

## Space Program Operations Contract

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# Mechanical Systems Training Manual

**MECH SYS 21002**

November 11, 2008

### Final Version

**This document has been reviewed and updated.  
No subsequent updates to this document are anticipated or required due to the  
approaching shuttle program closure.**

Contract NNJ06VA01C

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**Mechanical Systems Training Manual**  
**MECH SYS 21002**

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D-1 – D-4	Rev B

## FOREWORD

The content of this document was provided by the Systems Training Group, Vehicle Systems Department, Space Transportation Vehicle Division, Mission Operations Directorate (MOD), Lyndon B. Johnson Space Center (JSC), National Aeronautics and Space Administration (NASA). Bastion Technologies, Inc. provided technical documentation support. Any questions concerning this workbook or any recommendations should be directed to the book manager, Genie Rheinhardt at DS45, (281) 244-7696.

This material is for training purposes only and should not be used as a source of operational data. All numerical data, displays, and checklist references are intended as examples. To determine any prerequisites before using this document, consult the applicable Certification Plan. For shuttle manuals, consult the Flight Operations Support Personnel Training Guide (Blue Book) or the Crew Training Catalog. For Space Station manuals, consult the appropriate Space Station Certification Training Guide or Training Administration Management System (TAMS). The applicable training package should be studied before attending any classroom session or lesson for which this is a prerequisite.

A Training Materials Evaluation is included at the end of this document. Inputs to this sheet will be used to evaluate the lesson material. You do not need to sign the sheet.

## PREFACE

The Space Shuttle Mechanical Systems Training Manual consists of components that must be opened, closed, deployed, or stowed. The orbiter has two types of mechanical systems: electromechanical and electrohydraulic. Electrical actuators drive the electromechanical mechanisms, and hydraulic actuators drive the electrohydraulic mechanisms.

This training manual provides an overview of the mechanical subsystems listed below. It discusses how each subsystem operates and how the crew interfaces with it.

- Active Vent System
- External Tank Umbilical Door System
- Payload Bay Door System
- Deployable Radiator System
- Landing and Deceleration System

In addition to the mechanical subsystems, this training manual also provides an overview of the orbiter's window system.

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## 1.0 POWER DRIVE UNITS

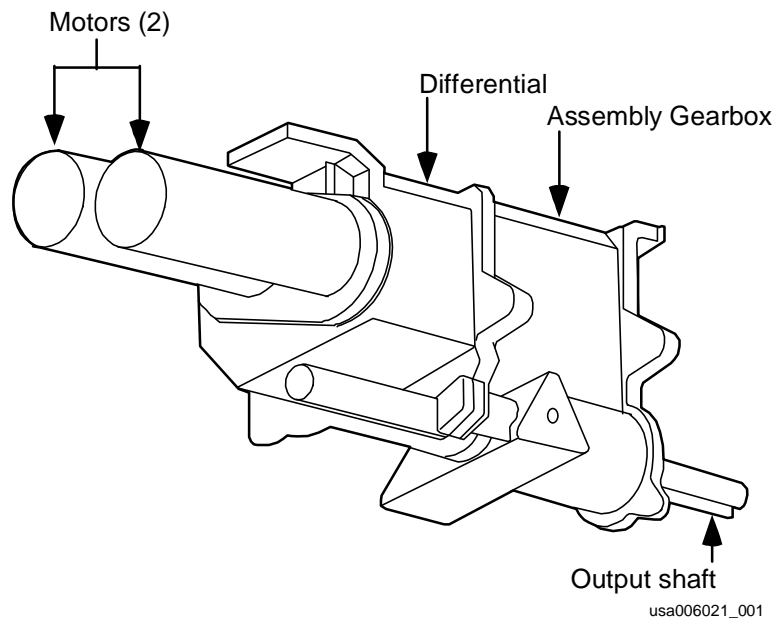
### 1.1 OBJECTIVES

Upon completion of this section, the student should be able to

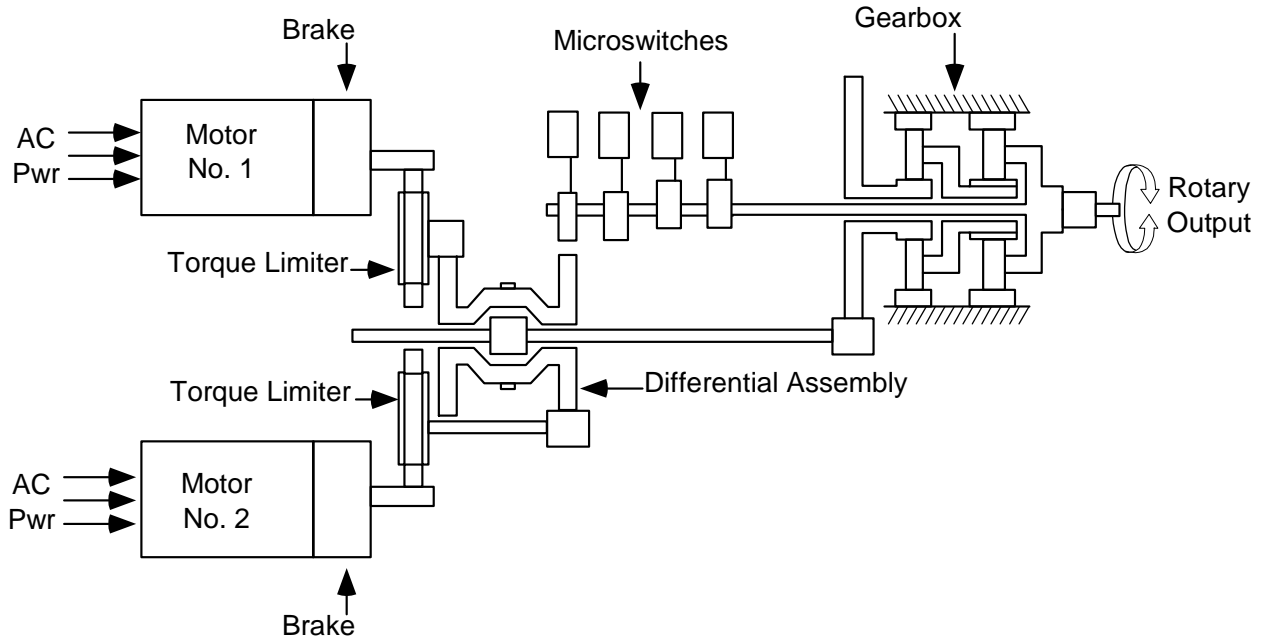
- Identify the components of a Power Drive Unit and state their functions
- Explain the difference between single motor drive and dual motor drive
- Recognize the function of motor control assemblies

### 1.2 SYSTEM OVERVIEW

A common element of the electromechanical systems is the Power Drive Unit (PDU). The PDU uses electric motors to drive equipment to a desired position (opened/closed, stowed/deployed, or latched/released). Figures 1-1 and 1-2 show the basic design of the orbiter PDUs.



**Figure 1-1. Power drive unit**



usa006021\_002

**Figure 1-2. Power drive unit schematic**

### 1.3 PDU COMPONENTS

#### 1.3.1 Three-Phase AC Motors

Two three-phase, Alternating Current (AC), electrical motors (117 V and 400 Hz) provide the rotational shaft power that drives a piece of equipment to a particular position. Each motor is reversible to allow equipment to be driven in both directions (opened or closed, deployed or stowed, latched or released).

A different AC bus from the orbiter Electrical Power System (EPS) powers each motor. This allows equipment to still be driven by a single motor if one of the AC power sources is lost. The loss of a single AC phase will not significantly affect motor startup or operation. However, a motor cannot run on a single AC phase.

#### 1.3.2 Brakes

Each motor has a brake to prevent the output shaft from turning when the motor is unpowered. When power is removed from a motor, the brake engages and locks the motor output shaft in place. This holds the equipment in a fixed position. When power is applied to the motor, the brake disengages and allows the motor output shaft to rotate.

#### 1.3.3 Differential Assembly

The differential assembly combines the two AC motor shaft outputs into one shaft input to the gearbox. The differential provides an input to the gearbox whether one or two motors are driving. This allows the system to still operate if one of the motors fails, or if one of the power sources to the motors is lost.

If only one motor is operating, it is referred to as single motor drive. If both motors are operating, it is referred to as dual motor drive. The time required to drive equipment with a single motor is twice as long as with two motors.

### **1.3.4 Torque Limiters**

Torque limiters protect against mechanical or structural damage in case a mechanism binds or jams. If the torque limit is exceeded, the torque limiter will not allow the torque to be transmitted to the mechanism.

### **1.3.5 Gearbox**

The gearbox links the differential assembly with the mechanism that is being driven. It contains a series of reduction gears that transfers the low torque and high speed output produced by the motors to a high torque and low speed input to the mechanism. This allows large mass mechanisms to be driven at slow enough speeds to prevent damage to the actuators or equipment.

### **1.3.6 Microswitches**

When a mechanism reaches its commanded position, it activates microswitches (sometimes referred to as limit switches). Microswitches are used to indicate the state of a mechanism (open/closed, stowed/deployed, or latched/released).

Although microswitches are included here as a component of the PDU, they are not always located within the PDU itself. This will be discussed further in the Payload Bay Door section.

Typically, there are two microswitches for each state. The microswitches provide feedback on the status of a mechanism through telemetry, Data Processing System (DPS) displays, or talkbacks. They are also used to turn off the motors once the mechanism is driven to the desired position. This is discussed further in the next section.

## **1.4 ELECTRICAL POWER**

Motor Control Assemblies (MCAs) provide the power for the PDU motors. The orbiter has 10 MCAs: 3 in the forward area, Forward Motor Control Assemblies 1, 2, and 3 (FMCA1, FMCA2, FMCA3); 4 in the midbody area, Mid Motor Control Assemblies 1, 2, 3, and 4 (MMCA1, MMCA2, MMCA3, MMCA4); and 3 in the aft area, Aft Motor Control Assemblies 1, 2, and 3 (AMCA1, AMCA2, AMCA3).

The function of an MCA is to provide 3-phase AC power to the orbiter's non-continuous AC loads. Both AC and direct current (DC) power are supplied to the MCAs through the MCA logic switches and circuit breakers on Panel MA73C (Figure 1-3). Refer to Figure 1-4 for a schematic of MMCA1.

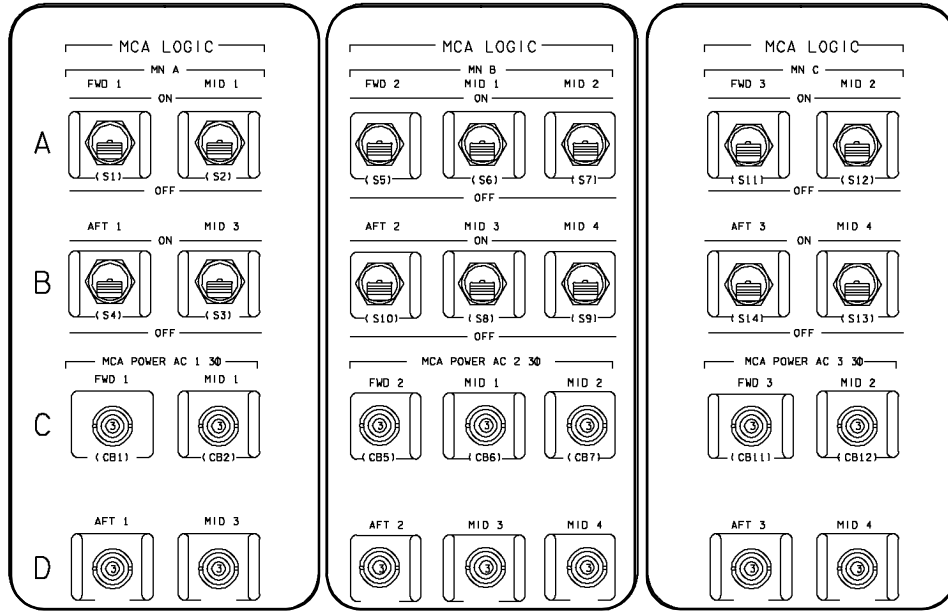
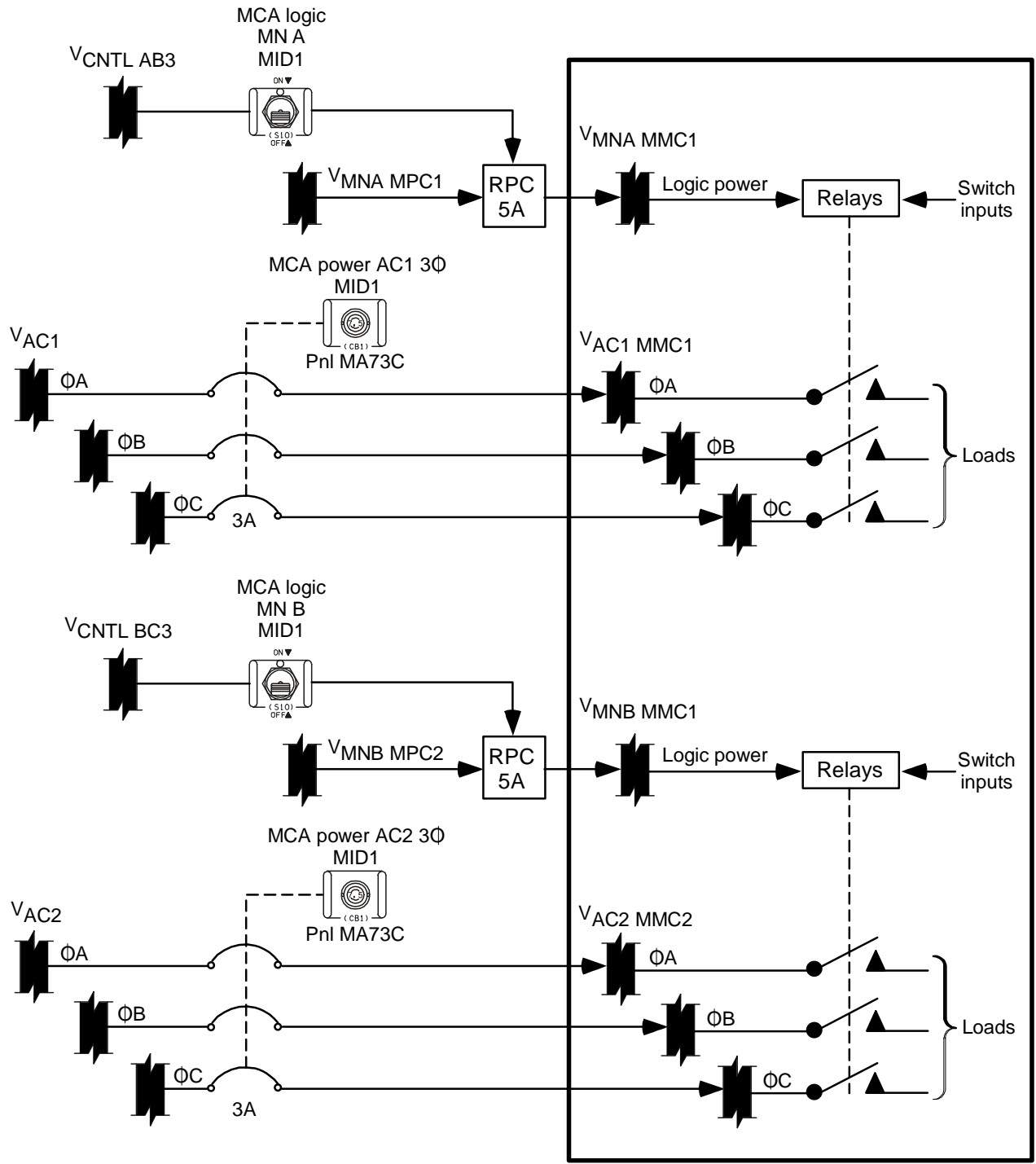


Figure 1-3. Upper portion of Panel MA73C



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Figure 1-4. Mid motor control assembly 1

The DC power is supplied to relays within the MCAs that allow the AC power to the motors to be commanded on and off. Depending upon the system, the commands can come from various sources: software sequences contained in the General Purpose Computers (GPCs), item entries on a DPS display, or hard-wired switches.

The MCAs also provide DC power to the microswitches. When a mechanism reaches its commanded position, microswitches are activated. When activated, each microswitch sends a signal back to the MCA that opens a relay to remove AC power from the associated motor.



## QUESTIONS

Answers provided in Appendix B

1. What is a function of the PDU differential assembly?
  - (a) Reverses the direction of the motor output shaft
  - (b) Transfers the low torque/high speed motor output to a high torque/low speed mechanism input
  - (c) Combines the two motor shaft outputs into one shaft input to the gearbox
  - (d) Protects against mechanical or structural damage if a mechanism jams
2. What PDU component turns off the motors once a mechanism reaches its commanded position?
  - (a) Brakes
  - (b) Torque Limiters
  - (c) Gearbox
  - (d) Microswitches
3. True or False: Dual motor drive time is twice as long as single motor drive time.
4. True or False: Motor control assemblies provide 3-phase AC power to all of the orbiter's AC loads.

## **2.0 ACTIVE VENT SYSTEM**

### **2.1 OBJECTIVES**

Upon completion of this section, the student should be able to

- State the functions of the Active Vent System (AVS).
- Identify the vent door configuration during the various mission phases.
- Identify how the crew interacts with the AVS.

### **2.2 SYSTEM OVERVIEW**

The AVS consists of vent ports in the orbiter fuselage that allows the unpressurized compartments to equalize with the ambient environment during launch and entry. During ground operations, the AVS also assists the purge system in protecting the internal environments of these unpressurized compartments.

