

# Flight Procedures Handbook

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## Contingency Deorbit Prep

Mission Operations Directorate  
Operations Division

Final, Rev A  
February 28, 1990



National Aeronautics and  
Space Administration

Lyndon B. Johnson Space Center  
Houston, Texas

CONTINGENCY DEORBIT PREP  
FLIGHT PROCEDURES HANDBOOK

FINAL

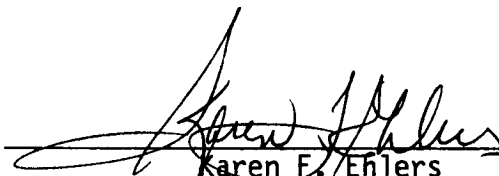
February 28, 1990

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PURPOSE

This document is designed to present the user with sufficient rationale and background information on the activities contained in the Contingency Deorbit (C D/O). This handbook is intended primarily for use by flight crew-members and training personnel as a follow-on to Shuttle systems training.

SCOPE

The contingency cases covered in the C D/O are modeled on the nominal deorbit as closely as possible. The Contingency Deorbit Prep Flight Procedures Handbook covers eleven contingency cases:

- Launch Day Deorbit Prep (Orbit 2)
- Launch Day Deorbit Prep (Orbit 3)
- Loss of 2 FC Launch Day Deorbit Prep (Orbit 2 or Orbit 3)
- Loss of 2 Fuel Cells Deorbit Prep
- Loss of FES Deorbit Prep
- Loss of 2 H2O Loops (CONUS TIG > 2.5 hours)
- Loss of 2 H2O Loops Deorbit Prep/Entry
- Emergency Deorbit Prep/Entry
- Loss of 2 Freon Loops Deorbit Prep/Entry
- Quick Response Jettison
- Bailout

NOTES: This handbook is based on procedures in the FINAL, PCN-11 version of the STS-32 Contingency Deorbit Prep. It is recommended that these procedures be used in conjunction with this handbook.

The pictorials in section three of the C D/O are taken from the nominal Deorbit Prep and apply to the two Launch Day Deorbit Prep cases and the Emergency Deorbit Prep case. The pictorials in section six apply to only section five, Loss of FC 2 Fuel Cells Deorbit Prep case.

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**ACKNOWLEDGEMENT**

Major contributions to the Contingency Deorbit Prep Flight Procedures Handbook were made by Stephen Vrana including the following sections:

Loss of 2 FC Launch Day Deorbit Prep  
Loss of 2 Fuel Cells Deorbit Prep  
Loss of H2O Loops (CONUS TIG > 2.5 HR)  
Loss of 2 H2O Loops Deorbit Prep/Entry  
Loss of 2 Freon Loops Deorbit Prep/Entry  
Quick Response Jettison

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## SECTION 1 LAUNCH DAY DEORBIT PREP (ORBIT 2)

### OVERVIEW

As its name implies, the Launch Day Deorbit Prep (Orbit 2) section of the C D/O provides the procedures used by the crew to configure the Orbiter for entry if a failure occurs requiring a rev 2 deorbit after the last AOA opportunity. The rev 2 deorbit procedures provide a transition from either the OPCL or the APCL to the Entry Checklist. These procedures are initiated only if a failure occurs that would require a rev 2 deorbit. Such failures include: loss of 2 cabin fans, loss of cabin pressure, loss of 1 Freon loop, and loss of communications and no U/L command. According to Flight Rule # 11-31A, if both voice and command are lost during ascent, a rev 2 deorbit is recommended in order to minimize state vector degradation.

Before a rev 2 deorbit, the crew configures the various Orbiter systems for entry. Since the time at which payloads are deactivated is flight specific, a generic callout for payload deactivation is provided at the top of the orbit 2 deorbit timeline. If a payload deactivation is necessary, the procedures for the deactivation can be found in the P/L OPS C/L. The SPOC is unstowed and activated to serve as a backup source of information used during deorbit prep (e.g. deorbit target information). The IMU's do not need to be realigned with star data in a rev 2 deorbit since the 3 $\sigma$  predicted misalignment is within the entry interface limit of 0.5 deg. The Data Processing System (DPS) is reconfigured to provide a redundant set of OPS 3 software. At this time, the event timer is set to count down to the TIG of the deorbit burn. The APU steam vent heaters are powered on before the APU's are activated; likewise, the APU tank/fuel and water line heaters are turned on so as to prevent possible fuel or water freeze up. The pilot then maneuvers the Orbiter into the correct attitude for the deorbit burn. The crew also verifies the correct positions for all of the switches, forward and aft, as an overall check of Orbiter systems as per specific callouts and panel pictorials found in section three of the C D/O. The NH3 boiler system is enabled to remove excess heat from the vehicle at approximately 120,000 feet since the PLBD's have not been opened by orbit 2, and no cold soak has been initiated. At approximately TIG -00:35, the crew exits the rev 2 deorbit section of the C D/O and enters the Entry C/L. Since no coldsoak occurs on-orbit, the crew does not need to configure the RAD BYP VALVE MODE and CNTLR LOOP switches.

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**ASSUMPTIONS/INITIAL CONDITIONS**

These procedures for a rev 2 deorbit can be entered from either the APCL or the OPCL. Since deorbit will occur during rev 2 after the last AOA opportunity, none of the nominal post-insertion procedures will have been completed. Only the MS's need to egress their seats in order to unstow the SPOC and to configure the aft station switches for entry. In order to complete the required configurations for entry, the crew should start these procedures at approximately MET 01:00.

**PROBLEM DESCRIPTION/RATIONALE**

The rev 2 deorbit procedures are used by the crew in case of a failure that requires a rev 2 deorbit after the last AOA opportunity. Certain failures that would lead to a rev 2 deorbit are specifically referenced in either the OPCL or the APCL. These failures include:

- Loss of 2 Cabin Fans
- Loss of Cabin Pressure (Major)
- Loss of 1 Freon Loop
- Loss of Communication and No U/L Command



**PAYLOAD DEACT**

Payload procedures and the timing of those procedures are flight specific. Depending on the flight and mission phase, a payload may have to be deactivated in a rev 2 deorbit. A generic callout for payload deactivation is located at the top of the orbit 2 deorbit detailed timeline.

If no payload deactivation is necessary, "N/A" is pen-and-inked in the appropriate blank space as part of the Errata Package before flight. If a payload deactivation is required, the TIG time at which it is deactivated is written in as part of the Errata Package; the procedures for deactivating the payload are located in the DEORB PREP tab of the P/L OPS C/L.

**L4: B,Q,R, All cbs closed**

During ascent, only minimum lighting is used so as to minimize the risk of transients on ac buses which could result in the loss of a Main Engine Controller. These cbs are closed in order to enable power for the panel lighting during deorbit prep and entry.

**SPOC UNSTOW/SET UP/ACTIVATION**

The MS unstows, sets up, and activates the SPOC. The SPOC provides information such as ground track, comm AOS/LOS, and day/night cycles. In case MCC cannot provide the correct target information, the SPOC serves as a backup source of deorbit targets for a rev 2 deorbit.

**DPS ENTRY CONFIG (OPS 1 TO OPS 3)**

No post-insertion procedures have been performed before an orbit 2 deorbit. Since the GPC's are in the OPS 1 configuration, the crew must perform an OPS 1 to OPS 3 transition.

GPC 3 is freeze-dried in the OPS 3 (entry) configuration for two reasons. First, by freeze-drying GPC 3, the crew can verify that the MMU is indeed a valid OPS 3 source. Also, if the two MMU's fail, the freeze-dried GPC can serve as an OPS 3 backup source while the other GPC's transition. Before freeze-drying GPC 3, its string is reassigned to another GPC in MC 1 by updating the GPC memory configuration table. The CRT previously commanded by GPC 3 is also reassigned. GPC 3 is currently in OPS 106; an OPS 106 PRO command accomplishes an OPS mode recall. The OPS mode recall is a special software sequence that quickly assigns buses without interrupting normal software execution.

Since GPC 3 may have to be activated on-orbit, it should control all of the strings, CRT's, and MMU's. Consequently, the MC 3 NBAT is reconfigured via SPEC 0. (The MC 3 NBAT is not initialized in this configuration in case an AOA is necessary in which case the crew would go directly from OPS 1 to OPS 3 with all GPC's). The reconfiguration of MC 3 NBAT does not affect the currently active OPS.

GPC 3 must be in OPS 0 prior to freeze-drying. An OPS 000 PRO command would take GPC 3 to OPS 0, but it would also take the three other PASS GPC's in the redundant set to OPS 0. Therefore, GPC 3 must be taken out of the redundant set by moding it to STBY and then back to RUN. This will cause GPC 3 to fail-to-sync, and it will come back in OPS 0. The remaining PASS GPC's can continue with processing OPS 1 software.

Once in OPS 0, GPC 3 can be loaded with GNC OPS 3 via the STORE controls on SPEC 0. Before loading the OPS 3 software into GPC 3, a CRT has to be assigned to that GPC. In order to permit assignment of a CRT to a GPC not processing applications software, the CRT's major function switch is placed in the PL position (an unsupported major function). Placing the major function switch in PL causes the GPC currently in command of that CRT to retain control. Therefore, a GPC/CRT command is necessary to reassign the CRT to GPC 3. ITEM 45 + 3 selects MC 3; ITEM 46 + 3 selects the targeted GPC; and ITEM 47 EXEC initiates the loads without executing the OPS 3 software.

The procedure in asterisks is provided in case the freeze-dry operation is not successful. The power is cycled on the MMU's in order to clear any transient problems. The FD procedure is retried. If the FD is unsuccessful again, then the problem may be due to a GPC. If no GPC's have failed, then the strings are reassigned in OPS 1 so that GPC 2 can be used as the freeze-dried GPC. If only one GPC has failed, then the strings are reassigned to the lowest ID GPC. The crew will then attempt to freeze-dry another GPC. If either of these steps are successful, then GPC 3 is declared to have an MMU interface problem. If not successful, then both MMU's are declared failed, and MCC will uplink the OPS 3 MC.

C D/O procedures are referenced to TIG of the deorbit burn. The crew can set either the CRT timer or the event timer to countdown to the deorbit burn. The CRT timer however cannot be set during OPS 1 or OPS 3 or if the BFS has been engaged. Therefore, the CRT timer is not used in the rev 2 deorbit procedures as it is in the rev 3 deorbit procedures. Instead, the crew uses the event timer to countdown to the time of the rev 2 deorbit burn. The crew selects the minutes and seconds on the event timer via thumbwheels located on panel C2.

The dedicated displays and flight control systems used during entry are required to be powered on before entry because of certain equipment requirements before and during the OPS 3 transition. The RGA's, the AA's, the ASA's, and the IMU's are all verified to be on by the crew before the OPS 3 transition in order to maintain Orbiter stability. If two of the first three ASA's have not been powered on at the time of the OPS 3 transition, then the GPC's will receive inaccurate data on aerosurface position. If the OPS 3 transition is executed with the ASA's off, aerosurface and hydraulic system damage could occur at APU activation. Likewise, the RGA's must be powered on before the OPS 3 transition. During OPS 3, the DAP uses RGA rate feedbacks. If the RGA's are not powered on prior to OPS 3, then the vehicle will spin out of control (unless the DAP has been configured for free drift in OPS 3).

Next, GNC OPS 3 is loaded into GPC's 1, 2, and 4 by modifying MC 3 via SPEC 0. The BFS GPC is also transitioned to OPS 3 in preparation for entry. The BFS is capable of loading a specified low data rate (LDR) TFL during ascent or entry. When ITEM 29 on "BFS MEMORY" SPEC 0 is enabled, the BFS will automatically initiate a LDR telemetry format load when a power switchover to the other PCMMU is sensed. Finally, GPC 3 (the FD GPC) is added to the redundant set of GNC OPS 3 GPC's.

A landing site update is also performed if necessary after the OPS 3 transition via the "HORIZ SIT" display. This update has to be performed after the final OPS 301 PRO else the software will default to the I-Loaded site. The correct landing site, runway, and TACAN are located on the DEL pad in the Entry C/L; information on 15 other landing sites is found on the Land Site Data Chart (which is included in the back of the C D/O Flight Books).

The targets previously uplinked to the "DEORB MNVR COAST" SPEC are compared to the targets on the D/O MNVR pad included on the Entry C/L. (The SPOC provides the deorbit targets if MCC cannot.) These targets are then loaded, causing the GPC's to begin computing the required deorbit solution. The crew compares this solution with the D/O MNVR pad's solution. At this time, the CRT timers begin counting down to TIG of the deorbit burn.

Finally, the crew checks the MC 9 NBAT for correct string assignment so as to minimize required keystrokes for postlanding. MC 3 is then recalled in case the crew needs to reconfigure MC 3 during entry.

#### **PRESS H2O TK A**

During ascent, H2O tank A is unpressurized to reduce the ascent acceleration head pressure on the fuel cells; water produced by the fuel cells is able to flow into the water storage system. Tank A is normally repressurized during Post Insertion; therefore, Tank A must be pressurized prior to a rev 2 deorbit. Once the pressure in Tank A is brought up to 17.5 psig, it can serve as a back up source of supply water to the FES which normally uses Tank B water. If the fuel cell water fills Tank A before the tank is pressurized, Tank A may be damaged due to pressure gradients across the tank bellows.

#### **APU HTRS & FWD SWITCH CONFIG**

The APU steam vent heaters are required to be on approximately two hours before the APU's are activated. However, due to the time constraints of a rev 2 deorbit, these heaters are powered on at the first opportunity. One set of APU TK/FU LINE/H2O heaters are also required to be on to prevent APU fuel or water line freeze up. A Detailed Test Objective (DTO) on STS-4 showed that hydrazine freeze-up can occur approximately two hours after heater deactivation. Since these heaters are off during ascent and are not turned on until approximately MET 01:00 in the Post Insertion, they should be activated prior to a rev 2 deorbit. Furthermore, if the heaters are not activated, a Fault Detection and Annunciation (FDA) will occur at 65 minutes

MET. More importantly, fuel and H<sub>2</sub>O line freeze-up could occur if the heaters are not turned on prior to a rev 2 deorbit.

The Microwave Landing System (MLS) provides slant range, azimuth angle, and elevation angle for vehicle control. The only crew interaction with the MLS is to select the correct channel and to power the 3 MLS units on. The MLS channel can be determined from the Land Site Data Chart. All three TACAN MODE switches are placed in the GPC position to enable power to the TACAN system transmitter/receiver and to allow TACAN ground station selection via the "HORIZ SIT" display. The TACAN supplies slant range and bearing angle data for vehicle control.

The flight critical dedicated displays and APU/hydraulic indicators are also powered on via the instrumentation power switches. In a rev 2 deorbit, the EIU is powered off since the EIU is used only during ascent to transmit commands and data between GPC's and ME controllers.

#### **AUTO MNVR TO BURN ATT**

Before the rev 2 deorbit burn, the pilot maneuvers the Orbiter into the correct deorbit burn attitude and remains there inertially. The vehicle's attitude at deorbit burn is generally as follows: tail forward and payload bay towards the earth. The Orbiter may also have some out-of-plane yaw in order to waste propellant.

The Orbiter is not maneuvered to a deorbit comm attitude as it is in nominal deorbit. Maneuvering to a comm attitude would only provide approximately 10 minutes of optimal S-band comm coverage over TDRE and TDRW. Due to the time constraints in a rev 2 deorbit, this is not a sufficient amount of time to call for an additional maneuver to a comm attitude. Even if the failure leading into the rev 2 deorbit is loss of comm, the Orbiter will go to a deorbit burn attitude. This particular failure is not linked to the Orbiter's attitude. If the crew should regain comm by performing the MAL procedures, then the Orbiter can then be maneuvered to the comm attitude.

#### **SWITCH CONFIG AFT**

The aft panel switches are configured for entry. First, the crew verifies that the fuel cell H<sub>2</sub>O line heater switches are in the A AUTO position; these switches are launched in A AUTO to protect non-flowing alternate water lines.

As part of the aft switch panel configuration for a rev 2 deorbit, the C/W temperature limits are reset for the Freon Loop Evaporators. During ascent, the upper limits are raised so as to prevent triggering an unwanted C/W alarm. These limits are lowered for on-orbit and entry; these new values are identical to those found in Post-Insertion.

The eight hydraulic heaters maintain an acceptable level of hydraulic fluid viscosity on-orbit. These heaters are turned off for a rev 2 deorbit since they are no longer needed to heat the hydraulics. Entry heating is sufficient for the entry phase. The RCS/OMS FWD AFT RCS JET heaters are also

reconfigured as part of the aft switch panel configuration. The normal RCS jet heaters (Manifolds 1,2,3,4) are placed in AUTO for ascent in order to prevent violating the LCC jet injector temperature limit of 65 degrees F on cold launch days. The crew checks to make sure that these heaters are still activated prior to the rev 2 deorbit since the normal jets are used during entry. The vernier jet heaters are also on during ascent to prevent excessive warm up time on-orbit; they however are not used during entry. Therefore these heaters are powered off before the rev 2 deorbit.

### STATION SW VERIFICATION (FWD & AFT)

The switches on the forward and aft panels are configured for entry as per the pictorials located in section three. The switches fall into one of three categories:

1. ACTION REQUIRED: These switches need to be configured for entry; they can be identified by the solid box surrounding them.
2. VERIFICATION REQUIRED: These switches only need to be verified since they should already be in the correct position for entry. These switches are neither boxed nor shaded.
3. NO ACTION REQUIRED: These switches do not need to be configured or verified for entry. These switches are shaded gray (ziptoned).

The C D/O pictorials are taken from the nominal Deorbit Prep. Depending on how far (if at all) the crew has proceeded into Post Insertion, the pictorials may or may not reflect the correct switch positions a launch day deorbit. The NOTE below the switch verification callout in the timeline lists any discrepancies the crew will find in performing the switch verification.

### PAYLOAD ENT SWITCH LIST/VER

Switch configuration for panel R1 and any flight specific SSP's is located in the P/L OPS C/L in the DEORB PREP tab along with any payload deactivation procedures.

### ENTRY COMM CONFIG

The crew configures the communication channels for entry. (The entry communications configuration for the aft station are located in the SWITCH CONFIG AFT procedure.) The two AUD A/G switches are enabled to transmit/receive (T/R) in order to provide S-band and/or UHF COMM to the crew. During a rev 2 deorbit, the crew will already be wearing their LES helmets for entry; they do not need to disconnect and stow the wireless headsets as they would in a nominal deorbit.

**NH3 CNTLR A(B) - PRI/GPC**

The ammonia boiler is set to PRI/GPC in order to remove excess heat from the Orbiter during entry. The ammonia boiler systems (A and B) are enabled by GPC command. The ammonia boiler system can only be used to cool the Freon after EI since some gravity is required to feed the ammonia.

**FINAL DEORB UPDATE/UPLINK**

At approximately TIG -00:35 in the rev 2 deorbit timeline, the crew exits the rev 2 deorbit procedures and enters the Entry C/L at the DEORBIT BURN. The RAD BYP VLV MODE and the CNTLR LOOP commands are deleted for the ENT MNVR cue card. In a rev 2 deorbit, the PLBDs are not opened, and a coldsoak is not initiated. Therefore, the crew does not need to activate the radiators for entry.

## SECTION 2 LAUNCH DAY DEORBIT PREP (ORBIT 3)

### OVERVIEW

These procedures are entered from the ascent phase, the post-insertion phase, or the on-orbit phase via the appropriate MAL and/or pocket checklists if a failure occurs that requires a rev 3 launch day deorbit. Since the procedures can be entered from either the ascent phase or the on-orbit phase, the rev 3 D/O timeline is structured such that it can be entered at different TIG times to allow for the completion of phase specific tasks.

As in a rev 2 deorbit, the rev 3 deorbit procedures are designed to reconfigure the various Orbiter systems for entry. If a failure occurs during OPS 1 or OPS 2 prior to the GO FOR RAD/PLBD OPS call in Post Insertion, crew will enter the rev 3 deorbit timeline at TIG-2:30. The procedures from TIG -2:30 to TIG -2:00 are provided to complete necessary post-insertion activities. The APU heaters are powered on in preparation for APU activation. The heaters for the APU tank, fuel lines, and H2O lines are set to AUTO to prevent APU fuel or water line freeze up. The SPOC is unstowed as a backup in case MCC cannot uplink the correct deorbit targets. The procedures for an OPS 1 to OPS 2 transition are also provided in case an SM GPC is required on-orbit.

The timeline is entered at TIG - 2:00 if a failure occurs during OPS 2 after the GO FOR RAD/PLBD OPS call but prior to the GO FOR ORBIT OPS call. In preparation for the closing of the PLBD's, any payloads that have been activated are deactivated at a flight specific time. The radiators are bypassed, and the FES is activated to provide cooling after the PLBD's are closed. The aft heaters are reconfigured, and the fuel cells are purged prior to PLBD closing. Once the PLBD's are closed, an OPS 2 to OPS 3 transition is performed if needed. (The IMU's do not need to be realigned since the predicted misalignment at the rev 3 deorbit burn is less than 0.25 degrees and inside the entry interface limit of 0.5 deg.) The crew then maneuvers the Orbiter into the correct comm attitude. The forward and aft switch configurations are verified by the crew. The ammonia boiler system is then enabled to provide cooling during entry at relatively low altitudes. After securing the middeck, the crew transitions to the Entry C/L with several pen-and-ink changes to the Entry C/L.

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**ASSUMPTIONS/INITIAL CONDITIONS**

These procedures are entered from either the ascent phase (Ascent C/L) or the orbit phase (Post-Insertion and Orbit Ops C/L) via the appropriate MAL and pocket checklists. These MAL and pocket checklist procedures should be completed before entering the rev 3 deorbit procedures.

**PROBLEM DESCRIPTION/RATIONALE**

These procedures are entered only if a failure occurs that would require a rev 3 deorbit, including any failure that results in a Fail Safe condition. An Orbiter system is considered Fail Safe if it can sustain any one failure and still have the capability to perform its critical functions. Failures which require a rev 3 deorbit include:

- Loss of 2 Cabin Fans
- Loss of Cabin Pressure
- Loss of 1 Freon Loop

The rev 3 deorbit procedures are also entered if one of the failures listed in the RAD/PLBD OPS NO GO block (PI,1-9) occurs. (See Figure 1.) Failures requiring a next PLS deorbit are listed in Flight Rule 2-200.

If any of these failures occur during a low inclination flight, the first opportunity at a next PLS deorbit occurs on either rev 2 or 3. For a high inclination flight, the first PLS opportunity is a rev 7 deorbit. The rev 7 deorbit procedure is located in the Post Insertion book for flights utilizing a high inclination orbit.

RAD/PLBD OPS NO GO FOR FOLLOWING FAILURES			
OMS/RCS	GNC	ECLS/EPS	MECH
2 OMS Eng	2 IMUs	1 H2O or Freon Lp	2 LG DPY METHODS
1 OMS Eng & 1 +X	3 RCAs	Both RFCAs	PRES or REDNT
RCS jet	3 AAs	Both Cab Fans	WINDOW PANE
1 OMS Inlet line	3 ADTAs	3 of 6 Av Bay Fans	FAILURE
OMS Prop Tk Leak	3 Elevon or	2 FCs	DPS
Att RCS He or Prop	BF Pos	Any MN or 3@ AC Bus	3 GPCs
Leak	Fdbks (same	Any CNTL or MPC Bus	2 PL MOMs
COMM	surface)	3 IMU Fans	2 FF or FA MOMs
No Voice and	2 FCS Ch(same		APU/HYD
No CMD	surface)		2 APU/HYD/WSB

Figure 1: RAD/PLBD OPS NO GO Block

**NOTES**

The orbit 3 deorbit procedure is structured such that it can be entered at two different TIGs depending on how far the crew has progressed in the Post Insertion book. If the crew receives a NO GO on RAD/PLBD OPS at an MET of 01:28, they will enter the rev 3 deorbit procedure at TIG-2:30. The crew activates the APU heaters, unstows the SPOC, and transitions the GPCs to OPS 2 in the time between TIG-2:30 and TIG-2:00. All of these activities are

nominal Post Insertion procedures that may not have been completed if the crew transitioned to the C D/O before an MET of 01:28.

