.8-I is a flight data file (FDF) logic diagram which shows usage times of the FDF for off-nominal entries requiring MPS actions.

According to Flight Rule A5-209, the entry helium purge and manifold repressurization are "highly desirable," but attempts to recover will only be made *time-permitting* (Ref. 3). For Nominal/AOA entry profiles, attempts to recover the purge and repressurizations are only made if it does not impact critical capability in other orbiter systems. For critical power or critical cooling cases (i.e., loss of two fuel cells or two Freon loops), the purge and repressurization are inhibited per the crew procedures described above. For nominal and AOA entries, the hazardous propellants would have been inerted as part of the MPS dump, and the need for the purge is low. However, a temporary port-mode (but not restring) to latch the commands may be attempted to recover the entry purge, situation permitting (Ref. 3).

For TAL/RTLS entry profiles, recovering the entry purge will only be attempted if it doesn't impact critical capability in other orbiter systems and on a time-permitting basis. Unlike the uphill cases, residual propellants may still be present in abort landings, and explosive mixtures may be reached if air is ingested into the  $LH_2$  manifold. Situation permitting, the manifold repressurization will be recovered by a switch throw, port mode, or restring (in order of preference). For the TAL/RTLS landings, an Expedited Powerdown / Mode V egress will be required if the  $LH_2$  manifold repressurization is not completed. No attempts to repress the  $LO_2$  manifold will be made for TAL/RTLS.

Note that in cases that require an Expedited Powerdown / Mode V egress, the Booster operator should contact the EGIL operator to inform them about the required powerdown and the FDO to inform the convoy of the remaining  $LH_2$  in the vehicle.

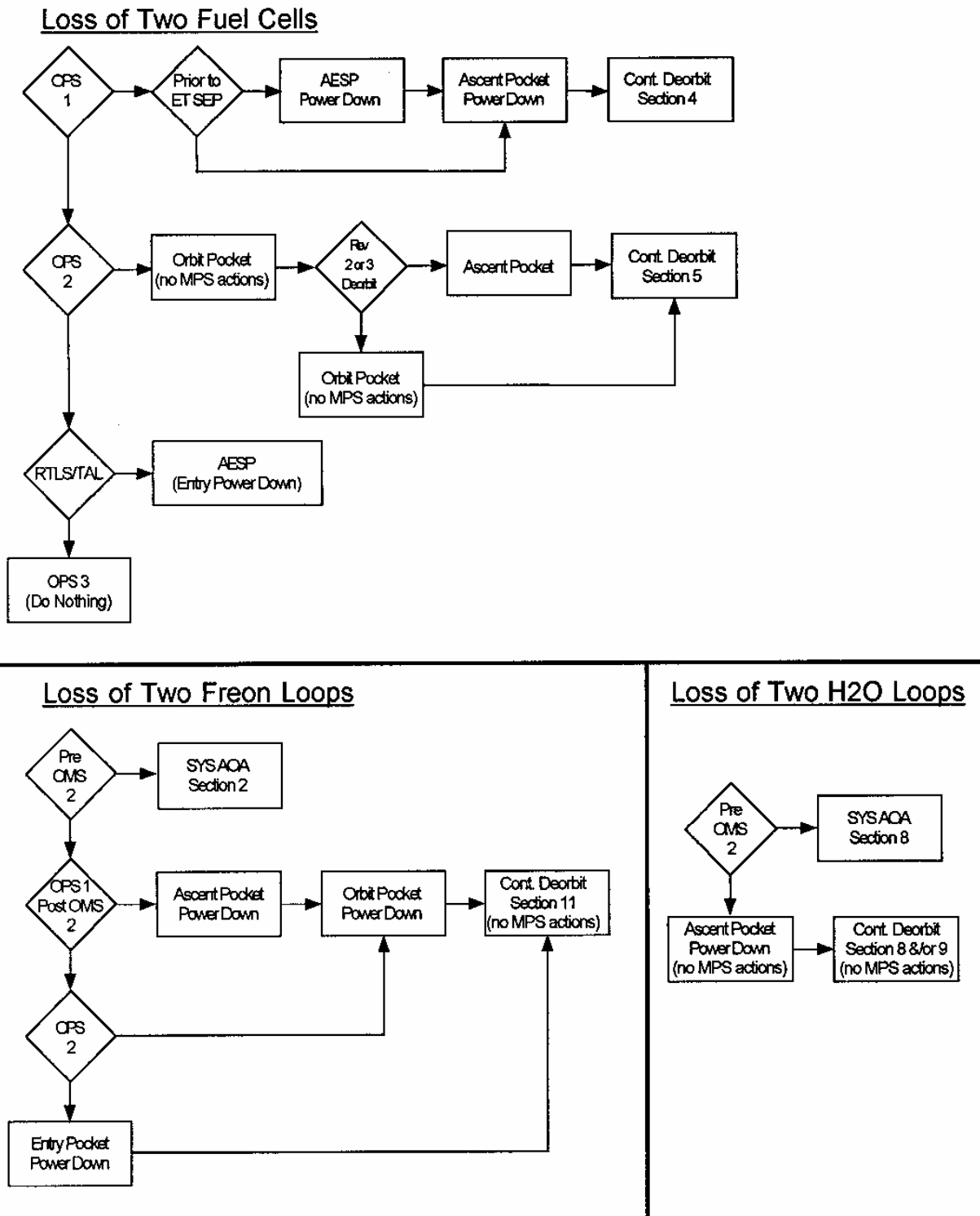


Figure 2.2.8-I. - MPS Off-Nominal Entry Flight Data File Logic Diagram



### MPS System Failure Resolution

The procedures mentioned above cover preplanned reconfiguration of the MPS system performed by the crew; however, if a failure in the MPS system develops, then real time MCC actions will be required. MPS system failures that could occur during entry would be either leaks or hardware failures.

The aft compartment purge will be lost, due to one or both of the blowdown valves being inoperable, if either the main A power supply, FA3 or FA4 is lost. If main A is lost, and the loss is not due to an internal bus short, main B or main C can be cross-tied to regain aft compartment purge capability. The Booster operator should request that these actions are performed as the purge is considered "highly desirable" per the above cases.

At  $V_{REL} < 5300$  (or 3800 for an RTLS), the MPS operator should verify that the LO<sub>2</sub> prevalves are closed thus allowing only a 4-SCFM flow (per engine) through the HPOT intermediate seal package. If one of the LO<sub>2</sub> prevalves cannot be closed, the LO<sub>2</sub> manifold repress will still be performed unless the total helium mass is less than 62 lbm (note, there is currently no Flight Rule covering this - reference BQM 686).

The manifold repress can be monitored by observing the manifold pressures on the MPS Entry or Ascent display. The manifold pressure transducers are useful for evaluating manifold leaks due to a shifted manifold repress regulator. The regulator control band is normally 17 - 30 psig. The manifold pressure transducers read in psia; therefore, nominally the manifold pressure should never read more than 45 psia (30 psi regulator and 14.7 psi atmosphere). For the LH<sub>2</sub> manifold, the LH<sub>2</sub> inlet pressure readings may be used to confirm the LH<sub>2</sub> manifold pressure reading because the LH<sub>2</sub> prevalves remain open during entry leaving a path down to the inlet pressure transducers. This is useful in the event of an LH<sub>2</sub> manifold pressure transducer failure.

If a leak develops, the valve configuration should first be verified to ensure valves are not out of configuration and thus are responsible for the high helium usage. If the valve configuration is nominal and time permits, proceed with the helium leak procedure in Table 2.2.8-II. Note that there are separate procedures for different leak cases. So the first step in using this table is to first allow the leaking system(s) tank pressure(s) to be equal or less to the remaining system's tanks so that a correct determination of which system(s) are leaking can be made. During entry, the crew can not receive the BFS Helium DP/DT fault message, because it is not available after OPS103. Therefore, the crew does not have any accurate indications of a helium leak and must rely solely on the MCC.

Good judgment should be employed when dealing with helium leaks. Little evaluation time is available during periods when the vent doors are closed (MM 304/602 through M<2400) due to the possibility of over-pressurizing the aft compartment. A 1.0 lb/sec leak will overpress the aft compartment in 17 seconds. In this case, the fastest way to stop the leak should be used instead of taking the time to exactly evaluate where the leak is. As stated in the note at the top of Table 2.2.8-II, for leaks that occur when the vent doors are closed, immediate isolation should be

performed by closing the affected helium isolation valve(s), per Flight Rule A5-208A, Post-MECO and Entry Helium Isolation (Ref. 3). On the other hand, during times when the vent doors are open (prior to MM 304/602 and after M<2400) more time may be taken to evaluate the leak because over-pressurization of the aft compartment is not a concern. However, one must keep in mind helium is being wasted and if too long is taken to isolate the leak, insufficient helium may be available for the entry purge.

TABLE 2.2.8-II. - ENTRY HELIUM LEAK PROCEDURE (Ref. 1)

NOTE: For leaks post vent door closure** close affected isol(s); otherwise, work this isolation procedure time permitting.		
HIGH USAGE:	ACTION:	LEAK:
C or R	C or R He ISOLs - CL	Center or Right He System
C, R and Pneu	PNEU ISOLs - CL	Pneumatic Leg
	If no joy: C & R He I'CNCT - In Open	Pneumatic Bottle or Interconnect Manifold
All	Left HE XOVER - CL	
	If L He Sys Stops Leaking: PNEU ISOLs - CL	Downstream of Pneumatic Check Valve (CV 8)
	If L He Sys Still Leaking: L He I'CNCT - Out Open L He ISOLs - CL	Left System
	If L He Sys Stops Leaking:	Left Lower System (Left He Still Available)
	If L He Sys Still Leaking:	Left Upper System
He Reg P Shift ↑ or ↓	Close Affected Isol	He Reg Shift High or He Relief Valve Failed Open

\* A failed open relief valve (1 lb/sec leak) could overpress the aft compartment in 17 seconds if the vent doors are closed

\*\* Vent Doors closure times: Nom/ATO - @ MM304 transition  
AOA - closed manually just prior to MM304  
TAL - @ ET Sep cmd  
RTLS - @ MM602 transition. Due to the limited flight duration and the crew workload, there may not be adequate time to work the Helium isolation procedure and then reconfigure the MPS helium system to support the entry purge.

Vent Doors open @ Mach=2.4 for all entry profiles

REFERENCES

1. Booster Cue Card Book (BCCB), Basic Rev A, PCN-16.
2. Flight Data File - Entry Pocket Checklist (EPCL), Vol. I, Generic, Rev. J, 5/19/03.
3. STS Operational Flight Rules, All Flights, Final PCN-3, NSTS-12820, January 13, 2005.

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## TITLE

MPS DUMP INHIBIT

## PURPOSE

The purpose of this SCP is to document the MPS dump inhibit procedure and to describe the crew procedure in place to perform the dump inhibit.

## DESCRIPTION

The MPS dump inhibit procedure is performed if there is a leak in an SSME feedline post-SSME shutdown (Ref. 1). MCC identifies the leak by monitoring the LH<sub>2</sub> and LO<sub>2</sub> inlet pressures, found on the MPS Ascent display (PASS only). Post- shutdown inlet pressure for LH<sub>2</sub> less than 30 psia or for LO<sub>2</sub> less than 40 psia would suggest that the SSME feedline integrity downstream of the prevalves had been lost. The MPS dump inhibit actions will prevent excessive leakage of propellant into the aft compartment during the MPS propellant dump and vacuum inert, thereby minimizing a potentially hazardous condition in the aft compartment (Ref. 2).

With valid insight to SSME LH<sub>2</sub> and LO<sub>2</sub> inlet pressures, the MPS dump procedure is performed only for an SSME that shuts down (manually or controller initiated) prior to main engine cut-off (MECO) for nominal, AOA, ATO, TAL, or RTLS (with the above inlet conditions). The MPS dump inhibit is only performed for an SSME that shuts down prior to MECO because loss of line integrity is not expected with nominal MECO and the inlet pressures drop below the leak detection limits in case of a low level cut-off.

The low pressure fuel pump (LPFP) discharge pressure can be used as a backup to the LH<sub>2</sub> inlet pressure and would also use the 30 psia cue as the dump inhibit criterion. The LPFP discharge pressure is also found on the MPS Ascent display (PASS only). If a breach of one or more of the LH<sub>2</sub> propellant lines has occurred, the possibility exists of LH<sub>2</sub> propellant in the aft, which constitutes a flammability and explosive hazard on a RTLS or TAL abort. This condition requires the most expeditious powerdown of the vehicle (emergency powerdown) and crew egress (Mode V egress). An LO<sub>2</sub> leak is not considered as hazardous as an LH<sub>2</sub> leak and therefore does not require an emergency powerdown and Mode V egress. However, both kinds of leaks do warrant an early APU shutdown after an RTLS or TAL abort in order to eliminate an ignition source in a hydrogen or oxygen enriched environment. These postlanding actions are not required after a nominal, ATO, or AOA mission since no uncontained residuals will remain in the aft compartment at the time of landing.

Loss of insight into the inlet pressures (and the LPFP discharge pressure for the fuel side) results in the inability to assess the inlet conditions. In this case, the MPS dump will be inhibited (time permitting) for any SSME that shuts down prior to MECO for nominal, ATO, or AOA case since a contained shutdown cannot be guaranteed. In the case where there was no leakage, any residuals trapped in the engine by the dump inhibit procedure will have time to bleed out prior to landing. There is an extremely low probability of a having an uncontained shut down without it

being catastrophic. The probability of occurrence is even more remote when coupled with a loss of insight into the inlet pressures. Therefore, the cases of survivable shut downs with leakage hidden due to loss of insight on a TAL and RTLS will not be covered. If the MPS dump is inhibited for the RTLS and TAL cases due to loss of insight and no leakage existed, it would induce an unnecessary risk of trapped LH<sub>2</sub> residuals (approximately 26 lbs LH<sub>2</sub> on a RTLS and approximately 8 lbs LH<sub>2</sub> on a TAL abort, at touchdown). These amounts of LH<sub>2</sub> are enough to cause a venting concern for the convoy and preclude normal convoy operations and would require as a minimum an expedited powerdown and Mode V egress per Flight Rule A16-11F, Expedited Powerdown. However, if leakage were assumed, an emergency powerdown and Mode V egress would also be performed.

Note that in cases that require an Expedited or Emergency Powerdown and Mode V egress, the Booster operator should contact the EGIL operator to inform them about the required powerdown as well as the FDO to inform the convoy of the remaining LH<sub>2</sub> in the vehicle.

## PROCEDURE

Since the crew does not have insight into the LH<sub>2</sub> or LO<sub>2</sub> inlet pressures to detect loss of SSME feedline integrity following a pre-MECO shutdown, they rely on the MCC to inform them if a dump inhibit is required. If requested by MCC, the crew will follow the MPS dump inhibit procedure (Ref. AESP):

### **MPS DUMP INHIBIT**

Post MECO:

Aff MPS ENG PWR (two) – OFF  
LO<sub>2</sub>(H<sub>2</sub>) PRE VLV – CL

The MPS dump inhibit is performed by manually closing the prevalve on the side which was determined to be leaking and powering off the controller for the SSME by taking both engine power switches to OFF. The SSME controller is powered off to close the bleed valves and hydraulic valves. Optimally, controller power down would be performed prior to the SSME going into post-shutdown standby during ascent (SSME shutdown plus sixteen seconds), but is performed immediately post MECO because of the consequences of turning off the wrong SSME's controller power prior to MECO.

## REFERENCES

1. STS Operational Rules, All Flights, Final, PCN-1, NSTS-12820, November 21, 2002, A5-201, MPS Dump Inhibit.
2. PSIG Minutes - Flight Rule Review on 2/25/88.

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TITLE

FEEDLINE MANIFOLD RELIEF VALVE/ISOLATION VALVE FAILURE

PURPOSE

This SCP describes the off-nominal condition of high engine LO<sub>2</sub> or LH<sub>2</sub> manifold pressures (post-MECO). The crew and main propulsion system (MPS) console operator's procedures and responsibilities for monitoring the LO<sub>2</sub> and LH<sub>2</sub> propellant manifold system are described.

DESCRIPTION

LO<sub>2</sub> and LH<sub>2</sub> propellant remaining in the MPS lines after main engine cutoff (MECO) will begin to boil off as the propellant temperature rises from its cryogenic state. This boil off will cause a pressure increase in the closed MPS manifolds. The MPS propellant dump, vacuum inert, and post OMS-2 vacuum inert are performed to remove this residual propellant and to reduce pressure in the manifolds. An incomplete dump or vacuum inert will cause the remaining propellant to boil-off, causing off-nominal pressure rises in the manifolds. To relieve any off-nominal pressure increase that occurs each propellant manifold (LO<sub>2</sub> and LH<sub>2</sub>) is fitted with a feedline manifold relief valve. The LO<sub>2</sub> valve is set to crack (relieve) at 190 to 220 psig and the LH<sub>2</sub> valve cracks at 40 to 55 psig. The maximum flow rate of the LO<sub>2</sub> relief isolation valve is 24 lb/sec (LO<sub>2</sub> at 200 psig). The maximum flow of the LH<sub>2</sub> relief isolation valve is 2.4 lb/sec (LH<sub>2</sub> at 50 psig). The relief settings are significantly below the burst pressures of the manifolds. The line burst pressures are 390 psig for the LO<sub>2</sub> and 83 psig for the LH<sub>2</sub> manifold.

Mounted in series, upstream of each relief valve, is an isolation valve that is spring loaded open and electrically powered closed during ascent. The isolation valves are powered closed to protect against a failed open relief valve. Without the isolation valves, if a relief valve were to fail open during flight, Shuttle performance would be degraded due to a loss of propellant.

The position of each relief isolation valve is controlled by the LO<sub>2</sub> and LH<sub>2</sub> FEEDLINE RLF ISOL switches on panel R4. Normally these switches are left in the GPC position, allowing the isolation valves to be immediately opened automatically after MECO. During the external tank separation sequence (ET SEP), power is removed and the isolation valves open. The relief valve is then exposed to any manifold pressure buildup and should relieve if the relief setting pressure limit is reached.



With a nominal dump and vacuum inert, pressures in the manifolds should never reach the relief settings. However, an incomplete dump or vacuum inert will cause excess residuals in the manifolds that over time will boil-off causing increased manifold pressures that may reach the relief setting. Refer to SCP 2.2.11 and 2.2.12 for dump and vacuum inert failures, respectively (Ref. 1). A subsequent failure of an isolation valve or a relief valve to open at the appropriate time could result in excessive manifold pressures to be held within the propellant manifolds. Excessive pressures could rupture the feedline manifold and result in damage to the aft compartment and possible loss of vehicle. There are several failures that could lead to such a situation:

1. The failure of two multiplexer/demultiplexers (MDMs) can prevent the isolation valve from opening automatically during the ET SEP sequence.
2. Mechanical jamming of the valve itself could cause the relief valve to not function.

For the case of MDM failures, the crew is trained to recognize the multiple MDM failures and to manually open the isolation valves per their Multiple Data Path Loss procedure in the AESP FDF (Figure 2.2.10-I). In addition, per Flight Rule A5-203C, MPS Propellant Manifold Overpressure (Ref. 3), the Booster flight controller will remind the crew to work this procedure immediately post-MECO.

**MULT DATA PATH LOSS (Non-Recov)**

NOTE

If LRU data path loss due to GPC problem and not MDM, BFS will pick up MDMs/LRU when engaged

FAILURE	TYPE	ACTIONS
GPC/FA any combo	I/O	D √BFS MM at each transition Expect 'SEP INH' (FDLN Fail) combos 2&3,2&4
		Post MECO: Before MECO + 25 sec:** 1. MPS FDLN RLF ISOL (two) – OP 2. MPS PREVLVs (six) – OP RTLs/TAL: MPS LH2 FILL/DRAIN INBD,OUTBD – OP
GPC/FF 1&2	I/O or B	Use R BODY FLAP & TRIM ENA SWs
GPC/FF 3&4	I/O or B	Use L BODY FLAP & TRIM ENA SWs

Note: The crew will work only Block D if have a BCE xD down along with a GPC/FA or another BCE xD. If 2 GPCs/FA MDMs are down, the crew will work both blocks

Figure 2.2.10-I.- AESP FDF Multiple Data Path Loss Procedure (Ref. 2).

For a mechanical failure of one of the valves, normally no action is required because a nominal MPS dump and vacuum inert will relieve any residuals. However, if an OMS burn is required prior to initiation of the automated vacuum inert, Flight Rule A5203 (Ref. 3) requires that the backup dump valves be opened prior to the OMS burn in order to manage the pressure build up caused by increased sublimation of residuals during the burn. Additionally, the automated fuel manifold repress at MM106 will be manually inhibited by taking the LH<sub>2</sub> MANF PRESS switch to close on panel R4. The switch will then be returned to GPC after the MM106 transition + 3 minutes in order to avoid continuously applying closed power to the valve on orbit.

In addition to the above failures, another reason the relief valve would not open would be due to the ET SEP sequence software never commanding it (i.e. removing the close power). This situation occurs whenever the MECO CONFIRMED flag is not set or the ET SEP switch is to taken to (or fails to) the MAN (manual enable) position. The MECO confirmed flag is not set whenever multiple SSME data path failures exist (note that multiple SSME data paths are different from multiple DPS failures for which the "Multi Data Path" procedure is written). Until the appropriate action is taken to set MECO Confirmed, the ET SEP sequence will not begin. The ET SEP switch will be taken to MAN and left there through MECO in the event that a non-isolatable aft or forward RCS leak occurs during ascent per the crew's Aft and Fwd RCS Leak Procedures in the AESP FDF (Ref. 2). Taking the switch to MAN, stops the ET separation until the RCS jets required for the -Z translation, used to separate from the tank, are recovered. In both of these cases, the ET SEP sequence is never called and therefore the 17-inch disconnect valves remain open after MECO. With the disconnects still open, over-pressure in the manifolds will be prevented by venting the manifold pressure through the 17-inch disconnect and out the ET vent valves. The LH<sub>2</sub> tank vent valve relieves at 36 psig, while the LO<sub>2</sub> tank's vent valve relieves at 31 psig.

Although no action should be required for a relief system failure, the Booster and MPS operators will carefully monitor the manifold pressures post-MECO to ensure that there is not an off-nominal pressure in the manifold. If an incomplete dump or vacuum inert causes high manifold pressures, that can not be relieved via the relief system, then manual action will be taken to open the manifold via either the backup dump or fill/drain valves. These procedures are covered in SCPs 2.2.11 and 2.2.12 (Ref. 1).

In order to alert the crew and the ground that either the LO<sub>2</sub> or LH<sub>2</sub> relief system is not operating, the LO<sub>2</sub> and LH<sub>2</sub> manifold pressure C&W values are set between the relief pressure setting and the burst pressure, thereby alerting the crew and the ground that there is high manifold pressure that was not relieved via the respective manifold relief valve. The C&W limit for the LH<sub>2</sub> manifold is 65 psig and 249 psig for the LO<sub>2</sub> manifold. The crew has software caution and warning (C&W) on the manifold pressures during OPS 1 and OPS 6, and the crew also has hardware C&W throughout the mission until it is inhibited for entry in the Deorbit Prep Checklist procedure. Refer to the MPS Caution and Warning cue card for more detailed information on manifold pressure C&W (Ref. 4). In addition, during OPS 1, 3, and 6, the crew can view the manifold pressures on their GNC SYS SUMM 1 display (BFS). The Booster operator watches the manifold pressures on the MPS Ascent and Entry displays as well as monitoring the Onboard Fault Summary display for any C&W fault messages.

In OI-29, if the LH2 manifold pressure is greater 60 psia and less than 90 psia (not commfaulted) after MECO + 22 seconds but before the scheduled MPS Dump Start, the dump will start immediately. Note that the 60 psia cue is less than the C&W limit. Without comm, if the C&W limit of 65 psia is reached, the crew will attempt to vent the entire LH<sub>2</sub> system by immediately opening the LH<sub>2</sub> Backup Dump valves, opening the Pneumatic Helium Isols, and opening the LH<sub>2</sub> Fill/Drain valves per the MPS LH<sub>2</sub>/O<sub>2</sub> MANF procedure in the Ascent Pocket Checklist (Ref. 5).

#### REFERENCES

1. Booster Systems Standard Console Procedures (SCPs), JSC-17239, Final, Rev. F.
2. Flight Data File – Ascent Entry Systems Procedures (AESP), Vol. I, Gen Rev J-3, 9/3/99.
3. STS Operational Flight Rules, JSC-12820, Volume A, All Flights, Final, PCN-1, November 21, 2002.
4. Booster Cue Card Book (BCCB), Basic Rev A, PCN-2.
5. Flight Data File – Ascent Pocket Checklist, Vol. I, Gen Rev J, PCN-3, July 12, 2002.

TITLE

LH<sub>2</sub> DUMP FAILURE

PURPOSE

This SCP addresses the failed closed mode of MPS valves used to dump LH<sub>2</sub> residuals and the proper response to such failures.

DESCRIPTION

The evacuation of LH<sub>2</sub> propellant residuals (approximately 304 lbm after ET sep) from the MPS LH<sub>2</sub> manifold begins with a venting of the manifold by opening the LH<sub>2</sub> backup (B/U) dump valves at MECO Confirmed + 13.4 seconds (which reduces the LH<sub>2</sub> residuals to approximately 145 lbm by MECO Confirmed + 122 seconds). The SSME fuel bleed valves (FBVs) are opened by the SSME controllers at approximately MECO + 16 seconds allowing the LH<sub>2</sub> residuals in the engines to dump into the LH<sub>2</sub> recirculation line.

1. Nominal, ATO, and AOA – No Failures:

For Nominal, ATO, and AOA missions, the LH<sub>2</sub> portion of the MPS dump will automatically begin 122 seconds or 2:02 after MECO Confirmed or anytime after MECO Confirmed + 22 seconds if the LH<sub>2</sub> manifold pressure is between 60 and 90 psia and is not commfaulted (refer to Flight Rule A5-203, MPS Propellant Manifold Overpressure, Ref. 1). At MPS dump start, the following LH<sub>2</sub> valves open: LH<sub>2</sub> inboard (I/B) fill/drain (F/D) valve, LH<sub>2</sub> outboard (O/B) F/D valve, the LH<sub>2</sub> topping valve, and the LH<sub>2</sub> prevalues. As shown in Figure 2.2.11-I, opening the F/D valves opens the manifold to the vacuum of space and opening the topping valve allows residuals in the recirculation line (as well as residuals from the engines via the fuel bleed valve) to also be dumped through the F/Ds. Opening the prevalues provides an additional dump path for the fuel residuals in the engine. Both the LH<sub>2</sub> backup (B/U) dump valves and the LH<sub>2</sub> O/B F/D valve vent the LH<sub>2</sub> residuals out the port side of the vehicle.

For a nominal OPS 1 MPS dump, the MPS dump lasts for 2 minutes and is terminated by closing the LH<sub>2</sub> OB F/D, topping, backup dump, and SSME bleed valves. The post-dump residual mass is approximately 3.85 lbm (Ref. 2).

2. RTLS and TAL – No Failures:

The RTLS and TAL LH<sub>2</sub> portion of the entry MPS dump valve sequences are the same, but the entry MPS dump start and stop cues are different. The entry MPS dump itself is started at MM602 transition for an RTLS abort (approximately MECO + 27 seconds) or at MM304 transition (immediately after crew performs OPS 301 PRO) for a TAL abort.

Unlike the OPS 1 LH<sub>2</sub> portion of the MPS dump, the LH<sub>2</sub> I/B F/D valve is closed after 20 seconds and the LH<sub>2</sub> RTLS repress valves are opened for 80 seconds to provide a helium purge. Due to the short time frame of the abort cases, the helium purge is needed to ensure that the maximum amounts of residuals are removed before landing. The IB F/D valve is closed so that the helium doesn't flow right out the F/Ds, but there is still a dump path through the FBVs, topping and OB F/D valves. For a nominal RTLS entry MPS dump, the helium purge vaporizes approximately 2.77 lbm of the 4 lbm of solid hydrogen left after the 20 second vacuum dump, leaving approximately 1.23 lbm of residual hydrogen at dump stop. For a nominal TAL entry MPS dump, the residual mass is 0.23 lbm at dump stop (Ref. 2). The lower amount of residuals on a TAL is due to the additional dump time (approximately 20 minutes) that allows an additional 1 lbm to sublime after the manifold pressure has dropped below the triple point. Analysis indicates the sublimation rate is approximately 0.05 lbm/min with the manifold exposed to vacuum. Even with this low amount of residuals, analysis shows that for both RTLS and TAL, the pressure will increase in the LH<sub>2</sub> manifold enough to reach the relief setting and begin venting approximately 63 minutes after landing (Ref. 4). The relief valve vents hydrogen out the flame arrestor next to the vertical stabilizer.

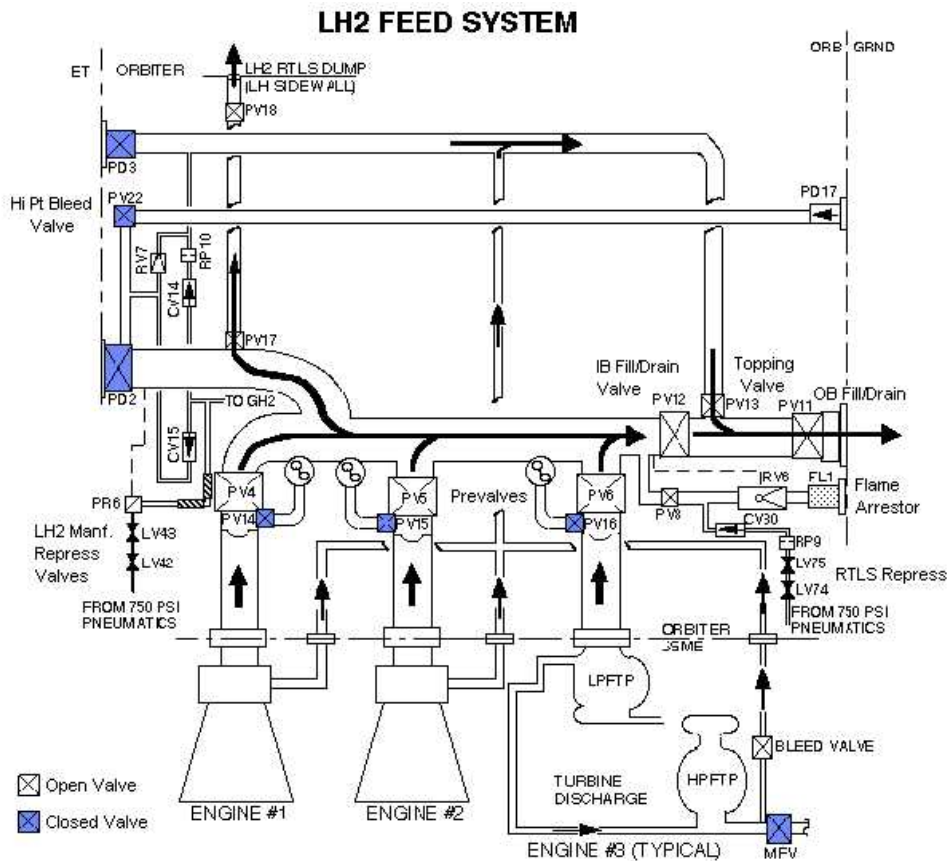


Figure 2.2.11-I - LH<sub>2</sub> Dump Paths for MPS Dump

The RTLS/TAL entry MPS dump is terminated by closing the LH<sub>2</sub> O/B F/D, topping and backup dump valves at a velocity of 3800 ft/sec for the RTLS case or 5300 ft/sec for the TAL case. The LH<sub>2</sub> manifold repressurization valves are opened at this time to dilute the residuals and provide a positive pressure purge and repressurization for the manifold which helps preclude air ingestion and the explosive mixture it could create with the residual hydrogen (detonation of one pound of hydrogen in stoichiometric mixture with air is equivalent to exploding 33 pounds of TNT - Ref. 12).

For additional information on the MPS dump, refer to System Brief 3.5, "MPS Propellant Dump" (Ref. 5).

## PROCEDURES

The failure modes for the MPS dump operations can be grouped into two major categories: (1) loss of and/or reduced dump flow path, and (2) loss of helium pressurization (loss of helium pressurization in this SCP only applies to the RTLS repress valves used during RTLS and TAL dumps – see Flight Rule A5-209 and SCP 2.2.8 for impacts and actions for loss of the Entry MPS LH<sub>2</sub> Manifold Pressurization). Table 2.2.11-I provides a summary of the post-dump residual masses for each of these failure cases. A 40% loss of helium through the manifold relief valve on the RTLS and TAL is assumed, based on STS-65 data (Ref. 3). This table also assumes approximately 0.3 lbm trapped residuals in the 4" recirculation and 8" fill/drain lines.

### A. LH<sub>2</sub> O/B F/D Valve Failure, Nominal, ATO, and AOA:

The worst-case scenario is the failed closed mode of the LH<sub>2</sub> O/B F/D valve where the only dump path is through the LH<sub>2</sub> backup dump valves. This case will leave approximately 55.7 lbm of hydrogen residuals (2.5 lbm for TAL, 40.3 lbm for RTLS) in the manifold at the end of the MPS dump. For the nominal, ATO, and AOA cases, Flight Rule A5-205 requires the crew to open the backup dump valves prior to MPS dump stop to remove the excess H<sub>2</sub> residuals (Ref. 1). If the LH<sub>2</sub> backup dump valves are opened prior to the completion of the MPS dump, they will remain open until either they are commanded closed at the termination of the first automated vacuum inert or the switch is taken the close. With the backup dump valves open, the LH<sub>2</sub> will reach its triple point approximately 5 minutes after MPS dump stop (at an MET of approximately 17.5 minutes) and leave approximately 3.76 lbm of solid hydrogen in the manifold by the time of the end of the first automated vacuum inert (Ref. 2 and 6). Per Flight Rule A5-205, the crew is to manually close the backup dump valves between MECO + 7 min and MECO + 10 min. This manual action will allow residual pressure to build-up, forcing a more effective inert. If the manual close action is completed, only 0.55 lbm of solid hydrogen are expected after the first automated vacuum inert, as shown in Table 2.2.11-I. The switch is read in both PASS and BFS after the end of the automated dump while in OPS 1.

TABLE 2.2.11-I. - PREDICTED LH<sub>2</sub> PROPELLANT DUMP RESIDUALS (Ref. 2)

LH <sub>2</sub> Residual Matrix  <u>FAILURE SCENARIO</u>	Nominal (NOM, ATO, AOA)						TAL Abort	RTLS Abort
	Post Dump Mass (lbm) <sup>1</sup> (108.6 sec vent + 2 min Dump; No helium purge)	Post Dump Max Press (psia) <sup>2</sup>	Post 1 <sup>st</sup> Vacuum Inert		Post 2 <sup>nd</sup> Vacuum Inert		Post Dump Mass (lbm) <sup>1</sup> (20 sec vent + 20 min dump; w/80 sec purge)	Post Dump Mass (lbm) <sup>1</sup> (20 sec vent + 150 sec dump; w/80 sec purge)
			Mass (lbm)	Max Press (psia) <sup>3</sup>	Mass (lbm)	Max Press (psia) @ 70° F		
1. No Failure -Hi Point Bleed Valve Leakage	3.85 4.1 <sup>4</sup>	19.2 20.2	.39 .40	9.8 9.8	.07 .07	30.7 30.7	0.23	1.23
2. Loss of He Pressurization	N/A	N/A	N/A	N/A	N/A	N/A	3.0	4.0
3. Loss of/or reduced Dump Path: I/B F/D Valve Fails Closed <sup>5</sup> O/B F/D Valve Fails Closed -RTLS Dump Valves Closed at MECO + 600 sec <sup>5</sup> -RTLS Dump Valves Remain Open Through 1 <sup>st</sup> VI <sup>8</sup> -RTLS Dump Valves Closed at Dump Stop RTLS Dump Valve Fails Closed <sup>10</sup> Topping Valve Fails Closed <sup>11</sup> Pre-Valve Fails Closed SSME FBV Fail Closed	3.43 <sup>6</sup>   55.7 <sup>7</sup>  55.7  55.7  4.0 4.0 4.0 4.0	13.4   21.6  0.0  29.0  19.8 19.8 19.8 19.8	0.47   0.55  3.76  11.4  4.0 0.39 0.39 0.39	10.2   10.7  21.8  43.0  31.7 9.8 9.8 9.8	0.09   0.10  0.24  1.9  4.0 0.07 0.07 0.07	31.6   33.1  8.9  ~70.5 <sup>9</sup>  149 <sup>9</sup> 30.7 30.7 30.7	1.9   N/A  N/A  2.5  0.8 1.5 0.9 0.9	2.9   N/A  N/A  40.3  1.8 2.5 1.9 1.9

NOTES:

1. Values taken from SHA0-01-042 / SI-01-093 "MPS LH<sub>2</sub> Dump Performance Model Conversion."
2. Manifold pressure at start of 1<sup>st</sup> vacuum inert.
3. Manifold pressure at start of 2<sup>nd</sup> vacuum inert.
4. 0.25 lbm trapped LH<sub>2</sub> in Hi Point Bleed line. Reference Boeing IL# 287-100-990-030.
5. Assumes LH<sub>2</sub> RTLS Dump Valves opened prior to Dump Stop and closed at MECO+600 seconds per Flight Rule A5-205B.
6. 3.13 lbm solid H<sub>2</sub> remaining at time of RTLS dump valves closure.
7. 4.47 lbm solid H<sub>2</sub> remaining at time of RTLS dump valves closure.
8. Assumes LH<sub>2</sub> RTLS Dump Valves were not closed prior to nominal 1<sup>st</sup> vacuum inert; therefore, the manifold repress was inhibited per FR A5.1.5-2B.
9. Pressure assumes a sealed system and no manifold repress post 2<sup>nd</sup> Vac. Inert. Relief valve may begin venting at 45 psia. LH<sub>2</sub> manifold burst pressure is 88 psia.
10. With RTLS dump valves failed closed, primary vacuum inert can not be performed. If manual vacuum inerts performed through Fill/Drain valves, values approximate the "no-failure" case.
11. Values do not include potential H<sub>2</sub> trapped in Recirc/Replenish lines.

The software will automatically close the backup dump valves at the termination of the first automated vacuum inert, if the switch had not previously been closed manually. At the end of the second automated vacuum inert, 0.24 lbm will remain (Ref. 2). If the backup dump valves are manually closed between MECO + 7 min and MECO + 10 min per Flight Rule A5-205, only 0.10 lbm of H<sub>2</sub> will remain in the manifold, as shown in Table 2.2.11-I.

There are two nominal ways for further removal of hydrogen from the manifold: system leakage and the feedline relief and relief isolation valves. If system leakage is insufficient to keep the pressure low and the manifold pressure exceeds the relief valve cracking pressure (40 - 55 psig), the pressure will be relieved (and residuals will be evacuated) via the LH<sub>2</sub> relief valve. It takes approximately 1 lbm of LH<sub>2</sub> at 70 deg F to cause the manifold pressure to reach the 40 psig minimum relief valve cracking pressure. The manifold pressure at this point will be reliant on correct operation of the manifold relief isolation valve and the relief valve. Refer to SCP 2.2.10, Feedline Manifold Relief Valve/Isolation Valve Failure, and SCP 2.2.12, MPS Vacuum Inerting Failure, for more information on these post MPS dump situations.

Recall that if the backup dump valves are not manually closed between MECO + 7 min and MECO + 10 min per Flight Rule A5-205, the manifold will have 0.24 lbm of residuals. These residuals are high enough to raise the manifold pressure to 41 psia, which is enough to open the LH<sub>2</sub> feedline relief valve (Ref. 1). In order to avoid opening the feedline relief valve for this case (OB F/D failed closed, B/U dump valves not manually closed on time), the automatic fuel feedline manifold press checkout at the MM 106 transition is inhibited per Flight Rule A5-205. The manifold press checkout is inhibited by taking the LH<sub>2</sub> Manifold Press switch on panel R4 to close prior to the MM 106 transition. The switch is then taken to the GPC position after MM 106 plus 3 minutes.

Similarly, if the backup dump valve switch is not manually opened at all, the backup dump valves will automatically close at dump stop. In this case, 1.9 lbm of residuals remain after the second auto vacuum inert (as shown in Table 2.2.11-I), and the fuel manifold press checkout at MM 106 is inhibited as above per Flight Rule A5-205.

#### B. LH<sub>2</sub> O/B F/D Valve Failure, TAL and RTLS:

For the OB F/D valve failure on a TAL, 2.5 lbm of hydrogen remains. For the RTLS case, 40.3 lbm of hydrogen remains. In these failure cases, concern exists for crew and convoy safety because analysis (reference 8) predicts the MPS LH<sub>2</sub> manifold will exceed its relief setting, and venting of hydrogen residuals (potentially explosive mixture) will occur as early as 10.8 minutes after touchdown. In addition, nominal leakage in the MPS system could lead to the buildup of an explosive mixture of hydrogen in or around the aft compartment. After discussion at the Ascent/Entry Flight Techniques Panel (AEFTP #168 on 10/27/00) and subsequent discussions with KSC ground operations and KSC safety, it was decided that the appropriate action for MPS dump failures on RTLS and TAL aborts is to perform an expedited powerdown. Rationale for this decision is based on the potential hazard to the flight crew and ground personnel due to uncertainties in the



hazards of the trapped hydrogen residuals. Although, residuals due to a failure in the MPS system on a TAL abort can be lower than the residuals on a nominal RTLS abort, an expedited powerdown will still be performed on the TAL because of the limited ground operations equipment available to assess and manage the situation at the TAL site. Expedited powerdown actions are not required for AOA aborts or nominal missions because sufficient time exists on orbit to fully inert the MPS LH<sub>2</sub> manifold of all LH<sub>2</sub> residuals. Reference rationale of Flight Rule A16-11, Expedited Powerdown.

Per Flight Rules A5-210, Entry MPS Propellant Dump Failures, and A16-11, Expedited Powerdown, the Booster Systems Engineer (BSE) should alert the flight director (FD) and convoy (via the flight dynamics officer - FDO) of the “negative inert” and high LH<sub>2</sub> residuals in the manifolds (aft compartment) and request an expedited powerdown and mode V egress (Ref. 1). The venting hydrogen represents a fire and explosion hazard (at stoichiometric conditions, 0.1 lbm of hydrogen is equivalent to 3.3 lbm of TNT (Ref. 6)). The Booster operator should also alert the EGIL operator to inform them of the required powerdown.

#### C. LH<sub>2</sub> I/B F/D Valve Failure, Nominal, ATO, AOA, TAL, and RTLS:

With the failure of the LH<sub>2</sub> inboard F/D valve, LH<sub>2</sub> in the manifold can only be dumped through the FBVs and recirculation system (via topping valve) to the outboard F/D and through the backup dump valves. This failure will result in a residual mass of 3.43 lbm at dump stop. Although this small amount of LH<sub>2</sub> residuals is not as great a concern as the residuals due to the OB failure, per Flight Rule A5-205 for the uphill cases (Nom/AOA/ATO), the LH<sub>2</sub> backup dump valves are opened to allow an additional 2.96 lbm of hydrogen to be vented and the valves will be closed between MECO +7 minutes and MECO +10 minutes. Since the FBV closes at MPS dump stop, the automated vacuum inerts will not vent any further residuals in the recirculation line; therefore, not opening the backup dump valves for the IB failure results in the entire 3.43 lbm of hydrogen residuals remaining at MPS dump stop (Ref. 6). If the LH<sub>2</sub> backup dump valves are opened before dump stop and closed between MECO + 7 min and MECO +10 min per Flight Rule A5-205, this mass will decrease to 0.47 lbm after the MPS dump (Ref. 1). However, according to Flight Rule A5-205, the fuel manifold press checkout at MM 106 will be inhibited for failure to complete the backup dump valve manual switch throws, as described above for OB F/D failures.

#### D. Topping Valve, Pre-Valve, or SSME Fuel Bleed Valve Failure, Nominal, ATO, AOA, TAL, and RTLS:

Opening the LH<sub>2</sub> backup dump valves is not required for the case of the topping valve, pre-valve, or SSME fuel bleed valve failure because the post dump residuals are acceptable (4.0 lbm). Additionally, not opening the LH<sub>2</sub> backup dump valves will allow pressure to build up (boil-off) and be subsequently relieved during the automated vacuum inerts, thus resulting in lower post vacuum inert residuals (0.07 lbm) and pressure.

E. LH<sub>2</sub> Relief Isolation Valve Failure, Nominal, ATO, AOA, TAL, and RTLS:

If the LH<sub>2</sub> relief isolation valve fails closed on a RTLS or TAL, not only will the relief valve not be able to provide its pressure relief function, but the Entry MPS dump will be unpressurized (because the RTLS repress helium flow enters the LH<sub>2</sub> manifold through the LH<sub>2</sub> relief isolation valve). This will result in exceeding the spec. burst pressure (83 psig) approximately 98 minutes after landing for RTLS, 129 minutes for TAL (Ref. 4). But the manifold pressure should be within the demonstrated capability of the line (209 psi; Ref. 9). However, the FD and convoy should still be alerted of the high residuals. As stated previously, in these cases, the Booster operator should inform the EGIL operator and the FDO of the required powerdown, egress, and remaining propellants. Refer to SCP 2.2.10, Feedline Manifold Relief Valve/Isolation Valve Failure, for further information on relief system failures.

F. LH<sub>2</sub> Backup Dump Valve Failure, Nominal, ATO, AOA, TAL, and RTLS:

If the LH<sub>2</sub> B/U dump valves do not open at MECO Confirmed + 13.4 seconds, the LH<sub>2</sub> manifold pressure will begin to rise at approximately 1 psi/second. Such a rise would result in the manifold pressure reaching the maximum relief valve setting in about 15 seconds (per STS-1 data when the software did not open the B/U dump valves as part of its dump sequence). As long as the LH<sub>2</sub> manifold relief isolation valve is open and the LH<sub>2</sub> relief valve is functional, no action is required. If either valve fails, then the action taken depends on the cause of failures. If there are no GPC or MDM failures that could explain the high manifold pressure (by causing loss of command capability to the valves), the MCC and crew should verify that the MPS dump is initiated when the LH<sub>2</sub> manifold pressure reaches 60 psia. If the MPS dump doesn't start and the LH<sub>2</sub> manifold pressure reaches 65 psia (crew receives Class 2 Backup C&W), the crew will be instructed to manually initiate the MPS dump by taking the LH<sub>2</sub> IB and OB F/D valves and the LH<sub>2</sub> backup dump valves to open, per the Ascent Pocket Checklist procedure (Ref.'s 1, 11). Flight Rule A5-203.A does not list manual actions explicitly for this case (reference BQM-394).

If valve function was lost due to multiple GPC and/or FA MDM failures (GPC/FA MDM combinations of 1 & 3, 1 & 4, and 3 & 4), such that all vent, dump, and relief paths were failed closed, then the crew is to open the LH<sub>2</sub> relief isolation valve by taking the MPS FDLN RLF ISOL- LH<sub>2</sub> switch on panel R4 to OPEN, per Flight Rule A5-203.C. The crew's MULTI DATA PATH procedure in the Ascent Entry Systems Procedures (AESP) book (Figure 2.2.11-II) also instructs them to open the MPS FDLN RLF ISOL (two) – both LH<sub>2</sub> and LO<sub>2</sub> valves – for all multiple data path cases since the crew does not have insight into the functionality of the MPS valves. The onboard procedure has the crew take both the LO<sub>2</sub> and LH<sub>2</sub> relief isolation valve switches to open for procedural simplicity. The Booster operator should remind the crew that that procedure needs to be worked immediately post-MECO. This will provide the manifold pressure with a relief

path through the LH<sub>2</sub> manifold relief valve. Note that the crew may enter the MULTI DATA PATH procedure if only a single GPC or FA MDM fails, in combination with a Bus Control Element (BCE) card D . However, since the BCE card failure only takes away insight (thus the multi data path) but not commanding through the MDM, a relief path for the LH<sub>2</sub> manifold still exists. In this case, the crew will only perform the steps in the ‘D’ block (which does not include opening the relief isolation valves).

**MULT DATA PATH LOSS (Non-Recov)**

NOTE

If LRU data path loss due to GPC problem and not MDM, BFS will pick up MDMs/LRU when engaged

FAILURE	TYPE	ACTIONS
GPC/FA any combo	I/O	D √BFS MM at each transition Expect 'SEP INH' (FDLN Fail) combos 2&3,2&4
		Post MECO: Before MECO + 25 sec:** 1. MPS FDLN RLF ISOL (two) – OP 2. MPS PREVLVs (six) – OP RTLS/TAL: MPS LH2 FILL/DRAIN INBD,OUTBD – OP
GPC/FF 1&2	I/O or B	Use R BODY FLAP & TRIM ENA SWs
GPC/FF 3&4	I/O or B	Use L BODY FLAP & TRIM ENA SWs

Figure 2.2.11-II. – AESP FDF: DPS multiple GPC/FA MDM failure Procedure (Ref. 10).

G. Failure of Automatic MPS Dump Sequence, Nominal, ATO, AOA, TAL, and RTLS:

Failure of the automatic MPS dump sequence can be caused by loss of GPC/MDM control of the valves used in the MPS dump sequence. For single GPC/FA MDM failures prior to LH<sub>2</sub> dump (uphill case only), the crew will follow PASS GPC and FA MDM I/O failure procedures in the Ascent Pocket Checklist (APCL; Ref. 11). This procedure directs the crew to open the backup dump valves, but only after contacting the ground to determine if this step is necessary (this is designated by the diamond (◊) symbol in front of the procedure). The ground will use Flight Rule A5-205 along with their insight into the functionality of the backup dump valves to determine if the step is required. If multiple GPC/FA MDM failures occur, these procedures also direct the crew to perform the MULTI DATA PATH procedure to open all six MPS prevalues and the LH<sub>2</sub> relief isolation valve for all failure combinations prior to the MPS dump initiation (refer to Figure 2.2.11-II). Additionally for RTLS and TAL cases, the MULTI DATA PATH procedure directs the crew to open the LH<sub>2</sub> inboard and outboard fill/drain valves

to assure MPS dump capability in the event a restring is not obtained on the TAL/RTLS OPS transition.

Failure of the automatic MPS dump sequence can also be caused by the loss of main bus power to a valve driver. The MPS valves are powered by MNA ALC1 and MNB ALC2 sub-buses. However, a power failure of the associated APC (APC4 and APC 5 respectively) or failure of the entire associated bus will also result in a power failure of the ALC. For these failures, the crew will follow the applicable main bus (or sub-bus) failure procedures to open the LH<sub>2</sub> backup dump valves via the LH<sub>2</sub> backup dump valve switch on panel R2. Reference the EPS section of the APCL for these procedures. The APCL EPS procedures state to perform the actions essentially after ET Sep and that the actions are not required if the bus fails after the OMS-2 burn. Flight Rule A5-205, B more precisely states that the LH<sub>2</sub> backup dump valves are to be opened prior to the end of the MPS Dump, and closed again between MECO + 7 minutes and 10 minutes. Due to the complexity of the Flight Rule, and since these actions are optimizing the configuration, these will remain ground calls.

Note that in the following APCL procedures, the crew will check with the MCC prior to opening the back-up dump valves. The Booster operator should coordinate with the DPS or EGIL operator the requirement for the backup dump valve switch throw.

DPS: PASS GPC (1st FAIL), FA MDM I/O ERROR

EGIL: MNA DA1 (Entire Bus), MNA APC4, MNA ALC1, MNB DA2 (Entire Bus), MNB APC5, MNB ALC2

In addition to the FDF procedures, Flight Rule A5-210, requires manual opening of the LH<sub>2</sub> fill/drain valve(s) on a TAL/AOA if all the LH<sub>2</sub> dump paths have failed (the backup dump valves *and* the fill/drains). For the RTLS case, if either LH<sub>2</sub> fill/drain valve fails closed due to GPC/FA MDM failures, the affected valve(s) will be opened based on a ground call since the B/U dump valves will not provide an adequate dump path (the vehicle will be venting H<sub>2</sub> through the relief valve and flame arrestor post-landing).

Refer to SCP 2.2.12, MPS Vacuum Inert Failures, for information on how failures with the MPS dump can affect the vacuum inert and/or post-vacuum inert procedures.

## REFERENCES

1. STS Operational Flight Rules, All Flights, Final, NSTS-12820, PCN-1, November 21, 2002.
2. "LH<sub>2</sub> Residuals after Vacuum Inerts (OI-29 Software Update)," Boeing Letter from MPS Integration Analysis/Arash Sadeghian, March 6, 2002.

3. Boeing (Rockwell) Internal Letter No. 287-100-94-186, "MPS LH<sub>2</sub> Propellant Dump Performance with OI-23 Software Update," M. E. Lozano, October 12, 1994.
4. PSIG Charts, February 23, 2002, "Action Item: 000119-03 RTLS/TAL Post-Landing GH<sub>2</sub> Venting Analysis," Boeing-Huntington Beach—A. Sadeghian and M. Lozano.
5. Booster Systems Briefs, Basic Rev F; SB 3.5, MPS Propellant Dump.
6. Boeing (Rockwell) Internal Letter No. 287-100-94-171, "Post-Dump LH<sub>2</sub> Feed System Pressure Rise and Vacuum Inert Prediction (OI-23 Patch)," T. Lak, August 12, 1994.
7. Launch Commit Criteria, NSTS 16007, SSID MPS-12, MPS LH<sub>2</sub> High Point Bleed Valve Anomaly, note 7.
8. Boeing Internal Letter No. SHA0-01-043/SI-01-094, "Prediction of MPS LH<sub>2</sub> Relief Vent Valve Cycles for RTLS and TAL Abort Missions," Arash Sadeghian, April 26, 2001.
9. PSIG Charts, August 17, 1994, "STS-64 OI-23 MPS Dump Verification Telecon," Rockwell.
10. Flight Data File – Ascent Entry Systems Procedures (AESP), Vol. I, Gen Rev J, PCN 13; November 9, 2001, Pg. 3-6, MULTI DATA PATH LOSS (Non-Recov).
11. Flight Data File (FDF) – Ascent Pocket Checklist, Vol I, Gen Rev I, PCN 12, October 8, 2001.
12. Overpressure wave characteristics due to hydrogen detonation: Hydrogen overpressure tests (HOT), Vandenberg AFB, 1986.

TITLE

MPS VACUUM INERT FAILURE

PURPOSE

This SCP discusses the possible causes of high LO<sub>2</sub> or LH<sub>2</sub> manifold pressure post-propellant dump and describes the appropriate correction action.

DESCRIPTION

*First Automated Vacuum Inert*

The first automated MPS vacuum inert is initiated at MPS dump start + 17 minutes (nominally MECO + 19:02 (mm:ss) or approximately 27:30 (mm:ss) mission elapsed time, MET) on nominal, AOA, and ATO missions. The first automated inert opens the LH<sub>2</sub> and LO<sub>2</sub> systems to the vacuum of space for 2 minutes to vent residuals overboard that were not vented during the MPS dump (approximately 200 lbm of LO<sub>2</sub> and 4 lbm of LH<sub>2</sub> - see Ref. 1). The inerting sequence consists of opening the LO<sub>2</sub> inboard and outboard fill/drain valves, the LH<sub>2</sub> backup dump valves (opens feedline manifolds), and the LH<sub>2</sub> topping valve (opens recirculation line into manifold). The valves are pneumatically actuated valves with pressure being nominally supplied by the MPS pneumatic helium system.

The first automated MPS vacuum inert is terminated after 2 minutes by closing and terminating power to the LO<sub>2</sub> outboard fill/drain valves and the LH<sub>2</sub> topping and backup dump valves. Closing up the LH<sub>2</sub> manifold between dump stop and the first automated vacuum inert and again between the first automated vacuum inert and the second automated vacuum inert allows pressure to rise above the triple point, thus allowing frozen residuals to boil off more quickly. Thus, performing two separate vacuum inerts is more effective in removing residuals than a single, continuous vacuum inert.

*Second Automatic Vacuum Inert and Manifold Repress*

The second automated MPS vacuum inert is nominally initiated at the Major Mode (MM) 106 transition (post OMS-2 burn) on nominal and ATO missions. The second automated inert opens the LH<sub>2</sub> system to the vacuum of space for 2 minutes to vent any remaining residuals overboard that were not previously vented during the first automated MPS vacuum inert (approximately 0.4 lbm of LH<sub>2</sub> - see Ref. 1). The inerting sequence consists of opening the LH<sub>2</sub> backup dump valves (opens feedline manifolds), and the LH<sub>2</sub> topping valve (opens recirculation line into manifold). The second vacuum inert can be performed manually if required.