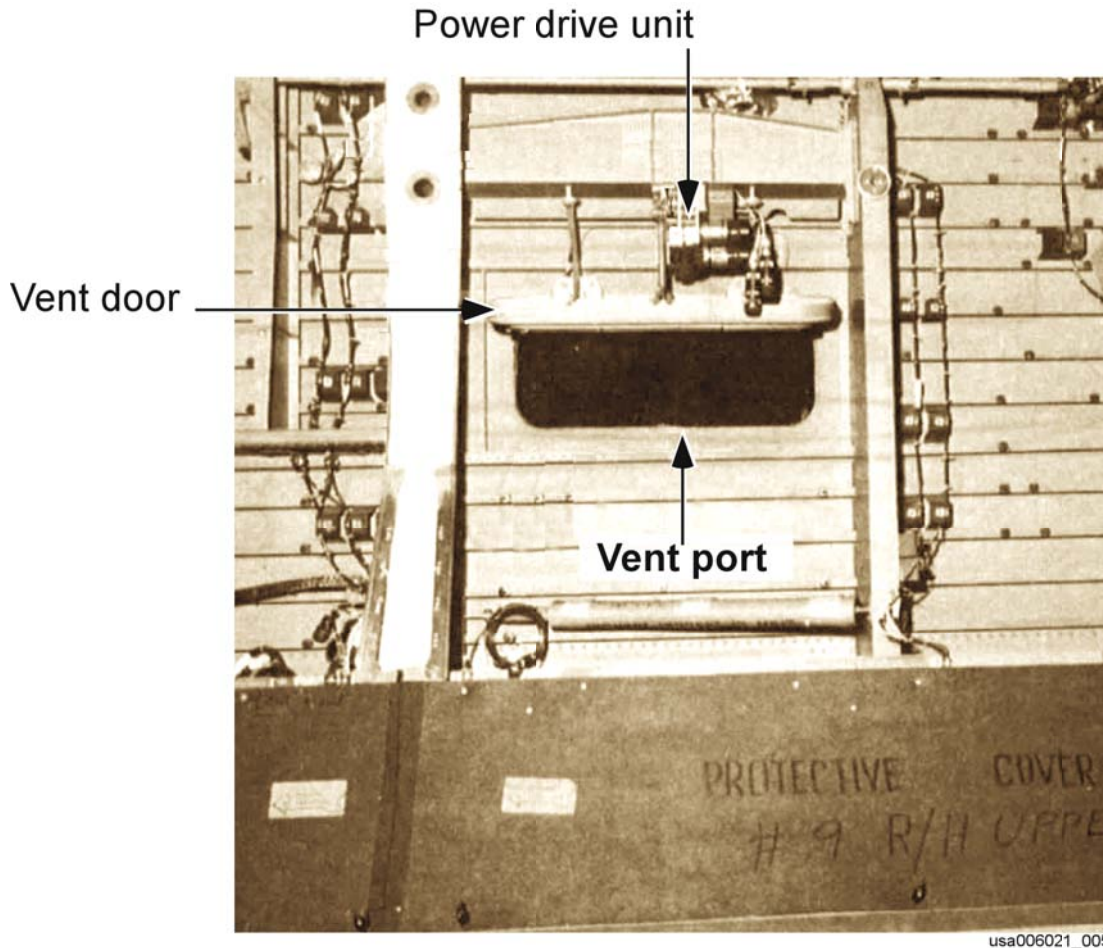
### **2.3 VENT PORTS AND DOORS**

The orbiter vent ports are covered by vent doors that open and close. Some of the vent doors also have purge positions. During a mission, PDUs drive the vent doors to these various positions in order to perform the functions of the AVS.

It takes 5 seconds to open or close each vent door with dual motor drive. Microswitches indicate when a door is in the closed, purge, or open position. There are two microswitches for each door position.

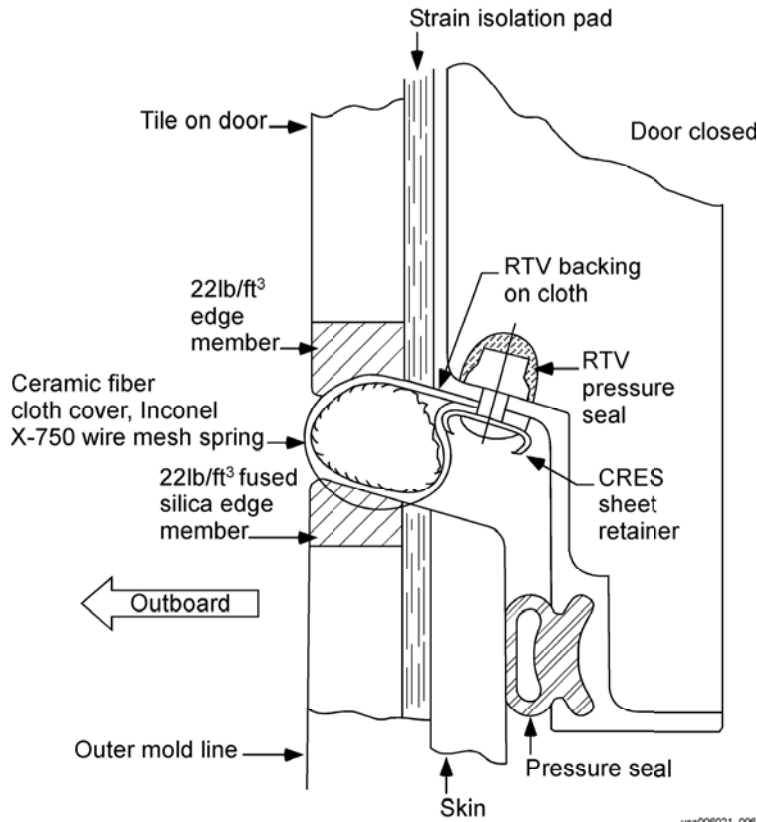
The crew does not have insight into individual vent door positions. However, the signals from the vent door microswitches are downlinked to the ground, allowing the Mission Control Center (MCC) to monitor the vent door configuration.

Each vent port opening is sized according to the area that it is venting. When a vent door is driven to a purge or open position, the door drives inward. Figure 2-1 shows a view of a vent port and door from inside the payload bay.



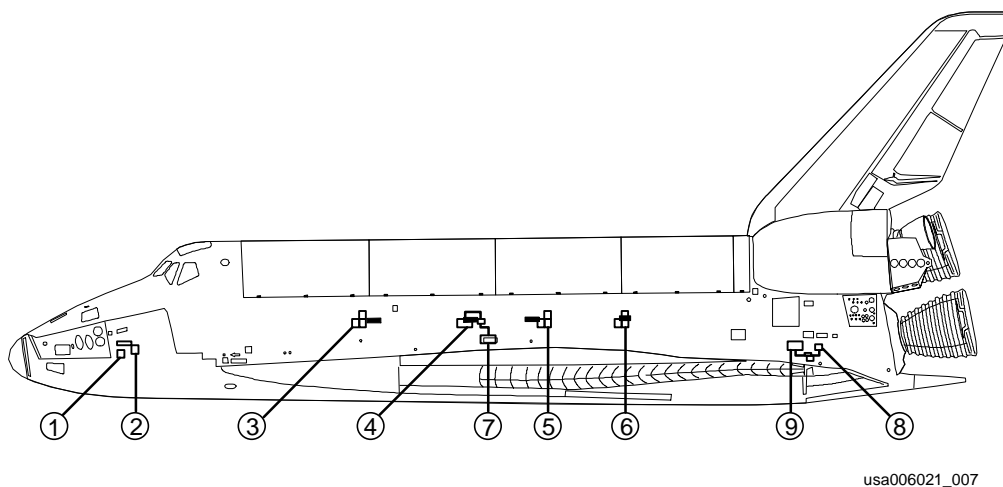
**Figure 2-1. View of vent port and door from payload bay**

Each vent door has both a pressure seal and a thermal seal (Figure 2-2). The pressure seal, which is between the vent door and the interior surface of the orbiter skin, prevents contaminants from entering the compartments. The thermal seal consists of a ceramic fiber cloth over a wire mesh form. The covered mesh form blocks the space between the vent door and the port opening, providing a thermal barrier against the hot plasma encountered during reentry.



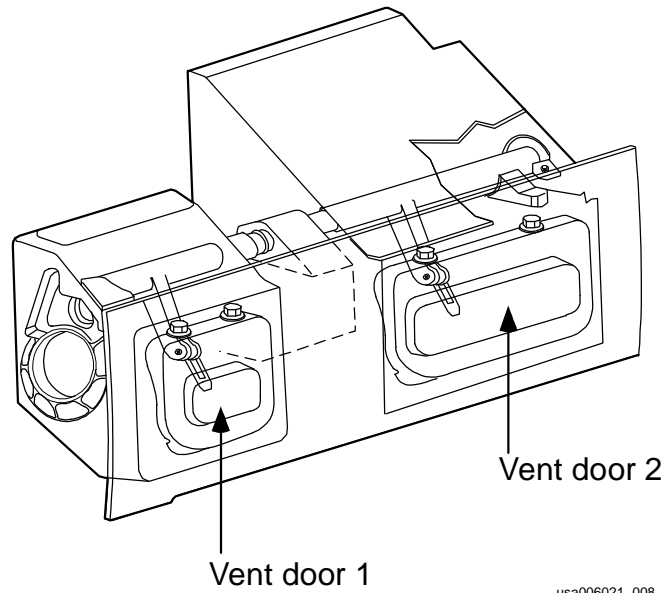
**Figure 2-2. Vent door pressure and thermal seals**

The AVS has 14 functional vent doors: 7 on each side of its fuselage (Figure 2-3). Each vent door is numbered for identification. Engineering analysis showed that vents 3, 5, and 6 provided sufficient venting of the payload bay and mid fuselage volumes. Therefore, vent ports 4 and 7 were permanently capped shut on both sides of Atlantis and Discovery, and the associated PDUs and mechanical linkages were removed. Endeavour did not have the equipment installed.



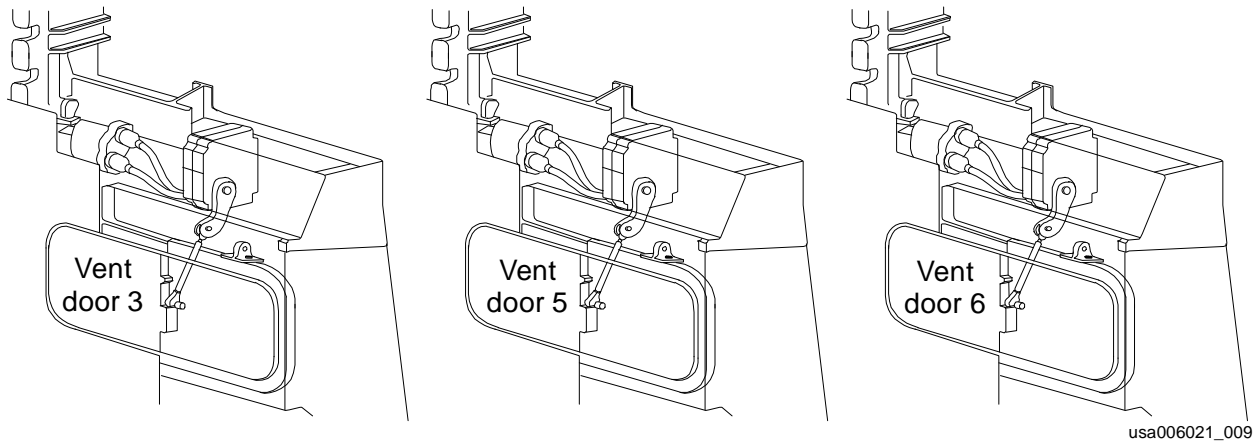
**Figure 2-3. Vent door locations**

Vent doors 1 and 2 vent the forward Reaction Control System (RCS) and forward fuselage volumes respectively (Figure 2-4). These doors have three positions: closed (0°), purge (12°), and open (90°). Vent doors 1 and 2 are both driven by the same PDU.



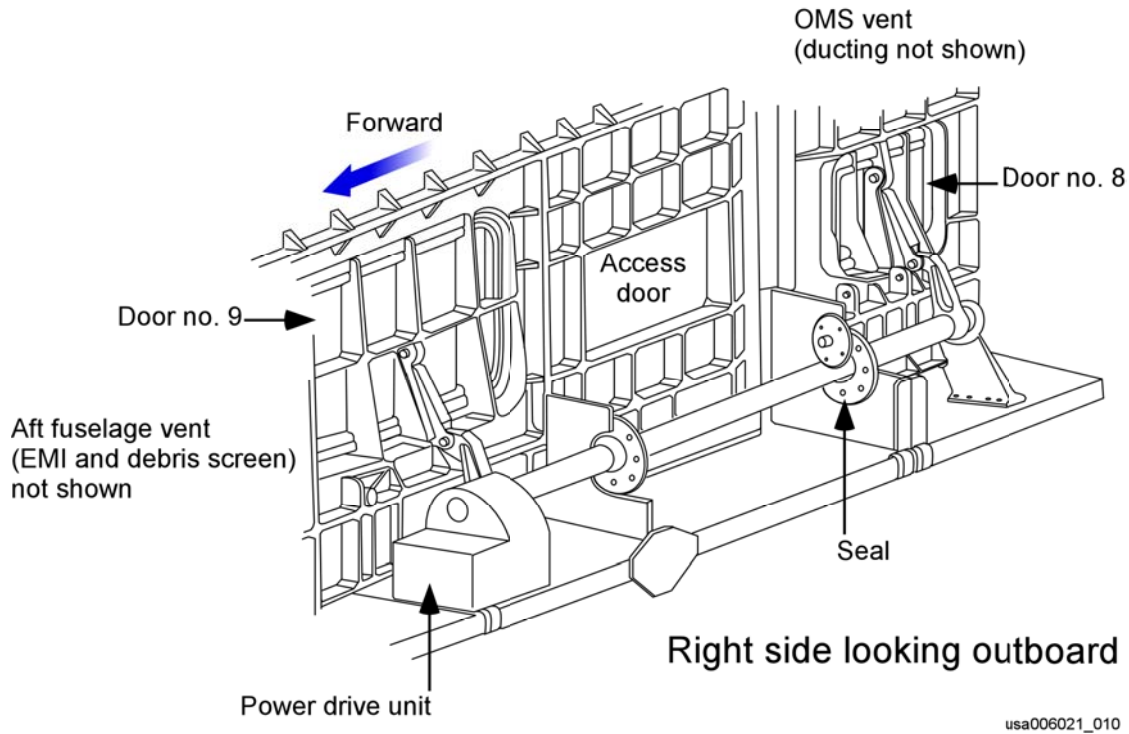
**Figure 2-4. Port vent doors 1 and 2**

Vents doors 3, 5, and 6 vent the payload bay and mid fuselage volumes (Figure 2-5). Vent doors 3 and 5 have two positions: closed (0°) and open (75°). Vent door 6 has four positions: closed (0°), purge 1 (10°), purge 2 (25°), and open (75°). Each of these doors is driven by its own PDU.



**Figure 2-5. Port vent doors 3, 5, and 6**

Vent doors 8 and 9 vent the Orbital Maneuvering System (OMS)/RCS pods and aft fuselage volume (Figure 2-6). The doors have three positions: closed (0°), purge (20°), and open (90°). Like vent doors 1 and 2, vent doors 8 and 9 share one PDU.



**Figure 2-6. Starboard vent doors 8 and 9**

## 2.4 VENT DOOR OPERATIONS

The AVS is controlled by software contained in the GPCs. The vent doors may be positioned by automatic software commands or keyboard item entries.

### 2.4.1 Prelaunch

Prelaunch, the internal environment of the orbiter's unpressurized compartments is controlled by purging the volumes with cool, dry air. If an inert environment is required, nitrogen may be used as the purge gas.

Purging is a ground function that provides thermal conditioning, moisture control, and hazardous gas dilution. It also maintains a positive internal pressure that prevents contaminants from entering the compartments.

During the purge, vent doors 1, 2, 8, and 9 will be in their purge positions, allowing the gases to exit the compartments. Vent door 6 may also be placed in a purge position depending upon the requirements of the payload. All other vent doors are closed. The vent doors remain in this configuration until T - 28 seconds.

The vent doors must be opened prior to liftoff. The vent door opening sequence is automatically initiated at T - 28 seconds. The vent doors are commanded open in a staggered sequence at approximately 2.5-second intervals. At T - 7 seconds, the Redundant Set Launch Sequence (RSLS) checks that all vent doors are open. If any door is out of configuration, a launch hold will be issued.

### 2.4.2 Ascent

All vent doors remain open during ascent. This allows the unpressurized compartments to vent as the vehicle travels from the pressurized atmosphere of Earth to the vacuum of space.

### 2.4.3 Orbit

All vent doors remain open during orbit operations. This allows for molecular venting of vehicle insulation in the unpressurized compartments.

### 2.4.4 Pre-Entry

During Major Mode (MM) 301, at Time of Ignition (TIG) - 25 min, the Entry Checklist directs the crew to close all vent doors with item 44 on Guidance, Navigation, and Control (GNC) SPEC 51 OVERRIDE (Figure 2-7). Nominally, this is the first time the crew interacts with the AVS. Up to this point, vent door operations have occurred automatically. An asterisk will be displayed next to the item after it has been commanded. "CL" will also be displayed after the sequence is complete.

XXXX / 051 /		VERRIDE	XX X	DDD / HH : MM : SS
ABORT MODE		ENTRY FCS		
TAL	1X	ELEVON	FILTER	ATMOSPHERE
ATO	2X	AUTO 17X	NOM 20X	NOM 22X
ABORT	3X	FIXED 18X	ALT 21X	N POLE 23X
THROT MAX	4X	SSME REPOS 19	XXX	S POLE 24X
ABT	50X			
NOM	51X			
PRPLT DUMP		IMU STAT	ATT DES	PRL
XXX ICNCT	5 XXXX	1S XXXX	X 25X	SYS AUT DES
OMS DUMP		2S XXXX	XXX 26X	1S 28X 31X
ARM	6X	3S XXXX	27X	2S 29X 32X
START	7X			
STOP	8X	ADTA	H	α M DES
9 QUAN / SIDE	XXX	L 1S	XXXXXX ±XX.X	X.XX 34X
OMS DUMP TTG	XXX	3S	XXXXXX ±XX.X	X.XX 35X
AFT RCS 13 XXX		R 2S	XXXXXX ±XX.X	X.XX 36X
14 TIME	XXX	4S	XXXXXX ±XX.X	X.XX 37X
FWD RCS 15 XXX		ET SEP	ROLL MODE XXXXXXXX	
16 TIME	XXX	AUTO 38X	AUTO SEL 42X	
		SEP 39X	WRAP MODE 45 XXX	
		ET UMB DR	VENT DOOR CNTL	
		CLOSE 40X	OPEN 43X XX	
		RCS RM MANF	CLOSE 44X XX	
		CL OVRD 41		

Figure 2-7. GNC SPEC 51 OVERRIDE

During the MM301 closing sequence, all the vent doors are commanded closed and then vent doors 1, 2, 8, and 9 on the port side are commanded back open. This allows any hazardous gases to vent during the deorbit burn. These doors are then automatically commanded closed at the MM304 transition, prior to Entry Interface (EI).

### 2.4.5 Entry

During entry, the vent doors remain closed to prevent hot plasma from entering the vehicle. When the orbiter's Relative Velocity (Vrel) reaches 2400 ft/s, the vent door opening sequence is automatically commanded. Opening the vent doors allows the unpressurized compartments to equalize with the ambient environment as the orbiter returns to Earth.

### 2.4.6 Postlanding

Once in OPS 9, the Entry Checklist directs the pilot to perform item entries on GNC SPEC 105 TCS CONTROL. These item entries execute software that positions the vent doors for postlanding purge operations.