If the crew transitions to the C D/O after MET 1:28 but before MET 1:36, the rev 3 deorbit procedure is entered at a TIG of -2:00. After the GO FOR ORB OPS callout (MET 1:36), the Launch Day Deorbit (Orbit 3) are no longer relevant.

NOTE: All starred procedures are similar to ones performed for a rev 2 deorbit prep.

#### L4: B,Q,R All cbs closed\*

During ascent, only minimum lighting is used so as to minimize the risk of transients on AC buses which could result in the loss of a Main Engine Controller. The cbs are closed in order to enable power for the panel lighting during deorbit prep and entry.

#### APU TK/FU LINE HTR ACT\*

One set of APU TK/FU LINE/H2O heaters are also required to be on to prevent APU fuel or water line freeze up. A DTO (Detailed Test Objective) on STS-4 showed that hydrazine freeze up can occur approximately 2 hours after heater deactivation. Since these heaters are off during ascent and are not turned on until approximately MET 01:00 in the Post-Insertion, a callout for heater activation must be placed in the C D/O. Furthermore, if the heaters are not activated, an FDA (Fault Detection and Annunciation) will occur at 65 minutes MET. More importantly, fuel and H2O line freeze up could occur if the heaters are not turned on before a rev 3 deorbit.

#### SPOC UNSTOW/SET UP/ACTIVATION\*

The MS unstows, sets up, and activates the SPOC. The SPOC provides information such as ground track, earth observation cues, comm AOS/LOS, and day/night cycles. In case MCC cannot provide the correct target information, the SPOC serves as a backup source of deorbit targets for a rev 3 deorbit.

#### DPS CONFIG

This DPS CONFIG is provided in case the crew did not complete the OPS 1 to OPS 2 transition nominally performed at MET 0:54 in the Post Insertion book. Since the GPC's are in the OPS 1 configuration, the crew must perform an OPS 1 to OPS 3 transition. An OPS 1 to OPS 2 transition is also provided in the rev 3 deorbit procedures in case an SM GPC is required while on-orbit.

The procedural steps for DPS configuration (OPS 1 to OPS 3) are similar for both rev 2 and rev 3 deorbits. The first 4 steps involved in the DPS configuration procedure in the rev 3 section are identical to those in the rev 2 section.

The orbit 3 procedures also contain additional steps to allow for an OPS 2 transition. OPS 2 would be required, for example, to recover an RHC that failed during ascent. If the commander's RHC fails during ascent and a subsequent failure creates an RHC dilemma, then the commander's RHC will be inoperable during entry. In order to correct such a malfunction, the crew will have to use SPEC 25 which is available only in OPS 2 to deselect the RHC channel and thus recover the RHC. If OPS 2 (or OPS 8) is not available, the pilot's RHC will have to be used during entry.

The following rationale applies only to the orbit 3 deorbit procedures for transitioning from OPS 1 to OPS 2. Since the BFS is not needed during OPS 2, it is taken to OPS 0, and control of its CRT is given to a PASS GPC. The BFS CRT is then turned OFF. GPC's 1 and 2 are then transitioned to OPS 2. Since the BFS cannot listen to the PASS GPC's in OPS 2, it annunciates its loss of track with lights on panels F2 and F4. These lights can be turned off with the MSG RESET button. GPC 4 is then transitioned to OPS 2 and assigned a CRT. The SM GPC can automatically control the uplink block function. The uplink switch is taken to ENABLE and the uplink control to AUTO on Spec 1. TDRS is selected on the S2 OPS display; the SM GPC will automatically select TDRS East or TDRS West. The SM GPC is assigned CRT 3. The orbit telemetry format is then loaded. MCC provides any payload specific TFL's that are required. The BFS GPC and FD GPC are first taken to STBY, and then taken to HALT. The BFS GPC 5 is taken to NORM before powering it off to prevent the BFS from inadvertently engaging on-orbit. The SM GPC is also taken to TERM at the same time to prevent it from commanding any flight-critical buses. Finally, the CRT timer is set to countdown to the TIG of the deorbit burn. The crew enters the TIG into ITEMS 17-19 on SPEC 2. The software calculates the time remaining until TIG and displays it in the CRT's upper right hand corner underneath MET.

The last 6 steps in the DPS configuration procedures for the rev 3 deorbit are identical to those for the rev 2 deorbit.

#### **PRESS H2O TK A\***

During ascent, H2O tank A is unpressurized to reduce the ascent acceleration head pressure on the fuel cells. It must be repressurized for a rev 3 deorbit. If H2O tank A is not pressurized, tank A will not be able to supply water to the FES if needed because the other tanks are at a higher pressure. Furthermore, if the fuel cell water fills tank A before it is repressurized, tank A may be damaged due to pressure gradients across the tank bellows.

#### **PAYLOAD DEACT\***

Payload procedures and the timing of those procedures are flight specific. Depending on the flight and mission phase, a payload may have to be deactivated in a rev 3 deorbit. A generic callout for the payload deactivation during rev 3 is located at TIG -2:00 in the orbit 3 deorbit timeline.

If no payload deactivation is necessary, "N/A" is pen-and-inked in the appropriate blank as part of the Errata Package before flight. If a payload deactivation is required, the TIG time at which it is deactivated is pen-and-inked into the appropriate blank as part of the Errata Package. The payload deactivation procedures are located in the DEORB PREP tab in the P/L OPS C/L.

## FLASH EVAP CONFIG/RAD BYP

In a nominal deorbit, the radiators are cold soaked so that they can provide cooling during entry from FES cutoff to GSE hookup. In a rev 3 deorbit however, an effective coldsoak is not obtained. Therefore the FES is used during entry until the NH3 boiler system is activated. FES configuration is verified during a rev 3 deorbit to reduce ground turnaround time. The HI LOAD DUCT HTR must be powered on prior to enabling the HI LOAD EVAP. By enabling the HI LOAD EVAP, a TOPPING and HI LOAD evaporator operation is established. These evaporators are activated prior to the closing of the PLBD's to provide cooling until the ammonia boilers are activated. The radiators are completely bypassed before the PLBD's are closed. Although the radiators are bypassed in this procedure, no effective coldsoak occurs since the PLBD's are closed soon after the radiator bypass. Once the PLBD's are closed, the radiators are no longer exposed to deep space; any continuation of Freon flow through the radiators would only increase radiator temperature. Since the radiators cannot be used during entry, the ammonia controller is activated to provide freon loop cooling from FES deactivation to GSE hookup. (The FES is deactivated in the ENTRY SW LIST/VERIF.)

## APU STEAM VENT HTR ACT\*

The APU steam vent heaters are required to be on approximately 2 hours before the APU's are activated. However, due to the time constraints involved in a rev 3 deorbit, these heaters are powered on at the first opportunity.

## AFT HTR CONFIG

The 8 hydraulic heaters maintain an acceptable level of hydraulic fluid viscosity on-orbit. These heaters are turned off for a rev 3 deorbit as they are for a rev 2 deorbit since they are no longer needed to heat the hydraulics. Entry heating is sufficient for the entry phase.

The RCS/OMS FWD AFT RCS JET heaters are also reconfigured as part of the aft switch panel configuration. The normal RCS jet heaters (Manifolds 1,2,3,4) are placed in AUTO for ascent in order to prevent violating the Launch Commit Criteria (LCC) jet injector temperature limit of 65 degrees F on cold launch days. If the vehicle is launched with cold jets, the jet valve seats could shrink due to low temperatures which could cause the jets to leak when fired. A leaking jet would be deselected for the rest of the ascent phase. The crew checks to make sure that these heaters are still activated prior to the rev 3 deorbit since the normal jets are used during entry. The vernier jet heaters are also on during ascent to prevent excessive warm up time on-orbit; they however are not used during entry so they are powered off before the OPS 3 transition.

The FC H2O line heaters are placed in the A AUTO position in order to enable the thermostatically controlled heaters. These heaters prevent freeze up of the water produced by the fuel cells.

The crew should verify that the fuel cell purge heater and valve switches are in the GPC position so that if a purge is necessary, the GPC's will control the purge sequence. (This is not done in a rev 2 deorbit.) The purge heaters prevent ice from forming and blocking the lines during a purge. MCC can command the FC Purge heaters off if required. The heaters should be off at least two hours before the deorbit burn so that the nozzles will not be damaged.

### PLBD CLOSING

Once the payloads are deactivated and the radiators are reconfigured for a rev 3 deorbit, the PLBD's are closed if necessary. The automatic PLBD closing procedure is controlled by an SM GPC. The BFS GPC serves as a backup in case the SM GPC fails. More detailed PLBD closing procedures can be found in the Deorbit Prep book. The crew uses the "PL BAY DOORS" display on CRT 4 along with the controls on panel R13L to close the PLBD's, as in the nominal deorbit prep procedures. If the PLBD's do not close properly, the MAL book is referenced. In a nominal PLBD closing, the "PL BAY DOORS" display on CRT 4 is used along with the controls on panel R13L.

### OPS 2 TO 3 TRANSITION

If a transition from OPS 2 to OPS 3 is required before the rev 3 deorbit, the following procedure is followed, assuming also that the BFS has not been engaged. (If a problem occurs with the IMU's or the RHC's, then the crew should not proceed with the OPS 3 transition.) The RGA's, AA's, ASA's, and IMU's are all verified to be on before the OPS 3 transition. [See DPS CONFIG, Launch Day Deorbit Prep (Orbit 2).] The aft CRT is powered off since it is not used during entry. Next, the PASS GPC's are powered on, and the SM and BFS GPC's are restricted from outputting.

Prior to the OPS 3 transition, the pulse code modulation master unit (PCMMU) formats or telemetry format loads (TFL) are loaded for entry. The OI PCMMU FORMAT switch is in the GPC position in order to allow the crew to select the data format for the downlink data outputs. The SM COM BUFF should indicate "RDY". The formats are selected via ITEM 1 on SPEC 62 - PCMMU/PL COMM display; these fixed formats are provided for telemetry while the programmable formats are being changed. The crew enters these numbers into ITEM 3 and enters the loads via ITEM 4. The SM GPC then requests the indicated TFL from mass memory which is then loaded into the PCMMU. The software automatically loads the TFL into the proper formatter. "CMPT" or "FAIL" will appear next to ITEM 4 depending on the success of the load. When both TFL's are loaded, the crew selects the program format via ITEM 2.

After GPC's 1 and 2 are reconfigured to OPS 3, a checkpoint is taken on both MMU's 1 and 2. A checkpoint is basically a "snapshot" of SM data that is taken in case a transition back to the SM function is necessary (e.g. a 24 hour deorbit wave-off). The data included in the checkpoint includes FDA status such as limit values, noise filter constants, telemetry constants, parameter annunciation inhibits, and current time. The checkpoint is taken so that any changes made since the last checkpoint will not have to be uplinked. The crew initiates checkpoints on SPEC 60 - SM TABLE MAINT via

ITEM 18. A checkpoint is written on both mass memories by first selecting ITEM 4 on DPS UTILITY and then initiating the checkpoint on MMU 2 via ITEM 18. Next, the crew selects ITEM 3 and initiates a checkpoint on MMU 1. ITEM 12, CKPT RETRV ENA, on DPS UTILITY is executed to allow the retrieval of a checkpoint. The UL CNTL ENA, ITEM 36, allows the GPC's to process all uplinks; ITEM 36 is executed only when no SM GPC exists to control the uplink.

Next, the BFS GPC is transitioned to OPS 3. The BFS output is put in BACKUP to allow the BFS the capability of engaging. The crew then verifies that the TFL is enabled; the TFL serves to load the PCMMU and will verify the PCMMU whenever a switchover occurs.

Finally, GPC's 1, 2, 3, and 4 are transitioned to OPS 3. Before adding GPC's 3 and 4 to the OPS 3 redundant set, the SM GPC is moded to OPS 0 so that it will release the payload buses. The BFS (GPC 5) takes control of the payload buses when it is moded to RUN. The BFS GPC will be running in OPS 3. GPC 3 is also moded to RUN, but it is only processing OPS 0 software at this time. GPC 3 retains the OPS 3 software in main memory. Memory configuration 3 is reconfigured to include GPC's 1, 2, 3, and 4. The string assignments are divided among the GPC's in case a GPC fails. The BFS CRT is powered off before GPC's 3 and 4 are added to the OPS 3 redundant set with an OPS 301 PRO command. The BFS CRT is then turned on so that GPC 5 can be moded to OPS 3. This powering off and on of the BFS CRT is done to prevent the crew from transitioning only one GPC set (BFS or PASS) to OPS 3.

The last three procedural steps are identical to those contained in the DPS ENTRY CONFIG (OPS 1 to OPS 3) procedure for the Launch Day Deorbit Prep (Orbit 2) section. These steps include: LAND SITE UPDATE, LOAD IN TGTS, and VERIFY MC 9 TABLE.

#### **H2O PUMP LOOP 1 - OFF,B**

On-orbit, the H2O pump loop 1 switch is in the GPC position to thermally condition the stagnant water loop by commanding the selected pump on for six minutes every 50 hours. For a rev 3 deorbit, this is not required so the switch is placed to OFF for entry. (This switch is not reconfigured for a rev 2 deorbit since it is already in the OFF position from ascent.)

#### **AUTO MNVR TO COMM ATT**

Before the rev 3 deorbit burn, the pilot maneuvers the Orbiter into the correct attitude for optimal S-Band comm coverage over TDRE and TDRW. In order to minimize maneuvering during the deorbit prep timeframe, the deorbit burn attitude is checked first to see if it provides good comm coverage. Next, the IMU align attitude is checked. If neither of these attitudes provides good enough comm coverage, the Orbiter is taken to a deorbit comm attitude. This inertial attitude points the Orbiter's + X axis towards

either the celestial north or south pole. This specific comm attitude depends on the deorbit burn attitude. The deorbit comm attitude is in general as follows:

R = Minimum maneuver to deorbit burn attitude  
 P = 90, if  $0 < \text{deorbit burn attitude pitch} < 180$   
     = 270, if  $180 < \text{deorbit burn attitude pitch} < 360$   
 Y = 0

#### PRE INGRESS AFT CONFIG\*

The crew reconfigures the communication channels for entry. The 2 AUD A/G switches are enabled to transmit/receive (T/R) in order to provide S-band and/or UHF COMM to the crew; for redundancy, both of these switches are enabled on to transmit/receive.

As part of the aft switch configuration in the rev 3 deorbit procedures, the C/W temperature limits are reset for the Freon Loop Evaporators. During ascent, the upper limits are raised so as to prevent triggering an unwanted C/W alarm; these limits are lowered for on-orbit and entry. These new limits match the Post-Insertion values.

#### PRE INGRESS FORWARD CONFIG

The Microwave Landing System (MLS) provides slant range, azimuth angle, and elevation angle for vehicle control. The MLS channel can be determined from the Land Site Data chart. The TACAN supplies slant range and bearing angle data for vehicle control. All three TACAN MODE switches are placed in the GPC position to enable power to the TACAN system transmitter/receiver and to allow TACAN channel selection via the "HORIZ SIT" display.

During the forward switch configuration for a rev 3 deorbit, the crew prepares the MPS so that it can be pressurized at an altitude of approximately 225,000 ft. Hydraulic fluid pressurizes the lines to the actuators and to the engine control valves, to ensure that the valves are closed. In order to prepare for the SSME repositioning, the four FCS channels which control power to the ATVS's are verified to be in AUTO. The four ATVC's are then powered on. ATVC's provide command signals to the engine hydraulic actuators. They also detect any faults and provide isolation commands to the actuators if a high hydraulic delta P occurs or if an ATVC power supply fails. The ATVC's are powered on during ascent. They are turned on again during deorbit prep to position the engines to the entry stow position. If the engines are not positioned correctly for entry, bell thermal damage could occur.

The flight critical dedicated displays and APU/hydraulic indicators are also powered on for a rev 3 deorbit via the instrumentation power switches. Finally, the MNA and MNC DDU AFT circuit breakers are opened to turn off the aft RHC, THC, and ADI since they may have been powered on on-orbit.



**ENTRY SW LIST/VER\***

The switches on the forward and aft panels are configured for entry as per the pictorials located in section three of the C D/O. The switches fall into one of three categories:

1. **ACTION REQUIRED:** These switches need to be configured for entry; they can be identified by the solid box surrounding them.
2. **VERIFICATION REQUIRED:** These switches only need to be verified since they should already be in the correct position for entry. These switches are neither boxed nor shaded.
3. **NO ACTION REQUIRED:** These switches do not need to be configured or verified for entry. The switches are shaded gray (zipped).

The C D/O pictorials are taken from the nominal Deorbit Prep. Depending on how far (if at all) the crew has proceeded into Post Insertion, the pictorials may or may not reflect the correct switch positions for a launch day deorbit. The NOTE below the switch verification callout in the timeline lists any discrepancies the crew will find in performing the switch verification.

**PAYLOAD ENT SWITCH LIST/VER\***

Switch configuration for panel R1 and any flight specific SSP's is located in the P/L OPS C/L in the DEORB PREP tab along with any payload deactivation procedures.

**NH3 CNTLR A(B) - PRI/GPC\***

In an orbit 3 D/O, the ammonia boiler is set to PRI/GPC in order to remove excess heat from the Orbiter during entry since radiator coldsoak is not available. The ammonia boiler systems (A and B) are enabled by GPC command during entry. The ammonia boiler system can only be used to cool the Freon after EI since some gravity is required to feed the NH3.

**SECURE MIDDECK**

After reconfiguring the communication channels for entry, the MS makes sure that the lockers are secure for the rev 3 deorbit as a safety precaution. Likewise, the foot loops are taped down to prevent the crew from tripping on the foot loops during egress.

**DISCONNECT, STOW WIRELESS HEADSETS**

Before a rev 3 deorbit, the crew disconnects and stows the wireless headsets (if they have been activated). The crew then dons their LES helmets for entry.

**FINAL DEORB UPDATE/UPLINK\***

At approximately TIG -00:34 in the rev 3 deorbit timeline, these procedures are exited, and DEORBIT BURN in the ENTRY C/L is entered. The RAD BYP VLV MODE and the CNTLR LOOP commands are deleted from the ENT MNVR cue card. In an orbit 3 deorbit, the PLBD's may or may not have been opened depending on where the crew enters the C D/O rev 3 timeline. However, even if the PLBD's are opened, no effective coldsoak will have been initiated. Therefore, the crew does not need to activate the radiators for entry.

**SECTION 3**  
**LOSS OF 2 FC LAUNCH DAY DEORBIT PREP**  
**(ORBIT 2 OR ORBIT 3)**

**OVERVIEW**

This procedure was developed from the LOSS OF 2 FUEL CELLS DEORBIT PREP which configures the orbiter for entry after several on-orbit failures. The LOSS OF 2 FC LAUNCH DAY procedure transitions the orbiter from a failure that occurs during ascent or shortly thereafter to an entry opportunity at a primary landing site (PLS). Consequently, the activities in this procedure are nearly identical to the Loss of 2 FC on-orbit deorbit prep, but the number of activities is reduced because the orbiter is already in an ascent configuration which is similar to entry. Thus the rationale for the launch day deorbit prep is very similar to the on-orbit prep, and that section should be referenced for each of the activities of the launch day deorbit prep. Only those differences from the on-orbit deorbit prep will be included here.

The thermal analysis for this case is LEMSCO-24581 and the electrical analysis is RSOC TAPE R09407.

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\* Refer to LOSS OF 2 FUEL CELLS DEORBIT PREP rationale.

**ASSUMPTIONS/INITIAL CONDITIONS**

This procedure was built to transition from the loss of 2 fuel cells during the ascent phase of flight to the entry checklist. The LOSS OF 2nd FC (ASC PKT, PWRDN) is performed and allows a transition from either OPS 1 or OPS 2 to OPS 3. If the failure occurs while in OPS 1, the powerdown transitions to OPS 3 and the PRE DPS TRANSITION SWITCH CONFIG and DPS ENTRY CONFIG are not performed. If the failure occurs while in OPS 2 the powerdown is performed and exits to this procedure which then transitions from OPS 2 to OPS 3. The procedure assumes that the fuel cells would most likely fail during ascent and thus the RAD ACT, PLBD OPENING and other Post Insertion activities will not have been completed.

**PROCEDURE NOTES**

These are the same as the on-orbit loss of 2 FC case except no reference is made to a gravity gradient attitude, which is done only in the TIG > 4 hour powerdown.

**AC BUS CONFIG**

This activity is identical to the on-orbit case except that the LOSS OF 2 FC SWITCH VERIFICATION LIST is not marked up with the changes. The pictorials are not used for the launch day case as there is insufficient time to do the verification.

**PREL DEORB UPDATE/UPLINK**

The only difference here is that a maneuver to the deorbit burn attitude is initiated here as no IMU alignment is performed.

**COMM CONFIG**

This configuration is similar to the Loss of 2 FC D/O PREP comm configuration. However, for a Loss of 2 FC launch day deorbit case, the hydraulic system C/W parameters do not need to be reset since these channels are already activated for ascent.

**PRE INGRESS CONFIG**

The heads up display (HUD) covers are already off from ascent.

## SECTION 4 LOSS OF TWO FUEL CELLS DEORBIT PREP

### OVERVIEW

The LOSS OF 2 FUEL CELLS Deorbit Prep is entered after the completion of either the Orbit Pocket Checklist powerdown LOSS OF 2nd FC ON-ORBIT TIG < 4 hr or LOSS OF 2nd FC ON-ORBIT TIG > 4 hr. The principal difference between these two powerdowns is the amount of equipment left running. If TIG is less than four hours, more equipment can remain powered on since it will soon be used in the C D/O. If, on the other hand, TIG is greater than four hours, more equipment must be powered off to reduce loads on the last fuel cell. Both the powerdowns and the contingency deorbit prep use 4 hours as a breakpoint as to which procedures are performed. The deorbit prep assumes 4 hours remain until the deorbit burn and that the TIG > 4 hours powerdown has been performed. If the TIG < 4 hours powerdown was performed, not all of the deorbit prep procedures need be performed. An Activity Priority table has been included to prioritize the procedures in this case where the deorbit prep must be completed in less than 4 hours.

Since only 1 fuel cell remains operating, the major difference from a nominal deorbit prep is that the power available is severely restricted and must be budgeted for essential loads. This includes adopting a single fault tolerance (SFT) level of redundancy for all entry critical equipment, limiting activities to only those required to deorbit, enter, and land safely, maneuvering to a cool attitude while waiting to deorbit to limit the amount of cooling needed, performing an AC power transfer cable installation to allow one AC inverter to be shut down, performing a fuel cell purge to have the fuel cell operate as efficiently as possible, and disabling vent door operations during entry because there may not be enough power to open all of the vent doors.

The LOSS OF 2 FUEL CELLS has a case specific pictorial section (section 6) because of the large differences in equipment configuration compared to the nominal deorbit prep pictorials in section 3. (No pictorials exist for the orbit 2 or 3 Loss of 2 FC case as there is insufficient time to perform a switch verification.)

The thermal analysis done for this case is LEMSCO - 24240 and LEMSCO - 24383. The electrical analysis is RSOC TAPE - R01800 and R07187.

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## ASSUMPTIONS/INITIAL CONDITIONS

This procedure may be entered after performing LOSS OF 2nd FC ON-ORBIT (TIG > 4 hr) (OPCL, PWRDN), and all activities are performed at their scheduled time starting at TIG -4:00. It may also be entered from LOSS OF 2nd FC ON-ORBIT (TIG < 4 HR) (OPCL, PWRDN) with a few modifications because of the less extensive powerdown, and because there will be less than the nominal 4 hours to complete the procedure. For the TIG < 4 hours case, there is an Activity Priority Table to determine which activities must be performed to deorbit and land safely.

Flight Rules limit the electrical load that may be placed on a fuel cell after a failure to 10 kW continuous load, 13 kW for a 4 hour period, and up to 16 kW for 15 minutes as long as the bus voltages and fuel cell temperatures are satisfactory. These loads allow a successful deorbit and entry. Electrical analysis predicts a load of 10-12 kW with periods where the power requirement will peak to 14 kW momentarily during the deorbit prep and entry phases.