The second automated MPS vacuum inert is terminated after 2 minutes by closing and terminating power to the LH<sub>2</sub> topping and backup dump valves. Following the second

automated MPS vacuum inert, the LH<sub>2</sub> manifold is pressurized with helium in order to perform an in-flight checkout of the manifold leakage in order to save ground processing time (i.e. no ground checkout required since it is performed in-flight). Note that the maximum flow rate through the 20 psi helium regulators which feed the manifold repress is only 0.320 lbm/sec (Ref. 2). Therefore, even if the system is open to space, the repress will only waste 3.2 lbm of helium, which is considered insignificant.

On an AOA, the second automated vacuum inert is performed when the MPS dump sequence runs the nominal TAL entry dump (except the fuel bleed valves remain closed during this dump).

### *Nominal Flight Operations*

The LH<sub>2</sub> pressurization line is inerted for 1 minute through the press line vent valve during the crew's MPS GH2 Inerting procedure in the Ascent Checklist (Ref. 3) in the post OMS-1 procedures. The press line vent valve is opened to allow venting of the GH2 press line through the LH<sub>2</sub> ET umbilical compartment prior to closure of the umbilical doors. This inert is only permitted prior to the umbilical door closure per Flight Rule A5-207, LH<sub>2</sub> Pressurization Vent Control (Ref. 4).

The Booster and MPS console operators will verify proper valve configuration and note any discrepancies and the resulting additional residuals (Ref. 1 lists estimated residuals for each type of valve failure). Verification of a good vacuum inert is accomplished by cross-checking the manifold and inlet pressure readings with the nominal values. The nominal values are based on the previous flight readings of the transducers which are vehicle specific (see previous flight log). If these are not available, the preflight biases from KSC are used. In addition, an almost instantaneous drop in manifold pressure can be seen.

### *Manual LO<sub>2</sub> Inerting Requirements*

For a BCE STRING 2C failure, the automated LO<sub>2</sub> vacuum inert will not work because the sequence is not run when the GPCs do not have insight into the LO<sub>2</sub> manifold pressure due to a comm fault. Therefore, the crew must perform a manual LO<sub>2</sub> vacuum inert per Flight Rule A5-206, B, Manual Vacuum Inerting Requirements (Ref. 4). The manual vacuum inert steps are located in the crew procedures (Ref. 5) and should be performed after MPS dump stop plus 20 minutes and when the LO<sub>2</sub> manifold pressure is less than 30 psia, unless the pressure is approaching the burst pressure of the manifold as discussed later. The manual vacuum inert procedure is only used for off-nominal situations such as the above avionics failures, high manifold pressures or suspected LO<sub>2</sub> or LH<sub>2</sub> residuals. If the failure of the automated vacuum inert was due to main bus failures (i.e. valve power) or actual hardware failures, then a manual inert will not be effective. For these cases, the manifold pressure will rise until it reaches the relief setting of the manifold and will be relieved through the manifold relief valve.

*MPS Dump Failure Impacts to Inerting*

Problems with the nominal MPS dump can also affect the vacuum inert. If GPC/MDM failures resulted in failure of the LH<sub>2</sub> IB or OB fill/drain valve to open, the backup dump valves would have been opened per Flight Rule A5-205, B, Nominal, AOA, and ATO MPS Dump Failures (Ref. 4). Since the backup dump valves stay open after dump stop, the LH<sub>2</sub> manifold will vent until pressures and temperatures drop below the triple point for hydrogen when further boil-off of LH<sub>2</sub> residuals is not possible. A small amount (~5 lbm) of hydrogen will remain frozen in the manifold and will sublime very slowly. Since the manifold is already open, the LH<sub>2</sub> vacuum inert will not remove any additional hydrogen residuals; therefore, higher than normal LH<sub>2</sub> manifold pressures could result after the software commands the backup dump valves closed at the end of the first automated vacuum inert (dump start + 19 minutes) or by crew switch throw before the automated vacuum inert (backup dump valves to CLOSE then GPC between 7 and 10 minutes post MECO) per Flight Rule A5-205, B (Ref. 4). If the crew switch throw is not made, the LH<sub>2</sub> manifold repressurization following the second automated vacuum inerted will be inhibited by closing the LH<sub>2</sub> MANF PRESS switch until after MM106 + 3 minutes. Inhibiting the LH<sub>2</sub> manifold repressurization prevents the relatively warm helium from vaporizing the excess frozen H<sub>2</sub> residuals causing a greater than normal pressure rise in the manifold and potentially opening the LH<sub>2</sub> feedline relief valve.

If dump failures cause the LH<sub>2</sub> manifold pressure to increase to between 60 and 90 psia any time between dump stop and vacuum inert start and the manifold sensor is not commfaulted, the software will immediately start the LH<sub>2</sub> vacuum inert by commanding the LH<sub>2</sub> outboard fill/drain and topping valves to open as described in Flight Rule A5-203, A, MPS Propellant Manifold Overpressure (Ref. 4). The first LO<sub>2</sub> inert will begin at the normal time and both inerts will end at the nominal inert stop time. However, if the same GPC/MDM failures that caused the problems with the dump also effect the vacuum inert, then a manual vacuum inert will be required.

Similarly with the LO<sub>2</sub> system, problems with the LO<sub>2</sub> side of the MPS dump could cause high LO<sub>2</sub> manifold pressures. If an incomplete LO<sub>2</sub> dump results in LO<sub>2</sub> manifold pressures greater than 30 psia after the first automated vacuum inert, a manual LO<sub>2</sub> inert will be required per Flight Rule A5-206, A. This manual inert will be delayed until the manifold pressure drops below 30psia to prevent a possible propulsive force of LO<sub>2</sub> being ejected from the fill/drain causing the vehicle to roll per Flight Rules A5-206, A and A5-205, C. The manifold pressure will eventually decrease below 30 psia on its own because LO<sub>2</sub> will vent overboard through the High Pressure Oxidizer Turbopump (HPOTP) InterMediate SeaL (IMSL) package.

*TAL and RTLS Inerting*

The vacuum inert procedure is different for RTLS and TAL aborts due to the limited time frame. There is no LH<sub>2</sub> vacuum inert, but rather an extended LH<sub>2</sub> dump. The LO<sub>2</sub> vacuum inert for an RTLS begins at  $Q \geq 20$  and LO<sub>2</sub> dump start + 30 sec. and ends at  $V_{REL} = 3,800$  ft/s. For a TAL abort, the LO<sub>2</sub> vacuum inert begins at  $V_{REL} < 20K$  ft/s and ends at  $V_{REL} = 5,300$  ft/s. For TAL or AOA aborts, if the LO<sub>2</sub> manifold pressure is greater than 30 psia (or commfaulted), the



automated vacuum inerting of the LO<sub>2</sub> manifold will be inhibited until the manifold pressure vents below 30 psia prior to a  $V_{REL} = 5,300$  ft/s. There are no work around procedures should this occur. Due to the small time frame and the effectiveness of the aerosurfaces in overcoming the rolling moment caused by a potentially propulsive vent on RTLS aborts, the LO<sub>2</sub> system is inerted regardless of the manifold pressure. For all aborts, the LH<sub>2</sub> manifold will be inerted regardless of the pressure reading because vent forces will not significantly roll the vehicle.

### *Manual Vacuum Inerting*

Should the LO<sub>2</sub> fill/drain valves or LH<sub>2</sub> backup dump valves not open during any of the inerting operations, high engine LO<sub>2</sub> or LH<sub>2</sub> manifold pressure may subsequently result. As a backup, the LH<sub>2</sub> manifold may be inerted by opening the backup LH<sub>2</sub> dump valves while in OPS 1 or the LH<sub>2</sub> fill/drain valves (the action depends on the failure mode). The backup dump valves will automatically go closed at the OPS 2 transition if they had been opened after the second automated vacuum inert stop. Although the ability to open the backup dump valves does not exist in OPS 2, should high LH<sub>2</sub> manifold pressure again necessitate the need to inert the LH<sub>2</sub> manifold, the crew could temporarily transition to MM 303 via MM 301 to open them per Flight Rule A5-205, B. The LH<sub>2</sub> fill/drain valves can be manually opened in any OPS mode as long as helium is supplied for valve actuation. Although there is not an alternate dump path for the LO<sub>2</sub> other than through the HPOTP IMSL package, with at least a partial LO<sub>2</sub> dump, it is not expected that the LO<sub>2</sub> manifold pressure will ever reach the relief setting.

The LH<sub>2</sub> or LO<sub>2</sub> pressures may reach their manifold relief pressures (190-220 psig for LO<sub>2</sub> and 40-55 psig for LH<sub>2</sub>) if the LH<sub>2</sub> backup dump valves or the HPOTP IMSL are unable to relieve their respective system's high manifold pressures. If these high manifold pressures are not subsequently relieved by the feedline relief system, due to a failure of the relief isolation valve or relief valve itself, rupture of the feedline manifold could occur resulting in damage to the aft compartment, and possible loss of crew and vehicle. Refer to SCP 2.2.10, Feedline Manifold Relief Valve/Isolation Valve Failure, for more information.

An additional manual vacuum inert will be performed on orbit for suspected LO<sub>2</sub> or LH<sub>2</sub> residuals per Flight Rule A5-206, E., Manual Vacuum Inerting Requirements (Nominal, ATO, AOA) (Ref. 4). Before proceeding with this inert, the mission evaluation room (MER) staff will be consulted to evaluate the need to repeat the manual vacuum inert.

REFERENCES

1. "LH2 and LO2 Residuals for OI-29 Software Change," Boeing Letter from MPS Integration Analysis/Arash Sadeghian, 1/25/02.
2. Charles Eberhart, MPS Components, Boeing, Huntington Beach, CA, May 10, 2002.
3. Flight Data File (FDF) – Ascent Checklist, pg. 3-5 "MPS GH2 Inerting."
4. STS Operational Flight Rules, JSC-12820, Volume A, All Flights, Final, PCN-1, November 21, 2002.
5. Flight Data File (FDF) – Ascent Pocket Checklist, pg. 9-3 "MPS Vacuum Inerting" procedure.
6. Boeing Internal Letter No. 287-100-99-030, "Performance Analysis of LH2 RTLS Dump System for MPS Vacuum Inerting Operations," M. E. Lozano, Feb. 9, 1999.

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TITLE

MPS CRITICAL INSTRUMENTATION LOSS IMPACT

PURPOSE

The purpose of this SCP is to list MPS critical instrumentation and to provide impact/work around procedure for loss of this instrumentation. This SCP does not contain failure recognition or procedures for the parameters that are already discussed in other SCPs, but rather the parameters that have not been covered in other SCPs.

DESCRIPTION

MPS critical instrumentation can be lost due to a transducer, MDM, or GPC failure. A transducer can fail off scale high, fail off scale low, drift, or have an erratic shift. An MDM and/or GPC failure can cause the displayed data to go static. Reference the Booster Cue Card Handbook (BCCH), MPS Ascent TLM Loss and Bilevel TLM Loss cue cards, for an overview of GPC and/or MDM failure impacts. This SCP focuses on the failure impact rather than the failure mode for the instrumentation loss.

The MPS system has many parameters, but for the purpose of this SCP only critical parameter instrumentation loss will be discussed. These parameters are considered critical because loss of instrumentation will take away insight into a critical system. Table 2.2.13-I lists the MPS critical instrumentation, and the associated impacts.

The procedure listed below for the loss of each of these parameters includes the following: failed parameter, associated flight rule(s), onboard operation (failure recognition & work around procedure), and ground operation (failure recognition and work around procedure). The failure recognition and work around procedures are listed in a tabular format. Even though the SCPs are for ground operation, a brief description of the onboard operation is included here to provide the ground operators with the crew's prospective and limitations. The failure recognition table consists of the parameter names (with associated MSIDs), failure values/trends, and displays on which the failed parameters and values can be observed. Onboard failure recognition tables include all of the orbiter caution and warning indications for failure trend regardless if the crew uses them for failure recognition or not.

An MPS critical instrumentation failure causing violation of the onboard caution and warning (C&W) will result in any of the following: class 2 alarm, class 3 tone, associated fault message, Master Alarm light, MPS light on panel F7 matrix, and/or panel R13U status light. The three onboard C&W systems have multitudes of idiosyncrasies, most of which are not covered in this SCP. Other references on C&W include the MPS Hardware & Software C&W Cue Card (Ref. BCCH), the REF DATA book, and the C&W 2102 workbook.

Table 2.2.13-I - MPS Critical Instrumentation List

MPS Critical Instrumentation	Impact due to Instrumentation Failure
A. Helium tank pressure.	Loss of onboard capability to identify helium leak in the engine system. Ground does have secondary instrumentation to identify helium leak, but makes helium leak isolation difficult.
B. Helium regulator outlet pressures.	Loss of onboard and ground capability to identify helium regulator shift without working the helium leak isolation procedure. During entry, it is critical to identify and isolate a regulator shift within 17 seconds to prevent over pressurization of the aft compartment when the vent doors are closed.
C. LH2 or LO2 manifold pressures.	Loss of onboard capability to identify manifold over pressurization. Ground does have secondary instrumentation to monitor the manifold pressure. During mainstage operation, loss of manifold pressure is not an impact, but it will impact post MECO and Entry MPS dump operations.
D. LH2 or LO2 inlet pressure.	Loss of ground capability to determine if the MPS dump inhibit is required on an SSME with a premature shut down. Ref. SCP 2.2.9, MPS Dump Inhibit.
E. LH2 ullage pressure.	Failure to control the LH2 flow control valve properly. Ref. SCP 2.2.4, ET LH2 Ullage pressurization Failures/NPSP Problems.
F. GH2 outlet pressure or the GO2 outlet temperature.	Loss of onboard and ground capability to use these parameters as a cue to determine if the SSME has shut down behind a data path failure. Ref. SCP 2.1.3, Data Path Failure.

Just like the crew, the MCC will see the fault message on the onboard fault summary display; therefore, the fault messages are not repeated in the ground failure recognition sections below. The MCC also sees telemetry on the mps\_ascent and mps\_entry displays rather than the meters and does not hear any of the audible cues. Observing other related parameters typically compensates for the loss of data. The ground procedure contains the related parameters that the MPS and BSE operator should monitored in case of the instrumentation loss. The ground procedure also includes recommended information that should be communicated between various positions in the MCC.

PROCEDURE

A. Helium Tank Pressure Failure

1. Flight Rule - None
2. Onboard Operations
  - a. Onboard Recognition

Table 2.2.13-II - Helium Tank Pressure Failure, Onboard Failure Recognition

Parameter no.	Failure value/trend	Displayed on
(He Tk P) (C) V41P1150C (L) V41P1250C (R) V41P1350C	Tank pressure <1150 PSIA "MPS He P C (L, R)" Class 2 alarm, light	BFS GNC SYS SUMM 1 FAULT MESSAGE PNL F7, R13U
Pneu Tk P (P) V41P1600A	Tank pressure <3800 PSIA "MPS PNEU TK" Class 3 tone, light	BFS GNC SYS SUMM 1 FAULT MESSAGE PNL F7

b. Onboard Procedures

Reference the following FDF: AESP A8-4, MPS He P (Pre-MECO), and AESP E8-2, MPS He P/MPS C&W LIGHT.

3. Ground Operations

a. Ground Recognition

Table 2.2.13-III - Helium Tank Pressure Failure, Ground Failure Recognition

Parameter no.	Failure value/trend	Displayed on
(He Tk P) (C) V41P1150C (L) V41P1250C (R) V41P1350C (P) V41P1600A	Out of limits High or Low Off scale High or Low Static or Erratic	mps_ascent and mps_entry
(BFS He Tk P) (C) V98P2155C (L) V98P2156C (R) V98P2157C (P) V41P1600A	Out of limits High or Low Off scale High or Low Static or Erratic	BFS_mps_ascent

b. Ground Procedures

Table 2.2.13-IV - Helium Tank Pressure Failure, Ground Failure Procedures

Step	Procedure	Position
1	Inform BSE that the L (C, R, or Pneu) He Tk P is out of limits or static, monitoring the He AFT TK T, MID TK T, and He REG PA and PB.	MPS/BSE
2	If the other data for the affected He system in step 1 is consistent with the other He systems, inform BSE that the L (C, R, or Pneu) He Tk P is an instrumentation failure and loss of class 2 or 3 C/W on the affected system. No actions for the crew. Inform FD that the L (C, R, or Pneu) He Tk P is an instrumentation failure, no actions for the crew.	MPS/BSE  BSE/FD
3	If the other data for the affected He system in step 1 is inconsistent with the other He systems, inform BSE of problems within that helium system (possible He leak). Work the procedure per SCP 2.2.7, Helium Leak Isolation/Evaluation/Interconnection.	MPS/BSE/ FD

B. Helium Regulator Pressure Failure

1. Flight Rule – FR A5-208
2. Onboard Operations
  - a. Onboard Recognition

Table 2.2.13-V - Helium Regulator Pressure Failure, Onboard Failure Recognition

Parameter no.	Failure value/trend	Displayed on
(He Reg P A) (C) V41P1154A (L) V41P1254A (R) V41P1354A	Reg P <679 or >810 PSIA “MPS He P C (L, R)” Class 3 tone, light	BFS GNC SYS SUMM 1 FAULT MESSAGE PNL F7
	Reg P <680 or >810 PSIA Class 2 alarm, lights	BFS GNC SYS SUMM 1 PNL F7, R13U
(He Reg P B) (C) V41P1153A (L) V41P1253A (R) V41P1353A	Reg P <679 or >810 PSIA “MPS He P C (L, R)” Class 3 tone, light	BFS GNC SYS SUMM 1 FAULT MESSAGE PNL F7
(Pneu He Reg P) (P) V41P1605A	Reg P <700 or >810 PSIA “MPS PNEU REG” Class 3 tone, light	BFS GNC SYS SUMM 1 FAULT MESSAGE PNL F7

b. Onboard Procedures

Reference the following FDF: AESP A8-4, MPS He P (Pre-MECO), and AESP E8-2, MPS He P/MPS C&W LIGHT.



3. Ground Operations

a. Ground Recognition

Table 2.2.13-VI - Helium Regulator Pressure Failure, Ground Failure Recognition

Parameter no.	Failure value/trend	Displayed on
(He Reg PA) (C) V41P1154A (L) V41P1254A (R) V41P1354A (He Reg PB) (C) V41P1153A (L) V41P1253A (R) V41P1353A (Pneu He Reg P) (P) V41P1605A	Out of limits High or Low Off scale High or Low Static or Erratic	mps_ascent and mps_entry

b. Ground Procedures

Table 2.2.13-VII - Helium Regulator Pressure Failure, Ground Failure Procedure

Step	Procedure	Position
1	Inform BSE that the L (C, R, or Pneu) He Reg A or B P is out of limits or static, monitoring MPS He TK P, He dp/dt, He AFT TK T, MID TK T, and He REG B or A P.	MPS/BSE
2	For Ascent: If the other data for the affected He system in step 1 is consistent with the other He systems, inform BSE that the Reg A or B P is an instrumentation failure. Loss of class 3 (Reg B and Pneu Reg) or class 2 and 3 (Reg A) C/W on the affected system, no actions at this time. Inform FD that the L (C, R, or Pneu) He Reg A or B P is an instrumentation failure, no action for the crew.	MPS/BSE  BSE/FD

Table 2.2.13-VII - Helium Regulator Pressure Failure, Ground Failure Procedure (Continued)

<p>2 (Cont.)</p>	<p>For NOM/ATO Entry only (prior to Mach 2.4): If the other data for the affected He system in step 1 is consistent with the other He systems, inform BSE that the L (C, R, or Pneu) Reg A or B P is an instrumentation failure. Loss of class 3 (Reg B and Pneu Reg) or class 2 and 3 (Reg A) C/W on the affected system, take the associated MPS He Isolation Valve on Panel R2 to CLOSE. Ref. FR A5-208. Inform FD that the L (C, R, or Pneu) He Reg A or B P is an instrumentation failure, lost all C/W on the associated Reg. Take the associated MPS He Isolation Valve on Panel R2 to CLOSE.</p>	<p>MPS/BSE  BSE/FD</p>
<p>3</p>	<p>If the other data for the affected He system in step 1 is inconsistent with the other He systems, inform BSE of problems within that helium system (possible He leak or Reg shift). Work the procedure per SCP 2.2.7.</p>	<p>MPS/BSE/ FD</p>

C. Manifold Pressure Failure

1. Flight Rules: A5-203, A5-205, A5-206 and A5-210
2. Onboard Operations
  - a. Onboard Recognition

Table 2.2.13-VIII – Manifold Pressure Failure, Onboard Failure Recognition

Parameter no.	Failure value/trend	Displayed on
(LO2 MANF P) V41P1533C	LO2 MANF P > 249 PSIA “MPS LH2/O2 MANF” Class 2 alarm and lights	BFS GNC SYS SUMM 1 FAULT MESSAGE PNL F7, R13U
(LH2 MANF P) V41P1433C	LH2 MANF P > 65 PSIA “MPS LH2/O2 MANF” Class 2 alarm and lights	BFS GNC SYS SUMM 1 FAULT MESSAGE PNL F7, R13U

b. Onboard Procedures

Reference the following FDF: ORB OPS C/L 8-2, MPS Vacuum Inert.

3. Ground Operations

a. Ground Recognition

Table 2.2.13-IX – Manifold Pressure Failure, Ground Failure Recognition

Parameter no.	Failure value/trend	Displayed on
(LO2 MANF P) V41P1533C	Out of limits High or Low Off scale High or Low Static or Erratic	mps_ascent and mps_entry
(LH2 MANF P) V41P1433C	Out of limits High or Low Off scale High or Low Static or Erratic	mps_ascent and mps_entry

b. Ground Procedures

Table 2.2.13-X – Manifold Pressure Failure, Ground Failure Procedure

Step	Procedure	Position
1	If the LO2 or LH2 MANF P is out of limits or static, inform BSE and monitor inlet pressure (IN P). With prevalves open, IN P should be approximately equal to MANF P.	MPS
2	If MANF P is consistent with IN P, inform BSE of the high LO2 or LH2 MANF P and work the procedure per SCP 2.2.10, Feedline Manifold Relief/Isolation Valve Failure.	MPS/BSE
3	If the LO2 or LH2 MANF P is not consistent with IN P, inform BSE that the LO2 or LH2 MANF P is an instrumentation failure and loss of class 2 C/W on the affected system.	MPS/BSE
4	<p>LO<sub>2</sub> Failures</p> <p>NOM/ATO/AOA: For a BCE String 2C failure (which commfaults the LO2 MANF P) a manual LO<sub>2</sub> vacuum inert will be performed after MPS Dump start + 22 min (~MECO + 24 min). The manual vacuum inert is performed through the LO<sub>2</sub> Fill/Drain valves if the manifold pressure is confirmed less than 30 psia, per APCL procedure MPS VACUUM INERT as part of the BCE STRING X procedure in APCL. Software will inhibit the LO<sub>2</sub> automatic vacuum inert at MECO + 19 min. Reference FR A5-206, B.</p> <p>If the LO<sub>2</sub> MANF P is failed above 249 psia post-1st Auto Vacuum Inert, the LO<sub>2</sub> Outboard Fill/Drain valve will be manually opened immediately as part of the Orbit Pocket Checklist (OPCL) MPS C/W procedure. Ref. FR A5-203, A.</p> <p>TAL/RTLS: If the LO2 MANF P is commfaulted, FA2(C), or fails &gt; 30 psia, the software will not command the LO<sub>2</sub> fill/drain valves open at Vrel = 20k ft/sec. No action is required.</p>	<p>MPS/BSE/ FD</p> <p>MPS/BSE/ FD</p>



- D. LH2 or LO2 Inlet Pressure Failure - Refer to SCP 2.2.9.
- E. LH2 Ullage Pressure Failure - Refer to SCP 2.2.4.
- F. GH2 outlet pressure or the GO2 outlet temperature Failure– Refer to SCP 2.1.3.

#### REFERENCES

- 1) STS Operational Flight Rules, All Flights, Final, PCN-1, JSC-12820, November 21, 2002.
- 2) Booster Standard Console Procedures, Rev E, PCN-8, JSC-17239, November 23, 1999
- 3) Booster Systems Briefs, Basic, Rev D, PEN & INK #1, JSC-19041, July 1, 1997.
- 4) Booster Cue Card Book, Rev A, PCN-9, BSE-001, March 27, 2002.
- 5) Flight Data Files (FDF) – AESP, APCL, OPCL, and Ref Data, Generic, Rev I, PCN-1, January 31, 2002.

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## TITLE

MPS Low-Level Cutoff Sensor Failures

## PURPOSE

This SCP describes the crew and main propulsion system (MPS) console operator's procedures and responsibilities for low-level cutoff (LLCO) sensor failures during ascent.

## DESCRIPTION

The LH<sub>2</sub> and LO<sub>2</sub> Low Level Cutoff (LLCO) system protects against running the SSMEs to propellant depletion by commanding a preemptive shutdown of the engines when low level sensors detect the liquid gas interface of either propellant approaching the engines. A nominal main engine cut-off (MECO) is initiated when the vehicle reaches a desired I-loaded velocity, however an early engine failure or performance problem can cause propellant depletion to occur before the targeted velocity is reached. If a LLCO occurs, the SSME operations sequence will shut down the three engines when the liquid/gas interface is detected by propellant low level sensors before the propellant supply (LO<sub>2</sub> or LH<sub>2</sub>) to the engines is depleted. Without the active LLCO sensors, depletion of LO<sub>2</sub> to a running engine will cause pump cavitation and uncontained damage to engine components. With the depletion of LH<sub>2</sub> during a LLCO, a LO<sub>2</sub>-rich shutdown of a running engine will occur, causing higher than normal temperatures and resulting in burning and severe erosion of engine components

Four LO<sub>2</sub> low level sensors are located in the orbiter 17-inch LO<sub>2</sub> feedline and four LH<sub>2</sub> low level sensors are located in the bottom of the ET LH<sub>2</sub> tank. These sensors are positioned to ensure sufficient propellant between the sensors and the SSME low pressure pump inlets to prevent propellant depletion during SSME shutdown. A possible failure mode for the LLCO sensor is failed-wet by loss of power or open sensor circuit. A pre-launch LLCO sensor checkout is performed after ET propellant loading (~T-4 hours) per S0007, Volume 2, Sequence 16 to detect failed-wet condition. A launch commit criteria (MPS-21, MPS-22) will also inhibit launch for a failed-dry sensor prior to T-31 sec. To prevent a premature MECO caused by failed-dry sensors during flight, the low level sensors are not enabled until an arm command is sent by guidance. After arm, two dry indications are required on the same propellant to initiate a LLCO.

There are four power supplies used for the point sensor electronics. The power supplies for sensors 2, 3, and 4 are single power source with an "on" command sent from an FA MDM. Loss of the electrical bus results in loss of power to the sensor which causes it to fail "wet". A power fail of the MDM associated with the point electronics also causes a loss of power to the sensor, but that indication is masked by comm faulted indication since the sensor power and telemetry are over the same MDM. The fourth power supply used on sensor number 1 receives power from two separate Remote Power Controllers (RPC). Each RPC output is powered from an ALC



and APC on the same main bus (e.g. ALC2 and APC2). Loss of either, or both, would result in the loss of an RPC, but the point sensor electronics would still be powered through the redundant RPC. Similarly, a power fail of the MDM associated with an RPC would give the same indication. Loss of both RPCs results in a “wet” indication for sensor 1. On CRANS, an RPC loss would be indicated for the affected sensor to warn the user that that sensor is now fail critical.

The ET LOW LEVEL SENSOR ARM CMD is initiated by the ascent second stage guidance function or the powered Return-to-Launch Site (RTL) abort guidance function. The ARM command is set if two SSMEs are shut down or if the current calculated vehicle mass becomes less than an I-loaded value (MASS LOW LEVEL, V97U4432C). This I-loaded value is selected to provide the orbiter with approximately two percent propellant remaining when the ARM command is received.

When the ET LOW LEVEL SENSOR ARM CMD is issued, the SSME operations sequence will begin to monitor the eight low level sensors for dry indications or commfault indications. Sensors that have been commfaulted are disregarded. On the first pass through the software logic after the arm command if one sensor is indicating dry on the given propellant system, the logic will disable that sensor. If more than one sensor for a given propellant indicates dry, the lower numbered one is disabled. This check allows a prematurely failed dry sensor to be removed from the LLCO logic. If a sensor that was not previously disabled or commfaulted indicates dry, an internal flag is set, indicating that sensor is dry. When any two sensor dry flags are set after arm, MECO will be commanded immediately or after 0.358 seconds according to the appropriate I-loaded delay timer (see Ref. 2, SB 2.4).

#### Failure: 3 LLCO Sensors Failed Dry

If three of the four sensors on a given propellant fail dry, one will be disqualified upon the first logic cycle after the arm flag is set and the other two sensors indicating dry will cause MECO to be commanded as soon as the appropriate LLCO delay timer expires. If three or more sensors fail dry on the same tank and uphill capability does not exist for MECO at ARM, a Trans-Oceanic Abort Landing (TAL) abort will be performed to either a TAL site or Augmented Contingency Landing Site (ACLS) abort site if no TAL site is available, per Flight Rule A5-157 (Ref. 1). A preflight-evaluation will be required to determine if uphill capability exists for MECO at the ARM command. This evaluation is based on the predicted I-loaded mass at which ARM will be set. Two sensors failed dry will not require an abort, since one will be disabled at ARM, and two valid sensors remain.

There is a procedure to avoid MECO at ARM. A failed dry sensor may be commfaulted by power cycling the appropriate Multiplexer-DeMultiplexer (MDM) (sensor #1 – FA3, sensor #2 – FA2, sensor #3 – FA4, sensor #4 – FA1). The now-commfaulted sensor will be disregarded, one failed dry sensor will be disabled at ARM, a second dry sensor will stay dry, and the final sensor will initiate LLCO correctly if it indicates dry. However, this procedure is outside of the flight rules and is not recommended. After experiencing three failures of the same type of sensor, the fourth sensor is considered highly suspect and should not be relied upon for a LLCO.

Failure: Loss of LLCO Protection

Certain Data Processing System (DPS) / Electrical Power System (EPS) failure combinations may result in the loss of LLCO protection. If 3 or more sensors have comm faulted or failed to the wet state (any combination), then LLCO can never be sensed. Recall that two sensors must indicate dry after ARM to initiate LLCO. Comm faults can occur due to a loss of GPC, FA MDM, or BCE Card D.

In the case of lost LLCO protection, the current procedure agreed by the flight director office and Booster group is as follows. If 3-sigma confidence of guided MECO does not exist as predicted by the Abort Region Determinator (ARD), then in order to regain the LLCO sensor, the crew may take the following actions, in order of preference, on the MDM associated with a comm faulted sensor: 1) port mode, 2) power-cycle, 3) restrung. If the sensor is failed wet due to an electrical problem, a bus tie to regain the appropriate main bus may be in order. If the above actions are not feasible in the flight conditions or do not recover low level cut-off protection, then a TAL abort will be performed. With nominal performance and 3-sigma confidence of nominal MECO, then LLCO protection would not be required and no abort is performed. 3-sigma confidence is required since a propellant starvation cutoff would result in a catastrophic failure.

Failure: MECO after arm for loss of two engines

Since the loss of two engines immediately sets the arming flag for monitoring the LLCO sensors, the loss of two engines with 3 or more LLCO sensors failed dry would result in an immediate MECO. One method to avoid this is to comm fault one of the failed sensors prior to the second engine failing. Comm faulting the sensor(s) after the second engine fail will not alleviate the problem since the SSME OPS sequence will latch a sensor to the dry state once the Arming command is issued. As stated previously, comm faulting a sensor is outside of the flight rules and is not recommended. After experiencing three failures of the same type of sensor, the fourth sensor is considered highly suspect and should not be relied upon for a LLCO protection.

Example: 1 SSME is failed and 2 LLCO sensors are failed dry. If a second engine failed, the Arm flag would be set, one sensor would be disqualified and the other sensor would be latched dry. A third sensor failing dry would create MECO even if the crew were to comm fault one of the previously failed sensors. Therefore, any sensor masking must be done prior to setting the Arm flag.

REFERENCES

1. STS Operational Flight Rules, All Flights, Final, PCN-3, NSTS-12820, Volume A, January 13, 2005.
2. Booster Systems Briefs, Basic Rev F; July 7, 2004.
3. Level C, Functional Software Subsystem Requirements (FSSR), Sequence Requirements, May 30, 2003.

TITLE

Control Bus Failure Indications

PURPOSE

This SCP describes the MPS and Booster operators actions to identify and report potential control bus failures.

DESCRIPTION

Control buses are commonly used to power crew panel switches, but in the main propulsion system, they are also used to indicate the position of the 17 inch feedline disconnects. If a switch loses its control bus power, the valve may lose all or some manual capability, but automatic capability is maintained. Control buses are generally wired in a daisy-chain fashion, such that a partial control bus loss does not necessarily result in an entire bus loss, but instead only groups of proximate panels may be affected. Partial control bus losses typically result in the crew manually unpowering the entire bus when time permits.

Booster operators monitor telemetry on switches on Panels C3, R2, R4, and O17. For example, on Panel R2, the switch for the Left Engine Helium Isolation Valve A is powered by Control Bus BC3, shown schematically in Figure 2.2.15-I. This switch is normally open during ascent, and if the control bus fails, the switch position indicator telemetry (V41S1255E) would appear to be unpowered on the Bilevel\_Display, even though the valve would still be commanded open by the GPCs via string FA2 (Ref. 1).

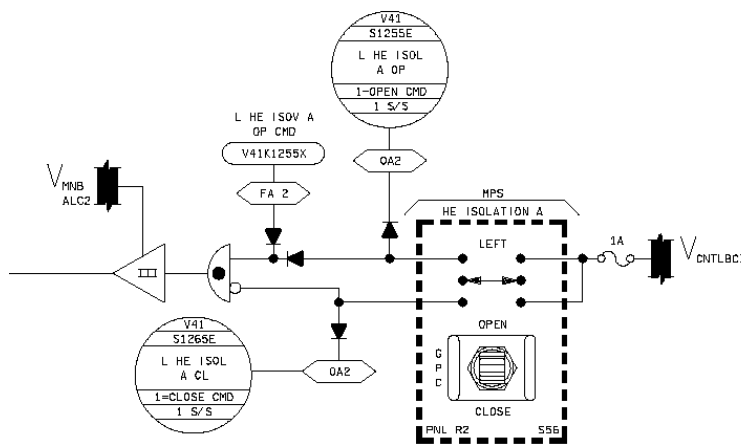


Figure 2.2.15-I. Example Wiring Schematic for Helium Isolation Valve Switch (Ref. 1)

Other switches have multiple contacts and single control bus losses may not result in a failed switch indicator or loss of manual capability, but instead result in a failure of a single Remote Power Controller (RPC). For example, the helium isolation valve commands are removed at the end of the MPS dump, but the switch is not moved from the OPEN position until later (see Figure 2.2.15-II). During that time, the RPCs will be powered only by the control buses via the switch position. If Control Bus CA1 failed, then the RPC C indicator telemetry would be OFF on the Bilevel\_Display, but the switch indication telemetry would still be powered on and shown in the OPEN position via Control Bus AB2 power.

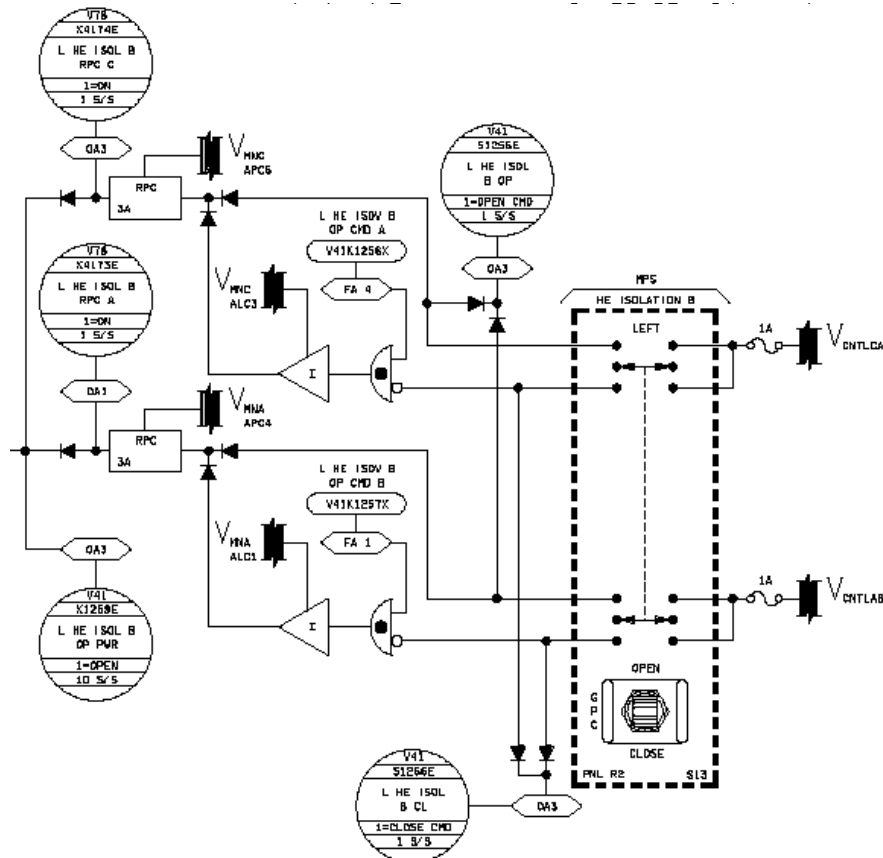


Figure 2.2.15-II. Wiring Schematic of Left Engine Helium Isolation Valve B (Ref. 1)

If an electrical control bus is suspected to have a short, the Electrical, General Instrumentation, and Lighting Engineer (EGIL) will call for the other flight control positions to check for telemetry that would indicate the health of the control bus. The Booster, MPS, and Main Engine operators should check their telemetry available on the MPS\_Ascent\_Display, DDD\_Display, Bilevel\_Display, and Entry\_Display, and the Booster operator will report any panel location health indicators to the EGIL. These actions are taken on a time-permitting basis for the Booster team. Note that in the case of a suspected control bus loss, the telemetry will appear in the unpowered state (typically OFF) on the console displays, instead of status-colored as driven by ISPATOM. The Booster operator should also coordinate with the EGIL operator before using a switch or pushbutton with a contact that uses a control bus with a known short.

The Booster operator will contact EGIL on the MOCR SYS 1 voice loop, or the Booster operator may assign the MPS or Main Engine operators to contact EGIL's MPSR support, EPS, on the SSR CONF 1 voice loop. Note that the MPS and Main Engine operators should continuously monitor the MOCR SYS 1 and SSR CONF 1 loop for other disciplines reporting possible bus indications. Additional information on the use of the voice loops may be found in SCP 3.3.2. The Booster team operator should report, "EGIL, Booster. We see Control Bus XYZ down at panel XYZ," or in the case of disconnect or latch indication failures, "we see Control Bus XYZ down at the LO2 [LH2] 17" Disconnect."

The SSME limit shutdown control switch and shutdown pushbutton control bus indications are described in SCP 2.1.12. Note that monitoring these switches is primarily the responsibility of the Main Engine operator instead of the MPS operator, and further actions and details are included in SCP 2.1.12.

#### REFERENCES

1. Space Shuttle Systems Handbook (SSSH), JSC-11174, Rev. G, DCN-1, September 15, 2003.

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TITLE

ME CONSOLE LOCATION/CONFIGURATION

PURPOSE

The purpose of this SCP is to describe the location and configuration of the Main Engine (ME) console.

DESCRIPTION

The ME console is located in room 2334 of building 30S. The console configuration consists of two DVIS communication panels (#4716 and #4717) and three monitors that are driven by two DEC Alpha workstations (named White-MPSR-19 and White-MPSR-20). For use of the DVIS system, reference SCP 3.3.2 – BSE/ME/MPS Communication Panels. For an explanation of the displays listed below, reference SCP 3.1.2 – ME Console CRT Displays.

PROCEDURE

The ME console is configured by selecting either a flight or a simulation activity during the login process and executing the required software applications.

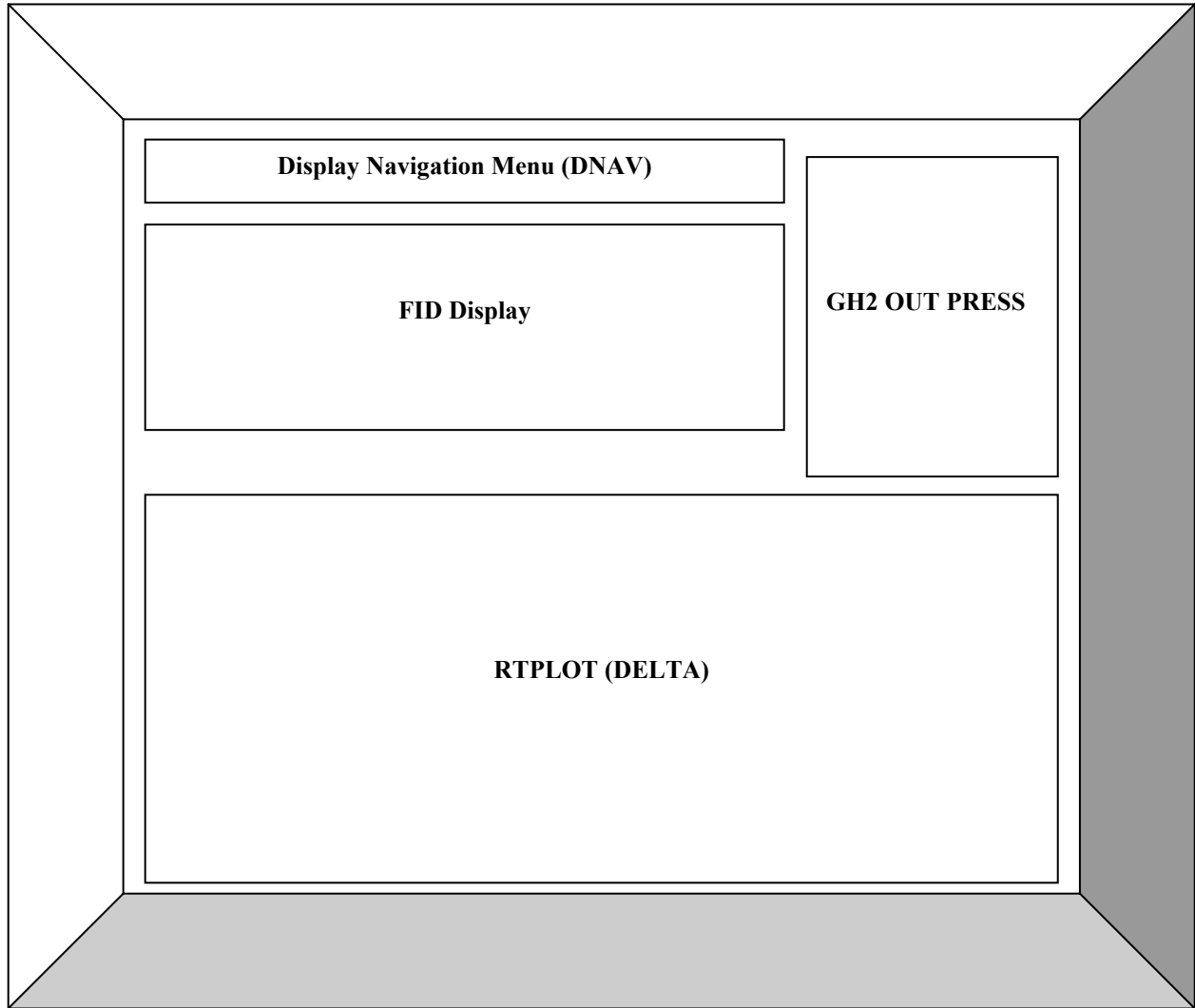
The software applications used by the ME operator are listed in Table 3.1.1-I. These applications are located in the Display Navigation Menu (DNAV). Figures 3.1.1-I, 3.1.1-II, and 3.1.1-III show a typical software arrangement for the left, center, and right monitors, respectively. The exact configuration of the ME console is up to the individual user.



Table 3.1.1-I. - ME SOFTWARE APPLICATIONS

APPLICATION	DNAV LOCATION
Main Engine	BOOSTER-Displays
PASS Header	BOOSTER-Displays
BFS Main Engine	BOOSTER-Displays
BFS Header	BOOSTER-Displays
Delta	BOOSTER-Displays
DDD Panel	BOOSTER-Displays
FID	BOOSTER-Displays
BOSS Menu	BOOSTER-Displays
BSE Channel	BOOSTER-Channel
RTPLOT (SSME)	BOOSTER-RTPLOT
RTPLOT (DELTA)	BOOSTER-RTPLOT
Onboard Fault Summary	MASTER-Shuttle/DPS/Real-Time (data from DPS)
Onboard Fault Summary (FDO/BSE simulations)	MASTER-Shuttle/DPS/Real-Time (data from local servers)
Wall Clock Display	MASTER-Global Apps/Timers & Clocks
VCR	BOOSTER-Applications

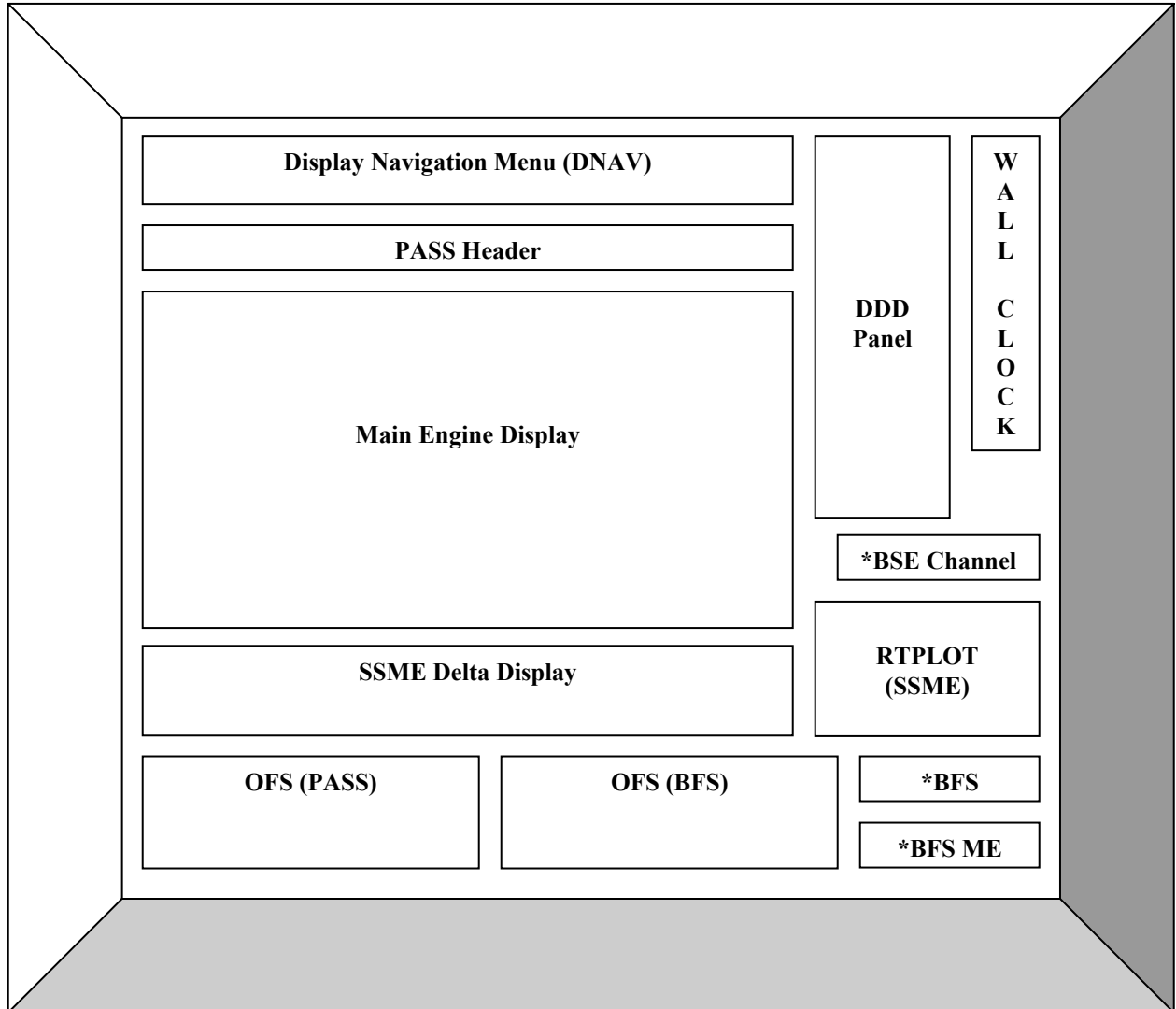
## White MPSR 19 – Monitor 0



LEFT

Figure 3.1.1-I – Typical ME Console Configuration

## White MPSR 19 – Monitor 1



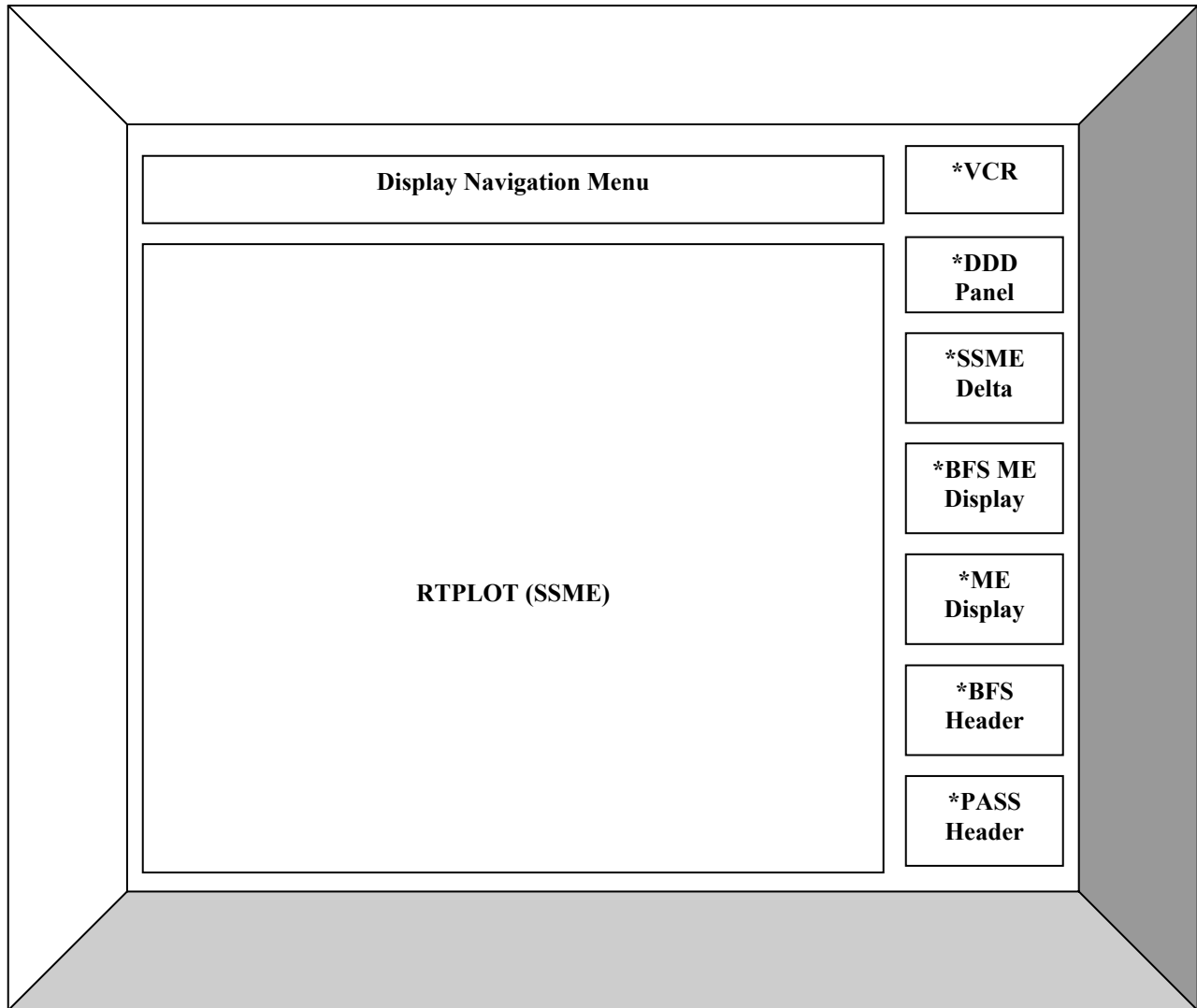
Notes:

\* = Minimized

CENTER

Figure 3.1.1-II – Typical ME Console Configuration

## White MPSR 20 – Monitor 0



Notes:

\* = Minimized

RIGHT

Figure 3.1.1-III – Typical ME Console Configuration

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TITLE

ME CONSOLE CRT DISPLAYS

PURPOSE

This SCP lists the software applications used by the Main Engine (ME) operator to monitor the performance of the engines and the status of SSME avionics. This SCP also describes the function of these applications and discusses the information displayed on them. A sample copy of each display is also included in this SCP.

DESCRIPTION

The Main Engine display, shown in Figure 3.1.2-I, is the primary display of real-time telemetry for the ME operator during ascent. The Main Engine display contains information on the performance of the SSME turbomachinery such as turbine discharge temperatures and pressures, pump composite and/or synchronous vibration levels (depends on what is being downlisted - see Systems Briefs 1.6 and 1.19), and intermediate seal pressures. This display also shows the position of the five SSME hydraulic valves. Other important SSME parameters such as engine power level, Engine Status Word (ESW), reference time (T-REF), Main Combustion Chamber (MCC) pressure, GH2 outlet pressure and temperature, GO2 outlet temperature, and hydraulic supply pressure are also shown on the Main Engine display. Although the FID display is the primary display of FIDs, the Main Engine display also shows FIDs generated by the SSMEC. However, only the last FID generated by the SSMEC is displayed on the Main Engine display due to space limitations. In the event of an SSME performance case, the Main Engine display will give the performance case and the associated level and time of occurrence for both inflight and preflight predictions. Figure 3.1.2-II shows the Main Engine display keymap for the parameters listed in Table 3.1.2-I. Table 3.1.2-I gives the MSID, nomenclature, units, and source for each parameter displayed on the Main Engine display.

The PASS Header, shown in Figure 3.1.2-III, provides flight data such as the Mission Elapsed Time, predicted MECO time, time to go (TGO), and launch countdown time (T-). Several vehicle parameters such as the relative velocity and the inertial velocity of the vehicle are also shown on the PASS Header. The acceleration of the vehicle and the GPC Major Mode are shown as well. Another important parameter that is also displayed on the PASS Header is the Thrust Factor. This parameter is one of the cues used by the ME operator to verify an engine out behind a Data Path failure (see SCP 2.1.14). Information regarding the selected abort is also displayed for situational awareness. Therefore, the PASS Header is utilized for both situational awareness and engine out recognition. Table 3.1.2-II gives the MSID, nomenclature, units, and source for each parameter displayed on the PASS Header display. The keymap for this table is shown in Figure 3.1.2-IV.

The DDD panel, shown in Figure 3.1.2-V, shows the status of SSME components such as the Digital Computer Unit (DCU) and the Engine Interface Unit (EIU) Multi Interface Adapter (MIA) ports. The DDD panel also shows the status of the SSME shutdown pushbuttons, Limit Shutdown Switch (the individual contacts as well as the switch position as determined by the computation), and AC Bus Sensors. DPS and EPS failures are also annunciated on this display. It is important to know the status of these other systems since these failures can significantly impact the functionality of the pushbuttons and SSME command/data capability. Information regarding manual throttles and selected abort(s) is also displayed for situational awareness. Table 3.1.2-III gives the MSID, nomenclature, units, and source for each parameter displayed on the PASS Header display. The keymap for this table is shown in Figure 3.1.2-VI.