### 2.4.7 Abort Sequences

If a Return to Launch Site (RTLS) or Transoceanic Abort Landing (TAL) is declared, the vent door software automatically commands the vent doors closed at MM 602 and External Tank (ET) separation, respectively. If an Abort Once Around (AOA) is declared, the Ascent Checklist directs the crew to close all vent doors with item 44 on GNC SPEC 51 OVERRIDE at approximately EI - 5 minutes. For each of these aborts, the vent doors automatically reopen at Vrel = 2400 ft/s. If an Abort To Orbit (ATO) is declared, the vent doors remain open.

### 2.4.8 Vent Door Commands During Entry

As mentioned earlier, the crew can interface with the AVS through item entries on GNC SPEC 51 OVERRIDE. During ascent, manual commands to the AVS are not available. However, the crew does have manual command capability during entry.

Figure 2-8 provides an overview of the vent door command capabilities available during each entry major mode. The open command (item 43) is legal in OPS 3, MM602, and MM603. The close command (item 44) is legal in MM301 through MM304, MM602, and after the rollout flag has been set in MM305 and MM603.

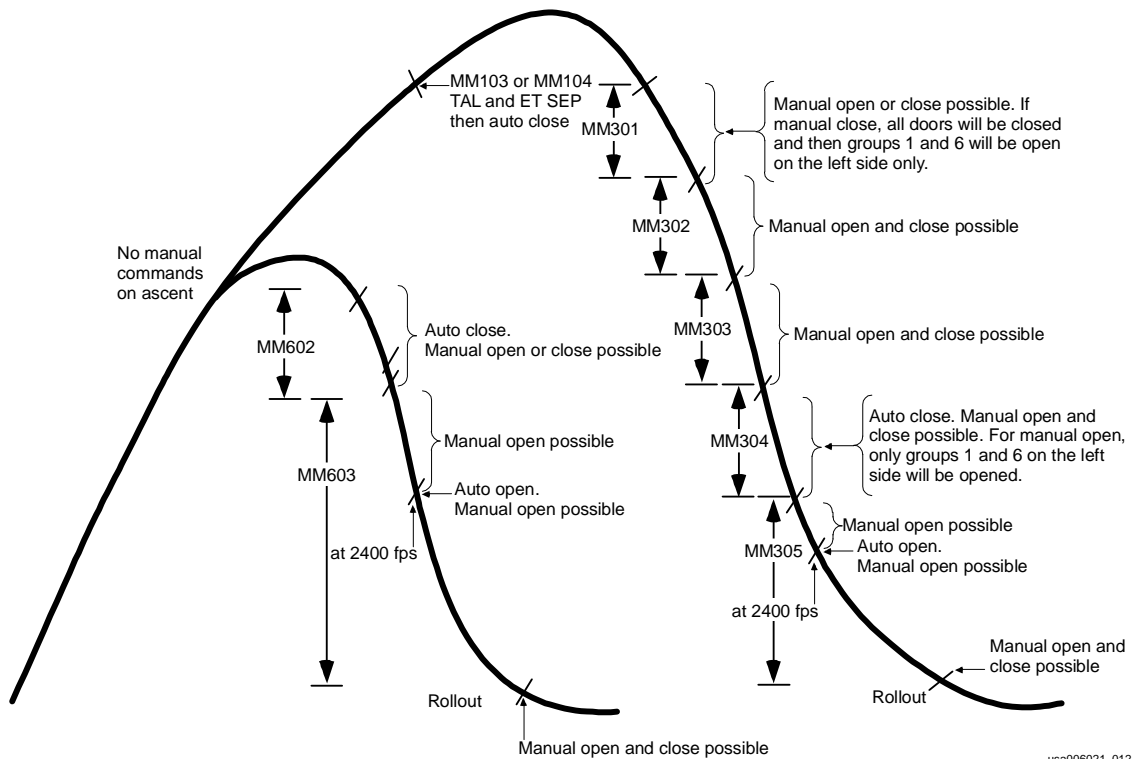


Figure 2-8. Entry vent door command capability



When a manual command is initiated, the vent door sequence that occurs depends upon the major mode. Table 2-1 lists the manually commanded vent door sequences that will occur during each entry major mode for both the Primary Avionics Software System (PASS) and the Backup Flight System (BFS).

**Table 2-1. Manually commanded vent door sequences**

<b>PASS/BFS</b>		
<b>Major Mode (RTLS)</b>	<b>Command</b>	
	<b>OPEN Item 43</b>	<b>CLOSE Item 44</b>
301	All doors open	All doors close; then port 1, 2, 8, 9 auto reopen
302	All doors open	All doors close
303	All doors open	All doors close
304	Port 1, 2, 8, 9 open	All doors close
305	All doors open	Command not available until rollout flag set
(602)	All doors open	All doors close
(603)	All doors open	Command not available until rollout flag set

## QUESTIONS

Answers provided in Appendix B

1. What is the vent door configuration during ascent?
  - (a) All vent doors closed
  - (b) All vent doors open
  - (c) All vent doors in purge positions
  - (d) All vent doors open, except for vent doors 1, 2, 8, and 9, which are in purge positions
2. During a nominal entry, when do the vent doors open?
  - (a) MM304 transition
  - (b) MM305 transition
  - (c)  $V_{rel} = 2400$  ft/s
  - (d)  $M = 1$
3. How does the crew send commands to the Active Vent System?
  - (a) Switches on Panel R2
  - (b) Item entries on GNC SPEC 51 OVERRIDE
  - (c) Both (a) and (b)
  - (d) The crew cannot send commands to the system

### **3.0 EXTERNAL TANK UMBILICAL DOOR SYSTEM**

#### **3.1 OBJECTIVES**

Upon completion of this section, the student should be able to

- State the purpose of the External Tank Umbilical Door System.
- Identify the components of the External Tank Umbilical Door System.
- Describe the External Tank (ET) door closure methods and recognize when each method should be used.
- Describe postlanding ET door operations.

### 3.2 SYSTEM OVERVIEW

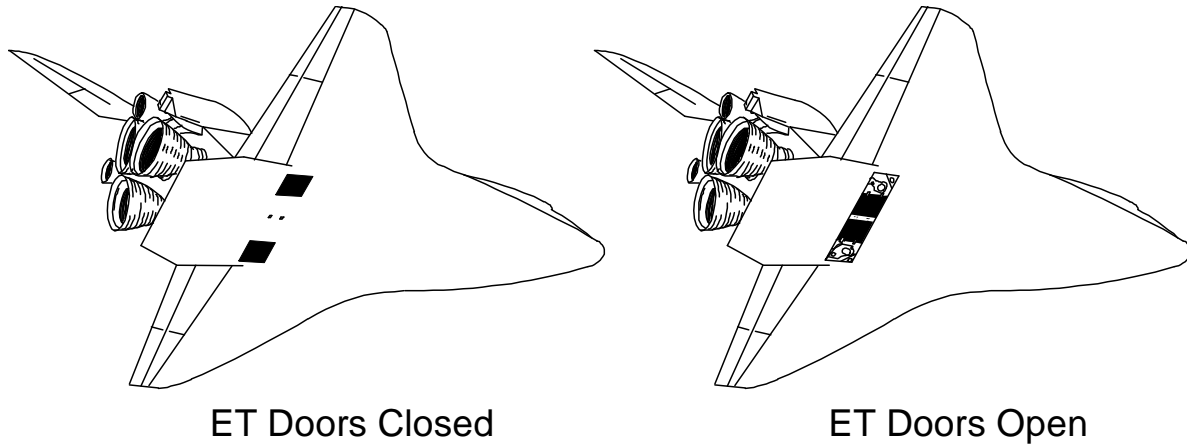
The ET contains liquid hydrogen and liquid oxygen and supplies them to the orbiter main engines during ascent. Electrical and propellant umbilicals between the tank and orbiter enter the shuttle through two aft umbilical openings located on the underside of the orbiter. These umbilical cavities contain the orbiter/ET attachment points and the propellant and electrical disconnects (Figure 3-1).



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**Figure 3-1. Orbiter umbilical cavities**

There are two ET doors associated with the umbilical openings. These doors are open to allow mating of the umbilicals between the tank and the orbiter during powered flight. The doors are then closed post-Main Engine Cutoff (MECO) to protect the umbilical cavities during entry and landing (Figure 3-2).



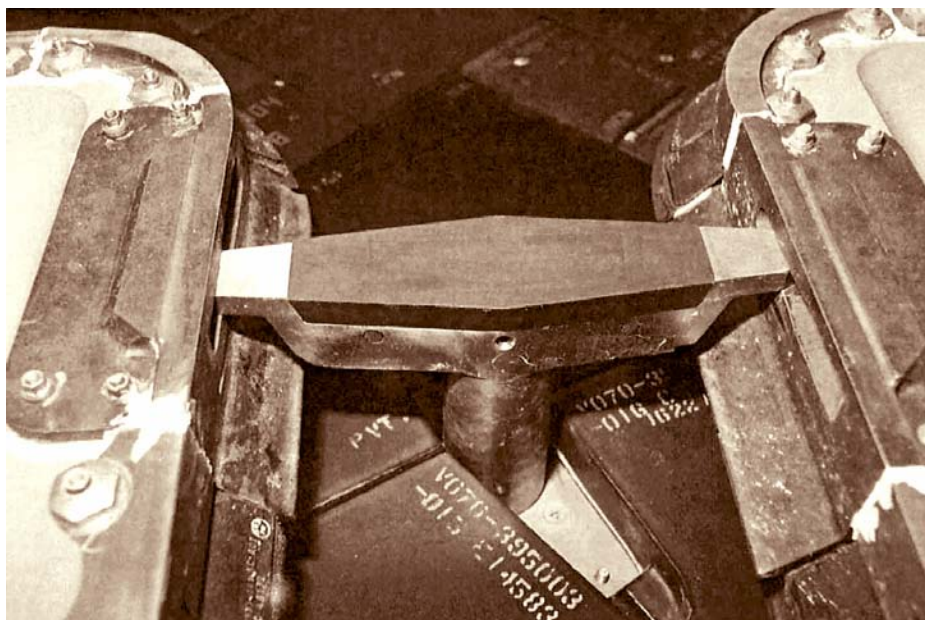
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**Figure 3-2. ET umbilical door positions**

### 3.3 ET UMBILICAL DOOR COMPONENTS

#### 3.3.1 Centerline Latches

The ET doors are held open during ascent by two centerline latches. Each centerline latch engages a fitting on the outboard edge of each door. Figure 3-3 shows this configuration for one of the centerline latches.

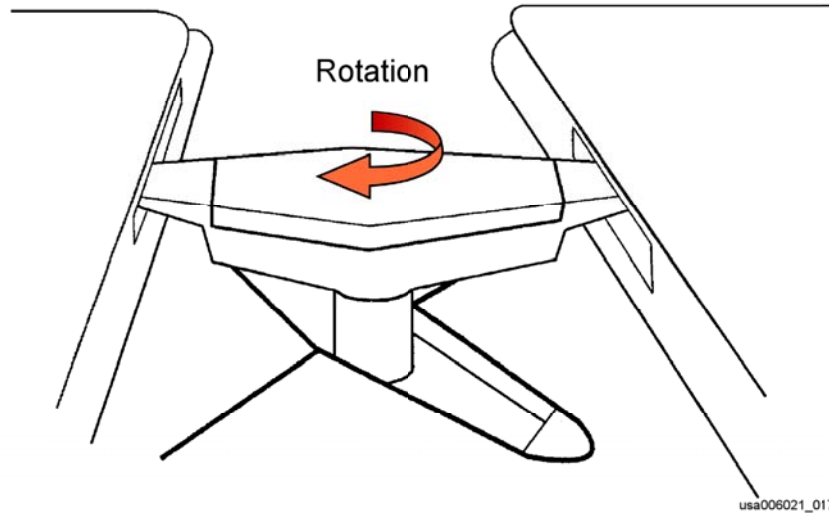


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**Figure 3-3. ET door centerline latch**

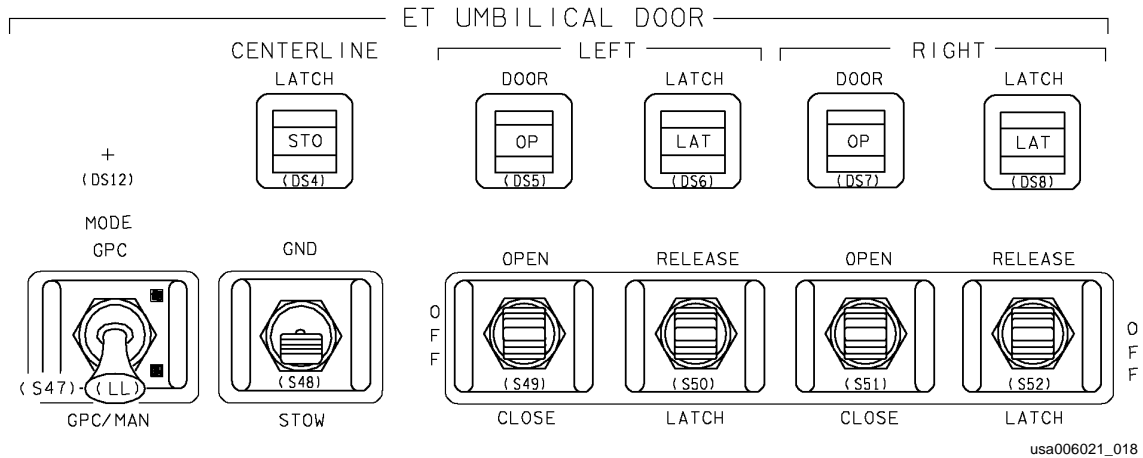
Before the ET doors are closed, the centerline latches must be stowed. Each centerline latch is driven by one PDU. It takes 6 seconds to stow the latch with dual motor drive.

When the centerline latches are stowed, they rotate and retract into the body of the orbiter (Figure 3-4). Once they have been stowed, the crew does not have the capability to redeploy the latches. This can only be done by ground crews or by real-time commands from MCC.



**Figure 3-4. ET door centerline latch movement**

The status of each centerline latch is provided by two stow and two deploy microswitches. The stow microswitches provide feedback to the crew via a talkback on Panel R2 (Figure 3-5). When the centerline latches are stowed, the talkback will indicate “STO.” The talkback will be barberpole if the latches are deployed or are in transition to the stowed position. Although the deploy microswitches do not drive the R2 talkback, the indications are available to MCC.



**Figure 3-5. Lower portion of Panel R2**

### 3.3.2 ET Umbilical Doors

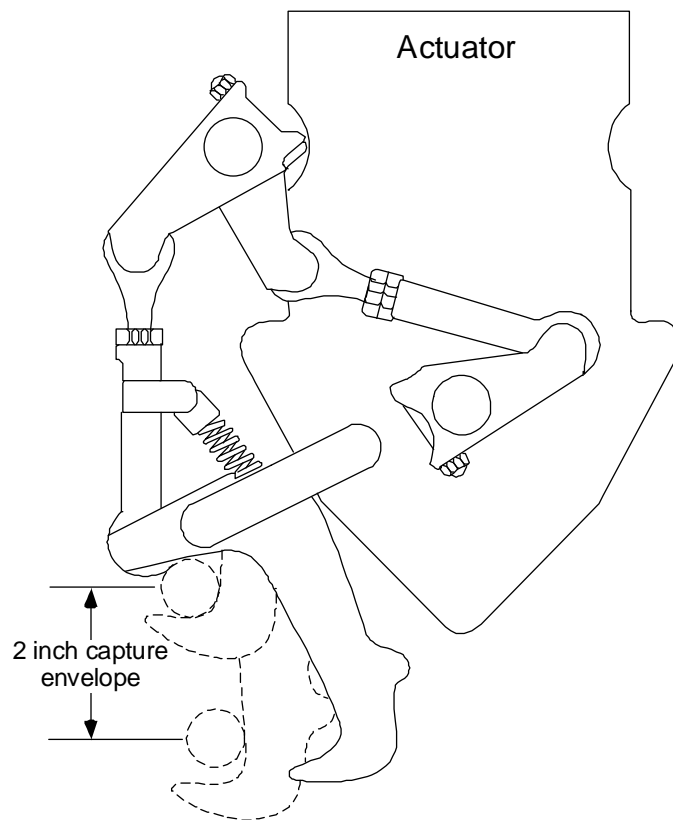
Each ET door is driven by one PDU. It takes 24 seconds to drive the door open or closed with dual motor drive. The status of each door is provided by microswitches. Each door has two open microswitches, three ready-to-latch microswitches, and two closed microswitches.

Only MCC has insight into the individual microswitch indications. The crew must rely on Panel R2 talkbacks for the position of the doors. Each door has its own position talkback. The open microswitches drive the “OP” position of the talkback, and at least two of the three ready-to-latch indications drive the “CL” position. The closed microswitches do not drive any onboard talkbacks, but the indications are available to MCC.

In addition to driving the door “CL” talkback, the ready-to-latch microswitches enable the door uplock latch motors. This is discussed further in the next section.

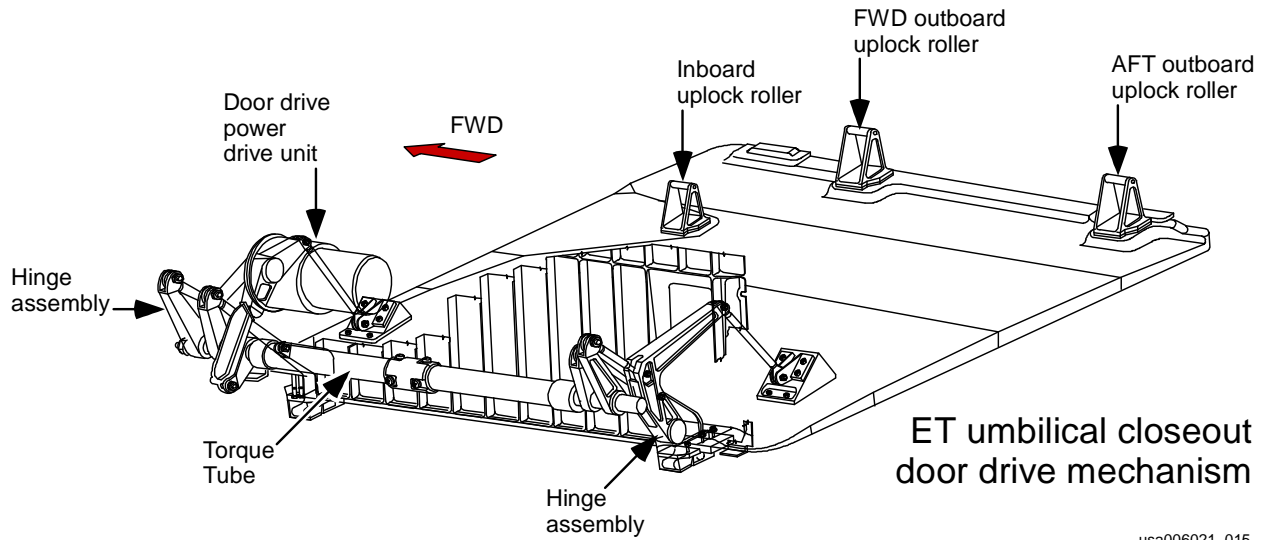
### 3.3.3 Uplock Latches

Each ET door has a set of three uplock latches. These latches, which are located inside the umbilical cavity, engage rollers located on each door to pull it against aerothermal seals and secure it closed (Figures 3-6 and 3-7). Latching the ET doors prevents them from vibrating or reopening during entry.