### IF TIME TO TIG < 4:00

When the TIG < 4 hours powerdown is performed, the Activity Priority Table is used to select those activities necessary to perform the deorbit prep depending on the time available before the deorbit burn. This table was built assuming the TIG < 4 hours powerdown has been performed, whereas the procedure as written assumes the TIG > 4 hours powerdown was performed. Thus, not all of the activities done from the TIG > 4 hours deorbit prep are applicable. The table lists all the activities for the TIG > 4 hours case, with two columns under the EXPEDITED D/O heading. If an activity is necessary to accomplish a deorbit, entry, and landing, it is listed under the mandatory (MAND) column. An activity is listed under the optional (OPT) column to indicate that it may be performed after the mandatory activities have been completed if there is time before transitioning to the ENT checklist. The number refers to the activity block number of the listed activity. T/L indicates the activity is found on the timeline itself, and a dash in both columns means that the activity is not applicable to the expedited case, i.e. the equipment was not turned off in the TIG < 4 hours powerdown. Thus, if this procedure was entered from the TIG < 4 hours case, the mandatory activities are performed as expeditiously as possible in the listed sequence, then any optional activities are done as time permits. Test simulator runs of this procedure indicate that at least 1.5 hours are needed to complete all the mandatory activities. If this procedure was entered from the TIG > 4 hours powerdown, and less than 4 hours remain until TIG, all activities should be performed. If the second fuel cell failure occurs after nominal Deorbit Prep has been started, some of these activities may already have been performed, and all activities should be reviewed to ensure a proper configuration for entry.

**IF TIME TO TIG > 4:00**

As stated above, the Activity Priority Table is applicable only to the TIG < 4 hours powerdown. If the TIG > 4 hour powerdown was performed, all activities in this section should be done.

**PROBLEM DESCRIPTION/RATIONALE**

There is only one fuel cell remaining to power all equipment in the Orbiter, and it is critical that it not be overstressed. The electrical analysis assumed a 50% fuel cell, i.e. its performance is midway between that of a new fuel cell and the minimum launch criteria fuel cell. Thus a newer fuel cell could power more equipment, and an older fuel cell may not be able to support the power requirements of this procedure. The more a fuel cell is loaded, the lower its voltage becomes and undervoltage alarms may occur.

**PROCEDURE NOTES**

In order to limit the power level, only two GPC's and only one CRT, instrument power, and DDU should be used if possible. If the TIG > 4 hours powerdown was performed, the Orbiter is in a gravity gradient (GG) attitude with the RCS powered down. Thus, no maneuvers are done until the aft RCS powerup at TIG -3:36. Only the lights needed to perform the procedure should be on to limit power use. The configuration of the Orbiter can support two PASS GPC's during entry so an additional PASS GPC is powered up around TIG -20 minutes. If the voltage on the last remaining fuel cell is too low, the vent doors might not reopen during the final stages of entry which could result in a loss of vehicle. Therefore, the vent doors will remain open throughout entry except for the left and right vent doors 1 and 2. These doors are allowed to close by turning on FF4 at the OPS 304 transition. The doors are then reopened at a relative velocity of 2400 fps. These vent doors are left operating to protect against excessive thermal damage during entry. Since STS flights regularly have several MS's onboard, they are delegated to perform aft and middeck procedures.

**OVERVIEW**

These tables give a summary of the configuration of major Orbiter equipment during this procedure, as well as crew activities during the 4 hour timeline. These tables are for reference only and should not be used to execute the procedure.

## **CRT TIMER SETUP**

This is a nominal deorbit prep procedure to give the crew a means to correlate procedure flow and time to the deorbit burn until the targets can be entered on the MNVR display in OPS 3. Although the timer continues to count over OPS transitions, it must be entered into the different major functions. A pad for a one day wave-off is also included.

## **ENTRY STOWAGE**

The middeck equipment that has been out for on-orbit use is now stowed. A partial WCS config is done to allow specialist seat installation, the escape pole is setup, and egress route foot loops are taped out of the way.

## **FES HTR ACTIVATION**

The FES was deactivated in the TIG > 4 hours powerdown and the topper heaters need to be reactivated to allow time for them to heat up prior to topping FES restart.

## **FDF CONFIG/ENTRY STOW**

The FDF articles needed for entry are unstowed and deployed, and the on-orbit articles and photo equipment are stowed.

## **RCS/OMS HTR AFT RCS JET**

These heaters are checked on in preparation for reselecting the aft RCS jets and for the deorbit burn.

## **MDM CONFIG**

To allow communication between the GPC's and the equipment to be repowered, the MDM's turned off in the TIG > 4 hours powerdown are turned on and an I/O RESET performed. Three FF MDM's provide SFT in PROP and GNC systems. This procedure block is not performed for the TIG < 4 hours case since the MDM's were not powered off in the APCL powerdown, Loss of 2nd FC.

## **AC BUS CONFIG**

Power is removed from the main engine controllers by opening all of their cb's on panel L4 rows D and E. Also, various panel/instrumentation lighting and the Course Optical Alignment Sight (COAS) have power removed by opening their cb's on row Q. Although this equipment is OFF, the cb's are opened for shortage protection during entry.

The ac bus reconfiguration is done at this time to protect the remaining fuel cell (FC) from an inverter failure during entry. Only the ORB PKT bus loss procedure should be worked and the MAL procedures should not be done. The LOSS OF 2 FUEL CELL pictorials (section 6) are then marked up to

correspond to the steps performed in the BUS LOSS ACTIONS. The fuel cell pump receives power from its inverter (i.e. AC1, AC2, or AC3). A fuel cell needs at least two phases ( $\phi$ 's) to keep running; therefore, the ac power transfer cable is installed to provide a redundant source of phase power. The power transfer cable installation is performed at the indicated time to avoid possibly dragging down the primary ac system if the redundant ac source has a short.

To prevent automatic inverter trip-off on the single operating fuel cell, the ac bus sensors are turned off. If FC 1 is okay, then AC1 is the primary bus and AC3 is the paralleled powered bus and vice versa if FC 2 or FC 3 is okay.

### SELECT AFT RCS JETS

The FA MDM's and RJDA logics and drivers are verified on for aft jet control, and Jet OPT 3 selects pitch/yaw tail only jets. Tail only is selected to limit the power required for attitude control. Attitude control is regained at this time to allow FES startup and radiator cold soak. This configuration is consistent with the SFT philosophy.

If the RCS manifold pressure has remained  $> 130$  psi after being secured in the powerdown, the He press and RCS isolation valves may be reopened. If not, then the manifold must be repressurized per the MAL procedures to avoid possible damage from pressure transients.

This procedure block and gravity gradient (GG) attitude are done only for the TIG  $> 4$  hours case.

### LOSS OF 2 FC SW VERIF LIST

Only the airlock and airlock hatch pictorials are checked at this time. The full LOSS OF 2 FUEL CELLS pictorials will be checked after most of the activities have been performed and time permits before transitioning to ENT.

### FES RESTART

To get the freon temperature above the 41 to 47 degrees F range where a FES shutdown would occur if a start would be attempted, the RAD CNTLR OUT TEMP is taken to HI to partially bypass the radiators. The primary controller B is turned on after the freon coming out of the evaporator reaches 50 degrees F. Only the topping FES will be used since the HI load evaporator will not be enabled until just before PLBD closing when radiator cooling will no longer be available. The H2O supply crossover is opened to provide redundant sources of water to the FES.

### MNVR TO TAIL TO SUN

The tail to sun attitude allows for heating up the aft systems. (The APU lube oil, hydraulic, and RCS/OMS heaters were turned off in both of the powerdowns.) The tail to sun attitude also provides an attitude for cold soaking the radiators.

## **PRESS CNTL SYS ENTRY CONFIG**

The Pressure Control System (PCS) is configured essentially as in the nominal deorbit prep, which protects the crew in the event of a large cabin leak. The middeck O2 bleed orifice is removed as O2 will be supplied to the LES helmets which indirectly supply O2 to the cabin. The LEH (sic) helmet valves are configured as in other contingency deorbit procedures.

## **SEAT INSTALLATION**

The MS's install their seats in preparation for entry. The actual time this is performed is not critical and may be performed later at the crew's discretion.

## **MCA CONFIG**

The Motor Control Assemblies (MCA's) are turned on to supply power to motors for Ku-band antenna stow, PLBD closing, ADTA deploy, and vent doors 1 and 2 operation. Some of these will later be turned off to disable the remaining vent doors operation.

## **KU-BD ANT STOW**

The ORB OPS checklist procedure is used to stow the KU-band antenna. However, as the CAUTION on the AFT MS page states, only PL BAY MECH PWR SYS 2 should be used to have single motor ops. This reduces the power demand on the fuel cell.

## **RAD BYP**

The HI load FES is now enabled in preparation for PLBD closing. Only one controller is on, and the B heaters configured to prevent the exhaust duct from freezing up. The radiators are manually fully bypassed and their controllers turned off to preserve the cold soak for entry. The freon loops are taken to the interchanger (ICH) position to maximize cooling to the cabin via the water loops. Although turning off one freon pump would save power, the additional fuel cell cooling would be lost, so both loops were left on the powerdowns.

## **PLBD CLOSING**

This procedure has been moved earlier in the timeline in order to spread out the power demands on the fuel cell and limit the peak load. It is now done before the OPS transition to avoid having RGA's, ASA's, and AA's on while closing the doors, and to be more consistent with nominal deorbit prep. Again, only MECH PWR SYS 2 (single motors) is used to stow the radiators if required to limit power demands on the fuel cell.

Equipment used to close the doors is turned off to reduce power levels. The aft CRT 4 will no longer be used so it is deassigned and turned off, and the cameras used to photograph the door closing are stowed.

**CRYO QTY CONFIG**

The O2 and H2 tanks have quantity sensors that are no longer needed. With these circuit breakers open, the power is removed from the sensors.

**PRE DPS TRANS SWITCH CONFIG**

Entry critical equipment is powered to a SFT level prior to the OPS 3 transition. The RGA's and ASA's must be turned on before the OPS 3 transition in order to maintain Orbiter stability. RGA's are the only source of rate information to the DAP in OPS 3; attitude control will be lost if the RGA's are not on prior to the ops transition (unless the DAP has been configured for free drift). Likewise, at least 2 of ASA's 1,2, or 3 must be on for the GPC's to get valid aerosurface information at the OPS 301 transition; otherwise hydraulic line and ASA damage may occur when the APU's are taken to normal pressure in MM 303 since the GPC commands a step change based on the erroneous position information.

**DPS ENTRY CONFIG**

Once the entry critical equipment is powered on, the crew can start transitioning a GNC GPC and BFS GPC to OPS 3. Only two GPC's are powered on at this time to reduce power demands on the last remaining fuel cell. (Another PASS GPC will be powered up at approximately TIG-20 minutes as a pen-and-ink to the Entry C/L.)

Before transitioning the GPC's to OPS 3, the crew should perform an SM checkpoint. If a transition back to OPS 2 should become necessary, this checkpoint eliminates having to uplink any changes to SM parameters that were made after the initialization of SM OPS during Post-Insertion.

Once the SM checkpoint is completed, SM GPC 4 is powered off rather than being taken to OPS 3 with GPC 1. Before powering off the SM GPC, all CRT MAJ FUNC should be in GNC to prevent losing CRT's that have their MAJ FUNC in SM.

After GPC 4 is powered off, GPC 1 is transitioned to OPS 3 as is the BFS GPC 5. The land site update is checked following the transition as in a nominal deorbit prep. Once the transition is complete, the MMU's and ASA's which were powered on at the start of the procedure are turned off. (All four ASA's are powered on again later as a pen and ink to the Entry C/L.)

**PREL DEORB UPDATE/UPLINK**

MCC voices up the preliminary updates to the OMS Deorbit, Entry, and Landing (DEL), Deorbit Maneuver, and IMU Align Pads, and uplinks the PASS and BFS state vector and deorbit targets, which requires GPC uplink enabled. If no MCC comm available, the SPOC is used for the deorbit targets. After the onboard software calculates the solutions, they are compared to the MCC solutions.

## **HORIZ SIT CONFIG**

This is a standard check of landing aids, except it is performed early to allow the crew the time to pen and ink the ENT checklist with the two pages of changes located in this section after the timeline pages.

## **IMU RECOVERY**

The IMU's lost when the FF MDM's were turned off in the TIG > 4 hour powerdown or when the fuel cells failed are recovered using the appropriate MAL procedures. The BFS is taken to OPS 0 and back to OPS 301 to let the BFS obtain IMU data. Since an OPS 301 PRO was performed, the BFS runway selected must be checked.

## **FLUID LOADING PREP**

The standard water and containers and salt tablets are prepared for intake prior to entry.

## **GALLEY or H2O DISPENSER DEACT**

Either the galley or water dispenser is flown. Power for the valves, pumps, heaters, and electronics is turned off when no longer needed.

## **HTR CONFIG**

The fuel cell purge heater is turned on in preparation for the purge to be performed later. The hydraulic and APU heaters are turned off since the tail to sun attitude will prevent these lines from freezing. The RCS/OMS heaters are turned off in preparation for entry. These are area heaters and are not needed during a dynamic phase of flight. The crossfeed lines are verified off to save power. This occurs close enough to entry that fuel line freezing should not occur. The OMS crossfeed line heaters are also verified off since the crossfeed line is not required except in OMS/RCS failure scenarios. This procedure assumes no additional failures. The jet 5 (verniers) heaters are turned off as they do not support entry.

## **APU STEAM VENT HTR ACT**

Depending on which fuel cell is operating and which buss loss actions were performed, different BLR CNTLR/HTR configurations are used to heat the steam vents. In order to obtain a gray talkback for APU ready to start, the steam vents must be at least 130 degree F. Based on flight data, the heaters may need up to 2 hours to clear the vents of ice if any was present.



**ACT -Z STAR TRKR**

Both star trackers are verified on, although neither were turned off in either powerdown, in preparation for the IMU alignment. The I/O RESET reestablishes comm between the GPC and the star trackers if they had been off. The BFS does not support IMU alignments.

**MNVR TO IMU ATT**

Using data either voiced up from MCC or the STAR PAIRS table, a maneuver is initiated to the IMU align attitude. Pads are provided to record data for the alignment.

**IMU ALIGNMENT**

The IMU alignment is a standard entry procedure, except that the BFS CRT display is powered off prior to the alignment since the crew should limit use of CRTs whenever possible. The BFS CRT is powered on again after the alignment is completed.

**WCS DEACTIVATION**

Configuring the WCS for entry is completed at this time or it may be delayed at the crew's discretion.

**FUEL CELL PURGE**

In order to have the last remaining fuel cell operating as efficiently as possible, a purge is initiated to help remove inert gases and contaminants that slowly accumulate around the electrodes. However, to prevent freezing the dual gas regulator from too great a flow of cryogenic O<sub>2</sub> and H<sub>2</sub> and thus losing the last fuel cell, the purge should not be performed if its output is greater than 430 Amps.

**MNVR TO BURN ATT**

Once the IMU align is complete, the maneuver to the burn attitude is begun. The attitude was either voiced up from MCC or calculated onboard earlier in the PREL DEORB UPDATE/UPLINK.

**DEACT STAR TRACKERS & CLOSE DOORS**

Once the IMU alignment is complete the star trackers can be turned off and their doors closed. This activity is identical to nominal Deorbit Prep.

**C/W, COMM CONFIG**

This configuration is similar to nominal Deorbit Prep. STDN-LO is used since it is the low power comm with data system. These hydraulics system caution and warning (C/W) parameters for low pressure are activated in order that an alarm will sound when the hydraulic pressure drops below 2760 psia during deorbit to landing. When enabled, an alarm will sound and the HYD PRESS C/W and MASTER ALARM (MA) lights will illuminate since the hydraulic system is still deactivated. The MA is reset, but the HYD PRESS C/W will remain lit until the hydraulic systems are activated and brought up to operating pressures.

**VENT DOOR OPS DISABLE**

Before disabling the vent doors, the forward MCA logics are verified on in order to support the FWD RCS dump in the Entry C/L. Because there may not be enough power available during entry to ensure the vent doors will open, all vent doors except the left and right doors 1 and 2 are left open throughout entry. Doors 1 and 2 are allowed to close at the OPS 304 transition by turning on MDM FF4, and then turning FF4 off after the doors close; FF4 is turned back on at Mach 4 to allow left and right vent doors 1 and 2 to open at a relative velocity of 2400 fps. If these doors were to be left open at OPS 304, thermal damage to the door boxes would result in excessive turn around time. If left closed at 2400 fps, structural damage would result from the pressure differential.

The two circuit breakers MCA PWR AC1(3) 3 $\phi$  FWD1(3) are opened to prevent dual motor operation for the ADTA probes and L,R vent doors 1 and 2. If an AC 2 or MNB problem has caused the fuel cell failure, the step to pull these breakers should not be performed. Their power is needed to have these operations.

**LOSS OF 2 FC SW VERIF LIST**

All crewmembers use section 6 to check their respective panels as to the proper switch configuration. This is a double check of the powerdown and deorbit prep procedure steps and no switch-throws should be required. This activity is optional in the expedited case.

**CLOTHING CONFIG**

The crew dons their LES, harness, and boots early enough to provide time to complete the donning before entry, but late enough to minimize the time spent in the suits. The commander and pilot don their suits prior to performing the final configuration before transitioning to ENT, and before the specialists to stagger the donning. In the expedited case, the donning may need to be delayed until after the deorbit burn.

**WIRELESS STOW**

If the wireless headsets were used, they are stowed at this time. The crew will soon be in their suits and able to communicate through the LES helmets. The aft deck lights are minimized to reduce power demands.

**Begin FLUID LOADING**

The standard consumption of water and salt to replace body fluids lost on-orbit is begun. This is an optional activity for the expedited case.

**PRE INGRESS CONFIG**

The MPS/H2 PURGE PREP is done before seat ingress to configure for actual feedline pressurization with He during entry. The RCS/OMS quantity gage is powered for fuel available during the deorbit burn. Radar altimeter 1 is selected to provide data to the GPC's. The manual TACAN and MLS channels are set according to which landing site is selected. This information is obtained from the Land Site Data Chart which is included as a tab in the back of the Contingency Deorbit Prep flight books. The crew selects forward flight critical data buses 3 and 4 as the data sources for panels F6/F8 dedicated displays. The proximity package circuit breakers are closed for landing gear proximity sensor systems 1 and 2 electronics which drive the landing gear talkbacks. For short circuit protection the humidity separator and IMU fan signal conditioner circuit breakers are opened. The HUD covers are removed in preparation for landing. The ADTA, BRAKES, ANTISKID and NWS normally activated here are not activated until EI-5 to help maintain the overall power profile under 12 kW and to be consistent with other SFT procedures.

**LEH 02 VLV**

The 02 valves for the LES helmets are opened to provide 02 for the flight deck crew members.

**SEAT INGRESS**

To minimize power demands, the seats are adjusted in only one direction at a time. The brake pedals are exercised to ensure they are operable before needed during landing. The LES PRESS INTEGRITY CHECK is performed to verify proper configuration of the suit.

**P & I CHANGES TO ENT**

The av bay fans are cycled to keep av bay equipment cool, but an av bay fan should be on for any bay with powered GPC's. GPC's 2 and 3 remain off all through entry. All deletions to ENT are to reduce total power levels. The HYD LG HYD ISOL VLV's check is delayed until after the first APU is started since the circ pumps are off. The humidity separator is off to save power. The FES heaters are turned off to allow an additional PASS GPC to be powered. These lines should not freeze in the time left that the FES is needed. All four ASA's are needed during MM 304 and 305 to configure the

FCS in a SFT posture. Entry will be flown with 3 FCS channels active and the fourth isolated (bypassed). With MDM FF4 off, 4 ASA's are required to be SFT. GPC 4 is activated to provide PASS redundancy. All four FCS channels are put in override to inhibit auto fault detection to protect against the next worse failure, which is a 2 on 2 channel dilemma where a 50% chance exists that the good channel would be voted out. The landing site and runway must be verified since an OPS 301 PRO has occurred; OPS 301 PRO defaults to the I-loaded landing site, and it must be reselected if an alternate site is chosen. Two DDU's and FLT CNTLR PWR's are used during the burn and only 1 DDU afterward per SFT philosophy. Av bay fans are turned off for the burn, but repowered afterwards to reduce power demands on the fuel cell. The SECONDARY ACTUATOR CHECK, if performed, places the FCS CH switches to AUTO; they need to be returned to ORIDE. Steps to power up equipment for a forward RCS dump are included if required.

#### **ENTRY MANEUVERS Cue Card**

The brakes, ADTA's, DDU's, and the left INST and FLT CNTLR are activated at EI-5 to delay the associated load until it is required to support entry. The TACAN's used for entry depend on which set of AC inverters have been deactivated during the AC BUS CONFIG. The ADTA probes are deployed one at a time, and only one is heated if heat is required to avoid unnecessary power demands. The cabin and av bay fans are deactivated at Mach 2.9 to provide voltage margin for landing and nav aids. The ANTISKID and PLT's INST/FLT CNTLR PWR are powered at Mach 0.9, and if NWS is required, it will also be powered at this time. Landing and nav aids are deactivated ASAP after wheelstop to relieve some of the load on the fuel cell, and fans are restarted to help cool the avionics.

## SECTION 5 LOSS OF FES DEORBIT PREP

### OVERVIEW

The LOSS OF FES section is entered only after the EVAP OUT T HIGH and LOSS OF FES procedures in the OPCL are completed. This procedure starts at TIG - 04:00 and exits to the Entry C/L.

The LOSS OF FES procedures attempt to follow the nominal deorbit prep sequence as closely as possible with some changes to allow for an extended radiator cooling. Since the FES is not functional, only the coldsoaked radiators can be used to cool the vehicle during entry [until entry interface (EI) when the NH3 system is activated.] Changes to the nominal deorbit prep timeline are dictated by the need to coldsoak the radiators for as long as possible with the minimum amount of power loads.

When these procedures are entered, certain systems have already been powered down via the OPCL in order to reduce the cooling requirements on the radiators. A supply water dump is performed to get rid of excess water normally used by the FES during entry. An IMU alignment is also performed as it is in a nominal deorbit prep so that attitude data is correct for entry. However, the Orbiter is not maneuvered to the attitude for optimal TDRS communication after the IMU alignment is completed. Instead, the Orbiter is maneuvered to a biased-XSI attitude (tail sun) for thermal conditioning. Activation of critical NAV and LDG aids is delayed to reduce the cooling loads during the radiator coldsoak. Pen-and-ink changes are made to the Entry C/L to reflect these delayed activations. Use of the CRT's, FLT CNTLR PWR, INST PWR, SPOC, and lighting is limited to reduce heating requirements on the degraded cooling system. Likewise, the dedicated display entry config, the hydraulic repress prep, and the dedicated display config are all delayed in the timeline. Activities dealing with PLBD closure are also delayed to allow the radiators to coldsoak longer.

The CDR/PLT exit the LOSS OF FES procedures at TIG -00:30 whereas the MS's continue the procedures until the deorbit burn. The extra time is provided for the MS's to stow the radiators and close the PLBD's.

The thermal analysis for this case is LEMSCO -24833, and the electrical analysis is RSOC TAPE R05809.

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## ASSUMPTIONS/INITIAL CONDITIONS

Prior to entering this section of the C D/O, the EVAP OUT T HIGH (ORB PKT, ECLS) and LOSS OF FES (DEORBIT PREP) (ORB PKT, PWRDN) procedures must be completed. If the FES cannot be recovered in the EVAP OUT T HIGH procedure, the crew will exit to the LOSS OF FES procedure and perform a powerdown to reduce the cooling requirements on the degraded system.