The BOSS Menu, shown in Figure 3.1.2-VII, is an interface that allows the Booster, ME, and MPS operators to control settings for various computations used by the entire team. The BOSS Menu permits the selection of either preflight tags or inflight tags and allows the user to clear FIDs on the FID display. The BOSS Menu also allows the user to either enable or disable the performance data averaging function.

The Delta display, shown in Figure 3.1.2-VIII, shows the difference between the pre-flight predicted (or in-flight replacement) and actual values of several parameters. Only the following parameters are shown: HPOT DP, HPFT DP, HPOT TDT, HPFT TDT, OPOV, and FPOV. This display can be configured to show either preflight tags or inflight tags by using the BOSS Menu as explained above. Table 3.1.2-IV gives the MSID, nomenclature, units, and source for each parameter displayed on the Delta display. The keymap for this table is shown in Figure 3.1.2-IX.

The FID display, shown in Figure 3.1.2-X, shows the Failure Identification (FID) Word. The first line of the FID syntax is comprised of the FID text and the FID number. The second line is comprised of the FID delimiter text and the FID delimiter number. The FID display shows a summary of all FIDs received and decoded by the FID comp.

The VCR application, shown in Figure 3.1.2-XI, allows the user to record real-time data. For use of the VCR application, reference SCP 4.1.2, "Post-Launch Data Playbacks".

The Onboard Fault Summary (OFS) displays the fault messages seen by the crew onboard the vehicle. The ME operator needs to monitor both PASS and BFS generated fault messages. Figure 3.1.2-XII and Figure 3.1.2-XIII show the PASS OFS and BFS OFS displays, respectively. Both the PASS OFS and the BFS OFS displays must be manually configured to show the time for each fault message in MET. Moreover, the Auto Acknowledge feature should be deselected so that each fault message appears highlighted for easy identification.

The SSME RTPlot, shown in Figure 3.1.2-XIV, shows important Main Engine parameters as a function of time. This display allows the user to visually determine any off-nominal SSME performance condition. In the event that an engine is approaching a redline limit, the user can use this display to estimate the time of the redline violation. The DELTA RTPlot, shown in Figure 3.1.2-XV, shows the SSME tag deltas as a function of time. Although the information displayed on both the SSME RTPlot and the DELTA RTPlot is shown digitally on both the Main

Engine display and the DELTA display, this information is also presented graphically so that two methods are available for the user to quickly identify any off-nominal condition.

In the event of a BFS engage, many of these displays (PASS Header, Main Engine, et al) are of no use. Analogous BFS displays exist for use in this situation. The BFS Header is almost identical to the PASS Header and therefore is self-explanatory. The BFS equivalent of the Main Engine is shown in Figure 3.2.2-XVI. Table 3.2.2-XVII gives the MSID, nomenclature, units, and source for each parameter displayed on the BFS Main Engine display. The keymap for this table is shown in Figure 3.1.2-V.

main_engine.oi30			
ENG OUT	00:00	00:00	00:00
AVIONICS FAIL	00:00	00:00	00:00
GH2/GO2 OUT P/T	0 3060 / 349	0 2980 / 329	3200 / 359
PC AVG / PC DELTA	2869 / 0	2873 / 0	2866 / 0
MCC PC A/B 104	2869 2869	2862 2862	2866 2866
PL / PL HPOT	104.5 / 104.3	104.1 / 104.6	104.5 / 104.3
ESW / T REF	0185 00:21	0185 00:20	0185 00:21
LIMITS / PHASE	ENA / Mainstage	ENA / Mainstage	ENA / Mainstage
MODE / STATUS	Normal / OK	Normal / OK	Normal / OK
FID-DEL / T FAIL	-	-	-
HARD FID			
MECO C			
FU FLOW GPM/LBS	16150 / 154.5	16180 / 153.7	16126 / 153.6
LPFT DISCH T/P	42.6 / 227	42.1 / 228	42.6 / 228
HE TK P / MDOT	4174 / 0.000	4139 / 0.000	4217 / 0.010
HPOT ISP P A/B	204 / 204	203 / 203	205 / 205
HPOT VIB G 1/2/3	1.0/ 1.5/ 1.0	1.5/ 1.5/ 1.5	1.5/ 1.5/ 1.5
HPFT VIB G 1/2/3	1.5/ 1.5/ 1.0	1.0/ 1.0/ 1.5	1.5/ 1.0/ 1.0
HPOT TDT A2/B2	1168 / 1152	1152 / 1136	1152 / 1152
HPOT TDT A3/B3	1168 / 1152	1136 / 1136	1152 / 1152
HPFT TDT A2/B2	1600 / 1584	1600 / 1584	1600 / 1584
HPFT TDT A3/B3	1600 / 1584	1600 / 1584	1600 / 1584
HPOT/HPFT DS P	3797 / 5653	3810 / 5618	3786 / 5678
OPOV / FPOV	62.9 / 76.0	62.9 / 76.4	62.8 / 76.3
MOV / MFV / CCV	100 /100 /100	100 /100 /100	100 /100 /100
APU P / TVC / ME	3064 OP 3071	3064 OP 3071	3064 OP 3069
MR / ISP	6.093 / 453.3	6.027 / 452.8	6.086 / 451.5
DRIFT MR			
DRIFT LVL/PWR LVL	/	/	/
INFLT PERF CASE			
LEVEL/TIME	/	/	/
PREFLT PERF CASE			
LEVEL/TIME	/	/	/
NPSP / LO2 IMP	11.8 / 136	12.8 / 134	11.8 / 139
ENG TYPE/FID DEC	B2 / 0	B2 / 0	B2 / 0
MSID: perf_PL_AVG1 @256/23:23:13 Value: 71.719024658 Status: ' ' N			

Figure 3.1.2-I – Main Engine Display



<i>main_engine</i>			
ENG OUT	2	5	1
AVIONICS FAIL	8	11	7
GH2/GO2 OUT P/T	14	17	13
PC AVG / PC DELTA	23	26	22
MCC PC A/B	29	35	28
PL / PL HPOT	39	42	38
ESW / T REF	48	51	47
LIMITS / PHASE	54	57	53
MODE / STATUS	60	63	59
FID-DEL / T FAIL	66	69	65
HARD FID	75	74	76
MECO C	80	81	78
FU FLOW GPM/LBS	83	86	82
LPFT DISCH T/P	89	92	88
HE TK P / MDOT	95	98	94
HPOT ISP P A/B	101	104	100
HPOT VIB G 1/2/3	107	110	106
HPFT VIB G 1/2/3	116	119	115
HPOT TDT A2/B2	125	128	124
HPOT TDT A3/B3	131	134	130
HPFT TDT A2/B2	137	140	136
HPFT TDT A3/B3	143	146	142
HPOT/HPFT DS P	149	152	148
OPOV / FPOV	155	158	154
MOV / MFV / CCV	161	164	160
APU P / TVC / ME	170	173	169
MR / ISP	179	182	178
DRIFT MR	185	184	184
DRIFT LVL/PWR LVL	188	191	187
INFLT PERF CASE	194	193	195
LEVEL/TIME	197	200	196
PREFLT PERF CASE	203	202	204
LEVEL/TIME	206	209	205
NPSP / LO2 INP	212	215	211
ENG TYPE/FID DEC	218	221	217
ISP data server connection established			

Figure 3.1.2-II – Main Engine Display MSID map

Table 3.1.2-I – Telemetry on the Main Engine Display

Block	MSID	Nomenclature	Units	Source
1	ssme_ENG1	engine 1	EVENT	Avionics Comp
2	ssme_ENG2	engine 2	EVENT	Avionics Comp
3	ssme_ENG3	engine 3	EVENT	Avionics Comp
4	ssme_TIME_SD1	engine shutdown time	MM:SS	Avionics Comp
5	ssme_TIME_SD2	engine shutdown time	MM:SS	Avionics Comp
6	ssme_TIME_SD3	engine shutdown time	MM:SS	Avionics Comp
7	ssme_AVION_FAIL1	Fail string in ssme primary, secondary or command	EVENT	Avionics Comp
8	ssme_AVION_FAIL2	Fail string in ssme primary, secondary or command	EVENT	Avionics Comp
9	ssme_AVION_FAIL3	Fail string in ssme primary, secondary or command	EVENT	Avionics Comp
10	ssme_AVION_FAIL_TIME1	avion fail time stamp in met	MM:SS	Avionics Comp
11	ssme_AVION_FAIL_TIME2	avion fail time stamp in met	MM:SS	Avionics Comp
12	ssme_AVION_FAIL_TIME3	avion fail time stamp in met	MM:SS	Avionics Comp
13	V41P1160A	MPS E1 GH2 PRESS OUTLET PRESS	PSIA	Downlist
14	V41P1260A	MPS E2 GH2 PRESS OUTLET PRESS	PSIA	Downlist
15	V41P1360A	MPS E3 GH2 PRESS OUTLET PRESS	PSIA	Downlist
16	V41T1171A	MPS E1 GO2 PRESS OUTLET TEMP	DEG F	Downlist
17	V41T1271A	MPS E2 GO2 PRESS OUTLET TEMP	DEG F	Downlist
18	V41T1371A	MPS E3 GO2 PRESS OUTLET TEMP	DEG F	Downlist
19	V41X1661E	MPS GH2 PRESS FCV 1 (LV56) CL PWR	EVENT	Downlist
20	V41X1662E	MPS GH2 PRESS FCV 2 (LV57) CL PWR	EVENT	Downlist
21	V41X1663E	MPS GH2 PRESS FCV 3 (LV58) CL PWR	EVENT	Downlist
22	E41P1023B	ME-1 MCC PRESSURE (AVG) DW 6	PSIA	Downlist
23	E41P2023B	ME-2 MCC PRESSURE (AVG) DW 6	PSIA	Downlist
24	E41P3023B	ME-3 MCC PRESSURE (AVG) DW 6	PSIA	Downlist
25	perf_Pc_DELTA1	Pc delta for C Engine	PSIA	Perf Comp
26	perf_Pc_DELTA1	Pc delta for L Engine	PSIA	Perf Comp
27	perf_Pc_DELTA1	Pc delta for R Engine	PSIA	Perf Comp
28	E41P1016B	ME-1 MCC PRESSURE CH A DW 22	PSIA	Downlist
29	E41P2016B	ME-2 MCC PRESSURE CH A DW 22	PSIA	Downlist
30	E41P3016B	ME-3 MCC PRESSURE CH A DW 22	PSIA	Downlist
31	E41P1017B	ME-1 MCC PRESSURE CH B DW 23	PSIA	Downlist
32	E41P2017B	ME-2 MCC PRESSURE CH B DW 23	PSIA	Downlist
33	E41P3017B	ME-3 MCC PRESSURE CH B DW 23	PSIA	Downlist
34	perf_PC_A_B_DISCREPANCY1	Discrepancy between PC A and B sensor	N/A	Perf Comp
35	perf_PC_A_B_DISCREPANCY2	Discrepancy between PC A and B sensor	N/A	Perf Comp
36	perf_PC_A_B_DISCREPANCY3	Discrepancy between PC A and B sensor	N/A	Perf Comp
37	V90U1948C	COMMANDED SSME THROTTLE SETTING	PCT	Downlist
38	perf_PL_AVG1	average power level 1	PCT	Perf Comp
39	perf_PL_AVG2	average power level 2	PCT	Perf Comp
40	perf_PL_AVG3	average power level 3	PCT	Perf Comp
41	perf_ALT_PC1	alt Pc, if true=a, else=blank	PCT	Perf Comp
42	perf_ALT_PC2	alt Pc, if true=a, else=blank	PCT	Perf Comp
43	perf_ALT_PC3	alt Pc, if true=a, else=blank	PCT	Perf Comp
44	perf_PC_HPOT1	Pc HPOT	PCT	Perf Comp
45	perf_PC_HPOT2	Pc HPOT	PCT	Perf Comp
46	perf_PC_HPOT3	Pc HPOT	PCT	Perf Comp

Table 3.1.2-I – Telemetry on the Main Engine Display, Continued

Block	MSID	Nomenclature	Units	Source
47	E41M1003P	ME-1 ENGINE STATUS WORD DW 3	N/A	Downlist
48	E41M2003P	ME-2 ENGINE STATUS WORD DW 3	N/A	Downlist
49	E41M3003P	ME-3 ENGINE STATUS WORD DW 3	N/A	Downlist
50	E41W1004B	ME-1 TIME REFERENCE DW 4	MM:SS	Downlist
51	E41W2004B	ME-2 TIME REFERENCE DW 4	MM:SS	Downlist
52	E41W3004B	ME-3 TIME REFERENCE DW 4	MM:SS	Downlist
53	esw_ENABLE1	LIMITS INHIBITED/ENABLE	N/A	ESW Comp
54	esw_ENABLE2	LIMITS INHIBITED/ENABLE	N/A	ESW Comp
55	esw_ENABLE3	LIMITS INHIBITED/ENABLE	N/A	ESW Comp
56	esw_PHASE1	ENGINE PHASE	N/A	ESW Comp
57	esw_PHASE2	ENGINE PHASE	N/A	ESW Comp
58	esw_PHASE3	ENGINE PHASE	N/A	ESW Comp
59	esw_MODE1	ENGINE MODE	N/A	ESW Comp
60	esw_MODE2	ENGINE MODE	N/A	ESW Comp
61	esw_MODE3	ENGINE MODE	N/A	ESW Comp
62	esw_STATUS1	MCF posted status	N/A	ESW Comp
63	esw_STATUS2	MCF posted status	N/A	ESW Comp
64	esw_STATUS3	MCF posted status	N/A	ESW Comp
65	fid_NUM1	fid table number	N/A	Fid Comp
66	fid_NUM2	fid table number	N/A	Fid Comp
67	fid_NUM3	fid table number	N/A	Fid Comp
68	fid_DELNUM1	fid delimiter table number	N/A	Fid Comp
69	fid_DELNUM2	fid delimiter table number	N/A	Fid Comp
70	fid_DELNUM3	fid delimiter table number	N/A	Fid Comp
71	fid_TREF1	fid t-ref time	MM:SS	Fid Comp
72	fid_TREF2	fid t-ref time	MM:SS	Fid Comp
73	fid_TREF3	fid t-ref time	MM:SS	Fid Comp
74	fid_TEXT1	fid output text	N/A	Fid Comp
75	fid_TEXT2	fid output text	N/A	Fid Comp
76	fid_TEXT3	fid output text	N/A	Fid Comp
77	fid_DEL1	fid delimiter text	N/A	Fid Comp
78	fid_DEL2	fid delimiter text	N/A	Fid Comp
79	fid_DEL3	fid delimiter text	N/A	Fid Comp
80	V90X8561X	MECO CONFIRMED FLAG	EVENT	Downlist
81	V98X3546X	AS33 MECO CONFIRMED BFS	EVENT	Downlist
	V98X3689X	AB36 MECO CONFIRMED BFS	EVENT	Downlist
82	E41R1021B	ME-1 FUEL FLOWRATE (AVG) DW 7	GAL/MIN	Downlist
83	E41R2021B	ME-2 FUEL FLOWRATE (AVG) DW 7	GAL/MIN	Downlist
84	E41R3021B	ME-3 FUEL FLOWRATE (AVG) DW 7	GAL/MIN	Downlist
85	perf_LH2_LBS1	LH2 in LBS	LBS/MIN	Perf Comp
86	perf_LH2_LBS2	LH2 in LBS	LBS/MIN	Perf Comp
87	perf_LH2_LBS3	LH2 in LBS	LBS/MIN	Perf Comp
88	E41T1019B	ME-1 LPFT DISCH TEMP (AVG) DW 10	DEG R	Downlist
89	E41T2019B	ME-2 LPFT DISCH TEMP (AVG) DW 10	DEG R	Downlist
90	E41T3019B	ME-3 LPFT DISCH TEMP (AVG) DW 10	DEG R	Downlist
91	E41P1018B	ME-1 LPFT DISCH PRESS (AVG) DW 9	PSIA	Downlist
92	E41P2018B	ME-2 LPFT DISCH PRESS (AVG) DW 9	PSIA	Downlist
93	E41P3018B	ME-3 LPFT DISCH PRESS (AVG) DW 9	PSIA	Downlist

Table 3.1.2-I – Telemetry on the Main Engine Display, Continued

Block	MSID	Nomenclature	Units	Source
94	V41P1150C	MPS E1 HE SUPPLY BOTTLE PRESS	PSIA	Downlist
95	V41P1250C	MPS E2 HE SUPPLY BOTTLE PRESS	PSIA	Downlist
96	V41P1350C	MPS E3 HE SUPPLY BOTTLE PRESS	PSIA	Downlist
97	helium_DM_DT1	TK DEC RT C	LBM/SEC	He Comp
98	helium_DM_DT2	TK DEC RT L	LBM/SEC	He Comp
99	helium_DM_DT3	TK DEC RT R	LBM/SEC	He Comp
100	E41P1014B	ME-1 HPOT I-SEAL PGE P CH A DW 20	PSIA	Downlist
101	E41P2014B	ME-2 HPOT I-SEAL PGE P CH A DW 20	PSIA	Downlist
102	E41P3014B	ME-3 HPOT I-SEAL PGE P CH A DW 20	PSIA	Downlist
103	E41P1015B	ME-1 HPOT I-SEAL PGE P CH B DW 21	PSIA	Downlist
104	E41P2015B	ME-2 HPOT I-SEAL PGE P CH B DW 21	PSIA	Downlist
105	E41P3015B	ME-3 HPOT I-SEAL PGE P CH B DW 21	PSIA	Downlist
106	E41D1149B	ME-1 HPOTP ACCEL 39 DEG CH A2	Gs	Downlist
107	E41D2149B	ME-2 HPOTP ACCEL 39 DEG CH A2	Gs	Downlist
108	E41D3149B	ME-3 HPOTP ACCEL 39 DEG CH A2	Gs	Downlist
109	E41D1157B	ME-1 HPOTP ACCEL 151 DEG CH B2	Gs	Downlist
110	E41D2157B	ME-2 HPOTP ACCEL 151 DEG CH B2	Gs	Downlist
111	E41D3157B	ME-3 HPOTP ACCEL 151 DEG CH B2	Gs	Downlist
112	E41D1158B	ME-1 HPOTP ACCEL 130 DEG CH C2	Gs	Downlist
113	E41D2158B	ME-2 HPOTP ACCEL 130 DEG CH C2	Gs	Downlist
114	E41D3158B	ME-3 HPOTP ACCEL 130 DEG CH C2	Gs	Downlist
115	E41D1144B	ME-1 HPFTP ACCEL 21 DEG CH A1	Gs	Downlist
116	E41D2144B	ME-2 HPFTP ACCEL 21 DEG CH A1	Gs	Downlist
117	E41D3144B	ME-3 HPFTP ACCEL 21 DEG CH A1	Gs	Downlist
118	E41D1145B	ME-1 HPFTP ACCEL 219 DEG CH B1	Gs	Downlist
119	E41D2145B	ME-2 HPFTP ACCEL 219 DEG CH B1	Gs	Downlist
120	E41D3145B	ME-3 HPFTP ACCEL 219 DEG CH B1	Gs	Downlist
121	E41D1146B	ME-1 HPFTP ACCEL 231 DEG CH C1	Gs	Downlist
122	E41D2146B	ME-2 HPFTP ACCEL 231 DEG CH C1	Gs	Downlist
123	E41D3146B	ME-3 HPFTP ACCEL 231 DEG CH C1	Gs	Downlist
124	E41T1628B	ME-1 HPOTT DISCH TEMP CHA2 DW 18	DEG R	Downlist
125	E41T2628B	ME-2 HPOTT DISCH TEMP CHA2 DW 18	DEG R	Downlist
126	E41T3628B	ME-3 HPOTT DISCH TEMP CHA2 DW 18	DEG R	Downlist
127	E41T1631B	ME-1 HPOTT DISCH TEMP CHB2 DW 19	DEG R	Downlist
128	E41T2631B	ME-2 HPOTT DISCH TEMP CHB2 DW 19	DEG R	Downlist
129	E41T3631B	ME-3 HPOTT DISCH TEMP CHB2 DW 19	DEG R	Downlist
130	E41T1629B	ME-1 HPOTT DISCH TEMP CHA3 DW 18	DEG R	Downlist
131	E41T2629B	ME-2 HPOTT DISCH TEMP CHA3 DW 18	DEG R	Downlist
132	E41T3629B	ME-3 HPOTT DISCH TEMP CHA3 DW 18	DEG R	Downlist
133	E41T1632B	ME-1 HPOTT DISCH TEMP CHB3 DW 19	DEG R	Downlist
134	E41T2632B	ME-2 HPOTT DISCH TEMP CHB3 DW 19	DEG R	Downlist
135	E41T3632B	ME-3 HPOTT DISCH TEMP CHB3 DW 19	DEG R	Downlist
136	E41T1622B	ME-1 HPFTT DISCH TEMP CHA2 DW 16	DEG R	Downlist
137	E41T2622B	ME-2 HPFTT DISCH TEMP CHA2 DW 16	DEG R	Downlist
138	E41T3622B	ME-3 HPFTT DISCH TEMP CHA2 DW 16	DEG R	Downlist
139	E41T1625B	ME-1 HPFTT DISCH TEMP CHB2 DW 17	DEG R	Downlist
140	E41T2625B	ME-2 HPFTT DISCH TEMP CHB2 DW 17	DEG R	Downlist
141	E41T3625B	ME-3 HPFTT DISCH TEMP CHB2 DW 17	DEG R	Downlist
142	E41T1623B	ME-1 HPFTT DISCH TEMP CHA3 DW 16	DEG R	Downlist
143	E41T2623B	ME-2 HPFTT DISCH TEMP CHA3 DW 16	DEG R	Downlist
144	E41T3623B	ME-3 HPFTT DISCH TEMP CHA3 DW 16	DEG R	Downlist
145	E41T1626B	ME-1 HPFTT DISCH TEMP CHB3 DW 17	DEG R	Downlist

Table 3.1.2-I – Telemetry on the Main Engine Display, Continued

Block	MSID	Nomenclature	Units	Source
146	E41T2626B	ME-2 HPFTT DISCH TEMP CHB3 DW 17	DEG R	Downlist
147	E41T3626B	ME-3 HPFTT DISCH TEMP CHB3 DW 17	DEG R	Downlist
148	E41P1030B	ME-1 HPOT DISCHARGE PRESS DW 30	PSIA	Downlist
149	E41P2030B	ME-2 HPOT DISCHARGE PRESS DW 30	PSIA	Downlist
150	E41P3030B	ME-3 HPOT DISCHARGE PRESS DW 30	PSIA	Downlist
151	E41P1029B	ME-1 HPFT DISCHARGE PRESS DW 29	PSIA	Downlist
152	E41P2029B	ME-2 HPFT DISCHARGE PRESS DW 29	PSIA	Downlist
153	E41P3029B	ME-3 HPFT DISCHARGE PRESS DW 29	PSIA	Downlist
154	E41H1028B	ME-1 OPOV ACTUATOR POSITION DW 28	PCT	Downlist
155	E41H2028B	ME-2 OPOV ACTUATOR POSITION DW 28	PCT	Downlist
156	E41H3028B	ME-3 OPOV ACTUATOR POSITION DW 28	PCT	Downlist
157	E41H1027B	ME-1 FPOV ACTUATOR POSITION DW 27	PCT	Downlist
158	E41H2027B	ME-2 FPOV ACTUATOR POSITION DW 27	PCT	Downlist
159	E41H3027B	ME-3 FPOV ACTUATOR POSITION DW 27	PCT	Downlist
160	E41H1025B	ME-1 MOV ACTUATOR POSITION DW 25	PCT	Downlist
161	E41H2025B	ME-2 MOV ACTUATOR POSITION DW 25	PCT	Downlist
162	E41H3025B	ME-3 MOV ACTUATOR POSITION DW 25	PCT	Downlist
163	E41H1024B	ME-1 MFV ACTUATOR POSITION DW 24	PCT	Downlist
164	E41H2024B	ME-2 MFV ACTUATOR POSITION DW 24	PCT	Downlist
165	E41H3024B	ME-3 MFV ACTUATOR POSITION DW 24	PCT	Downlist
166	E41H1026B	ME-1 CCV ACTUATOR POSITION DW 26	PCT	Downlist
167	E41H2026B	ME-2 CCV ACTUATOR POSITION DW 26	PCT	Downlist
168	E41H3026B	ME-3 CCV ACTUATOR POSITION DW 26	PCT	Downlist
169	V58P0116C	HYDR SYS 1 SUPPLY PRESS C	PSIA	Downlist
170	V58P0216C	HYDR SYS 2 SUPPLY PRESS C	PSIA	Downlist
171	V58P0316C	HYDR SYS 3 SUPPLY PRESS C	PSIA	Downlist
172	V58X1136E, V58X1136X	HYD SYS 1 ME/TVC ISLN V OP IND	N/A	Downlist
173	V58X1236E, V58X1236X	HYD SYS 2 ME/TVC ISLN V OP IND	N/A	Downlist
174	V58X1336E, V58X1336X	HYD SYS 3 ME/TVC ISLN V OP IND	N/A	Downlist
175	E41P1054B	ME-1 HYDRAULIC SYS PRESS CHB DW 32	PSIA	Downlist
176	E41P2054B	ME-2 HYDRAULIC SYS PRESS CHB DW 32	PSIA	Downlist
177	E41P3054B	ME-3 HYDRAULIC SYS PRESS CHB DW 32	PSIA	Downlist
178	perf_MR_AVG1	average mixture ratio 1	N/A	Perf Comp
179	perf_MR_AVG2	average mixture ratio 2	N/A	Perf Comp
180	perf_MR_AVG3	average mixture ratio 3	N/A	Perf Comp
181	perf_ISP_AVG1	average ISP 1	s	Perf Comp
182	perf_ISP_AVG2	average ISP 2	s	Perf Comp
183	perf_ISP_AVG3	average ISP 3	s	Perf Comp
184	perf_MR_MECO1	inflight mixture ratio meco 1	N/A	Perf Comp
185	perf_MR_MECO2	inflight mixture ratio meco 2	N/A	Perf Comp
186	perf_MR_MECO3	inflight mixture ratio meco 3	N/A	Perf Comp
187	perf_MECO_LVL1	inflight MECO mixture ratio level 1	N/A	Perf Comp
188	perf_MECO_LVL2	inflight MECO mixture ratio level 2	N/A	Perf Comp
189	perf_MECO_LVL3	inflight MECO mixture ratio level 3	N/A	Perf Comp
190	perf_PL_MECO1	power level meco 1	PCT	Perf Comp
191	perf_PL_MECO2	power level meco 2	PCT	Perf Comp
192	perf_PL_MECO3	power level meco 3	PCT	Perf Comp

TABLE 3.1.2-I – Telemetry on the Main Engine Display, Concluded

Block	MSID	Nomenclature	Units	Source
193	perf_INFLT_PERF_CASE1	performance case string	EVENT	Perf Comp
194	perf_INFLT_PERF_CASE2	performance case string	EVENT	Perf Comp
195	perf_INFLT_PERF_CASE3	performance case string	EVENT	Perf Comp
196	perf_INFLT_PERF_CASE_LVL1	performance case in level number	N/A	Perf Comp
197	perf_INFLT_PERF_CASE_LVL2	performance case in level number	N/A	Perf Comp
198	perf_INFLT_PERF_CASE_LVL3	performance case in level number	N/A	Perf Comp
199	perf_INFLT_PERF_CASE_TIME1	performance case in met time	MM:SS	Perf Comp
200	perf_INFLT_PERF_CASE_TIME2	performance case in met time	MM:SS	Perf Comp
201	perf_INFLT_PERF_CASE_TIME3	performance case in met time	MM:SS	Perf Comp
202	perf_PREFLT_PERF_CASE1	performance case string	EVENT	Perf Comp
203	perf_PREFLT_PERF_CASE2	performance case string	EVENT	Perf Comp
204	perf_PREFLT_PERF_CASE3	performance case string	EVENT	Perf Comp
205	perf_PREFLT_PERF_CASE_LVL1	performance case in level number	N/A	Perf Comp
206	perf_PREFLT_PERF_CASE_LVL2	performance case in level number	N/A	Perf Comp
207	perf_PREFLT_PERF_CASE_LVL3	performance case in level number	N/A	Perf Comp
208	perf_PREFLT_PERF_CASE_TIME1	performance case in met time	MM:SS	Perf Comp
209	perf_PREFLT_PERF_CASE_TIME1	performance case in met time	MM:SS	Perf Comp
210	perf_PREFLT_PERF_CASE_TIME1	performance case in met time	MM:SS	Perf Comp
211	perf_NPSP_LH2_1	NPSP LH2 C	PSIA	Perf Comp
212	perf_NPSP_LH2_2	NPSP LH2 L	PSIA	Perf Comp
213	perf_NPSP_LH2_3	NPSP LH2 R	PSIA	Perf Comp
214	V41P1130C	MPS E1 LO2 INLET PRESS	PSIA	Downlist
215	V41P1230C	MPS E2 LO2 INLET PRESS	PSIA	Downlist
216	V41P1330C	MPS E3 LO2 INLET PRESS	PSIA	Downlist
217	perf_ENG_TYPE1	engine type selection	N/A	Perf Comp
218	perf_ENG_TYPE2	engine type selection	N/A	Perf Comp
219	perf_ENG_TYPE3	engine type selection	N/A	Perf Comp
220	E41M1005P	ME-1 FAILURE IDENT WORD DW05	N/A	Downlist
221	E41M2005P	ME-2 FAILURE IDENT WORD DW05	N/A	Downlist
222	E41M3005P	ME-3 FAILURE IDENT WORD DW05	N/A	Downlist

<i>pass_header</i>						
Flt/Vehicle 096/103	GPC MM 102	Q Bar	6			
OGMT 133/16:32:32	PL CMD 104	H Dot	104	OI	129	
T- -00:06	MECO 00:00	THR FAC 1.00	V REL 105			
OMET 000/00:00:06	TGO 00:00	ACCEL 1.627	VI 0			
MSID: V90U1979C @133/16:28:20 Value: 0.997999966 Status: ' ' Nomen.						

Figure 3.1.2-III – PASS Header

<i>pass_header</i>						
Flt/Vehicle 1 // 2	22	GPC MM 8	Q Bar 12	17		
OGMT 3	23	PL CMD 9	H Dot 13	21	OI 16	
T- 4	6	THR FAC 10	V REL 14	18		
OMET 5	7	ACCEL 11	VI 15	19	20	
MSID: V90U1979C @133/16:28:20 Value: 0.997999966 Status: ' ' Nomen.						

Figure 3.1.2-IV Pass Header Display MSID map

Table 3.1.2-II MSIDs for PASS Header Display

Location Number	Label	Nomenclature	MSID	Units	Source
1	Flt	Flight	M50Q0003HP	STS Number	download
2	Vehicle	Vehicle	M50Q0005HP	OV Number	download
3	OGMT	Greenwich Mean Time	M50Q0027HP	DDD/HH:MM:SS	download
4	T-	Countdown Time	V90W8380C	S	download
5	OMET	Mission Elapsed Time	M50Q0030HP	DDD/HH:MM:SS	download
6	MECO	Predicted SSME C/O Time in MET	V90W1970C	S	download
7	TGO	Time to go to Velocity Cutoff	V90W1941C	S	download
8	GPC MM	Major Mode Code	V90Q8001C	SPECIAL	download
9	PL CMD	Commanded SSME Throttle Setting	V90U1948C	PCT	download
10	THR FAC	Thrust Scaling Factor	V90U1979C	ND	download
11	ACCEL	Total Load Factor	V95U0163C	ft/s <sup>2</sup>	download
12	Q Bar	GN&C Dynamic Pressure	V95P3011C	lb <sub>f</sub> /ft <sup>2</sup>	download
13	H Dot	LH AVVI Vertical Velocity	V72R5354B	ft/s	download
14	V REL	GND REL VEL MAG IN M50 SYS	V95L0151C	ft/s	download
15	VI	LH AMI MACH/VELOCITY	V72L7252B	Mach	download
16	OI	PCM Format ID	V75X4070D	ND	download
17	BFS	BFS Engaged BFS	V98X0643X	Event	download
18	TAL	Abort TAL engaged Flag	lgt_TAL	N/A	Comp
19	RTLS	Abort RTLS engaged Flag	lgt_RTLS	N/A	Comp
20	PPA	DSCR IND START OF TURN AROUND	V90X2089X	Event	download
21	ATO	Abort ATO engaged Flag	lgt_ATO	N/A	Comp
22	LPS HOLD	LPS COUNTDOWN HOLD	V90X8768X	Event	download
23	RS HOLD	RS COUNTDOWN HOLD FLAG	V90X8667X	Event	download



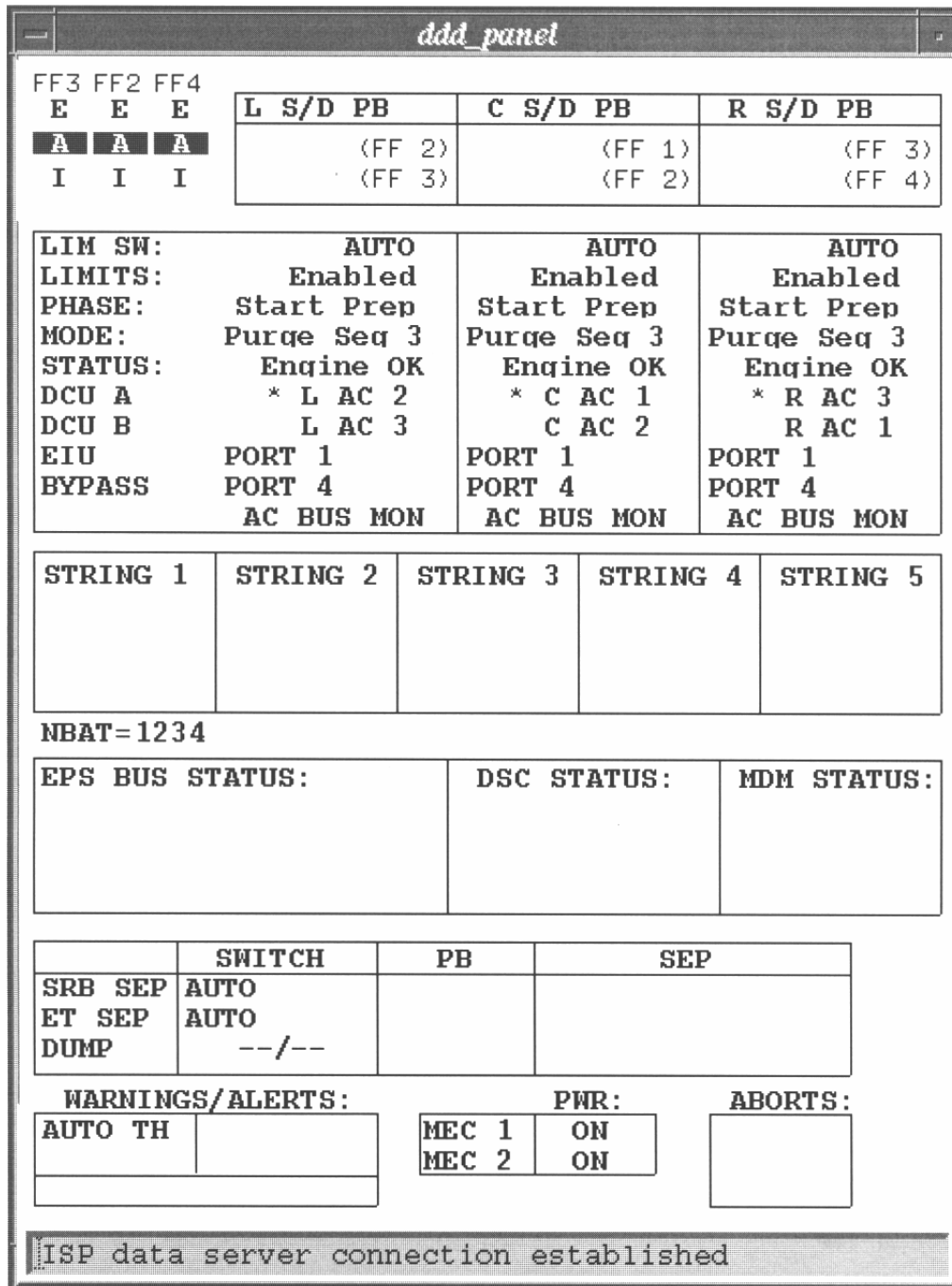


Figure 3.1.2-V – DDD Panel

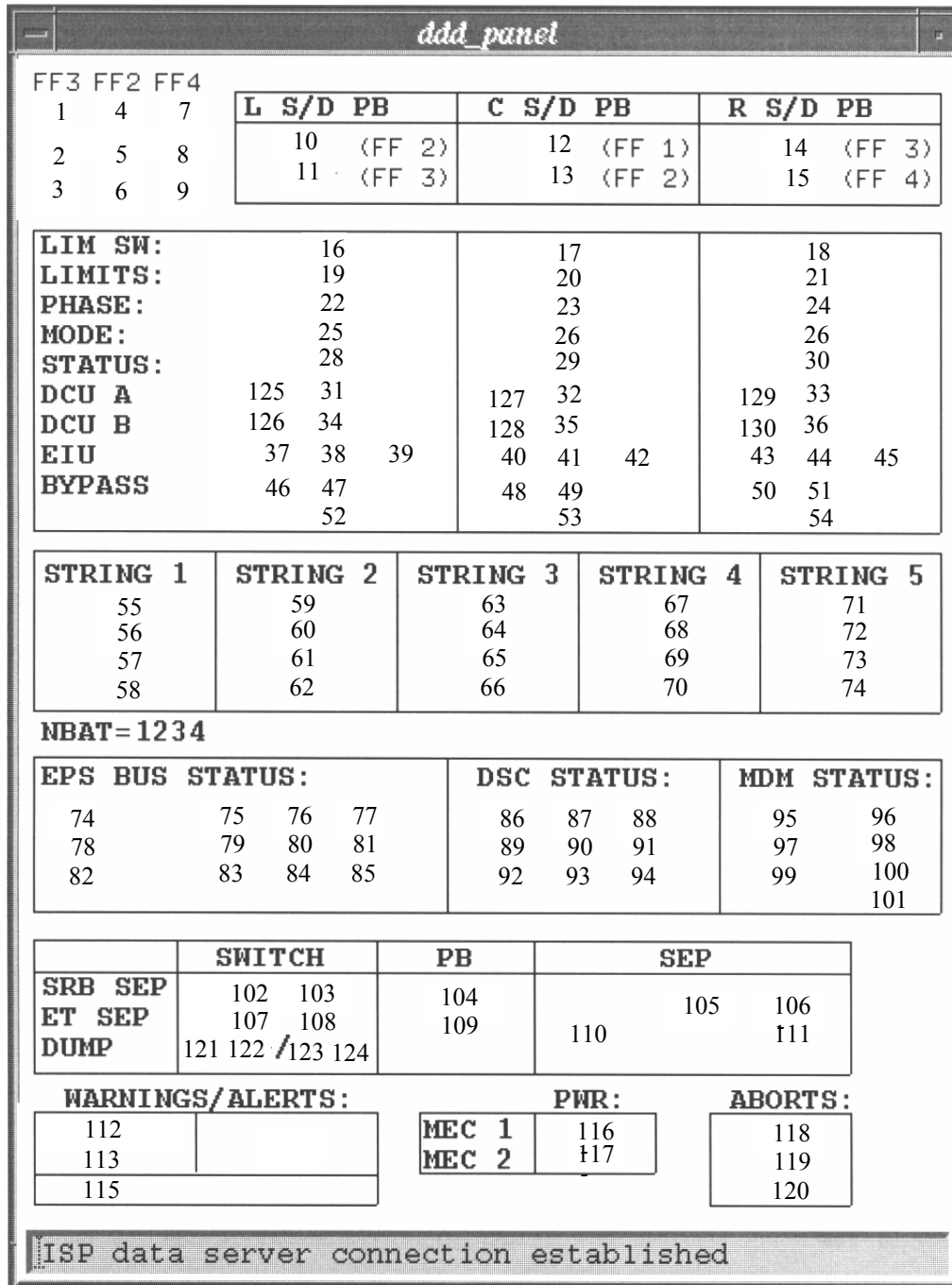


Figure 3.1.2-VI – DDD Panel MSID map

Table 3.1.2-III – DDD Panel MSIDs

No.	Parameter	Nomenclature	MSID	Source
1	E	MPS ENG LIMIT CONTROL NO 2 ENABLE	V72K0052X	Downlist
2	A	MPS ENG LIMIT CONTROL NO 2 AUTO	V72K0072X	Downlist
3	I	MPS ENG LIMIT CONTROL NO 2 INHIBIT	V72K0062X	Downlist
4	E	MPS ENG LIMIT CONTROL NO 1 ENABLE	V72K0051X	Downlist
5	A	MPS ENG LIMIT CONTROL NO 1 AUTO	V72K0071X	Downlist
6	I	MPS ENG LIMIT CONTROL NO 1 INHIBIT	V72K0061X	Downlist
7	E	MPS ENG LIMIT CONTROL NO 3 ENABLE	V72K0053X	Downlist
8	A	MPS ENG LIMIT CONTROL NO 3 AUTO	V72K0073X	Downlist
9	I	MPS ENG LIMIT CONTROL NO 3 INHIBIT	V72K0063X	Downlist
10	L S/D PB (FF 2)	ME PB CMD ISSUED LEFT	lgt_MEP2	Comp
11	L S/D PB (FF 3)	ME PB CMD ISSUED LEFT (BACKUP CONTACT)	lgt_MEB2	Comp
12	C S/D PB (FF 1)	ME PB CMD ISSUED CENTER	lgt_MEP1	Comp
13	C S/D PB (FF 2)	ME PB CMD ISSUED CENTER (BACKUP CONTACT)	lgt_MEB1	Comp
14	R S/D PB (FF 3)	ME PB CMD ISSUED RIGHT	lgt_MEP3	Comp
15	R S/D PB (FF 4)	ME PB CMD ISSUED RIGHT (BACKUP CONTACT)	lgt_MEB3	Comp
16	LIM SW:	LIM SWITCH POSITION	lgt_LIM_SWCMD2	Comp
17	LIM SW:	LIM SWITCH POSITION	lgt_LIM_SWCMD1	Comp
18	LIM SW:	LIM SWITCH POSITION	lgt_LIM_SWCMD3	Comp
19	LIMITS:	LIMITS INHIBITED/ENABLE	esw_ENABLE2	Comp
20	LIMITS:	LIMITS INHIBITED/ENABLE	esw_ENABLE1	Comp
21	LIMITS:	LIMITS INHIBITED/ENABLE	esw_ENABLE3	Comp
22	PHASE:	ENGINE PHASE	esw_PHASE2	Comp
23	PHASE:	ENGINE PHASE	esw_PHASE1	Comp
24	PHASE:	ENGINE PHASE	esw_PHASE3	Comp
25	MODE:	ENGINE MODE	esw_MODE2	Comp
26	MODE:	ENGINE MODE	esw_MODE1	Comp
27	MODE:	ENGINE MODE	esw_MODE3	Comp
28	STATUS:	Nomenclature	esw_STATUS2	Comp
29	STATUS:	Nomenclature	esw_STATUS1	Comp
30	STATUS:	Nomenclature	esw_STATUS3	Comp
31	DCU A:	PRIMARY DCU STATUS (LEFT ENGINE)	lgt_DCUA2	Comp

Table 3.1.2-III – DDD Panel MSIDs (continued)

No.	Parameter	Nomenclature	MSID	Source
32	DCU A:	PRIMARY DCU STATUS (CENTER ENGINE)	lgt_DCUA1	Comp
33	DCU A:	PRIMARY DCU STATUS (RIGHT ENGINE)	lgt_DCUA3	Comp
34	DCU B:	SECONDARY DCU STATUS (LEFT ENGINE)	lgt_DCUB2	Comp
35	DCU B:	SECONDARY DCU STATUS (CENTER ENGINE)	lgt_DCUB1	Comp
36	DCU B:	SECONDARY DCU STATUS (RIGHT ENGINE)	lgt_DCUB3	Comp
37	EIU BYPASS:	EIU2/P1 DATA BYPASS(HFE INPUT)	V91X2930XX	Downlist
38	EIU BYPASS:	EIU 2 PRIMARY PORT BFS	V98X0826X	Downlist
39	EIU:	EIU 2 RPC B ON/OFF	V72S0099E	Downlist
40	EIU BYPASS:	EIU1/P1 DATA BYPASS(HFE INPUT)	V91X2927XX	Downlist
41	EIU BYPASS:	EIU 1 PRIMARY PORT BFS	V98X0821X	Downlist
42	EIU:	EIU 1 RPC A ON/OFF	V72S0097E	Downlist
43	EIU BYPASS:	EIU3/P1 DATA BYPASS(HFE INPUT)	V91X2933XX	Downlist
44	EIU BYPASS:	EIU 3 PRIMARY PORT BFS	V98X0831X	Downlist
45	EIU:	EIU 3 RPC C ON/OFF	V72S0102E	Downlist
46	EIU BYPASS:	EIU2/P4 DATA BYPASS(HFE INPUT)	V91X2817XX	Downlist
47	EIU BYPASS:	EIU 2 SECONDARY PORT BFS	V98X0828X	Downlist
48	EIU BYPASS:	EIU1/P4 DATA BYPASS(HFE INPUT)	V91X2813XX	Downlist
49	EIU BYPASS:	EIU 1 SECONDARY PORT BFS	V98X0824X	Downlist
50	EIU BYPASS:	EIU3/P4 DATA BYPASS(HFE INPUT)	V91X2821XX	Downlist
51	EIU BYPASS:	EIU 3 SECONDARY PORT BFS	V98X0832X	Downlist
52	AC BUS:	AC BUS SENSOR STATUS	lgt_SSMEC2	Comp
53	AC BUS:	AC BUS SENSOR STATUS	lgt_SSMEC1	Comp
54	AC BUS:	AC BUS SENSOR STATUS	lgt_SSMEC3	Comp
55	STRING 1:	GPC 1 FAIL INDICATOR	V72X7011E	Downlist
56	STRING 1:	fc_fail5	gpc_FC_FAIL5	Comp
57	STRING 1:	FA MDM & CARD C & D	lgt_FA1	Comp
58	STRING 1:	FF MDM & CARD A & B	lgt_FF1	Comp
59	STRING 2:	GPC 2 FAIL INDICATOR	V72X7012E	Downlist
60	STRING 2:	fc_fail6	gpc_FC_FAIL6	Comp
61	STRING 2:	FA MDM & CARD C & D	lgt_FA2	Comp
62	STRING 2:	FF MDM & CARD A & B	lgt_FF2	Comp
63	STRING 3:	GPC 3 FAIL INDICATOR	V72X7013E	Downlist
64	STRING 3:	fc_fail7	gpc_FC_FAIL7	Comp

Table 3.1.2-III – DDD Panel MSIDs (continued)

No.	Parameter	Nomenclature	MSID	Source
65	STRING 3:	FA MDM & CARD C & D	lgt_FA3	Comp
66	STRING 3:	FF MDM & CARD A & B	lgt_FF3	Comp
67	STRING 4	GPC 4 FAIL INDICATOR	V72X7014E	Downlist
68	STRING 4	fc_fail8	gpc_FC_FAIL8	Comp
69	STRING 4	FA MDM & CARD C & D	lgt_FA4	Comp
70	STRING 4	FF MDM & CARD A & B	lgt_FF4	Comp
71	STRING 5	GPC 5 FAIL INDICATOR	V72X7015E	Downlist
72	STRING 5	BFS ENGAGED	V98X0643X	Downlist
73	NBAT=	NBAT	lgt_NBAT	Comp
74	EPS BUS STATUS:	BUS LOGIC	MNA Status	Comp
75	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_AB1	Comp
76	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_BC1	Comp
77	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_CA1	Comp
78	EPS BUS STATUS:	BUS LOGIC	MNB Status	Comp
79	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_AB2	Comp
80	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_BC2	Comp
81	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_CA2	Comp
82	EPS BUS STATUS:	BUS LOGIC	MNC Status	Comp
83	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_AB3	Comp
84	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_BC3	Comp
85	EPS BUS STATUS:	CONTROL BUS FAIL STRING	lgt_CB_CA3	Comp
86	DSC STATUS:	DSC STATUS	OM1_DSC	Comp
87	DSC STATUS:	DSC STATUS	OA1_DSC	Comp
88	DSC STATUS:	DSC STATUS	OF1_DSC	Comp
89	DSC STATUS:	DSC STATUS	OM2_DSC	Comp
90	DSC STATUS:	DSC STATUS	OA2_DSC	Comp
91	DSC STATUS:	DSC STATUS	OF2_DSC	Comp
92	DSC STATUS:	DSC STATUS	OM3_DSC	Comp
93	DSC STATUS:	DSC STATUS	OA3_DSC	Comp
94	DSC STATUS:	DSC STATUS	OF3_DSC	Comp
95	MDM STATUS:	MDM WRAP Status	OA1_MDM_WRAP	Comp
96	MDM STATUS:	MDM WRAP Status	OF1_MDM_WRAP	Comp
97	MDM STATUS:	MDM WRAP Status	OA2_MDM_WRAP	Comp
98	MDM STATUS:	MDM WRAP Status	OF2_MDM_WRAP	Comp
99	MDM STATUS:	MDM WRAP Status	OA3_MDM_WRAP	Comp
100	MDM STATUS:	MDM WRAP Status	OF3_MDM_WRAP	Comp
101	MDM STATUS:	MDM WRAP Status	OF4_MDM_WRAP	Comp
102	SRB SEP, Switch	SEL SRB SEPARATION AUTO CMD	V90X7570X	Downlist

Table 3.1.2-III – DDD Panel MSIDs (concluded)

No.	Parameter	Nomenclature	MSID	Source
103	SRB SEP, Switch	SEL SRB SEPN MNL/AUTO ENABLE CMD	V90X7571X	Downlist
104	SRB SEP, PB	SEL SRB SEP INITIATE/WOW- WONG CMD	V90X7572X	Downlist
105	SRB SEP, SEP	SEL SRB SEPARATION INITIATION FLAG	V90X8333X	Downlist
106	SRB SEP, SEP	SRB SEPARATION COMMAND FLAG	V90X8331X	Downlist
107	ET SEP, Switch	SEL ET SEP AUTO	V90X7554X	Downlist
108	ET SEP, Switch	SEL ET SEP MNL ENABLE	V90X7556X	Downlist
109	ET SEP, PB	SEL ET SEP INITIATE/WOW- WONG CMD	V90X7564X	Downlist
110	ET SEP, SEP	ET AUTO SEP INHIBIT CREW ALERT	V90X8259X	Downlist
111	ET SEP, SEP	ET SEPARATION CMD FLAG	V90X8250X	Downlist
112	WARNINGS/ALERTS:	RH SPEEDBRAKE MANUAL	V72X5135X	Downlist
113	WARNINGS/ALERTS:	TAKE 2% THROTTLES MESSAGES	lgt_TWO_PCT_THR	Comp
114	WARNINGS/ALERTS:	DUMP SWITCH FAILURE STRING	lgt_DUMP_SW	Comp
115	WARNINGS/ALERTS:	MECO CONFIRMED	V98X3546X V98X3689X V90X8561X	Downlist
116	PWR: MEC 1	MEC 1 BUS A PWR ON	V76S4601E	Downlist
117	PWR: MEC 2	MEC 2 BUS B PWR ON	V76S4605E	Downlist
118	ABORTS:	ABORT RTLS	lgt_RTLS	Comp
119	ABORTS:	ABORT TAL	lgt_TAL	Comp
120	ABORTS:	ABORT AOA	lgt_ATO	Comp
121	DUMP START, Switch	DUMP START A	V72K0081X	Downlist
122	DUMP START, Switch	DUMP START B	V72K0083X	Downlist
123	DUMP STOP, Switch	DUMP STOP A	V72K0082X	Downlist
124	DUMP STOP, Switch	DUMP STOP B	V72K0084X	Downlist
125	LSSME DCU A	DCU A in Control Indication	lgt_DCUA2	Comp
126	LSSME DCU B	DCU B in Control Indication	lgt_DCUB2	Comp
127	CENTER DCU A	DCU A in Control Indication	lgt_DCUA1	Comp
127	CENTER DCU B	DCU B in Control Indication	lgt_DCUB1	Comp
129	RIGHT DCU A	DCU A in Control Indication	lgt_DCUA3	Comp
130	RIGHT DCU B	DCU B in Control Indication	lgt_DCUB3	Comp

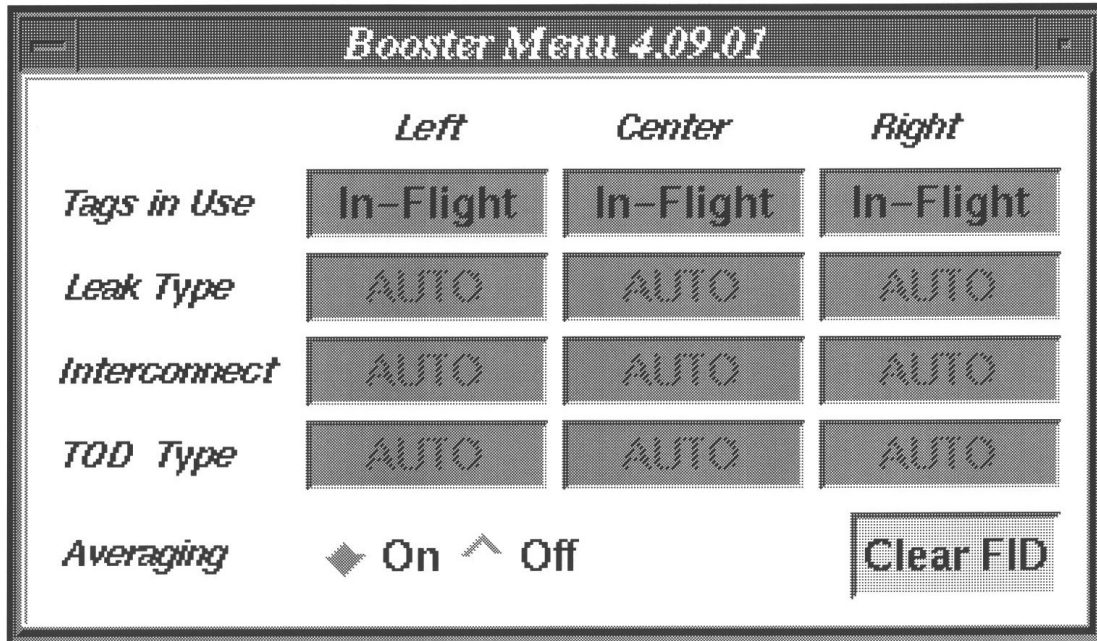


Figure 3.1.2-VII – BOSS Menu

<i>delta</i>											
	LEFT		INFLIGHT		CENTER		INFLIGHT		RIGHT		
HPOT TDT A/B tag	-3	/	2		13	/	11		173	/	147
HPFT TDT A/B tag	6	/	-5		4	/	-2		123	/	69
HPOT/HPFT DP tag	-7	/	3		-9	/	17		33	/	-46
OPOV/FPOV tag	0.0	/	-0.4		-0.5	/	-0.2		2.1	/	-0.6
MSID: perf_HPOTB_REP1 @017/03:12:24 Value: 0.000000000 Status: ' '											

Figure 3.1.2-VIII – Delta Display

<i>delta</i>															
	1				2				3						
HPOT TDT A/B tag	4	28	/	7	31	5	29	/	8	32	6	30	/	9	33
HPFT TDT A/B tag	10	34	/	13	37	11	35	/	14	38	12	36	/	15	39
HPOT/HPFT DP tag	16	40	/	19	43	17	41	/	20	44	18	42	/	21	45
OPOV/FPOV tag	22	46	/	25	49	23	47	/	26	50	24	48	/	27	51
MSID: perf_HPOTB_REP1 @017/03:12:24 Value: 0.000000000 Status: ' '															