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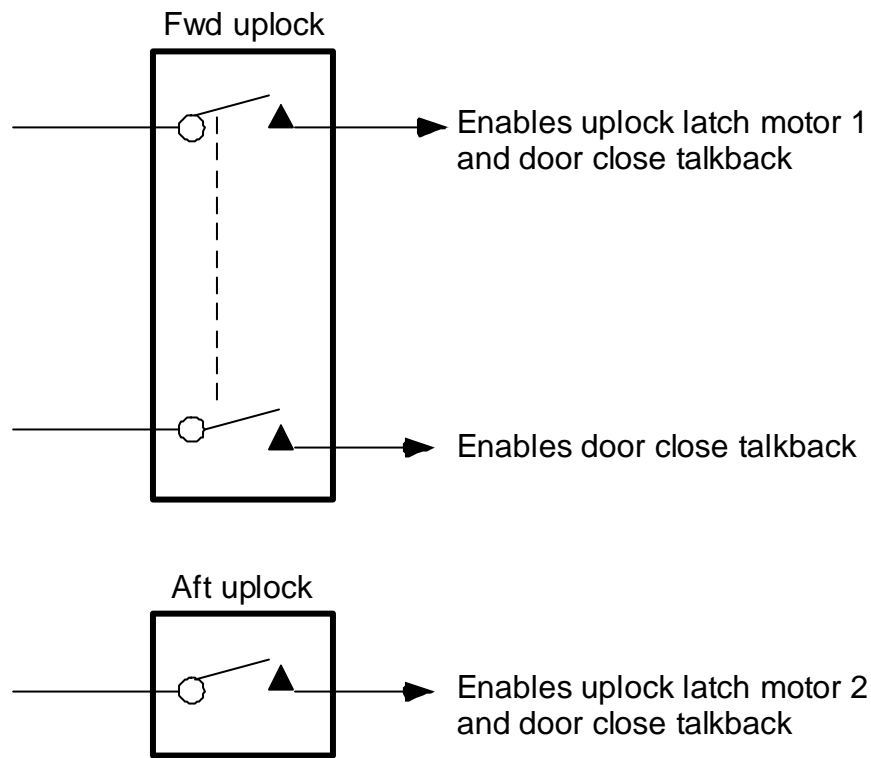
**Figure 3-6. ET door uplock latch and roller**



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**Figure 3-7. Right ET umbilical door**

When an ET door is driven closed, the rollers on the outboard edge of the door contact two ready-to-latch paddles in the umbilical cavity. These paddles activate the three ready-to-latch microswitches mentioned earlier (Figure 3-8). These microswitches indicate when the rollers on the door are within the capture range of the uplock latches. They also enable the uplock latch motors.



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**Figure 3-8. ET door ready-to-latch microswitches**



In case multiple microswitch failures prevent enabling the uplock latch motors, there is an override of the ready-to-latch indications. The left latch switch overrides the right ready-to-latch microswitches and the right latch switch overrides the left ready-to-latch microswitches.

To perform the override and close the latches, both the left and right latch switches must be in the latch position at the same time. One switch overrides the missing microswitches and enables the motors. The other switch sends the latch command. If the override is required, it should only be performed after MCC has verified that the doors are in the ready-to-latch position.

Each group of three latches is driven by one PDU. It requires 6 seconds to open or close the latches with dual motor drive. The status of each group is provided by two latched and two released microswitches. These microswitches drive the uplock latch "LAT" and "REL" talkbacks on Panel R2.

### **3.4 ET DOOR OPERATIONS**

There are different methods available to close and latch the ET doors. This section discusses each method and when that method should be used. Postlanding door opening is also discussed.

#### **3.4.1 Manual ET Door Closure**

Nominally, the ET doors are manually closed using switches on Panel R2. The doors are closed after the OMS 1 burn and Main Propulsion System (MPS) vacuum inerting are complete. Refer to the post OMS 1 section of the Ascent Checklist for the ET Umbilical Door Closure procedure.

The manual door closure method is also used during an AOA. The procedure is located in the AOA section of the Ascent Checklist.

Before the Panel R2 switches can be used for door operations, the MODE switch must be placed in the GPC/MAN position. This enables manual control by supplying control bus power to the ET door and latch switches. The switches are then used to command the doors and latches closed.

First, the centerline latches are stowed. Next, the left and right doors are closed simultaneously. When the doors are within capture range, the left and right uplock latches are closed simultaneously to secure the doors in place.

#### **3.4.2 Automatic ET Door Closure**

During RTLS and TAL aborts, ET door closure occurs automatically. During this automatic closure, the centerline latches are stowed and the doors are closed and latched through sequential software commands sent by the GPCs.

The software sequence commands each mechanism for its associated single motor drive time. It allows for single motor drive time to elapse before sending the next command, except in the case of the centerline latches.

The centerline latches are commanded for 12 seconds (single motor time), but the door close commands are sent 6 seconds after the centerline latch commands are initiated. However, if a failure causes a centerline latch to drive on a single motor, it will rotate enough during the 6-second command to disengage the doors and allow them to close.

During an RTLS, this software sequence is automatically initiated at the MM602 transition. For a TAL, the sequence is automatically initiated at the MM304 transition.

With the automatic door closure, the status of the doors and latches can be monitored with the Panel R2 talkbacks. During an RTLS or TAL, if the software sequence fails to close and latch the doors, the pilot must use the manual method.

The crew also has the capability to initiate the software sequence. They can do so with item 40 (PASS) or item 30 (BFS) on GNC SPEC 51 OVERRIDE (Figures 3-9 and 3-10). The crew can only initiate the software closure during MM104, MM105, and MM106.

XXXX/051/		OVERRIDE		XX X DDD/HH:MM:SS	
ABORT MODE		ELEVON		ENTRY FCS	
TAL	1X	AUTO	17X	FILTER	NOM 20X
ATO	2X	FIXED	18X	ATMOSPHERE	NOM 22X
ABORT	3X	ALT	21X	N POLE	23X
THROT MAX	4X	SSME REPOS	19 XXX	S POLE	24X
ABT	50X				
NOM	51X				
PRPLT DUMP		IMU STAT	ATT DES	PRL	
XXX ICNCT	5 XXXX	1S	XXXX X 25X	SYS	AUT DES
OMS DUMP		2S	XXXX XXX 26X	1S	28X 31X
ARM	8X	3S	XXXX 27X	2S	29X 32X
START	7X	3S 30X 33X			
STOP	8X	ADTA	H	α	M DES
9 QUAN/SIDE	XX	L	1S XXXXXX	±XX.X	X.XX 34X
OMS DUMP TTG	XXX	3S	XXXXXX	±XX.X	X.XX 35X
AFT RCS 13 XXX		F	2S XXXXXX	±XX.X	X.XX 36X
14 TIME	XX	4S	XXXXXX	±XX.X	X.XX 37X
FWD RCS 15 XXX		ET SEP	ROLL MODE		XXXXXXXX
16 TIME	XX	AUTO	38X	AUTO SEL	42X
		SEP	39X	WRAP MODE	45 XXX
		ET UMB DR			
		CLOSE	40X	VENT DOOR CNTL	
		RCS RM MANF			
		CLOSE	44X	OPEN	43X XX
		CL OVRD	41	CLOSE	44X XX

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Figure 3-9. PASS GNC SPEC 51 OVERRIDE

XXXX/061/	OVERRIDE	XX X	DDD/HH:MM:SS
		BFS	DDD/HH:MM:SS
ABORT MODE		ENTRY FCS	
TAL 1X	ELEVON	FILTER	ATMOSPHERE
ATO 2X	AUTO 17X	NOM 20X	NOM 22X
ABORT 3X	FIXED 18X	ALT 21X	N POLE 23X
THROT MAX 4X	SSME REPOS 19	XXX	S POLE 24X
PROPLT DUMP	IMU DES ATT	AA	RGA SURF
XXX ICNCT 5 XXXX	1 25X X	LRU DES	DES DES
OMS DUMP	2 26X	1 31X	35X 38X
ARM 6X	3 27X	2 32X	36X 40X
START 7X		3 33X	37X 41X
STOP 8X		4 34X	38X 42X
9 QUAN/SIDE XXX			
OMS DUMP TTG XXX			
AFT RCS 13	ET SEP		VENT DOOR CNTL
14 TIME XXX	AUTO 28X		OPEN 43X
	SEP 29X		CLOSE 44X
FWD RCS 15	ET UMB DR		
16 TIME XXX	CLOSE 30X		

**Figure 3-10. BFS GNC SPEC 51 OVERRIDE**

Although the crew has the capability to start the automatic closure sequence, it is not always desirable for them to do so since the automatic closure sequence does not receive any feedback from the microswitches.

For example, the centerline latches are commanded to the stow position first. Because the software does not check the position of the centerline latches before sending the next command to the doors, there is a possibility that the doors could be trying to close against a latch that failed to stow.

Because the software sequence sends commands based on time and does not look at microswitch indications, it should only be considered as a backup closure method during an AOA. The ET Umbilical Closure procedure in the AOA section of the Ascent Checklist directs the crew to perform the item entry on SPEC 51 if the ET doors will not manually close and latch.

Because the automatic closure is the backup method during an AOA, it is important that the doors are closed and latched prior to the OPS 301 transition. Again, the sequence may only be initiated during MM104, MM105, and MM106. If the sequence has been initiated, the OPS 3 transition must be made after the sequence is completed. Otherwise, the transition will terminate the sequence.

### 3.4.3 ET Door Real-Time Commands

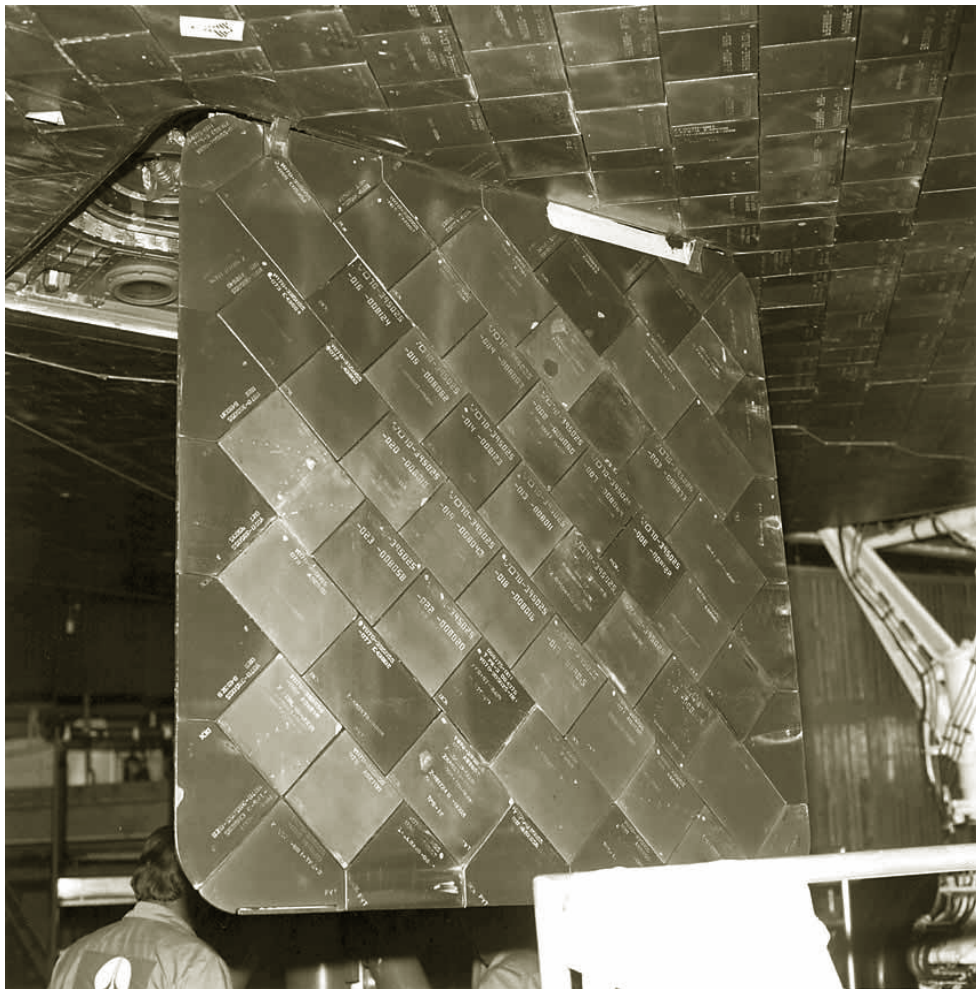
If the manual ET door closure method does not work, the doors may be closed and latched with real-time commands from MCC during OPS 2. MCC can send individual door and latch commands. This allows them to monitor the position of each mechanism before sending the next command. Real-time commands are preferred over the automatic closure since the automatic software does not receive position feedback.

### 3.4.4 Postlanding ET Door Opening

Soon after landing, the ET doors are opened to allow the ground crews to access the umbilical cavities and the aft support points. For RTLS and TAL aborts, the ET doors are opened as soon as possible to help vent any hydrogen that may have built up.

The crew uses the Panel R2 switches to unlatch and open the doors. The ET Door Opening procedure is located in the postlanding section of the Entry Checklist. Unlike the closing procedure, the uplock latches and doors are each driven separately.

On the ground, the PDUs are not strong enough to drive the doors fully open. Therefore, each door is driven open until it is perpendicular to the ground (Figure 3-11). Because the R2 talkbacks do not give any insight into intermediate door position, the pilot must use drive time to determine when to stop each door.



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**Figure 3-11. ET Door Postlanding Position**

## QUESTIONS

Answers provided in Appendix B

1. What holds the ET doors open during ascent?
  - (a) One centerline latch
  - (b) Two centerline latches
  - (c) Three uplock latches
  - (d) Six uplock latches
2. What secures each ET door closed during entry?
  - (a) One centerline latch
  - (b) Two centerline latches
  - (c) Three uplock latches
  - (d) Six uplock latches
3. True or False: During Post OMS 1, if the pilot is unable to close the ET doors with the Panel R2 switches, he or she should initiate the automatic closure on GNC SPEC 51 OVERRIDE.
4. True or False: During postlanding ET door opening, the pilot must rely on Panel R2 talkbacks for the position of the ET doors.

## **4.0 PAYLOAD BAY DOORS**

### **4.1 OBJECTIVES**

Upon completion of this section, the student should be able to

- Identify the components of the Payload Bay Door System.
- Describe the information provided on the PL BAY DOORS display.
- Explain auto mode and manual mode payload bay door operations.
- Recognize the microswitch configurations that will cause a dilemma for a payload bay door latch gang.
- Recognize the microswitch failures that will cause “PBD CONFIG” and “PBD SEQ FAIL” fault messages during auto payload bay door operations.

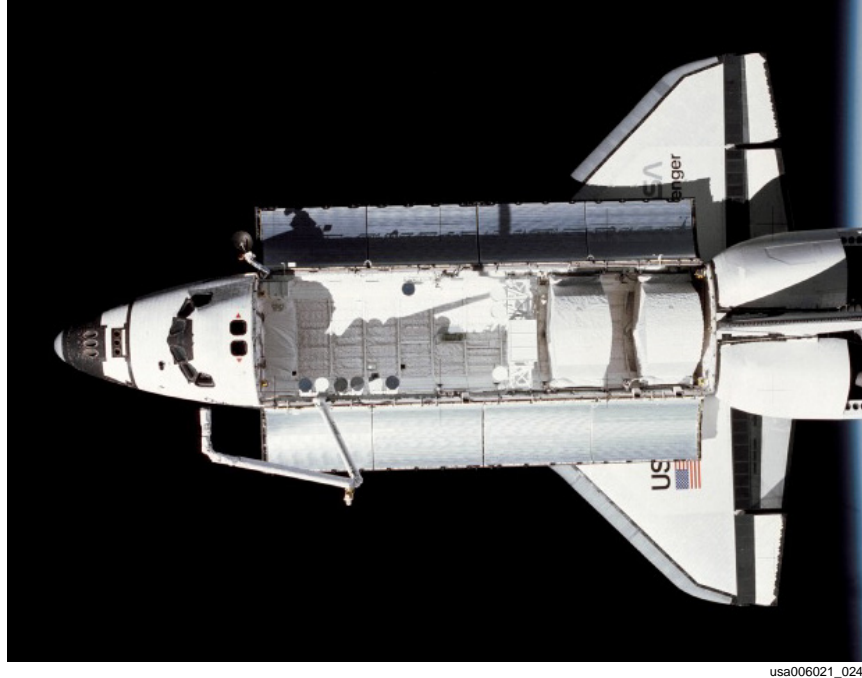
### **4.2 SYSTEM OVERVIEW**

Two doors cover the orbiter’s payload bay. These payload bay doors have several functions. They provide vehicle structural support during ascent and entry. They provide an aerodynamic fairing over the payload bay and protect payloads from contamination. They also provide an opening for payload deployment and retrieval and structural support for the Environmental Control and Life Support System (ECLSS) radiators.

### **4.3 PAYLOAD BAY DOOR COMPONENTS**

#### **4.3.1 Payload Bay Doors**

Figure 4-1 shows a picture of the shuttle during orbit with the payload bay doors open. The payload bay doors consist of a port (left) and a starboard (right) door. Each door is approximately 60 feet long, and together they have a combined area of about 1600 square feet.