These procedures assume that deorbit prep has not been entered yet. If the failure occurs after deorbit prep has been entered, then some of the activities in this section will have previously been performed. In this case, the crew should compare the activities already completed in the D/O Prep timeline with the activities in the LOSS OF FES timeline (beginning at TIG -04:00)

## PROBLEM DESCRIPTION/RATIONALE

These procedures are entered if a failure occurs that results in the loss of the FES. The FES normally provides cooling during entry (along with the radiator coldsoak and NH3 boiler system). If the FES is not functional, the crew has to rely solely on the radiator coldsoak until entry interface (EI) when the NH3 system is activated. Since the FES is used during entry, immediate deorbit is not necessary as long as both freon loops are operating and radiator flow has been established to provide cooling on-orbit. As long as a coldsoak attitude is maintained and an adequate powerdown performed, the radiators can be coldsoaked while cooling the Orbiter at its normal 38 degree F radiator outlet temperature. The radiators provide sufficient cooling to allow normal on-orbit power levels without creating thermal problems. During deorbit prep however, the power levels must be limited so as to increase the effectiveness of the radiator coldsoak.

## PROCEDURE NOTES

These procedures follow the nominal deorbit prep sequence as closely as possible with some changes to allow for the loss of FES. The radiator coldsoak is maintained for as long as possible with minimum cooling loads since it alone provides cooling during entry until the ammonia boilers are activated at EI. In order to extend the effective life of the coldsoak, critical equipment is not turned on until late in the entry sequence. Powerup of the NAV and LDG aids is delayed as long as possible to reduce the cooling loads. Likewise, use of the CRT's, FLT CNTLR PWR, INST PWR, SPOC, and lighting is limited during entry. The GPC's are not transitioned to OPS 3 until TIG -45 minutes so as to delay full GPC powerup.

In order to maintain the radiator coldsoak for as long as possible, PLBD closure is delayed to TIG -10 minutes. Since time is limited, the crew will close the PLBD's using the emergency PLBD closing procedure. (If problems are experienced in closing the PLBD's, deorbit may be delayed if the doors remain open since thermal problems arise only after radiator cooling is lost after the doors are closed.) Likewise, the Orbiter remains in the radiator coldsoak attitude (tail sun) until TIG -15 minutes (except for the IMU-alignment attitude).

The commander and pilot exit these procedures at TIG -30 minutes and go directly to the Entry C/L. The MS's however continue in the C D/O with the deorbit prep procedures until TIG. In the extra time provided for the MS's, the radiators are stowed and the PLBD's closed.

During entry, a HYD circulation pump is operated for ten minutes prior to each APU startup for additional cooling. The hydraulic loops help to reduce the peak temperatures reached during entry before the ammonia boilers are activated. The NH3 system is activated at EI and provides cooling until GSE hookup. The ammonia boiler system is activated at EI because gravity is required to properly feed the NH3.



## CRT TIMER SETUP

C D/O procedures are referenced to the TIG of the deorbit burn. The CRT timer is set by the crew to count down to TIG. First, the crew enters the D/O TIG time in HH:MM:SS in MET into GNC SPEC 2 for both GNC and SM displays via ITEM 17. Since the CRT timer is major function dependent, the entry must be made to both GNC and SM. The timer will continue to count across OPS transitions, even though it can only be set in OPS 2. The CRT timer pad also allows for one day wave-off contingency.

## DAP CONFIG

The standard DAP config is used for deorbit prep.

## SUPPLY WATER DUMP (ORB OPS, ECLS)

Normally, the H2O tanks are kept full before closing the PLBD's in case a failure occurs requiring an EVA to close the doors. In a loss of FES case, the crew should perform a H2O dump to prevent filling the tank ullage and possibly flooding the fuel cells should the overboard relief fail. If the crew cannot obtain the H2O dump information from MCC, a fifty percent ullage in one tank is considered sufficient.

## FLUID LOADING PREP

The crew members will be losing more body fluids than normal during entry due to perspiration and respiration. Fluid loading prevents dehydration and reduces detrimental changes in heart rate and blood pressure caused by orthostatic stress experienced postflight. As in a nominal deorbit, the crew drinks 32 ounces of water with eight salt tablets. The salt prevents the water from being expelled too quickly from the body by the kidneys. Fluid consumption begins at TIG -1:05 and continues over the next 1.5 hours.

## DPS CONFIG FOR D/O PREP

The GPC's are in their nominal on-orbit configuration when the Loss of FES procedure is entered. GPC 2 may have been powered off while on-orbit to preserve consumables. Therefore, steps are provided for activating GPC 2 (if it was previously turned off). First, the crew verifies that GPC 2 is moded to HALT; in the HALT mode, the GPC is in a hardware controlled state and can execute no software. Likewise, the crew verifies that the output switch for GPC 2 is in the NORMAL position; PASS GPC's are placed in NORMAL to allow output on the flight-critical data buses. Next, GPC 2 is powered ON and moded to STBY. The STBY discrete from the mode switch places the GPC under software control. It also allows for an orderly start-up of processing.

Once GPC 2 is added to the GNC redundant set, the buses are restrung by reconfiguring MC 2 per the NBAT. An OPS 201 PRO command brings GPC's 1 and 2 to OPS 2. The crew also verifies that the BFS GPC can drive a CRT. Consequently, the BFS GPC is powered on and moded to STBY. The STBY discrete only inhibits the BFS from commanding the payload data buses; it

does not prevent the BFS from processing software. After the crew verifies that the BFS can command a CRT, the BFC CRT DISP switch is turned OFF, and the select switch is placed in the 3 + 1 position which is standard for entry.

#### KU-BD ANT STOW

The Ku-band antenna may or may not have been stowed prior to deorbit prep, depending on communication requirements and antenna failure status. If the antenna has not been stowed, then it has to be stowed prior to PLBD closing since it extends beyond the payload bay envelope while deployed. The timing of this procedure is important since the Ku-band antenna is required for TAGS operations, and some entry related messages are usually uplinked during deorbit prep.

#### AUTO MNVR TO IMU ATT

The Orbiter is maneuvered to the correct IMU align attitude. The IMU align attitude is the attitude required to place a recognizable navigation star in both the -Y and -Z star trackers.

#### ENTRY STOWAGE

This procedure includes the stowing and reconfiguring of various articles and equipment not used during entry. Loose articles, such as personal hygiene equipment, the flight plan, the backup SPOC, the middeck camera accessories, window shades and filters, and the treadmill, are stowed for crew safety during entry.

A partial waste collection system (WCS) configuration is also performed to allow the specialists' seats to be installed. The foot restraints are stowed and latched, and the privacy curtain is stowed. The WCS is fully deactivated at TIG -0:51. Next the escape pole is unstowed and set up in case of an emergency landing requiring a bailout. The crew also configures the egress route as a safety precaution. The foot loops are taped down, and the interdeck access ladder footholds are deployed. On-orbit, these footholds are folded up for better zero-g mobility between the middeck and flight deck. The footholds are deployed prior the deorbit, as a safety precaution. The LES helmets limit the crewmembers' field of vision (FOV) during egress, increasing the possibility of overlooking folded-up ladder footholds.

## IMU ALIGNMENT

An IMU alignment is necessary before entry to ensure IMU accuracy. Star data can be obtained with only one S TRK if the other fails. A second attitude maneuver is required however when only one S TRK is available to obtain data on both stars.

The IMU ALIGNMENT procedure is entered in a previously established attitude. Two displays are used during the IMU alignment: SPEC 22 (S TRK/COAS CNTL) and SPEC 21 (IMU ALIGN). First, the crew verifies that the required ID numbers for the two star trackers are set to zero, thus ensuring that the auto star-select mode is active. Next, the status of the S TRK's is checked by the crew to verify that no BITE indications are present. The shutters are then verified open. If the shutters are closed, the crew verifies that the Orbiter is at the correct attitude; the S TRK's should not be looking at a bright object such as the sun. An off-nominal procedure is provided to open the shutters if necessary. If the shutters have to be manually opened, they are returned to AUTO after the data is collected and before any subsequent maneuvers to protect against damage from bright objects.

The crew then checks the IMU status on SPEC 21. The crew also verifies that asterisks appear in ITEMS 4,5, and 6 before selecting the IMU's. These asterisks indicate that the IMU's are in the Operate mode.

The IMU alignment attitude is checked again before the star tracker table is cleared of unwanted data entries. For a two star tracker operation, the table is cleared of all entries. For a one star tracker operation, the table is cleared the first time through so that the data on the first star will be retained while obtaining data for the second star.

The S TRK's are then enabled via ITEMS 3 and 4 on SPEC 22. The crew watches the star table for input of the specified star ID's. If the vehicle is in the correct attitude, the ID's should appear in approximately one minute. It is necessary to wait one minute or until the IMU delta angles are observed to change to ensure that they reflect the selected star pair.

The crew also checks the angular error (ANG ERR) value; the maximum allowable value for ANG ERR is .08. The ANG ERR is calculated by the S TRK's subsystem operating program (SOP) and is based on a 3-sigma star tracker and a 1-sigma selected IMU operation. If no data or bad data appears after three minutes, then the crew checks the attitude, star ID's and MET. The crew also verifies that the trackers are enabled. A self-test is then performed on both trackers. If both star trackers fail, the crew proceeds with trouble shooting per MCC direction. If a single star tracker fails, the crew performs a single S TRK IMU alignment. If neither star tracker fails, then the crew maneuvers the Orbiter to a new attitude and performs an alternate dual star tracker IMU alignment. The attitude and specific star ID's for any of these three failure cases are obtained from MCC or from information contained in the ORB OPS FS.

If a single S TRK alignment is necessary, data is taken on one star from the dual tracker attitude. The Orbiter is then maneuvered to the single tracker

attitude for the one good star tracker, and data is taken on the second star.

Once good star data is obtained, the crew verifies that the correct star pair is selected for computing the IMU delta angles; asterisks should appear next to ITEM's 17 and 18 on SPEC 22 to indicate star pair selection. Next, the crew selects the IMU's to be aligned via ITEMS 10, 11, and 12 on SPEC 21. The STAR ALIGN option is selected automatically the first time this display is called and remains active unless another mode is selected by the crew. Selection of the STAR ALIGN option causes the IMU's to be aligned to the desired orientation indicated by the delta ANG display.

Computed for each IMU in operation, the misalignment angles are the angles through which each axis of each IMU will have to rotate to be realigned. The accepted misalignment value is 0.8 degrees. If the angles are greater than 0.8, then the IMU alignment should not be performed due to erroneous data; new star data should be collected, after notifying MCC. The crew should not torque the platforms until MCC has time to determine the possible cause of the misalignment.

Execution of ITEM 16 on SPEC 21 results in torquing signals being sent to actually move the IMU platform. Once the torquing of the platforms begins, the misalignment angles for the selected IMU's should grow smaller. The alignment is complete when no '\*' appears behind ITEM 16. If the asterisk does not blank, the crew member will terminate alignment and contact MCC.

Since entry IMU alignment is such a critical procedure, a verification is performed. The Orbiter is maneuvered to a new attitude with the normal jets until the verification star pair are present in the trackers. The IMU align verification ensures that there is no star tracker error. New data is obtained on the verification star pair. The IMU misalignment error for the verification star pair is required to be less than 0.1 degree. This maximum value provides the required accuracy (0.26 degree) for entry interface. If the misalignment angles exceed 0.1 degree, then the crew notifies MCC and maneuvers to a different star pair for verification.

The alignment data is recorded in the IMU-STAR ALIGN LOG for future IMU performance analysis.

#### **GALLEY or WATER DISPENSER DEACTIVATION**

Either the galley or the water dispenser is flown for each mission. Whichever one is flown is deactivated prior to deorbit. The galley fan cb's are opened to minimize the risk of a short on the ac buses. Likewise, the galley water heaters are powered off to prevent possible overpressurization and subsequent rupture of the hot water tank. Other cb's are pulled to remove power from systems not used during entry.

#### **PREL DEORB UPDATE/UPLINK**

The preliminary deorbit update/uplink is provided at this time since the information contained on the target and deorbit maneuver pads is used to

maneuver the Orbiter into the correct deorbit burn attitude. The OMS propellant and deorbit, entry, landing (DEL) pads (Entry C/L) are updated by MCC. The deorbit maneuver pad is also voiced up by MCC. If MCC cannot uplink the correct deorbit target information, the crew will use the SPOC as a backup source of information.

#### **ENT SWITCH LIST/VER**

Only the airlock and airlock switch positions are verified prior to entry. This procedure is performed at this time since the airlock is not accessible once the MS seats are installed.

#### **HYD THERM COND - TERM**

On-orbit, hydraulic fluid is circulated as required to prevent the landing gear from getting too cold for entry. No thermal conditioning is needed during entry, and the landing gear hydraulic isolation valves are closed to prevent contaminant buildup in the brakes and to close a potential leak path.

#### **SPECIALIST SEAT INSTALLATION**

The MS seats are unstowed and installed. After the seats have been installed, FDF containers can be attached to the sides of the seats.

#### **APU STEAM VENT HTR ACT**

The water boiler steam vent heaters are required to be turned on at least two hours before the APU's are activated. (These heaters warm up to at least 130 degrees F.) The APU steam vent heaters remove any ice on the water spray boiler vent openings. If any ice is present, 2 hours is sufficient time to remove the ice. Heater controller A is selected via the BLR CNTLR/HTR switch.

#### **MNVR (TRK) BIASED-XSI ATT**

The Orbiter is maneuvered to a biased-XSI attitude (tail sun) from the IMU alignment attitude. This attitude is necessary to continue the thermal conditioning of the Orbiter and to reduce overall heating of the Orbiter. The radiators are coldsoaked so they can serve as a heat sink once the PLBD's are closed.

#### **DEACT STAR TRKRS & CLOSE DOORS**

The star trackers are no longer needed once the IMU alignment is completed. Therefore, the S TRK's are deactivated; they are powered off, and the cb's are opened to prevent inadvertent door opening during entry. Next, the S TRK doors are closed; it normally takes eight seconds for the doors to close.

The ST TRK's are not needed after the final IMU alignment. If another alignment should become necessary however, the star trackers will take at least fifteen minutes to warm-up.

### C/W RESET

The C/W parameters for the hydraulic systems are enabled so that an alarm will sound if the hydraulic pressure drops below 2400 psia during entry. Should the pressure drop below its minimum value, the alarm will sound, and the "HYD PRESS" C/W and "MASTER ALARM" lights will illuminate. The crew can reset the master alarm, but the "HYD PRESS" C/W light will remain lit since the hydraulic system is still deactivated.

### ENTRY SWITCH CONFIG

The crew configures various systems for entry at this time. First, the crew verifies that the correct landing site runway MLS stations are selected. Likewise, the three TACAN's are verified off. The MLS's and TACAN's are not powered on until late in the entry sequence in order to reduce the heat loads during entry. The hydraulic brake heaters are placed in AUTO to enable the heaters on the hydraulic line main gear brakes. The flight deck pressure control system (PCS) is also configured for entry in order to ensure vehicle and crew O<sub>2</sub> and N<sub>2</sub> supplies in the event of a cabin leak. The PCS system is configured to provide crew O<sub>2</sub> and to provide O<sub>2</sub>/N<sub>2</sub> to the cabin in the event of a cabin leak. Next, the crew configures the communication channels for entry. For redundancy management, the two AUD A/G and one A/A switches are configured to T/R, thereby enabling S-band and/or UHF communications. The MS's also configure the middeck panels L9 and R10 for entry communications. One of the MS's deactivates the teleprinter by turning the dc UTILITY PWR MNC to off. The teleprinter is deactivated this late in the timeline to allow any entry-related messages to be uplinked.

### P & I changes to ENTRY C/L

These changes to the Entry C/L reflect an attempt to maintain a reduced heat load as long as possible since the FES cannot provide any cooling. The crew has the option of either pen-and-inking these changes or removing this page and referring to it as each checklist/cue card is performed.

Certain navigational and landing instruments are not powered on prior to entry interface (EI) as they are in a nominal deorbit. Instead, they are turned on late in the entry sequence to prevent them from overheating and consequently failing during entry. These NAV and LDG aids include: ANTISKID, NWS, and NAV AIDS.

The brakes and ADTA's are powered on at EI-5. Single Fault Tolerance LRU management is maintained on the CRT's, DDU's, FLT CNTLR PWR, and INST PWR up to EI in order to prolong the effectiveness of the radiator coldsoak. After EI, the NH<sub>3</sub> boiler system provides enough cooling to allow Dual Fault Tolerance for these components.

Prior to EI, a forward RCS dump may be needed to reposition the vehicle's c.g. If the FRCS dump is needed, the FRCS MANF valves are opened, and the RJD logic circuits and drivers are activated. Once the dump is completed, the RJDF's are deactivated since no active cooling is available until EI.

Shortly after the deorbit burn, temperatures begin to increase as the radiator coldsoak is used up. Some cooling can be obtained from the hydraulic loops. Therefore, one of the hydraulic circulating pumps is powered on at EI-21 to reduce the peak temperatures slightly. After operating for ten minutes, the pump is turned off, and a second APU is activated. (The first APU is activated before the deorbit burn as in a nominal deorbit.) Once the second APU is started, the second HYD CIRC PMP is powered on for another ten minutes to provide additional cooling. At EI-5, the pump is deactivated, and the third APU is started.

The NH3 boiler system provides cooling after EI. The NH3 CNTLR is placed in the SEC/ON position. When using the SEC/ON position, no undertemp protection exists in the NH3 system. Consequently, a second water loop is activated to prevent loop freezing.

The first NH3 system is not exhausted until just prior to landing, when the crew is busiest. Therefore, at V = 6K, a second NH3 system is brought on-line to avoid temperature transients and crew distraction.

#### CLOTHING CONFIG

Each crewmember unstows and dons a launch and entry suit (LES), harness, and boots as part of crew safety preparations. The LES prevents the pooling of body fluids in the legs during entry. The LES also creates an artificial air pressure if a cabin leak occurs or a bail out is necessary at an ambient pressure below 2.8 psia. This clothing configuration process is cumbersome and requires a lot of room. Consequently, the donning of the suits is staggered to allow more room per crew member. Furthermore, the LES's are donned as late as possible before EI in consideration of crew comfort since the LES's restrict movement and can become warm.

#### N2 QTY COMPUTATION

The nitrogen (N2) quantity is determined prior to the OPS 3 transition by adding the nitrogen quantities in systems 1 and 2. This value is then annotated on the cabin pressure leak nomograph located in the EPCL. The crew uses this data to determine the maximum amount of time available for deorbit in case a cabin leak occurs during OPS 3. Since SPEC 66 is available only in OPS 2, this computation must be performed prior to the OPS 3 transition.

**HUD SETUP**

The pilot and commander remove the HUD covers prior to entry, making sure that any remaining cloth cover does not obscure the light sensor on the HUD.

**SEAT INGRESS**

When ready for seat ingress, the commander and pilot adjust their seats and exercise the brake pedals. They also perform a LES pressure integrity check to test the suit connections and suit pressure integrity. The CDR/PLT close their visors and suit controller valves. The O2 manifold valves are then opened. The suits should inflate within a few minutes. If a suit does not inflate properly, the suit connections are checked. According to the Flight Rules, the deorbit burn will not be delayed even if an LES fails the pressure integrity test.

**WIRELESS STOW**

The commander and pilot disconnect their wireless headsets and connect their LES comm systems. The MS's stow these headsets along with their own prior to MS seat ingress at TIG -00:05.

**WCS DEACTIVATION**

The WCS is deactivated as late as possible before the deorbit burn. The WCS vacuum valve is closed to isolate the commode outlet valve from the vacuum vent. The crew stows any loose WCS equipment in preparation for entry. The vacuum vent isolation valve is closed to protect against an air leak through the vent lines during entry. The WCS door is also latched at this time. Finally, the middeck lights are minimized to reduce power requirements during entry.

**RCS ENTRY CONFIGURATION**

Prior to OPS 3, the aft RJD drivers are verified on to ensure that the jets can fire. Since only the aft normal jets are used for entry, the forward RJD drivers and logics are powered off. Likewise, the vernier jets are no longer needed; therefore, the RJD MANF L5/F5/R5 driver is turned off. The forward RCS manifold isolation valves are closed in this procedure. The dump, if required for cg control, is delayed until post deorbit burn so as to reduce the heat load as long as possible. The RCS/OMS heaters used to heat the propulsion lines while on-orbit are powered off.

**DED DISP ENT CONFIG**

The flight control systems and dedicated displays used for atmospheric flight are configured prior to entry interface. Certain equipment must be powered on prior to the OPS 3 transition in order to maintain Orbiter stability and to prevent vehicle damage. The RGA's must be powered on prior to OPS 3 since the transition DAP uses both IMU and RGA data for attitude control. (The orbit DAP uses only IMU-derived data.) If the RGA's are not on prior to the OPS 3 transition, then the Orbiter will spin out of control



(unless the DAP is configured for free drift). Likewise, two of the first three ASA switches must be configured on prior to OPS 3 to prevent inaccurate aerosurface position feedback to the GPC's, which would result in incorrect GPC commands to the aerosurfaces at APU startup. The actuators and hydraulic lines could possibly be damaged in this case when full hydraulic pressure is reached.

In order to maintain a reduced heat load as long as possible, the crew does not activate all of the dedicated displays that are activated in a nominal deorbit prep. Certain navigational and landing aids are not powered on until late in the entry sequence to ensure that they will not over heat and fail during entry. The navigational instruments not powered on at this time include: ADTA's, DDU's, TACAN's, RADAR ALTM's, MLS's and other equipment.

### DPS ENTRY CONFIG

After MCC gives the go for the OPS 3 transition, the crew reconfigures the DPS for entry. The RGA's, AA's, ASA's, and IMU's are all verified on at this time. The RGA's and ASA's must be on prior to the OPS 3 transition to maintain Orbiter stability. The AA's and IMU's are also verified on since this is the best time considering power usage and crew workload. GPC 3 is then powered on, and the mode switch positions for each of the five GPC's are verified. All five GPC's must be in the correct configuration prior to the OPS 3 transition. Next, a CRT is assigned to the SM GPC (GPC 4). Since the PCMMU PL COMM display is not available in OPS 3, the PCMMU format is reconfigured before the OPS 3 transition. The format is changed to 105 (low data rate format) and to 164 (high data rate format). The event timer is set to count down to the TIG of the deorbit burn after the forward event timer circuit breaker is closed.

Next, the MC 3 NBAT is reconfigured via SPEC 0 before GPC's 1 and 2 are brought to OPS 3. An OPS 301 PRO loads GNC OPS 3 into GPC's 1 and 2. After GPC's 1 and 2 are transitioned to OPS 3, a checkpoint is taken on MMU 1 in case a transition back to SM OPS is required. First, the crew selects ITEM 3 and then initiates the checkpoint via ITEM 18 on SPEC 60, SM TABLE MAINT. ITEM 12, CKPT RETRV ENA, on DPS UTILITY is executed to allow the retrieval of a checkpoint. ITEM 36, UL CNTL ENA, allows the GPC's to process all uplinks. ITEM 36 is executed only when no SM GPC exists to control the uplink.

Next, the BFS GPC is transitioned to OPS 3. First, the BFS GPC is allowed to communicate with CRT 3 preengaged. The BFS output is put in BACKUP to allow the BFS engage capability. The crew then verifies that the TFL is enabled; the TFL serves to load the PCMMU whenever a switchover occurs. Finally, the BFS GPC is brought to OPS 3 with an OPS 301 PRO command.

GPC's 1,2,3, and 4 are transitioned to OPS 3. Before GPC's 3 and 4 are added to the OPS 3 redundant set, the SM GPC is moded to OPS 0 causing it to release the payload buses. (The BFS GPC takes control of the payload buses when it is moded to RUN.) GPC's 3 and 5 are moded to RUN to allow normal processing of all active software. The MC 3 NBAT is then reconfigured to include GPC's 1,2,3, and 4. The string assignments are

divided among the GPC's in case of a GPC failure. GPC's 3 and 4 are added to the OPS 3 redundant set by an OPS 301 PRO. Finally, the BFS GPC is brought to OPS 3. The CRT commanded by the BFS is powered off and then on again to give GPC 3 command of the CRT.

A landing site update is also performed if necessary after the OPS 3 transition via the "HORIZ SIT" display. This update must be performed after the final OPS 301 PRO else the software will default to the I-loaded site. The correct landing site, runway, and TACAN are located on the DEL pad in the ENTRY C/L; information on 15 other landing sites is found on the Land Site Data chart located at the back of the C D/O Flight Books.