Figure 3.1.2-IX – Delta Display MSID map



Table 3.1.2-IV – Delta Display MSIDs

Location Number	Label	Parameter Name	MSID	Units	Source
1	INFLIGHT/ PREFLIGHT LEFT	BOSS Menu TAG Selection, L	button_FLT_TAG1	N/A	Performance Comp
2	CENTER	BOSS Menu TAG Selection, C	button_FLT_TAG2	N/A	Performance Comp
2	RIGHT	BOSS Menu TAG Selection, R	button_FLT_TAG2	N/A	Performance Comp
4	HPOT TDT A In-flight tag LEFT	High pressure oxygen turbine discharge temperature sensor A	perf_HPOTA_D2	°F	Performance Comp
5	CENTER		perf_HPOTA_D1	°F	Performance Comp
6	RIGHT		perf_HPOTA_D2	°F	Performance Comp
7	HPOT TDT B In-flight tag LEFT	High pressure oxygen turbine discharge temperature sensor B	perf_HPOTB_D2	°F	Performance Comp
8	CENTER		perf_HPOTB_D1	°F	Performance Comp
9	RIGHT		perf_HPOTB_D3	°F	Performance Comp
10	HPFT TDT A In-flight tag LEFT	High pressure fuel turbine discharge temperature sensor A	perf_HPFTA_D2	°F	Performance Comp
11	CENTER		perf_HPFTA_D1	°F	Performance Comp
12	RIGHT		perf_HPFTA_D3	°F	Performance Comp
13	HPFT TDT B In-flight tag LEFT	High pressure fuel turbine discharge temperature sensor B	perf_HPFTB_D2	°F	Performance Comp
14	CENTER		perf_HPFTB_D1	°F	Performance Comp
15	RIGHT		perf_HPFTB_D3	°F	Performance Comp
16	HPOT DP In-flight tag LEFT	High Pressure Oxygen Turbine Pressure Change	perf_HPOTP_D2	psi	Performance Comp
17	CENTER		perf_HPOTP_D1	psi	Performance Comp
18	RIGHT		perf_HPOTP_D3	psi	Performance Comp
19	HPFT DP In-flight tag LEFT	High Pressure Fuel Turbine Pressure Change	perf_HPFTP_D2	psi	Performance Comp
20	CENTER		perf_HPFTP_D2	psi	Performance Comp
21	RIGHT		perf_HPFTP_D2	psi	Performance Comp

Table 3.1.2-IV – Delta Display MSIDs (continued)

Location Number	Label	Parameter Name	MSID	Units	Source
22	OPOV In-flight LEFT	Oxygen Preburner Oxidizer Valve	perf_OPOV_D2	Percent Open	Performance Comp
23	CENTER		perf_OPOV_D1	Percent Open	Performance Comp
24	RIGHT		perf_OPOV_D3	Percent Open	Performance Comp
25	FPOV In-flight LEFT	Fuel Preburner Oxidizer Valve	perf_FPOV_D2	Percent Open	Performance Comp
26	CENTER		perf_FPOV_D1	Percent Open	Performance Comp
27	RIGHT		perf_FPOV_D3	Percent Open	Performance Comp
28	HPOT TDT A Preflight tag LEFT	High pressure oxygen turbine discharge temperature sensor A	Perf_HPOTA_REP2	°F	Performance Comp
29	CENTER		Perf_HPOTA_REP1	°F	Performance Comp
30	RIGHT		Perf_HPOTA_REP2	°F	Performance Comp
31	HPOT TDT B Preflight tag LEFT	High pressure oxygen turbine discharge temperature sensor B	perf_HPOTB_REP2	°F	Performance Comp
32	CENTER		perf_HPOTB_REP1	°F	Performance Comp
33	RIGHT		perf_HPOTB_REP3	°F	Performance Comp
34	HPFT TDT A Preflight tag LEFT	High pressure fuel turbine discharge temperature sensor A	perf_HPFTA_REP2	°F	Performance Comp
35	CENTER		perf_HPFTA_REP1	°F	Performance Comp
36	RIGHT		perf_HPFTA_REP3	°F	Performance Comp
37	HPFT TDT B Preflight tag LEFT	High pressure fuel turbine discharge temperature sensor B	perf_HPFTB_REP2	°F	Performance Comp
38	CENTER		perf_HPFTB_REP1	°F	Performance Comp
39	RIGHT		perf_HPFTB_REP3	°F	Performance Comp
40	HPOT DP Preflight tag LEFT	High Pressure Oxygen Turbine Pressure Change	perf_HPOTP_REP2	psi	Performance Comp
41	CENTER		perf_HPOTP_REP1	psi	Performance Comp
42	RIGHT		perf_HPOTP_REP3	psi	Performance Comp

Table 3.1.2-IV – Delta Display MSIDs (concluded)

Location Number	Label	Parameter Name	MSID	Units	Source
43	HPFT DP Preflight tag LEFT	High Pressure Fuel Turbine Pressure Change	perf_HPFTP_REP2	psi	Performance Comp
44	CENTER		perf_HPFTP_REP1	psi	Performance Comp
45	RIGHT		perf_HPFTP_REP3	psi	Performance Comp
46	OPOV Preflight LEFT	Oxygen Preburner Oxidizer Valve	perf_OPOV_REP2	Percent Open	Performance Comp
47	CENTER		perf_OPOV_REP1	Percent Open	Performance Comp
48	RIGHT		perf_OPOV_REP3	Percent Open	Performance Comp
49	FPOV Preflight LEFT	Fuel Preburner Oxidizer Valve	perf_FPOV_REP2	Percent Open	Performance Comp
50	CENTER		perf_FPOV_REP1	Percent Open	Performance Comp
51	RIGHT		perf_FPOV_REP3	Percent Open	Performance Comp

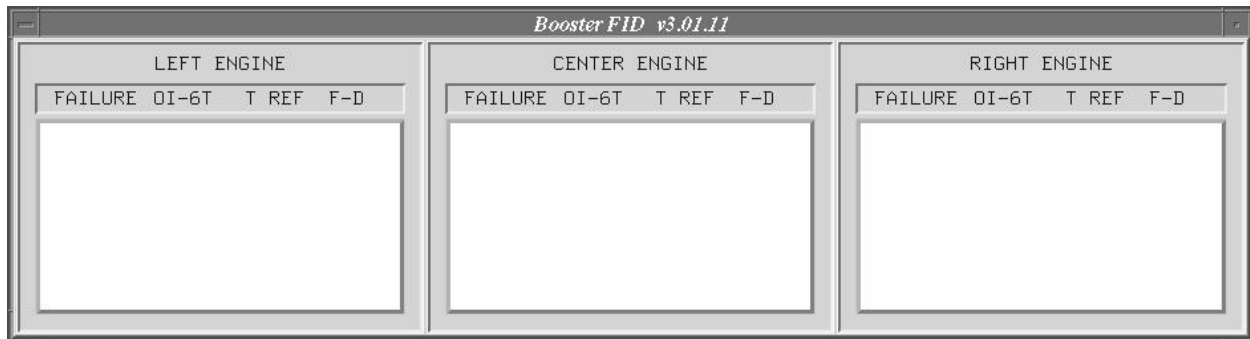


Figure 3.1.2-X – FID Display

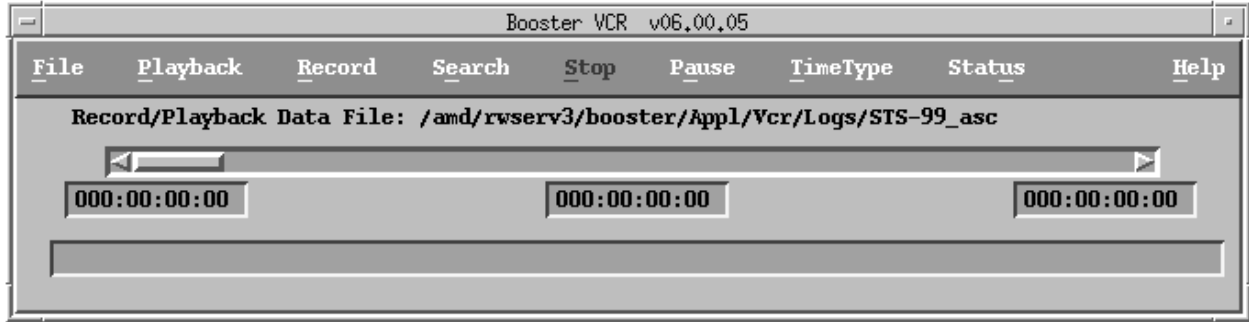


Figure 3.1.2-XI – VCR

SSP096 Onboard Fault Summary v3.03

File View Downlister Acknowledge Timetag Help

PASS Faults (GNC)			GPC	Time (GMT)
127	L OMS	QTY	1234	026/14:21:01.89
126	L OMS	PC	1234	026/14:18:22.54
125	BCE STRG 3	STKR	1234	026/13:25:07.65
124	BCE STRG 3	MLS	1234	026/13:25:07.65
123	BCE STRG 3	ADTA	1234	026/13:25:07.65
122	L OMS	QTY	1234	026/14:21:01.89
121	L OMS	PC	1234	026/14:18:22.54
120	BCE STRG 3	STKR	1234	026/13:25:07.65
119	BCE STRG 3	MLS	1234	026/13:25:07.65
118	BCE STRG 3	ADTA	1234	026/13:25:07.65
117	L OMS	QTY	1234	026/14:21:01.89
116	L OMS	PC	1234	026/14:18:22.54

Figure 3.1.2-XII – PASS OFS

BFS Faults				Time (GMT)
1139	I/O	ERROR	PCM	026/14:33:10.37
1138	I/O	ERROR	PCM	026/14:33:00.77
1137	I/O	ERROR	PCM	026/14:32:47.33
1136	I/O	ERROR	PCM	026/14:32:42.52
1135	I/O	ERROR	PCM	026/14:32:36.75
1134	I/O	ERROR	PCM	026/14:32:25.25
1133	I/O	ERROR	PCM	026/14:32:18.53
1132	I/O	ERROR	PCM	026/14:32:13.71
1131	I/O	ERROR	PCM	026/14:31:44.91
1130	I/O	ERROR	PCM	026/14:31:33.41
1129	I/O	ERROR	PCM	026/14:31:20.92

Figure 3.1.2-XIII – BFS OFS



Figure 3.1.2-XIV – SSME RTPlot

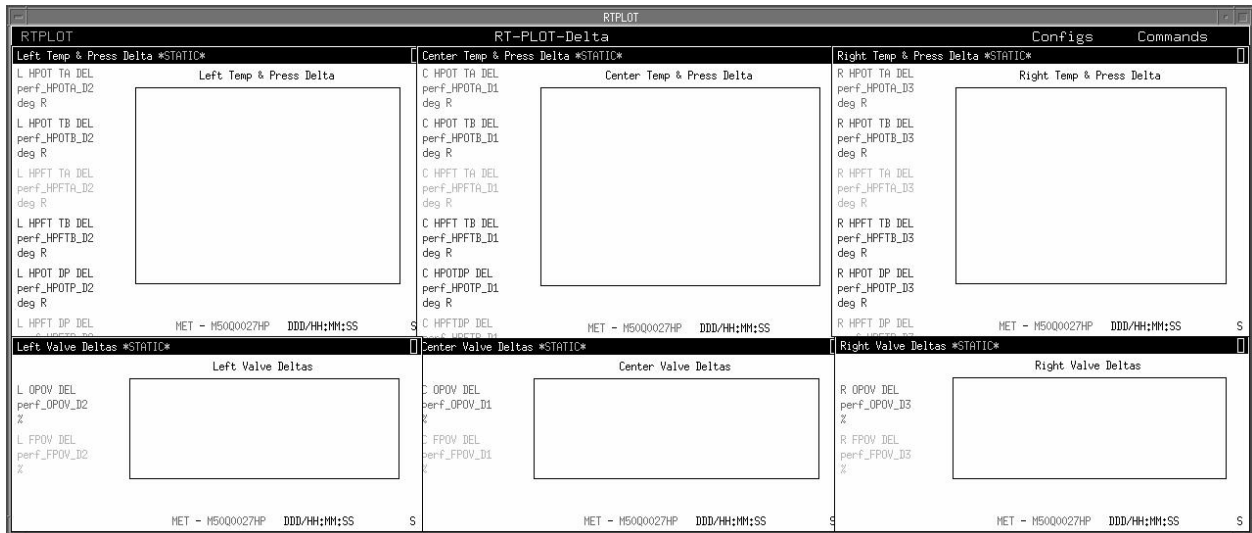


Figure 3.1.2-XV – DELTA RTPlot

bfs_main_engine			
ENG OUT	00:00	00:00	00:00
AVIONICS FAIL	00:00	00:00	00:00
GH2/GO2 OUT P/T	0 3060 / 349	0 2980 / 329	3200 / 359
PC AVG / PC DELTA	/	/	/
MCC PC A/B	104	104	104
PL / PL HPOT	104 / 104.1	104 / 104.7	104 / 104.4
ESW / T REF	0185 00:20	0185 00:20	0185 00:20
LIMITS / PHASE	ENA / Mainstage	ENA / Mainstage	ENA / Mainstage
MODE / STATUS	Normal / OK	Normal / OK	Normal / OK
FID-DEL / T FAIL	-	-	-
HARD FID			
MECO C			
FU FLOW GPM/LBS	/	/	/
LPFT DISCH T/P	/	/	/
HE TK P / MDOT	4170 / 0.002	4150 / 0.001	4190 / 0.048
HPOT ISP P A/B	/	/	/
HPOT VIB G 1/2/3	/	/	/
HPFT VIB G 1/2/3	/	/	/
HPOT TDT A2/B2	/	/	/
HPOT TDT A3/B3	/	/	/
HPFT TDT A2/B2	/	/	/
HPFT TDT A3/B3	/	/	/
HPOT/HPFT DS P	/	/	/
OPOV / FPOV	/	/	/
MOV / MFV / CCV	/	/	/
APU P / TVC / ME	3056	3056	3056
MR / ISP	/	/	/
DRIFT MR	/	/	/
DRIFT LVL/PWR LVL	/	/	/
INFLT PERF CASE	/	/	/
LEVEL/TIME	/	/	/
PREFLT PERF CASE	/	/	/
LEVEL/TIME	/	/	/
NPSP / LO2 INP	/	/	/
ENG TYPE/FID DEC	B2 /	B2 /	B2 /

ISP data server connection established

Figure 3.1.2-XVI – BFS Main Engine Display



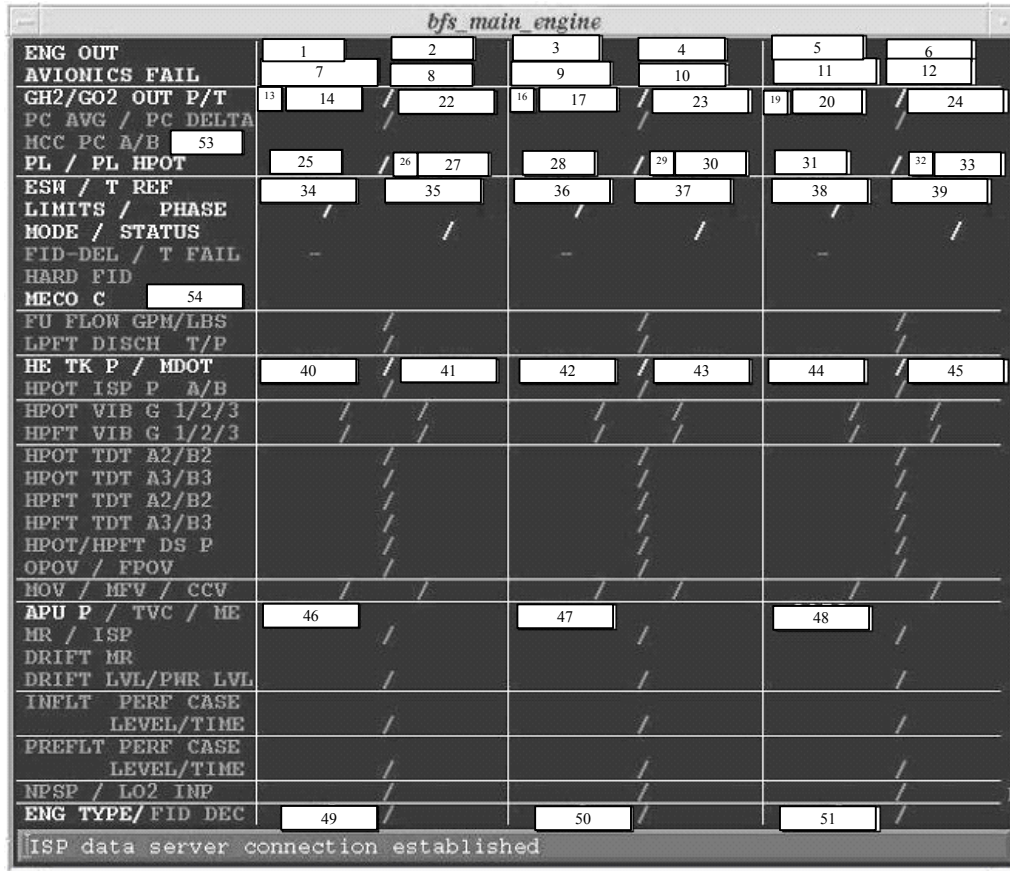


Figure 3.1.2 – XVII –BFS Main Engine Display MSID map

Table 3.1.2-V – MSIDs used for BFS Main Engine Display

Location	Parameter Name	MSID	Units	Source
1	Engine 2	ssme_ENG2	N/A	Avion Comp
2	E2 Shutdown Time	ssme_TIME_SD2	mm:ss	Avion Comp
3	Engine 1	ssme_ENG1	N/A	Avion Comp
4	E1 Shutdown Time	ssme_TIME_SD1	mm:ss	Avion Comp
5	Engine 3	ssme_ENG3	N/A	Avion Comp
6	E3 Shutdown Time	ssme_TIME_SD3	mm:ss	Avion Comp
7	E2 Avionics Failure	ssme_AVION_FAIL2	Event	Avion Comp
8	E2 Avionics Failure Time	ssme_AVION_FAIL_TIME2	mm:ss	Avion Comp
9	E1 Avionics Failure	ssme_AVION_FAIL1	Event	Avion Comp
10	E1 Avionics Failure Time	ssme_AVION_FAIL_TIME1	mm:ss	Avion Comp
11	E3 Avionics Failure	ssme_AVION_FAIL3	Event	Avion Comp
12	E3 Avionics Failure Time	ssme_AVION_FAIL_TIME3	mm:ss	Avion Comp
13	MPS GH2 PRESS FCV 2 (LV57) CL PWR	V41X1662E	Event	Downlist
14	MPS E2 GH2 PRESS OUTLET PRESS	V41P1260A	Psia	Downlist

Table 3.1.2-V – MSIDs used for BFS Main Engine Display (concluded)

Location	Parameter Name	MSID	Units	Source
16	MPS GH2 PRESS FCV 1 (LV56) CL PWR	V41X1661E	Event	Downlist
17	MPS E1 GH2 PRESS OUTLET PRESS	V41P1160A	Psia	Downlist
19	MPS E3 GH2 PRESS OUTLET PRESS	V41P1360A	Event	Downlist
20	MPS E2 GO2 PRESS OUTLET TEMP	V41T1271A	Psia	Downlist
22	MPS E3 GO2 PRESS OUTLET TEMP	V41T1371A	Deg F	Downlist
23	L ENGINE PC BFS	V98P2110C	Deg F	Downlist
24	Alternate L Engine HPOT PC	perf_ALT_PC2	Deg F	Downlist
25	L Engine HPOT Pc	perf_PC_HPOT2	Pct	Downlist
26	C ENGINE PC BFS	V98P2100C	Pct	Perf Comp
27	Alternate C Engine HPOT PC	perf_ALT_PC1	Pct	Perf Comp
28	C Engine HPOT Pc	perf_PC_HPOT1	Pct	Downlist
29	R ENGINE PC BFS	V98P2120C	Pct	Perf Comp
30	Alternate R Engine HPOT PC	perf_ALT_PC3	Pct	Perf Comp
31	R Engine HPOT Pc	perf_PC_HPOT3	Pct	Downlist
32	ME-2 ENGINE STATUS WORD BFS	V98M2220P	Pct	Perf Comp
33	ME-2 TIME REFERENCE BFS	V98W1391C	Pct	Perf Comp
34	ME-1 ENGINE STATUS WORD BFS	V98M2200P	N/A	Downlist
35	ME-1 TIME REFERENCE BFS	V98W1390C	mm:ss	Downlist
36	ME-3 ENGINE STATUS WORD BFS	V98M2240P	N/A	Downlist
37	ME-3 TIME REFERENCE BFS	V98W1392C	mm:ss	Downlist
38	L HELIUM SUPPLY PRESSURE BFS	V98P2156C	N/A	Downlist
39	Eng 2 He Mass Flow Rate	helium_DM_DT2	mm:ss	Downlist
40	C HELIUM SUPPLY PRESSURE BFS	V98P2155C	Psia	Downlist
41	Eng 1 He Mass Flow Rate	helium_DM_DT1	Lbm/Sec	He Comp
42	R HELIUM SUPPLY PRESSURE BFS	V98P2157C	Psia	Downlist
43	Eng 3 He Mass Flow Rate	helium_DM_DT3	Lbm/Sec	He Comp
44	HYDR SYS 2 SUPPLY PRESS B	V58P0215A	Psia	Downlist
45	HYDR SYS 1 SUPPLY PRESS B	V58P0115A	Lbm/Sec	He Comp
46	HYDR SYS 3 SUPPLY PRESS B	V58P0315A	Psia	Downlist
47	LEFT ENGINE TYPE	perf_ENG_TYPE2	Psia	Downlist
48	CENTER ENGINE TYPE	perf_ENG_TYPE1	Psia	Downlist
49	RIGHT ENGINE TYPE	perf_ENG_TYPE3	N/A	Perf Comp
50	MPS PNEU VLVS HE SUP BOTTLE PRESS	V41P1600A	N/A	Perf Comp
51	RIGHT ENGINE TYPE	perf_ENG_TYPE3	N/A	Perf Comp
52	MPS PNEU VLVS HE SUP BOTTLE PRESS	V41P1600A	Psia	Downlist
53	CMD THROTTLE BFS	V98U2001C	Pct	Downlist
54	AS33 MECO CONFIRMED BFS	V98X3546X	Event	Downlist
	AB36 MECO CONFIRMED BFS	V98X3689X	Event	Downlist

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## TITLE

MPS CONSOLE LOCATION/CONFIGURATION

## PURPOSE

The purpose of this SCP is to describe the location and configuration of the Booster Main Propulsion System (MPS) console.

## DESCRIPTION

The primary MPS console is located in room 2334 of building 30S at the workstations designated white-mpsr17 and white-mpsr18, but can be configured in building 30 wherever workstations and DVIS communication panels are available to support flight operations. The DVIS panels for MPS are 4715 (left) and 4714 (right).

The MPS console consists of two DEC Alpha workstations that are used to execute the required Booster Systems software. Typically, the first of these workstations drives two monitors (IGPs). The second of these workstations drives one monitor for a total of three available screens. The workstations comprising the MPS console utilize the UNIX operating system. Inputs to the workstations are made via keyboard or mouse point-and-click as required. Telemetry data required by selected applications arrives via the MCC local area network to which the workstation is connected.

## PROCEDURE

The MPS console is configured by selecting a flight or simulation activity during the login process and executing the required Booster Systems software using the display navigation (DNAV) pull-down menus. At login, the user enters a user id and password. After successful completion of this step, the user is prompted to select an activity. The title of the selected activity should correspond to the title of the MCC event the operator is supporting. After successful selection of an activity, the workstation operating system executes the DNAV software. When DNAV menus appear, application selection and execution can begin.

The applications used by the MPS operator during ascent are listed in Table 3.2.1-I and may be arranged on the three available monitors according to operator preference. A typical arrangement is shown in Figure 3.2.1-I.

TABLE 3.2.1-I. - ASCENT MPS SOFTWARE CHECKLIST

<u>APPLICATION (DNAV LOCATION)</u>	<u>CONFIGURATION</u>
Booster Software Display (BOOSTER-Displays)	<ol style="list-style-type: none"> <li>1. MPS Ascent</li> <li>2. Bi-Level</li> <li>3. DDD Panel</li> <li>4. Pass Header</li> <li>5. BFS Header (hidden or minimized)</li> <li>6. BFS MPS Ascent (hidden or minimized)</li> <li>7. BOSS Menu</li> <li>8. Prelaunch (prelaunch only)</li> <li>9. Launch Status (prelaunch only)</li> <li>10. Entry (entry only)</li> </ol>
Onboard Fault Summary (select twice) (Master-Shuttle-DPS-Real-Time (data from DPS)-OFS)	<ol style="list-style-type: none"> <li>1. PASS Faults Selected</li> <li>2. BFS Faults Selected</li> </ol>
RTPLOT (Booster- RTPLOT-MPS, Mdot)	<ol style="list-style-type: none"> <li>1. User's MPS* plot</li> <li>2. User's Mdot** plot</li> <li>3. User's SRB** plot (hidden or minimized)</li> <li>4. User's BFS** plot (hidden or minimized)</li> </ol>
CRANS RT (BOOSTER-CRANS/ELOG-CRANS RT)	User's Configuration**
ELOG (BOOSTER-CRANS/ELOG-CRANS RT)	User's Configuration** (hidden or minimized)
COMMAND MANAGER (Ascent only) (MASTER-GLOBAL APPS-Command Server-Start Command Manager. After started: Global Apps-Command Server-TELECOM displays-SSP-Command Inventory)	Select MRTCs 5650-5654 (display hidden or minimized)
MCC CLOCK (MASTER-GLOBAL APPS-TIMERS/CLOCKS -WALL CLOCK DISPLAY)	WFCR Clock Selected
FLIGHT DATA FILE (N/A)	Appropriate books per operator preference

\* After Selecting MPS RTPLOT, the operator must select from their list of prearranged plot configurations by clicking on Config-NAME and choosing from one of 5 prearranged configurations: Prelaunch, OPS2, OPS3, OPS4, and Entry. If the user has not previously configured these selections, a generic arrangement will appear which may be altered and saved.

\*\* Same as above, but the user only has one prearranged configuration

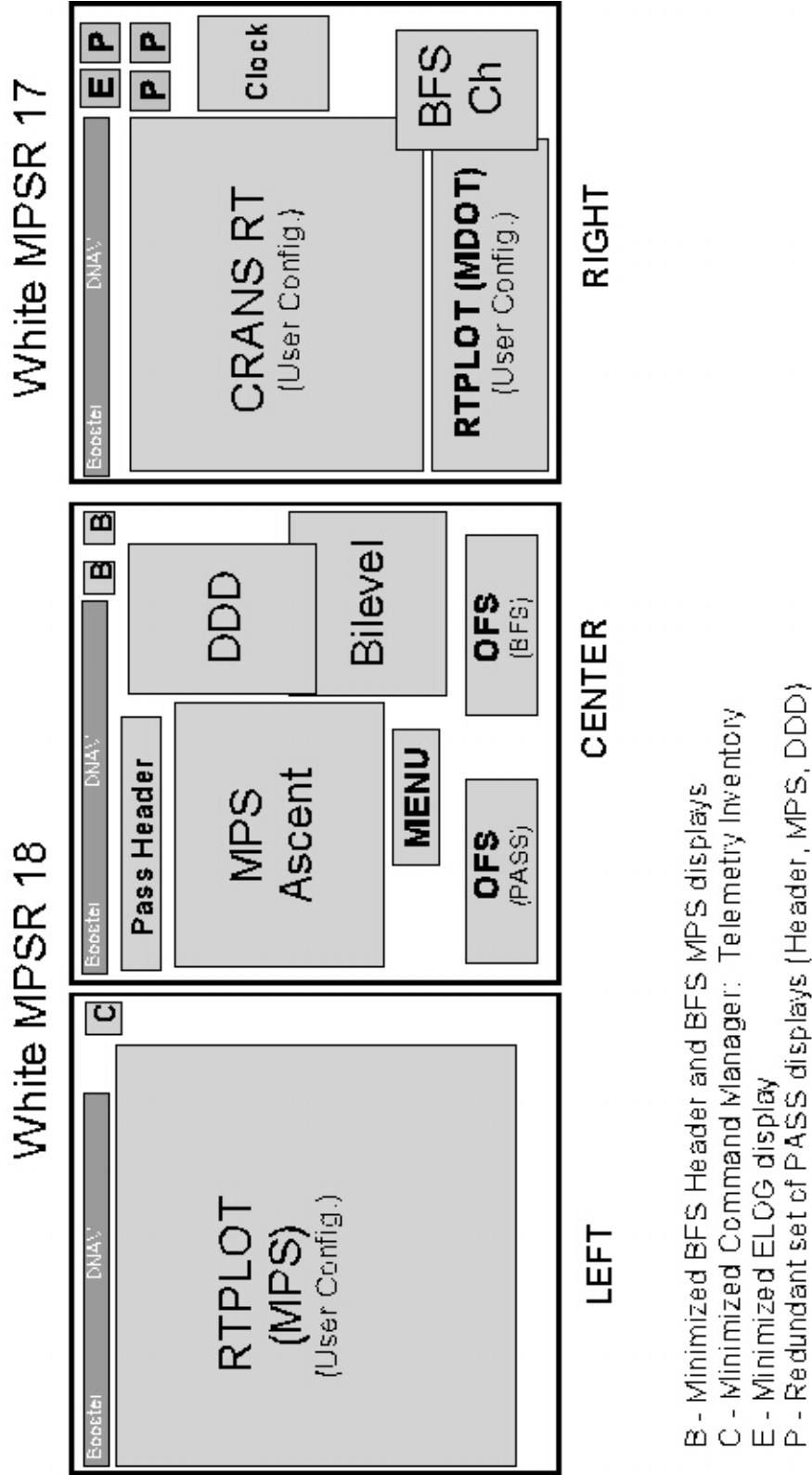


Figure 3.2.1-I – Typical MPS Console Configuration (Ascent)

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## TITLE

MPS CONSOLE DISPLAYS

## PURPOSE

This SCP lists the displays and tools used by the MPS operator to monitor the MPS systems during various phases of flight. Additionally, this SCP briefly discusses the information displayed or a description of the intended use, and gives a figure for each display used by the MPS console operator. SCP 3.2.1, MPS CONSOLE LOCATION/CONFIGURATION, describes a typical workstation configuration for MPS console operator.

## DESCRIPTION

Displays and tools used by the MPS operator include several displays under the application RTPLOT, many displays under the application MSK VIEW, and additional displays and tools such as HTAB, ELOG, BOSS Menu, OFS, SPECS, CRANS, and BFS Channel.

Standard RTPLOT displays used by the MPS operator include MPS, BFS MPS, SRB, and Mdot. The MPS RTPLOT is the primary set of plots used by the MPS operator and it shows the most important parameters as a function of time. The BFS MPS RTPLOT is usually kept minimized unless BFS is engaged and serves the same purpose as the MPS RTPLOT. The SRB RTPLOT shows SRB data as a function of time and is usually kept minimized until an SRB malfunction occurs. The Mdot RTPLOT shows Helium usage as a function of tank pressure, and is used to help verify whether an engine helium leak is above or below the regulators.

MSK VIEW displays used by the MPS operator include the PASS Header, MPS Ascent display, DDD Panel, Bilevel, Entry, Prelaunch, and Launch Status.

The PASS Header, shown in Figure 3.2.2-I, gives basic information for situational awareness such as Mission Elapsed Time, Major Mode, Relative and Inertial Velocity, and more. The data displayed on the PASS Header are discussed in detail in SCP 3.1.2.

The Prelaunch display, shown in Figure 3.2.2-II, summarizes the pressures and temperatures of the MPS helium tanks, ullage pressures, status of liquid level sensors in the ET, positions of the five hydraulically actuated valves on each SSME, and pressures and temperatures of the Fuel Supply Modules for the SRB TVC system. These parameters are monitored in the prelaunch timeframe to track the progress of the tanking procedures. Table 3.2.2-I gives the MSID, nomenclature, units, and source for each parameter displayed on the Prelaunch display. The keymap for this table is shown in Figure 3.2.2-III.



The Launch Status display, shown in Figure 3.2.2-IV, provides insight into various GLS LPS & RSLS holds in the launch count down.

The MPS Ascent display, shown in Figure 3.2.2-V, is the primary display for the MPS console operator during ascent. It gives data for the helium system, the ullage pressurization systems, the SRB TVC systems and SRB chamber pressures, the MPS valves, and the SRB and ET separation sequences. Figure 3.2.2-VI shows the MPS Ascent display with telemetry spaces numbered to correspond to the parameters listed in Table 3.2.2-II. Table 3.2.2-II gives the MSID, the parameter name, the units, and source for each parameter displayed on the MPS Ascent display.

The DDD Panel, shown in Figure 3.2.2-VII, presents Limit Switch information, SSME shutdown pushbutton information, information decoded from the Engine Status Word, alerts for EPS and DPS failures, information regarding SRB and ET separation sequences, and warnings for Manual Throttles, dump switch failures, and aborts. The data displayed on the DDD Panel are discussed in detail in SCP 3.1.2.

The MPS Bilevel display, shown in Figure 3.2.2-VIII, gives more complete data for the MPS valves. Wherever applicable, the Bilevel display presents telemetry for valve position microswitches, corresponding switches in the cockpit, valve actuation power, and power from individual RPC's (Remote Power Controllers) for those valves with redundant power circuitry. The Bilevel display also gives SRB and ET separation sequence parameters for both PASS and BFS logic and valve power indications for those valves that control the flow of Hydrazine to the SRB Hydraulic Power Units. Table 3.2.2-III gives the MSID, nomenclature, units, and source for each parameter displayed on the MPS Bilevel display. The keymap for this table is shown in Figure 3.2.2-IX.

The MPS Entry display, shown in Figure 3.2.2-X, has all the same data as the Bilevel display for Helium and propellant valves, but propellant manifold pressures and Helium tank temperatures and pressures are substituted for the SRB and ET separation sequence and SRB Hydrazine flow control valve data.

HTAB is an application that will automatically take snapshots of data at regular intervals and at major mode transitions. This data may be used to observe long-term trends. This application is left running at the MPS console through all phases of flight, including while the vehicle is on orbit to monitor the helium tanks. HTAB is usually kept hidden or minimized except to review the recorded snapshots of data.

ELOG logs events such as switch throws, valve actuations, major mode changes and some Caution & Warning limits violations. Each event is logged with a time stamp in both Mission Elapsed Time (MET) and Greenwich Mean Time (GMT). This application can be used by the MPS operator to verify the timing of events. For example, when the crew works the MPS PWRDN/ISOL and MPS GH2 INERTING procedures, ELOG may be used to verify that the

Press Line Vent was opened for one minute. ELOG may be kept minimized or hidden, or may be left partially visible during less active phases of flight so newly logged events may catch the MPS operator's eye.

BOSS Menu is an interface that allows the MPS, Main Engine, and Booster operators to control certain settings within various computations used by the entire team. The MPS operator is primarily interested in the settings associated with the helium comp. When configured for MPS, BOSS Menu shows only those features used to set the leak type and interconnect status of the helium comp.

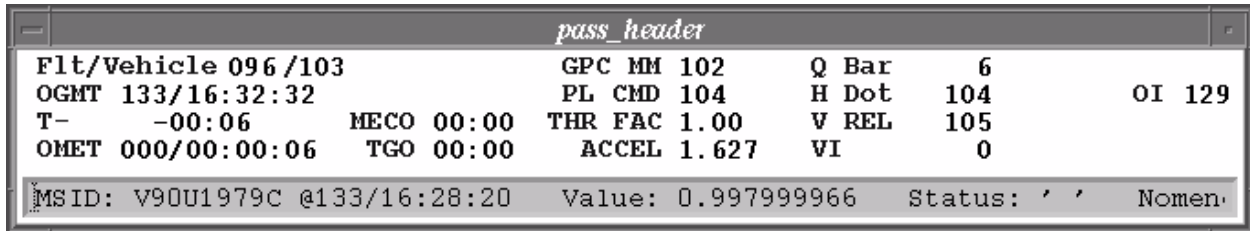
OFS (Onboard Fault Summary) displays the fault messages that the crew sees on their CRTs onboard. The MPS operator uses two of these windows; one configured to display PASS messages and the other to display BFS messages. Both OFS windows should be configured to give the time stamp for each message in MET. Also, the Auto Acknowledge feature should be deselected so that each new message appears highlighted to catch the console operator's eye. This use of the OFS is not unique to the MPS console and is discussed in SCP 3.1.2.

SPECs shows what displays the crew is showing on their CRTs and shows the keyboard entries that they make. By selecting "Condensed" on the View pull-down, the size of the display is reduced to show only the keyboard entries made by the crew. This display is useful in tracking the crew's progress through standard procedures, as well as verifying completion of SPEC Item Entries for such MPS failures as ET Sep Man messages.

CRANS (Configurable Real-time Analysis System) is a tool used in the booster group to give the impact of EPS and DPS failures (Power Bus, Control Bus, GPC, and MDM failures) on Booster systems. CRANS is automatically statused for real-time failures, by subscribing to failure parameters published by other flight control disciplines. Failures may also be manually configured for hypothetical failures and failure combinations. Hypothetical failures may be configured in conjunction with real-time failures, or real-time failure statusing may be disabled while considering purely hypothetical failures. This tool is discussed in detail in Systems Brief 7.12.

BFS Channel is a tool that statuses parameters as bad when there is a failure affecting the insight for that parameter. For instance when the power bus Main A, ALC1 fails, the center engine LO2 prevalve open position microswitch (among others) isn't powered. By selecting Main A and the appropriate sub-bus (ALC1), all parameters affected by that failure will be statused as bad and will appear purple on the MSK view displays. BFS Channel will respond automatically to failures of most of the DSC's (Dedicated Signal Conditioners), MDM's, power buses and control buses represented in BFS. Main Bus and sub-bus failures are not handled automatically by BFS Channel, but a tool run by the Booster operator coordinates capabilities of CRANS and ISP Atom to automatically status the parameters affected by these failures. While BFS Channel and other applications will automatically respond to most failures, these tools often rely on outputs from other tools and other flight control disciplines. It is incumbent upon the MPS operator to be aware that BFS Channel may not respond automatically, and may require manual configuration to properly status parameters as failed.

In the event of a BFS engage, many of these displays (PASS Header, MPS ASCENT, et al) are of no use. Analogous BFS displays do exist for use in this situation. The BFS Header is almost identical to the PASS Header and therefore is self-explanatory. The BFS equivalent of the MPS ASCENT is shown in Figure 3.2.2-XI. Table 3.2.2-IV gives the MSID, nomenclature, units, and source for each parameter displayed on the PASS Header display. The keymap for this table is shown in Figure 3.2.2-XII.



<i>pass_header</i>				
Flt/Vehicle 096/103	GPC MM 102	Q Bar	6	
OGMT 133/16:32:32	PL CMD 104	H Dot	104	OI 129
T- -00:06	MECO 00:00	THR FAC 1.00	V REL 105	
OMET 000/00:00:06	TGO 00:00	ACCEL 1.627	VI 0	
MSID: V90U1979C @133/16:28:20 Value: 0.997999966 Status: ' ' Nomen.				

Figure 3.2.2-I – PASS Header

<i>prelaunch</i>									
	LEFT	CENTER	RIGHT	PNEU	TANK LEVELS				
HE TANK P	3877	4155	4124	4360					
HE REG A P	764	764	760	766	LOW LVL	1-W 2-W	1-W 2-W		
HE REG B P/AC	763	765	763	766		3-W 4-W	3-W 4-W		
HE MASS	63.2	66.5	66.0	13.3	5%	WET	WET		
HE TANK T	33	33	35	38	98% -1	WET	WET		
HE MID T	98	103	103		98% -2	WET	WET		
		LO2		LH2	100% -	WET	DRY		
VALVES - VENT		CL		- CL	100% -1	DRY	DRY		
- OVBD BLEED		AX	BX		100% -2	DRY	DRY		
MAN PRESS		133		33	100% +	DRY	DRY		
ULLAGE - P LEFT		15.6		32.8	OVERFILL	DRY	DRY		
CTR		15.5		33.0	LH2 RECIRC PUMP SPEED				
RT		15.4		33.0	L- 80	C- 0	R- 0		
ENG IN - P LEFT		135		27	-POS-	L	C	R	
CTR		133		30	CCV	100	100	100	
RT		138		25	OPOV	61.8	69.3	65.7	
- T LEFT		-296.6			FPOV	74.3	79.4	81.1	
CTR		-296.8			MOV	100	100	100	
RT		-296.6			MFV	100	100	100	
MAN DISC T A/B	-296.9	-305.3	-418.4		MFV T1	-427	-427	-427	
DIFF PRESS	40.2		0.0		T2	-336	-336	-190	
					OPOV T1	-334	-334	H	
HE MASS TOTAL	209.26				T2	-336	239	-336	
					AFV T1	-331	-334	-334	
					T2	-334	-334	-334	
					-SRB-	LEFT	RIGHT		
					FSM A P	359	360		
					FSM B P	357	354		
					FSM A T	61.1	60.8		
					FSM B T	60.4	59.2		

ISP data server connection established

Figure 3.2.2-II – Prelaunch Display

<i>prelaunch</i>									
	LEFT	CENTER	RIGHT	PNEU	TANK LEVELS				
HE TANK P	1	2	3	4	LO2		LH2		
HE REG A P	5	6	7	8	LOW LVL	1-52 2-53	1-64 2-65		
HE REG B P/AC	9	10	11	12		3-54 4-55	3-66 4-67		
HE MASS	13	14	15	16	5%	56	68		
HE TANK T	17	18	19	20	98% -1	57	69		
HE MID T	21	22	23		98% -2	58	70		
					100% -	59	71		
VALVES - VENT		LO2		LH2	100% -1	60	72		
- OVBD BLEED		A 27	B 28	25 26	100% -2	61	73		
MAN PRESS		29		30	100% +	62	74		
ULLAGE - P LEFT		31		34	OVERFILL	63	75		
CTR		32		35	LH2 RECIRC PUMP SPEED				
RT		33		36	L- 76	C- 77	R- 78		
ENG IN - P LEFT		37		40	-POS- L C R				
CTR		38		41	CCV	79	80	81	
RT		39		42	OPOV	82	83	84	
- T LEFT		43			FPOV	85	86	87	
CTR		44			MOV	88	89	90	
RT		45			MFV	91	92	93	
MAN DISC T A/B	46		47	48	MFV T1	94	95	96	
DIFF PRESS		49		50	T2	97	98	99	
					OPOV T1	100	101	102	
					T2	103	104	105	
					AFV T1	106	107	108	
					T2	109	110	111	
					-SRB- LEFT RIGHT				
					FSM A P	112		113	
					FSM B P	114		115	
					FSM A T	116		117	
					FSM B T	118		119	
ISP data server connection established									

Figure 3.2.2-III – Keymap for Prelaunch Display

Table 3.2.2-I MSIDs for Prelaunch Display

Location Number	Label	Parameter Name	MSID	Units	Source
1	HE TANK P L	MPS E2 HE SUPPLY BOTTLE PRESS	V41P1250C	psia	downlist
2	HE TANK P C	MPS E1 HE SUPPLY BOTTLE PRESS	V41P1150C	psia	downlist
3	HE TANK P R	MPS E3 HE SUPPLY BOTTLE PRESS	V41P1350C	psia	downlist
4	HE TANK P PNEU	MPS PNEU VLVS HE SUP BOTTLE PRESS	V41P1600A	psia	downlist
5	HE REG A P L	MPS E2 REG A HE OUTLET PRESS	V41P1254A	psia	downlist
6	HE REG A P C	MPS E1 REG A HE OUTLET PRESS	V41P1154A	psia	downlist

Table 3.2.2 –I MSIDs for Prelaunch Display (Continued)

7	HE REG A P R	MPS E3 REG A HE OUTLET PRESS	V41P1354A	psia	downlist
8	HE REG A P PNEU	MPS PNEU VLVS REG HE OUTLET PRESS	V41P1605A	psia	downlist
9	HE REG B L P/AC	MPS E2 REG B HE OUTLET PRESS	V41P1253A	psia	downlist
10	HE REG B C P/AC	MPS E1 REG B HE OUTLET PRESS	V41P1153A	psia	downlist
11	HE REG B R P/AC	MPS E3 REG B HE OUTLET PRESS	V41P1353A	psia	downlist
12	HE REG B PNEU P/AC	MPS PNEU ACCUMULATOR PRESSURE	V41P1650A	psia	downlist
13	HE MASS L		mass_MASS_TOT 2	lb <sub>m</sub>	Perf Comp
14	HE MASS C		mass_MASS_TOT 1	lb <sub>m</sub>	Perf Comp
15	HE MASS R		mass_MASS_TOT 3	lb <sub>m</sub>	Perf Comp
16	HE MASS PNEU		mass_MASS_TOT 4	lb <sub>m</sub>	Perf Comp
17	HE TANK T L	MPS E2 AFT FUSELAGE HE SUPPLY TEMP	V41T1251A	°F	downlist
18	HE TANK T C	MPS E1 AFT FUSELAGE HE SUPPLY TEMP	V41T1151A	°F	downlist
19	HE TANK T R	MPS E3 AFT FUSELAGE HE SUPPLY TEMP	V41T1351A	°F	downlist
20	HE TANK T PNEU	MPS PNEU VLVS HE SUP BOTTLE TEMP	V41T1601A	°F	downlist
21	HE MID T L	MPS E2 MID FUSELAGE HE SUPPLY TEMP	V41T1252A	°F	downlist
22	HE MID T C	MPS E1 MID FUSELAGE HE SUPPLY TEMP	V41T1152A	°F	downlist
23	HE MID T R	MPS E3 MID FUSELAGE HE SUPPLY TEMP	V41T1352A	°F	downlist
24	VALVES – VENT LO2	ET – LO2 VENT VLV NO 1 CLOSED IND	T41X1774E	Event	downlist
25	VALVES – VENT LH2	ET – LH2 VENT VLV NO 1 OPEN IND	T41X1727E	Event	downlist
26	VALVES – VENT LH2	ET – LH2 VENT VLV NO 1 CLOSED IND	T41X1724E	Event	downlist
27	- OVBD BLEED A	MPS LO2 OVBD B/V (PV19) CL IND A	V41X1580X	Event	downlist
28	- OVBD BLEED B	MPS LO2 OVBD B/V (PV19) CL IND B	V41X1581X	Event	downlist
29	MAN PRESS LO2	MPS LO2 17IN FEED MANF DISC PRESS	V41P1533C	psia	downlist
30	MAN PRESS LH2	MPS LH2 17IN FEED MANF DISC PRESS	V41P1433C	psia	downlist

Table 3.2.2 –I MSIDs for Prelaunch Display (Continued)

31	ULLAGE – P LEFT LO2	ET-LO2 ULLAGE PRESSURE NO 2	T41P1751C	psig	downlist
32	ULLAGE – P CTR LO2	ET-LO2 ULLAGE PRESSURE NO 1	T41P1750C	psig	downlist
33	ULLAGE – P RT LO2	ET-LO2 ULLAGE PRESSURE NO 3	T41P1752C	psig	downlist
34	ULLAGE – P LEFT LH2	ET-LH2 ULLAGE PRESS NO 2	T41P1701C	psia	downlist
35	ULLAGE – P CTR LH2	ET-LH2 ULLAGE PRESS NO 1	T41P1700C	psia	downlist
36	ULLAGE – P RT LH2	ET-LH2 ULLAGE PRESS NO 3	T41P1702C	psia	downlist
37	ENG IN – P LEFT LO2	MPS E2 LO2 INLET PRESS	V41P1230C	psia	downlist
38	ENG IN – P CTR LO2	MPS E1 LO2 INLET PRESS	V41P1130C	psia	downlist
39	ENG IN – P RT LO2	MPS E3 LO2 INLET PRESS	V41P1330C	psia	downlist
40	ENG IN – P LEFT LH2	MPS E2 LH2 INLET PRESS	V41P1200C	psia	downlist
41	ENG IN – P CTR LH2	MPS E1 LH2 INLET PRESS	V41P1100C	psia	downlist
42	ENG IN – P RT LH2	MPS E3 LH2 INLET PRESS	V41P1300C	psia	downlist
43	ENG IN – T LEFT LO2	MPS E2 LO2 INLET TEMP	V41T1231C	°F	downlist
44	ENG IN – T CTR LO2	MPS E1 LO2 INLET TEMP	V41T1131C	°F	downlist
45	ENG IN – T RT LO2	MPS E3 LO2 INLET TEMP	V41T1331C	°F	downlist
46	MAN DISC T A/B LO2	MPS LO2 17IN FEED MANF DISC TEMP A	V41T1528A	°F	downlist
47	MAN DISC T A/B LO2	MPS LO2 17IN FEED MANF DISC TEMP B	V41T1527A	°F	downlist
48	MAN DISC T A/B LH2	MPS LH2 17IN FEED MANF DISC TEMP	V41T1428A	°F	downlist
49	DIFF PRESS LO2	MPS LO2 MANF TO ET ULL DELTA PRESS	V41P1464A	psid	downlist
50	DIFF PRESS LH2	MPS LH2 MANF TO ET ULL DELTA PRESS	V41P1564A	psid	downlist
51	HE MASS TOTAL		mass_MASS_AL L	lb <sub>m</sub>	Perf Comp
52	TANK LEVELS LO2 LOW LVL	MPS LO2 LEFT ECO SENSOR 1	V41X1555X	Event	downlist
53	LO2 LOW LVL	MPS LO2 LEFT ECO SENSOR 2	V41X1556X	Event	downlist
54	LO2 LOW LVL	MPS LO2 RIGHT ECO SENSOR 2	V41X1557X	Event	downlist
55	LO2 LOW LVL	MPS LO2 RIGHT ECO SENSOR 1	V41X1558X	Event	downlist

56	LO2 5%	ET-LO2 5 PCT LIQ LEVEL SENSOR	T41X1762E	Event	downlist
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Table 3.2.2 –I MSIDs for Prelaunch Display (Continued)

57	LO2 98% -1	ET-LO2 98 PCT LIQ LVL SNSR NO 1	T41X1765E	Event	download
58	LO2 98% -2	ET-LO2 98 PCT LIQ LVL SNSR NO 2	T41X1766E	Event	download
59	LO2 100% -	ET-LO2 100% - LLS XT415.5	T41X1767E	Event	download
60	LO2 100% -1	ET-LO2 100% LLS NO 1 XT412.6	T41X1768E	Event	download
61	LO2 100% -2	ET-LO2 100% LLS NO 2 XT412.6	T41X1769E	Event	download
62	LO2 100% +	ET-LO2 100% + LLS XT409.5	T41X1770E	Event	download
63	LO2 OVERFILL	ET-LO2 OVERFILL LLS XT399.7	T41X1771E	Event	download
64	LH2 LOW LVL	ET-LH2 LOW LEVEL LIQ SENSOR NO 1	T41X1730X	Event	download
65	LH2 LOW LVL	ET-LH2 LOW LEVEL LIQ SENSOR NO 2	T41X1731X	Event	download
66	LH2 LOW LVL	ET-LH2 LOW LEVEL LIQ SENSOR NO 3	T41X1732X	Event	download
67	LH2 LOW LVL	ET-LH2 LOW LEVEL LIQ SENSOR NO 4	T41X1733X	Event	download
68	LH2 5%	ET-LH2 5 PCT LIQUID LVL SNSR	T41X1712E	Event	download
69	LH2 98% -1	ET-LH2 98 PCT LIQUID LVL SNSR NO 1	T41X1715E	Event	download
70	LH2 98% -2	ET-LH2 98 PCT LIQUID LVL SNSR NO 2	T41X1716E	Event	download
71	LH2 100% -	ET-LH2 100% - LLS XT1048.6	T41X1717E	Event	download
72	LH2 100% -1	ET-LH2 100% LLS NO 1 XT1044.6	T41X1718E	Event	download
73	LH2 100% -2	ET-LH2 100% LLS NO 2 XT1044.6	T41X1719E	Event	download
74	LH2 100% +	ET-LH2 100% + LLS XT1040.6	T41X1720E	Event	download
75	LH2 OVERFILL	ET-LH2 OVERFILL LLS XT1033.4	T41X1721E	Event	download
76	LH2 RECIRC PUMP SPEED L	MPS E2 LH2 RECIRC PUMP (PP2) SPEED	V41R1215A	RPM	download
77	LH2 RECIRC PUMP SPEED C	MPS E1 LH2 RECIRC PUMP (PP1) SPEED	V41R1115A	RPM	download
78	LH2 RECIRC PUMP SPEED R	MPS E3 LH2 RECIRC PUMP (PP3) SPEED	V41R1315A	RPM	download
79	CCV L	ME-2 CCV ACTUATOR POSITION DW 26	E41H2026B	PCT	download
80	CCV C	ME-1 CCV ACTUATOR POSITION DW 26	E41H1026B	PCT	download

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81	CCV R	ME-3 CCV ACTUATOR POSITION DW 26	E41H3026B	PCT	downlis t
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Table 3.2.2 –I MSIDs for Prelaunch Display (Continued)

82	OPOV L	ME-2 OPOV ACTUATOR POSITION DW 28	E41H2028B	PCT	downlist
83	OPOV C	ME-1 OPOV ACTUATOR POSITION DW 28	E41H1028B	PCT	downlist
84	OPOV R	ME-3 OPOV ACTUATOR POSITION DW 28	E41H3028B	PCT	downlist
85	FPOV L	ME-2 FPOV ACTUATOR POSITION DW 27	E41H2027B	PCT	downlist
86	FPOV C	ME-1 FPOV ACTUATOR POSITION DW 27	E41H1027B	PCT	downlist
87	FPOV R	ME-3 FPOV ACTUATOR POSITION DW 27	E41H3027B	PCT	downlist
88	MOV L	ME-2 MOV ACTUATOR POSITION DW 25	E41H2025B	PCT	downlist
89	MOV C	ME-1 MOV ACTUATOR POSITION DW 25	E41H1025B	PCT	downlist
90	MOV R	ME-3 MOV ACTUATOR POSITION DW 25	E41H3025B	PCT	downlist
91	MFV L	ME-2 MFV ACTUATOR POSITION DW 24	E41H2024B	PCT	downlist
92	MFV C	ME-1 MFV ACTUATOR POSITION DW 24	E41H1024B	PCT	downlist
93	MFV R	ME-3 MFV ACTUATOR POSITION DW 24	E41H3024B	PCT	downlist
94	MFV T1 L	ME-2 MFV DOWNSTREAM TEMP #1	E41T2153A	°F	downlist
95	MFV T1 C	ME-1 MFV DOWNSTREAM TEMP #1	E41T1153A	°F	downlist
96	MFV T1 R	ME-3 MFV DOWNSTREAM TEMP #1	E41T3153A	°F	downlist
97	MFV T2 L	ME-2 MFV DOWNSTREAM TEMP #2	E41T2154A	°F	downlist
98	MFV T2 C	ME-1 MFV DOWNSTREAM TEMP #2	E41T1154A	°F	downlist
99	MFV T2 R	ME-3 MFV DOWNSTREAM TEMP #2	E41T3154A	°F	downlist
100	OPOV T1 L	ME-2 OPOV LOX SUPPLY LINE TEMP #1	E41T2151A	°F	downlist
101	OPOV T1 C	ME-1 OPOV LOX SUPPLY LINE TEMP #1	E41T1151A	°F	downlist

Table 3.2.2 –I MSIDs for Prelaunch Display (Concluded)

102	OPOV T1 R	ME-3 OPOV LOX SUPPLY LINE TEMP #1	E41T3151A	°F	downlis t
103	OPOV T2 L	ME-2 OPOV LOX SUPPLY LINE TEMP #2	E41T2152A	°F	downlis t
104	OPOV T2 C	ME-1 OPOV LOX SUPPLY LINE TEMP #2	E41T1152A	°F	downlis t
105	OPOV T2 R	ME-3 OPOV LOX SUPPLY LINE TEMP #2	E41T3152A	°F	downlis t
106	AFV T1 L	ME-2 AFV DOWNSTREAM TEMP #1	E41T2155A	°F	downlis t
107	AFV T1 C	ME-1 AFV DOWNSTREAM TEMP #1	E41T1155A	°F	downlis t
108	AFV T1 R	ME-3 AFV DOWNSTREAM TEMP #1	E41T3155A	°F	downlis t
109	AFV T2 L	ME-2 AFV DOWNSTREAM TEMP #2	E41T2156A	°F	downlis t
110	AFV T2 C	ME-1 AFV DOWNSTREAM TEMP #2	E41T1156A	°F	downlis t
111	AFV T2 R	ME-3 AFV DOWNSTREAM TEMP #2	E41T3156A	°F	downlis t
112	SRB FSM A P L	LH PRESS N2H4/GN2 BOTTLE OUT SYS A	B46P1305C	psia	downlis t
113	SRB FSM A P R	RH PRESS N2H4/GN2 BOTTLE OUT SYS A	B46P2305C	psia	downlis t
114	SRB FSM B P L	LH PRESS N2H4/GN2 BOTTLE OUT SYS B	B46P1306C	psia	downlis t
115	SRB FSM B P R	RH PRESS N2H4/GN2 BOTTLE OUT SYS B	B46P2306C	psia	downlis t
116	SRB FSM A T L	LH TEMP GAS N2H4/GN2 BOTTLE SYS A	B46T1501C	°F	downlis t
117	SRB FSM A T R	RH TEMP GAS N2H4/GN2 BOTTLE SYS A	B46T2501C	°F	downlis t
118	SRB FSM B T L	LH TEMP GAS N2H4/GN2 BOTTLE SYS B	B46T1502C	°F	downlis t
119	SRB FSM B T R	RH TEMP GAS N2H4/GN2 BOTTLE SYS B	B46T2502C	°F	downlis t