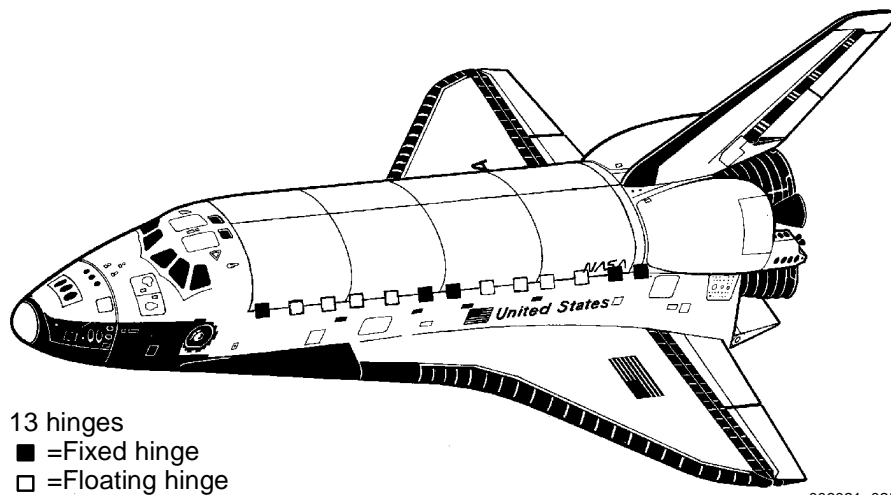


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**Figure 4-1. Shuttle on orbit with payload bay doors open**

Each door is connected to the midfuselage by 13 hinges (Figure 4-2). Five of the hinges are fixed, which means that they hold the attach point on the payload bay door to a constant location relative to the midbody and only allow rotation about the axis of the hinge pin. The eight remaining hinges are floating hinges. Floating hinges allow translation along and rotation about the axis of the hinge pin. Since these hinges allow translational movement, orbiter shape changes due to thermal expansion and contraction do not apply loads to the doors.

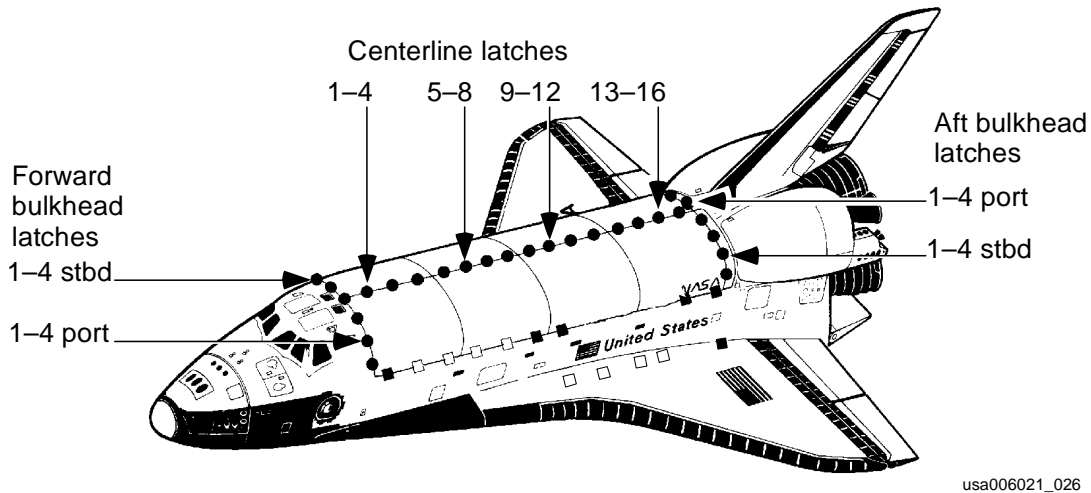
When closed, various latches secure the doors (Figure 4-3). There are 16 centerline latches, 8 forward bulkhead latches, and 8 aft bulkhead latches.



- 13 hinges  
■ =Fixed hinge  
□ =Floating hinge

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**Figure 4-2. Payload bay door hinge locations**



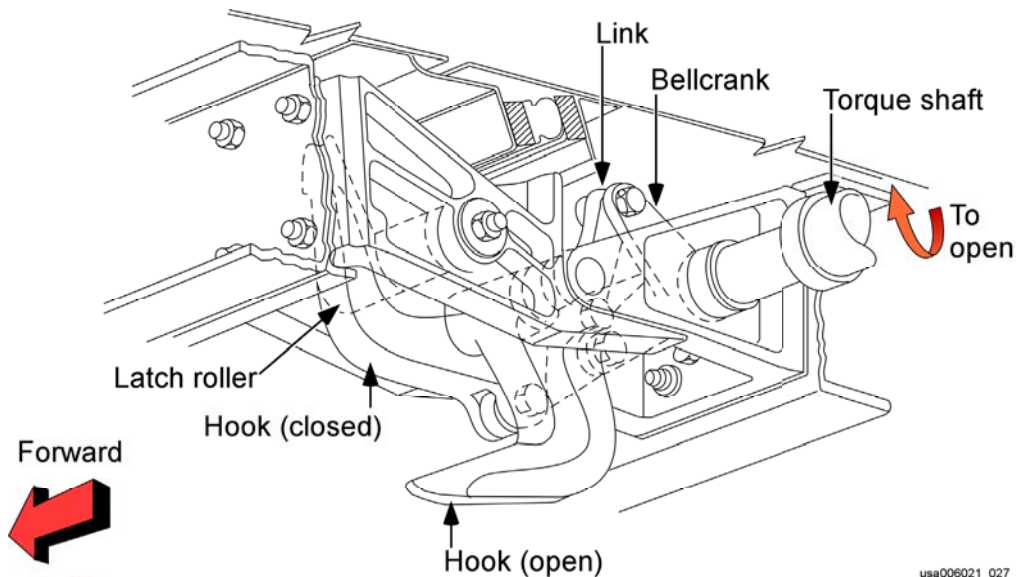
**Figure 4-3. Payload bay door latch locations**

### 4.3.2 Centerline Latches

The payload bay door centerline latches secure the doors together along the centerline. The latches are numbered 1 to 16 from forward to aft. The latches are divided into four groups, or gangs, of four latches each.

The hooks, which are the active portion of the centerline latch system, are located on the starboard door. The hooks rotate and grasp the latch rollers, which are located on the port door (Figure 4-4).

Each latch gang has a dedicated PDU that drives it to the desired position. It takes 20 seconds to drive a centerline latch gang open or closed with dual motor drive. The status of the centerline latch gangs is provided by microswitches. There are two open and two closed microswitches to indicate the position of each centerline latch gang.

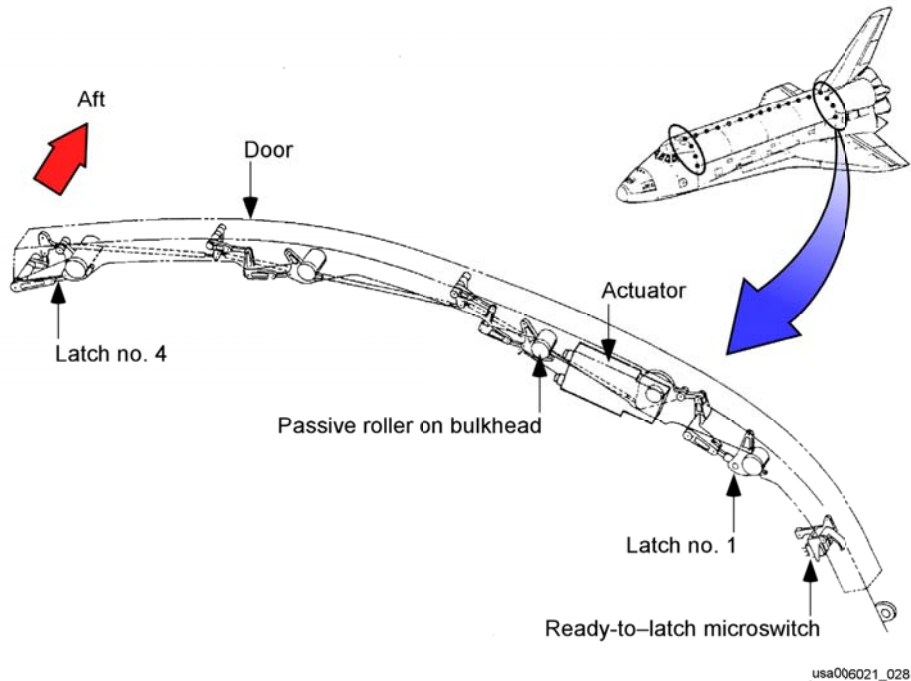


**Figure 4-4. Payload bay door centerline latch**



### 4.3.3 Bulkhead Latches

The payload bay door bulkhead latches secure the doors at the forward and aft bulkheads. Like the centerline latches, they are grouped in gangs of four latches. The latches in each gang are numbered 1 to 4 starting with the latch closest to the door hinge line (Figure 4-5).



**Figure 4-5. Payload bay door bulkhead latches**

The hooks for the bulkhead latches are located on the forward and aft edges of each door. The hooks rotate and grasp the latch rollers located on the forward and aft bulkheads.

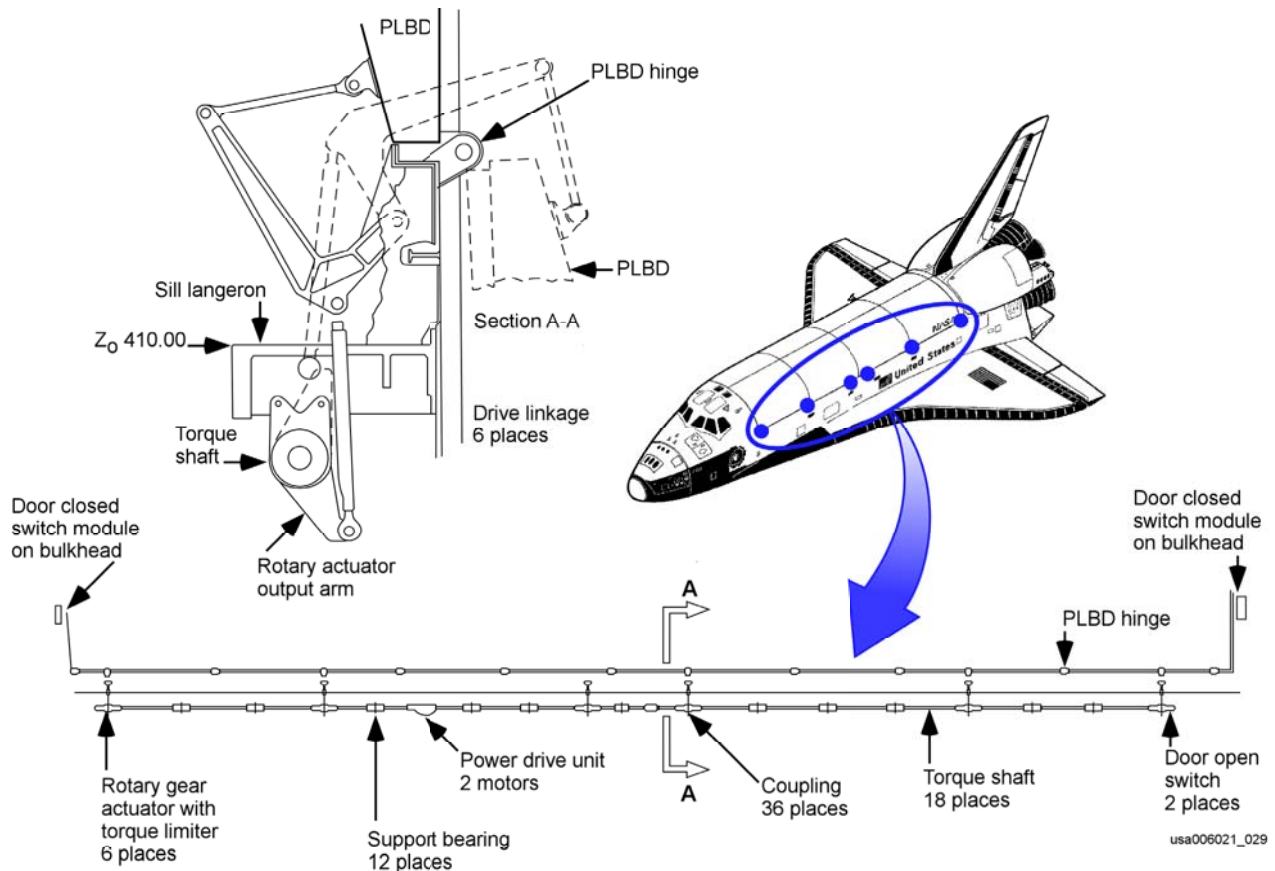
Each bulkhead latch gang is driven by one PDU. It takes 30 seconds to drive a bulkhead latch gang open or closed with dual motor drive. The microswitches for the bulkhead latches are similar to those for the centerline latches. There are two open microswitches and two closed microswitches associated with each latch gang.

Each bulkhead latch gang opens and closes in a staggered sequence. The latches are latched in ascending order and unlatched in descending order. In other words, during latching, latch 1 will rotate and begin to grasp its roller before latch 2 does. By closing latch 1 first, the door angle decreases and makes the other three latches easier to close.

#### 4.3.4 Payload Bay Door Drive System

Each payload bay door is driven open or closed by one PDU. It takes 63 seconds to drive a door open or closed with dual motor drive.

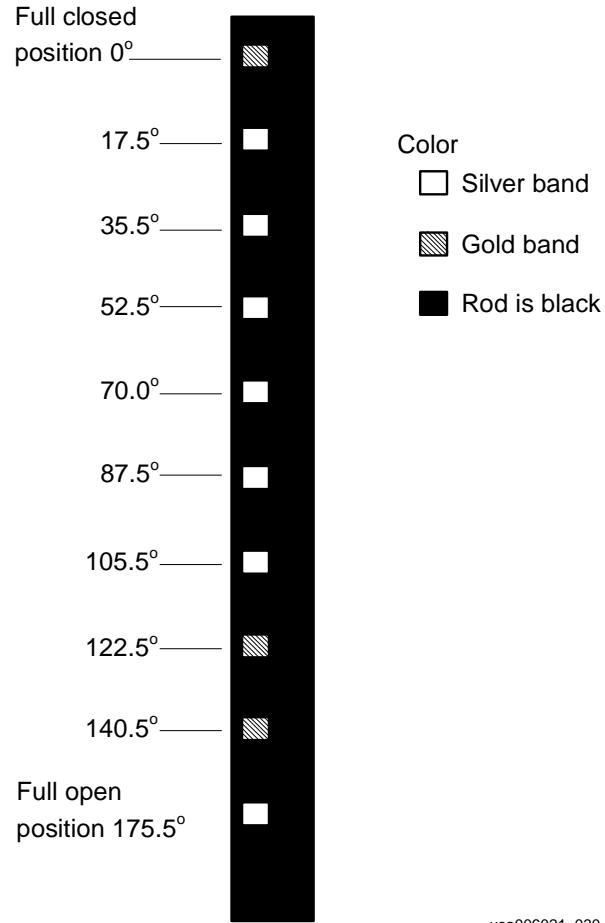
Each payload bay door PDU drives a 55-foot long torque shaft that runs beneath the sill longeron of the payload bay. The torque shaft runs through six rotary actuators. As the torque shaft turns the actuators, the movement is transferred through mechanical linkages to six push-pull rods that are connected to the door. As the torque shaft turns, the push-pull rods will push the door open or pull it closed (Figure 4-6).



**Figure 4-6. Payload bay door drive system**

Each push-pull rod is marked with gold and silver colored bands to indicate the rotational position of the door (Figure 4-7 and Figure 4-8). There are seven silver bands and three gold bands. Each band represents an angular orientation of the door in degrees. The full open position of each door is 175.5°.

When a door is closed, the push-pull rods retract beneath the liner and only one gold band at the top of each push-pull rod should be partially visible. There should be no silver bands showing when the latching sequence is started.



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**Figure 4-7. Push-pull rod bands**

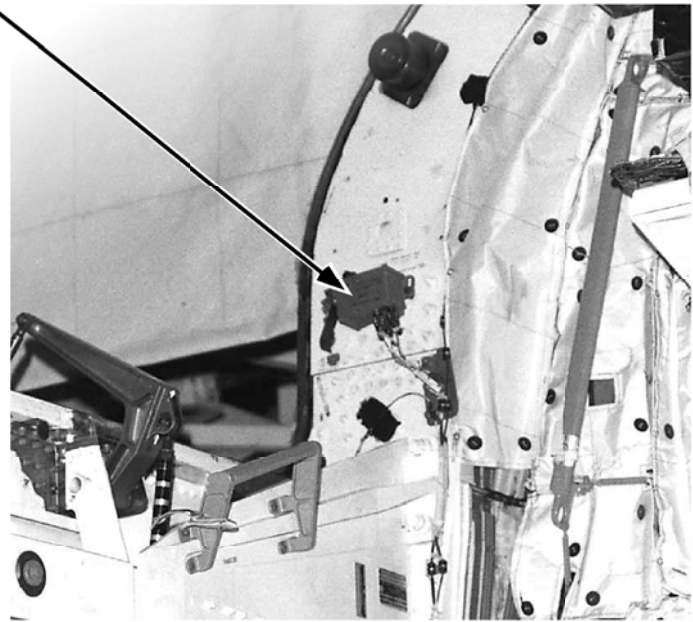
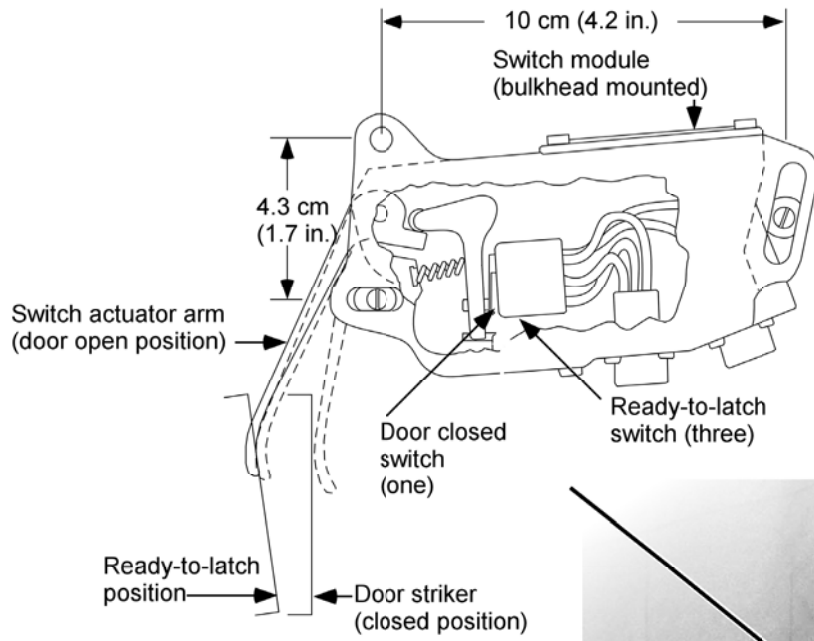


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**Figure 4-8. Payload bay door push-pull rod**

The status of each payload bay door is provided by microswitches. Each door has two open microswitches, three ready-to-latch microswitches, and two closed microswitches. The two door open microswitches are located on the forward and aft rotary actuators connected to the torque shaft. The ready-to-latch microswitches and the closed microswitches are located inside switch modules (Figure 4-9) mounted on the forward and aft bulkheads.