The targets previously uplinked to the "DEORB MNVR COAST" SPEC are compared to the targets on the D/O MNVR pad included in the Entry C/L. (The SPOC provides the deorbit targets if MCC cannot.) These targets are then loaded, causing the GPC's to begin computing the required deorbit solution. The crew compares this solution with the D/O MNVR pad's solution.

Finally, MMU 1 is powered off, and MMU 2 is verified off as part of the effort to reduce power loads during entry. No need exists for the two MMU's until postlanding.

#### **Stow ORB PKT, Orbit Cue Cards**

At TIG -00:30, the commander and pilot stow the OPCL and Orbit Cue Cards and go to the Deorbit Burn section of the Entry C/L. Changes resulting from the powerdown procedures and C D/O timeline have been pen-and-inked earlier. The MS's continue to configure the various Orbiter systems for entry using the C D/O procedures until the deorbit burn.

#### **RADIATOR STOW**

The radiators have been previously deployed in this contingency case since the FES is not functional. The procedure for deploying the radiators is located in the powerdown section of the OPCL, and is completed before the C D/O procedures are entered. Deploying the radiators increases their cooling capability by radiating heat from both sides of the radiator. Only the forward two panels on each door can be deployed. The radiators are stowed at this time in preparation for PLBD closing.

#### **PLBD CLOSING CONFIG**

Preparations for PLBD closing include deactivating the RMS heaters and RMS power at this time if the RMS is flown. The floodlights are also activated to provide optimal lighting observing the PLBD's. The number of lights activated should be minimized as much as possible to reduce the heat load for this contingency case. The television/video tape recorder (TV/VTR) system is activated only if it is required for the viewing and recording of the PLBD closure.

## EMER PLBD CLOSING

The PLBD's are closed as late as possible to prolong the radiator coldsoak. Since the transition to OPS 3 has already occurred, the crew has to perform an emergency PLBD closing using the BFS GPC. (A nominal PLBD closing uses an SM GPC which is available only in OPS 2.)

The procedures for the emergency PLBD closing are located in the EPCL. First, the radiators are verified stowed and latched. The "PL BAY DR SYS" switches are enabled to provide power to the door and latch open/close relays in the motor control assemblies (MCA's), which will allow the GPC's PLBD commands to be enacted. These PLBD enable switches are designed to prevent erroneous commands from reaching the motors and causing an AC phase short or premature operation of the doors. AC power is then applied to the MCA's. The AUTO MODE is selected to enable the automatic sequencing of the doors. ITEM 14, PBD SW BYPASS, is used to bypass the switch on panel R13 (which places the doors in stop mode). When the bypass is initiated, ITEM 17 becomes operative. Execution of ITEM 17 initiates door closure. The crew monitors the CRT for the proper sequence. After the PLBD's are closed, the doors are placed in the stop mode, AC power is removed from the MCA's, and the PLBD enable switches are disabled. Finally, the flood light switches on panel A7U are verified off.

## POST CLOSING CONFIG

The equipment associated with PLBD closing is deactivated and stowed at this time. This includes the flight deck cameras and accessories. The PLBD floodlights are all powered off since the PLBD's no longer need to be observed. Since CRT 4 is powered off at the end of the PLBD closing procedure, CRT 3 is powered on, if required, in order to obtain the nominal entry configuration.

As a safety precaution, the foot loops are taped down in the egress route to prevent the crew from tripping. Likewise, the interdeck access ladder footholds are deployed at this time to remove any tripping hazard. These footholds are stowed on-orbit for better zero-g mobility. During egress, the LES's obstruct a crew member's field of vision, making it possible to overlook folded up stairs.

After configuring the egress routes, the MS's ingress their seats and perform an LES pressure integrity check at TIG -00:05.

SECTION 6  
LOSS OF 2 H2O LOOPS (CONUS TIG > 2.5 HOURS)

**OVERVIEW**

This section is entered from one of two powerdowns: either ASC PKT, LOSS OF 2 H2O LOOPS POST OMS 2 or ORB PKT, LOSS OF 2 H2O LOOPS TIG > 2.5 HR. These powerdowns keep the Orbiter in a powered down configuration while waiting for a continental US (CONUS) landing site. After completing this section of the C D/O, the crew transitions to the following section, LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY.

**PART 1: ON ORBIT WAIT**

The crew performs an IMU ALIGN/CABIN DE/REPRESS cycle once every orbit during the latter portions of the night pass to realign the IMU left on in the powerdown. The IMU has been running without pulse torquing since all GPC's have been powered down, and must be realigned before the IMU drifts beyond the star tracker star acquisition tolerances. While the GPC is on, a cabin depress/repress is performed to reduce cabin humidity and PPCO2 and to provide thermal relief. Venting causes a propulsive torque on the vehicle which requires attitude control, so venting must be done while a GPC is on. After the IMU is aligned the orbiter is taken to a biased tail-sun attitude (pitch down 45 degrees) to minimize solar heat input into the cabin. The Orbiter remains in tail sun for as long as possible; free drift is begun near orbital sunrise. The GPC is then powered off.

**PART 2: ON ORBIT WAIT BACKOUT**

This section prepares for transition to LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY. The FES is activated to provide for freon loop cooling after the PLBD's are closed. GPC 4 is activated to close the PLBD's and perform a time update. SM GPC 4 is deactivated and GNC GPC 1 is activated to align the IMU, and have a state vector and fine time update uplinked. LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY is entered at TIG-0:30.

The thermal analysis performed for this case was LEMSCO-24843, and the electrical analysis was FDD-SA-87-210-044.

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## ASSUMPTIONS/INITIAL CONDITIONS

This procedure is entered from LOSS OF 2 H2O LOOPS (CONUS TIG > 2.5 HR) (ORB PKT, PWRDN). It may also be entered from LOSS OF 2 H2O LOOPS (POST OMS 2) (ASC PKT, PWRDN) unless a rev 2 deorbit is necessary. Both of these powerdowns power down the orbiter to minimize heat input to the cabin.

Only one IMU and FF MDM (nominally #2) are left on in the powerdown to maintain a coarse inertial reference. IMU 2 and MDM FF2 were chosen out of thermal considerations since the IMU and MDM will be on for an extended period without cooling. IMU 1 and MDM FF1 are not used since FF1 is in av bay 1 which is relatively hot due to GPC's 1 and 4 being used for the alignments each orbit. IMU 3 is not used since MDM FF3 is in av bay 3 which is being kept as cool as possible for entry when GPC 3 will be used as the PASS GPC. Heating is also minimized in av bay 3 to keep the communications equipment as cool as possible. The BFS GPC 5 is in av bay 2, but the PASS GPC is the primary computer for entry, and MDM FF2 does not generate a significant heat load.

If it is determined that the uncompensated drift rate on IMU 2 is large enough to prohibit IMU realignment with the star trackers after 1 rev of drift, the MCC may direct the crew to use another IMU/MDM combination. This determination is normally made by the GNC officer after the first water loop fails. Precoordination of procedural changes with the crew and ground controllers is necessary to minimize the possibility of turning off the MDM associated with the IMU as these are cycled elsewhere in the procedure for reasons not necessarily associated with IMU alignment. If the IMU or MDM is turned off, the IMU will cage and lose its reference. Normally, the GPC's provide pulse torquing to the IMU gyros. However, the GPC's are powered off since they have a limited lifetime without cooling, and also input a large amount of heat into the av bays. Without a GPC, the IMU maintains a coarse alignment, drifting at a rate unique to each IMU, as long as the FF MDM associated with the IMU is left on. The MDM provides an operate mode command to the IMU without which the IMU will mode to standby and lose its inertial reference (cage), which would require a COAS alignment to recover the IMU. This recovery would require at least one hour of additional powered up activity before deorbit and would significantly reduce the probability of entering safely before thermal conditions in the cabin and avionics bays became unacceptable. Thermal analysis of the procedures required to do a COAS alignment show that cabin temperature would exceed 120 F and be at 100 % humidity for several hours, which is not survivable. However, if the IMU reference is lost and a COAS align is required, an alignment would be left until the last rev before entering Part 2 at TIG - 1:30. This would eliminate the need to power up a GPC every orbit and save heat loading in the cabin.

The star tracker subsystem operating program will not accept a star if its measured position differs from its catalogued position by more than 1.4 degrees. However, depending on the relative directions of the stars and error vector of the platform, IMU torquing angles of up to 2 degrees root sum square (RSS) of the three axes are possible. Typical RSS uncompensated

drift rates for the IMU's is 1 to 2 degrees per hour. Since the GPC will be on approximately 20 minutes of a 90 minute orbit, drifts up to 2 degrees may be seen. Accurate recording of GPC on and off times is important because it allows the MCC to determine how long pulse torquing was applied to the operating IMU. If the crew cannot get a star align, this information enables the MCC to generate a gyro compensation uplink that will pull the IMU platform back into a position that will allow a star align prior to deorbit. Refer to the GNC Standard Console Procedures, JSC-12843, for LOSS OF 2 H2O LOOPS.

Communication is cycled on and off per the ORB PKT powerdown MS COMM pages, whether the ASC PKT or ORB PKT powerdown is the entering procedure. This reduces the heat into the cabin as well as protects the communication equipment from failing. The preferred priority of comm usage is UHF, STDN LO PWR, then TDRS. Preference is based on least heat generation.

### PROBLEM DESCRIPTION/RATIONALE

The water loops are the only system designed to remove heat and humidity from the cabin atmosphere. Thus, with this failure air and water cooled equipment have no active cooling and if left on, may overheat and fail, as well as add heat to the cabin. Crew members also add heat, as well as increase the humidity through respiration and perspiration. Analysis indicates that 100 % humidity may be reached 2 hours after the second water loop fails, and cabin pressure may increase enough to relieve some air overboard due to high cabin temperatures.

The IMU is aligned once every orbit to keep it from drifting outside of the 1.4 degree error limit. This is done during the night pass to minimize solar heating through the cabin windows.

The alignment cycle will end with the orbiter in a biased (45 degrees pitch down) tail-sun attitude near sunrise to maximize the time in tail-sun attitude during daylight. The orbiter is put in free drift with the GPC off at sunrise. Part 2 requires 1 hour to perform, and the pre-TIG portion of Section 9, LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY requires 30 minutes. Therefore, 90 minutes is the minimum amount of time needed to do both of these procedures. The longer a GPC and other equipment is on, the worse the cabin environment will become.

Cabin depressurizations to 10.2 psi are done to dump hot, humid air overboard and replace with dry, cooler N2 and O2. These cabin depress procedures are similar to the EVA depress procedures. The number of depresses depends on the amount of N2 available which was recorded in the powerdown. These are done coincident with the last IMU aligns performed in Part 1. One more align is done in Part 2 but without a cabin de/repress. If three cabin depresses to 10.2 psi are performed, analysis indicates that cabin temperature would be reduced 12 degrees F during the last hour of flight, and total time at 100 % humidity will be reduced by 2 hours. Cabin depresses are propulsive, causing a 3 axes RSS rotation acceleration of 0.085 degrees per second squared according to flight data on STS-51I. Therefore the depress is started just after attitude control is established,

terminated just before free drift is re-established, and limits the amount of time the depress can be done since attitude control is available only with a GPC on.

IMU aligns provide an inertial reference for the orbiter attitude with respect to the celestial sphere, so an orbiter state vector is not required to perform an IMU align. A state vector is required for deorbit and will be uplinked along with a GPC time update in Part 2.

#### PROCEDURE NOTES

Minimum lighting is maintained to reduce heat input into the cabin. A flashlight should be used in the airlock.

Wrist watches are the only source of time since the GPC's and MTU are all powered down, and not continuously repowered until Part 2. A coarse time update is done in Part 2 based on wrist watch time.

GPC's 1 and 4 are used alternatively as they are both in av bay 1, along with much of the other equipment that is powered during the on-orbit wait. This preserves av bays 2 and 3 as much as possible for entry. Alternating GPC's allows heat from the individual GPC's to dissipate as much as possible between alignments. The faster the align procedures are done the better. GPC on and off times are required since they tell the MCC how much time the IMU is being pulse torqued.

MDM FF1 controls the lights on the forward DAP panel, but the push-button controls still function if the MDM is off.

Although the procedures are designed to be done during night passes until entering Part 2, it is possible during high inclination orbits to have the orbiter sunlit for the entire orbit. The procedure will work without night passes, but the MCC should tell the crew which stars to use to keep the Orbiter as close to a biased tail sun as possible.

The star pair used during the IMU alignments should be selected prior to powering up the GPC so that the GPC is not heating itself and the cabin while the stars are being selected. The crew should ensure the stars are available during the time the align is performed, approximately 20 minutes before sunrise until the orbiter passes into sunlight.

If the IMU alignment fails, the crew will not attempt any further alignments, and the MCC will compute and uplink a gyro compensation load to recover the IMU prior to the pre-deorbit IMU star align. If that fails, a COAS align will be required. Alignments are done each orbit to prevent losing the reference due to uncompensated IMU drift at the expense of heating the cabin with a GPC. Once the reference is lost, there is little reason to have the reference regained until prior to entering Part 2 other than to ensure it will be done before needed for deorbit.

Since it is predicted that cabin humidity will reach 100 % and temperature exceed 95 degrees F, the LES helmet with HRA can be used to breathe cooler,



dry O2 to provide some relief from the cabin environment. Since one freon loop is enough to handle the Orbiter heat load after the powerdown, loop 2 is used. Loop 2 is left on since it uses NH3 system B which requires only one PL MDM, #2, to be powered on for entry. Loop 1 is powered down since its NH3 system (A) requires 2 MDM's instead of only one. O2 System 1 is isolated to prevent the cold O2 from freezing the stagnant freon loop. The LES helmets cannot be used during the repress, since a repress requires the full capacity of O2 SYS 2, and the LES helmets would be starved for O2 if they were being used.

## FLUID LOADING

Due to the high temperature and humidity of the cabin atmosphere, the crew members will be losing more body fluids than normal through perspiration and respiration. One 8 ounce container of water every 15 minutes with a salt tablet taken with every other container (half the nominal salt intake) is recommended to prevent dehydration. Once thirst becomes apparent, the body is already dehydrated; therefore, fluid loading should begin before the crew becomes thirsty. Less salt is taken to reduce the possibility of emesis. Some salt is still required as 100% water would merely pass through the body and be eliminated.

## IMU ALIGN & DE/REPRESS DETERMINATION

An IMU align needs to occur at least once every 90 minutes (1 rev) so as to not risk losing the inertial reference. In Part 1 of this procedure, the IMU's are aligned every night pass starting at 20 minutes until sunrise. (If the orbital inclination and beta angle are such that the orbiter is always in sunlight, the align is done once each rev starting one rev after the GPC's are powered down.) If in darkness when block 1 is entered and greater than 20 minutes remain until sunrise, another IMU align is performed. The possibility exists for yet another IMU align if the time from the last IMU align in Part 1 to the align in Part 2 is greater than 90 minutes. This align, if required, should be started prior to TIG -01:50 so that it will be completed before entering Part 2. The last IMU align is performed in Part 2 at TIG -0:47.

Up to three cabin de/represses to 10.2 psi are performed depending on the remaining N2 quantity (recorded from the powerdown). If the number of IMU aligns required exceeds the number of de/represses allowed, the crew will wait until the last aligns to perform the cabin purges. No de/represses are performed in Part 2. However, a constant cabin purge is initiated late in the LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY procedure.

The IMU BITE mask is used to protect for an overtemperature BITE, which is possible under these environmental conditions. RM will inhibit the single IMU from providing attitude information if the BITE is not masked.

The star pairs should be selected before powering the GPC on for the IMU align in order to minimize GPC on time.

## STR TRKR CONFIG CHECK

The star trackers are checked on in preparation for the IMU align. The aft MDM's and aft RJD logic and drivers are checked on and the forward RJD logics and drivers are checked off. Tail only attitude control is used as the aft RJD's are cooled by the freon loops. The forward RJD's are not used since they are in the cabin av bays and are cooled by the failed water loops. The vernier RJD's are checked off.

**PCS SETUP**

The O2 and N2 systems are setup to control partial pressure of O2 and total cabin pressure during the cabin depress and repress. Both N2 systems are used to feed the cabin. The O2/N2 CNTLR VLV SYS 1 is opened to supply N2, and system 2 is closed to supply O2. O2 SYS 1 SPLY is closed, and only SYS 2 supplies O2. O2 system 1 crossover is closed to prevent drawing from system 1 since the systems freon loops is off, and system 2 crossover is opened to supply O2 to the LES helmets and O2 bleed orifice. The LES helmets can be used for relief from high temperature and humidity only during times the cabin is not being repressurized.

**CABIN FAN B - ON**

Cabin fan B is turned on in the timeline during every orbit to circulate cabin air through the LiOH canisters to remove CO2. The fan also provides circulation to mix the cabin air to prevent N2 pockets from forming, to allow accurate PPO2 sensor readings, and to circulate cabin air around the cool outer cabin structure. Analysis indicates that cooling from the cabin wall is sufficient to remove the additional heat from the fan motor. Fan B (AC 2 inverter in av bay 2) was chosen over fan A (AC3) to keep av bay 3 cooler.

**CABIN DEPRESS SETUP**

The vacuum vent airlock depress valves are set up to prepare for the cabin depress. The nozzle heater is turned on to prevent it from icing up. The 14.7 CAB REG INLET SYS 1 valve is closed to prevent N2 from flowing during the initial portion of the depress. System 2 is opened to begin flowing O2 on demand as the cabin is usually O2 deficient. This is the configuration when the depress is begun. O2 REG INLET SYS 1 is checked closed and system 2 open since system 2 only will supply O2. The airlock hatch is opened and stowed, and the AIRLK DEPRESS valve is used to depress the cabin. A flashlight should be used inside the airlock to avoid heating from the lights. The airduct does not need to be installed since the crew member should not be in the airlock for very long. With the PPO2 SNSR/VLV in NORM and O2/N2 CNTLR VLV SYS 2 in AUTO to supply both O2 and N2 during the repress, PPO2 sensor B will automatically control O2 partial pressure. Thus OI SIG CONDR OF 2/3 is powered since PPO2 sensor B uses MDM OF 2.

**GNC GPC ACTIVATION**

This block begins with a reminder to alternate between GPC's 1 and 4 to distribute the heat load, and space to record the MET when the GPC is turned on. CRT 2 is used to save the CDR's CRT for entry. GNC software is used for the IMU alignment and AV BAY 1 FAN A cools the GPC during its operation. FAN A is powered from AC1, whose inverter is in av bay 1.

## RESTRING TO GNC GPC

The GPC will be in OPS 0 from when the GPC is powered in the previous procedure block. Memory config is set for GNC MC2 and all strings given to the appropriate GPC. MC2 software was loaded into both GPC's 1 and 4 in the ORB PKT powerdown. An MMU will need to be powered the first time GPC 4 is used if entered from the ASC PKT powerdown.

## IMU ALIGN ATT MNVR

The IMU align attitude is entered on the UNIV PTG spec which is the top level display in OPS 201. Both star trackers are used since they do not heat the cabin; using both also minimizes the time required for an alignment. The PLT's DDU is powered to monitor the maneuver initiated by ITEM 18 and started by putting the DAP in AUTO. DAP A was configured in the powerdown to provide quick maneuvers to and from star align attitudes. A maneuver rate of 1 degree per second is used which provides for a maximum maneuver time of three minutes and is toward the upper limit for a tail only PRCS control. Higher maneuver rates are judged to be of no additional benefit because the procedures will keep the crew busy during the maneuver. Furthermore, while not prohibitive, the propellant usage is significant. Higher maneuver rates cause propellant usage to increase in a nonlinear manner. A one degree per second rate is very acceptable from a crew perspective. MDM FF 1 and 3 are needed to allow the star trackers and GPC to communicate. Once attitude control is established the MS can begin CAB DEPRESS. The IMU ALIGN spec is called up and if the IMU has a BITE it is masked since RM will fail that IMU and it cannot provide attitude data. The orbiter will not auto maneuver if the running IMU has a BITE.

## CABIN DEPRESS

This procedure parallels the cabin depress to 10.2 psi in the CEVA book. Panel 01 gauges are used since there is no SM GPC running. The CABIN DEPRESS TO 10.2 PSIA figure (identical to the one in CEVA) is used to plot cabin pressure versus PPO2 aiming for the target zone. The AIRLK DEPRESS and 14.7 CAB REG INLET SYS 1 and 2 valves are configured, based on where the current plot is on the figure, until either the control zone is reached, or the CDR has achieved a tail to sun attitude and is ready to go into free drift. Usually in the SMS the CDR has finished the IMU align before the control zone is reached. The depress is stopped by closing the AIRLK DEPRESS valve and CAB REPRESS is started.

## IMU ALIGN

When the star align attitude is reached the DAP is switched to B DAP to provide tighter control needed for IMU alignments and in preparation for free drift. DAP B is typical for tail only PRCS. The star tracker align is started and if no data or bad data is obtained, the orbiter is taken to tail-sun attitude and no further aligns are attempted. A COAS alignment will be avoided if possible because it would require the GPC to be on an excessive amount of time adding much heat to the cabin. The MCC will try to

uplink IMU gyro compensations to enable another star tracker alignment to succeed.

### **TAIL SUN ATT MNVR**

MDM FF 1 and 3 are turned off after the data from the star aligns is acquired. The warning block emphasizes that the MDM associated with the IMU used (IMU 2 assumed in the procedure) should not be turned off, else the IMU will cage, having lost the operate command from the MDM, and the attitude reference will be lost. The sun is chosen as the TGT ID, and a biased tail sun attitude is input. The nose is pitched down 45 degrees to reduce the possibility that pitch axis drift would allow sun in the cabin overhead windows. Omicron could be voiced up from the MCC. The A DAP is used to maneuver quickly. When the maneuver is completed, the orbiter is ready to go into free drift so venting should be terminated. CAB REPRESS does not require attitude control thus CAB REPRESS and ESTABLISH FREE DRIFT can be performed simultaneously.

### **CABIN REPRESS**

The crew is warned to not use the WCS and LES helmets during the repress. N2 enters the cabin from the ceiling of the WCS compartment; asphyxiation could occur since there is no cabin fan to constantly move the air. Also, the flow rate of O2 SYS 2 is approximately 20 lbs per hour, which is insufficient to both repress the cabin and supply the LES helmets. N2 from system 1 and O2/N2 from system 2 quickly repress the cabin. Once normal cabin pressure and O2 is reached, the OI SC is no longer needed for O2 measurement and auto O2 control. The cabin fan is turned off to save power since it is no longer needed as described in CAB FAN B above.

### **ESTABLISH FREE DRIFT**

The finer B DAP is used to minimize the residual errors and rates and allow the orbiter to remain in tail sun for as long as possible. Free drift is begun near orbital sunrise to maximize the time in tail sun during daylight. Gravity gradients, drag, and residual attitude rate errors will cause the vehicle to drift since there is no GNC GPC powered to provide attitude control. The DDU is powered down since it is not needed to monitor orbiter attitude.

### **GNC GPC POWERDOWN**

The GPC is taken to OPS 0 to allow a clean software transition to OFF. The CRT and av bay fan are no longer needed. The time the GPC is powered down is needed in the event the MCC must calculate IMU gyro compensations.

**CAB FAN B - OFF**

In the event no depress/repress is done, cabin fan B should be turned off to limit heat input to the cabin. It is already turned off in CAB REPRESS if a de/repress is performed.

**CABIN ENVIRONMENT MONITOR**

The MCC needs trend data on the cabin environment to decide if consider an ELS rather than a CONUS landing site is required because of degrading cabin conditions. To provide this data, instrumentation and communication equipment is powered up. S-BD STDN LO per the powerdown should be used to save the power amp for critical communication such as the state vector uplink in Part 2. Any equipment turned on should be powered down when data transmission is completed.

**CABIN PREP**

The standard preparations for deorbit are done prior to entering Part 2 to allow the crew to do the time critical procedures in that section.

**PART 2: ON ORBIT WAIT BACKOUT****ASSUMPTIONS/INITIAL CONDITIONS**

These are a reiteration of conditions as presented in Part 1. Part 2 is entered from Part 1 at TIG-1:30. Part 2 is always performed if Part 1 was executed and is never performed apart from Part 1.

**PROBLEM DESCRIPTION/RATIONALE**

Summary of Part 1 and Part 2. Part 2 transitions to LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY at TIG-0:30.