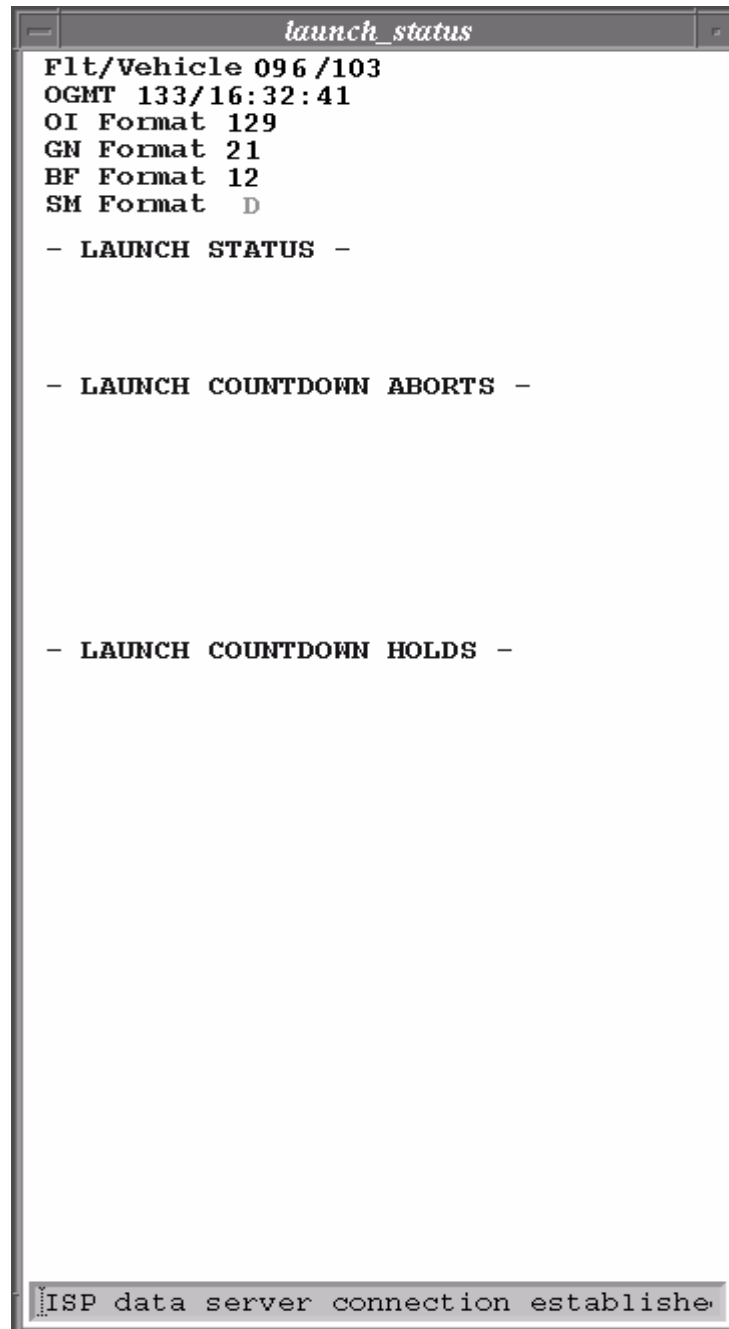


Figure 3.2.2-IV – Launch Status

mps_ascent.new														
HE TANK P	L	4296		C	4303		R	4300		P	4404			
INTERCONNECTS		-----/-----			-----/-----			-----/-----			-----			
ISO A/B OP PWR		0/-	0/-		0/-	0/-		0/-	0/-		0/-	0/-		
REG A/B P		751	739		756	749		751	747		766			
HPOT IMSL P		186	186		179	179		187	188		Accum P 759			
BFS DP/DT		9984			9984			9984			0.002			
COMP Mdot		0.000			0.000			0.000			0.002			
LkType/Intcnct		/			/			/						
Recmnded SHDN														
ZG TOD/SHDN P		00:00	0		00:00	0		00:00	0		00:00	2800		
PN TOD/SHDN P		00:00	0		00:00	0		00:00	0		00:00	2036		
HYD TOD/SHDN P		00:00	0		00:00	0		00:00	0		00:00	639		
MID/AFT TK T		80 / 23			80 / 23			80 / 20			-/ 33	TOT HE M		
HE MASS		70.86			70.97			70.99			13.62	226.44		
PWR LVL 100		D			D			D			LO2	LH2		
FCV		-LO2-		VENT X	HIFL -	-LH2-		VENT -/X		PV OP O	OOO	---		
GH2 OUT P		0	0	0	-	-	-	-	-	PV CL X	---	XXX		
DISCONNECT P		40			40	40	40	40	40	FD DSC	OO--	OO--		
ULLAGE P		20.4	20.1	20.3	41.8	41.8	41.9	41.9	41.9	FD LTCH	LL--	LL--		
NPSP					D	D	D	D	D	RLF ISO	-X	-X		
MANIFOLD P		94			43			43			IB F/D	-X	-X	
INLET P		107	103	104	46	48	50	50	50	OB F/D	0-	0-		
IN T/LPFT P		-283.3	-283.8	-283.5	51	52	52	52	52	OVB/TOP	0-	-X		
PROP REM		D 5 CO WWW			D 5 CO WWW			D 5 CO WWW			R DSC	X	-	
-SRB-		LEFT			RIGHT			M M			P LN V O		-	
IGN S&A		ARM/ M		ARM/ M		M M			M M			POGO1/2	--XX	
PC 1		9		7		M			M			BU DMP	IB/OB	-X/-X
PC 2		11		7		M			M			MN P120	- -	- -
PC 3		7		9		M			M			RTLS RPRSS12	- -	- -
FSM P RCK/TLT		388 / 384		391 / 387		SWITCH			PB			CMD		
TRBSPD RCK/TLT		0.2 / 0.2		0.2 / 0.2		-SRB- AUTO/---			---			---		
HYD P RCK/TLT		21 / 21		L / 21		-ET- AUTO/---			---			---		
PRI P RCK/TLT		FAIL/ FAIL		FAIL/ FAIL		THROT AUTO/---			MEC1/2 ON /ON					
ISP data server connection established														

Figure 3.2.2-V – MPS Ascent Display



Table 3.2.2-II – Telemetry on the MPS Ascent Display

	MSID	Parameter Name	Units	Source
1	V41P1250C	MPS E2 HE SUPPLY BOTTLE PRESS	Psia	Downlist
2	V41P1150C	MPS E1 HE SUPPLY BOTTLE PRESS	Psia	Downlist
3	V41P1350C	MPS E3 HE SUPPLY BOTTLE PRESS	Psia	Downlist
4	V41P1600A	MPS PNEU VLVS HE SUP BOTTLE PRESS	Psia	Downlist
5	V41X1264E	MPS E2 HE INTCN IN (LV61) OP PWR	Psia	Downlist
6	V41X1270E	MPS E2 HE INTCN OUT (LV62) OP PWR	Psia	Downlist
7	V41X1164E	MPS E1 HE INTCN IN (LV59) OP PWR	Psia	Downlist
8	V41X1170E	MPS E1 HE INTCN OUT (LV60) OP PWR	Psia	Downlist
9	V41X1364E	MPS E3 HE INTCN IN (LV63) OP PWR	Psia	Downlist
10	V41X1370E	MPS E4 HE INTCN OUT (LV64) OP PWR	Psia	Downlist
11	V41X1614E	MPS REG HE XOVER VLV (LV10) OP PWR	Psia	Downlist
12	V41X1258E	MPS E2 HE ISO VLV A (LV3) OP PWR	Event	Downlist
13	V41X1259E	MPS E2 HE ISO VLV B (LV4) OP PWR	Event	Downlist
14	V41X1158E	MPS E1 HE ISO VLV A (LV1) OP PWR	Event	Downlist
15	V41X1159E	MPS E1 HE ISO VLV B (LV2) OP PWR	Event	Downlist
16	V41X1358E	MPS E3 HE ISO VLV A (LV5) OP PWR	Event	Downlist
17	V41X1359E	MPS E3 HE ISO VLV B (LV6) OP PWR	Event	Downlist
18	V41X1645E	MPS PNEU HE ISO VLV 1 (LV7) OP PWR	Event	Downlist
19	V41X1646E	MPS PNEU HE ISO VLV 2 (LV8) OP PWR	Event	Downlist
20	V41P1254A	MPS E2 REG A HE OUTLET PRESS	Psia	Downlist
21	V41P1253A	MPS E2 REG B HE OUTLET PRESS	Psia	Downlist
22	V41P1154A	MPS E1 REG A HE OUTLET PRESS	Psia	Downlist
23	V41P1153A	MPS E1 REG B HE OUTLET PRESS	Psia	Downlist
24	V41P1354A	MPS E3 REG A HE OUTLET PRESS	Psia	Downlist
25	V41P1353A	MPS E3 REG B HE OUTLET PRESS	Psia	Downlist
26	V41P1605A	MPS PNEU VLVS REG HE OUTLET PRESS	Psia	Downlist
27	V41P1650A	MPS PNEU ACCUMULATOR PRESSURE	Psia	Downlist
28	E41P2014B	ME-2 HPOT I-SEAL PGE P CH A DW 20	Psia	Downlist
29	E41P2015B	ME-2 HPOT I-SEAL PGE P CH B DW 21	Psia	Downlist
30	E41P1014B	ME-1 HPOT I-SEAL PGE P CH A DW 20	Psia	Downlist
31	E41P1015B	ME-1 HPOT I-SEAL PGE P CH B DW 21	Psia	Downlist
32	E41P3014B	ME-3 HPOT I-SEAL PGE P CH A DW 20	Psia	Downlist
33	E41P3015B	ME-3 HPOT I-SEAL PGE P CH B DW 21	Psia	Downlist
34	V98P4998C	SSME HE TK PRESS 2 CHG RATE BFS (aka dP/dt)	Psia/3Sec	Downlist
35	V98P4997C	SSME HE TK PRESS 1 CHG RATE BFS	Psia/3Sec	Downlist
36	V98P4999C	SSME HE TK PRESS 3 CHG RATE BFS	Psia/3Sec	Downlist



Table 3.2.2-II – Telemetry on the MPS Ascent Display, Continued

	MSID	Parameter Name	Units	Source
37	helium_MDOT_GOOD	Helium Comp Initialized	Event	He Comp
38	helium_DM_DT2	Eng 2 He Mass Flow Rate (aka Mdot)	Lbm/Sec	He Comp
39	helium_DM_DT1	Eng 1 He Mass Flow Rate	Lbm/Sec	He Comp
40	helium_DM_DT3	Eng 3 He Mass Flow Rate	Lbm/Sec	He Comp
41	helium_DM_DT4	Pneu He Mass Flow Rate	Lbm/Sec	He Comp
42	helium_LK_CONFRM2	Eng 2 Leak Type	“U, L, S”	He Comp
43	helium_LK_CONFRM1	Eng 1 Leak Type	“U, L, S”	He Comp
44	helium_LK_CONFRM3	Eng 3 Leak Type	“U, L, S”	He Comp
45	helium_INCONFLG2	Eng 2 He Interconnect Status	“N, P, A”	He Comp
46	helium_INCONFLG1	Eng 1 He Interconnect Status	“N, P, A”	He Comp
47	helium_INCONFLG3	Eng 3 He Interconnect Status	“N, P, A”	He Comp
48	helium_RECD_SD_MODE2	Eng 2 Recommended Shut Down Mode	“Zero-G,	He Comp
49	helium_RECD_SD_MODE1	Eng 1 Recommended Shut Down Mode	Velocity,	He Comp
50	helium_RECD_SD_MODE3	Eng 3 Recommended Shut Down Mode	Redline”	He Comp
51	helium_TOD_ZG2_CUR	Eng 2 Zero-G Shut Down Time of Depletion	mm:ss	He Comp
52	helium_TOD_ZG1_CUR	Eng 1 Zero-G Shut Down Time of Depletion	mm:ss	He Comp
53	helium_TOD_ZG3_CUR	Eng 3 Zero-G Shut Down Time of Depletion	mm:ss	He Comp
54	helium_TOD_ZG4_CUR	PnTk Zero-G Shut Down Time of Depletion	mm:ss	He Comp
55	helium_TOD_PNEU2_CUR	Eng 2 Pneu Shut Down Time of Depletion	mm:ss	He Comp
56	helium_TOD_PNEU1_CUR	Eng 1 Pneu Shut Down Time of Depletion	mm:ss	He Comp
57	helium_TOD_PNEU3_CUR	Eng 3 Pneu Shut Down Time of Depletion	mm:ss	He Comp
58	helium_TOD_PNEU4_CUR	PnTk Pneu Shut Down Time of Depletion	mm:ss	He Comp
59	helium_TOD_HYD2_CUR	Eng 2 Hyd Shut Down Time of Depletion	mm:ss	He Comp
60	helium_TOD_HYD1_CUR	Eng 1 Hyd Shut Down Time of Depletion	mm:ss	He Comp
61	helium_TOD_HYD3_CUR	Eng 3 Hyd Shut Down Time of Depletion	mm:ss	He Comp
62	helium_TOD_HYD4_CUR	PnTk Hyd Shut Down Time of Depletion	mm:ss	He Comp
63	helium_P_ZERO2	Eng 2 Zero-G Shut Down Pressure	Psia	He Comp
64	helium_P_ZERO1	Eng 1 Zero-G Shut Down Pressure	Psia	He Comp
65	helium_P_ZERO3	Eng 3 Zero-G Shut Down Pressure	Psia	He Comp
66	helium_P_PNEU2	Eng 2 Pneu Shut Down Pressure	Psia	He Comp
67	helium_P_PNEU1	Eng 1 Pneu Shut Down Pressure	Psia	He Comp
68	helium_P_PNEU3	Eng 3 Pneu Shut Down Pressure	Psia	He Comp
69	helium_P_HYD2	Eng 2 Hyd Shut Down Pressure	Psia	He Comp
70	helium_P_HYD1	Eng 1 Hyd Shut Down Pressure	Psia	He Comp
71	helium_P_HYD3	Eng 3 Hyd Shut Down Pressure	Psia	He Comp
72	V41T1252A	MPS E2 MID FUSELAGE HE SUPPLY TEMP	DegF	Downlist
73	V41T1152A	MPS E1 MID FUSELAGE HE SUPPLY TEMP	DegF	Downlist
74	V41T1352A	MPS E3 MID FUSELAGE HE SUPPLY TEMP	DegF	Downlist
75	V41T1251A	MPS E2 AFT FUSELAGE HE SUPPLY TEMP	DegF	Downlist
76	V41T1151A	MPS E1 AFT FUSELAGE HE SUPPLY TEMP	DegF	Downlist
77	V41T1351A	MPS E3 AFT FUSELAGE HE SUPPLY TEMP	DegF	Downlist
78	V41T1601A	MPS PNEU VLVS HE SUP BOTTLE TEMP	DegF	Downlist

Table 3.2.2-II – Telemetry on the MPS Ascent Display, Continued

	MSID	Parameter Name	Units	Source
79	mass_MASS TOT2	Eng 2 Helium Mass	Lbm	Mass Comp
80	mass_MASS TOT1	Eng 1 Helium Mass	Lbm	Mass Comp
81	mass_MASS TOT3	Eng 3 Helium Mass	Lbm	Mass Comp
82	mass_MASS TOT4	PnTk Helium Mass	Lbm	Mass Comp
83	mass_MASS ALL	Total Helium Mass	Lbm	Mass Comp
84	V90U1948C	COMMANDED SSME THROTTLE SETTING	Percent	Downlist
85	perf_PL_AVG2	Eng 2 Power Level	Percent	Perf Comp
86	perf_PL_AVG1	Eng 1 Power Level	Percent	Perf Comp
87	perf_PL_AVG3	Eng 3 Power Level	Percent	Perf Comp
88	V41S1477E	MPS LH2 ULL PRESS HI FLOW SW SCN	Event	Downlist
89	T41X1774E	ET-LO2 VENT VLV NO 1 CLOSED IND	Event	Downlist
90	T41X1727E	ET-LH2 VENT VLV NO 1 OPEN IND	Event	Downlist
91	T41X1724E	ET-LH2 VENT VLV NO 1 CLOSED IND	Event	Downlist
92	V41X1598E	MPS GO2 PRESS FCV 2 (LV54) CL PWR	Event	Downlist
93	V41X1596E	MPS GO2 PRESS FCV 1 (LV53) CL PWR	Event	Downlist
94	V41X1603E	MPS GO2 PRESS FCV 3 (LV55) CL PWR	Event	Downlist
95	V41X1662E	MPS GH2 PRESS FCV 2 (LV57) CL PWR	Event	Downlist
96	V41X1661E	MPS GH2 PRESS FCV 1 (LV56) CL PWR	Event	Downlist
97	V41X1663E	MPS GH2 PRESS FCV 3 (LV58) CL PWR	Event	Downlist
98	V41P1260A	MPS E2 GH2 PRESS OUTLET PRESS	Psia	Downlist
99	V41P1160A	MPS E1 GH2 PRESS OUTLET PRESS	Psia	Downlist
100	V41P1360A	MPS E2 GH2 PRESS OUTLET PRESS	Psia	Downlist
101	V41P1590A	MPS GO2 PRESSURIZATION DISC PRESS	Psia	Downlist
102	V41P1490A	MPS GH2 PRESSURIZATION DISC PRESS	Psia	Downlist
103	T41P1751C	ET-LO2 ULLAGE PRESSURE NO 2	Psig	Downlist
104	T41P1750C	ET-LO2 ULLAGE PRESSURE NO 1	Psig	Downlist
105	T41P1752C	ET-LO2 ULLAGE PRESSURE NO 3	Psig	Downlist
106	T41P1701C	ET-LH2 ULLAGE PRESS NO 2	Psia	Downlist
107	T41P1700C	ET-LH2 ULLAGE PRESS NO 1	Psia	Downlist
108	T41P1702C	ET-LH2 ULLAGE PRESS NO 3	Psia	Downlist
109	perf_NPSP_LH2_2	Eng 2 Net Positive Suction Pressure	Psia	Perf Comp
110	perf_NPSP_LH2_1	Eng 1 Net Positive Suction Pressure	Psia	Perf Comp
111	perf_NPSP_LH2_3	Eng 3 Net Positive Suction Pressure	Psia	Perf Comp
112	V41P1533C	MPS LO2 17IN FEED MANF DISC PRESS	Psia	Downlist
113	V41P1433C	MPS LH2 17IN FEED MANF DISC PRESS	Psia	Downlist
114	V41P1230C	MPS E2 LO2 INLET PRESS	Psia	Downlist
115	V41P1130C	MPS E1 LO2 INLET PRESS	Psia	Downlist
116	V41P1330C	MPS E3 LO2 INLET PRESS	Psia	Downlist
117	V41P1200C	MPS E2 LH2 INLET PRESS	Psia	Downlist
118	V41P1100C	MPS E1 LH2 INLET PRESS	Psia	Downlist
119	V41P1300C	MPS E3 LH2 INLET PRESS	Psia	Downlist

Table 3.2.2-II – Telemetry on the MPS Ascent Display, Continued

	MSID	Parameter Name	Units	Source
120	V41T1231C	MPS E2 LO2 INLET TEMP	DegF	Downlist
121	V41T1131C	MPS E1 LO2 INLET TEMP	DegF	Downlist
122	V41T1331C	MPS E3 LO2 INLET TEMP	DegF	Downlist
123	E41P2018B	ME-2 LPFT DISCH PRESS (AVG) DW 9	Psia	Downlist
124	E41P1018B	ME-1 LPFT DISCH PRESS (AVG) DW 9	Psia	Downlist
125	E41P3018B	ME-3 LPFT DISCH PRESS (AVG) DW 9	Psia	Downlist
126	V90X1942X	ET LEVEL SENSOR ARM CMD	Event	Downlist
127	perf_LO2_PROP_REM	LO2 Propellant Remaining	Percent	Perf Comp
128	T41X1762E	ET-LO2 5 PCT LIQ LEVEL SENSOR	Event	Downlist
129	V41X1555X	MPS LO2 LEFT ECO SENSOR 1	Event	Downlist
130	V41X1556X	MPS LO2 LEFT ECO SENSOR 2	Event	Downlist
131	V41X1557X	MPS LO2 RIGHT ECO SENSOR 2	Event	Downlist
132	V41X1558X	MPS LO2 RIGHT ECO SENSOR 1	Event	Downlist
133	perf_LH2_PROP_REM	LH2 Propellant Remaining	Percent	Perf Comp
134	T41X1712E	ET-LH2 5 PCT LIQUID LVL SNSR	Event	Downlist
135	T41X1730X	ET-LH2 LOW LEVEL LIQ SENSOR NO 1	Event	Downlist
136	T41X1731X	ET-LH2 LOW LEVEL LIQ SENSOR NO 2	Event	Downlist
137	T41X1732X	ET-LH2 LOW LEVEL LIQ SENSOR NO 3	Event	Downlist
138	T41X1733X	ET-LH2 LOW LEVEL LIQ SENSOR NO 4	Event	Downlist
139	V41X1234X	MPS E2 LO2 PREVLV (PV2) OP IND	Event	Downlist
140	V41X1134X	MPS E1 LO2 PREVLV (PV1) OP IND	Event	Downlist
141	V41X1334X	MPS E3 LO2 PREVLV (PV3) OP IND	Event	Downlist
142	V41X1204X	MPS E2 LH2 PREVLV (PV5) OP IND A	Event	Downlist
143	V41X1104X	MPS E1 LH2 PREVLV (PV4) OP IND A	Event	Downlist
144	V41X1304X	MPS E3 LH2 PREVLV (PV6) OP IND A	Event	Downlist
145	V41X1235E	MPS E2 LO2 PREVLV (PV2) CL IND	Event	Downlist
146	V41X1135E	MPS E1 LO2 PREVLV (PV1) CL IND	Event	Downlist
147	V41X1335E	MPS E3 LO2 PREVLV (PV3) CL IND	Event	Downlist
148	V41X1205E	MPS E2 LH2 PREVLV (PV5) CL IND	Event	Downlist
149	V41X1105E	MPS E1 LH2 PREVLV (PV4) CL IND	Event	Downlist
150	V41X1305E	MPS E3 LH2 PREVLV (PV6) CL IND	Event	Downlist
151	V41X1529X	MPS LO2 17IN DISC VLV(PD1)OP IND A	Event	Downlist
152	V41X1545X	MPS LO2 17IN DISC VLV(PD1)OP IND B	Event	Downlist
153	V41X1530X	MPS LO2 17IN DISC VLV(PD1)CL IND A	Event	Downlist
154	V41X1534X	MPS LO2 17IN DISC VLV(PD1)CL IND B	Event	Downlist
155	V41X1429X	MPS LH2 17IN DISC VLV(PD2)OP IND A	Event	Downlist
156	V41X1445X	MPS LH2 17IN DISC VLV(PD2)OP IND B	Event	Downlist
157	V41X1430X	MPS LH2 17IN DISC VLV(PD2)CL IND A	Event	Downlist
158	V41X1434X	MPS LH2 17IN DISC VLV(PD2)CL IND B	Event	Downlist

Table 3.2.2-II – Telemetry on the MPS Ascent Display, Continued

	MSID	Parameter Name	Units	Source
159	V41X1891X	MPS LO2 17IN(PD1)LATCH LCKED IND A	Event	Downlist
160	V41X1892X	MPS LO2 17IN(PD1)LATCH LCKED IND B	Event	Downlist
161	V41X1893X	MPS LO2 17IN(PD1)LTCH UNLCKD IND A	Event	Downlist
162	V41X1894X	MPS LO2 17IN(PD1)LTCH UNLCKD IND B	Event	Downlist
163	V41X1991X	MPS LH2 17IN(PD2)LATCH LCKED IND A	Event	Downlist
164	V41X1992X	MPS LH2 17IN(PD2)LATCH LCKED IND B	Event	Downlist
165	V41X1993X	MPS LH2 17IN(PD2)LTCH UNLCKD IND A	Event	Downlist
166	V41X1994X	MPS LH2 17IN(PD2)LTCH UNLCKD IND B	Event	Downlist
167	V41X1541E	MPS LO2 FDLN RLF SOV (PV7) OP IND	Event	Downlist
168	V41X1542E	MPS LO2 FDLN RLF SOV (PV7) CL IND	Event	Downlist
169	V41X1441E	MPS LH2 FDLN RLF SOV (PV8) OP IND	Event	Downlist
170	V41X1442E	MPS LH2 FDLN RLF SOV (PV8) CL IND	Event	Downlist
171	V41X1510E	MPS LO2 INBD F/D VLV (PV10) OP IND	Event	Downlist
172	V41X1509X	MPS LO2 INBD F/D VLV (PV10) CL IND	Event	Downlist
173	V41X1409E	MPS LH2 INBD F/D VLV (PV12) OP IND	Event	Downlist
174	V41X1410X	MPS LH2 INBD F/D VLV (PV12) CL IND	Event	Downlist
175	V41X1513E	MPS LO2 OTBD F/D VLV (PV9) OP IND	Event	Downlist
176	V41X1514X	MPS LO2 OTBD F/D VLV (PV9) CL IND	Event	Downlist
177	V41X1388E	MPS LH2 OTBD F/D VLV (PV11) OP IND	Event	Downlist
178	V41X1389X	MPS LH2 OTBD F/D VLV (PV11) CL IND	Event	Downlist
179	V41X1587E	MPS LO2 OVBD B/V (PV19) OP IND	Event	Downlist
180	V41X1580X	MPS LO2 OVBD B/V (PV19) CL IND A	Event	Downlist
181	V41X1453E	MPS LH2 TOPPING VLV (PV13) OP IND	Event	Downlist
182	V41X1456X	MPS LH2 TOPPING VLV (PV13) OP IND	Event	Downlist
183	V41X1420E	MPS LH2 4IN DISC VLV (PD3) CL IND (aka Recirc Disconnect)	Event	Downlist
184	V41X1492E	MPS GH2 PRESS LN VENT(LV52) OP PWR	Event	Downlist
185	V41X1811X	MPS LO2 POGO RECRC 1 (PV20) OP IND	Event	Downlist
186	V41X1821X	MPS LO2 POGO RECRC 2 (PV21) OP IND	Event	Downlist
187	V41X1818E	MPS LO2 POGO RECRC 1 (PV20) CL IND	Event	Downlist
188	V41X1828E	MPS LO2 POGO RECRC 2 (PV21) CL IND	Event	Downlist
189	V41X1927E	MPS LH2 RTLS INBD DV (PV17) OP IND	Event	Downlist
190	V41X1929X	MPS LH2 RTLS INBD DV (PV17) CL IND	Event	Downlist
191	V41X1917E	MPS LH2 RTLS OTBD DV (PV18) OP IND	Event	Downlist
192	V41X1919X	MPS LH2 RTLS OTBD DV (PV18) CL IND	Event	Downlist
193	V41X1538E	MPS LO2 MANF REPRSS 1(LV40) OP PWR	Event	Downlist
194	V41X1539E	MPS LO2 MANF REPRSS 2(LV41) OP PWR	Event	Downlist
195	V41X1436E	MPS LH2 MANF REPRSS 1(LV42) OP PWR	Event	Downlist
196	V41X1438E	MPS LH2 MANF REPRSS 2(LV43) OP PWR	Event	Downlist

Table 3.2.2-II – Telemetry on the MPS Ascent Display, continued

C	MSID	Parameter Name	Units	Source
197	V41X1901E	MPS LH2 RTLS REPRSS 1(LV74) OP PWR	Event	Downlist
198	V41X1902E	MPS LH2 RTLS REPRSS 2(LV75) OP PWR	Event	Downlist
199	V41X1632E	MPS HE SPLY BLWDWN 1 (LV26) OP PWR	Event	Downlist
200	V41X1634E	MPS HE SPLY BLWDWN 2 (LV27) OP PWR	Event	Downlist
201	B55X1842X	LH EVENT IGN S&A DEVICE ARMED	Event	Downlist
202	B55X1843X	LH EVENT IGN S&A DEVICE SAFED	Event	Downlist
203	B55X2842X	RH EVENT IGN S&A DEVICE ARMED	Event	Downlist
204	B55X2843X	RH EVENT IGN S&A DEVICE SAFED	Event	Downlist
205	B47P1300C	LH PRESS A SRM CHAMBER	Psia	Downlist
206	B47P1301C	LH PRESS B SRM CHAMBER	Psia	Downlist
207	B47P1302C	LH PRESS C SRM CHAMBER	Psia	Downlist
208	B47P2300C	RH PRESS A SRM CHAMBER	Psia	Downlist
209	B47P2301C	RH PRESS B SRM CHAMBER	Psia	Downlist
210	B47P2302C	RH PRESS C SRM CHAMBER	Psia	Downlist
211	B46P1305C	LH PRESS N2H4/GN2 BOTTLE OUT SYS A	Psia	Downlist
212	B46P1306C	LH PRESS N2H4/GN2 BOTTLE OUT SYS B	Psia	Downlist
213	B46P2305C	RH PRESS N2H4/GN2 BOTTLE OUT SYS A	Psia	Downlist
214	B46P2306C	RH PRESS N2H4/GN2 BOTTLE OUT SYS B (aka FSM Pressures)	Psia	Downlist
215	B46R1408C	LH RATE APU A TURBINE SPEED SNSR 2	KRPM	Downlist
216	B46R1409C	LH RATE APU B TURBINE SPEED SNSR 2	KRPM	Downlist
217	B46R2408C	RH RATE APU A TURBINE SPEED SNSR 2	KRPM	Downlist
218	B46R2409C	RH RATE APU B TURBINE SPEED SNSR 2	KRPM	Downlist
219	B58P1303C	LH PRESS HYDR FLUID SUPPLY 1	Psia	Downlist
220	B58P1304C	LH PRESS HYDR FLUID SUPPLY 2	Psia	Downlist
221	B58P2303C	RH PRESS HYDR FLUID SUPPLY 1	Psia	Downlist
222	B58P2304C	RH PRESS HYDR FLUID SUPPLY 2	Psia	Downlist
223	B58X1860X	LH EV ROCK SERVO ACTR PRI PRESS OK	Event	Downlist
224	B58X1859X	LH EV TILT SERVO ACTR PRI PRESS OK	Event	Downlist
225	B58X2860X	RH EV ROCK SERVO ACTR PRI PRESS OK	Event	Downlist
226	B58X2859X	RH EV TILT SERVO ACTR PRI PRESS OK	Event	Downlist
227	MECO_AT_ARM	MECO At The Arming Mass	Event	Booster
228	LL_PROT_LOSS	Low Level Protection Lost	Event	Publishing
229	MULT_DATA_NO2	Multi Data Path Without A 2	Event	CRANS
230	lgt_DUMP_SW	Bad Dump Switch due to Control Bus	Event	Lgt
231	V98X3546X	AS33 MECO CONFIRMED BFS	Event	Downlist
	V98X3689X	AB36 MECO CONFIRMED BFS	Event	Downlist
	V90X8561X	MECO CONFIRMED FLAG	Event	Downlist

Table 3.2.2-II – Telemetry on the MPS Ascent Display, Concluded

C	MSID	Parameter Name	Units	Source
232	V90X7570X	SEL SRB SEPARATION AUTO CMD (sw)	Event	Downlist
233	V90X7571X	SEL SRB SEPN MNL/AUTO ENABLE CMD (sw)	Event	Downlist
234	V90X7572X	SEL SRB SEP INITIATE/WOW-WONG CMD (pb)	Event	Downlist
235	V90X8333X	SRB SEPARATION INITIATION FLAG	Event	Downlist
236	V90X8331X	SRB SEPARATION COMMAND FLAG	Event	Downlist
237	V90X7554X	SEL ET SEP AUTO (sw)	Event	Downlist
238	V90X7556X	SEL ET SEP MNL ENABLE (sw)	Event	Downlist
239	V90X7564X	SEL ET SEP INITIATE/WOW-WONG CMD (pb)	Event	Downlist
240	V90X8259X	ET AUTO SEP INHIBIT CREW ALERT	Event	Downlist
241	V90X8250X	ET SEPARATION CMD FLAG	Event	Downlist
242	V72X5135X	RH SPEEDBRAKE MANUAL (aka Manual Throttle)	Event	Downlist
243	V76S4601E	MEC 1 BUS A PWR ON	Event	Downlist
244	V76S4605E	MEC 2 BUS B PWR ON	Event	Downlist

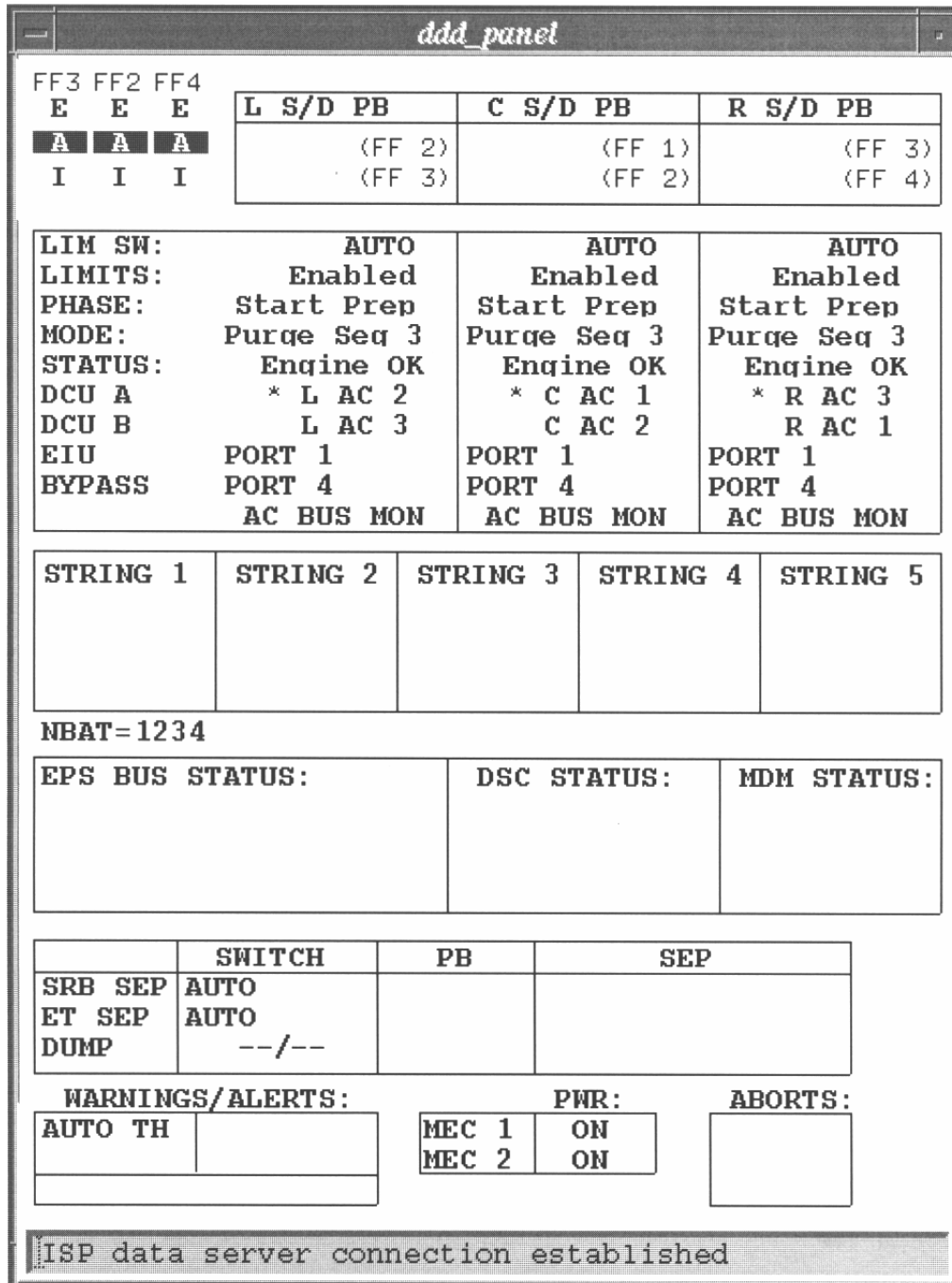


Figure 3.2.2-VII – DDD Panel (see 3.1.2 for MSID map)

bilevel																				
-LO2-				POS	S/W	PWR	A	B	C	-LH2-				POS	S/W	PWR	A	B	C	
L	LO2	PV	O/-	-/-	O/-			O/-	O/-	L	LH2	PV	--/X	-/-	-/X			-/X	-/X	
		PV2			O/-			O/-	O/-											
C	LO2	PV	O/-	-/-	O/-	O/-	O/-			C	LH2	PV	--/X	-/-	-/X	-/X	-/X			
		PV2			O/-	O/-	O/-													
R	LO2	PV	O/-	-/-	-/-	O/-		-/-		R	LH2	PV	--/X	-/-	-/-	-/-			-/-	
		PV2			-/-	O/-		-/-			LH2	DISC	OO--		O/-			O/-	O/-	
LO2	DISC	OO--			O/-		O/-	O/-				LATCH	--/LL		-/X			-/X	-/X	
		LATCH	--/LL		-/X		-/X	-/X		FD	RIS	-/X	-/-	X	X				X	
FD	RIS	-/X	-/-	X	X		X			IB	F/D	-/X	-/-	-/X						
IB	F/D	O/-	-/-	-/-						OB	F/D	O/-	-/-	-/-						
OB	F/D	O/-	-/-	O/-						LH2	TOP	O/-	-/-	O						
OVBD	BL	O--								BU	DMP	IB	-/X	--/--	-	-			-	
MAN	P1/P2	-/-	-	-						BU	DMP	OB	-/X	--/--	-	-			-	
POGO	1/2	O-/O-		-/-						MAN	P1/P2	-/-	-	-	-					
DUMP	SEQ	--/--								HI	PT	BL	O/-		O					
										PR	LN	VT	-/-		-					
-HELIUM-				PWR	S/W	A	B	C	-SRB-				PFS	BFS	-ET-				PFS	BFS
L	HE	A		O	O/-					AUTO	ENAB	*	-	AUTO	ENAB	*	-			
		B		O	O/-	O		O		SEP	INIT			INIT	SEQ					
INT	IN/OUT		-/-	-/-						SEP	ARM	-		SEP	ARM					
C	HE	A		O	O/-					MAN	ENAB			MAN	ENAB					
		B		O	O/-			O	O	INIT	CMD			INIT	CMD					
INT	IN/OUT		-/-	-/-						CMD/INH	/			CMD/INH	/					
R	HE	A		O	O/-					SRB		L	R	SRB	SEP		L	R		
		B		O	O/-	O	O			HPU	A	ISO	-/X	-/X	IND	A				
INT	IN/OUT		-/-	-/-						HPU	B	ISO	-/X	-/X	IND	B				
PN	HE	A/B		O/O	O/-					A/B	PCV	O/O	O/O							
L	HE	XVR		-	-/-					A/B	SCV	X/X	X/X							
BD	1/2			-/-																
ISP data server connection established																				

Figure 3.2.2-VIII – Bilevel Display



bilevel													
-LO2-						-LH2-							
L LO2 PV	POS	S/W	PWR	A	B	C	L LH2 PV	POS	S/W	PWR	A	B	C
	1/2	3/4	5/6		7/8	9/10		155-	158/159	160/16		162/163	164/165
	PV2		11/12		13/14	15/16							
C LO2 PV	17/18	19/20	21/22	23/24	25/26		C LH2 PV	166-	169/170	171/172	173/174	175/176	
	PV2		27/28	29/30	31/32								
R LO2 PV	33/34	35/36	37/38	39/40		41/42	R LH2 PV	177-	180/181	182/18	184/185		186/187
	PV2		43/44	45/46		47/48	LH2 DISC	188-89/190-91		192/19		194/19	196/19
LO2 DISC	49-50/51-52		53/54		55/56	57/58	LATCH	198-99/200-01		202/20		204/20	206/20
	LATCH	59-60/61-62	63/64		65/66	67/68	FD RIS	208/209	210/211	212	213		214
FD RIS	69/70	71/72	73	74		75	IB F/D	215/21	217/21	219/22			
IB F/D	76/77	78/79	80/81				OB F/D	221/22	223/22	225/22			
OB F/D	82/83	84/85	86/87				LH2 TOP	227/22	229/23	23			
OVBD BL	88-89/90		91		92	93	RTLS IB	232/23	294-5/296-	23	235		236
MAN P1/P2		94/95	96-97				RTLS OB	237/23	294-5/296-	23	240		241
POGO 1/2	98-99/100-101		102/103				MAN P1/P2		242/24	244-245			
DUMP SEQ	290-291 / 292-						HI PT BL	246/24		248			
							PR LN VT	249/25		251			
-HELIUM-						-SRB-			-ET-				
L HE A		PWR	S/W	A	B	C	AUTO ENAB	PFS	BFS	AUTO ENAB	PFS	BFS	
		104	105/106				SEP INIT	252	-	INIT SEQ	263	-	
B		107	108/109	110		111	SEP ARM	253	254	SEP ARM	264	265	
INT IN/	112/113	114/115		116	117		MAN ENAB	-	255	MAN ENAB	-	266	
C HE A	118	119/120					INIT CMD	256	257	INIT CMD	267	268	
	B	121	122/123		124	125	CMD/INH	258	259	CMD/INH	269	270	
INT IN/	126/127	128/129	130	131				260/26	262		271/27	273	
R HE A	132	133/134					SRB						
	B	135	136/137	138	139		HPU A ISO	274/275	276/277				
INT IN/	140/141	142/143	144		145		HPU B ISO	278/279	280/281				
PN HE A	146/147	148/149					A/B PCV	282/283	284/285				
L HE X	150	151/152					A/B SCV	286/287	288/289				
BD 1/2	153/154												

ISP data server connection established

Figure 3.2.2-IX – Bilevel Display Keymap

Table 3.2.2- III Bilevel Displays MSIDs

ID	MSID	Nomenclature	Unit	Location
1	V41X1234X	MPS E2 LO2 PREVLV (PV2) OP IND	EVENT	Downlist
2	V41X1235E	MPS E2 LO2 PREVLV (PV2) CL IND	EVENT	Downlist
3	V41S1236E	MPS E2 LO2 PREVLV (PV2) OP SW SCN	EVENT	Downlist
4	V41S1239E	MPS E2 LO2 PREVLV (PV2) CL SW SCN	EVENT	Downlist
5	V41X1233E	MPS E2 LO2 PREVLV OP PWR 1 (LV14)	EVENT	Downlist
6	V41X1232E	MPS E2 LO2 PREVLV CL PWR 1 (LV15)	EVENT	Downlist
7	V76X4136E	PCA-MPS LOX PREVLV 2 OP RPC B ON	EVENT	Downlist
8	V76X4139E	PCA-MPS LOX PREVLV 2 CL RPC B ON	EVENT	Downlist
9	V76X4137E	PCA-MPS LOX PREVLV 2 OP RPC C ON	EVENT	Downlist
10	V76X4140E	PCA-MPS LOX PREVLV 2 CL RPC C ON	EVENT	Downlist
11	V41X1245E	MPS E2 LO2 PREVLV OP PWR 2 (LV84)	EVENT	Downlist
12	V41X1244E	MPS E2 LO2 PREVLV CL PWR 2 (LV81)	EVENT	Downlist
13	V76X4043E	PCA-MPS LO2 PREVLV 2-2 OP RPC B ON	EVENT	Downlist
14	V76X4013E	PCA-MPS LO2 PREVLV 2-2 CL RPC B ON	EVENT	Downlist

Table 3.2.2- III Bilevel Displays MSIDs (continued)

15	V76X4044E	PCA-MPS LO2 PREVLV 2-2 OP RPC C ON	EVENT	Downlist
16	V76X4014E	PCA-MPS LO2 PREVLV 2-2 CL RPC C ON	EVENT	Downlist
17	V41X1134X	MPS E1 LO2 PREVLV (PV1) OP IND	EVENT	Downlist
18	V41X1135E	MPS E1 LO2 PREVLV (PV1) CL IND	EVENT	Downlist
19	V41S1136E	MPS E1 LO2 PREVLV (PV1) OP SW SCN	EVENT	Downlist
20	V41S1139E	MPS E1 LO2 PREVLV (PV1) CL SW SCN	EVENT	Downlist
21	V41X1133E	MPS E1 LO2 PREVLV OP PWR 1 (LV12)	EVENT	Downlist
22	V41X1132E	MPS E1 LO2 PREVLV CL PWR 1 (LV13)	EVENT	Downlist
23	V76X4130E	PCA-MPS LOX PREVLV 1 OP RPC A ON	EVENT	Downlist
24	V76X4133E	PCA-MPS LOX PREVLV 1 CL RPC A ON	EVENT	Downlist
25	V76X4131E	PCA-MPS LOX PREVLV 1 OP RPC B ON	EVENT	Downlist
26	V76X4134E	PCA-MPS LOX PREVLV 1 CL RPC B ON	EVENT	Downlist
27	V41X1145E	MPS E1 LO2 PREVLV OP PWR 2 (LV83)	EVENT	Downlist
28	V41X1144E	MPS E1 LO2 PREVLV CL PWR 2 (LV80)	EVENT	Downlist
29	V76X4040E	PCA-MPS LO2 PREVLV 1-2 OP RPC A ON	EVENT	Downlist
30	V76X4010E	PCA-MPS LO2 PREVLV 1-2 CL RPC A ON	EVENT	Downlist
31	V76X4041E	PCA-MPS LO2 PREVLV 1-2 OP RPC A ON	EVENT	Downlist
32	V76X4011E	PCA-MPS LO2 PREVLV 1-2 CL RPC B ON	EVENT	Downlist
33	V41X1334X	MPS E3 LO2 PREVLV (PV3) OP IND	EVENT	Downlist
34	V41X1335E	MPS E3 LO2 PREVLV (PV3) CL IND	EVENT	Downlist
35	V41S1336E	MPS E3 LO2 PREVLV (PV3) OP SW SCN	EVENT	Downlist
36	V41S1339E	MPS E3 LO2 PREVLV (PV3) CL SW SCN	EVENT	Downlist
37	V41X1333E	MPS E3 LO2 REVLV OP PWR 1 (LV16)	EVENT	Downlist
38	V41X1332E	MPS E3 LO2 PREVLV CL PWR 1 (LV17)	EVENT	Downlist
39	V76X4143E	PCA-MPS LOX PREVLV 3 OP RPC A ON	EVENT	Downlist
40	V76X4146E	PCA-MPS LOX PREVLV 3 CL RPC A ON	EVENT	Downlist
41	V76X4142E	PCA-MPS LOX PREVLV 3 OP RPC C ON	EVENT	Downlist
42	V76X4145E	PCA-MPS LOX PREVLV 3 CL RPC C ON	EVENT	Downlist
43	V41X1345E	MPS E3 LO2 PREVLV OP PWR 2 (LV85)	EVENT	Downlist
44	V41X1344E	MPS E3 LO2 PREVLV CL PWR 2 (LV82)	EVENT	Downlist
45	V76X4046E	PCA-MPS LO2 PREVLV 3-2 OP RPC A ON	EVENT	Downlist
46	V76X4016E	PCA-MPS LO2 PREVLV 3-2 CL RPC A ON	EVENT	Downlist
47	V76X4047E	PCA-MPS LO2 PREVLV 3-2 OP RPC C ON	EVENT	Downlist
48	V76X4017E	PCA-MPS LO2 REVLV 3-2 CL RPC C ON	EVENT	Downlist
49	V41X1529X	MPS LO2 17IN DISC VLV(PD1)OP IND A	EVENT	Downlist
50	V41X1545X	MPS LO2 17IN DISC VLV(PD1)OP IND B	EVENT	Downlist
51	V41X1530X	MPS LO2 17IN DISC VLV(PD1)CL IND A	EVENT	Downlist
52	V41X1534X	MPS LO2 17IN DISC VLV(PD1)CL IND B	EVENT	Downlist
53	V41X1807E	MPS LO2 17IN DISC VLV OP PWR(LV46)	EVENT	Downlist
54	V41X1806E	MPS LO2 17IN DISC VLV CL PWR(LV47)	EVENT	Downlist
55	V76X4196E	PCA-MPS LOX FEED D/V OP RPC B ON	EVENT	Downlist
56	V76X4199E	PCA-MPS LOX FEED D/V CL RPC B ON	EVENT	Downlist
57	V76X4197E	PCA-MPS LOX FEED D/V OP RPC C ON	EVENT	Downlist
58	V76X4200E	PCA-MPS LOX FEED D/V CL RPC C ON	EVENT	Downlist
59	V41X1893X	MPS LO2 17IN(PD1)LTCH UNLCKD IND A	EVENT	Downlist
60	V41X1894X	MPS LO2 17IN(PD1)LTCH UNLCKD IND B	EVENT	Downlist
61	V41X1891X	MPS LO2 17IN(PD1)LATCH LCKED IND A	EVENT	Downlist
62	V41X1892X	MPS LO2 17IN(PD1)LATCH LCKED IND B	EVENT	Downlist
63	V41X1809E	MPS LO2 17IN DISC UNLOCK PWR(LV66)	EVENT	Downlist
64	V41X1808E	MPS LO2 17IN DISC LOCK PWR(LV65)	EVENT	Downlist
65	V76X4422E	MPS LO2 FD DISC UNLOCK V RPC B ON	EVENT	Downlist

Table 3.2.2- III Bilevel Displays MSIDs (continued)

66	V76X4420E	MPS-LO2 FD DISC LOCK VLV RPC B ON	EVENT	Downlist
67	V76X4423E	MPS-LO2 FD DISC UNLOCK V RPC C ON	EVENT	Downlist
68	V76X4421E	MPS-LO2 FD DISC LOCK VLV RPC C ON	EVENT	Downlist
69	V41X1541E	MPS LO2 FDLN RLF SOV (PV7) OP IND	EVENT	Downlist
70	V41X1542E	MPS LO2 FDLN RLF SOV (PV7) CL IND	EVENT	Downlist
71	V41S1543E	MPS LO2 FDLN RLF SOV(PV7)OP SW SCN	EVENT	Downlist
72	V41S1547E	MPS LO2 FDLN RLF SOV(PV7)CL SW SCN	EVENT	Downlist
73	V41X1549E	MPS LO2 FDLN RLF SOV CL PWR (LV24)	EVENT	Downlist
74	V76X0551E	MPS-LO2 RELIEF SOV RPC A ON	EVENT	Downlist
75	V76X0553E	MPS-LO2 RELIEF SOV RPC C ON	EVENT	Downlist
76	V41X1510E	MPS LO2 INBD F/D VLV (PV10) OP IND	EVENT	Downlist
77	V41X1509X	MPS LO2 INBD F/D VLV (PV10) CL IND	EVENT	Downlist
78	V41S1511E	MPS LO2 INBD F/D (PV10) OP SW SCN	EVENT	Downlist
79	V41S1512E	MPS LO2 INBD F/D (PV10) CL SW SCN	EVENT	Downlist
80	V41X1506E	MPS LO2 INBD F/D VLV OP PWR (LV30)	EVENT	Downlist
81	V41X1505E	MPS LO2 INBD F/D VLV CL PWR (LV31)	EVENT	Downlist
82	V41X1513E	MPS LO2 OTBD F/D VLV (PV9) OP IND	EVENT	Downlist
83	V41X1514X	MPS LO2 OTBD F/D VLV (PV9) CL IND	EVENT	Downlist
84	V41S1518E	MPS LO2 OTBD F/D (PV9) OP SW SCN	EVENT	Downlist
85	V41S1515E	MPS LO2 OTBD F/D (PV9) CL SW SCN	EVENT	Downlist
86	V41X1508E	MPS LO2 OTBD F/D VLV OP PWR (LV28)	EVENT	Downlist
87	V41X1507E	MPS LO2 OTBD F/D VLV CL PWR (LV29)	EVENT	Downlist
88	V41X1587E	MPS LO2 OVBD B/V (PV19) OP IND	EVENT	Downlist
89	V41X1580X	MPS LO2 OVBD B/V (PV19) CL IND A	EVENT	Downlist
90	V41X1581X	MPS LO2 OVBD B/V (PV19) CL IND B	EVENT	Downlist
91	V41X1582E	MPS LO2 OVBD B/V CL PWR (LV76)	EVENT	Downlist
92	V76X4178E	PCA MPS POGO BLEED RPC B ON	EVENT	Downlist
93	V76X4179E	PCA MPS POGO BLEED RPC C ON	EVENT	Downlist
94	V41S1535E	MPS LO2 MANF REPRSS VLVS OP SW SCN	EVENT	Downlist
95	V41S1531E	MPS LO2 MANF REPRSS VLVS CL SW SCN	EVENT	Downlist
96	V41X1538E	MPS LO2 MANF REPRSS 1(LV40) OP PWR	EVENT	Downlist
97	V41X1539E	MPS LO2 MANF REPRSS 2(LV41) OP PWR	EVENT	Downlist
98	V41X1811X	MPS LO2 POGO RECRC 1 (PV20) OP IND	EVENT	Downlist
99	V41X1818E	MPS LO2 POGO RECRC 1 (PV20) CL IND	EVENT	Downlist
100	V41X1821X	MPS LO2 POGO RECRC 2 (PV21) OP IND	EVENT	Downlist
101	V41X1828E	MPS LO2 POGO RECRC 2 (PV21) CL IND	EVENT	Downlist
102	V41X1813E	MPS LO2 POGO RECRC 1 CL PWR (LV77)	EVENT	Downlist
103	V41X1823E	MPS LO2 POGO RECRC 2 CL PWR (LV78)	EVENT	Downlist
104	V41X1258E	MPS E2 HE ISO VLV A (LV3) OP PWR	EVENT	Downlist
105	V41S1255E	MPS E2 HE ISO VLV A(LV3) OP SW SCN	EVENT	Downlist
106	V41S1265E	MPS E2 HE ISO VLV A(LV3) CL SW SCN	EVENT	Downlist
107	V41X1259E	MPS E2 HE ISO VLV B (LV4) OP PWR	EVENT	Downlist
108	V41S1256E	MPS E2 HE ISO VLV B(LV4) OP SW SCN	EVENT	Downlist
109	V41S1266E	MPS E2 HE ISO VLV B(LV4) CL SW SCN	EVENT	Downlist
110	V76X4173E	PCA MPS ENG 2 HE VLV B RPC A ON	EVENT	Downlist
111	V76X4174E	PCA MPS ENG 2 HE VLV B RPC ON	EVENT	Downlist
112	V41X1264E	MPS E2 HE INTCN IN (LV61) OP PWR	EVENT	Downlist
113	V41X1270E	MPS E2 HE INTCN OUT (LV62) OP PWR	EVENT	Downlist
114	V41S1262E	MPS E2 HE INTCN IN(LV61) OP SW SCN	EVENT	Downlist
115	V41S1268E	MPS E2 HE INTCN OUT(LV62)OP SW SCN	EVENT	Downlist

Table 3.2.2- III Bilevel Displays MSIDs (continued)