Each door has a forward switch module and an aft switch module. Each switch module contains three ready-to-latch microswitches and one closed microswitch. When the door is within 4 degrees of being closed, a force is applied against the switch module's actuator arm and the ready-to-latch microswitches are activated. As the door continues to close and pushes the actuator arm completely in, the closed microswitch is activated.

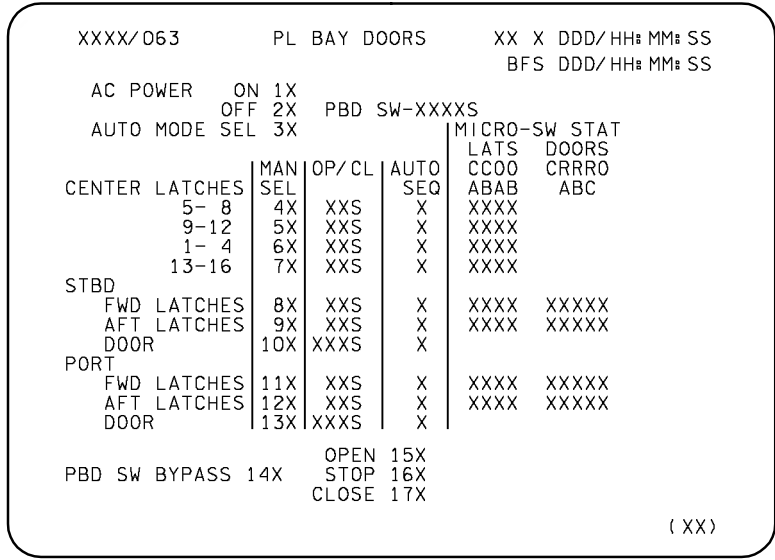


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**Figure 4-9. Payload bay door switch module**

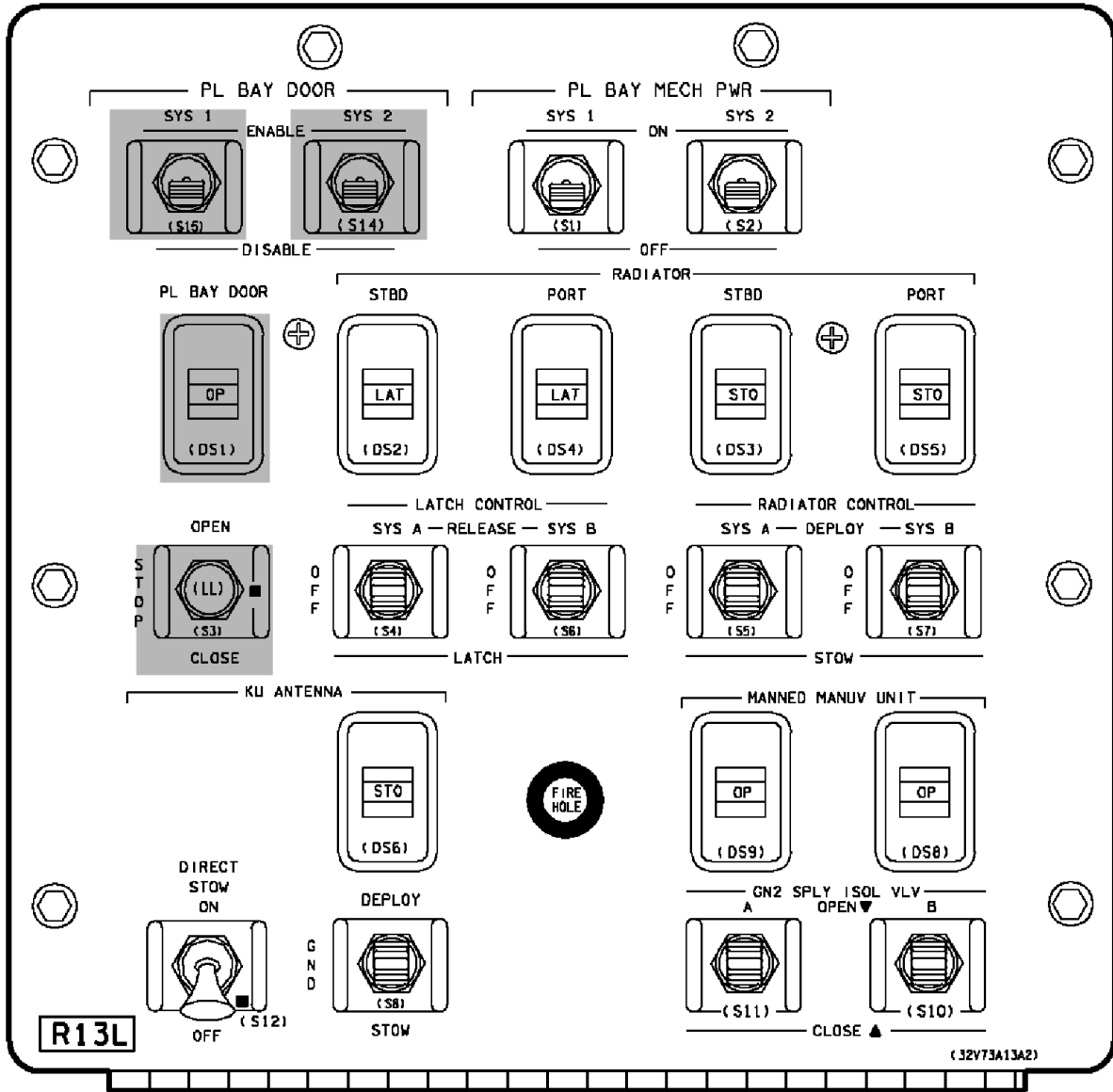
#### 4.4 PAYLOAD BAY DOOR OPERATIONS

Payload bay door operations are monitored and controlled with the PL BAY DOORS display (Figure 4-10) and switches on Panel R13L (Figure 4-11). This section discusses the display, the opening and closing sequences, and the two modes of operation: auto mode and manual mode. Some of the failures that may occur during payload bay door operations are also discussed.



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**Figure 4-10. PL BAY DOORS display**



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Figure 4-11. Panel R13L

#### 4.4.1 PL BAY DOORS Display

The PL BAY DOORS display provides information necessary to monitor and control payload bay door operations. The crew nominally uses the PASS SM OPS 202 display to perform payload bay door operations. The same display is available as SM SPEC 63 for BFS operations.

The PL BAY DOORS display contains the following information:

- a. AC POWER - Items 1 and 2 provide the capability to apply and remove AC power to all payload bay door and latch motor control assemblies. An asterisk is displayed next to the option currently selected. The display is initialized with OFF selected.
- b. PBD SW - This field reflects the status of the PL BAY DOOR control switch on Panel R13. The text output includes "OP," "STOP," "CL," and "FAIL" (for switch failures). An "M" is displayed if data is missing.
- c. AUTO MODE SEL - Item 3 selects or deselects the auto mode of operation. An asterisk is displayed after the item number when auto mode is selected.
- d. MAN SEL - Items 4 to 13 provide the capability to select or deselect individual latch gangs or doors. These item entries are used during the manual mode of operation. An asterisk is displayed next to the item number when it is selected.
- e. OP/CL - This column indicates a status for each latch gang or door. This status is determined by the microswitch indications. The following indications may be seen in this column:
  1. "OP" - Indicates that both open microswitches for that door or latch are activated.
  2. "CL" - Indicates that both closed microswitches for that door or latch are activated.
  3. "RDY" - Indicates that at least two of the three ready-to-latch microswitches from the forward and aft bulkhead switch modules are activated. This text is only shown for the doors.
  4. "?" - Indicates a dilemma. The definition of a dilemma is discussed later in the chapter.
  5. "M" - Indicates data is missing due to a GPC or data bus failure (Multiplexer/Demultiplexer (MDM) PL1 or PL2).
  6. <blank> - When a mechanism is in transit, the column will be blank. A blank status may also be caused by microswitch failures.



Payload bay door microswitch logic tables are provided in Appendix C. These tables can be used to determine what status will be displayed in the OP/CL column for a specific microswitch configuration.

- f. AUTO SEQ - During auto mode operations, a down arrow (↓) will be displayed in this column next to a latch gang or door that fails to open or close within its single motor drive time.
- g. MICRO-SW STAT - The status of the individual microswitches associated with each latch group and door is output as a numeric value, "0," if the microswitch is not activated (indication is not present), and "1" if the microswitch is activated (indication is present).

Under the latches column (LATS), the statuses of the four microswitches associated with each latch gang are displayed. There are two closed microswitches (CA, CB) and two open microswitches (OA, OB).

Under the doors column (DOORS), the statuses of the door microswitches are displayed. For each door, there are two groups (FWD and AFT) of five microswitches each. For each group, there is one closed microswitch (C), three ready-to-latch microswitches (RA, RB, RC), and one open microswitch (O).

- h. PBD SW BYPASS - Item 14 allows the crew to bypass the PL BAY DOOR control switch on Panel R13. When the bypass is selected, items 15, 16, and 17 (open, stop, and close) may be used instead of the Panel R13 switch to control the payload bay door sequence.

#### **4.4.2 Payload Bay Door Opening**

The payload bay doors are opened at approximately 01:25 Mission Elapsed Time (MET). The opening procedures are located in the Post Insertion checklist. Before the doors are opened, the crew should verify that none of the failures listed in the RAD/PLBD OPS NO-GO block are present. This block, which is found at approximately 01:20 MET in the detailed timeline of the Post Insertion checklist, lists failures that will require entry at the first day Primary Landing Site (PLS). If any of these failures are present, the payload bay doors will not be opened.

The payload bay doors are unlatched and opened in a specific sequence to accommodate any thermal expansion/contraction, bending, or twisting of the doors. The opening sequence begins with the mechanisms listed at the top of the PL BAY DOORS display and proceeds down.

Nominally, all latches are opened two gangs at a time, beginning with centerline latches 5 to 8 and 9 to 12. Opening the middle sets of latches relieves any tension on the doors. Next, centerline latches 1 to 4 and 13 to 16 are opened. This relieves any tension on the bulkhead latches.

After the centerline latches have been opened, the starboard forward and aft bulkhead latches are opened together. The starboard door may now be driven open. Next, the port forward and aft bulkhead latches are opened. Finally, the port door is opened.

#### **4.4.3 Payload Bay Door Closing**

The payload bay doors are closed approximately 2 hours and 40 minutes prior to the deorbit burn. The closing procedures are located in the Deorbit Prep Checklist. Just as the payload bay doors have a specific opening sequence, there is also a specific closing sequence.

The closing sequence is the reverse of the opening sequence. It begins with the mechanism listed at the bottom of the PL BAY DOORS display, the port door, and proceeds up.

After the port door closes, the port forward and aft bulkhead latches are closed. Just as in the opening sequence, latches are commanded in gangs of two.

Next, the starboard door is commanded closed. When closing the starboard door, the procedure directs the crewmember to stop the door just before it reaches the port door. This allows the crewmember to check the centerline latch trajectory and verify that an overlap condition does not exist. Refer to the “C/L Latch Extended Guide Roller Trajectory” diagram in the payload bay door closing procedure for the NO-GO criteria. If no overlap condition exists, the starboard door is driven closed, and the starboard forward and aft bulkhead latches are closed.

The centerline latching sequence begins with latches 1 to 4 and 13 to 16. In the event that the payload bay doors are slightly warped, these latch gangs can be latched easier than the middle gangs (5 to 8 and 9 to 12) because the bulkhead latches have already been latched. Finally, latches 5 to 8 and 9 to 12 are closed.

#### **4.4.4 Auto Mode Operation**

Refer to the Post Insertion checklist for the Auto Payload Bay Door Opening procedure or the Deorbit Prep Checklist for the Auto Payload Bay Door Closing procedure. In auto mode, the latches and doors are automatically opened or closed in a predetermined sequence. These opening and closing sequences were discussed earlier in the chapter.

After selecting auto mode on the PL BAY DOORS display, the automatic sequence is initiated by taking the Panel R13 PL BAY DOOR control switch (or the software bypass) to open or close. The sequence can be stopped at any point by placing the control switch (or the software bypass) in the STOP position.

During the auto sequence, the software monitors the microswitches and OP/CL statuses for failures. If a failure is detected, a “PBD CONFIG” or “PBD SEQ FAIL” fault message annunciates. The failures that cause these fault messages are discussed later in the chapter.

Although the auto software monitors for failures, the crew should still use the PL BAY DOORS display, drive times, and visual cues to determine if the mechanisms are opening or closing properly.

#### **4.4.5 Manual Mode Operation**

Refer to the Post Insertion checklist for the Manual Payload Bay Door Opening procedure or the Deorbit Prep Checklist for the Manual Payload Bay Door Closing procedure. In manual mode, the crew may select individual latch gangs or doors on the PL BAY DOORS display. The selected sequence is initiated by taking the Panel R13 PL BAY DOOR control switch (or the software bypass) to open or close.

During manual mode operations, the software does not monitor the OP/CL statuses or the microswitch indications for failures. The crew should use the PL BAY DOORS display, drive times, and visual cues to determine if the mechanisms are opening or closing properly.

#### **4.4.6 Dilemma**

When a dilemma occurs, a “?” is displayed in the OP/CL status column next to the affected mechanism. This indicates that an off-nominal microswitch configuration has confused the software, and therefore, it is unable to determine a status for the mechanism. Refer to the payload bay door microswitch logic tables in Appendix C for the microswitch configurations that will cause dilemmas.

Note that a dilemma may occur during manual mode or auto mode operations. If a dilemma occurs during auto mode operations, a “PBD CONFIG” or a “PBD SEQ FAIL” fault message may also accompany it. However, the dilemma does not have its own associated message.

#### **4.4.7 Definition of Active Group**

In order to aid in understanding the discussion of failures that may occur during payload bay door operations, the term “active group” is defined in this section. Active group refers to a mechanism that is currently being commanded open or closed. Below are some examples of when mechanisms are considered the active group.

- Nominally, two gangs of centerline latches are opened or closed at a time. When they are commanded open or closed, both latch gangs are considered the active group.
- Bulkhead latches are also opened two gangs at a time. When the starboard bulkhead latches are opening, they are considered the active group. When the port bulkhead latches are opening, they are considered the active group.
- When a door is commanded open, it is considered the active group.
- When a door is commanded closed, it is considered the active group. However, when the auto software begins to drive the bulkhead latches closed, the door close command is still enabled. Therefore, the software considers the bulkhead latches and the associated door to be the active group at this time.

#### **4.4.8 PBD CONFIG During Auto Mode Operations**

During auto mode operations, the software monitors the OP/CL status column for all the mechanisms except the active group. The software is looking for an “OP” or “CL” status for all the inactive groups. However, it does not distinguish an “OP” status from a “CL” status. It only checks to see if either one or the other is present.

If the auto software detects something out of configuration in this column (a blank status, a “?”, or a “RDY” for the doors), it terminates the auto sequence. It also generates a Systems Management (SM) alert and a “PBD CONFIG” fault message. Additionally, the AC power is automatically turned off.

In PASS, if a mechanism is out of configuration, payload bay door operations must be performed in manual mode until that mechanism is reached. Once the affected mechanism is next to drive, auto mode may be resumed. This is due to the affected mechanism now becoming the active group. Once it is considered the active group, the software will no longer check its OP/CL status.

In BFS, if a mechanism is out of configuration and manual payload bay door operations are required, the crew should remain in manual mode for the rest of the mission (during BFS operations). In the BFS, if auto mode is preceded by manual mode operations, the software will initiate the auto sequence with the last manually driven mechanism selected as the active group. If any mechanisms were manually driven out of sequence, it may also cause the auto mode to drive mechanisms out of sequence. In order to protect against this, the crew should only return to auto mode if MCC or a procedure specifically directs them to do so.

#### **4.4.9 PBD SEQ FAIL During Auto Mode Operations**

During auto mode operations, the software monitors the active group for an end of travel indication. During opening, the active group is at the end of travel when all the open microswitch indications for that group are present. During closing, end of travel for the latch groups is reached when all the close microswitch indications are present. For the door groups, closed end of travel is reached when two or more ready-to-latch indications are present in both the forward and aft bulkhead switch modules.

The auto software checks that the microswitch indications determining end of travel (in other words - the microswitches in the currently commanded direction of travel) are present within single motor time. For example, when centerline latches 5 to 8 and 9 to 12 are commanded open, the auto software checks that all of the open microswitches are activated (or present) within 40 seconds. The software does not monitor the closed microswitches for a sequence failure.

If the auto software does not see the end of travel indications within single motor time, it terminates the auto sequence. It also generates an SM alert and a “PBD SEQ FAIL” fault message. A down arrow is also displayed in the AUTO SEQ column next to the mechanism with the failure. Auto mode capability is lost in this case, and the sequence must be completed in manual mode.

After the bulkhead latch gangs reach end of travel, the auto software checks to see that both closed microswitch indications (FWD C and AFT C) for the associated door are present. If they are not, the software will terminate the sequence and generate a "PBD SEQ FAIL" fault message for the door.

## QUESTIONS

Answers provided in Appendix B

1. How many centerline latches secure the payload bay doors closed?
  - (a) 8
  - (b) 10
  - (c) 16
  - (d) 20
2. How many microswitches does each payload bay door switch module contain?
  - (a) 2 open and 2 closed
  - (b) 1 open, 3 ready to latch, and 1 closed
  - (c) 3 ready to latch and 1 closed
  - (d) 6 ready to latch and 4 closed
3. True or False: On the PL BAY DOORS display, the field next to "PBD SW" reflects the selected position of the software bypass for the PL BAY DOOR control switch.
4. True or False: During auto mode operations, the AUTO SEQ column on the PL BAY DOORS display shows which mechanism is currently being driven.

5. An auto mode payload bay door opening is in progress. It is a nominal opening up to, and including, the starboard door. While the port bulkhead latches are opening, the PL BAY DOORS display looks like Figure 4-12. Assuming all of the port bulkhead latch open microswitch indications will be received, what will eventually occur?