**NOTES**

Since Part 2 is performed on a very tight timeline, no cabin de/repress is performed. A constant cabin purge will be done in LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY. Fluid loading begun in Part 1 should be continued through Part 2.

**MTU ACTIVATION**

The MTU is powered up early to allow it to warm and stabilize, and allow MCC the opportunity to uplink GMT/MET deltas to re-establish the GPC time reference.

## FES HTR ACTIVATION

The Topping FES exhaust nozzle and duct heaters are verified on in preparation for FES operation during the radiator bypass. Only the Topping evaporator is used during the radiator bypass since no GNC GPC is active to provide attitude control; the Topping evaporator's exhaust ducts are paired to prevent any propulsive force during venting. The Hi Load evaporator which vents to the port side will be enabled only after attitude control has been established (TIG -0:52). The Hi Load FES duct heater is powered on at this time since the Hi Load evaporator will be powered on later; the heater should be on for approximately 30 minutes before the evaporator is enabled. The feedline heaters are also verified on, and the water supply to the FES is established.

## FES CHECKOUT

The radiators are partially bypassed by taking the RAD CNTLR OUT TEMP to HIGH in order to enable the FES to start above the 41 to 47 degrees F region where an automatic shutdown might occur. The primary controller once activated at 50° F should start properly and control the freon temperature to around 39° F. Since the radiators are providing some cooling and no attitude control is available, only the Topping flash evaporator will be used for cooling. The Topping evaporator has sufficient capacity to remove the remaining heat not removed by the partially bypassed radiators.

## ACTIVATE GPC 4

All GPC's will be off when entering this procedure. The MMU is powered to allow SM software to be loaded into GPC 4. The GPC is powered on and taken to OPS 201. CRT 4 is used to save CRT 2 for entry and the PLBD's will be closed using GPC 4. The coarse GMT/MET update will also be done on GPC 4.

## RAD BYP CONFIG

The FES replaces the radiators as a means of cooling during the radiator bypass. The FES consists of two evaporators, the Topping and the Hi Load. The Topping evaporator is used instead of the Hi Load since it vents equally to both sides of the vehicle (resulting in nonpropulsive venting.) The venting has to be nonpropulsive since no GNC GPC is active at this time to provide attitude control. The Topping evaporator cannot maintain as low a temperature as the Hi Load evaporator can. To keep the FES from automatically shutting down at the higher temperatures, the secondary controller is used instead of the primary controller. The secondary controller does not protect for an overtemp like the primary controller does. (Once attitude control is established again (at TIG -0:52), the Hi Load evaporator and primary controller are activated.

The radiators are bypassed a few minutes before the PLBD's are closed, so no effective coldsoak is obtained. The ammonia boiler system is used during entry in place of the coldsoaked radiators.

**PLBD CLOSING**

The mid MCA logics are turned on to power the motors to close the PLBD's. MDM PL 1 and 2 are needed to command the doors to close. The doors are then closed in auto.

**POST CLOSING CONFIG**

The MCA logics are powered off once the PLBD's are closed. Likewise, the MDM's are turned off since they are no longer needed.

**GMT AND MET UPDATE (COARSE)**

After the PLBD's are closed, the GPC is taken to OPS 0 by cycling the MODE switch to STBY and back to RUN. An update of greater than 15 milliseconds can only be done if the GPC is in OPS 0 and is the only common set GPC. TIME SYNC resets the MTU to GPC time. Once the reset occurs the time difference between the GPC and wristwatch is calculated and updated in ITEM 24-27. The MET is reset to 0:00 at an even GPC minute to simplify the calculation of an MET update time difference. This MET delta is input into ITEM 28-31. Updates may require up to 2 minutes, because the GPC software uses a "coincident time" update scheme and updates the time one minute after the next exact minute.

**ACTIVATE GPC 1/DEACT GPC 4**

GPC 1 is turned on and GPC 4 is turned off to limit the time each is on. OPS 2 GNC software should still be freeze dried in GPC 1. GNC software is needed to perform the IMU alignment.

**STATE VECTOR/TIME UPLINK**

Both an accurate orbiter state vector and GPC time reference must be uplinked before the deorbit targeting is performed. An estimate from the guidance community is that the GPC time could be in error up to two seconds without adversely affecting the orbiter. Thus a manual time update based on wristwatch time should be sufficient. However, a state vector must be uplinked to allow proper targeting so a time delta could be uplinked as well. S-band with data is necessary for this uplink. Since the S-band power amp has a limited uncooled lifetime of approximately 10 minutes, it should not be used until this uplink since there may not be a S-band GSTDN available. The MS COMM pages from the ORB PKT powerdown are used to power up and power down the comm system until TIG-0:10 in LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY where an entry config is done. Also, MDM FF 3 is required to allow a link from the comm system to the GPC.



**MNVR TO IMU ALIGN ATT**

An appropriate star pair attitude is loaded into the UNIV PTG spec and the maneuver initiated using the fast DAP A. An IMU star align pad is provided to record star data obtained from the MCC or Star Pairs cue card. Since attitude control is now established, the Hi Load evaporator is enabled and the primary controller selected. When the maneuver is complete, the fine control DAP B is selected.

**IMU ALIGN**

The FF MDM's are turned on (FF 3 may already be on from the state vector/time uplink) to provide communication between the star trackers and the GPC. The align is similar to the one done in Part 1. A warning is again given to keep the MDM associated with the running IMU on. The other MDM's are turned off until the other IMU's are powered up in LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY.

**GMT AND MET UPDATE (FINE)**

This update is similar to the coarse update but with deltas supplied by MCC. Since a GPC will be kept on until TIG, a CRT timer can be set up to count down to TIG.

**TRANSITION CONFIG**

These two steps are to set up the Orbiter in a configuration assumed by Section 9.

**GALLEY/H2O DISPENSER DEACT**

Depending on whether the galley or water dispenser is flown it is deactivated after enough water containers for fluid loading are filled. It is delayed as late as possible to allow longer access to cooler water rather than have water heating up in the adverse cabin environment.

**EXIT**

At TIG-0:30 this procedure is exited and LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY is entered.

## SECTION 7 LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY

### OVERVIEW

The LOSS OF 2 H2O LOOPS DEORBIT PREP/ENTRY is entered after completing LOSS OF 2 H2O LOOPS (CONUS TIG < 2.5 HR)(ORB PKT, PWRDN) or from LOSS OF 2 H2O LOOPS CONUS TIG > 2.5 HR (CONT DEORB). It may also be entered from LOSS OF TWO H2O LOOPS (ENTRY) (ENT PKT) if End Of Mission (EOM) TIG is more than 45 minutes away.

There is less time until the deorbit burn and thus less time to heat up the cabin atmosphere in the TIG < 2.5 HR case. Consequently, not as extensive of a powerdown is necessary. One GPC is left on in the powerdown so that an IMU retains its reference. The comm system has been powered down as in the TIG > 2.5 hr case.

This procedure takes the Orbiter from the powered down configuration of the pocket checklists to a Single Fault Tolerant (SFT) configuration for entry and landing. The IMU's, if turned off, are repowered and aligned to the running IMU. PASS GPC 3 and BFS GPC 5 are turned on and GPC 1 is powered down. At TIG-0:15 a constant cabin purge is started to dump hot and humid air overboard and replace with cooler, dry N2 and O2. All 3 APU's are started after TIG, and a forward RCS reactivation is done if a FRCS dump is required. The clothing config is delayed until just prior to EI.

The Entry C/L does not need to be unstowed since the crew will use the C D/O through touchdown. A modified entry maneuvers cue card is included since a full page of pen and inks to the standard cue card would be required for this case.

The analyses performed for this case were LEMSCO-24279 (thermal) and FDD-DCA-87-540-266 (electrical).

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## ASSUMPTIONS/INITIAL CONDITIONS

If the second water loop fails at a point where the earliest deorbit burn for a landing opportunity is greater than 2.5 hours away, the LOSS OF 2 H2O LOOPS (CONUS TIG > 2.5 HR) (ORB PKT, PWRDN) is performed, which exits to LOSS OF 2 H2O LOOPS TIG > 2.5 HR (CONT DEORB). The LOSS OF 2 H2O LOOPS TIG > 2.5 HR is an on-orbit wait and back out procedure. This procedure then leads to the LOSS OF 2 H2O LOOPS DEORB PREP/ENTRY.

If the failure occurs at a point less than 2.5 hours from the deorbit burn, the CONUS TIG < 2.5 HR powerdown is performed which exits directly to this procedure. A loss of both water loops during ascent will also lead to this procedure if it is an orbit 2 deorbit via the APCL. A failure during entry will lead here via the ORB PKT powerdown if the EOM TIG is more than 45 minutes away.

No matter how this procedure is entered, the Orbiter's configuration should be the same.

## PROBLEM DESCRIPTION/RATIONALE

The cabin atmosphere will continually increase in temperature and humidity as described earlier in LOSS OF 2 H2O LOOPS (CONUS TIG > 2.5 HR). However, since there is less time spent on orbit waiting for the deorbit burn, the thermal analysis indicates that a less severe powerdown is acceptable. It should be noted that the G189 model used for the ECLSS analysis was not designed or validated to predict conditions when no air is flowing in the cabin or in the avionics bays, or when no water is flowing in the water loops. In the powerdowns, GPC 1 is left on to maintain IMU alignment and attitude control, and GPC 4 and all IMU's are left on if TIG is less than 50 minutes away. If there is more than 90 minutes until TIG in the powerdown, a 10.2 psi cabin de/repress is performed. The powerdown is maintained until TIG-0:30 since approximately 30 minutes is needed to configure the Orbiter for the deorbit burn.

## PROCEDURE NOTES

The repowering of equipment needed for entry is delayed as long as possible to minimize heat input to the cabin, but still allow sufficient time for the crew to repower this equipment. Single fault tolerance on LRU's was chosen for this case based on thermal analysis.

The MS page is provided at the beginning of the procedure to remind the CDR that the MS has configurations to perform in this time critical procedure. The CDR has callouts in the procedural flow to give the MS a "GO" to perform the MS procedures.

MS COMM pages from the ORB PKT powerdown are used to cycle the comm system as needed during the powerdown until TIG-0:10, when the AFT PANEL CONFIG FOR ENTRY COMM configures the S-BD system for low power S-band ground station communications at V = 12K.

Nominal DEORBIT BURN and MONITOR cue cards are used for these phases of flight, but a stand alone ENTRY MANEUVERS cue card has been built for this failure because the pen and inks to the nominal cue card were too extensive and time consuming.

## MCA CONFIG

The MCA logic circuits are repowered to enable vent door ops, star tracker door closure, and air data probe deployment.

## CONSTANT CABIN PURGE

Before the MS begins this procedure, the commander must power on cabin fan B in order to circulate the cabin air to prevent N2 pockets.

The cabin atmospheric purge is started at TIG-0:15 to dump hot, humid air overboard and replace it with cooler, dry N2 and O2. The warning not to use the WCS is to protect the crew from asphyxiation from the N2 coming in from the overhead panel. The REG INLET system is configured to let in only N2, while O2 will be supplied to the LES's through the DIRECT O2 valve. The LES's would be starved for O2 if O2 were to be flowing through the REG INLET system during the purge. The DIRECT O2 valve is left open to maintain a breathable atmosphere in the cabin in the event a crewmember opens their LES helmet visor. The DIRECT O2 valve is closed post landing to prevent O2 concentration from exceeding the flammability limit. The purge is started by opening the VAC VENT ISOL VLV, the AIRLK DEPRESS valve in the airlock, and the Equalization valve on the hatch. The hatch is then closed for entry.

## AFT PANEL CONFIG FOR ENTRY COMM

The S-BD PM system 2 is configured for low power mode and ground commanding. STDN LO produces less heat than TDRS mode and is compatible with GSTDN. This configuration is enabled at V=12K on the ENTRY MANEUVERS cue card. Up to this time the MS COMM pages from the ORB PKT powerdown have been used to cycle comm. If the powerdown pages are used for comm after TIG-0:10, this AFT PANEL CONFIG must be re-established. Note that this config assumes that S-BD PM comm coverage is available for the landing site. System 2 is used since only PL MDM 2 is powered and PL MDM 1 has been powered down to limit heat input to the cabin. PL MDM 1 is not desirable because it does not, by itself, support an NH3 controller. NH3 controller B requires only PL MDM 2, while NH3 controller A requires both PL MDM's. Also, NH3 system B cools freon loop 2, which is why that freon loop was left on in the powerdown.

## LEH VLV CONFIG

This is a standard procedure to remove the bleed orifice used to supply O2 to the cabin on orbit, and configure the LEH O2 valves as needed depending on crew size on the middeck.

**CLOTHING CONFIG**

The LES's are donned as late as possible before EI, before the effects of gravity are felt. This delay takes advantage of any evaporative cooling that may be occurring, although at the conditions expected during this failure (temperatures above 95 deg F and close to 100 % humidity), little evaporative cooling is expected. (The only evaporative cooling would come from condensation on colder parts of the cabin.) Also, the suit fan heats up the air before it reaches the crew member. The CDR dons the LES last as the CDR is the critical crewmember during landing and requires the benefit of any cooling. The LES's are needed to force blood to the body core.

**MDM POWERUP**

The MDM's needed for the IMU's are turned on in preparation for the IMU to IMU alignment.

**VERIFY DAP/SELECT NORMS**

This is a standard DAP config for deorbit prep. It is also a carry-over from EMERGENCY DEORBIT PREP from which this procedure was built. Vernier jets were turned off in the powerdown.

**IMU ACTIVATION**

If this section was entered from the TIG >2.5 hour procedures, or from the TIG <2.5 hour powerdown if the time to TIG was >50 minutes, IMU's 1 and 3 were turned off and need to be recovered. An IMU to IMU alignment is performed, and when complete the IMU's are reselected.

**DEORBIT TARGET**

The SPOC is used to calculate deorbit targets, and these are recorded on the deorbit pad, or they may be supplied by the MCC.

**APU STEAM VENT HTR ACT**

The APU water spray boiler power is turned on in preparation for the APU start post TIG.

**SWITCH CONFIG FOR OPS 3**

These are standard switch configurations done prior to transitioning to OPS 3; however, SFT is maintained on the LRU's. Three RGA's are powered on, since the vehicle will spin out of control if they are not on prior to OPS 3. Four ASA's are needed as RM treats an unpowered ASA as failed but it cannot be deselected. The GPC's do a snapshot check of ASA configuration at the OPS 301 transition but not at later times.

**STAR TRACKER DEACT**

This is a standard procedure as used in nominal deorbit prep. The MS was given a GO earlier to power MCA logics.

**DPS ENTRY CONFIG**

GPC 1 is assumed on if entered either from the powerdown or LOSS OF 2 H2O LOOPS TIG > 2.5 HR (CONT D/O). The MMU requires at most 34 seconds to position to the center of the tape. PASS GPC 3 and BFS GPC 5 are turned on and GPC 1 is taken to OPS 301 separate from GPC 3. To avoid a potential loss of the GNC set, the OPS transition and set expansion are done separately. MMU 2 is turned off since all software loading is complete. The av bay fans are swapped to circulate air to cool the GPC's now running in av bays 2 and 3. Three seconds allows motor AC starting currents to decay before starting another fan. Cab fan B is turned on to circulate air to minimize N2 pockets from the constant cabin purge which is started after TIG-0:15. The MS is given a GO to perform the AFT PANEL CONFIG after TIG-0:10.

**CLOSE VENT DOORS**

MDM FF4 is turned on to provide SFT on vent door operations. After the doors are closed, the MDM is turned off to reduce heat input.

**LANDING SITE UPDATE**

This is a standard check as in the ENT checklist. If a landing site other than the nominal EOM site is selected, it must be performed after the final OPS 301 PRO in the DPS ENTRY CONFIG, else the software will default to the I-loaded landing site and runway, which may be different from the selected site especially in a contingency situation.

**DRAG ALT ATM SELECTION**

The atmospheric model most appropriate to the entry conditions is selected as in the ENT checklist. It also will default to the I-loaded value if an OPS 301 transition occurs after it is selected.

**CHECK CG**

This callout is to have the crew enter the amount of propellant to be used during the deorbit burn if prop wasting is required to adjust the Orbiter center of gravity. A forward RCS dump procedure is done after TIG if Xcg requires adjustment.



**OMS BURN PREP**

These are standard ENT checklist steps to prepare for the deorbit burn. Tail only RCS is used so FRCS He pressurization is deleted.

**LOAD TGTS AND MNVR**

Targeting data either from the SPOC or MCC is entered and the processing begun. The DDU's and FLT CNTLR PWR are turned on to monitor the maneuver and provide SFT. The DEORBIT BURN cue cards are used to perform the deorbit burn. The crew should select the secondary right gimbals since there is no control of the right OMS gimbals with FF4 off.

**CLOTHING CONFIG**

See CLOTHING CONFIG above.

**MNVR TO EI-5 ATT**

The left DDU circuit breakers are cycled as required to monitor the maneuver to EI-5 attitude. The right DDU circuit breakers are opened as the CDR will be monitoring the maneuver. Originally the PLT performed this maneuver to preserve the CDR's instruments for landing, but the PLT is already busy at this time. The LVLH table is used in case an INRTL attitude cannot be supplied by MCC. The landing gear sensors and brakes are powered up when the maneuver is completed.

**OMS/RCS POST BURN RECONFIG**

The aft left and right RCS and OMS valves are checked in their proper configuration as for a nominal entry.

**APU PRESTART**

This is a standard ENT checklist procedure except that it is not performed until after the deorbit burn. It is assumed that the failure this section is concerned with is the only major failure that will occur. Thus assuming all APU's will start, the start can be delayed until after the deorbit burn to provide time before the burn for those activities required to deorbit. Also landing can be performed with less than 3 APU's running.

**FORWARD RCS DUMP**

The Xcg is checked to determine if a forward dump is required. The forward RJD logic circuits and drivers, signal conditioners, and MDM FF4 are powered up to allow the dump. The JET RESET reselects jets that annunciated a fail-leak because of the powerdown when the OI signal conditioners were turned off. The dump uses the standard ENT procedure. When completed the equipment no longer needed for the dump is powered down.

## APU START

All three APU's are started simultaneously after the deorbit burn but before EI since there is no capability to wave off and in order to reduce crew workload at TIG. All three are started as the freon loops can still provide cooling to the APU controller coldplates. This procedure is like the ENT procedure for starting APU's after the deorbit burn except that OI PCMMU 1 is powered to allow monitoring of the start, and the hydraulic landing gear isolation valve 3 is not cycled for the brake checkout since this is a time of heavy crew workload. Software will open the valve at rollout. The PCMMU is turned off after the APU's start.

## SECONDARY ACTUATOR CHECK

This procedure checks for flight control system failures as in the ENT checklist if time permits and no on-orbit FCS C/O has been performed.

## EQUIPMENT STOWAGE AND SEAT INGRESS

A reminder to perform final preparations to the cabin before entry if not already done.

## ENTRY SWITCH CHECK

These are standard switch checks as in ENT. NH3 controller B is selected as explained above since only freon loop 2 is operating. Antiskid and nose wheel steering are delayed until  $M=0.9$  to delay their powerup. Powerup of the nav aids is delayed until after EI as well. MCC provides fault detection for the radar altimeter and microwave landing system during entry.

## HORIZ SIT CONFIG

The items on this SPEC are checked as in ENT, as well as the elevon selection based on Xcg, and the filter selection based on returned payload weight. Turning the AC BUS SNSR-OFF then to MON resets the sensors and allows C/W to annunciate voltage spikes but does not trip the circuit breakers.

## G SUIT INFLATION

The LES's G-suits are inflated by turning the valve 1.5 turns as in ENT.

## ENTRY MANEUVERS

Equipment is turned on during the entry phase to attain a SFT configuration and to delay the powerup until the equipment is needed. The comm system is powered at  $V=12K$  which is near post blackout, and PL MDM 2 is powered to allow MCC commanding and freon loop 2 control. At  $M = 0.9$  the R FLT CNTLR PWR is turned on to enable NWS. The pilot's instruments are also powered on as a backup to the CDR during landing. The DIRECT O2 valve is closed to limit O2 concentration which has been increasing from the time the constant

cabin purge was started. The EXPEDITED PWRDN is performed to limit unnecessary heat input once the vehicle is stopped.

## SECTION 8 EMERGENCY DEORBIT PREP/ENTRY

### OVERVIEW

The EMERGENCY DEORBIT PREP/ENTRY procedure can be used for any failure case requiring a deorbit in less than 2 hours 40 minutes, including loss of cabin pressure. According to the Flight Rules, an emergency deorbit is required if cabin pressure cannot be stabilized at 8 psi or higher until the next PLS.

If a cabin leak occurs, the crew performs the "O<sub>2</sub>(N<sub>2</sub>) FLOW HIGH/CAB P LOW/DP DT" procedure to control the cabin pressure to 8 psi. The crew then performs the "LOSS OF CABIN PRESSURE" powerdown since cabin cooling will not be as effective at lower pressures. This powerdown will lead to one of two procedures depending on the time to TIG. If TIG > 2:40, the 8 PSI D/O PREP procedure (DEORBIT PREP) is performed. If TIG < 2:40, the EMERGENCY DEORBIT PREP/ENTRY procedure (CONTINGENCY DEORBIT PREP) is used.

As the emergency deorbit procedures are designed for a worst case scenario, only those activities that are absolutely necessary are performed. In addition, many verifications and failure action steps are omitted to further expedite these procedures. At least 20 minutes are needed to complete the essential activities. A matrix is provided as a general summary of which nominal deorbit activities must be performed. Those procedures marked by a check must be performed, whereas those procedures with dashes beside them are not mandatory for deorbit and can be performed as time permits. A - ✓ indicates those activities performed prior to TIG, and a + ✓ indicates those activities performed between TIG and EI. If enough time is available, additional activities can be performed.

Once the emergency deorbit activities are completed, the crew will either transition to the ENTRY C/L or perform a bailout depending on whether or not a landing site is available.

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## ASSUMPTIONS

This procedure can be entered from LOSS OF CABIN PRESSURE POWERDOWN (ORB PKT). However, these emergency deorbit procedures are also applicable to any failure case that requires a deorbit in less than 2 hours 40 minutes. A minimum of 20 minutes is needed to complete the essential deorbit prep activities. A maximum of 2 hours 40 minutes is provided. If the time to TIG is greater than 2 hours 40 minutes, a nominal deorbit will be performed as there is enough time to complete all of the nominal deorbit procedures.

## PROBLEM DESCRIPTION/RATIONALE

The crew determines the maximum time to TIG ( $T_{max}$ ) using the CAB PRESS LEAK NOMOGRAPH located in the ORB PKT C/L. This  $T_{max}$  is based on cabin pressure, leak rate, and total N<sub>2</sub> quantity.  $T_{max}$  can be exceeded; however, the cabin pressure will drop to below 8 psi. The actual time to TIG depends on landing site availability.

## PROCEDURE NOTES

These procedures are designed for a worst case scenario and can be completed in twenty minutes. Any deorbit prep activity that is not absolutely necessary is not performed. Likewise, any activity that is not required prior to the deorbit burn is delayed until after the burn. Of the deorbit activities performed in an emergency deorbit, many verifications and malfunction action steps are deleted to expedite the procedure. A matrix is provided as a general summary of deorbit activities that are performed in an emergency deorbit. A - ✓ indicates activities accomplished before TIG, and a + ✓ indicates activities accomplished between TIG and EI. If enough time is available, the crew can perform any additional deorbit prep activities deemed necessary.

The activities are divided among the middeck station MS, aft station MS, CDR, and PLT. The aft and middeck MS procedures are located on pullout pages. Extra copies are also included in the back of the PLT's book. The CDR and PLT procedures begin on page 10-9. The nominal DEORBIT BURN and MANEUVERS cue cards are used.

If a landing site is available, the crew exits these procedures with pen and inks to the nominal ENTRY MANEUVERS cue card. If a landing site is not available, the crew will use the bailout procedures beginning on page 10-19.