116	V76X4155E	PCA MPS E2 HE INTCN IN/OP RPC B ON	EVENT	Downlist
117	V76X4156E	PCA MPS E2 HE INTCN IN/OP RPC C ON	EVENT	Downlist
118	V41X1158E	MPS E1 HE ISO VLV A (LV1) OP PWR	EVENT	Downlist
119	V41S1155E	MPS E1 HE ISO VLV A(LV1) OP SW SCN	EVENT	Downlist
120	V41S1165E	MPS E1 HE ISO VLV A(LV1) CL SW SCN	EVENT	Downlist
121	V41X1159E	MPS E1 HE ISO VLV B (LV2) OP PWR	EVENT	Downlist
122	V41S1156E	MPS E1 HE ISO VLV B(LV2) OP SW SCN	EVENT	Downlist
123	V41S1166E	MPS E1 HE ISO VLV B(LV2) CL SW SCN	EVENT	Downlist
124	V76X4171E	PCA MPS ENG 1 HE VLV B RPC B ON	EVENT	Downlist
125	V76X4172E	PCA MPS ENG 1 HE VLV B RPC C ON	EVENT	Downlist
126	V41X1164E	MPS E1 HE INTCN IN (LV59) OP PWR	EVENT	Downlist
127	V41X1170E	MPS E1 HE INTCN OUT (LV60) OP PWR	EVENT	Downlist
128	V41S1162E	MPS E1 HE INTCN IN(LV59) OP SW SCN	EVENT	Downlist
129	V41S1168E	MPS E1 HE INTCN OUT(LV60)OP SW SCN	EVENT	Downlist
130	V76X4151E	PCA MPS E1 HE INTCN IN/OP RPC A ON	EVENT	Downlist
131	V76X4152E	PCA MPS E1 HE INTCN IN/OP RPC B ON	EVENT	Downlist
132	V41X1358E	MPS E3 HE ISO VLV A (LV5) OP PWR	EVENT	Downlist
133	V41S1355E	MPS E3 HE ISO VLV A(LV5) OP SW SCN	EVENT	Downlist
134	V41S1365E	MPS E3 HE ISO VLV A(LV5) CL SW SCN	EVENT	Downlist
135	V41X1359E	MPS E3 HE ISO VLV B (LV6) OP PWR	EVENT	Downlist
136	V41S1356E	MPS E3 HE ISO VLV B(LV6) OP SW SCN	EVENT	Downlist
137	V41S1366E	MPS E3 HE ISO VLV B(LV6) CL SW SCN	EVENT	Downlist
138	V76X4175E	PCA MPS ENG 3 HE VLV B RPC A ON	EVENT	Downlist
139	V76X4176E	PCA MPS ENG 3 HE VLV B RPC B ON	EVENT	Downlist
140	V41X1364E	MPS E3 HE INTCN IN (LV63) OP PWR	EVENT	Downlist
141	V41X1370E	MPS E3 HE INTCN OUT (LV64) OP PWR	EVENT	Downlist
142	V41S1362E	MPS E3 HE INTCN IN(LV63) OP SW SCN	EVENT	Downlist
143	V41S1368E	MPS E3 HE INTCN OUT(LV64)OP SW SCN	EVENT	Downlist
144	V76X4159E	PCA MPS E3 HE INTCN IN/OP RPC A ON	EVENT	Downlist
145	V76X4158E	PCA MPS E3 HE INTCN IN/OP RPC ON	EVENT	Downlist
146	V41X1645E	MPS PNEU HE ISO VLV 1 (LV7) OP PWR	EVENT	Downlist
147	V41X1646E	MPS PNEU HE ISO VLV 2 (LV8) OP PWR	EVENT	Downlist
148	V41S1607E	MPS PNEU HE ISO VLVS OP SW SCN	EVENT	Downlist
149	V41S1609E	MPS PNEU HE ISO VLVS CL SW SCN	EVENT	Downlist
150	V41X1614E	MPS REG HE XOVER VLV (LV10) OP PWR	EVENT	Downlist
151	V41S1613E	MPS REG HE XOVR VLV(LV10)OP SW SCN	EVENT	Downlist
152	V41S1619E	MPS REG HE XOVR VLV(LV10)CL SW SCN	EVENT	Downlist
153	V41X1632E	MPS HE SPLY BLWDWN 1 (LV26) OP PWR	EVENT	Downlist
154	V41X1634E	MPS HE SPLY BLWDWN 2 (LV27) OP PWR	EVENT	Downlist
155	V41X1204X	MPS E2 LH2 PREVLV (PV5) OP IND A	EVENT	Downlist
156	V41X1206X	MPS E2 LH2 PREVLV (PV5) OP IND B	EVENT	Downlist
157	V41X1205E	MPS E2 LH2 PREVLV (PV5) CL IND	EVENT	Downlist
158	V41S1219E	MPS E2 LH2 PREVLV (PV5) OP SW SCN	EVENT	Downlist
159	V41S1222E	MPS E2 LH2 PREVLV (PV5) CL SW SCN	EVENT	Downlist
160	V41X1203E	MPS E2 LH2 PREVLV OP PWR (LV20)	EVENT	Downlist
161	V41X1202E	MPS E2 LH2 PREVLV CL PWR (LV21)	EVENT	Downlist
162	V76X4116E	PCA-MPS LH2 PREVLV 2 OP RPC B ON	EVENT	Downlist
163	V76X4119E	PCA-MPS LH2 PREVLV 2 CL RPC B ON	EVENT	Downlist
164	V76X4117E	PCA-MPS LH2 PREVLV 2 OP RPC C ON	EVENT	Downlist
165	V76X4120E	PCA-MPS LH2 PREVLV 2 CL RPC C ON	EVENT	Downlist
166	V41X1104X	MPS E1 LH2 PREVLV (PV4) OP IND A	EVENT	Downlist

Table 3.2.2- III Bilevel Displays MSIDs (continued)

167	V41X1106X	MPS E1 LH2 PREVLV (PV4) OP IND B	EVENT	Downlist
168	V41X1105E	MPS E1 LH2 PREVLV (PV4) CL IND	EVENT	Downlist
169	V41S1119E	MPS E1 LH2 PREVLV (PV4) OP SW SCN	EVENT	Downlist
170	V41S1122E	MPS E1 LH2 PREVLV (PV4) CL SW SCN	EVENT	Downlist
171	V41X1103E	MPS E1 LH2 PREVLV OP PWR (LV18)	EVENT	Downlist
172	V41X1102E	MPS E1 LH2 PREVLV CL PWR (LV19)	EVENT	Downlist
173	V76X4110E	PCA-MPS LH2 PREVLV 1 OP RPC A ON	EVENT	Downlist
174	V76X4113E	PCA-MPS LH2 PREVLV 1 CL RPC A ON	EVENT	Downlist
175	V76X4111E	PCA-MPS LH2 PREVLV 1 OP RPC B ON	EVENT	Downlist
176	V76X4114E	PCA-MPS LH2 PREVLV 1 CL RPC B ON	EVENT	Downlist
177	V41X1304X	MPS E3 LH2 PREVLV (PV6) OP IND A	EVENT	Downlist
178	V41X1306X	MPS E3 LH2 PREVLV (PV6) OP IND B	EVENT	Downlist
179	V41X1305E	MPS E3 LH2 PREVLV (PV6) CL IND	EVENT	Downlist
180	V41S1319E	MPS E3 LH2 PREVLV (PV6) OP SW SCN	EVENT	Downlist
181	V41S1322E	MPS E3 LH2 PREVLV (PV6) CL SW SCN	EVENT	Downlist
182	V41X1303E	MPS E3 LH2 PREVLV OP PWR (LV22)	EVENT	Downlist
183	V41X1302E	MPS E3 LH2 PREVLV CL PWR (LV23)	EVENT	Downlist
184	V76X4123E	PCA-MPS LH2 PREVLV 3 OP RPC A ON	EVENT	Downlist
185	V76X4126E	PCA-MPS LH2 PREVLV 3 CL RPC A ON	EVENT	Downlist
186	V76X4122E	PCA-MPS LH2 PREVLV 3 OP RPC C ON	EVENT	Downlist
187	V76X4125E	PCA-MPS LH2 PREVLV 3 CL RPC C ON	EVENT	Downlist
188	V41X1429X	MPS LH2 17IN DISC VLV(PD2)OP IND A	EVENT	Downlist
189	V41X1445X	MPS LH2 17IN DISC VLV(PD2)OP IND B	EVENT	Downlist
190	V41X1430X	MPS LH2 17IN DISC VLV(PD2)CL IND A	EVENT	Downlist
191	V41X1434X	MPS LH2 17IN DISC VLV(PD2)CL IND B	EVENT	Downlist
192	V41X1382E	MPS LH2 17IN DISC VLV OP PWR(LV48)	EVENT	Downlist
193	V41X1381E	MPS LH2 17IN DISC VLV CL PWR(LV49)	EVENT	Downlist
194	V76X4186E	PCA-MPS LH2 FEED D/V OP RPC B ON	EVENT	Downlist
195	V76X4189E	PCA-MPS LH2 FEED D/V CL RPC B ON	EVENT	Downlist
196	V76X4187E	PCA-MPS LH2 FEED D/V OP RPC C ON	EVENT	Downlist
197	V76X4190E	PCA-MPS LH2 FEED D/V CL RPC C ON	EVENT	Downlist
198	V41X1993X	MPS LH2 17IN(PD2)LTCH UNLCKD IND A	EVENT	Downlist
199	V41X1994X	MPS LH2 17IN(PD2)LTCH UNLCKD IND B	EVENT	Downlist
200	V41X1991X	MPS LH2 17IN(PD2)LATCH LCKED IND A	EVENT	Downlist
201	V41X1992X	MPS LH2 17IN(PD2)LATCH LCKED IND B	EVENT	Downlist
202	V41X1384E	MPS LH2 17IN DISC UNLOCK PWR(LV68)	EVENT	Downlist
203	V41X1383E	MPS LH2 17IN DISC LOCK PWR(LV67)	EVENT	Downlist
204	V76X4432E	MPS-LH2 FD DISC UNLOCK V RPC B ON	EVENT	Downlist
205	V76X4430E	MPS-LH2 FD DISC LOCK VLV RPC B ON	EVENT	Downlist
206	V76X4433E	MPS-LH2 FD DISC UNLOCK V RPC C ON	EVENT	Downlist
207	V76X4431E	MPS-LH2 FD DISC LOCK VLV RPC C ON	EVENT	Downlist
208	V41X1441E	MPS LH2 FDLN RLF SOV (PV8) OP IND	EVENT	Downlist
209	V41X1442E	MPS LH2 FDLN RLF SOV (PV8) CL IND	EVENT	Downlist
210	V41S1443E	MPS LH2 FDLN RLF SOV(PV8)OP SW SCN	EVENT	Downlist
211	V41S1447E	MPS LH2 FDLN RLF SOV(PV8)CL SW SCN	EVENT	Downlist
212	V41X1449E	MPS LH2 FDLN RLF SOV CL PWR (LV25)	EVENT	Downlist
213	V76X0501E	MPS-LH2 RELIEF SOV RPC A ON	EVENT	Downlist
214	V76X0503E	MPS-LH2 RELIEF SOV RPC C ON	EVENT	Downlist
215	V41X1409E	MPS LH2 INBD F/D VLV (PV12) OP IND	EVENT	Downlist
216	V41X1410X	MPS LH2 INBD F/D VLV (PV12) CL IND	EVENT	Downlist
217	V41S1401E	MPS LH2 INBD F/D (PV12) OP SW SCN	EVENT	Downlist

Table 3.2.2- III Bilevel Displays MSIDs (continued)

218	V41S1412E	MPS LH2 INBD F/D (PV12) CL SW SCN	EVENT	Downlist
219	V41X1406E	MPS LH2 INBD F/D VLV OP PWR (LV34)	EVENT	Downlist
220	V41X1405E	MPS LH2 INBD F/D VLV CL PWR (LV35)	EVENT	Downlist
221	V41X1388E	MPS LH2 OTBD F/D VLV (PV11) OP IND	EVENT	Downlist
222	V41X1389X	MPS LH2 OTBD F/D VLV (PV11) CL IND	EVENT	Downlist
223	V41S1391E	MPS LH2 OTBD F/D (PV11) OP SW SCN	EVENT	Downlist
224	V41S1393E	MPS LH2 OTBD F/D (PV11) CL SW SCN	EVENT	Downlist
225	V41X1386E	MPS LH2 OTBD F/D VLV OP PWR (LV32)	EVENT	Downlist
226	V41X1385E	MPS LH2 OTBD F/D VLV CL PWR (LV33)	EVENT	Downlist
227	V41X1453E	MPS LH2 TOPPING VLV (PV13) OP IND	EVENT	Downlist
228	V41X1456X	MPS LH2 TOPPING VLV (PV13) CL IND	EVENT	Downlist
229	V41S1401E	MPS LH2 INBD F/D (PV12) OP SW SCN	EVENT	Downlist
230	V41S1412E	MPS LH2 INBD F/D (PV12) CL SW SCN	EVENT	Downlist
231	V41X1458E	MPS LH2 TOPPING VLV OP PWR (LV39)	EVENT	Downlist
232	V41X1927E	MPS LH2 RTLS INBD DV (PV17) OP IND	EVENT	Downlist
233	V41X1929X	MPS LH2 RTLS INBD DV (PV17) CL IND	EVENT	Downlist
234	V41X1921E	MPS LH2 RTLS INBD DV OP PWR (LV72)	EVENT	Downlist
235	V76X4161E	PCA MPS INBD RTLS DUMP RPC A ON	EVENT	Downlist
236	V76X4163E	PCA MPS INBD RTLS DUMP RPC C ON	EVENT	Downlist
237	V41X1917E	MPS LH2 RTLS OTBD DV (PV18) OP IND	EVENT	Downlist
238	V41X1919X	MPS LH2 RTLS OTBDDV (PV18) CL IND	EVENT	Downlist
239	V41X1911E	MPS LH2 RTLS OTBD DV OP PWR (LV73)	EVENT	Downlist
240	V76X4162E	PCA MPS OTBD RTLS DUMP RPC A ON	EVENT	Downlist
241	V76X4164E	PCA MPS OTBD RTLS DUMP RPC C ON	EVENT	Downlist
242	V41S1435E	MPS LH2 MANF REPRSS VLVS OP SW SCN	EVENT	Downlist
243	V41S1431E	MPS LH2 MANF REPRSS VLVS CL SW SCN	EVENT	Downlist
244	V41X1436E	MPS LH2 MANF REPRSS 1(LV42) OP PWR	EVENT	Downlist
245	V41X1438E	MPS LH2 MANF REPRSS 2(LV43) OP PWR	EVENT	Downlist
246	V41X1468E	MPS LH2 HI PT BL VLV (PV22) OP IND	EVENT	Downlist
247	V41X1469E	MPS LH2 HI PT BL VLV (PV22) CL IND	EVENT	Downlist
248	V41X1467E	MPS LH2 HI PT BL VLV OP PWR (LV79)	EVENT	Downlist
249	V41S1493E	MPS GH2 PR LN VENT(LV52) OP SW SCN	EVENT	Downlist
250	V41S1494E	MPS GH2 PR LN VENT(LV52) CL SW SCN	EVENT	Downlist
251	V41X1492E	MPS GH2 PRESS LN VENT(LV52) OP PWR	EVENT	Downlist
252	V90X7570X	SEL SRB SEPARATION AUTO CMD	EVENT	Downlist
253	V90X8333X	SRB SEPARATION INITIATION FLAG	EVENT	Downlist
254	V98X3532X	AS26 SRB SEP INIT BFS	EVENT	Downlist
255	V98X0744X	SRB SEPARATION ARM COMMAND BFS	EVENT	Downlist
256	V90X7571X	SEL SRB SEPN MNL/AUTO ENABLE CMD	EVENT	Downlist
257	V98X0742X	SRB SEP MAN/AUTO ENABLE A OR B BFS	EVENT	Downlist
258	V90X7572X	SEL SRB SEP INITIATE/WOW-WONG CMD	EVENT	Downlist
259	V98X0743X	SRB SEP INITIATE CMD A OR B BFS	EVENT	Downlist
260	V90X8331X	SRB SEPARATION COMMAND FLAG	EVENT	Downlist
261	V90X8340X	SRB AUTO SEP INHIBIT CREW ALERT	EVENT	Downlist
262	V98X3534X	AS28 SRB SEP CMD BFS	EVENT	Downlist
263	V90X7554X	SEL ET SEP AUTO	EVENT	Downlist
264	V90X8561X	MECO CONFIRMED FLAG	EVENT	Downlist
265	V98X3546X	AS33 MECO CONFIRMED BFS	EVENT	Downlist
266	V98X0752X	ET/ORB STR SEPARATION ARM BFS	EVENT	Downlist
267	V90X7556X	SEL ET SEP MNL ENABLE	EVENT	Downlist
268	V98X0748X	ET SEP MAN ENABLE A OR B BFS	EVENT	Downlist

Table 3.2.2 – III – MSIDs used on Bilevel Display (concluded)

269	V90X7564X	SEL ET SEP INITIATE/WOW-WONG CMD	EVENT	Downlist
270	V98X0749X	ET SEP INITIATE CMD A OR B BFS	EVENT	Downlist
271	V90X8250X	ET SEPARATION CMD FLAG	EVENT	Downlist
272	V90X8259X	ET AUTO SEP INHIBIT CREW ALERT	EVENT	Downlist
273	V98X3550X	AS34 ET SEP CMD BFS	EVENT	Downlist
274	B46X1851X	LH EVENT APU A ISLN VALVE OPEN	EVENT	Downlist
275	B46X1853X	LH EVENT APU A ISLN VALVE CLOSED	EVENT	Downlist
276	B46X2851X	RH EVENT APU A ISLN VALVE OPEN	EVENT	Downlist
277	B46X2853X	RH EVENT APU A ISLN VALVE CLOSED	EVENT	Downlist
278	B46X1852X	LH EVENT APU B ISLN VALVE OPEN	EVENT	Downlist
279	B46X1854X	LH EVENT APU B ISLN VALVE CLOSED	EVENT	Downlist
280	B46X2852X	RH EVENT APU B ISLN VALVE OPEN	EVENT	Downlist
281	B46X2854X	RH EVENT APU B ISLN VALVE CLOSED	EVENT	Downlist
282	B46X1862X	LH EV APU PRI SP CON VLV OP, SYS A	EVENT	Downlist
283	B46X1864X	LH EV APU PRI SP CON VLV OP, SYS B	EVENT	Downlist
284	B46X2862X	RH EV APU PRI SP CON VLV OP, SYS A	EVENT	Downlist
285	B46X2864X	RH EV APU PRI SP CON VLV OP, SYS B	EVENT	Downlist
286	B46X1861X	LH EV APU SEC SP CON VLV CLD, SYS A	EVENT	Downlist
287	B46X1863X	LH EV APU SEC SP CON VLV CLD, SYS B	EVENT	Downlist
288	B46X2861X	RH EV APU SEC SP CON VLV CLD, SYS A	EVENT	Downlist
289	B46X2863X	RH EV APU SEC SP CON VLV CLD, SYS B	EVENT	Downlist
290	V72K0081X	MPS PRPLT DUMP SEQUENCE START A	EVENT	Downlist
291	V72K0083X	MPS PRPLT DUMP SEQUENCE START B	EVENT	Downlist
292	V72K0082X	MPS PRPLT DUMP SEQUENCE STOP A	EVENT	Downlist
293	V72K0084X	MPS PRPLT DUMP SEQUENCE STOP B	EVENT	Downlist
294	V72K0085X	MPS PRPLT DUMP BU LH2 VLV OP A	EVENT	Downlist
295	V72K0086X	MPS PRPLT DUMP BU LH2 VLV OP B	EVENT	Downlist
296	V72K0087X	MPS PRPLT DUMP BU LH2 VLV CL A	EVENT	Downlist
297	V72K0088X	MPS PRPLT DUMP BU LH2 VLV CL B	EVENT	Downlist

entry													
-LO2-	POS	S/W	PWR	A	B	C	-LH2-	POS	S/W	PWR	A	B	C
L LO2 PV	O/-	-/-	O/-		O/-	O/-	L LH2 PV	--/X	-/-	-/X		-/X	-/X
	PV2		O/-		O/-	O/-							
C LO2 PV	O/-	-/-	O/-	O/-	O/-		C LH2 PV	--/X	-/-	-/X	-/X	-/X	
	PV2		O/-	O/-	O/-								
R LO2 PV	O/-	-/-	-/O/-		-/-		R LH2 PV	--/X	-/-	-/-	-/-		-/-
	PV2		-/O/-		-/-		LH2 DISC	OO--		O/-		O/-	O/-
LO2 DISC	OO--		O/-		O/-	O/-	LATCH	--/**		-/X		-/X	-/X
	LATCH	--/**	-/X		-/X	-/X	FD RIS	-/X	-/-	X	X		X
FD RIS	-/X	-/-	X	X		X	IB F/D	-/X	-/-	-/X			
IB F/D	-/X	-/-	-/X				OB F/D	O/-	-/-	-/-			
OB F/D	O/-	-/-	O/-				LH2 TOP	O/-	-/-	O			
OVBD BL	O--				-	-	BU DMP IB	-/X	--/--	-	-		-
MAN P1/P2		-/-	-				BU DMP OB	-/X	--/--	-	-		-
POGO 1/2	O-/O-		-/-				MAN P1/P2		-/-	-	-		
							HI PT BL	O/-		O			
DUMP SEQ		--/--					PR LN VT		-/-	-			
-HELIUM-		PWR	S/W	A	B	C			L	C	R	P	
L HE A		O	O/-				HE TK P		4175	4244	4252	4419	
B		O	O/-	O		O	HE REG AP		758	764	769	764	
INT IN/OUT		-/-	-/-		-	-	HE REG/PNA P		759	766	767	772	
L HE XVR		-	-/-				TK DEC RT		0.000	0.000	0.000	0.000	
C HE A		O	O/-			O	AFT HE TK T		40	35	38	38	
B		O	O/-		O	O	MID HE TK T		105	105	105		
INT IN/OUT		-/-	-/-	-	-		MASS		66.5	67.6	67.6	13.6	
R HE A		O	O/-				MASS TOTAL			215.45			
B		O	O/-	O	O		LH2 INLET/MAN		24	25	22	18	
INT IN/OUT		-/-	-/-	-		-	LH2/LO2 DSC P		12		12		
PN HE A/B		O/O	O/-				LO2 INLET/MAN		105	103	108	104	
BD 1/2		-/-					VENT DOORS		LEFT	1	-	RIGHT	1
									2	-	-		2

Figure 3.2.2-X – Entry Display



bfs_mps_ascent.new												
HE TANK P	L	3980		C	3970		R	3990		P	4350	
INTERCONNECTS		---- / ----			---- / ----			---- / ----			-----	
ISO A/B OP PWR		o/-	o/-		o/-	o/-		o/-	o/-		o/-	o/-
REG A/B P		751	751		747	747		750	753		755	
HPOT IMSL P											Accum P	760
BFS DP/DT		10			10			10				
COMP Mdot		0.038			0.039			0.038			0.000	
LkType/Intcnct		/ N			/ N			/ N				
Recomnded SHDN		NOMINAL			NOMINAL			NOMINAL				
ZG TOD/SHDN P		16:13	1288		15:27	1288		16:24	1288		00:00	2800
PN TOD/SHDN P		17:44	1085		16:54	1085		17:54	1085		00:00	2036
HYD TOD/SHDN P		21:15	659		20:16	659		21:25	659		00:00	639
MID/AFT TK T		98 / 35			98 / 30			98 / 33			-/ 38	TOT HE M
HE MASS		64.50			64.10			65.03			13.41	207.03
PWR LVL	104	105			105			105			LO2	LH2
FCV		-LO2- VENT X			HIFL - -LH2- VENT -/X						PV OP O	
GH2 OUT P		o	o	o		o		-	-		PV CL X	---
DISCONNECT P		372			3080			3220			FD DSC	
ULLAGE P		21.0			300			33.0			FD LTCH	
NPSP											RLF ISO	-X
MANIFOLD P		124			33						IB F/D	-
INLET P											OB F/D	-
IN T/LPFT P											OVV/TOP	-
PROP REM		5 CO			5 CO						R DSC X	-
-SRB-		LEFT			RIGHT						P LN V O	-
IGN S&A		/			/						POGO1/2	--
PC 1											BU DMP IB/OB	- /-
PC MID		608			608			M			MN P120	--
PC 3											RTLS RPRSS12	--
FSM P RCK/TLT		/			/						BLOWDOWNS	-
TRBSPD RCK/TLT		/			/							
HYD P RCK/TLT		/			/							
PRI P RCK/TLT		/			/							
								SWITCH			PB	CMD
								-SRB-		/---	---	----
								-ET-		/---	---	----
								THROT		/	MEC1/2 ON /ON	

ISP data server connection established

Figure 3.2.2-XI – BFS MPS ASCENT

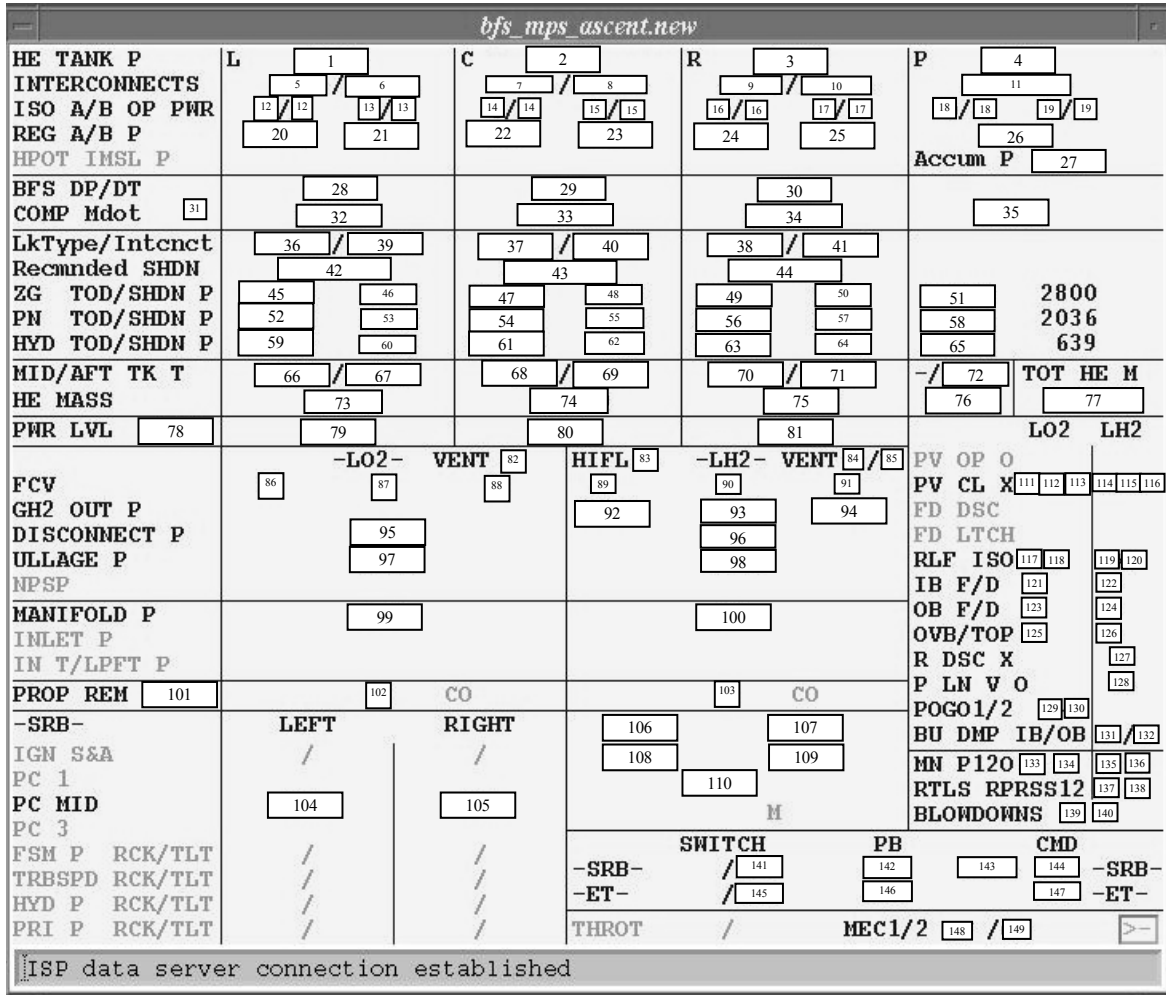


Figure 3.2.2-XII – Keymap for BFS MPS ASCENT

Table 3.2.2-IV – MSIDs used for BFS MPS ASCENT

	MSID	Parameter Name	Units	Source
1	V98P2156C	L HELIUM SUPPLY PRESSURE BFS	Psia	Downlist
2	V98P2155C	C HELIUM SUPPLY PRESSURE BFS	Psia	Downlist
3	V98P2157C	R HELIUM SUPPLY PRESSURE BFS	Psia	Downlist
4	V41P1600A	MPS PNEU VLVS HE SUP BOTTLE PRESS	Psia	Downlist
5	V41X1264E	MPS E2 HE INTCN IN (LV61) OP PWR	Event	Downlist
6	V41X1270E	MPS E2 HE INTCN OUT (LV62) OP PWR	Event	Downlist
7	V41X1164E	MPS E1 HE INTCN IN (LV59) OP PWR	Event	Downlist
8	V41X1170E	MPS E1 HE INTCN OUT (LV60) OP PWR	Event	Downlist
9	V41X1364E	MPS E3 HE INTCN IN (LV63) OP PWR	Event	Downlist
10	V41X1370E	MPS E3 HE INTCN OUT (LV64) OP PWR	Event	Downlist
11	V41X1614E	MPS REG HE XOVER VLV (LV10) OP PWR	Event	Downlist
12	V41X1258E	MPS E2 HE ISO VLV A (LV3) OP PWR	Event	Downlist
13	V41X1259E	MPS E2 HE ISO VLV B (LV4) OP PWR	Event	Downlist
14	V41X1158E	MPS E1 HE ISO VLV A (LV1) OP PWR	Event	Downlist
15	V41X1159E	MPS E1 HE ISO VLV B (LV2) OP PWR	Event	Downlist
16	V41X1358E	MPS E3 HE ISO VLV A (LV5) OP PWR	Event	Downlist
17	V41X1359E	MPS E3 HE ISO VLV B (LV6) OP PWR	Event	Downlist
18	V41X1645E	MPS PNEU HE ISO VLV 1 (LV7) OP PWR	Event	Downlist
19	V41X1646E	MPS PNEU HE ISO VLV 2 (LV8) OP PWR	Event	Downlist
20	V41P1254A	MPS E2 REG A HE OUTLET PRESS	Psia	Downlist
21	V41P1253A	MPS E2 REG B HE OUTLET PRESS	Psia	Downlist
22	V41P1154A	MPS E1 REG A HE OUTLET PRESS	Psia	Downlist
23	V41P1153A	MPS E1 REG B HE OUTLET PRESS	Psia	Downlist
24	V41P1354A	MPS E3 REG A HE OUTLET PRESS	Psia	Downlist
25	V41P1353A	MPS E3 REG B HE OUTLET PRESS	Psia	Downlist
26	V41P1605A	MPS PNEU VLVS REG HE OUTLET PRESS	Psia	Downlist
27	V41P1650A	MPS PNEU ACCUMULATOR PRESSURE	Psia	Downlist
28	V98P4998C	SSME HE TK PRESS 2 CHG RATE BFS	Psia/s	Downlist
29	V98P4997C	SSME HE TK PRESS 1 CHG RATE BFS	Psia/s	Downlist
30	V98P4999C	SSME HE TK PRESS 3 CHG RATE BFS	Psia/s	Downlist
31	helium_MDOT_GOOD	Mdot comp initialized	N/A	He Comp
32	helium_DM_DT2	Eng 2 He Mass Flow Rate	Lbm/Sec	He Comp
33	helium_DM_DT1	Eng 1 He Mass Flow Rate	Lbm/Sec	He Comp
34	helium_DM_DT3	Eng 3 He Mass Flow Rate	Lbm/Sec	He Comp
35	helium_DM_DT4	Pneu He Mass Flow Rate	Lbm/Sec	He Comp
36	helium_LK_CONFRM2	Eng 2 Leak Type	“Upper, Lower, Single Reg”	He Comp
37	helium_LK_CONFRM1	Eng 1 Leak Type		He Comp
38	helium_LK_CONFRM3	Eng 3 Leak Type		He Comp
39	helium_INCONFLG2	Eng 2 He Interconnect Status	“None, Pneumatic All”	He Comp
40	helium_INCONFLG1	Eng 1 He Interconnect Status		He Comp
41	helium_INCONFLG3	Eng 3 He Interconnect Status		He Comp
42	helium_RECD_SD_MODE2	Eng 2 Recommended Shut Down Mode	“Zero-G, Velocity, Redline”	He Comp
43	helium_RECD_SD_MODE1	Eng 1 Recommended Shut Down Mode		He Comp
44	helium_RECD_SD_MODE3	Eng 3 Recommended Shut Down Mode		He Comp

Table 3.2.2-IV – MSIDs used for BFS MPS ASCENT (continued)

	MSID	Parameter Name	Units	Source
45	helium TOD_ZG2_CUR	Eng 2 Zero-G Shut Down Time of Depletion	mm:ss	He Comp
46	helium P_ZERO2	Eng 2 Zero-G Shut Down Pressure	Psia	He Comp
47	helium TOD_ZG1_CUR	Eng 1 Zero-G Shut Down Time of Depletion	mm:ss	He Comp
48	helium P_ZERO1	Eng 1 Zero-G Shut Down Pressure	Psia	He Comp
49	helium TOD_ZG3_CUR	Eng 3 Zero-G Shut Down Time of Depletion	mm:ss	He Comp
50	helium P_ZERO3	Eng 3 Zero-G Shut Down Pressure	Psia	He Comp
51	helium TOD_ZG4_CUR	PnTk Zero-G Shut Down Time of Depletion	mm:ss	He Comp
52	helium TOD_PNEU2_CUR	Eng 2 Pneu Shut Down Time of Depletion	mm:ss	He Comp
53	helium P_PNEU2	Eng 2 Pneu Shut Down Pressure	Psia	He Comp
54	helium TOD_PNEU1_CUR	Eng 1 Pneu Shut Down Time of Depletion	mm:ss	He Comp
55	helium P_PNEU1	Eng 1 Pneu Shut Down Pressure	Psia	He Comp
56	helium TOD_PNEU3_CUR	Eng 3 Pneu Shut Down Time of Depletion	mm:ss	He Comp
57	helium P_PNEU3	Eng 3 Pneu Shut Down Pressure	Psia	He Comp
58	helium TOD_PNEU4_CUR	PnTk Pneu Shut Down Time of Depletion	mm:ss	He Comp
59	helium TOD_HYD2_CUR	Eng 2 Hyd Shut Down Time of Depletion	mm:ss	He Comp
60	helium P_HYD2	Eng 2 Hyd Shut Down Pressure	Psia	He Comp
61	helium TOD_HYD1_CUR	Eng 1 Hyd Shut Down Time of Depletion	mm:ss	He Comp
62	helium P_HYD1	Eng 1 Hyd Shut Down Pressure	Psia	He Comp
63	helium TOD_HYD3_CUR	Eng 3 Hyd Shut Down Time of Depletion	mm:ss	He Comp
64	helium P_HYD3	Eng 3 Hyd Shut Down Pressure	Psia	He Comp
65	helium TOD_HYD4_CUR	PnTk Hyd Shut Down Time of Depletion	mm:ss	He Comp
66	V41T1252A	MPS E2 MID FUSELAGE HE SUPPLY TEMP	DegF	Downlist
67	V41T1251A	MPS E2 AFT FUSELAGE HE SUPPLY TEMP	DegF	Downlist
68	V41T1152A	MPS E1 MID FUSELAGE HE SUPPLY TEMP	DegF	Downlist
69	V41T1151A	MPS E1 AFT FUSELAGE HE SUPPLY TEMP	DegF	Downlist
70	V41T1352A	MPS E3 MID FUSELAGE HE SUPPLY TEMP	DegF	Downlist
71	V41T1351A	MPS E3 AFT FUSELAGE HE SUPPLY TEMP	DegF	Downlist
72	V41T1601A	MPS PNEU VLVS HE SUP BOTTLE TEMP	DegF	Downlist
73	mass MASS_TOT2	Eng 2 Helium Mass	Lbm	Mass Comp
74	mass MASS_TOT1	Eng 1 Helium Mass	Lbm	Mass Comp
75	mass MASS_TOT3	Eng 3 Helium Mass	Lbm	Mass Comp
76	mass MASS_TOT4	PnTk Helium Mass	Lbm	Mass Comp
77	mass MASS_ALL	Total Helium Mass	Lbm	Mass Comp
78	V98U2001C	CMD THROTTLE BFS	Pct	Downlist
79	V98P2110C	L ENGINE PC BFS	Pct	Downlist
80	V98P2100C	C ENGINE PC BFS	Pct	Downlist
81	V98P2120C	R ENGINE PC BFS	Pct	Downlist
82	T41X1774E	ET-LO2 VENT VLV NO 1 CLOSED IND	Event	Downlist
83	V41S1477E	MPS LH2 ULL PRESS HI FLOW SW SCN	Event	Downlist
84	T41X1727E	ET-LH2 VENT VLV NO 1 OPEN IND	Event	Downlist
85	T41X1724E	ET-LH2 VENT VLV NO 1 CLOSED IND	Event	Downlist
86	V41X1598E	MPS GO2 PRESS FCV 2 (LV54) CL PWR	Event	Downlist
87	V41X1596E	MPS GO2 PRESS FCV 1 (LV53) CL PWR	Event	Downlist
88	V41X1603E	MPS GO2 PRESS FCV 3 (LV55) CL PWR	Event	Downlist
89	V41X1662E	MPS GH2 PRESS FCV 2 (LV57) CL PWR	Event	Downlist
90	V41X1661E	MPS GH2 PRESS FCV 1 (LV56) CL PWR	Event	Downlist
91	V41X1663E	MPS GH2 PRESS FCV 3 (LV58) CL PWR	Event	Downlist
92	V41P1260A	MPS E2 GH2 PRESS OUTLET PRESS	Psia	Downlist
93	V41P1160A	MPS E1 GH2 PRESS OUTLET PRESS	Psia	Downlist

Table 3.2.2-IV – MSIDs used for BFS MPS ASCENT (continued)

	MSID	Parameter Name	Units	Source
94	V41P1360A	MPS E3 GH2 PRESS OUTLET PRESS	Psia	Downlist
95	V41P1590A	MPS GO2 PRESSURIZATION DISC PRESS	Psia	Downlist
96	V41P1490A	MPS GH2 PRESSURIZATION DISC PRESS	Psia	Downlist
97	V98P2130C	ET-LO2 ULLAGE PRESSURE NO 1 BFS	Psig	Downlist
98	V98P2140C	LH2 ULLAGE PRESS BFS	Psia	Downlist
99	V98P1389C	LO2 ENG MANIFOLD PRESSURE BFS	Psia	Downlist
100	V98P1388C	LH2 ENG MANIFOLD PRESSURE BFS	Psia	Downlist
101	V98X3537X	AS30 MPS LOW MONITOR BFS	Event	Downlist
102	T41X1762E	ET-LO2 5 PCT LIQ LEVEL SENSOR	Event	Downlist
103	T41X1712E	ET-LH2 5 PCT LIQUID LVL SNSR	Event	Downlist
104	V98P1740C	L SRB CHAMBER PRESS BFS	Psi	Downlist
105	V98P1741C	R SRB CHAMBER PRESS BFS	Psi	Downlist
106	MECO_AT_ARM	MECO At The Arming Mass	Event	Booster Publishing CRANS
107	LL_PROT_LOSS	Low Level Protection Lost	Event	
108	MULT_DATA_NO2	Multi Data Path Without A 2	Event	
109	lgt_DUMP_SW	Bad Dump Switch due to Control Bus	Event	Lgt
110	V98X3546X	AS33 MECO CONFIRMED BFS	Event	Downlist
	V98X3689X	AB36 MECO CONFIRMED BFS	Event	Downlist
	V90X8561X	MECO CONFIRMED FLAG	Event	Downlist
111	V41X1235E	MPS E2 LO2 PREVLV (PV2) CL IND	Event	Downlist
112	V41X1135E	MPS E1 LO2 PREVLV (PV1) CL IND	Event	Downlist
113	V41X1335E	MPS E3 LO2 PREVLV (PV3) CL IND	Event	Downlist
114	V41X1205E	MPS E2 LH2 PREVLV (PV5) CL IND	Event	Downlist
115	V41X1105E	MPS E1 LH2 PREVLV (PV4) CL IND	Event	Downlist
116	V41X1305E	MPS E3 LH2 PREVLV (PV6) CL IND	Event	Downlist
117	V41X1541E	MPS LO2 FDLN RLF SOV (PV7) OP IND	Event	Downlist
118	V41X1542E	MPS LO2 FDLN RLF SOV (PV7) CL IND	Event	Downlist
119	V41X1441E	MPS LH2 FDLN RLF SOV (PV8) OP IND	Event	Downlist
120	V41X1442E	MPS LH2 FDLN RLF SOV (PV8) CL IND	Event	Downlist
121	V41X1510E	MPS LO2 INBD F/D VLV (PV10) OP IND	Event	Downlist
122	V41X1409E	MPS LH2 INBD F/D VLV (PV12) OP IND	Event	Downlist
123	V41X1513E	MPS LO2 OTBD F/D VLV (PV9) OP IND	Event	Downlist
124	V41X1388E	MPS LH2 OTBD F/D VLV (PV11) OP IND	Event	Downlist
125	V41X1587E	MPS LO2 OVBD B/V (PV19) OP IND	Event	Downlist
126	V41X1453E	MPS LH2 TOPPING VLV (PV13) OP IND	Event	Downlist
127	V41X1420E	MPS LH2 4IN DISC VLV (PD3) CL IND	Event	Downlist
128	V41X1492E	MPS GH2 PRESS LN VENT(LV52) OP PWR	Event	Downlist
129	V41X1818E	MPS LO2 POGO RECRC 1 (PV20) CL IND	Event	Downlist
130	V41X1828E	MPS LO2 POGO RECRC 2 (PV21) CL IND	Event	Downlist
131	V41X1927E	MPS LH2 RTLS INBD DV (PV17) OP IND	Event	Downlist
132	V41X1917E	MPS LH2 RTLS OTBD DV (PV18) OP IND	Event	Downlist

Table 3.2.2-IV – MSIDs used for BFS MPS ASCENT (concluded)

	MSID	Parameter Name	Units	Source
133	V41X1538E	MPS LO2 MANF REPRSS 1(LV40) OP PWR	Event	Downlist
134	V41X1539E	MPS LO2 MANF REPRSS 2(LV41) OP PWR	Event	Downlist
135	V41X1436E	MPS LH2 MANF REPRSS 1(LV42) OP PWR	Event	Downlist
136	V41X1438E	MPS LH2 MANF REPRSS 2(LV43) OP PWR	Event	Downlist
137	V41X1901E	MPS LH2 RTLS REPRSS 1(LV74) OP PWR	Event	Downlist
138	V41X1902E	MPS LH2 RTLS REPRSS 2(LV75) OP PWR	Event	Downlist
139	V41X1632E	MPS HE SPLY BLWDWN 1 (LV26) OP PWR	Event	Downlist
140	V41X1634E	MPS HE SPLY BLWDWN 2 (LV27) OP PWR	Event	Downlist
141	V98X0742X	SRB SEP MAN/AUTO ENABLE A OR B BFS	Event	Downlist
142	V98X0743X	SRB SEP INITIATE CMD A OR B BFS	Event	Downlist
143	V98X3532X	AS26 SRB SEP INIT BFS	Event	Downlist
144	V98X3534X	AS28 SRB SEP CMD BFS	Event	Downlist
145	V98X0748X	ET SEP MAN ENABLE A OR B BFS	Event	Downlist
146	V98X0749X	ET SEP INITIATE CMD A OR B BFS	Event	Downlist
147	V98X3550X	AS34 ET SEP CMD BFS	Event	Downlist
148	V76S4601E	MEC 1 BUS A PWR ON	Event	Downlist
149	V76S4605E	MEC 2 BUS B PWR ON	Event	Downlist

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TITLE

BSE CONSOLE LOCATION/CONFIGURATION

PURPOSE

The purpose of this SCP is to show the location and configuration of the Booster console.

DESCRIPTION

The Primary Booster console is located directly behind the CAPCOM console on the back row of consoles in the White FCR of building 30S (room 2306). Table 3.3.1-I shows the general console configuration. Other consoles in the control center that support 3 monitors can also be configured as a Booster console.

The Booster console is configured by selecting a Simulation or Flight activity subsequent to logging into the three workstations. The title of the activity should correspond to the title of the MCC event the operator is supporting. After the console is configured for an activity, the software used to support the Booster console can be initialized. The applications used by the Booster operator during ascent are shown in Table 3.3.1-II. Each Booster is not required to have their console configured the same way, but a Booster console recommended configuration cue card is included as Figure 3.3.1-I.

Table 3.3.1-I. - Booster Console Configuration.

Description	Location/Description
White_fcr8 Workstation	Left Dual Monitor Workstation
White_fcr27 Workstation	Right Single Monitor Workstation
Television Monitor	Left of console (shared with MOD)
DVIS Panel 4243	Left DVIS Panel
DVIS Panel 4244	Right DVIS Panel



Table 3.3.1-II. - Ascent Booster Software Applications

Application	Configuration
MSK_View	Various ME and MPS Displays
OFS	PASS & BFS
CRANS_RT	Personal Configuration
ELOG	Event Logger
RTPLOT	Necessary Plots
Command Manager	Command Inventory Display with MRTC and RTC - POGOs, Prevalves, and Overboard Bleed valves Commands.
IMGO	Flight Director Lights
ISP Server	On White-fcr8 - start ISP Server
ISP Comps	On White-fcr8 - start ISP Comps

BSE - FCR (recommended configuration)

Log on, select desired activity, iconify unwanted windows, then start BOSS displays (see below). Start AutoPilot on White\_fcr8 (starts ISPserver, ISPlimit, ISPchannel, BOSS comps, MENU comp, and FID display).

Pulldown: Booster/BOSS/Simulation/Start APLT

Select personal configurations on each workstation to start Booster displays, RTplot, CRANS\_RT, ELOG, BFS Channel, and/or BSE Channel.

Pulldown: Booster/Displays/User Disp Cnfg/2 Head WS(or 1 Head WS)/Booster/user\_name

Note: Command Manager and OFS must be started from pulldown (see below.)

BSEchannel is run by ME, BFSchannel is run by the MPS operator.

Left White_fcr8 (Monitor 0.0)	Center White_fcr8 (Monitor 0.1)	Right White_fcr27 (Monitor 0.0)
RTplot            FID display CRANS_RT        ISPchannel ELOG             ISPlimit Advisories      Cmd Inventory	pass_header      Imgo main_engine ddd_panel delta             (bfs_header) (launch_status) (bfs_me) menu_comp        OFS (PASS)	pass_header      ddd_panel mps_ascent       (bfs_header) (bilevel)        (bfs_mps) Advisories        OFS (BFS)
Software Pulldown Locations/Configuration:		
Booster/RTPLOT/MPS (SSME) Booster/CRANS/CRANS_RT Booster/ELOG/ELOG  Master/GlobalApps/Command Server/Start Command Manager Master/GlobalApps/Command Server/TELCOMdisplays/SSP/Command Inventory: Orbiter RTCs (5600-5630) Orbiter MRTCs (5650-5654)  Master/GlobalApps/Advisories	Master/Shuttle/FD/FD_Imgo  Booster/Displays/Special Disp Cnfg/Main Engine Booster/Displays/Special Disp Cnfg/BFS main_engine Booster/Displays/Launch Status  Master/Shuttle/DPS/Real-Time (data from DPS)/OFS - select options: <u>P</u> ASS/man <u>a</u> ck/ <u>M</u> ET	Booster/Displays/Special Disp Cnfg/MPS Ascent Booster/Displays/Special Disp Cnfg/BFS mps  Booster/Displays/Bi-Level  Master/Shuttle/DPS/Real-Time (data from DPS)/OFS - select options: <u>B</u> FS/man <u>a</u> ck/ <u>M</u> ET  Master/GlobalApps/Advisories

After each sim run: Restart ISPserver (restarts all comps, clears flags, etc.).

Pulldown: Booster/BOSS/simulation/Cycle APLT or

Master/Global Apps/Autopanel: booster-PTMSERVER <RMB> Restart...

FDO/BSE simulations: OFS must be started from:

Master/Shuttle/DPS/Real-Time (data from local servers)/OFS

If SVO FCR - run ISPserver on White-mps19.

D/O prep: SPECS: Master/Shuttle/DPS/Real-Time (data from DPS)/SPECS

HTAB: Booster/BSE Tools/HTAB

Flight notes are located on MODM PC at: U:\work\Booster

U:\fltnote\

U:\temp\ (sims)

DVIS		
Left	Right	Location
4243	4244	BSE-FCR-1
8243	8244	BSE-SVO
4190	4191	TRNG-FCR
4717	4716	ME-MPSR-1

MECO MR = 15:00 MET

Before logging off, remember to: Master/Global Apps/Command Server/Stop Command Manager/Yes

4715	4714	MPS-MPSR-1
------	------	------------

Turn ring volume down

Figure 3.3.1-I. - Ascent Booster Configuration Cue Card: (REV-E 05-16-00)

REFERENCE

- 1) Booster Cue Card Book, Rev A, PCN-2, BSE-001, April 3, 2000.

## TITLE

BSE/ME/MPS COMMUNICATION PANELS

## PURPOSE

This SCP describes the communication loops that the Booster Systems Engineer (BSE), the Main Engine (ME) operator and the Main Propulsion System operator (MPS) use when communicating with other console operators in the MCC. This SCP also includes a description of the loops that are used to monitor activities at KSC during the prelaunch countdown.

## DESCRIPTION

The console communication panels in the MCC are designed to give the operator the capability to talk and listen to other operators in the control center and other various locations. Each console can be configured with those loops required for an interface between operators. The communication panels are touch-sensitive digital voice intercommunication system (DVIS) units. This SCP only gives an overview of the system. The operator should reference the DVIS Keypad Quick-Reference Guide if more information is desired (duplicated in figure 3.3.2-I). Further details of DVIS operations are covered in the Training Academy curriculum or can be explained by an experienced console operator.

The operator can configure 10 pages of data, each containing 24 communication loops. The DVIS has a vertical layout of three columns by eight rows of communication loops, and a horizontal version with a layout of six columns by four rows. Each page may be reconfigured easily if a needed loop is not available on a page. All of the Booster Group DVIS keysets are of the vertical configuration.

Each communication loop is labeled to designate its primary function user. The communication loops are also labeled to indicate talk/listen/monitor capability. A loop labeled M is a listen only (monitor only) loop. A HM loop is a high volume monitor loop. A TL is a talk/listen loop, and a TLM is a talk/listen/monitor loop. The M, HM, and TL loops are activated and deactivated by touch. The M and HM loops indicate when they are active by highlighting the M and HM letters in reverse video. The TL loop indicates active by a blinking reverse video highlight of the TL letters. The TLM loop is activated by touch. TLM loops toggle between talk/listen mode (blinking) and monitor mode (non-blinking). TLM loops are deactivated by touching the RELEASE button and then the loop to be dropped.

**DVIS KEYSSET QUICK-REFERENCE GUIDE**

**SIGN ON**

Note: If screen is blank, touch screen anywhere to activate sign-on menu.

- 1 Touch **SIGN ON** key.
- 2 At **ENTER USER ID >** prompt, enter 1- to 8-digit user ID code on pop-up keypad.
- 3 Touch **ENTER** key on pop-up keypad.

**SIGN OFF**

- 1 Touch **SIGN ON/OFF** key.
- 2 Touch **ENTER** key on sign on/off pop-up keypad.

**CONFERENCE**

**Monitor or High Monitor Line Key Operation**

- 1 Touch desired M or HM line key.
- 2 When finished, touch activated line key.

**Talk/Listen Line Key Operation**

- 1 Touch desired TL line key.
- 2 When finished, touch activated line key or any other line key.

**Talk/Listen/Monitor Line Key Operation**

- 1 Touch desired TLM key once to activate monitor mode.
- 2 Touch selected TLM key second time to activate TL mode.
- 3 Subsequent touching alternates between monitor and TL modes.

**Deactivating TLM Key**

- 1 With either monitor or TL mode of TLM key activated, touch **RELEASE** key.
- 2 Touch activated TLM keys to deactivate.
- 3 After all desired TLM keys are deactivated, touch **RELEASE** key.

**STATION-TO-STATION CALLING OR PABX CALLING**

**Placing Call**

- 1 Touch **DIAL** or **PABX** line key.
- 2 Enter desired number on station-to-station pop-up keypad or **PABX** pop-up keypad.

**Answering Call**

- 1 **DIAL** or **PABX** line key flashes and ringer sounds.
- 2 Touch **DIAL** or **PABX** line key.
- 3 When call is finished, touch **DIAL** or **PABX** line key.

**Placing Call on Hold**

- 1 With **DIAL** or **PABX** line key in TL mode, touch **HOLD** key.
- 2 **DIAL** or **PABX** key displays **HOLD** legend with reverse video and no flashing.

**Retrieving Call on Hold**

- 1 Touch **DIAL** or **PABX** line key showing **HOLD** legend.
- 2 **HOLD** legend changes back to **TALK** legend.

**NOTES:**

- 1 **BUSY** legend indicates another keyset is using **PABX** line.
- 2 **KEYPAD** key may be used any time to recall **PABX** pop-up keypad to enable dialing.
- 3 **CANCEL** key erases pop-up keypad.

**MULTIACCESS CONFERENCE**

**Accessing Multiaccess Conferences (3 Max)**

- 1 Touch **MULTIACCESS** key.
- 2 Touch up to three **TULTM** line keys.

**Adding Third Conference**

- 1 Touch **MULTIACCESS** key.
- 2 Touch desired **TULTM** line key.

**Terminating Multiaccess Conferences**

- 1 Touch **RELEASE** key.
- 2 Touch **MULTIACCESS** key or, activate fourth **TULTM** key.

**Multiaccess Conference Recall**

- 1 To restore last multiaccess conference configuration, touch **MA RECALL** key.

**CONFERENCES WITH SIGNALING OPERATION**

**Answering Incoming Signal**

- 1 Line key flashes and ringer sounds.
- 2 Touch line key.
- 3 When finished, touch line key.

**Sending Outgoing Signal**

- 1 Touch desired line key to activate TL mode.
- 2 For manual signaling conferences, touch **SEND** key. For VDL and auto signaling conferences, signal sent automatically.

Figure 3.3.2-I - DVIS Keypad Quick-Reference Guide (sheet 1 of 2)

**DVIS KEYSSET QUICK-REFERENCE GUIDE**

**NOTE**

Line key configuration or reconfiguration can be accomplished using ID entry procedure or loop directory procedure. Loop directory procedure provides the convenience of not having to remember the exact conference name or ID number. Although all conferences are listed in the directory, user can only access those to which access rights are granted.

**LINE KEY CONFIGURATION/ RECONFIGURATION USING LOOP DIRECTORY**

- 1 Touch CONFIGURE key.
- 2 Touch desired conference line key.
- 3 Touch desired BLACK DMR or RED DMR key on pop-up keypad.
- 4 To Change Partition:
  - Touch SELECT PARTITION key.
  - Highlight desired partition, using arrow keys, and touch ENTER key.
- 5 To Highlight Conference In Loop Directory:
  - Touch SELECT ALPHA LIST or SELECT NUMERIC LIST key.
  - On alpha pop-up keypad, successively touch key containing first letter of selected conference until letter appears in LIST START POINT display key. Touch ENTER key.
  - On numeric pop-up keypad, enter ID for general loop directory area of selected conference and observe entered ID appears in LIST START POINT display key. Touch ENTER key.
  - Touch screen in area of desired conference.
  - If required, touch arrow keys to move highlight to selected conference.
- 6 Configure/reconfigure conference by touching appropriate SELECT M, MM, TL, or TLM key.

**LINE KEY CONFIGURATION/ RECONFIGURATION USING ID ENTRY**

- 1 Touch CONFIGURE key.
- 2 Key mode legends (M, MM, TL, TLM, DIAL, and PABX) appear on pop-up keypad along with numerals.
- 3 Touch desired conference line key. ENTER NEW KEY ID > prompt appears.
- 4 To add or change key:
  - Enter desired key mode (M, MM, TL, TLM, BLACK DUAL, RED DUAL, or PABX).
  - Enter 4 digit loop ID (not required for DIAL OR PABX).
- 5 Touch ENTER key.