- (a) Dilemma
- (b) "PBD CONFIG" message will annunciate
- (c) "PBD SEQ FAIL" message will annunciate
- (d) Both A and B
- (e) Both A and C

2021/XXX/XXX		PL BAY DOORS			XX X	DDD/HH:MM:SS	DDD/HH:MM:SS
AC POWER	ON	1*					
	OFF	2		PBD SW - OP			
AUTO MODE	SEL	3*					
					MICRO-SW	STAT	
					LATS	DOORS	
CENTER LATCHES	MAN	OP/CL	AUTO	CCOO	CRRRO		
	SEL		SEQ	ABAB	ABC		
5 - 8	4	OP		0 0 1 1			
9 - 12	5	OP		0 0 1 1			
1 - 4	6	OP		0 0 1 1			
13 - 16	7	OP		0 0 1 1			
STBD							
FWD LATCHES	8	OP		0 0 1 1	0 0 0 0 1		
AFT LATCHES	9	OP		0 0 1 1	0 0 0 0 1		
DOOR	10	OP					
PORT							
FWD LATCHES	11			0 0 0 0	1 1 1 1 0		
AFT LATCHES	12			0 1 0 0	1 1 1 1 0		
DOOR	13	CL					
PBD SW BYPASS	14						
			OPEN	15			
			STOP	16			
			CLOSE	17			

Figure 4-12. PL BAY DOORS display for question 5

6. With the configuration shown on the following PL BAY DOORS display (Figure 4-13), what will occur if an auto payload bay door opening is attempted?
- (a) Dilemma
  - (b) "PBD CONFIG" message will annunciate
  - (c) "PBD SEQ FAIL" message will annunciate
  - (d) Both (a) and (b)
  - (e) Nominal payload bay door opening sequence will start

2021/XXX/XXX		PL BAY DOORS		XX X	DDD/HH:MM:SS	DDD/HH:MM:SS
AC POWER	ON	1*				
	OFF	2				
AUTO MODE	SEL	3*				
			PBD SW - STOP			
				MICRO-SW	STAT	
				LATS	DOORS	
CENTER LATCHES	MAN	OP/CL	AUTO	CCOO	CRRRO	
	SEL		SEQ	ABAB	ABC	
5 - 8	4	CL		1 1 0 0		
9 - 12	5			1 0 0 0		
1 - 4	6	CL		1 1 0 0		
13 - 16	7	CL		1 1 0 0		
STBD						
FWD LATCHES	8	CL		1 1 0 0	1 1 1 1 0	
AFT LATCHES	9	CL		1 1 0 0	1 1 1 1 0	
DOOR	10	CL				
PORT						
FWD LATCHES	11	CL		1 1 0 0	1 1 1 1 0	
AFT LATCHES	12	CL		1 1 0 0	1 1 1 1 0	
DOOR	13	CL				
			OPEN	15		
PBD SW BYPASS	14		STOP	16		
			CLOSE	17		

**Figure 4-13. PL BAY DOORS display for question 6**



7. An auto payload bay door opening is in progress. Centerline latches 5 to 8 and 9 to 12 opened nominally. Twenty seconds after centerline latches 1 to 4 and 13 to 16 are commanded, the PL BAY DOORS display looks like Figure 4-14. What will eventually occur?
- (a) Dilemma
  - (b) "PBD CONFIG" message will annunciate
  - (c) "PBD SEQ FAIL" message will annunciate
  - (d) Both (a) and (b)
  - (e) Both (a) and (c)

2021/XXX/XXX		PL BAY DOORS		XX X	DDD/HH:MM:SS	DDD/HH:MM:SS
AC POWER	ON 1*					
	OFF 2		PBD SW - OP			
AUTO MODE SEL	3*			MICRO-SW STAT		
				LATS DOORS		
CENTER LATCHES	MAN SEL	OP/CL	AUTO SEQ	CCOO ABAB	CRRRO ABC	
5 - 8	4	OP		0011		
9 - 12	5	OP		0011		
1 - 4	6	OP		0011		
13 - 16	7			0001		
STBD						
FWD LATCHES	8	CL		1100	11110	
AFT LATCHES	9	CL		1100	11110	
DOOR	10	CL				
PORT						
FWD LATCHES	11	CL		1100	11110	
AFT LATCHES	12	CL		1100	11110	
DOOR	13	CL				
PBD SW BYPASS	14					
			OPEN 15			
			STOP 16			
			CLOSE 17			

Figure 4-14. PL BAY DOORS display for question 7

## 5.0 DEPLOYABLE RADIATOR SYSTEM

### 5.1 OBJECTIVES

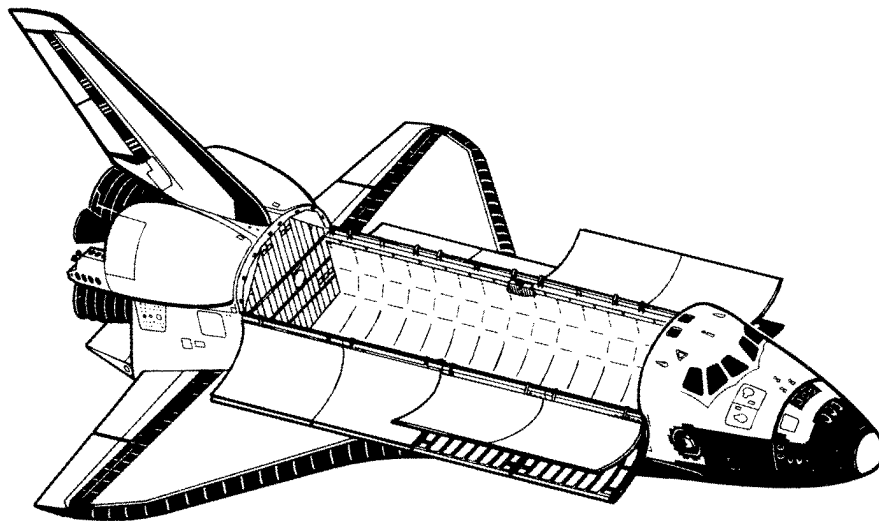
Upon completion of this section, the student should be able to

- State the purpose of radiator deployment
- Identify the components of the deployable radiator system
- Describe radiator deploy and stow operations

### 5.2 SYSTEM OVERVIEW

The radiator system, which includes four radiator panels attached to each payload bay door, is part of the orbiter's ECLSS. Freon coolant loop 1 flows through the port radiator panels, and Freon coolant loop 2 flows through the starboard radiator panels. During on-orbit operations, the Freon loops transfer their heat to these panels, which then radiate the heat to space.

There are four radiator panels attached to each payload bay door. The two forward panels on each door are deployable. This means that the panels may be rotated away from the payload bay doors (Figure 5-1).



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**Figure 5-1. Deployable radiators**

The deployable panels on each payload bay door are connected. Therefore, when a radiator is deployed, both panels will move together. The panels deploy 35.5° away from the payload bay doors.

Radiator deployment allows radiation from the lower surfaces of the panels, which can increase the system's heat rejection capability. However, the heat rejection from the lower surface is less effective than from the upper surface due to blockage from the payload bay door. It also depends upon the orbiter's attitude in relation to the Sun. Under the best conditions, radiator deployment may increase heat rejection capability by approximately 20 percent.

The radiators are not deployed during every mission. The decision to deploy the radiators is based on mission heat loads and thermal requirements.

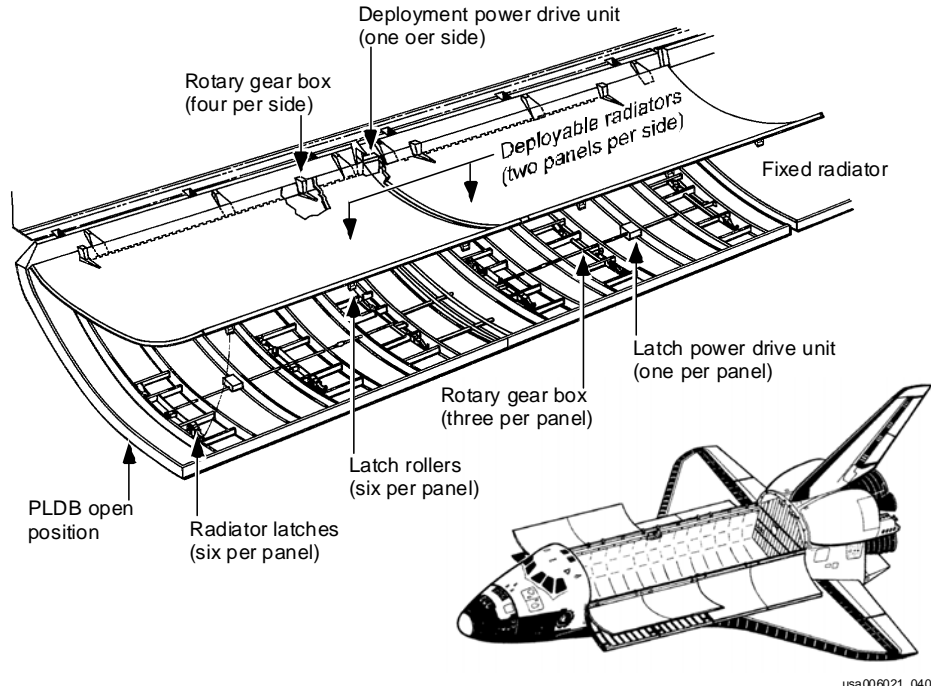
## **5.3 RADIATOR COMPONENTS**

### **5.3.1 Radiator Latches**

When the radiators are stowed, a gang of six latches secures each deployable panel to the payload bay door (Figure 5-2). Therefore, twelve latches (two gangs of six latches each) secure each deployable radiator (port or starboard).

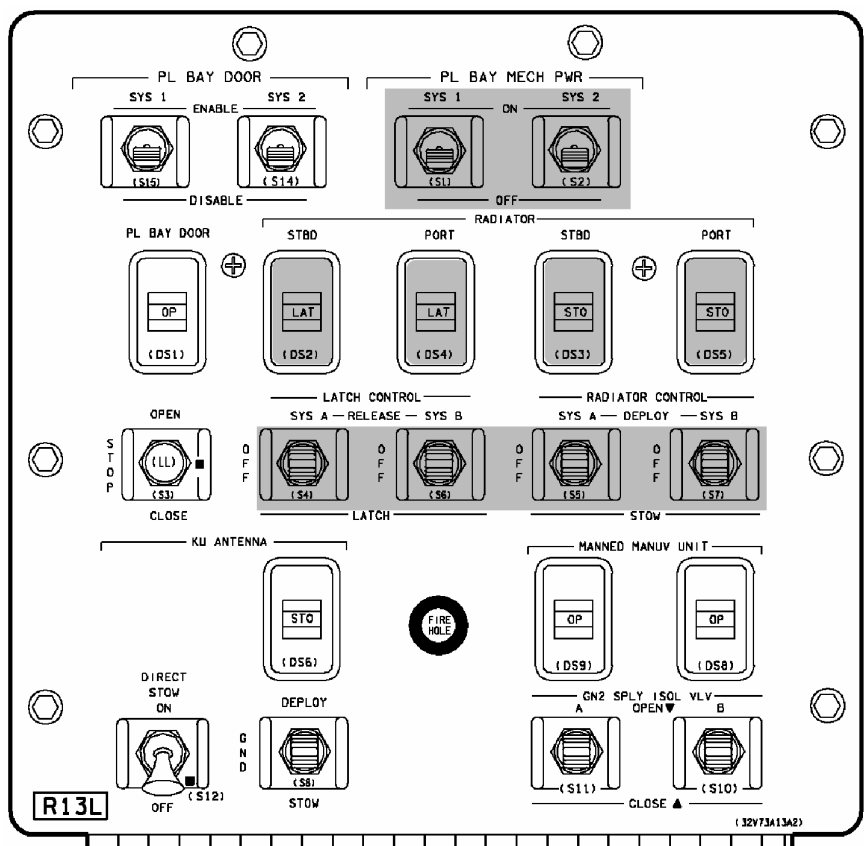
There are a total of four radiator latch gangs: port 1 to 6, port 7 to 12, starboard 1 to 6, and starboard 7 to 12. Each latch gang has a dedicated PDU that drives it to the desired position. It takes 30 seconds to drive a latch gang open or closed with dual motor drive.

The status of the latch gangs is provided by microswitches. There are two open and two closed microswitches to indicate the position of each latch gang. Only MCC has insight into the individual microswitch indications. The crew must rely on talkbacks on Panel R13L (Figure 5-3) for latch position. There is one position talkback for the port latch gangs and one position talkback for the starboard latch gangs.



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Figure 5-2. Deployable radiator latches and drive units

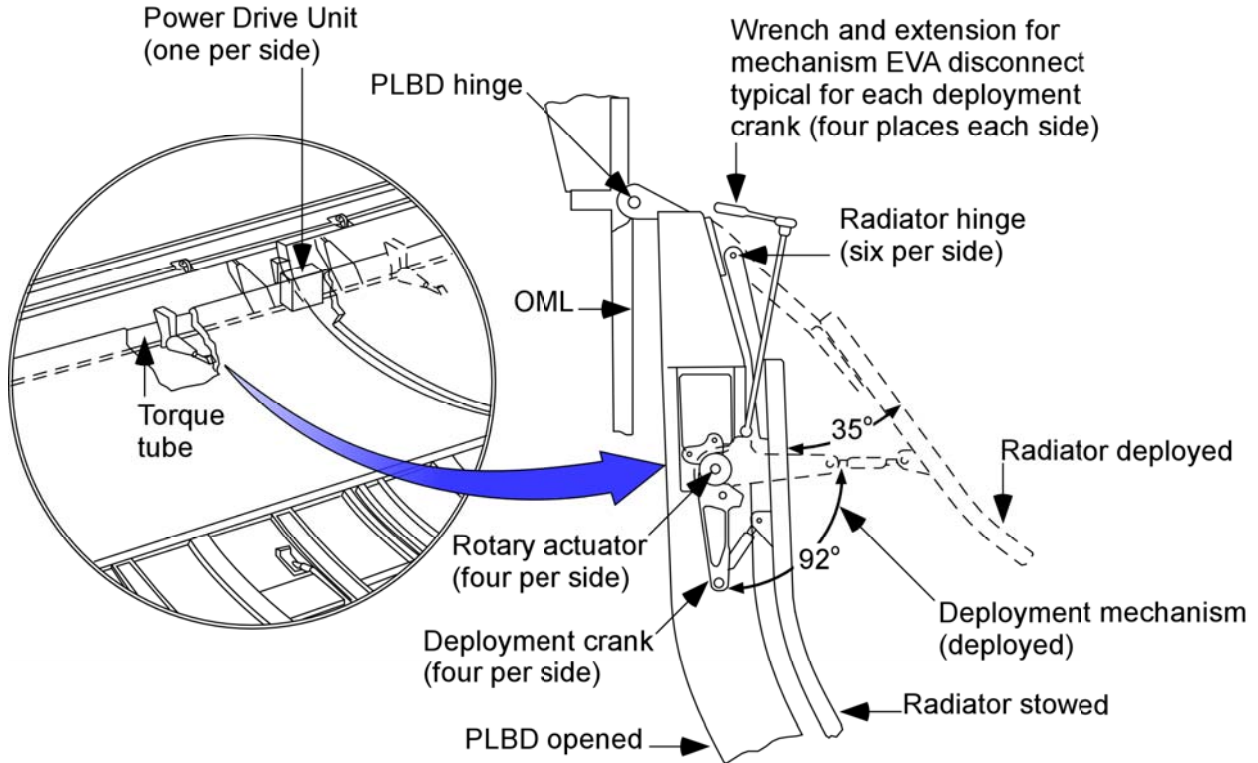


(32V73A13A2)  
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Figure 5-3. Panel R13L

### 5.3.2 Radiator Deploy/Stow System

Each deployable radiator is driven by one PDU (Figure 5-4). It takes 50 seconds to deploy or stow the radiator with dual motor drive. The status of each radiator is provided by microswitches. There are two deploy and two stow microswitches for each radiator. Only MCC has insight into the individual microswitch indications. The crew must rely on Panel R13 talkbacks and visual cues for the position of the radiators. There is one position talkback for the port radiator and one position talkback for the starboard radiator.



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**Figure 5-4. Radiator deploy/stow system**

## 5.4 RADIATOR DEPLOY AND STOW OPERATIONS

The Radiator Deploy and Radiator Stow procedures are located in the ECLSS section of the Orbit Ops Checklist. Radiator deploy and stow operations are performed manually with switches on Panel R13L.

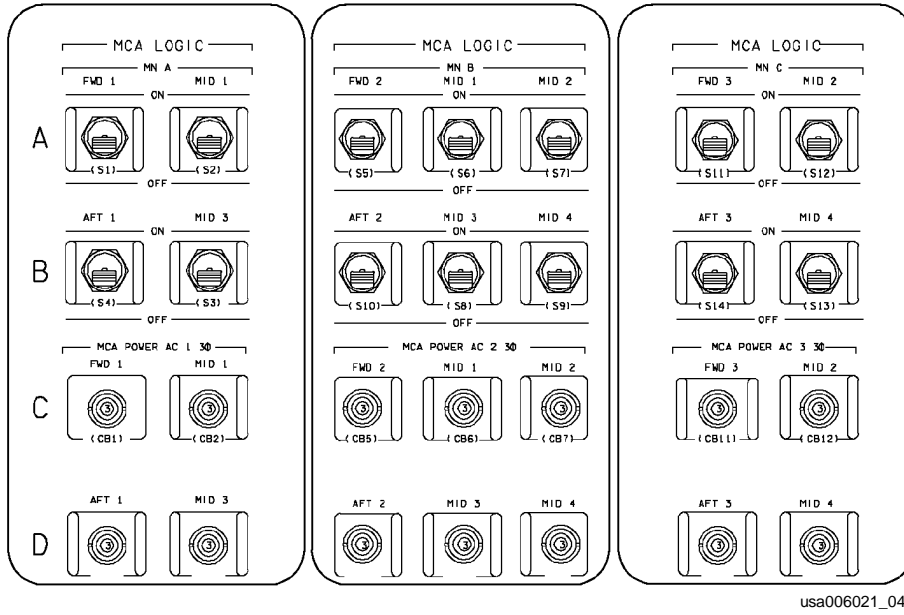
The PL BAY MECH PWR SYS 1 and SYS 2 switches enable AC power within the mid motor control assemblies to supply the radiator PDUs. These switches must be on during radiator deploy/stow operations.

If the radiators are to be deployed, the radiator latches must first be opened. The crew uses the Radiator Latch Control SYS A and SYS B switches. The system A switch controls one motor in each of the four radiator latch gang PDUs. The system B switch controls the other motor in each of the four radiator latch gang PDUs.

After the latches are open, the radiators may be deployed with the Radiator Control SYS A and SYS B switches. The system A switch controls one motor on the starboard radiator PDU and one motor on the port radiator PDU. The system B switch controls the other motor in each of the radiator PDUs.

If the radiators have been deployed, they must be stowed and latched before the payload bay doors are closed. Using the Panel R13L switches again, the crew will first drive the radiator panels to the stow position and then close the radiator latches to secure the panels in place.