A single fault tolerant (SFT) configuration is maintained on most of the air-cooled equipment since air supply temperatures are exceeded at pressures of 8 psi or lower with air-cooled equipment powered. If the cabin pressure stabilizes at 8 psi or higher, additional equipment can be activated as needed.

## AFT STATION MS

### PL SAFING

Safing of payloads may be required if they have not already been safed in the powerdown procedures. The PL SAFING procedures are located in the Orbit Pocket Checklist.

### RMS POWERDOWN

The RMS is powered down after the PL SAFING is completed in case the RMS is needed to safe the payloads. If the RMS cannot be cradled, it is jettisoned after the Ku-band antenna is stowed. The jettison procedures are found in the QUICK RESPONSE JETTISON section of the C D/O. Once cradled, the RMS is powered off as per the RMS PWRDN procedure in PDRS OPS.

### STOW KU-BD ANTENNA

The Ku band antenna must be stowed prior to closing the PLBD's. Stowing the Ku antenna involves positioning the antenna along the sill longeron and aligning the gimbal angles for sufficient clearance to close the starboard radiators and PLBD. This procedure is similar to the KU-BD ANT STOW procedure in the Orbit Ops C/L. However, in order to expedite this procedure, contingency steps from MAL 9.5b are included in case of any additional failure.

### STOW RADIATORS

The radiators are closed and latched in preparation for PLBD closing. This procedure is similar to the standard radiator stow procedure except that steps to deal with any additional failures have been deleted so that this procedure can be completed as fast as possible.

### CLOSE PLBD

The BFS GPC is used to close the PLBD's so as to allow the CDR and PLT to transition the PASS SM GPC's to OPS 3. If the BFS is not already in OPS 3 when the CLOSE PLBD procedures are entered, the crew will have to manually select the S-BD antenna. Before the BFS is taken to RUN, it takes control of MDM PL 1 and 2 which control the PLBD closing and also control the S-band antenna. Since the BFS does not have an accurate state vector (SV), it may select the wrong antenna based on the SV it had when last powered down. Therefore, the crew will have to manually select the S-band antenna unless the BFS has already been taken to OPS 3. (The BFS is taken to OPS 3 by the CDR in the TRANSITION TO OPS 3 step.) Once in OPS 3, the BFS receives data (including the SV) from the PASS. The BFS is then able to point the antennas accurately, and manual selection of the antenna is not required. If, however, the MS begins the PLBD closure prior to the OPS 301 PRO, the antenna select switch should be taken to the required antenna.



The MS closes the doors using the auto mode to save time. The auto sequence can be completed in as little as five minutes.

The closing of the PLBD's is not recorded on video tape or other photography in order to conserve time. Likewise, the visual target settings are deleted.

#### **RECONFIGURE FDF**

The MS unstows the FDF books and cue cards used during entry.

#### **ENTRY SWITCH LIST/VERIFICATION (AFT)**

If enough time is available, the aft station MS performs the aft switch list/verification as per pages 3-15 through 3-25 of the C D/O. Section 3 pictorials are taken from the nominal deorbit procedures.

The MS also configures the egress routes, stows any loose equipment, installs the MS seats, and dons the LES. If time permits, the MS will begin fluid loading to prevent dehydration and reduce the detrimental changes in heart rate and blood pressure caused by orthostatic stress experienced post-flight. The MS also performs an LES pressure integrity check to test the suit connections and suit pressure integrity.

At EI-10, the Flight deck SPOC is stowed.

#### **MIDDECK STATION MS**

##### **TAGS DEACTIVATION**

The TAGS deactivation procedure is taken from the ORB OPS C/L. The crew should check to see if any messages remain in the TAGS before powering it off in case a message needed for entry is still in the imager. Once powered off, the TAGS hardcopier takes approximately 30 minutes to warm up.

At this time, the middeck station MS will begin fluid loading if enough time is available. The MS will also remove the LES's and any other loose equipment from the airlock. Once these are removed, the airlock hatch is closed.

##### **ENTRY SWITCH LIST/VERIFICATION (MIDDECK)**

The middeck station MS checks the switch positions for entry as per pages 3-27 through 3-32 in the C D/O. The only delta to these pages is the closing of the vacuum vent isolation valve. When this valve is closed, the flow of condensate, airlock atmosphere, and waste collector air to the vacuum vent is stopped in order to reduce any loss of atmosphere.

In addition, several nominal deorbit activities are completed by the MS if not already accomplished. The LEH O2 valve 5 is closed before the bleed orifice is removed to prevent O2 from free flowing; valves 5,6,7, and 8 are opened as required. These steps for configuring the LEH O2 valves are

identical to those in the LOSS OF 2 H2O LOOPS and LOSS OF 2 FREON LOOPS sections of the C D/O. The egress routes are also configured as a safety precaution. The escape pole is set up in case a landing site is not available and a bailout becomes necessary. Loose equipment not used during entry is stowed. The treadmill is stowed to provide room for the MS seats to be installed. After donning LES, boots, and harness, the middeck station MS begins fluid loading if there is sufficient time.

## CDR

### VERIFY DAP/SELECT NORMS

The commander verifies that the digital auto pilot (DAP) is configured to A1/AUTO/NORM. Normal jets are selected instead of verniers as there is no need for verniers in an emergency deorbit. In a nominal deorbit, the DAP is first configured to A1/VERN for maneuvering prior to deorbit (i.e., maneuvering to IMU align attitude). Since the IMU's are not aligned during an emergency deorbit, the normal jets are selected instead of verniers. A1 NORM is preferable to B1 NORM because the A1 normals have a 5 degree deadband whereas the B1 normals have a 3 degree deadband. This wider deadband results in less propellant usage.

### FES HTR ACTIVATION

The FES was powered off in the powerdowns prior to entering the emergency deorbit. Prior to activating the FES, the high load duct heater B is activated to prevent freezing of the high load duct. The topping evaporator is used to cool the Freon temperature.

### STAR TRKR DEACT

Since the IMU's are not aligned in an emergency deorbit, the star trackers are not needed. Therefore, the S TRK's are deactivated by powering them off and pulling the S TRK's cb's to prevent an inadvertent door opening during entry. Next, the star tracker doors are closed; it normally takes eight seconds for the doors to close. Even if neither of the tb's go to CLOSED after 24 seconds, the STAR TRKR DR CNTL SYS is taken to OFF to ensure that a failed on condition can be disabled.

### DPS ENTRY CONFIG

This emergency deorbit prep DPS ENTRY CONFIG is considerably shorter than the nominal DPS ENTRY CONFIG. The RGA's, AA's, ASA's, and IMU's are all verified on prior to the OPS 3 transition in order to maintain Orbiter stability during the OPS transition. The UPLINK ENABLE and GPC downlist are performed using an SM display prior to the OPS 3 transition. ITEM 36 enables all uplinks. A hardware fixed TFL which is programmed preflight is selected. A FXD TFL is used instead of a programmable TFL in order to conserve time.

The commander also configures all 5 GPC's as per the table provided. All four PASS GPC's and the BFS GPC are powered on and taken to RUN. The PASS

output is in NORM, and the BFS output is in BACKUP. No GPC's are powered down, since a full PASS redundant set and BFS should be used in all loss of cabin pressure entries. Each string is assigned to one of the PASS GPC's. Finally, the PASS GPC's and the BFS are taken to OPS 3 with an OPS 301 PRO. The PASS GPC's are then transitioned to MM 302 with an OPS 302 PRO.

### **RAD BYPASS/FES ACTIVATION**

The radiators are completely bypassed so that they can be coldsoaked. The freon flow is stopped since once the PLBD's are closed, continued flow would only increase the radiator temperature. The cold-soaked radiators can be used as a heat sink during entry in place of the ammonia boiler system.

These RAD BYPASS procedures are similar to the nominal procedures found in the Orbit Ops C/L. However, the procedures are expedited for an emergency deorbit. The FES C/O procedures normally performed at the time of radiator bypass are deleted since these are noncritical redundant component checkouts that are performed to reduce Shuttle ground turn-around time.

### **LOAD TGTs and MNVR**

The target data which is obtained from either MCC or the SPOC is entered into the deorbit pad. For a bailout, the TIG of the deorbit burn is entered. The deorbit targets are then loaded into the "DEORB MNVR COAST" SPEC. ITEM 22 loads the target information; ITEM 23 starts the CRT timer to countdown to the TIG of the deorbit burn.

### **CLOTHING CONFIG**

If enough time is available, the commander dons LES, harness, and boots in preparation for entry. The four LEH O2 valves provide oxygen to the LES's. The commander also performs an LES pressure integrity check to check both the suit connections and suit pressure integrity.

At TIG-2, the commander is instructed to go to the deorbit burn cue cards.

### **PLT**

#### **DEORBIT TARGET**

The SPOC is used as a backup source of deorbit target if MCC cannot uplink the targets. The PLT uses the SPOC to compute the deorbit targets. This information is then recorded on page 10-11 on the deorbit pad.

## APU STEAM VENT HTR ACT

In a nominal deorbit case, the APU heaters are on for approximately 2 hours prior to APU activation and warm up to approximately 130 degree F. (The crew cannot monitor this temperature). In an emergency deorbit case, the APU heaters are activated as soon as possible even though they cannot possibly be on the length of time required in the nominal D/O prep case.

## SWITCH CONFIG

The UHF switch is normally moded to simplex throughout the mission, except during sleep periods.

The pilot configures the switches on panels 013, 014, 015, and 016. All of the switches are ON, and all of the cb's are closed with the following exceptions. All cb's marked with orange dots are left open on-orbit through entry. All 4 ADTA's are powered off at this time; 3 of the ADTA's will be turned on again at EI-5. The DDU cb's are opened. The CDR and PLT's DDU's, which power the flight controls, will be powered on no earlier than TIG-15 in the FLT CNTLR ACTIVATION procedure.

## FLT CNTLR ACTIVATION

At no earlier than TIG -15, both flight controllers and associated DDU's are activated for the deorbit burn. The activation of both FLT CNTLR's is consistent with the SFT tolerance philosophy.

NOTE: The following procedures should not be started until all of the DPS CONFIG steps are completed by the commander.

## CLOSE VENT DOORS

Since the vent doors close command is valid only in OPS 3 or in MM 602 or 603, the transition to OPS 3 must be completed before the vent doors are closed.

## LANDING SITE UPDATE

Since the HORIZ SIT display is available only in OPS 1,3, and 6, the transition to OPS 3 must be completed prior to the landing site update. The crew updates the landing sites by selecting a landing area and runway on the HORIZ SIT display.

## DRAG ALT ATM SELECTION

The atmospheric model most appropriate to the entry conditions is selected as it is in the Entry C/L. If the OPS 301 transition occurs after the atmospheric model is selected, the DRAG ALT ATM will default to an I-loaded value. Consequently, the OPS 3 transition must occur prior to the selection of the DRAG ALT ATM.

**CHECK CG**

After checking the vehicle's center of gravity (cg), the crew and/or MCC decides if the cg needs to be moved forward. The cg is moved by performing an out-of-phase burn to waste aft OMS propellant. The quantity of propellant to be expended during the burn is entered in ITEM 18.

**OMS BURN**

The OMS burn prep procedure is identical to its counterpart in the ENTRY C/L except that the OMS burn contingency steps are deleted.

**CLOTHING CONFIG**

If enough time is available, the pilot dons LES, harness, and boots. The pilot also performs LES pressure integrity check.

At TIG-2, the pilot goes to the deorbit burn cue cards.

**POST BURN ACTIVITIES****CDR**

The left DDU cb's are cycled as required to monitor the maneuver to the EI-5 attitude.

**MNVR TO EI-5 ATT**

If an INTRL EI-5 attitude has been supplied by MCC, the commander maneuvers the Orbiter to this inertial attitude and maintains this attitude inertially until EI-5. If no landing site is available, the commander uses the local vertical/local horizontal (LVLH) table provided, since the inertial EI-5 attitude is not known. The LVLH attitude at EI-5 is always  $R = 0$ ,  $P = 39$ ,  $Y = 0$ . A chart is included here to provide an instantaneous LVLH attitude to which the CDR maneuvers at any time before EI-5. If this attitude is maintained inertially, the Orbiter will be at the desired attitude of  $R = 0$ ,  $P = 39$ ,  $Y = 0$  at EI-5. At EI-5 and on OPS 304 transition, the software will begin maintaining an LVLH pitch of 40 degrees through entry.

**FORWARD RCS DUMP**

If required, the forward RCS dump is used to move the cg for a safe entry. The dump also helps to reduce the vehicle's landing weight. This procedure is identical to the standard Entry C/L four jet dump procedure.

**PLT**

The right DDU cb's are opened since the CDR is monitoring the maneuver to the EI-5 attitude.

## **OMS/RCS POST BURN RECONFIG**

The aft left and right RCS and OMS valves are verified to be in their proper positions as in a nominal deorbit.

## **APU PRESTART**

The APU prestart procedure is identical to the Entry C/L version, except that the APU fuel tank is not opened in the APU activity. In a nominal entry, the valve is opened during APU PRESTART so that the crew can verify a good APU as early as possible in case a waveoff is necessary. However, the opening of the APU fuel tank is delayed in an emergency deorbit since a waveoff is not possible.

## **APU START**

This APU START procedure is different from the nominal case (which is performed in the Entry C/L). Nominally, one APU is started prior to the burn to ensure that at least one APU is good before committing to a burn; the remaining 2 APU's are powered on after the burn. Since time is critical in an emergency deorbit, all 3 APU's are scheduled to be started at the same time after the burn. The two step procedure normally used takes too much time for an emergency deorbit.

## **SECONDARY ACTUATOR CHECK**

This procedure checks for flight control system failures as in the Entry C/L. This check is performed if time permits and it has not already been performed.

## **CDR AND PLT**

### **EQUIPMENT DONNING AND SEAT INGRESS**

If not already accomplished, the commander and pilot don their LES, harness, and boots, begin fluid loading, install the Entry cue cards, and adjust their seats in preparation for entry.

### **ENTRY SWITCH CHECK**

The entry switch check is identical to its Entry C/L counterpart except that some RA, MLS, and TACAN verifications are deleted. The ammonia boiler system is activated at this time to provide cooling from FES cutoff to GSE hookup.

### **HORIZ SIT CONFIG**

The horizontal situation configuration is the same as in the Entry C/L as well as the elevon selection based on Xcg and the filter selection based on returned payload weight.

The CDR and PLT stow the cue cards not used during entry and verify that the entry cue cards are installed. Turning AC BUS SNSR to OFF and then to MON resets the sensors and allows C/W to annunciate spikes but does not trip the cb's.

NOTE: At this point in the procedure, the crew will either transition to the Entry C/L or to the BAILOUT procedure depending on if a landing site is available.

#### LANDING SITE AVAILABLE

If a landing site is available, the crew transitions to the ENT MNVR cue card at EI-5 with several pen-and-ink changes. If the cabin pressure stabilizes at 8 psi, additional air-cooled equipment can be powered on since cabin air supply temperature limits will not be exceeded. The pen-and-inks power on various dedicated displays and flight control systems powered off earlier to prevent excessive heating. The commander's controllers are repowered at EI-5 for manual flight, and the pilot's controllers are activated at M = .9 as a backup to the commander's to support nominal landing procedures.

#### LANDING SITE NOT AVAILABLE

If a landing site is not available, the crew will perform a bailout. First, the crew repowers the ADTA's, left DDU, flight controller power, and instrument power that were turned off in the powerdown. The ADTA's are powered on since accurate air data is critical in Orbiter guidance during a bailout. All four ADTA's can be turned on for a bailout since less avionics equipment is powered on in the bailout case and a larger thermal margin is available.

After checking that the ADI attitude is LVLH, the crew maneuvers to an attitude of R = 1.0, P = 39.0, and Y = 358.0; this attitude is maintained in an LVLH reference frame.

At EI, the commander flies the vehicle using auto until  $q = .5$ . At this point, the commander changes to control stick steering (CSS) to manually control the vehicle. At a sink rate (H) of -200, the commander starts a 3 deg/sec roll to ENTRY ALPHA cue card ref bank angle while maintaining an alpha of 40 degrees. This alpha profile is used to trade energy and lift over drag requirements while observing thermal and structural constraints. This alpha profile must be strictly maintained during any maneuvers. The commander flies Phugoid damper bank commands to get a zero bias. A bias of zero initiates a canned velocity/drag profile incorporated in the phugoid damper. The drag altitude computation is initiated when the onboard sensed acceleration reaches 11 ft/s<sup>2</sup>. Using the model of air density versus altitude, the altitude can be deduced from the air density, which is deduced from the drag acceleration. (The drag is obtained from the IMU's and the air density from the onboard software model of the atmosphere.) Two TACAN's are used in the event a landing site may still be available for the Orbiter to reach given its current energy.

At  $M = 4$ , the DPS OVERRIDE display is called up by the pilot before ADS deployment. This display is used to monitor the following ADTA derived data: altitude, alpha, and Mach number. This display can be used to deselect or reselect an ADTA to resolve an RM dilemma. It can also be used to determine if a probe has been deployed.

At  $M = 3.4$ , the two Air Data Probes are deployed. The static pressure ports on each probe are used to obtain pressure altitude; the total pressure port is used to obtain dynamic pressure and Mach number; the upper and lower pressure ports are used to determine Orbiter angle of attack. The ADS probe heaters will be used if flight through visible moisture is anticipated.

The Air Data switch is taken to R to L, then to NAV so that the probe data can be compared to NAV data by monitoring the altitude and EAS on the AMI and AVVI. The Air Data switch is left in the NAV position so that NAV-derived data will be displayed during the  $1.1 < M < 1.6$  Mach jump region.

The ADTA altitude (ADTA H) is checked on GNC SPEC 50 HORIZ SIT. The ratio of actual residual to maximum allowable residual is displayed in the RATIO column. If this ratio is less than 1, the data pass the update edit test and are automatically incorporated into the state vector (SV). If this ratio is greater than one and the ADTA is erratic, the data is incorporated into the SV via ITEM 25. If the ratio is greater than one and the ADTA is steady, the crew selects ITEM 27 to force the navigation filter to use the data if the data are being processed. Once the ADTA altitude is taken to either AUTO or FORCE, the crew selects the source of air data parameters input to GNC via ITEM 28 (AUT) which provides auto transition from NAV-derived air data, to default NAV, to ADTA.

A contingency procedure is provided in case no air data is available at  $M < 1.5$ . Air data should be available by  $M = 3.5$ . If air data cannot be used for guidance or nav by  $M = 1.5$ , the crew must take manual control of the vehicle and fly theta limits or risk loss of control of the vehicle. No matter what nav aids are being used (TACAN, MLS, etc.), if the range to the runway is greater than 80 nm, the theta limits are not certified. The crew has to maintain a maximum L/D flight profile and manually control the vehicle until the theta limits are available. The numbers provided for maintaining the theta limits as determined by the SB position and roll angle ( $\phi$ ) were generated from a program (DF62/GNC) that was developed using flight software equations and shuttle aero data as referenced in the workbook "Entry Flight Training for CDR and PLT".

At  $M = 0.95$ , the crew exits these procedures and proceed to the BAILOUT procedure.



## SECTION 9 LOSS OF 2 FREON LOOPS DEORBIT PREP

### OVERVIEW

This section can be entered from either the APCL, OPCL or the EPCL. For both the APCL and OPCL, the procedural flow is the same. First, the FREON FLOW LOW procedure is completed, and then the LOSS OF 2 FREON LOOPS powerdown. If the crew starts in the EPCL, they will perform the LOSS OF 2 FREON LOOPS powerdown before transitioning to the C D/O.

The failure of both freon cooling loops is considered one of the worst system failures that can afflict the orbiter. The fuel cells are cooled by the freon loops via an intermediary freon loop. It is a continuously degrading situation and only a matter of time before all fuel cells flood or fail due to excessive stack temperature. Due to the lack of complete understanding of fuel cell behavior without cooling, and the severe consequences of flooding or stack failure, the procedure configures the orbiter to a zero fault tolerant (ZFT) level and is made to be executed as quickly as possible. Because of the severity of this failure and the uncertain behavior of uncooled fuel cells, the first opportunity to deorbit must be used, even if a primary landing site (PLS) is only a few minutes further.

The analyses performed for this case were LEMSCO-24203 (thermal) and RSOC R02673 (electrical).

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## ASSUMPTIONS/INITIAL CONDITIONS

This procedure is entered from ASC PKT, ORB PKT, or ENT PKT powerdowns and contains entry procedures to fly the orbiter to landing. Because of the limited and uncertain lifetime of uncooled fuel cells the first available landing site must be used. If the failure occurs where a landing site TIG is within 40 minutes, all fuel cells remain operating to distribute the load, and have a continuous purge to cool the cell and remove water to delay flooding.

## PROBLEM DESCRIPTION/RATIONALE

This section gives a brief description of what happens to a fuel cell without cooling. In order to baseline the analysis of fuel cell lifetime without cooling, it is assumed the total orbiter load is immediately taken to 8 kw upon loss of freon loop cooling. This provides a more certain starting point than trying to estimate a power profile as it would be performed by different crews. With this assumption, the fuel cells should last at least 120 minutes, which leaves one hour to perform the powerdown and the deorbit prep, and another hour from the deorbit burn to wheel stop. Testing on a 2 substack fuel cell indicated that three, 3 substack fuel cells supporting the projected power levels for this procedure will last about 120 minutes before failing.

## PROCEDURE NOTES

The MS COMM pages from the ORB PKT powerdown are used to turn on comm equipment when needed and then turn it off. Minimum lighting limits the demands on the fuel cells. Two APU's are consistent with the ZFT philosophy. Vent door operation (except left and right doors 1 and 2) is prevented to limit power demands as in the LOSS OF 2 FUEL CELLS deorbit prep. Due to the limited equipment powered and needed to deorbit, modified Deorbit Burn Monitor and Entry Maneuvers cue cards have been developed for this procedure. Two fuel cells may have been shut down in the powerdowns to extend their useful life; consequently, a fuel cell start up is included.

**MS PULL OUT PAGE****PREPARE LES's**

In all loss of cooling deorbit prep procedures, the crew does not don their LES's until the last moment to take advantage of any evaporative cooling, even though the cabin temperature and humidity may preclude this. No heat is lost by a human in an environment of greater than 95 degrees F and 100% humidity. The CDR is the critical crewmember and needs to be as cool as possible. The suits need to be donned to prevent blood pooling in the legs and possible blackout, and protect for bailout capability.

**MCA CONFIG**

This disables vent door operations during entry to avoid the chance that the fuel cells may not have enough voltage to reopen the vent doors. If they do not open below 100,000 feet, the structural damage incurred would be worse than the thermal damage sustained by leaving the vent doors open. However, vent doors 1 and 2 would sustain extensive thermal damage requiring a long turn around repair time, so they are closed at the OPS 304 transition by powering MDM FF 4 earlier, turning it off after the transition, and then repowering it at Mach 4 so the doors may be reopened at a relative velocity of 2400 feet per second.

**AFT PANEL CONFIG FOR ENTRY COMM**

Since it is difficult for the aft MS to reach the comm panel once strapped into the seat, the aft comm panel is configured for S-BD PM comm coverage around TIG-10 minutes. The S-BD PM system and the UHF system are powered at V = 12K for comm coverage during landing. The comm system is turned off in the powerdown, but powered up when comm is needed at available GSTDN sites. The MS comm pages in the powerdown provides procedures to powerup comm in the order of power usage and availability. UHF is the first option and lowest power mode; S-BD PM STDN LO is next, with S-BD PM STDN HI (TDRS) the last choice. Use of TDRS is very limited since without cooling, the S BD PM power amp is estimated to last about 10 minutes. Thus, this panel config selects STDN LO which is the low power S-BD mode. Note that S-BD PM is not necessarily available at ELS. If an ELS without S-BD PM is selected, only UHF would be available for voice comm at the site, or S-BD TDRS for a short while before the power amp overheats. Using the power amp during a power critical phase such as entry is undesirable as it would place an additional power demand on the fuel cells. System 2 LRU's are selected since MDM FF1 is off. (MDM FF 2 and 3 are left powered on.) If data is necessary, MDM PL 2 is powered in the MS COMM page, or at V = 12K on the Entry Maneuvers cue card. If system 1 comm equipment were to be used, an additional MDM (FF1) would need to be powered if data was needed. In order to reduce the complexity of the procedures, only the option of using system 2 and S-BD STDN LO (PLS) is provided.