**LINE KEY DELETION**

- 1 Touch desired line key to activate.
- 2 Touch CONFIGURE key.
- 3 Touch DEL key on pop-up keypad.
- 4 Touch ENTER key.

**PAGE SELECTION**

- 1 Touch PAGE key.
- 2 Successively touch DECR or INCR key until appropriate page appears.

**RING, MONITOR, SPEAKER, AND HEADSET VOLUME CONTROL**

- 1 Touch either RING VOL, MON VOL, SPKR VOL, or HEADSET VOL key.
- 2 Successively touch DECR or INCR key until desired volume level is reached (appropriate digit appears in VOL key).
- 3 When finished, touch activated VOL key.
- 4 If desired, touching RING TEST key enables user to hear ring volume at current setting.

**PAGE SELECTION AND VOLUME CONTROL USING NUMERIC KEYPAD**

- 1 Touch either RING VOL, MON VOL, SPKR VOL, HEADSET VOL, or PAGE key.
- 2 Touch KEYPAD key.
- 3 Touch desired number (0-7 for VOL or 1-10 for PAGE) on pop-up keypad.
- 4 When finished, touch activated VOL key.

**CRITICAL ALARM VOLUME CONTROL**

- 1 Touch CONFIGURE line key.
- 2 Touch CRT ALARM VOL key.
- 3 Successively touch DECR or INCR key until desired SCALE or HIGH level volume indicator appears in CRT ALARM VOL key.
- 4 When finished, touch CONFIGURE key.

Scaled level is controlled using regular volume control procedures.

Figure 3.3.2-I - DVIS Keysset Quick-Reference Guide (sheet 2 of 2)

PROCEDURE

The user signs on to the DVIS system by typing the keyset position number (see Table 3.3.2-I below) and password (although Booster uses one, a password is optional – check with any Booster Group console operator for the password). The user can sign on to any valid DVIS position from any location as long as the requested keyset position number is not in use by another operator. Calls can be made from one keyset to another by using the dial loop and entering the keyset position number. The dial loop on the receiving keyset flashes and the speaker generates a ringing tone

Table 3.3.2-I - DVIS position numbers

<u>Console</u>	<u>Left</u>	<u>Right</u>
BSE (WHT)	4243	4244
ME	4717	4716
MPS	4715	4714
BSE (BLUE)	8243	8244
BSE (RED)	4190	4191

Normally, there are at least two pre-built pages if the user signs on under the Booster password. The one page is for use during ascent, and another is for use during prelaunch. The remaining eight pages are left for assignment to specific operators – before claiming a page and making major changes, check with the other operators who regularly use that console position. The following is a list of general guidelines for using a keyset and configuring a DVIS page.

- a. For best results, the headset volume should be set to the maximum level (6 or 7), and the monitor volume set to the middle level (4). The ring volume should be turned down to 1 or 0 to avoid the loud ringing tone of outside calls during simulations (the default volume level in the FCR was made more reasonable in 1998 but the MPSR is still loud). During actual launches, the ring volume should be set to 0.
- b. The FCR operator must be able to talk to all other FCR operators (exceptions are MOD, Surgeon, PAO, Capcom, and Payloads). The FCR operator must always monitor FD, Booster MPSR, MOCR SPEC (calls from other FCR operators) and the three A/G loops.

The MPSR operators must always monitor FD, Booster MPSR, MOCR SPEC and MOCR DYN, SSR 1 CONF (to avoid calling Booster while the Booster is talking to other operators) and the three A/G loops.

Since there are a large number of loops to monitor during prelaunch, the loops may need to be divided equally among all team members. For a listing of communications loops used during prelaunch, see SCP 1.3.2, Booster Prelaunch.

A complete listing of loops available through DVIS can be retrieved by logging on to any DVIS keyset. Once logged on, depress the reconfigure button, then any non-selected key on a page.



When the keypad pops up, select the option PRIME DIR on the 8 key in the middle of the pad. Then select "SELECT ALPHA LIST", and a letter from the alphabet. A scrolling list will appear. Loops may also be added to the current page from this directory.

Table 3.3.2-II is a listing of DVIS ascent loops most frequently used or monitored by Booster Team members. A complete listing of all MCC FCR and MPSR positions with their appropriate call loops is provided in FCOH SOP 1.4.

Table 3.3.2-II - Booster Group DVIS Ascent Loops

<u>LOOP LEGEND</u>	<u>PURPOSE</u>
1 A/G 1	Crew voice link to MCC
1 A/G 2	Crew voice link to MCC
A/G UHF 1	Crew voice link to MCC
FD 1	Comm loop between Flight Director and FCR operators
BOOSTER MPSR 1	Comm loop between Booster and Booster MPSR operators
MOCR SPEC 1	Comm loop used by FCR operators to contact Booster (specialist console – also used by RMS/EVA during orbit operations)
AFD CONF 1	Alternate Flight Director (sim debrief loop / flight handover briefing loop)
MER 1	Comm loop between MCC operators and engineering (MER)
SPAN	Spacecraft Analysis Room
PABX	External phone line (Public Access Base Exchange)
MOCR DYN 1	Comm loop used by Booster to contact FDO/Guidance (dynamics)
MOCR SYS 1	Comm loop used by Booster to contact Systems: EGIL/EECOM/MMACS
MOCR DPS/CDMS 1	Comm loop used by Booster to contact DPS
MOCR GNC/PROP 1	Comm loop used by Booster to contact GNC or Prop
COMMAND 1	Comm loop used by Booster to reach command
OIS 232 NTD TD	KSC NASA Test Director comm loop monitored by Booster
SSR 1 CONF	Systems Support Room Conference – comm loop used by MPSR operators to contact other MPSR operators in other disciplines.
WSS CALL	Contact WSS for workstation problems
GC CALL 1	Contact GC for MCC configuration problems

In the Booster Console Cuecard Book there are two cue cards in the general section pertaining to DVIS: Typical DVIS Ascent Panel Config, and Typical DVIS Prelaunch Panel Config. Using the code numbers listed on these cue cards, a console operator can very quickly reconfigure a DVIS panel (bypasses the step of looking up the loops in the directory).

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## TITLE

CONSOLE LOGBOOKS

## PURPOSE

This SCP describes a standard to help maintain data for STS operations.

## DESCRIPTION

The flight logbook is a vital place to document and gather all information regarding a flight. Each lead operator for flight shares the responsibility to ensure that critical information is recorded, organized, and stored. Records need to be kept on preflight information, tanking attempts, flight information, problem analysis and resolution, and post-flight reporting.

## PROCEDURE

Each logbook will be labeled with the STS flight number and vehicle number.

The console logbook will be divided into sections, each with a labeled tab. The following is a list of required sections:

- Training Rosters
- Certificate of Flight Readiness/Flight Readiness Review/Delta Flight Readiness Review
- Trajectory Design Data Package/Main Engine Tables/Ullage Curves
- L-1 Log Sheets for Booster, Main Engine, and MPS; L-1 Crew Briefing package
- Prelaunch Log Sheets for Booster, Main Engine, and MPS
- Limits and Constants printouts
- Ascent Log Sheets for Booster, Main Engine, and MPS; including hardcopies and plots
- Orbit Log Sheets for Booster
- Deorbit Prep/Entry Log Sheets for Booster and MPS
- Anomalies and Quicklook reports

If more than one launch attempt occurs, each attempt will have an individual, tabbed section. The Prelaunch and Ascent Log Sheets sections will be kept together. Each set will be in chronological order. Each deorbit attempt will also have its own tab. The reason for the scrubs, aborts, and wave offs will be documented in the appropriate section's log sheets. If any of these were due to Booster Systems failures, the IPR, PR, and/or anomaly sheets for the failures should be placed in the "Anomalies and Quicklooks" section. Log sheets should be made on JSC or Booster Group forms (reference Figures 4.1.1-I and 4.1.1-II).

The following provides the minimum set of items to be included in each section.

A. Certificate of Flight Readiness/Flight Readiness Review/Delta Flight Readiness Review

1. DF55 COFR
2. DF55 FRR original and delta data packs
3. DF FRR data pack

B. Trajectory Design Data Package/Main Engine Tables/Ullage Curves

1. TDDP
2. SSME Tag Letter
3. Copy of the output of the Main Engine Table (MET) program used for flight
4. ET ullage curve SODB information
5. Any other data deemed required by the Booster System Engineer

C. Flight Log Sections (L-1, Prelaunch, Ascent, Orbit, & Deorbit Prep/Entry)

Each console operator will keep a log for each shift using JSC form 1441 (Flight Controller Log), or a facsimile thereof. The header on each page will be completed and operators must sign their log sheet at the end of the shift (reference FCOH 1.1). Log sheets must be filled out in blue or black ink. If possible entries should have an associated GMT or MET time-tag. Figure 4.1.1-I is an example of a log sheet. The following data should be included in the log sheet sections:

1. L-1 Log Sheets
  - a. The Ascent team's log sheets from the S0007 L-1 Crew Systems and Weather briefings, including any special instructions for the prelaunch team.
  - b. S0017 (TCDT) L-1 crew briefing package
  - c. S0007 (Launch Countdown) L-1 crew briefing package
2. Prelaunch Log Sheets
  - a. The Prelaunch team's log sheets.
  - b. The MPS operator's Prelaunch Checklist (reference SCP 1.3.3).
  - c. Copies of any applicable DR's

3. Limits and Constants printouts
  - a. Copies of the Limit Manager limit checkpoint printouts
  - b. Copies of the BOSS configuration constants files (file names are listed in the COFR addendum).
  
4. Ascent Log Sheets
  - a. The Ascent team's (including OJT's) log sheets.
  - b. Planned changes to the flight plan involving Ascent or Post Insertion activities that affect the Booster Systems.
  - c. Copies of any Booster-generated Flight Notes.
  - d. Write-ups on anomalies impacting Booster Systems.
  - e. Any pertinent crew reports (extensive conversations should be documented by obtaining transcripts from Houston Voice).
  - f. Copies of SPAN CHIT's or MDRF's submitted by the booster team or their MER counterparts.
  - g. Copies of any applicable DR's.
  - h. Hardcopies taken of displays - arranged in chronological order.
  - i. Hardcopies of plots (Rtplot, MEWS, plots from SSME Project).
  - j. Any other items deemed necessary by the Booster Systems Engineer.
  
5. Orbit Log Sheets
  - a. A copy of the Ascent handover sheet provided to MMACS at the end of the ascent shift.
  - b. Daily log sheets by the Booster System Engineer. These should include a vehicle status, system failure impacts to booster systems (if required), and MPS helium mass available (if telemetry available).
  - c. Copies of any SPAN CHIT's or MDRF's affecting Booster Systems.
  - e. Copies of any applicable DR's
  
6. Deorbit Prep/Entry Log Sheets
  - a. Log sheets from the Booster Systems Engineer, the MPS operator, and any OJT's
  - b. Information on deorbit opportunities.
  - c. Copies of any SPAN CHIT's, MDRF's or DR's affecting Booster systems.
  
- D. Anomalies and Quicklook Reports
  1. Any listing of KSC IPR's and PR's taken during countdown.
  2. The most current listing of anomalies (provided by SPAN) and MER funnies.
  3. Copies of any anomaly reports submitted against Booster systems.
  4. A copy of the baseline IFA's.
  5. IFA closure sheets.
  6. Any Quicklook/Flash reports received (typically from MSFC).
  7. DF55 Quick Look

The older logbooks will usually be located in the DF55 Booster Library (in their own cabinet). Prior to each flight, verify the logbooks of the previous flight and the previous flight of that vehicle are in the Booster MPSR cabinet. The logbooks from the most recent flight of each vehicle are generally kept in the MPSR cabinet – this saves moving them back and forth between the MPSR and the Office.

Project FRR data packages will be kept, organized by project, in the DF55 Booster Library, except during flight. During flight, the briefing packages for that flight will be kept in the Booster MPSR cabinet. This also applies to the Rocketdyne SSME Flight Operations Handbook (“White Book”).

Anomaly reports will be completed using the MIS Anomaly Report software. All Booster related anomaly reports must be approved by the Booster Systems Engineer on console prior to submission to SPAN. An example of an anomaly report is shown in Figure 4.1.1-III.

#### REFERENCE

FCOH - Flight Control Operations Handbook Shuttle Operations, Final Rev B, P&I 13 4/24/00, JSC-26843

AS-98 ASCENT DATE: 7-22-99 BSE: JDR PAGE: 1  
 GENERIC BSE/FDO JDR 4-15-98 OJT: JDR RUN#: 1 2 3 4 5 6 7 8

PRED MET	ACT MET	BOUNDARY /EVENT	MET	SSME	EVENT
0:00		3@100/MS	L/O REAL GMT:	11:20 PM LOCAL 11:40 12.	SGMT: 1998:106:18:19:00
0:04		↑104			11:24 LOCAL 11:31 = T0
		↓ (fd)			
0:33		↓ 3@67 (fd)			AC-1
0:53		↑ 3@104 (fd)	0.05 C		DCR A
2:04		SRB SEP (fd)	PERF: NOM LOW		R DCO B
2:42		2E-TAL	SUSPECTS: NO L C R		to U/PATAI fdo
<del>3:09</del> 3:13		1 <sup>st</sup> 1 2/3 (Asc CL)			CR 15 AC-2 JAGS
3:58		N-RTN		R	TOTALS - OFF. AC BUS SENS OFF
5:24		SE-DROOP			NOT A NORMAL LEAK #11
5:49		P-ATO			AC-1 CA
5:51 6:00		P-MECO			CARRIED ALL 3 Φ'S
		SE-LIM	1/2 →	R	SPTS HYD P DRAIN
<del>5:58</del> 6:00		SE-TAL			PERALIC
7:00		SE-PRESS	PRED U/S = 0		fdo
7:32		3-G (fd)	SUSPECTS: NO L C R		RTLS, gnc
<del>8:00</del> 7:26		23K			15 FT/S U/S
		LOX @ 5			
		FUEL @ 5			LOX LICO
		ARM CMD			
		FC			Am 4 Dry EMECO
8:29	8:27	MECO C fd	LLCO Wx		+ 1/2 ISS (and)
+17.4		ET SEP fd			
m+2	10:27	DUMP START ON → 3			16:10 - U/S COMPLETED.
st+2	12:27	DUMP STOP			41:04 - U/S
		PWR DOWN	if >25:00 call inco		
sp+15	21:29	VACUUM IN			

Figure 4.1.1-I. - Example of Ascent Log (normally handwritten).

FLIGHTS/SIM/TEST ID	DATE	ORB	CONSOLE POSITION	PAGE
STS-93	7/23/99	PT (ORIS)	BOOSTER	6
MST TIME	FLIGHT EVENTS/HISTORY/BRIEFING			
10:10	EWC - POSSIBLE TBA/CONTROL UNIT CAUSING THE QA SHIRT.			
34:27	CRT 3 PROBLEM X + PAU-FALL. (PROJECTOR SMOKED) TURN OFF			
1:04:00	MAN P - SS ✓ CREW 8 F7 FLASHED WATER LOOP LIGHT E LIFTOFF  3 ANOMALIES FROM BOOSTER - CTL DLV'S C OPERAND STOP. - RB SRB HPV HYD P GRATIC LOX LCO.			
1:09	MPP: FIDS WATER SINO (RAYBACK)  EWC LOOKING FOR MORE PRECISE TIMES FOR THE CONTROL UNIT FAULTS ~ 1/2 SECOND VOLTAGE EVENT ON B. AC-1 QA C R			
1:29	MPP - PULLING RY1M1005P / RY1M3005 GIVE MPP'S TO EWC AS WELL 25 SISE. ✓			

JSC Form 1441 (Rev Mar 79) (Perform Pro Plus Aug 93)

FLIGHT CONTROLLER'S

Figure 4.1.1-II. - Example of Flight Log  
(normally handwritten)



<b>BOOSTER 003</b>	GMT: 1999/04:04:31 MET: 001:00:00:05	In-flight Status OP	Orbiter Impact N	Payload Impact N	Vehicle ID OV-102	Track No.
<p><b>AUTHOR:</b> Munish P. Patel</p> <p><b>TITLE:</b> SSME Controllers Disqualification Due to Power Failure</p> <p><b>DESCRIPTION:</b> At 5 seconds MET, received SSME Failure ID (FID) Word "001-001" on Center SSME and "002-001" on the Right SSME. Center SSME FID (MSID E41M1005P) "001-001" decodes as Digital Computer Unit A (DCU A) Disqualification due to Power Failure. Right SSME FID (MSID E41M3005P) "002-001" decodes as DCU B Disqualification due to Power Failure. Both of these SSME controllers receive power from Main A, AC-1. SSME controller disqualification was believed to be the result of a momentary event on Main A, AC-1. Post MPS Dump (MET 12 min, 30 sec), Center SSME indicated a datapath failure (ie. loss of primary and secondary data from the SSME controller to the GPC).</p> <p><b>IMPACT:</b> Center SSME DCU A Disqualification due to power results in loss of controller redundancy, loss of primary data, and loss of command channel A. Center SSME DCU B assumes control and the SSME still had two command channels (one failure away from Command Path Failure). Center SSME was critical to AC-2 (loss of AC-2 would have caused engine shutdown). Right SSME DCU B Disqualification due to power results in loss of controller redundancy, loss of command channel B, and loss of channel B sensor data. Right SSME channel B sensor data was recovered with power recovery. Right SSME still had two command channels (one failure away from Command Path Failure). Right SSME was critical to AC-3 (loss of AC-3 would have caused engine shutdown). AC Bus Sensors were taken to OFF per Flight Rule A5.1.3-10.</p> <p><b>RESOLUTION:</b> Cause is under investigation.</p>						

Figure 4.1.1-III. - Example of Anomaly Report

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## TITLE

### POST-LAUNCH DATA PLAYBACKS

## PURPOSE

This SCP explains the method by which the Booster, MPS, and Main Engine console operators can play back data post-launch via the workstation VCR.

## DESCRIPTION

The launch data is recorded from the VCR application on the workstations. Typically, the data is recorded from T-1:00 through ET separation. The VCR log files may be viewed any time after the data recording has stopped. This is particularly valuable in collecting data for in-flight anomalies.

## PROCEDURE

### A. VCR Set-up and Recording

1. Call up the VCR from the Playback pull-down menu on the Booster Display Navigation (DNAV) menu. A VCR window appears as shown in Figure 4.1.2-I.
2. Under the File menu (Figure 4.1.2-I), click on Select Playback/Record File. A Select Playback/Record File window appears as shown in Figure 4.1.2-II. The file will be stored in the booster/Appl/Vcr/Logs directory.
4. Click on the field under Selection (Figure 4.1.2-II), type in the desired file name and click OK.
5. Back on the VCR window, select Record. A Record window appears as shown in Figure 4.1.2-III.
6. Click on the field to the right of Data Source Stream (Figure 4.1.2-III) and select PTM.
7. When ready to begin recording, click on Ready to record (Figure 4.1.2-III).
8. When recording is complete, select Stop on the VCR window (Figure 4.1.2-I).

### B. VCR Data Playback

Note: If playing the data while still on the same mission support activity or simulation activity where real-time data is still flowing, then change to a different server (on the Server pull-down menu on the Booster DNAV, select "Set ISPOWNER = xxxbse"). Kill and restart the displays so that they are connected to the new server you selected.

1. Call up the VCR from the Playback pull-down menu on the Booster DNAV. A VCR window appears as shown in Figure 4.1.2-I.

2. Under the File menu (Figure 4.1.2-I), click on Select Playback/Record File. A Select Playback/Record File window appears as shown in Figure 4.1.2-II. Choose the desired playback file . Recall that the files are located in the booster/App/Vcr/Logs directory.
3. Under the Playback menu on the VCR (Figure 4.1.2-I), select Normal. The data will start to flow but will not be displayed until a playback server is started. Select “Pause” on the VCR (Figure 4.1.2-I).
4. Start a playback server. On the Playback pull-down of the Booster DNAV, select Playback Server – Start APLT. Recorded data (paused) will appear on the displays.
5. Click “Pause” on the VCR (Figure 4.1.2-I) to un-pause the data. Data will begin to update. MET can be selected under the TimeType menu (Figure 4.1.2-I). The default is GMT.
6. When finished, select Stop from the VCR window, exit the VCR, and on the Playback pull-down of the Booster DNAV, select Playback Server – Stop APLT.

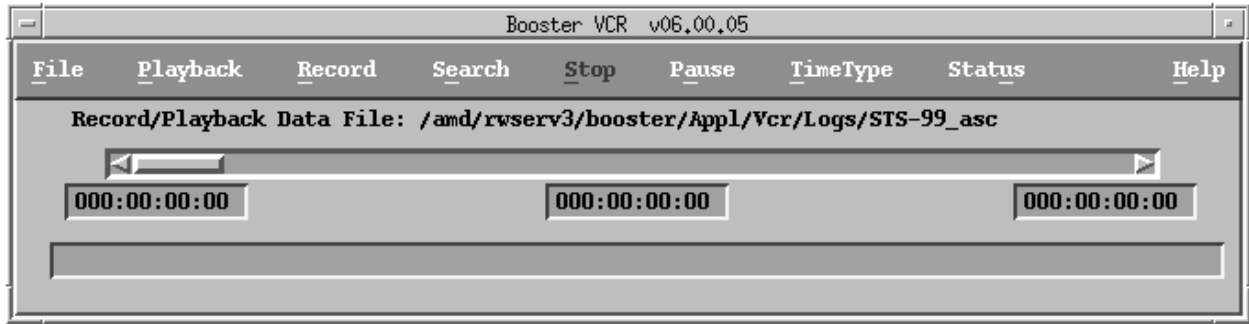


Figure 4.1.2-I. - VCR Window

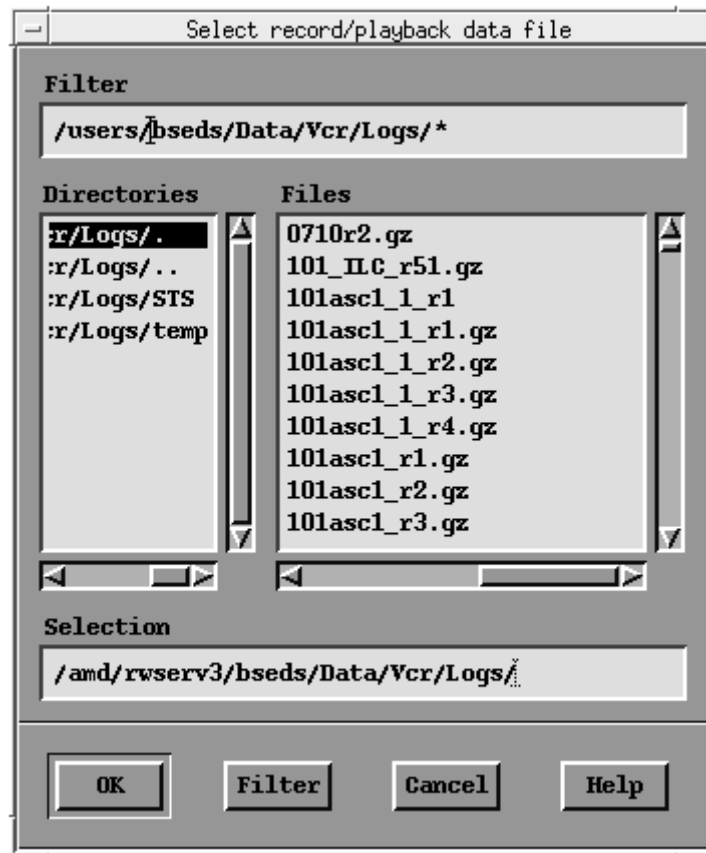


Figure 4.1.2-II. - Select Playback/Record File Window

The image shows a window titled "Record Setup Form" with a menu bar containing "File", "Ready to record", and "Help". The main area contains the following fields and controls:

- Flight ID:** A text box containing the value "092".
- Flight Data Type:** A dropdown menu showing "RR".
- Bound Size:** A dropdown menu showing "Not Bounded".
- Circular Recording:** A dropdown menu showing "NO".
- MSID Data File:** A text field containing the path "/amd/rwserv3/booster/Appl/Vcr/Bin/bse.msids".
- Recording Rate (packet/sec):** A text box containing the value "1".
- Data Source Stream:** A dropdown menu showing "PTM".
- Timing Mode:** A group box containing two radio buttons: "Manual" (selected) and "Auto".

Figure 4.1.2-III. - Record Window

## TITLE

BOOSTER SUPPORT OF INTEGRATED LOAD CHECKOUTS (ILCs)

## PURPOSE

This SCP describes the requirements for supporting an Integrated Load Checkout (ILC).

## DESCRIPTION

### A. Overview

During an integrated simulation, flight specific software “loads” are used in the Shuttle Mission Simulator (SMS), the Network System Simulator (NSS), and in the Mission Control Center (MCC). Prior to the first integrated simulation on a new flight specific software load, it is useful to verify that 1) any known SMS software updates (i.e., SMS model upgrades) are performing as expected, 2) the non-updated portions of the SMS models are performing as expected, and 3) Booster MCC workstations and software are configured to support a simulation on the new load. The verification that a load is ready to support integrated training is called an ILC.

Booster can be required to support an ILC for as little as one hour or as long as four hours (or more) depending on the number of SMS model updates affecting Booster on a given load. Typical ILC support is approximately 1.5 hours. In addition, ILCs are usually divided into an ascent/entry portion at the beginning followed by an orbit checkout. If the orbit checkout is expected to be lengthy, the ascent/entry ILC and orbit ILC may be scheduled for different days.

The ascent/entry portion of the ILC usually consists of an uphill run, an RTLS run, a TAL run, and a deorbit – 15 minutes (D/O-15) run. Additional ascent or entry runs may be planned as required to checkout the SMS model updates. Booster support for the D/O-15 is not required.

In addition, it is possible that several uphill ascent runs will be performed to calibrate the Abort Region Determinator (ARD). Prior to integrated ascent training, calibration runs are required to ensure that the ARD predicted capability agrees well with the SMS modeled ascent performance. If the ARD and SMS do not agree well, minor updates to the SMS model’s mass and available propellant will be made. Additional runs may then be attempted to ensure good agreement.

## B. Support Requirements

A single operator may support the ILC. The operator **MUST** be familiar with starting the Booster server. The operator should be Main Engine (ME) and MPS certified or in the certification process. However, when checking out extensive model updates, such as a new main engine model, it is recommended that two operators support the checkout (one with at least a ME certification, and one with at least an MPS certification).

The operator supporting the checkout will also need to do some initial research on what updates have been made in the SMS models. In addition, prior to the checkout the operator should notify the Booster software Group Administrator (GA) that an ILC will be performed. The Booster GA will need to configure the workstations to support a new load. In addition, the Booster GA should be available by pager (if not actually on console) in case there are any problems initializing the Booster server, displays, etc.

## PROCEDURE

The following procedure is divided into pre-ILC preparation procedures, ILC verification procedures, and post-ILC procedures. Figure 4.1.3-I is an ILC checklist that summarizes each of the following steps.

### A. Pre-ILC Preparation Procedures

1. The operator supporting the checkout must contact the Booster Monitors and ask them what model updates are being included in the new load. The Booster Monitors will be able to provide copies of the support requirements (SRs) that are being incorporated into the new load or anomaly reports (ARs) that are being fixed. The operator may want to contact the SMS programmer or the Booster Group's lead for the MPS and/or SSME model for additional information.
2. For extensive model updates, it is recommended that the operator and the Booster Monitors meet to discuss how many runs will be required, how the updates will be verified, which updates will be verified on which runs, etc. The first flight of a new flight software Operational Increment (OI) could also drive additional testing requirements.
3. Notify the Booster GA that a checkout is about to be performed on a new load. Ask the GA to setup the ISP Limit files, Booster start scripts, and BOSS input constant data files required to support a new load.
4. Tell the Booster GA to be available during the ILC to fix problems.



## B. ILC Verification Procedures

If there are any problems with the workstation (starting the server, calling up displays, using the Booster DNAV pull-down menus, etc.), contact the Booster GA immediately. Make hardcopies to try to capture the problem (if possible).

1. Login to the FCR workstation, and start the Booster server as usual (reference SCP 3.3.1). Verify that all of the applications that start with the Booster server (ISP Limit, ISP Channel, etc.) are working properly. Make sure to review the Advisory Services (AS) messages for warnings about applications that did not start properly.
2. Configure the workstation as a Booster would for ascent by calling up the appropriate displays, OFS, command server applications, etc (reference SCP 3.3.1). Verify each of these applications appears to be working properly.
3. Start each of the remaining Booster displays from the Booster DNAV. Make sure they start and are displaying reasonable data.
4. Start the BSE Overview display (and several others) from the Global, Shuttle, Booster DNAV. Make sure they start and are displaying reasonable data.
5. Start at least one version of each of the Booster tools (RTPLOT, ELOG, CRANS, Vcr, etc.). Make sure these applications appear to be running properly.
6. While the simulator is in run after lift-off, make sure all of the Booster computations are working properly (engine perf, helium TOD, helium mass, etc.). Also make sure each of the displays and other applications are working properly.
7. During the run, verify the SMS model/OI updates as discussed with the Booster Monitor prior to the sim.
8. After the run is complete, cycle the Booster server and prepare for the next run. In subsequent runs, it is not necessary to again verify each display and application. Instead, these runs should focus on verifying the SMS model updates (if any).

### C. Post-ILC Procedures

1. If any problems are identified with the SMS, the Booster Monitors will write an Anomaly Report (AR) against the SMS model. If any problems are identified with the MCC workstation, consult with the Booster GA before submitting an AR against the MCC software. If an AR against the MCC is warranted, submit it to the GC console prior to leaving the ILC (reference FCOH 1.7 "MCC/SMS Problem Reporting" for instructions on how to write an AR against the MCC).
2. Provide a summary to the Booster Group on the ILC (especially the flight specific Booster team that will use the new load). This summary could be performed during a Booster Group Meeting or via e-mail. Discuss new model improvements that were verified, and discuss any problems encountered during the checkout.

## **BOOSTER ILC CHECKLIST**

### **LOAD INFORMATION:**

Date: \_\_\_\_\_

SMS Load: \_\_\_\_\_

### **PRE-ILC PREPARATION CHECKLIST:**

- Contact the Booster Monitors to discuss what SMS model updates are scheduled to be included in the load. Discuss the plan to checkout each of the SMS model updates (if required).
- Ask the Booster GA to verify the workstations are configured to support new SMS load.
- Tell the Booster GA to be available during the ILC to fix problems.
- Contact the GA during the checkout if there are ANY Booster software problems.

### **ILC VERIFICATION CHECKLIST:**

- Login to the FCR workstation, and start the Booster server. Verify no problems.
- Configure the workstation as a Booster would for ascent. Verify no problems.
- Start each of the remaining displays on the Booster DNAV. Start the BSE Overview display and several other Booster displays from the Global, Shuttle, Booster DNAV. Verify no problems.
- Start at least one version of each of the Booster tools (RTPLOT, CRANS, ELOG, Vcr, etc.). Verify no problems.
- While the simulator is in run after lift-off make sure all Booster displays, computations, and tools continue to perform as expected.
- Verify the SMS model improvements/OI updates each run as discussed with the Booster Monitors prior to the sim.

### **POST-ILC CHECKLIST:**

- Discuss any MCC software problems with the Booster GA, and submit MCC Software ARs (if required) to the GC console prior to leaving the ILC (FCOH 1.7). Get copies of any SMS Model ARs submitted by the Booster Monitors.
- Summarize the results of the ILC for the Booster Group. Include a list of all relevant SRs and ARs that were verified during the checkout, and discuss any problems discovered during the checkout.

Figure 4.1.3-I.- Sample ILC Check List

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TITLE

BOOSTER CONSOLE DOCUMENTATION

PURPOSE

This SCP lists both the FCR and MPSR documents that are used for flight operations.

DESCRIPTION

The following documents are contained in both the FCR and MPSR:

Booster Standard Console Procedures (SCPs)  
Software OPS Notes  
Booster Systems Briefs  
Flight Data File (FDF)  
Flight Control Operations Handbook (FCOH)  
Launch Commit Criteria (LCC)  
MPS Flight Measurement Location Document  
OI MDM/DSC Failure Impacts  
Operations and Maintenance Instructions (OMIs)  
Redundant Computer Set Logic Flow Diagrams (Lockheed Flows)  
Space Shuttle Systems Handbook (SSSH)  
Space Shuttle Main Engine Controller Software: Vol. 1 & 2 (Part I Spec)  
Space Shuttle Operational Flight Rules  
Phone List  
SSME Orientation Manual  
Ground Launch Sequencer (GLS) Description Document  
PAD Camera Location Document  
SCAP  
MPS Sequence Verification Checklist History

The following documents are contained only in the MPSR:

MPS Components Manual  
Helium Cal Curves  
Flight Software Program Notes and Waivers  
Shuttle Operational Data Book (SODB): Vol. I & III  
SRB Measurement Location Document  
SSME/NPSP Constants for the BOSS Performance Computation (Appendix C)  
SSME Ground Turnaround Operations, Maintenance, and Support  
Sequencing FSSR  
Previous Flight Anomaly Reports

RSRM Countdown Data Book  
SRB Launch Data Book  
CCC, MIS, EFN, MEWS User Guides  
Space Shuttle External Tank-System Definition Handbook Vol. I & III (Blue Books)  
Flight Log Books  
SSME Flight Operations Handbook (The White Book)  
SRB and RSRM Level III FRR Books

The following documents from previous flights are also kept in the MPSR:

MSFC Report – SRB Flight Evaluation Report  
MSFC Report – RSRM Flight Evaluation Report  
Boeing Integrated MPS Post Flight Final Report (Blue Book) ET-MPS Engineering Evaluation  
Final Report

### Console Cue Cards

The individual operators are responsible for having the required cue cards on console. The Booster Cue Card Book contains a list of the cue cards that must be used on console.

### PROCEDURE

#### A. OMI Updates

The OMI updates arrive on console in the FCR and MPSR in-boxes. The BSE operator updates the FCR OMIs and the MPS operator updates the MPSR OMIs.

#### B. FDF Updates

The FDF updates are provided to the flight team for each flight by the FDF section Lead. Typically, the BSE operator, the MPS operator, and the Main Engine operator updates the FCR FDF, the MPSR FDF, and the office FDF, respectively. All updates must be incorporated prior to the flight.

#### C. SSME Flight OPS Handbook (White Book) Updates

The updates to the SSME Flight OPS Handbook are delivered from Rocketdyne to several section personnel. The Main Engine operator for the flight must get these updates and make two copies to incorporate into both the FCR and MPSR copies of the SSME Flight OPS Handbook. The originals are kept in the Booster Section library files.

D. SRB and RSRM Level III FRR Books

The section SRB/RSRM Technical Lead will provide the SRB and RSRM Level III FRR Books for the MPS operator to take to the MPSR.

E. Boeing MPS Blue Book

The MPS operator ensures that the Boeing MPS Blue Books from (1) the previous flight and (2) the previous flight of the vehicle are taken to the MPSR console.

F. Flight Log Books

The flight team ensures that the Flight Log Books from (1) the previous flight and (2) the previous flight of the vehicle are taken to the MPSR console.

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## TITLE

MIS QUERY OPERATIONS

## PURPOSE

This SCP introduces the user to the Mission Information System (MIS) Query Builder application. The use and purpose of MIS Query in the mission environment will be discussed. Information needed by the Booster System Section is highlighted in this SCP. For more information see the MIS Query Builder User's Guide.

## DESCRIPTION

MIS Query is a computer application designed to assist flight controllers in providing flight operations support of Space Shuttle systems. MIS Query is the successor of a group of computer programs known as Shuttle Configuration Analysis Programs (SCAP). MIS Query allows the user to research the channelization and calibration of Orbiter, External Tank (ET), Solid Rocket Booster (SRB), and Spacelab Measurement Stimulus Identifications (MSIDs), Space Shuttle Program (SSP) Anomaly Reports, SSP Chit Reports, as well as other aspects of the Orbiter's attitude and specific missions.

## PROCEDURE

Note- This SCP will be more useful to the user if MIS Query is run while reading this SCP. To initiate the MIS Query application the "Query" option is selected from the "MIS" selection on the Master DNAV Global Applications menu. The MIS window is displayed after selecting the Query option. Once the window entitled "Mission Information System" appears, the user may begin a search. A search is a routine by which the computer, given certain parameters (Bus Terminal Unit (BTU) name, BTU card number, MSID, etc.), looks through the MIS database and finds articles of interest to the user. In conducting searches, the user may select from a list of preformed searches, or the user may create a new search.

### A. Preformed Searches

Preformed searches are searches that were created by other users and saved to the MIS database. Any other user may view the results of these searches. In many cases the searches were created with variables that the user viewing the search must fill in. The MIS database includes searches that may be used to find a certain MSID's channelization, calibration, and downlist format. To access these searches, the user must deselect all disciplines in the "Discipline" column. After this is done the user can scroll through the preformed searches listed under "File Name." The entry under "Description" gives a brief explanation of the search being performed. The following is a list of the most commonly used preformed searches.

#### MSID Channelization -

The file titled "MSID\_CHANNELIZATION" gives the channelization for a single parameter given its MSID. Selection of this file allows for the "View" button to be selected. Selection of the "View" button results in the "Query Variable Input" window being displayed. By entering an MSID and selecting the "Ok" button, the "MIS Data Viewer" window will be displayed. The window will contain the channelization information on the input MSID. The information will include the number of bits in the MSID, the data type, transducer range and the owner(s).

#### MSID Commonality –

This is a very useful search in troubleshooting seemingly unrelated problems. By selecting the file titled "MSID\_COMMONALITY" any common channelization between two or more MSIDs can be determined. Selection of the file activates the "View" button. When the View option is selected, the "Query Variable Input" comes up and the user can enter up to five MSIDs (two MSIDs are required to use this option). When the OK button is depressed, a search is conducted. The "MIS Data Viewer" window will display the channelization for the specific MSIDs. Determining common channelization, if any, is a simple process from this point.

#### MSID Calibration -

The MSID calibration coefficients can be seen by selecting the file titled "MSID\_CALIBRATION". Selection of this file allows for the "View" button to be selected. Selection of the "View" button results in the "Query Variable Input" window being displayed. By entering an MSID and selecting the "Ok" button, the "MIS Data Viewer" window will be displayed containing the desired information.

#### MSID Downlist Formats -

Similar to the MSID calibration, the telemetry downlist availability can be determined by selecting the "SCAP1-Orbiter-Telemetry Telemetry Parameters for Single Orbiter MSID" option.

The "booster" discipline, found on the main MIS window also has several preformed searches that may be used for the same purposes as the searches on the MIS database. In order to access this or any other discipline, the user must scroll down the "Discipline" column until "booster" or the user's specific discipline is found. To further narrow the search the user may select a specific user's file.

## B. Creating a Search

While almost any search the user would like to do have already been preformed, it the user may also create a search that suits their needs. This is a powerful option that allows the user to seek information on anything in the MIS database.

To create a new search, the user will go to the pull down menu labeled "File," and click on the "New". The "UNTITLED" screen will appear. The user then selects the "Edit" button in the "Selections" subwindow. The "Selection Editor" window will appear. By placing the arrow in the box under "No Table Selected," the user can choose the table where the desired data is located by right clicking and then selecting the table from the menu. Once a table has been selected, the title will appear in place of "No Table Selected" as well as a list of parameters that are available under that table. These parameters can be selected with a left click, and added to "Selections" subwindow with left click on the "Add" button. The user can select one parameter from one table, or multiple parameters from multiple tables. Once the user has all of the necessary parameters to be viewed in the "Selections" subwindow, the "Selections Editor" may be exited by selecting the "Close" button.

The "Conditions" subwindow allows the user to select the conditions by which MIS will look through its database. After clicking the "Edit" button, the user can select a table by right clicking in the top box. The value that MIS will search the database for may be chosen from the list. The user must fill out the rest of the selections in order to meet the needs of their search. Once the user has made all of the necessary conditions, "End" is selected as the last "Logical Operator," and the window is closed by selecting the "Close" button. The details of the options are covered in the MIS Query Builder User's Guide and will not be covered entirely in this SCP since they are entirely dependent on the user's needs.

**Important:** If the user has selected two different tables in the "Selections" subwindow, these tables must be linked in the "Conditions Editor" in order to produce accurate results. To do this the user begins in the "Conditions Editor" window by selecting a table and value in the "Left Operand" box in the same manner as before. Selecting the "Column" entry under "Value Type" allows the user to match the value in the "Left Operand" subwindow with the same value from a different table in the "Right Operand" subwindow.

Next, the user selects the values by which the search results will be ordered with a left click on those values in the right box of the "Order By" subwindow. To move these values into the left box, the user clicks on the arrow pointing left beneath the left box. Finally, the proper flight must be selected in the "flight" subwindow. To initiate the search, the user left clicks on the "Query" button. If a variable value type was entered in the "Conditions Editor," it will be necessary to enter that data at the computer's prompting. These variables may also be selected as "optional" in which a search will be conducted even if the user does not fill this data in. When the search is done, the results may be viewed in table form once the user left clicks on the view button. This search may be saved for future use by selecting the "Save As" option from the "File" pull down menu.

In order to exit MIS the user selects “Exit” from the “File” pull down menu.

REFERENCES

1. Mission Information System (MIS) Query Builder User’s Guide.

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## TITLE

MISSION EVALUATION WORKSTATION SYSTEM (MEWS) OPERATIONS

## PURPOSE

The purpose of this procedure is to explain how to obtain Booster data requests via MEWS/ODRC on the CCC OPS class workstations (DEC alphas). This SCP also addresses how to use PCMEWS on the office PCs to access ODRC. MEWS is used to produce graphical plots and tabular lists of Operational Data Retrieval Complex (ODRC) flight data. Only the most commonly used functions of MEWS are described in this SCP. For more information refer to the MEWS users guide, a copy is on console and one is in the Booster library. Although MEWS and PC MEWS are basically the same, some commands are named differently. Therefore, the example given in this SCP will explain the MEWS actions/commands and any differences for PCMEWS will be noted afterwards in [ ].

## PROCEDURE

MEWS is accessed on the OPS class workstations from the Master Display Navigation (DNAV) menu by selecting MEWS/ODRC under Global Apps. This will open a MEWS interface window labeled "**Minit**" (refer to Figure 4.1.7-I). [PCMEWS is accessed on the office PCs. Prior to use, the user must obtain the "pcm040199.exe" file and load PCMEWS onto their machine. Afterwards, the user must submit an JSC Form 237, "Computer Access Request" to allow their computer to access the ODRC database. This form can be obtained electronically at <http://forms.jsc.nasa.gov> or <http://jsc-isd-lib15.jsc.nasa.gov/formsdata/WordForm/JF237.doc>. Unlike MEWS, PCMEWS has 4 interface windows that are accessed separately by opening the PCMEWS folder and selecting the desired file: COD to ASCII Converter, Data Request Interface, Plot, or Tab.]

The **Minit** window allows the user to access all function of MEWS. [For PCMEWS, the user must select the "Data Request Interface" file from the PCMEWS folder. This will open a **MEWS Request Interface** window, see Figure 4.1.7-II.b]. The following options are available in the **Minit** window: File, Applications, Utilities, and Help. From the Applications pull-down, the user can open the ODRC Interface, Plot, and Tab windows. [For PCMEWS these are accessed individually from the folder as previously stated.]

The underbar ( \_ ) under a letter in the toolbar options indicates that further options are available "underneath" those particular options. Be patient while the selected option is being processed, this may take a minute (particularly when selecting ODRC Interface, Plot or Tab under Applications).

## EXAMPLE MEWS DATA REQUEST PROCEDURE

**Step 1:** Launch MEWS/ODRC and in the MEWS interface window, “*Minit*,” under the Applications pushbutton select “Plot” (*Plot* window will come up). [Select “Plot” from the PCMEWS folder to open *PCPlot* window.]. Refer to Figure 4.1.7-IV.a [Figure 4.1.7-IV.b] for an example of the Plot window.

**Step 2:** In the *Plot* [*PCPlot*] window, select a format for use with your data request.

This format can also be used when requesting data, so it will save you a step later. On the MCC workstations many formats are saved that should suit your purpose or could be modified later to suit your needs.

a. Select Subsystem:

In the *Plot* window, select Subsys from the toolbar and select “Change Subsystem” from the pull-down menu. In window that comes up, scroll through the list of acronyms and select the system you want, e.g. MPS, SSME, etc and click OK.

NOTE: On the toolbar in the *Plot* window, note that the word “Subsys” changes to the system you selected. If a subsystem was previously selected, a subsystem name may already be displayed.

[In the *PCPlot* window, click on the Subsystem: None button and in the window that comes up select the system you want, e.g. MPS, SSME, etc and click OK. On the toolbar in the *PCPlot* window, note that the word Subsystem: will now be followed by the system you selected (e.g. Subsystem: MPS).

NOTE: If a subsystem was previously selected, a subsystem name may already be displayed following the word “Subsystem.”]

b. Select Format

In the *Plot* window, select Format from the toolbar and select “Select Format File” from the pull-down menu.

In window, “Lister\_popup,” that comes up under ‘File Type’ on the right-hand side of the screen, select “Plot Formats.” From the list of previously created format files displayed, select the one you want from the list (e.g. SRBHYD) and click “Done.” The purpose of the format file is to tell the program what MSIDs you want to look up. If you wish to create a new format file, refer to Appendix A for instructions.

[Click on the Format: None button and in the window that comes up, select the format you want, e.g. 93HYDP. Again, in the ODRC window toolbar, the Format: button will now be followed by the format you selected (e.g. Format: SRBHYDP).]

**Step 3:** Open a data request interface, access the “*Request Data*” window and submit your data request.

In *Mini* window select Applications from the toolbar and select “ODRC Interface” from the resulting pull-down menu. The *ODRC Interface* window is shown in Figure 4.1.7-II.a. [For PCMEWS, select “Data Request Interface” from the PCMEWS folder to open a window called *MEWS Request Interface*. This window is shown in Figure 4.1.7-II.b]

a. Select Subsystem:

In the *ODRC Interface* window, select Subsys from the toolbar and select “Change Subsystem” from the pull-down menu. In window that comes up, scroll through the list of acronyms and select the system you want, e.g. MPS, SSME, etc and click OK.

NOTE: On the toolbar in the *ODRC Interface* window, note that the word “Subsys” changes to the system you selected. If a subsystem was previously selected, a subsystem name may already be displayed.

[Click on the Subsystem: None button and in the window that comes up, select the system you want, e.g. MPS, SSME, etc and click OK. On the toolbar in the *ODRC Interface* window, note that the word Subsystem: will now be followed by the system you selected (e.g. Subsystem: MPS).

NOTE: If a subsystem was previously selected, a subsystem name may already be displayed following the word “Subsystem.”]

b. Select Flight:

In the *ODRC Interface* window, select Flight from the toolbar and select “Change Flight” from the pull-down menu. In the window that comes up, select the flight you want, e.g. STS-099, 101, etc. When you select a flight id you can verify that is the flight you are interested in by checking the Orbiter name and tail number that are displayed.

NOTE: On the toolbar in the *Plot* window, Flight will change to the flight number you selected. If a flight was previously selected, a flight name may already be displayed.

[Click on the Flight: None button and in the window that comes up select the flight you want, e.g. STS-093, 101, etc. When you select a flight id you can verify that is the flight you are interested in by checking the OV id at the top of



the window (orbiter name (tail number)). Again, in the **ODRC Interface** window toolbar, the word Flight will now be followed by the flight number you selected (e.g. Flight: STS-093.)

**Step 4:** In the **ODRC [MEWS Request] Interface** window, select Request SSP from the toolbar and select “Operational Downlink” [SSP Request and “Shuttle OD...” respectively] or “Main Engine/Main Engine 1(2, 3)” [SSME and engine number].

a. Build Request Items block:

Under *Item Type* select the format you want to use the data in (e.g. Plot Format or MSID/PUI)

1. If you are not using a plot format, select “MSID/PUI” [MSID]. Individually enter the MSIDs you desire in the *Add Item [Item Name]* block and click return [*Add Item* button on display] after each, noting that a list will be generated under the *Items List [Selected Item]* block with the *Type* being designated as “msid.”
2. If a plot format will be used, select “Plot Format.” The MSIDs you require are listed in the Plot format; therefore, select “Files” from the *Select from list:* block

In the window that comes up click on the plot format that you want - this is the plot format that you looked at (or made) earlier. When you click on it, it should be grayed out. Click on “Done”. [For PCMEWS, after clicking on the format, hit the “Select” button, note the format appears in the *Selected Files* block, and then click OK.] The window will go away and then you will see the plot format title (e.g. SRB-HYD) listed under the *Items List [Selected Item]* block and the *Type* will denote what the msids relate to (e.g. ‘P’ for pressure [‘pfmt’ for plot format]).

b. Data Request Times and Rate [Request Times and Update Rate] block:

1. Next to *Time Reference*, click on the button until the desired time reference is selected (GMT, MET or EVENTS).
2. If GMT is selected, enter the Start and Stop times (Year Day:Hour:Min:Sec) in GMT of the data you want. If the time is unknown the user can request a Mission Events Table from ODRC that will list the times of all the significant events of the mission and the associated event code (use instead of GMT). In the **ODRC Interface [MEWS Request Interface]** window, select Reports [ODRC Reports] from the toolbar and select “Mission Events Table” from the pull-down menu (note: must select Flight name first). This will generate the times and codes for the mission you selected under the Flight: button.

3. Using the event code is an easy way to pick mission times (especially if you do not know the GMT off hand). However, the codes may not be updated on the day of flight. Some key events are as follows:
  - A03 Main engine start
  - A05 SRB ignition
  - A06 L/O (same time as SRB ignition)
  - A13 SRB Sep
  - A14 MECO
  - A15 ET Sep
  - A20 OMS-2 C/O

If you put in the EVENT code (e.g. A05) you can add time (or subtract) on to it. For example, put in the code A20 (for post OMS-2) and then under time put in the extra time you want (e.g. add 10 minutes to A20 so you can see the post OMS-2 vacuum inert). Fill in all the blanks under DDD:HH:MM:SS.

4. Enter the desired sample rate in the *Update Rate* box. One sample per second is usually sufficient. If full rate data is desired enter "0". Be careful though, a lot of data will be retrieved.
5. In the *Run No* box {PC MEWS only}, enter one if required

c. Product Options block:

1. Under *Calibration* box click on the button to scroll through choices (uncalibrated, MCC calibrations, Shuttle Data Tape) until "Shuttle Data Tape" is displayed. [For PCMEWS select from the pull-down menu by clicking on the arrow button.]
2. Under the *Data Type* box, click through the options until "BEST" is displayed. [For PCMEWS a popup list is shown by clicking on the arrow button.]
3. Under *Product Type*, click through the options until COD is displayed. [For PCMEWS a popup list is shown by clicking on the arrow button.]
4. Under *Filename* {PCMEWS only} enter the name you want to call your datafile

d. Product destination block {Workstation MEWS only}:

1. *Node Address* should display the workstation you are logged into (e.g. white-mpsr19)
2. In the *Run Number* box, enter one if required
3. In the *Filename* box, enter the name you want to call your datafile.

**Step 5:** When complete with all entries in the *Request Data* window, click on the “Request” button. This will return you to the *ODRC [MEWS Request] Interface* window.

Under the *ODRC interface* window you will see the request being “SUBMITTED”, then “RUNNING” while it is gathering data. If there is a problem with your request, the status will be changed to “ODRCERR” or “ABORTED.” Read the comments in the “Messages” part of the window. If your request is accepted and is Running, wait for it to say “COMPLETED.” Refer to Figure 4.1.7-II.a [Figure 4.1.7-II.b]

Go back to *Plot* window

**Step 6:** *Plot* Window (after data requested)

1. Select Subsystem, Flight and Format:  
Select the appropriate Subsystem and Flight as you did in Step 3 for the *ODRC [MEWS Request] Interface* window. The Format should have been already selected in Step 2.
2. Select Data File:  
In the *Plot* window, select Data from the toolbar and select “Change Data” from the pull-down menu. In the window that comes up, scroll through the list until you find the name you assigned your datafile in the *Request Data* window, select it and click OK.

[Click on the Data File: None button and in the window that comes up select the name you assigned your data file in the *Request Data* window, click the “Select” button and then click OK. On the toolbar in the *Plot* window, note that the Plot: None button will now be followed by the file name you selected (e.g. Data File: 93HYDP).

NOTE: If a subsystem was previously selected, a subsystem name may already be displayed following the word “Subsystem.”]

3. On the *Plot* window toolbar, select Plot from the toolbar and select “View Plot”

Your plot should appear. Refer to Figure 4.1.7-IV.a [Figure 4.1.7-IV.b]

**Step 7** *Plot* Window (after data plotted)

After your plot is generated, you can zoom in on specific areas in your plot using “X-axis Zoom (mouse)” and “Y-Axis Zoom (mouse)” from the pull-down menu under Scale on the toolbar. Use the mouse to click on two points that set the new bounds and select “View Plot” from under the Plot option on the toolbar.

## Appendix A

If the format file that you wanted was not in the list under the format pull-down of the *Plot* window then you need to create your own format file as follows:

### Plot Window

Select Format from the toolbar:

Select: “Create Format File”

In the window that comes up: Type the name you want to call the format file (e.g. SRBHYDP). Choose permanent or temporary and then click on “create.” With permanent the format file will be available in the future. This will open an *Editor MEWS Format [NEW FMT]* window. Refer to Figure 4.1.7-V.

Under *Editor MEWS Format [NEW FMT]* window

- Type in the title you want to give the plot
- Type in the information requested under GRID, MSID and NOMENCLATURE. Click on APPLY. The MSID will now be listed under the grid box you chose (1,2,3).

Note:

- 1) MSID is the information you want to plot.
  - 2) Nomenclature is the English translation of what the MSID is that you want put on the plot.
  - 3) The grid tells it what plot to put it on (1,2 or 3). You have three grids (plots) that you can select. Each grid will give you a different plot but on the same page as the other plots. For example if you put MSIDs in each grid then you would get 3 plots on one page. If you put multiple (or single) MSIDs in only one grid then you would get a single plot of those MSIDs on a page.
- Once everything is setup how you want it click on SAVE

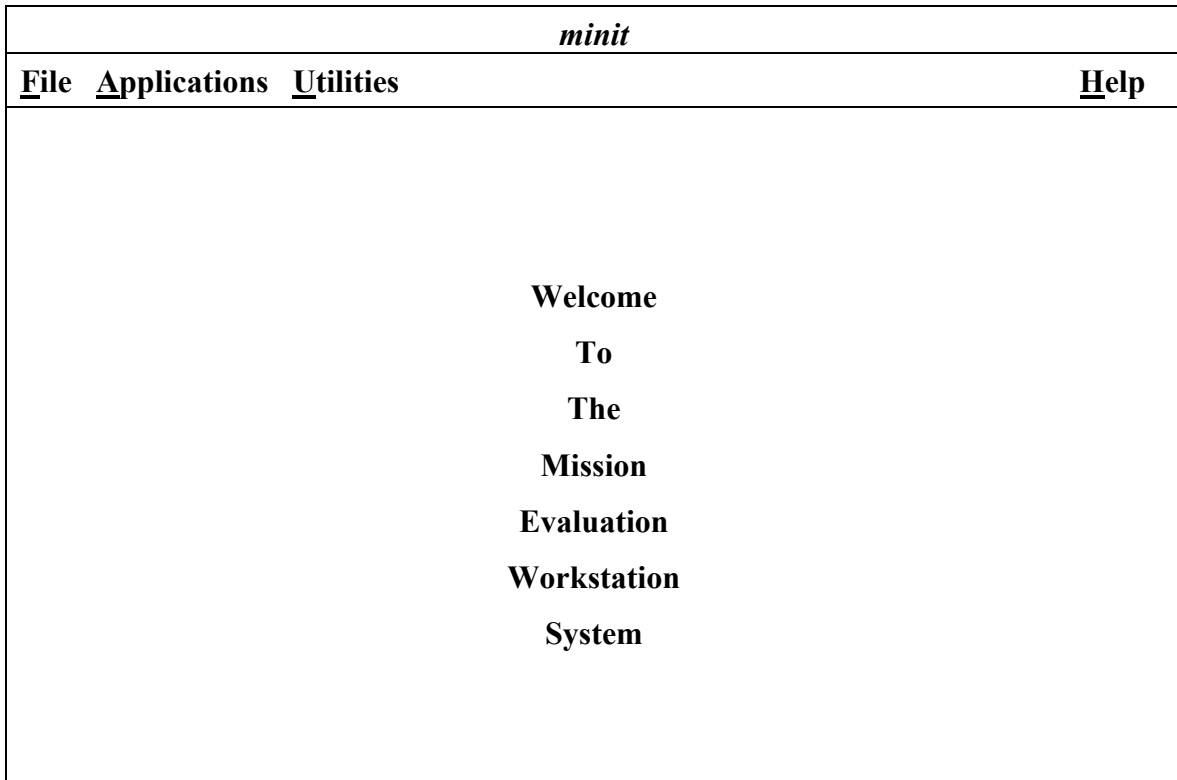


Figure 4.1.7-I– MEWS Interface window, “minit”

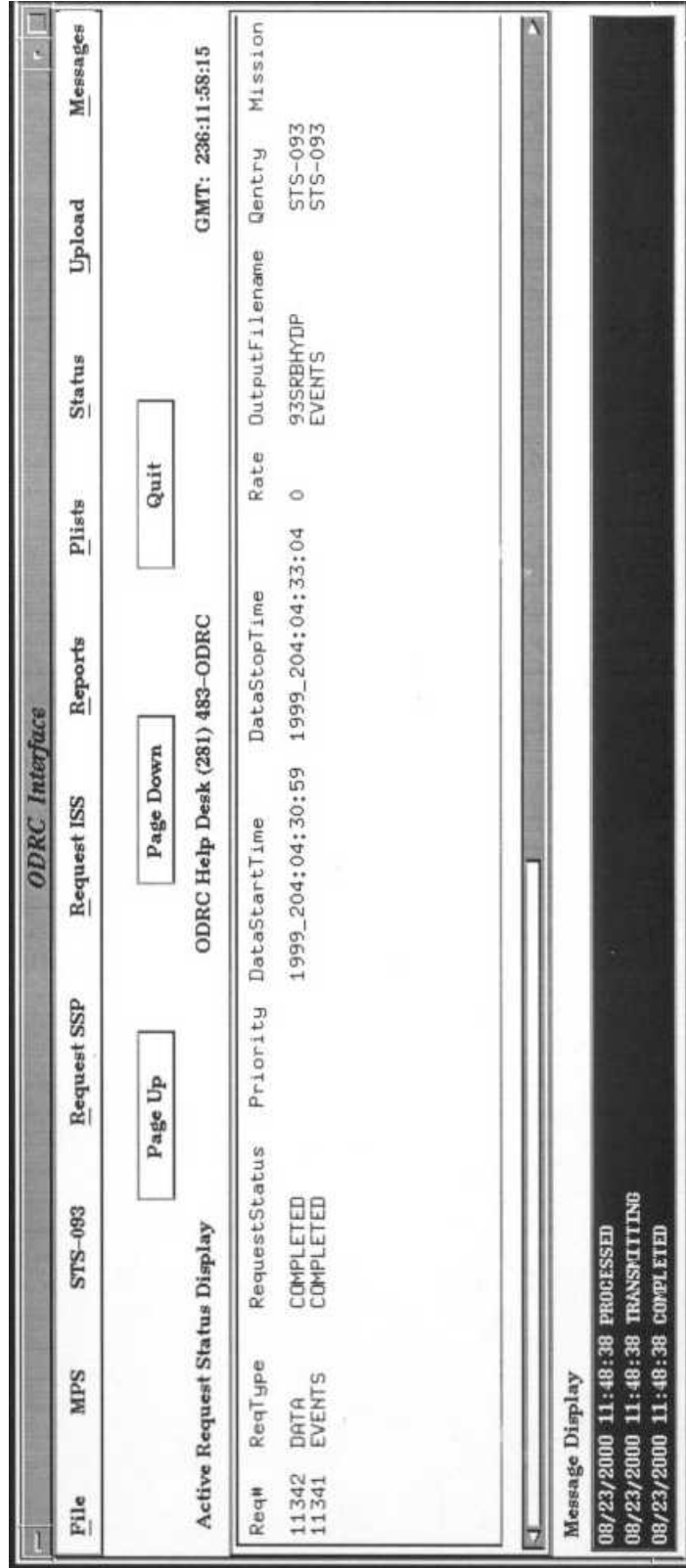


Figure 4.1.7-II.a –MEWS Interface window, “ODRC Interface.”

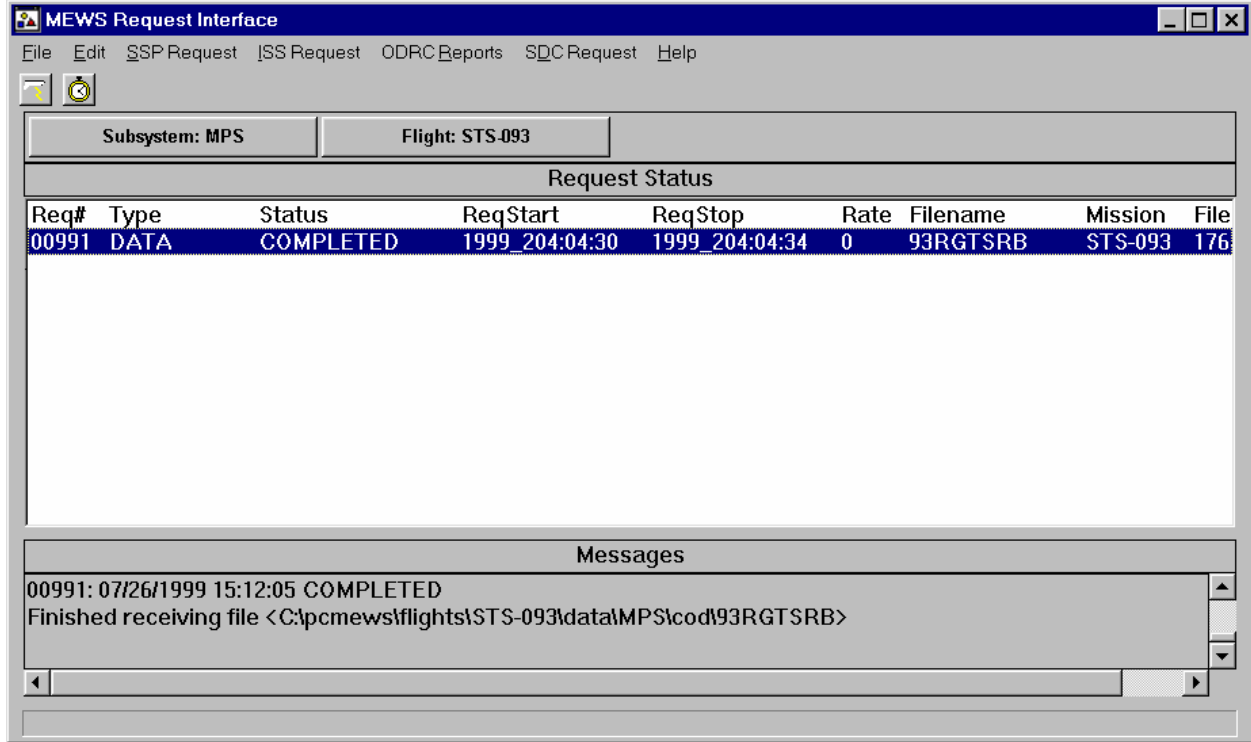


Figure 4.1.7-II.b – PCMEWS Interface window, MEWS Request Interface.”

**Request Operational Downlink Data**

**Options**

**Build Request Items List**

Add Item	Item Type	Items List	Type
<input type="text"/>	<input type="checkbox"/> Plot Format	<input type="text"/>	
	<input type="checkbox"/> Tab Format		
	<input type="checkbox"/> Plot Family		
	<input type="checkbox"/> Tab Family		
	<input type="checkbox"/> Verif Format		
	<input type="checkbox"/> MSID		
	<input type="checkbox"/> Local Plist		
	<input type="checkbox"/> DPS Format		

**ODRC Plist**

**MED Override**

**Data Request Times And Rate**

Start   :  :  :  :  Time Reference

Stop   :  :  :  :  Update Rate

(secs between samples 0=full)

**Select Product Options**

Calibration  Data Type  Product Type

**Product Destination**

Node Address  Run Number  Filename

**Select Action**

Figure 4.1.7-III.a – MEWS Data request window



Item Name	Item Type	Selected Item	Type
	◆ Plot Format	RgtSRB_Hyd	pfmt
	◇ Tab Format		
	◇ Plot Family		
	◇ Tab Family		
	◇ Verif Format		
	◇ MSID / PUI		
	◇ Local Plist		
	◇ DPS Format		
	◇ ODRC Plist		

Request Times and Update Rate

Event/Year	ddd	hh	mm	ss	Time Ref
Start 1999	204	04	30	00	G.m.t
Stop 1999	204	04	34	00	

Update Rate: 0 (secs/sample, 0=full rate)

Run No.: [ ] FM Group ID: [ ]

Product Options

Calibration	Data Type	Product Type	Filename
Shuttle Data Tape	Best	NCOD	93RGTSRB

Figure 4.1.7-III.b – PCMEWS Data request window

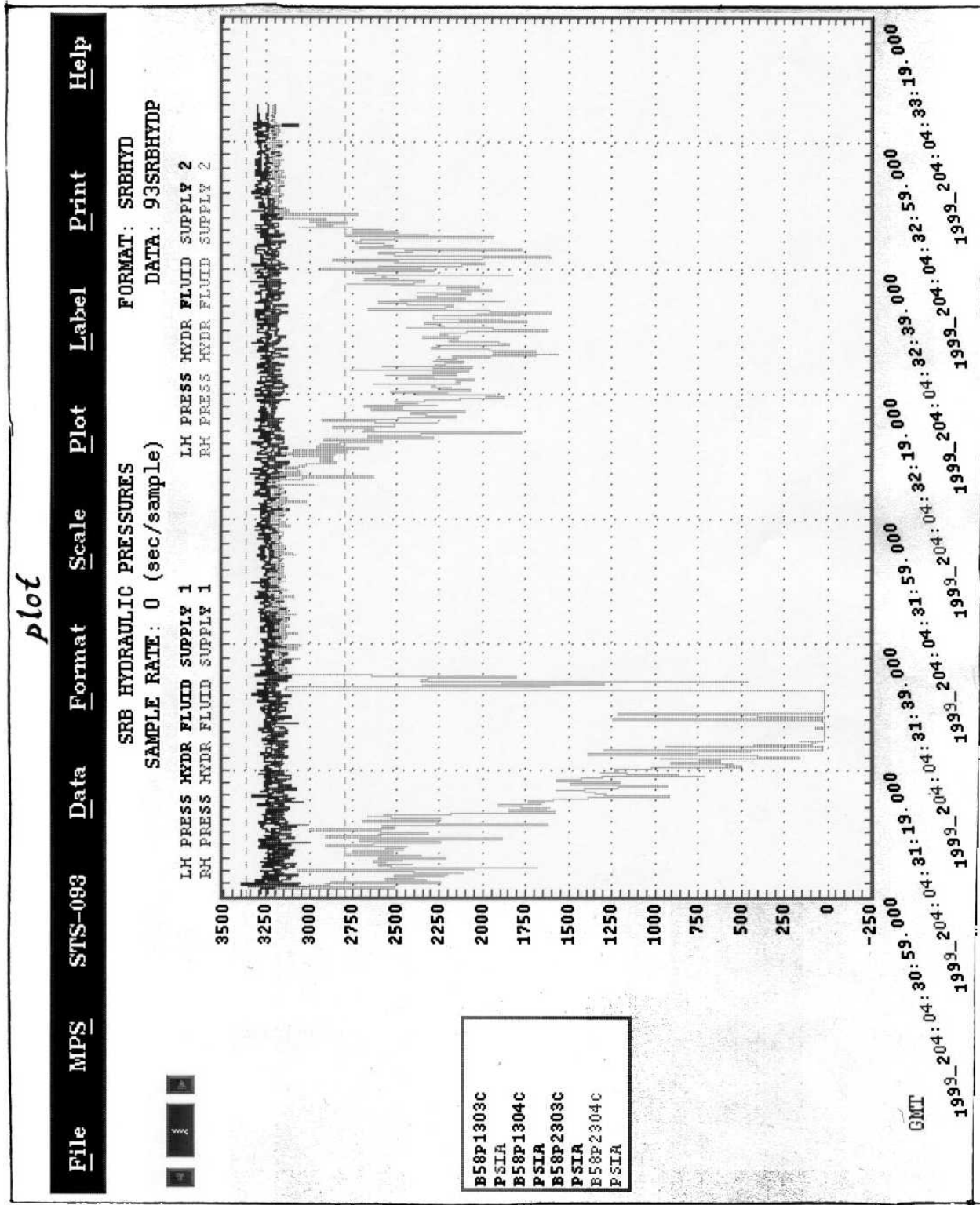


Figure 4.1.7-IV.a – MEWS Plot window

Plot of STS-93's RH SRB Hydraulic Pressures

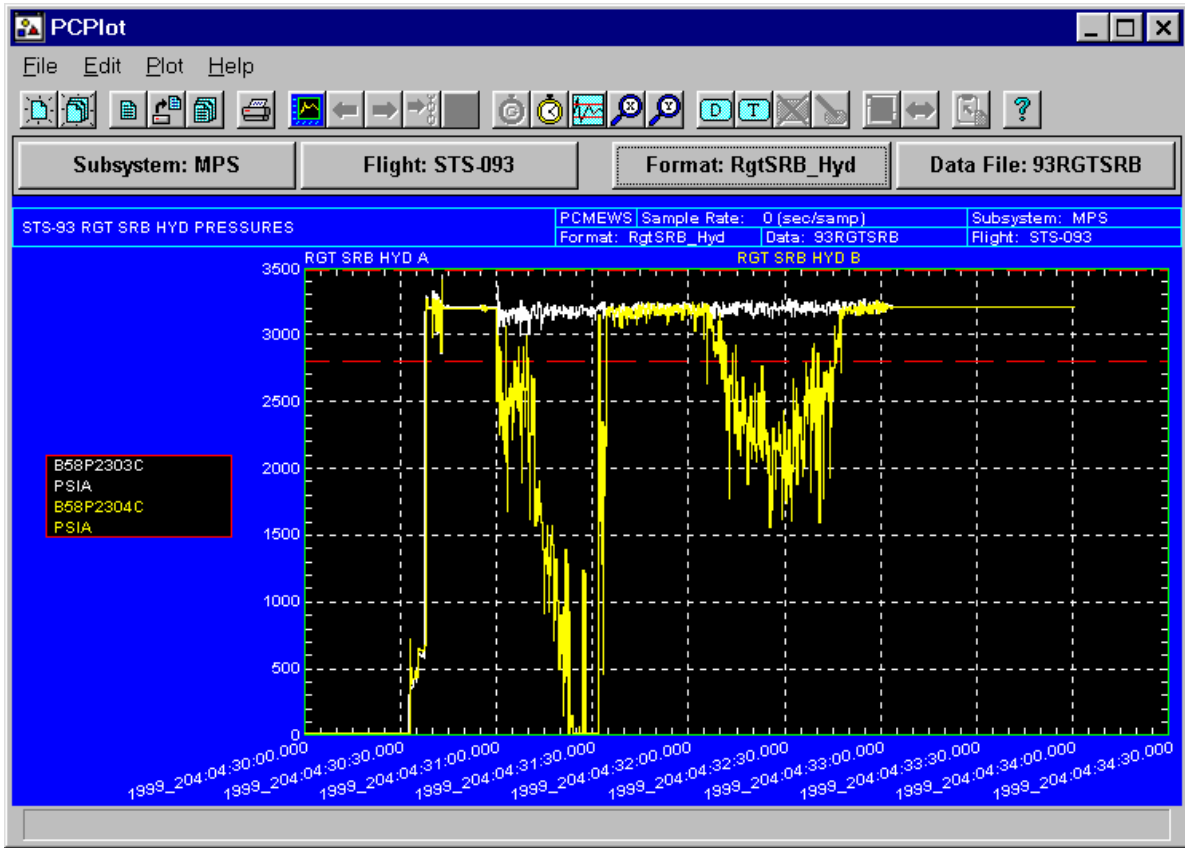


Figure 4.1.7-IV.b – PCMEWS Plot window

Plot of STS-93's RH SRB Hydraulic Pressures

The screenshot shows a software window titled "NEW\_FMT" with a close button (X) in the top right corner. The window is divided into several sections:

- Plot Title:** A text box containing "STS-93 RGT SRB HYD PRESSURES".
- Grid Management:** A table with columns "Grid", "MSID", and "Nomenclature".

Grid	MSID	Nomenclature	Add	Modify	Delete
1	B58P2304C	RGT SRB HYD PRESS B			
- Grid 1: ANALOG:** A panel for configuring the first grid. It includes:
  - Major Divisions: 7
  - List MSIDs: A button that opens a list containing "B58P2303C".
  - Y Low: 0
  - Y High: 3500
  - Limit 1: 2800
  - Limit 2: 3486
- Grid 2: ANALOG:** A panel for configuring the second grid, with empty input fields for Major Divisions, Y Low, Y High, Limit 1, and Limit 2.
- Grid 3: ANALOG:** A panel for configuring the third grid, with empty input fields for Major Divisions, Y Low, Y High, Limit 1, and Limit 2.
- Buttons:** "SAVE", "Cancel", and "X-Plot: INACTIVE" are located at the bottom of the window.

Figure 4.1.7-V – MEWS/PCMEWS New Plot Format Window

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TITLE

MCC PROBLEM/DISCREPANCY REPORTING PROCEDURES

PURPOSE

The procedures for reporting a problem in Mission Control Center (MCC) hardware or software are given in this SCP. Included are lists of whom to contact and how to fill out and submit the Discrepancy Report (DR) form.

DESCRIPTION

When a problem occurs in the MCC, it is usually necessary to inform someone responsible for that particular system or software of the problem so that they can correct it. Reporting problems can be accomplished in one of two ways. The correct person can be contacted over a voice loop, or a form may be submitted detailing the problem symptoms. On most occasions, both types of communication are required.

PROCEDURE

After consulting with the other operators to ensure that a real problem exists, the person discovering the problem must notify the appropriate personnel. A listing of the most frequently encountered problem areas, the appropriate console contact, and the voice loop or phone number to reach the responsible party is given in Table 4.1.10-I. A complete listing of contacts may be found in the Flight Control Operations Handbook (FCOH), Section 1.7, MCC/SMS Problem Reporting.

<b>Problem</b>	<b>Contact</b>	<b>Loop/Phone</b>
Console Hardware	WSS	WSS Call
Activity Initialization	GC	GC Call
Keypad, Headset, Footswitch	GC	GC Call
Platform Software/OS	WSS	WSS Call
MCC Facilities (Lights, A/C)	GC	GC Call
ODRC Problems	ODRC Help Desk	x3-ODRC or x36372
TV Monitor	FSM	DSS 2

TABLE 4.1.10-I. - MCC PROBLEM CONTACTS LIST

## Writing an Anomaly Report

If the problem is not easily resolved, an Anomaly Report (AR) must be submitted. Blank AR forms are available from either the GC (Ground Control) console position. The procedure for filling out this form is found in Section 1.7 of the FCOH. The user should make a copy for his/her own records of the completed AR form and any supporting documentation (hard copies of displays, additional descriptions of the problem, etc.). The AR and any supporting documentation are then submitted to the GC console. The operator should make every effort to submit the AR prior to the end of the activity that the problem was identified on (prior to end of prelaunch shift, end of simulation, etc.).

Note: Since the Booster monitor has more experience with the Shuttle Mission Simulator (SMS) model and with how it should respond, it is typically the Booster monitor's responsibility to AR problems with the SMS. However, nothing prevents the Booster operator from writing an AR against the SMS.

## Tracking Anomaly Reports

Each AR written by section personnel is tracked in a database maintained by SFOC called DRTS or the "DR Tracking System" (the term AR and DR are used somewhat interchangeably). This database is updated to show closeout dates and assigned actions. The closed ARs are eventually returned to the originator with a short explanation of why the AR has been closed out. If the originator disagrees with the rationale for the AR closure, it is his/her responsibility to contact the listed personnel and inform them why the AR should not be closed. Verification of closure on the AR is the primary reason the operator should keep copies of all the documentation that was submitted with the AR.

If a subsequent flight or load checkout is conducted and a previously AR'd problem remains, this database can be used to allow the new AR to reference an old one. Copies of the original AR and any received closeouts are kept on file for a period of approximately three years after the date of closure for major problems and one year for minor ones.

## REFERENCES

1. Flight Control Operations Handbook - Final Rev. B, CPN 7.

## TITLE

### USER DATA FILE CERTIFICATION PROCEDURE

## PURPOSE

This SCP describes standard Booster practices for initiating and certifying changes to user data files used on console. User data files include, but are not limited to, data files defining user interface or software interaction to such applications as MSK, CRANS, ELOG, RTPLOT, and ISP/BFS/BSE Channel.

NOTE 1: Flight unique data files such as the ISP Limit checkpoint for flight and the Tag and Vmass data files are controlled by the flight team and double verified per the Preflight Prep Checklist. The certification procedures described in this SCP DO NOT apply to those files (see Section 3, KNOWN EXEMPTIONS).

NOTE 2: The process contained in this SCP only applies to user-configurable data files, not to applications. Applications are governed under USA001235. The term “software” in this SCP refers to data files.

The information contained in the Software Change Procedure below was taken from the DF SMP (Document number WI DF-26).

## 1.0 SOFTWARE CHANGE PROCEDURE

The Configuration Management (CM) system, coupled with the certification process, baselines a certified version of software for a given mission, stage, or increment. The following policy defines how that baseline is modified. The procedure for identifying, authorizing, implementing, certifying, documenting, and maintaining configuration control of software changes is broken into three linear processes defined in the following sections. A flow chart of the entire process is located in Appendix A.

### 1.1 CHANGE PROCESS

The following paragraphs address the process to identify, approve, and assign changes to software maintained by the Systems Division (including updates to MCC workstation and PC based software applications). The USA CPR process applies for USA-sustained applications.

#### 1.1.1 Identifying and Authoring a Change Request

When an error or potential new capability for software is identified, users complete the standard Booster Change Request (CR) form documenting the file name, version number, and details of the proposed change. A paper or electronic copy, depending on the system currently implemented by the Booster Group, of this CR is submitted to the group lead for approval. Implementation of the CR will not begin before the group lead has approved the change, assigned the work to a specific implementer and tester, and given the CR form to the intended implementer. The number of each CR



is a sequential number prefixed with the word “Booster” The Group Lead or Discipline Technical Representative (DTR) is responsible for assigning CR numbers and maintaining a list of CR numbers with associated CR titles. The standard Booster CR form is located in Appendix B of this document.

NOTE: Updates to NON-FLIGHT SPECIFIC user data files defined in the Derivation of BOSS Constants document or in the Derivation of MET Constants document may also require a PCN to the associated notebook reflecting the changes made by the Booster Group CR.

#### 1.1.2 Change Approval

The group lead evaluates the merits of each change proposal based on technical rationale, urgency, timeframe, and resource requirements. If a change is deemed complex or controversial, the group lead may request the CR be presented for group discussion before approving the change. This process ensures that the change is beneficial to the group and that group resources are appropriately allocated. Change requests to division-wide applications will be reviewed with all affected disciplines.

#### 1.1.3 Work Assignments

Once the group lead approves the CR, the group lead then assigns personnel to implement the CR. This assignment may be one or more individuals to:

- a. Perform the actual software change
- b. Update the application notebook
- c. Develop the appropriate test plan/procedure (if required)
- d. Test/certify the software.

The group lead will assign at least two testers to each data file CR, with one of those being the implementer. Depending on the complexity of the change, the group lead may opt to assign more than two testers. The group lead will determine if specific test plans or procedures are required. For minor changes a test plan/procedure may not be required. It is recommended that the tester not implementing the change be in charge of the test plan development, in order to provide some independent testing authority.

#### 1.1.4 Real-Time Ops Addendums

During real-time ops (including prelaunch), the FCR operator can initiate the change process without initially completing a CR form or obtaining group lead approval for mission critical or mission success changes. In this instance, the FCR operator assumes the responsibility of the group lead in approving the request and assigning the implementation and certification team due to the urgency of the change. The FCR operator can choose to implement the desired change, or assign

other qualified personnel to make the modifications. If the FCR operator implements the change, another qualified person must test and certify the display, thus ensuring a minimum of two people verifies the change. GA personnel may not be qualified to serve these functions.

Only changes that meet the mission success/mission critical designation are exempt from the standard change process. Non-mission critical/mission success changes require all approvals, testing, and documentation be completed before promotion to the CERT repository. A waiver of the certification deadline described in section 2.1 may also be included.

Although a CR is not required prior to making a mandatory change in real-time, A CR must be filled out and submitted as soon as possible after the change has been completed. A CR is required to document the change and associated rationale. Details of the change should also be thoroughly documented in the console log and handovers.

***Change Control Procedures documented in USA001235 must be followed for this real-time process.***

## 1.2 CONFIGURATION MANAGEMENT PROCESS

The following paragraphs describe how software will be controlled and modified once a change request has been approved.

### 1.2.1 Checking Out Files

To implement the assigned CR, an authorized user checks out the desired file(s) from the specified CM system. When a file is checked out for edits, the CM system prevents any other user from also checking out the same file. This prevents the same file being modified by multiple users simultaneously. As stated previously, the group lead is responsible for identifying personnel with check-out/check-in permissions in the CM system.

### 1.2.2 Implementing the CR

After checking the file out, the user implements the assigned CR. In addition to technical changes, the implementer increments the version number of the software and, if comments are supported, updates the modification history of the file. During the implementation stage, the functionality of the change should be tested, if possible, before checking the file back into the CM system to begin formal certification testing. The file can remain checked out until all changes are finalized. A more thorough testing and evaluation by the implementer will likely expedite the certification process as a whole. When the change has been completed, the implementer signs the authorizing change request in the "Implementation Completed" section.

Notes on the use of RCS -

- 1) The first line of most of our display data files contains the version number when it is checked into RCS. It will start with # \$ID... or something like that. DON'T MESS WITH THAT LINE. DON'T CHANGE ANYTHING. LEAVE IT ALONE.
- 2) This line gets updated when it is checked in AFTER it is certified. The GA should be able to tell us what number will be there before it is checked in. That number will be the version number on the cert paperwork.
- 3) Since the version line gets updated AFTER it is checked in, you can't make hardcopies of the display until after it is checked in.

### 1.2.3 Moving Files Into Uncert

When the implementer completes the CR implementation and is ready for evaluation and testing, the file is moved into the uncert environment for testing and in order to gain shelf life during generic sims.

### 1.2.4 Real-Time Ops Addendums

If a FCR operator identifies a mission critical/mission success change during real-time operations, an authorized CM system user is needed to check out and subsequently check in the file. If there is no authorized CM system user available, the operator may copy the file from the appropriate operational subdirectory of the CERT repository and make the needed modifications. When an authorized CM system user becomes available, the modified file should be checked into the CM database.

There is no requirement for the GA to install this modified file in the same operational directory in the UNCERT repository for certification testing. In this case, the new software may be executed from a terminal window, such as X-Term, in the mission activity to evaluate and test the change.

***Change Control Procedures documented in USA001235 must be followed for this real-time process.***

### 1.3 CERTIFICATION AND DOCUMENTATION PROCESS

The following paragraphs describe how software will be certified and documented once a change request has been implemented.

#### 1.3.1 DIFF Generation and Review

One method of verifying a simple change to a data file is through the creation of a “DIFF” between the certified file and the updated file via the UNIX line command “*diff*”. Note that this is not the official DIFF that is created by the GA when the file is moved back into cert ops. The assigned implementer can use this DIFF to check the file for inadvertent changes. If the file type does not support the DIFF command, other methods of revision monitoring, such as “Track Changes” in Microsoft Office products, should be utilized to compare versions. For some complex changes, where extensive changes have been made to the file, a DIFF file may not be very beneficial because the massive amount of information the DIFF file might contain. In these cases, other forms of review and verification will be required.

When testing of the file is complete and the Certification Approval Page (CAP) has been signed off, the file is checked into cert ops. At this time, the GA creates the official DIFF of the original file and the newly certified file along with a change log. Printouts of these items are placed in the application notebook as discussed in 1.3.3.

#### 1.3.2 Technical and Functional Review of Changes

The assigned tester(s) evaluate the file in UNCERT activities for functionality and technical implementation of the CR per the test plan for the change. This testing will ensure that the change was implemented correctly and allow the new file to acquire shelf life. The test plan is to be designed to fully verify the functionality of the changed elements of the software, similar to certification of a new application, and documented in the Application Notebook. The required elements of the test plan to achieve this objective are left to the discretion of the group lead.

#### 1.3.3 Application Notebook

The Application Notebook provides traceability and tracking of how the software is updated over the years. The group lead designates an individual responsible for updating the Application Notebook to include the following:

- a. The Certification Approval Page (CAP) - This is the formal signoff paperwork for certification of the software. At a minimum, the tester(s), DTR, Group Lead, and Branch Chief sign-off that the software has been properly updated, tested and that all required documentation is provided in the Application Notebook. The CAP is always the first page of the Application Notebook. The standard Booster CAP form is located in Appendix C of this document. Since this document is

completed before the file is moved into cert ops (the point at which the revision number is set), a future revision number may be obtained for the CAP from the GA.

- b. A copy of the signed Change Request(s) – the CR(s) must be completed and all required signatures obtained prior to implementation.
- c. A printout of the DIFF report. – The GA shall generate, if possible, a difference report. This report may reference a file name on the target platform.
- d. Code Printout - A hardcopy of the new code
- e. Screen Print – If the software has a display that appears on the screen, a hard copy of this display is printed and the changes highlighted.
- f. An updated version change log – A change log documenting each configuration item version is required. The GA will create this log, and it shall include:
  1. Date of the change
  2. Name(s) of the implementer
  3. List of CR number(s) completed with the change.
- g. The Test Section (if required) – The test section of the application notebook consists of the following:
  1. The test plan – If the group lead or tester determines the change is complex enough to warrant a test plan, the application notebook must contain a test plan for the software. The test plan identifies the number of testers required and how the testing is performed. It is up to the Group Lead to decide on the actual number of testers required. However, a minimum of one tester who was not the software developer is required. The test plan also provides instructions on how to perform the tests. This may be a test script or other form of checklist. Test results are always documented by the tester.
  2. The completed test procedures – This is the results of the testing as described in the test plan.
  3. The test results statement – After testing, the tester is responsible for providing a statement of the test results. This can be a one or two line statement or several pages. The objective of this statement is a testament from the tester that all required testing was performed, satisfactorily completed, and the software is ready for operational use.
- h. A list of External Dependencies - This a list of all the external data sources used by the application file, such as SODB, Flight Rules, TDDP, outputs from other

external sources (e.g. applications) from other disciplines, etc. The values or equations may be hard coded into the application. **This list shall be updated/verified when the application file is re-certified.**

- i. A list of Dependent Users - This is a listing of all external users that use the output of your application file. This will serve as the contact list of the users to be notified when an application file is modified (the contact is simple - something on the order of "You are listed as a dependent user of XXX display. This email is to make you aware of the following changes made to XXX..."). **This list shall be updated/verified when the application file is re-certified**
- j. Applicability - This is a listing of applicability and/or any restrictions on the file such as all, vehicle specific, flight specific, INC/Stage specific, FSW compatibility (OI load), etc.

#### 1.3.4 Check into CERT RCS

Once the Application Notebook has been signed-off by all certifying parties, the DTR or group lead informs the GA that the file has been tested, documented and is ready for promotion within the CM system as the new certified baseline version for all UNCERT and CERT activities, and provides the GA with the cert paperwork so that the GA can update the change log.

NOTE: At this point, the Application Notebook should be complete, with the exception of the GA created DIFF and change log. These items are added after the GA checks the file into CERT RCS.

#### 1.3.5 Notification

Notification of the implemented changes will be provided to group members and dependent users. The group lead will select the process used to notify group and dependent users of changes to the baseline files. A list of dependent users is maintained in the Application Notebook.

#### 1.3.6 Real-Time Modifications

By utilizing the command line as well as other available tools (e.g. DIFF review), the FCR operator and a minimum one other certified operator or qualified GA certifies the implemented change. Once certification is complete, the FCR operator informs the GA to promote the file to the CERT repository for use during the current mission. The operator also notifies the group lead of the change at the next convenient opportunity.

There is no requirement in the DF SMP to immediately update the Application Notebook during the current mission. For a real-time change, the FCR operator documents the change details in the Handover Log so that the oncoming teams are aware that the current

version has been modified. As mentioned above, the FCR operator is also responsible for filling out a CR form at the earliest possible convenience. The GA must inform the GC of the change (per USA001235). If the change impacts other disciplines, then the GA must also inform the USA Mission Manager of the change (per USA001235). The FCR operator shall also be responsible for assessing if the change is relevant for subsequent missions and, if so, authoring a change request. If the change will not be retained, then post mission the file will be reverted to the previous version in the CM system. If the change is to be permanent, then full certification and documentation of the change utilizing the standard processes is required prior the next SSP flight. The Application Notebook should be updated and a thorough review performed prior to making any further real-time changes to the file. This ensures the notebook is up to date and captures all changes made during the current mission/stage/increment.

## 2.0 DEADLINE AND IMPLEMENTATION SCHEDULE

### 2.1 LAUNCH-30 days

A deadline on software promotion is established in order to ensure that software has been properly tested and verified, as well as to provide shelf life before use. The deadline for promotion of SSP software that will be used to support a particular shuttle mission is 30 days prior to launch of that mission. Any software identified as a critical processor is subject to the more stringent deadline schedule outlined in USA002295.

The above deadlines indicate when software promotion, not certification, will be completed. Accordingly, the implementer must allow sufficient time before the deadline for the GA to promote and verify the new software. To minimize the chances of delays in promotion, certified software should be checked in and the GA notified by L-35.

Software not meeting these deadlines requires the approval of the Systems Division Chief prior to promotion. The GA may promote files to the CERT repository inside of L-30 without approval of the managing board (e.g. JET).

### 2.2 CONFIGURATION AUDIT

Prior to each SSP mission, the flight team verifies that the software/application file version number shows the expected version. Additionally, prior to flight day, the GA should verify that the expected certified version of each software file is available for use and that all links/scripts navigate to the appropriate version. It should also be verified that no unexpected changes have been made to the certified version. This audit ensures that any updates have been promoted to the CERT repository as expected and that the Booster Group's files are ready for the mission. A listing (Configuration Item List) of all the certified versions of the software files will be maintained by the group lead/DTR and supplied to the Flight Team and GA for this audit. It is the group lead's discretion as to when and how within the L-30 timeframe this audit is performed.

Documentation/confirmation of this audit will be maintained by the group lead and made available for inputs to the delta Certification of Flight Readiness (CoFR) at L-1 week.

### 3.0 KNOWN EXEMPTIONS

The following paragraphs describe any known exemptions that cannot follow the SMP as written. Any files not mentioned below that do not meet the requirements of this SMP require a waiver from the Division.

#### 3.1 LIMIT MANAGER

Due to the dynamic nature of the Shuttle systems and the associated telemetry data, the DF SMP exempts Limit Manager files from the above procedure. Instead, the Flight Team updates and maintains the limit files, as described in the Limit Manager SCP. A baseline version of Limit Manager should be certified and this checkpoint controlled in the CM system if possible. For real time updates to limits, it is the Flight Team's discretion how to identify, manage, certify, and document these changes. The group lead should evaluate whether the new limits should be incorporated into the baseline checkpoint or if it is a mission-specific change.

#### 3.2 FLIGHT SPECIFIC ITEMS

Any software that is constrained by Flight Specific inputs may not be able to adhere to the L-30 constraint. These updates may be performed and verified pre-launch but are still required to follow defined change, certification, and documentation processes governed by the Booster SCPs. The Booster flight specific items that are updated within the L-30 window are the Vmass and Space Shuttle Main Engine (SSME) Tag files. Both of these updates are controlled by SCPs and verified before launch.

### 4.0 EXTERNAL APPLICATIONS

External applications are defined as applications used by DF that originate from external sources outside of the Division, such as Power Balance Model spreadsheets from Boeing/Rocketdyne. Tools and spreadsheets acquired from external sources should be certified by the originating organization prior to use by DF personnel. A copy of or access to the certification paperwork (i.e. signature page) should be obtained and verified prior to use by DF personnel.

### 5.0 REFERENCES

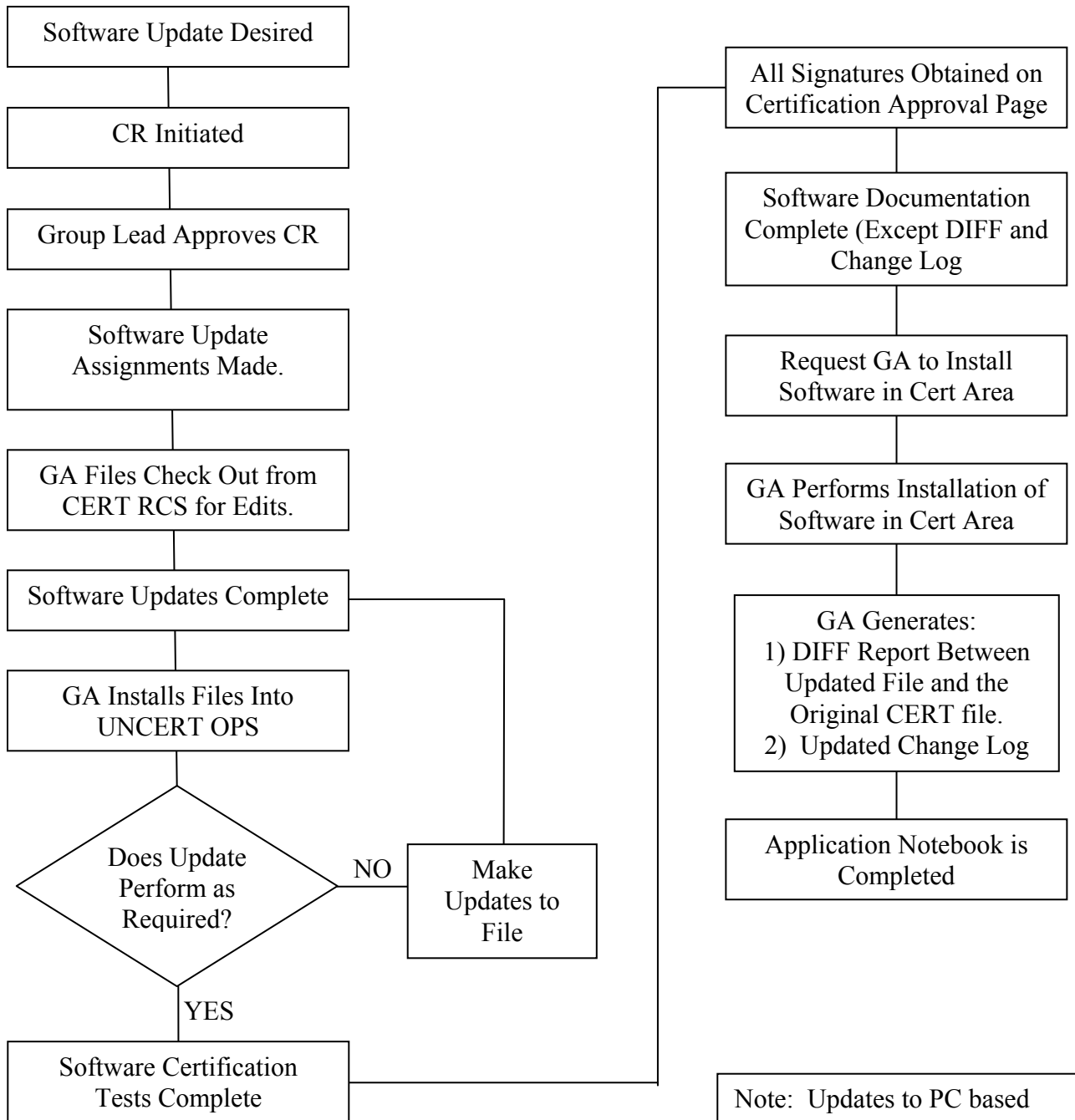
1. Systems Division Software Management Plan (WI DF-26), Rev Basic, February 13, 2004.



# Appendix A

## Process Flow

The following provides the basic flow diagram for making updates to Booster software



Note: Updates to PC based software (such as TODMAN) follow a similar Process Flow, except the GA is a Specific Booster Group member, and the uncert environment is an office desktop PC.

## Appendix B

The Booster Systems MCC Software Change Request (CR) Form is used to initiate the change process. See the following two pages for the form.

# Booster Systems MCC Software Change Request (CR) Form

<b>Initiated by:</b>	<b>Submit Date:</b>	<b>CR # (Group Lead):</b>
<b>File Title:</b>		
<b>Version #:</b>		
<b>Description of Change or Addition:</b>		
<input type="checkbox"/> <b>Mission Critical/Mission Success change made during real-time ops</b>		
<b>Rationale for Change or Addition:</b>		
<small>For Group Lead Use Only</small>		
<b>Implementer:</b>	<b>Target Completion Date:</b>	
<b>Tester:</b>	<b>Tester:</b>	
<b>Group Lead Authorization Signature</b>	<b>Implementation Completed</b>	
<b>Approved for Implementation:</b>	<b>Implementer:</b>	
Approval Date:	Completion Date:	

## Change Request Form Instructions

The Change Request (CR) form is required for ALL changes to software. The fields of the CR form are described as follows:

**Initiated By:** - This is the name of the individual requesting the change.

**Submit Date:** - This is the date the CR was written and submitted.

**CR#:** - This is the CR number supplied by the Group Lead

**File Title:** - This is the name of the Configuration Item or actual file name to be modified.

**Version #:** - This is the version number of the CI being modified.

**Description of Change or Addition:** - This is the actual description of the requested change, modification, or new work. Provide as much detail that is available. This includes the type of display file, MSID/PUI names, etc. If possible, attach a copy of the file with the desired modification mark-ups. Also if required, use any attached sheets.

**Mission Critical/Mission Success change made during real-time ops:** – Check this check-box if the change has already been made during real-time operations. This implies this CR is a follow up to the change already made and to assure all processes are followed after the fact.

**Rationale for Change or Addition:** - Provide a comprehensive statement justifying the change request.

**Implementer:** - Completed by the Group Lead. This documents the assigned implementer of the CR.

**Target Completion Date:** - Completed by the Group Lead. This documents the date in which the CR is to be completed.

**Tester:** - Completed by the Group Lead. This documents the name of one of the assigned testers.

**Tester:** - Completed by the Group Lead. This documents the name of a second assigned tester if required.

**Approved for Implementation:** - This is the Group Lead's signature. This signature is required prior to start work on the CR.

**Implementer:** - This is the implementer's signature indicating when the software was completed and authorizing start of certification tests.

**Completion Date:** - Completed by the Group Lead. This documents the date when the implementation was completed.

## Appendix C

The Application Notebook Certification Approval Page is the formal signature page for the CR. See the following two pages for the CAP.

**BOOSTER SYSTEMS DIVISION**  
**APPLICATION NOTEBOOK CERTIFICATION APPROVAL PAGE**

Data File Name \_\_\_\_\_

Data File Version Number \_\_\_\_\_

Associated CR Number \_\_\_\_\_

System (MCC or PC) \_\_\_\_\_

Usage (i.e. Pre-flight, Mission) \_\_\_\_\_

Dependent Products / Application Versions \_\_\_\_\_

Single or Multi Discipline Usage \_\_\_\_\_

If Multi Discipline users, the Dependent Users list must be updated/verified

Location of Documentation: \_\_\_\_\_

The software contained in this release has satisfied the minimum standards or is waived appropriately and is certified for use.

**VERIFICATION /VALIDATION SIGNATURES**

\_\_\_\_\_ Date \_\_\_\_\_ Date

\_\_\_\_\_ Date \_\_\_\_\_ Date

- External Sources List verified/updated (if required)
- Dependent Users List verified/updated (if required)
- Dependent Users notified of file change

I verify that this software certification complies with the DF SMP standards and is ready for use in the MCC.

**APPROVAL SIGNATURES**

\_\_\_\_\_ Date

DTR

\_\_\_\_\_ Date

Group Lead

\_\_\_\_\_ Date

Branch Chief

**WAIVER OF PROMOTION DEADLINE (IF REQUIRED)**

\_\_\_\_\_ Date

Division Chief

## Certification Approval Page Instructions

The Certification Approval Page is the document that “certifies” the configuration item. Once all signatures are obtained, the configuration item may be promoted to the certified repository for mission operations support. The Certification Approval Page is completed as follows:

**Data File Name:** - This is the name of the Configuration Item or actual data file name to be certified.

**Data File Version Number:** - This is the version number of the CI being certified. If this version number is different from the RCS version number, then that information must be clearly documented here. (This is usually obtained as a future version number from the GA)

**System:** - This is the location of the application (on the MCC workstations, PC, or other system)

**Usage:** - Pre-flight, Mission, Sim, Office, etc.

**Dependent Products / Application Versions:** - This is the products or application that is required to run/execute the data file (e.g. this MSKView data file “EECOM Orbit” is certified to run with MSKView version 5.0 application; or word file certified for use with Windows 2000/Microsoft Word version 10.0).

**Single or Multi Discipline Usage:** - Is this file (or associated file output) used by other disciplines? If so, the Dependent Users list (in the Application Notebook) must be verified/updated accordingly. The dependent users must also be notified of the file change.

**Compliance with Documentation & Standards** – Check the appropriate boxes indicating required documentation provided for this configuration item. For boxes not checked, documentation within the application notebook must provide an explanation as to why this documentation is not provided. The check box is checked for each delivery of the CI regardless if the section of the documentation has changed.

**Location of Documentation:** - Physical location of application documentation (if paper), or location (directory, website, etc.) if being maintained electronically.

**Verification / Validation Signatures:** Signatures of the certification testers for the software.

**External Sources / Dependent Users List updated/verified:** This is a checklist to verify that the External Sources list and the Dependent Users list has been verified and updated, if required. It also has a check box to verify that the Dependent Users have been notified of the change (if required).

**Approval Signature:** - In the spaces provided, the DTR, Group Lead, and Branch Chief signatures are required. They are verifying that the application notebook and certification process/paperwork complies with the DF SMP document standards. If the change is made after the promotion deadline, then the Division Chief or representative signature is also required.

TITLE

FLIGHT DATA FILE

PURPOSE

This SCP describes the use of the Flight Data File (FDF) for Booster procedures.

DESCRIPTION

Flight Data File (FDF) is the set of books and cue cards that contain crew procedures. FDF consists of many different books that are logically separated by flight phase (e.g. ascent, orbit, etc.). Both nominal and off-nominal procedures are contained in the FDF. Both the crew and flight controllers use the FDF. The crew will use the FDF to perform procedures if no communication with the ground is available or with communication, MCC may direct the crew to work a procedure in the FDF. The procedures in the FDF will usually cover only a couple of failures deep, enough to allow the crew to work a reasonable failure scenario.

The advantage of FDF is that it allows the crew to work procedures independently of the Mission Control Center (MCC), thus preventing the crew from relying on continuous instructions from the ground. Without FDF, every step would have to be told to the crew, an inefficient use of resources. With FDF, a discipline can request the crew to work a certain procedure with one call. The crew would then execute what could be a multiple page procedure without relying on further instructions. Figure 1.3.2-I shows an example FDF procedure where the crew would be told to work the MPS DUMP INHIBIT on one of the engines. With instructions to work the dump inhibit, the crew would turn off the engine power and close the prevalves on the requested engine. As demonstrated, a few instructions can result in a lot of actions by the crew.

**MPS DUMP INHIBIT**

Post MECO:

Aff MPS ENG PWR (two) – OFF

LO2(H2) PRE VLV – CL

Figure 1.3.2-I. - MPS DUMP INHIBIT Procedure

To reduce book sizes and complexity, FDF is broken up into many different books based on flight phase and conditions (nominal or off-nominal). Table 1.3.2-I lists the FDF books (by flight phase) containing information related to the main propulsion system (MPS) and the main engine system (ME). The FDF cue card, kept in the ISO9000 controlled Booster Cue Card Book, lists all MPS/ME procedures (book, page number, and brief description) contained in the FDF. Any FDF that has “pocket” in its title is an off-nominal procedure book. It is interesting



to note that the Ascent/Entry Systems Procedures (AESP) is the only book broken into two sections to cover two phases of flight (ascent/entry). The two sections are powered flight (white tabs) and glided flight (blue tabs). The sections are broken out this way because if an RTLS or TAL abort is performed, the entry procedures are quickly available without having to pull out a stowed book.

Table 1.3.2-I. - FDF Books Containing Booster Related Procedures

FDF BOOK	Nominal/Off Nominal Procedures	Associated Flight Phase
Ascent Checklist	Nominal	Ascent (T-02:25 to OMS 2) approx.
Ascent/Entry Systems Procedures (AESP)	Off Nominal	Ascent (launch to ET SEP) Entry (entry interface to rollout)
Ascent Pocket Checklist	Off Nominal	Ascent (MECO to OMS 2)
Systems AOA	Off Nominal	Entry (Abort Once Around)
Post Insertion	Nominal	Pre-orbit (MET 00:50 to 04:00) approx.
Orbit Operations Checklist	Nominal	Orbit (MET 04:00 to TIG-04:00) approx.
Orbit Pocket Checklist	Off Nominal	Orbit (MET 00:50 to TIG-02:15) approx.
Deorbit Prep	Nominal	Pre-entry (TIG-04:00 to TIG-00:30) approx.
Contingency Deorbit Prep	Off Nominal	Pre-entry (Post OMS 2 to TIG-00:30) approx.
Entry Checklist	Nominal	Entry (TIG-00:30 to rollout) approx.
Entry Pocket Checklist	Off Nominal	Entry (TIG-02:15 to entry interface ) approx.
Reference Data	Nominal	All phases but mostly orbit

The FDF is laid out in a precise manner to enhance interpretation of the procedures. All FDF is read from the top down performing the required steps as necessary until the procedure ends or exit indications are given. Exit indications are either the “>>” symbol seen on Step 2 of Figure 1.3.2-II, or the “⇒” symbol. If the “⇒” symbol occurs at the end of a procedure, it indicates a choice to continue to either the glided flight portion of the AESP and/or to the Ascent Pocket Checklist as dictated by the prevailing flight phase. In addition, a “⇒A” or “⇒G” symbol indicates that follow on procedures exist only in the Ascent Pocket Checklist or glided flight portion of the AESP. When the crew goes to the procedure in the appropriate FDF book, a “⇒” symbol will precede the step that they are supposed to start at. For example, the “⇒” in Figure 1.3.2-II directs the crew (when coming from the AESP) to begin working the procedure a couple of lines down from the start of the procedure (GPC MODE - STBY, RUN). Working the step prior to the “⇒” is unnecessary because it was already performed in the AESP.

- BFS GPC FAIL**
1. GPC MODE – STBY, HALT, pause  
⇒ – STBY, RUN
  2. If recovered: PRO to OPS 304  
BFS G50 /BFS R / W sel  
√ GPC OUTPUT – B / U >>

Figure 1.3.2-II. - BFS GPC Fail Procedure

To avoid confusion with conditional statements, indentation is used. Anything indented below a conditional step goes with that condition. Notice that step 3 on figure 1.3.2-III has the condition above it that the helium regulator pressure must be high or low. If that condition is true, the crew will work step 3. However, if the condition is not true, they will fall down to the “otherwise” condition and work step 4 (close the helium isolation valves). After that step is complete, the crew will check if the  $dP/dT$  is decreasing. If it is, they will fall out of that indented section and continue on with the next section having equal or less indentation. In this example, the crew will check the “if any ENG fail” condition next.

Other symbols are used in the FDF to simplify procedures. A diamond ( $\diamond$ ) symbol before a step indicates that if comm exists, the crew should check with MCC prior to performing the step. Without comm the crew will perform the step. The boxed G51 in the ET SEP MAN procedure (figure 1.3.2-IV) indicates the crew is to call up the spec 51 page (GNC SPEC 51 PRO). The spec 51 page will appear on the crew’s CRT display allowing them to input commands to the computer using item entries. Post MECO the crew will then enter an item 38 (BFS 28) on SPEC 51 to force the ET SEP sequence to automatic. Sometimes commas are used in procedural statements or callouts (e.g. MEC 1,2 - OFF). The comma in this case implies the word “and”; therefore, MEC 1,2 - OFF reads: take MEC 1 and 2 off. Parentheses on the other hand are used to imply the word “or”. For example APU CNTL 1(2)- OFF reads take APU CNTL 1 or 2 to off depending on prior instructions or selections.

**MPS He P (Pre MECO)**

1.  $\sqrt{dP / dT}$
- If after MECO -60:
  2. Shut dn MN ENG per MPS  
CMD / HYD / ELEC >>>
- If He REG P  $\uparrow$  or  $\downarrow$ :
  3. Aff He ISOL - CL
- Otherwise:
  4. Aff He ISOL A - CL
  - If no decr in dP / dT:
    5. Aff He ISOL A - OP  
B - CL
  - If no decr in dP/dT:
    6. Aff He ISOL B - OP
- If any ENG failed:
  7. Failed ENG He I'CNCT -  
OUT OP
- If nonisolatable:
  8. Shut dn MN ENG per  
MPS CMD / HYD / ELEC  
If / when TK P < 1150 or  
REG P < 679:
    9. Aff He I'CNCT - IN OP
- If isolated:
  10. Aff He I'CNCT - IN OP
  - If TK P < 2300 @ MECO -60:
    11. Shut dn MN ENG per  
MPS CMD / HYD / ELEC
- Post ET Sep:
  12. He I'CNCT(s) - GPC

Figure 1.3.2-III. - MPS Helium Leak Procedure

**'ET SEP MAN' ET SEP**

G51

Post MECO:

1. ET SEP AUTO - ITEM 38 (BFS 28)
2. If ET SEP pb reqd:  
ET SEP SEP - ITEM 39 (BFS 29)

Figure 1.3.2-IV. - ET SEP MAN Procedure

REFERENCES

1. Ascent/Entry Systems Procedures, Volume I, Generic Rev N, PCN-1, JSC-48001-I.
2. Space Shuttle Flight Data File Preparation Standards, Baseline, JSC-09958.
3. MPS/ME FDF Cue Card.

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## TITLE

TELEMETRY SERVICES VCR

## PURPOSE

This SCP describes the use of the Telemetry Services VCR console tool for pre-flight verification of Booster software flight configuration.

## DESCRIPTION

The Telemetry Services VCR is a console tool used pre-flight to verify the Booster software flight configuration. This method exercises flight-specific scripts, and is the only way to verify pre-flight Booster software independently without participating in an Integrated Load Checkout (ILC) with the entire mission operations team.

## PROCEDURE

1. After login, select the “No Data” flight-specific activity configured to the recon of the flight software to be verified in cert apps. If the appropriate activity does not exist, then call WSS on the “WSS Call” DVIS loop and request a build of the activity. The “activity information” of the selected activity should show type “SIM,” show the correct STS number, and show “Yes” for “Cert S/W.”
2. Start MSKview displays for both MPS and ME telemetry that will allow the user to verify the health off the BOSS comps in a later step.
3. Uncompress the VCR file per the following steps. On the DNAV menu, select Booster / Playback / Payback Options / VCR File Management/ Uncompress VCR File. Select the files, /users/bseds/DATA/VCR/STS/STS108\_asc.ptm.gz and STS108\_asc.ptmw.gz. These two files must both be uncompressed for the procedure to work correctly.
4. On the DNAV menu, select Master / Global Apps / Telemetry VCR.
5. On the Telemetry Services VCR menu, select “Stream,” “PTM.” The “Flight ID” should match the login activity of the specific flight. Under “Stream options,” select “Data Type” as “RT” for real-time. On the menu, select the file, /amd/user2/bseds/DATA/VCR/Logs/LOCAL/STS108\_asc.ptm.
6. Press the “Play” button on the Telemetry Services VCR console to begin playback.

7. On the DNAV menu, select Booster / BOSS / Flight / Start PTM to begin playback on the server. Note that this is the only non-flight instance in Booster console procedures that “Flight” is selected for data.
8. Verify that all MPS and Main Engine console displays, comps, and tools are fully functional, and run the data at least through MECO. Check the Advisory Services display for any error messages generated by the comps or comp failures.