**LEH VLV CONFIG**

This is a standard procedure to configure the middeck LEH O2 valves as needed from an on-orbit set up to entry.

**CLOTHING CONFIG**

The MS's don their LES, harness and boots prior to Entry Interface (EI) and the aft station MS's open their two LEH O2 valves to supply O2 to the LES's.

**ON-ORBIT WAIT BACKOUT**

These two pages are used only if 2 fuel cells have been deactivated in the powerdown when the second freon loop failed prior to 40 minutes before the next landing site opportunity.

**SWITCH TO COOL IMU**

IMU's 1 and 2 were turned off in the powerdown, and IMU 3 has been running with one IMU fan running, but with both cabin fans off. IMU 2 is used in order to have a fresh IMU on for deorbit and entry, and since only FF MDM's 2 and 3 will be left on throughout this procedure. It is deselected before being powered to prevent its data from being used until it is aligned to IMU 3. The IMU to IMU alignment procedures are included here to keep from having to use other books. MDM's FF 2 and 3 are required to have ZFT.

**ACTIVATE FUEL CELL 2 THEN 3**

The DC main busses are tied to optimize load sharing among the fuel cells. It is assumed that as a fuel cell picks up load, its stack temperature will increase; build-up of water and contaminants will limit further power output so that the other fuel cells would then pick up the load. Leaving the busses untied does not protect entry redundancy since the configuration is ZFT. Leaving all the busses tied provides optimum load sharing if any fuel cell fails. The only risk is a bus short taking down all three busses, but this is highly unlikely compared to the probability that one of the fuel cells will fail.

Fuel cell 2 is started followed by fuel cell 3. A continuous purge is initiated in an attempt to cool the cell and remove water which is no longer being condensed.

The caution block is provided to monitor fuel cell stack temperature. If it is greater than 250 degrees F, the structural integrity of the cell is at risk, which may lead to crossing over of reactants and subsequent destruction of the fuel cell. The fuel cell is shut down to allow it to cool and when its stack temperature is within 5 degrees F of the others, it is reconnected. If all cells are greater than 250 degrees F, shutting one down would only load the others further, increasing their temperature.

**POWERUP**

The FF MDM's 2 and 3 are verified on to process data for the flight control system. With FF 1 down, the CDR's instruments are stuck in the green dot position. The FA MDM's support operation of the jets, RGA's, and body flap.

**ENTRY CONFIG****MCA CONFIG**

The CDR gives the MS the GO to perform the MS MCA CONFIG described above.

**SW CONFIG FOR OPS 3**

Gages reflecting EPS, MPS, and OMS voltages and quantities are powered to provide a readout of flight critical voltages and quantities.

**DEORBIT TARGET**

Since comm capability is limited, the MCC may not be available to provide deorbit targeting. The SPOC must be used to provide these.

**APU STEAM VENT HTR ACTIVATION**

Although 2 hours is required to clear ice if it is present from the APU vents, these heaters are turned on at the earliest opportunity in this time constrained procedure.

**SW CONFIG FOR OPS 3**

This configures or verifies that the nav aids, ASA's and jet logic circuits and drivers are on in preparation for the OPS 3 transition. Two of the first 3 ASA's must be on at the transition to provide accurate position information to the GPC's.

**STAR TRKR DOOR CLOSURE**

This is a standard procedure to close the star tracker doors to protect them from entry heat. No note on excessive door closure time is provided as there is no time to trouble shoot and it is acceptable to enter with one door open.

**AFT PANEL CONFIG FOR ENTRY COMM**

The CDR gives the MS a GO to configure the aft panel for comm during entry.

**DPS ENTRY CONFIG**

The FCS channels, RGA's, and ASA's required to be on at the OPS transition are verified on. The MMU is used as the source of OPS 3 software. GPC 1 is powered off as it has been running since the powerdown. The MMU is turned off since it is no longer needed. The ASA's will not be needed until prior to EI. Since GPC 3 is now running and GPC 1 is off, the corresponding av bay fans are swapped to cool the GPC. A GPC should not be run without active cooling. MDM FA 4 is turned on to obtain data on OMS status during the deorbit burn. GPC 3 is the only GPC that will be running during entry per the ZFT philosophy.

**OMS BURN PREP**

The note prior to this step checks the DAP in free drift if the OMS/RCS are interconnected since the next steps will break interconnect. If the DAP is not in free drift when the interconnect is broken, the jets can fail off. The note prevents possible evacuation of RCS manifolds. The aft DAP panel is used since the forward DAP lights are down with MDM FF1 down.

The burn prep is similar to nominal procedures. The OMS and RCS steps pressurize the left and right OMS and RCS engines to support the deorbit burn. The OMS tank isolation valve is opened to allow propellant to flow to the crossfeed valves. The RCS He pressure fuel and oxidizer valves are opened for pressurization, and the tank isolation and crossfeed switches are configured to allow the GPC to control the respective valves.

**ATMOSPHERE SELECT  
 LAND SITE UPDATE  
 CG CHECK**

These activities were added when ENT procedures were added to make this deorbit prep stand alone. The atmosphere selection and landing site should not be performed until after the last OPS 301 PRO in the ENTRY CONFIG as the transition causes the selected atmosphere model and landing site to default to the I-loaded values.

**LOAD TGTs AND MNVR**

A SPOC deorbit pad is provided in the event MCC cannot supply deorbit target information. The targets are calculated and the maneuver to the burn attitude is started. Secondary gimbals are selected as MDM's FF 1 and 4 are needed for primary gimbals.

**CRT CONFIG FOR ENTRY**

Only one CRT is used for the burn. The last MTU is turned off and the GPC is allowed to run on internal time to save power. The PLT's DDU is used to save the CDR's DDU for entry and landing, and since it has both INRTL and LVLH available in this ZFT config.

**CLOTHING CONFIG**

The CDR and PLT have a callout to don their LES's as late as possible but prior to EI.

**Go to DEORBIT BURN CUE CARDS**

The standard ENT cue cards are used for the deorbit burn. A special Deorbit Burn Monitor card has been provided which reflects the systems management philosophy of this procedure and the strong need to deorbit rather than wave off. A special card was also required because there is no BFS; the normal cues are not supported.

**MNVR TO EI-5 ATT**

The left DDU circuit breakers are cycled as required to monitor the maneuver to EI-5 attitude. The right DDU circuit breakers are opened as the CDR will be monitoring the maneuver while the PLT continues with the preparations for entry. Although it would be preferable to have the PLT monitor the maneuver to preserve the CDR's instruments for landing, the PLT is already busy at this time. The LVLH table is used in case INRTL attitude is not supplied by MCC, as in the ENT checklist.

**OMS/RCS POST BURN RECONFIG**

The aft left and right RCS and OMS valves are checked in their proper configuration as for a nominal entry.

**OMS GIMBAL PWRDN**

Standard entry procedure.

**HORIZ SIT CONFIG**

Standard entry procedure.

**FWD RCS RECOVERY**

The forward RCS logic circuits and drivers, signal conditioners, and MDM FF 1 and 4 are turned on to allow a dump if one is required to maintain Xcg in the box. The JET RESET reselects jets and resets fail-leak annunciation that occurred because the OI signal conditioners were turned off in the powerdown.

**FORWARD RCS DUMP**

\* These are procedures from the ENT checklist to perform a forward RCS dump. When completed, the FF MDM's 1 and 4 and logic circuits and drivers are turned off to return to ZFT and reduce power demands. The CDR column has an Xcg criterion to select alternate or nominal elevons and an alternate filter if returning payloads greater than 10,000 pounds.



**SEAT INGRESS**

The CDR and PLT seats should be adjusted using only one seat and one motor at a time to reduce the instantaneous demands on the fuel cells. The brake pedals are exercised as in ENT.

**G-SUIT INFLATION**

The LES's G-suits are inflated by turning the valve 1.5 turns as in ENT.

**FC PERFORMANCE CHECK**

This is essentially a reiteration of the check procedures given for the fuel cell activation in the On-Orbit Wait Backout.

**APU PRESTART AND START**

The APU prestart and start are delayed until 5 minutes before EI to allow the crew to perform the necessary procedures for the deorbit burn. Only APU's 1 and 3 are started to be ZFT and be consistent with LOSS OF FREON LOOPS AOA (SYS AOA). FCS channels 2 and 3 and all 4 ASA's are required to be ZFT. The FCS channels are set to override to protect against the next worse failure which would be a one on one dilemma where there is a 50% chance the bad channel would be selected over the good channel. The INST PWR is cycled to monitor the start. APU 2 fuel line heaters were turned off in the powerdown since only 1 and 3 were to be started, but if a failure in 1 or 3 should require APU 2 to be started, the fuel should not have frozen by EI. Procedures are included for starting APU 2 and shutting down failed APU's. The AC Bus Sensors are cycled and taken to monitor to provide annunciation for over or under voltage conditions, but not allow automatic fault protection.

**ENTRY MANEUVERS Cue Card**

This cue card has been provided since the changes that would be required to the standard ENT cue card are too extensive to be pen-and-inked expeditiously or legibly. The systems configuration is ZFT, and delays powerup to keep the thermal loads as late as possible. The comm system is powered up at V = 12K which corresponds closely to post blackout. Only the CDR's instrument power is used. Only one TACAN is turned on at V = 10K. Only one air data probe heater is used if a dilemma occurs as the heater uses approximately 900 W. Only one Radar Altimeter is used at Mach = 2.9. The CDR uses his discretion to use any additional landing aids as necessary to safely land. At M = 2.7, both running APU's are taken to high speed because if one fails, high speed is needed to provide sufficient hydraulic pressure

from the remaining APU. Nose Wheel Steering steps are included at M = 0.9 if the CDR determines it is needed. Hydraulic Landing Gear Isolation valves 1 and 3 are opened at M = 0.7 to ensure full braking capability for rollout. At wheel stop, an emergency powerdown is performed because the overheated fuel cells must be unloaded as soon as possible.

## SECTION 10 QUICK RESPONSE JETTISON

### OVERVIEW

The need for a procedure to allow a means of jettisoning a failed Ku band antenna or RMS or both was identified after a policy letter on Rapid Safing (NSTS-JSC, TA-88-25, May 16, 1988) was issued. One of the requirements set in this letter was the ability to close the PLBD's in approximately 20 minutes and perform a deorbit burn in approximately 30 minutes. As a result, this procedure was developed for the cases where the Ku band antenna and/or RMS fail and cannot be stowed in a contingency situation, and no capability exists for manual stowage by an EVA. To support the potential for an emergency deorbit, the separation maneuver is designed to allow the final burn to be the deorbit burn.

The memo, Payload Safing and Securing the Payload Bay for Entry (DA8-88-32 FT, April 14, 1988) provides the reasoning behind the need for a Quick Response Jettison (QRJ) procedure and documents the decisions made to implement the payload safing policy.

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## ASSUMPTIONS/INITIAL CONDITIONS

This procedure is used when the Ku band antenna or RMS or both cannot be stowed using the nominal stowage procedures, and the PLBD's must be closed for entry. At the time this procedure was written, the jettison procedures were complex and not time constrained, and each included a separate integrated separation sequence. Also, if a jettison were performed, the separation sequence did not include the option for a deorbit burn to support the 20 minute payload safing and 30 minute deorbit criteria. The powerdown procedures refer to QUICK RESPONSE JETTISON if either the Ku band antenna or RMS are unable to be stowed.

OPS 2 GNC software must be available in order to use the vernier jets for the fine control necessary to ensure the proper separation rates are achieved. Note that this will require that QUICK RESPONSE JETTISON be completed before the transition to OPS 3 in the deorbit prep.

Full forward and aft RCS capability is required to perform the multi-axes separations, and the maneuvers are performed from the aft station.

The separation sequences have been designed to ensure a greater than 500 foot clearance between jettisoned hardware and the orbiter even if the jettison was performed in a less than optimum attitude. Time is better spent moving away from the jettisoned hardware rather than trying to maneuver to a more optimal jettison attitude. Also, the payload/RMS configuration may be such that a maneuver would not be possible.

## PROBLEM DESCRIPTION/RATIONALE

QUICK RESPONSE JETTISON is performed only after a series of failures that produce a situation requiring a deorbit at the next Primary Landing Site (PLS) or an Emergency Landing Site (ELS). It is performed when there is insufficient time to stow the Ku band or RMS after both an orbiter systems failure (or emergency deorbit situation) and failure to stow the Ku band antenna or RMS. Note that even in an emergency deorbit situation, the nominal Ku band antenna or RMS stow procedures are used, and QRJ performed only after a failure in either or both of these systems. The nominal stow procedures are in the Orbit Ops checklist for the Ku band antenna and in the PDRS Ops checklist for the RMS. These are normally unstowed and available on-orbit. However, for contingency situations the CONT DEORB checklist will have been unstowed and QRJ available if needed. One risk with using the nominal RMS and payload stow procedures is that if the RMS fails during the stow sequence, there may not be sufficient time to jettison the RMS in time to make the deorbit burn. However, if the RMS is fully operational, it is preferable to accept the risk of an RMS failure, rather than performing a contingency jettison and separation procedure to dump a healthy RMS just to protect for a subsequent failure.

**NOTES**

These notes are essentially a repetition of notes contained in the body of the procedure, and will be explained in the corresponding sections below.

There is a difference in the format in that the commander's (CDR's) column is on the left as in the other time critical deorbit preps, but the mission specialists' (MS's) procedures are in the right column, rather than the pilot's procedures as usual.

**SETUP FOR JETTISON**

The equipment needed for full RCS operation is verified on as it may have been turned off or closed in the powerdown. The aft DDU and hand controllers are used for good hardware visibility. Vernier jets are used for fine attitude control to provide for orbiter stability while the RMS/payload are positioned. Since vernier jets are used, the procedures must be done while in OPS 2. The DAP pulse mode is set to 0.10 feet per second (fps) for convenience to achieve the 0.8 fps initial separation.

**PREP FOR JETTISON**

This section is separated into RMS/payload only jettison, Ku band antenna only jettison, and both Ku antenna and RMS/payload jettison. Per SMS runs, the procedure was more quickly and conveniently executed when the steps were grouped according to the particular failure, rather than trying to perform common steps and then failure specific steps.

The procedures power off all equipment on the hardware to avoid shorts when the electrical cables are guillotined. The RMS/payload are positioned to avoid contacting the orbiter when the initial separation is done, and to prevent inducing motion in jettisoned hardware from RCS jets and possibly recontacting the orbiter. Positioning the RMS/payload may be time consuming, but it is necessary to avoid damaging the orbiter. When the proper configuration is attained, the cables are severed.

**INITIAL SEP MNVR**

The initial separation rate must be  $0.8 \pm 0.1$  fps in order to ensure no recontact of the orbiter and jettisoned hardware during subsequent maneuvers or the deorbit burn. Once the Ku antenna or RMS/payload are jettisoned, eight 0.1 fps pulses are fired to separate from the hardware. Once jettisoned and separated, fine attitude control is not as critical and the orbiter is taken to free drift in normal jets.

**KU/RMS/PAYLOAD JETTISON**

If the payload requires additional configuring before being jettisoned or deployed, the ORB PKT payload safing procedures are completed prior to jettisoning the RMS. Once the CDR sets up the DAP, the pyrotechnic devices used to sever the hardware from the orbiter are armed and then fired. The CDR then separates from the hardware by giving eight pulses.

## OUT OF PLANE SEP MNVR

If the initial separation maneuver was done within an  $-ZLV +10$  pitch degree attitude, the orbital dynamics are such that an out of plane maneuver is not necessary, thereby saving time and propellant. The 10 degree was chosen somewhat arbitrarily as being close enough to the  $-ZLV$  yet still readily ascertainable by the crew in an emergency situation. The RCS jets are selected on the ORB MNVR EXEC and four minutes later a 4 fps out of plane burn is performed. Four minutes was chosen as long enough to allow setup between burns yet short enough to complete the procedure quickly. Four fps was chosen based on the dynamics of waiting four minutes from the initial separation burn. Once the PEG 7 targets are loaded and executed, if the VGO Z is negative, the direction of the out of plane burn must be reversed so as to not null the out of plane component of the initial separation maneuver. Rather than maneuver to an optimal burn attitude, time is saved by performing the burn in the current orbiter attitude. The VGO's are trimmed to less than 0.2 fps to ensure good trajectory control.

## POST JETTISON CLEANUP

The circuitry for the pyrotechnic devices are safed, and the MCA's needed to stow the MPM's are verified on. The warning reminds the crew that the PLBD's cannot be closed until the MPM's are stowed. The 3 phase mid 2 and 4 circuit breakers are left open to protect against a Crit 1/1 failure of the MPM stow/deploy switch and need to be closed. The Ku antenna and RMS pyrotechnic circuit breakers are opened as they are no longer needed, and any post jettison or deploy cleanup steps needed are performed.

## FINAL (POSIGRADE) SEP MNVR

This maneuver need not be performed if either the deorbit burn is less than 28 minutes from the initial sep if done in an arbitrary attitude (outside of  $-ZLV +10$  degree) or less than 45 minutes from the initial sep if done in  $-ZLV +10$  degree. These maximum times were set to ensure the orbiter and jettisoned hardware would have adequate clearance (greater than 500 feet) based on the expected worse case deorbit delta V components.

The 3 fps +X and 2 fps -Z components are based also on the four minute wait time between burns to ensure adequate clearances for expected worse case conditions. The burn and trim are done as for the out of plane maneuver. If VGO Z is negative, it is trimmed first since it couples into the VGO X.

**POST SEP CLEANUP**

The timing and separation rates of the burns of this procedure are designed to protect for adequate clearance of the orbiter and jettisoned hardware, defined as 500 feet. If the deorbit burn is sooner than 9 minutes, this clearance cannot be guaranteed to exist for worst case deorbit burn delta V's. The equipment used for the separation burns are either powered off or configured as needed for the contingency deorbit prep.

**SECTION 11  
BAILOUT****OVERVIEW**

The BAILOUT procedure is entered from EMERGENCY DEORBIT PREP/ENTRY if a landing site is not available. Once subsonic, the crew arms the bailout autopilot via the abort PBI with the abort mode select switch set to "ATO". Once the desired airspeed and roll attitude are established, the bailout autopilot is engaged by moding the pitch and yaw/roll angle FCS channels to AUTO. Bailout can be terminated by returning to manual (i.e., CSS) control of the vehicle. The cabin is depressurized at 40,000 feet. Between 30,000 and 20,000 feet, the hatch is jettisoned, and the pole is deployed.



MACH | < .95

At  $M < .95$ , the speed brake and body flap are taken to AUTO to give control of the air speed and pitching moments of the Orbiter to the bailout autopilot during the bailout. The commander will fly the vehicle at an equivalent airspeed (EAS) suitable for bailout prior to engaging the autopilot. The pole system has been flight tested from 130 to 200 KEAS; section 5.1 of the program requirements document states that the pole escape system will operate from 175 to 200 KEAS. 185 to 195 KEAS was chosen as the target airspeed band for several reasons. This airspeed band is within the flight test envelope, and these are stable airspeeds; flight at these speeds minimizes the pitch rate transients present in bailout software at slower speeds. Bailout within this airspeed band will provide satisfactory crew clearance of the Orbiter. The 185 to 195 KEAS band was also chosen since flight at these speeds is near the angle of attack necessary for a minimum sink rate.

The GPC's must be in major mode 305 or 603 (TEAM/approach/land and RTLS glide) before arming the bailout autopilot. The bailout autopilot is not supported in BFS. If the BFS is engaged, the commander will have to manually control the vehicle until all of the crew members have bailed out of the Orbiter. The Orbiter will attempt to maintain a zero pitch rate since still in CSS mode.

The bailout autopilot is armed by selecting ATO on the abort rotary dial and then pressing the abort push button indicator (PBI). Arming the autopilot causes guidance to inhibit a transition to approach and land. The speed-brake is closed and the lateral ground track control commands are disabled.

Once the crew has established the desired airspeed and roll attitude for bailout, a "snapshot" of the vehicle's current attitude and external conditions is taken to be used by the autopilot during bailout to maintain Orbiter stability. This "snapshot" occurs when "AUTO" is selected. Moding the pitch and bank FCS channels to AUTO will cause guidance to engage the bailout autopilot and issue normal acceleration (within angle of attack constraints,  $\alpha \leq 18$ ) and roll commands which maintain these desired conditions.

The flight controller power is powered off once the autopilot is activated to prevent inadvertently moving the stick past softstop which would disengage the autopilot. If necessary, the crew can disengage the bailout by resuming manual control of the vehicle; the bailout commands will be terminated and the pitch commands will return to nominal glide range-dependent operations. However, the lateral ground track control commands will not automatically return with manual control. Reengaging the automode will engage the bailout mode again. A status indicator of the bailout system is provided on the VERT SIT display. The word "BAILOUT" will appear flashing double overbright on the display; once the bailout autopilot is engaged, the word will stop blinking.

**40K ft**

The LES O2 supply should be on and the visors down at an altitude of 40,000 ft to ensure oxygen flow during cabin depressurization. Once steps have been taken to prevent possible hypoxia, the cabin is depressurized by pulling the VENT T handle.

**30 - 20K ft**

After the cabin is vented, a MS jettisons the hatch via pyrotechnics between 30,000 and 20,00 ft. The MS then deploys the pole. The pole can also be manually ratcheted into position as a backup method of deployment. After the pole is deployed, crewmembers attach a ring on their harness to lanyards which are in a magazine on the pole, and parachute to safety.

ACRONYMS

ac	alternating current
ADI	attitude direction indicator
ADTA	air data transducer assembly
AOA	abort-once-around
AOS	acquisition of signal
APCL	ascent pocket checklist
APU	auxiliary power unit
ASA	aerosurface servo amplifier
ATO	abort to orbit
AVVI	altitude/vertical velocity indicator
BLR	boiler
BFS	backup flight system
cb	circuit breaker
C D/O	contingency deorbit
CDR	commander
C/L	checklist
COAS	crew optical alignment system
CONUS	continental US
CRT	cathode ray tube
CSS	control stick steering
C/W	caution and warning
DAP	digital autopilot
DDU	display driver unit
DPS	data processing system
DTO	detailed test objective
EI	entry interface
EIU	engine interface unit
ELS	emergency landing site
EOM	end of mission
EVA	extravehicular activity
FA	flight aft
FC	fuel cell
FD	freeze dried
FDA	fault detection and annunciation
FES	flash evaporator system
FF	flight forward
FOV	field of vision
FS	flight supplement
GNC	guidance and navigation computer
GPC	general purpose computer
HSI	horizontal situation indicator
HUD	heads-up display

ICH	interchanger
IMU	inertial measurement unit
INRTL	inertial
KEAS	knots equivalent airspeed
LCC	launch commit criteria
LDR	low data rater
LEH	launch/entry helmet
LES	launch/entry suits
LOS	loss of signal
LRU	line replaceable unit
LVLH	local vertical local horizontal
MA	master alarm
MCA	motor control assemblies
MCC	mission control center
MDM	multiplexer/demultiplexer
ME	main engine
MET	mission elapsed time
MLS	microwave landing system
MM	major mode
MMU	mass memory unit
MS	mission specialist
MTU	master timing unit
NBAT	nominal bus assignment table
NH3	ammonia
OMS	orbital maneuvering system
OPCL	orbit pocket checklist
PASS	primary avionics software system
PBI	push button indicator
PCMMU	pulse code modulation master unit
PCS	pressure control system
PI	post insertion
PLBD	payload bay door
PLS	primary landing site
PWRDN	powerdown
QRJ	quick response jettison
RCS	reaction control system
RGA	rate gyro assemblies
RJD	reaction jet driver
RMS	remote manipulator system
SFT	single fault tolerance
SM	systems management
SMS	shuttle mission simulator
SPOC	shuttle portable onboard computer

TACAN	tactical air navigation
TAEM	terminal area energy management
TAGS	text and graphics system
TDRSS	tracking and data relay satellite system
TFL	telemetry format load
THC	translational hand controller
U/L	uplink
WCS	waste collection system
ZFT	zero fault tolerance

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END