Capability for single radiator deploy/stow operations does exist. However, the Panel R13L switches do not allow the crew to control the starboard and port PDUs independently. In order to isolate control to a single radiator only, power must be removed from the opposite radiator's PDUs. This is accomplished by pulling the appropriate motor control assembly circuit breakers on Panel MA73C (Figure 5-5).



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Figure 5-5. Panel MA73C

## QUESTIONS

Answers provided in Appendix B

1. True or False: The forward two radiator panels on each payload bay door are deployable.
2. True or False: When the radiators are stowed, a gang of four latches secures each deployable panel to the payload bay door.
3. True or False: In order to deploy a single radiator, one of the PL BAY MECH PWR switches should be turned off to disable the PDUs associated with the opposite radiator.



## **6.0 LANDING AND DECELERATION SYSTEM**

### **6.1 OBJECTIVES**

Upon completion of this section, the student should be able to

- Identify the subsystems of the Landing and Deceleration System
- State the purpose of each Landing and Deceleration Subsystem
- Identify the methods available to release the main landing gear and nose landing gear uplock hooks
- Identify the primary and backup hydraulic systems that provide hydraulic pressure for braking and nose wheel steering operations

### **6.2 SYSTEM OVERVIEW**

The Landing and Deceleration System provides the crew the capability to safely land the orbiter and perform braking and steering operations. The Landing and Deceleration System consists of the following subsystems: the landing gear, brakes/anti-skid control, nose wheel steering, and drag chute.

### **6.3 LANDING GEAR**

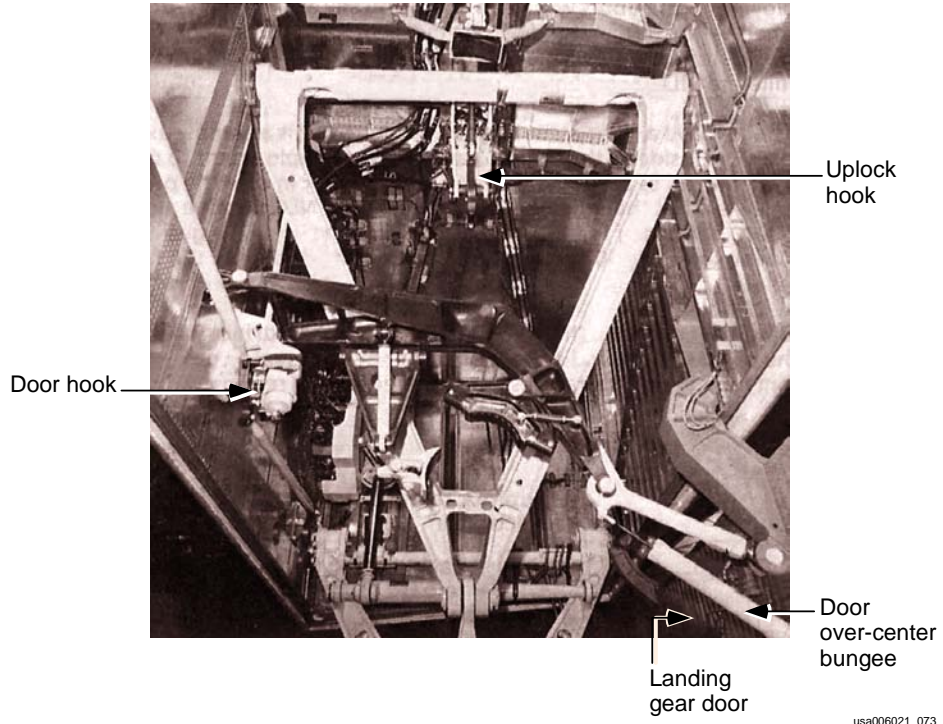
The orbiter landing gear consists of two Main Landing Gear (MLG) and one Nose Landing Gear (NLG) (Figure 6-1 and Figure 6-2). Each MLG retracts forward and up into the wings and is covered by one door. The MLG door is held closed by four door hooks. The NLG retracts forward and up into the forward fuselage and is covered by two doors. Each NLG door is held closed by two door hooks.

Each landing gear is held in the retracted position by an uplock hook. When the crew commands gear deployment, hydraulic actuators release the uplock hooks, and the gear free fall backwards to the extended position.

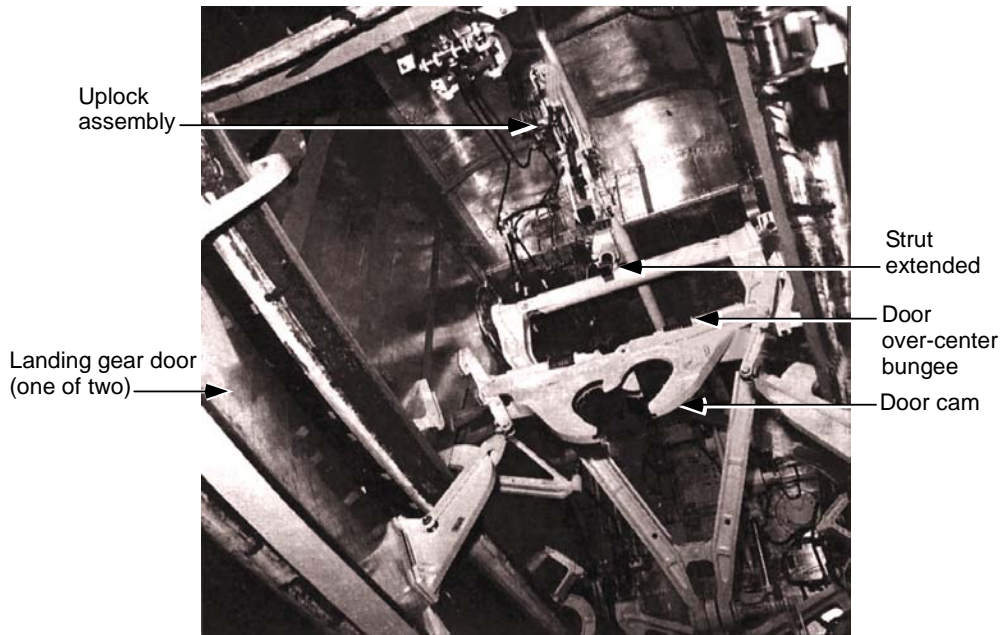
Each door is connected to its associated gear by mechanical linkages, so the doors open automatically as the gear falls. In order to help overcome aerodynamic forces, each door also has a bungee assist assembly that exerts an additional force on the inside of the door. Each MLG bungee assembly exerts approximately 5000 pounds of force on the door over the first two inches of travel, and the NLG bungee assembly exerts 2000 pounds of force on the doors over the first two inches of travel.

As the landing gear deploy, extend/retract strut actuators control the rate of gear extension. These strut actuators use hydraulic fluid as a damping medium to slow the gear as it falls, thereby preventing damage to the gear downlock linkages.

The NLG also has an extension booster pyrotechnic actuator that fires approximately 2 seconds after the gear uplock hook releases. This pyro assist fires during every entry to ensure NLG door opening during high aerodynamic loads and high angle of attack.



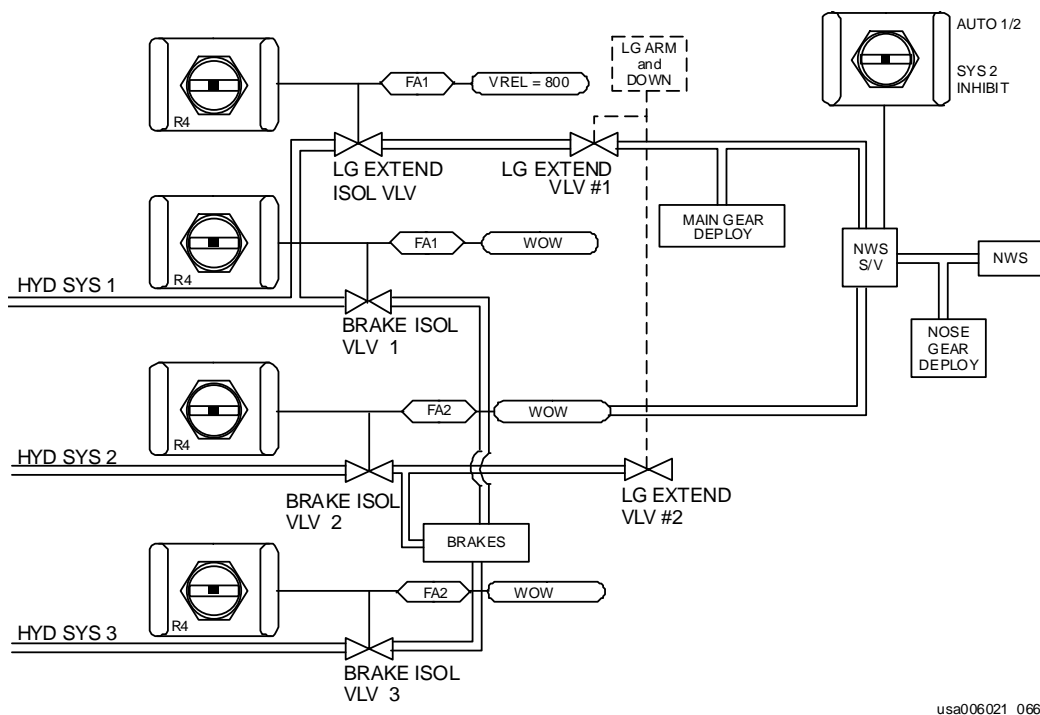
**Figure 6-1. Main landing gear assembly**



**Figure 6-2. Nose landing gear assembly**

Hydraulic system 1 pressure provides the primary method for landing gear deployment (Figure 6-3). If hydraulic system 1 is not available, there are two independent pyrotechnic systems that can release the uplock hooks. Pyrotechnic actuators are attached to both the MLG and NLG uplock hooks. They will fire if the gear is still uplocked one second after the crew has initiated deployment.

System 1 is the only hydraulic system that can release the MLG uplock hooks. If hydraulic system 1 pressure is not available, a switching valve will allow hydraulic system 2 to deploy the NLG. However, in order for hydraulic system 2 to deploy the NLG, brake isolation valve 2 must be opened early.



**Figure 6-3. Landing and deceleration system hydraulics**

#### 6.4 PROXIMITY SENSORS AND PROXIMITY SENSOR ELECTRONICS BOXES

The orbiter uses proximity sensors to determine the position of each landing gear and its associated door. Proximity sensors are also used to determine if Weight on Wheels (WOW) has occurred.

Proximity sensors respond to the presence of a metal object or target. They do not require physical contact to operate. If the target is sensed within a certain region, the proximity sensor will send a 5 V DC signal to one of the orbiter's two proximity sensor electronics boxes (prox boxes).

The prox boxes provide signal conditioning for the orbiter's 13 proximity sensors. These proximity sensors are listed below, along with their associated prox box. For a more detailed discussion on proximity sensors and prox boxes and how they affect the landing gear pyrotechnic deploy systems, refer to Appendix D.

Prox Box 1

NLG UP

NLG DN

NLG NO WOW 2

LMG NO WOW

LMG UP

LMG DN

RMG DOOR UP

Prox Box 2

NLG DOOR UP

NLG NO WOW 1

LMG DOOR UP

RMG NO WOW

RMG UP

RMG DN

## 6.5 BRAKE/ANTI-SKID CONTROL SYSTEM

Each of the four MLG wheels contains electrohydraulic disc brakes with a skid control system. Each wheel has a brake assembly that is supplied hydraulic pressure from two different hydraulic systems. There are eight hydraulic pistons in each brake assembly. Four of the pistons receive pressure from hydraulic system 1. The remaining four pistons receive pressure from hydraulic system 2. When the brakes are applied, the eight hydraulic pistons press the discs together to provide braking. If hydraulic system 1 or 2 pressure drops below approximately 1000 pounds per square inch (psi), switching valves will provide automatic switching to the backup system (hydraulic system 3).

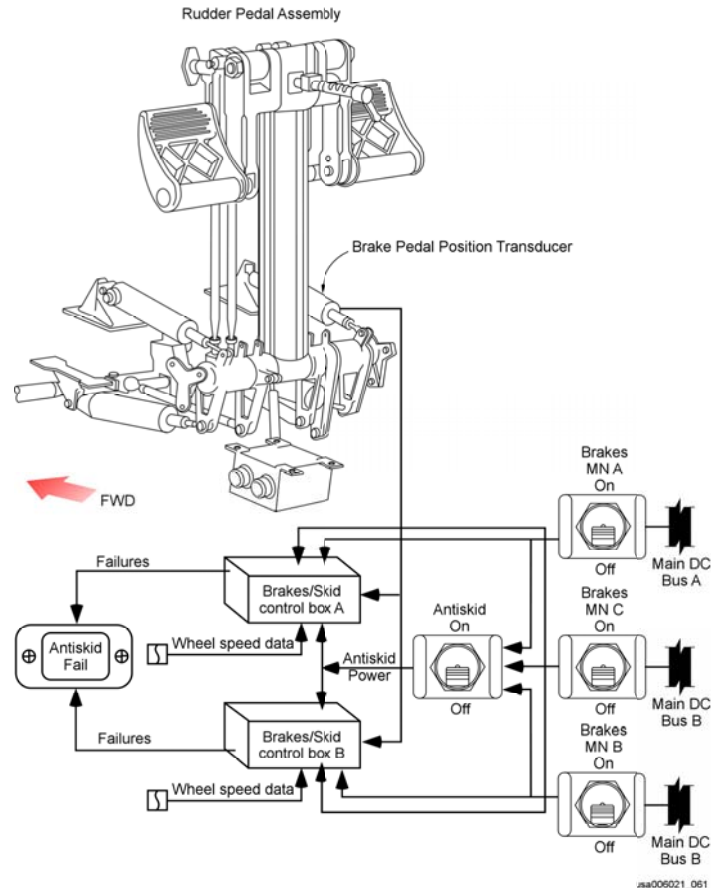
Braking is controlled electrically by signals from the commander or pilot's rudder pedal assembly (Figure 6-4). Braking commands are initiated by applying toe pressure to the pedals. Each pedal assembly has brake pedal position transducers. When toe pressure is applied to the pedal, the transducers send electrical signals proportional to the pedal deflection (0 to 5 V DC) to brake/skid control boxes A and B. These brake/skid control boxes send signals to brake/skid control valves to control the amount of hydraulic pressure being supplied to the brakes.

Each of the brake/skid control boxes contains four independent brake/skid control circuits. Each circuit individually controls one brake/skid control valve. There are two brake/skid control valves for each MLG wheel. One valve is controlled by brake/skid control box A, and the other is controlled by brake/skid control box B.

The skid control portion of the brake system prevents tire skid or wheel lock and maintains optimum braking. Both brake/skid control boxes use wheel velocity information to control the applied hydraulic pressure, if necessary, with the brake/skid control valves. The velocity of each wheel is continuously compared to the average velocity of all four wheels. If the velocity of one wheel is sixty percent below the average velocity, hydraulic pressure to the brakes on the slow wheel is reduced until the velocity increases to an acceptable range.

The brake/skid control circuits contain fault detection logic. There is a yellow ANTISKID FAIL light on Panel F3 that will illuminate if certain failures are detected within the skid control circuitry. A failure will only deactivate the failed circuit, not the entire skid control.

The BRAKES MN A, MN B, and MN C switches allow electrical power to reach the brake/skid control boxes. These switches are located on Panels O14, O15, and O16. Placing the ANTISKID switch, located on Panel L2, to the ON position enables the skid control portion of the of the control boxes.



**Figure 6-4. Brake/skid control system overview**

## 6.6 NOSE WHEEL STEERING

During landing, the orbiter's nose landing gear wheel has steering capability after nose wheel touchdown. A steering actuator on the nose landing gear strut allows lateral directional control of the orbiter during postlanding rollout. The Nose Wheel Steering (NWS) actuator is electronically controlled and hydraulically powered.

The crew performs NWS operations by applying heel pressure to the rudder pedal assembly. Hydraulic system 1 is the primary hydraulic pressure supply for the NWS actuator. If hydraulic system 1 is not available, hydraulic system 2 is the backup system (Figure 6-3).

## 6.7 DRAG CHUTE

The orbiter drag chute provides several advantages to the Landing and Deceleration System. Some of these advantages include reduced NLG strut loads, nose wheel slap-down rates, and MLG strut loads during derotation. The drag chute also reduces the rollout distance required to stop the vehicle and increases vehicle stability when directional control problems exist.

The drag chute is armed and deployed simultaneously by pushing the ARM and DPY Pushbutton Indicators (PBIs). These PBIs are located on Panel F2 for the commander (Figure 6-5) and Panel F3 for the pilot. The nominal drag chute deploy sequence is shown in Figure 6-6.

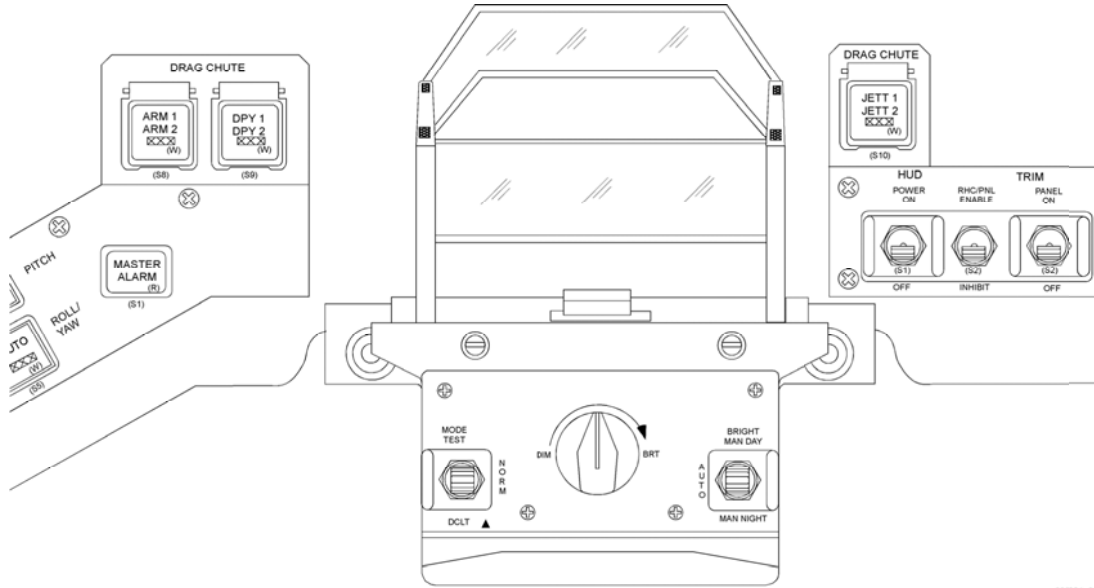


Figure 6-5. CDR drag chute pushbuttons on Panel F2

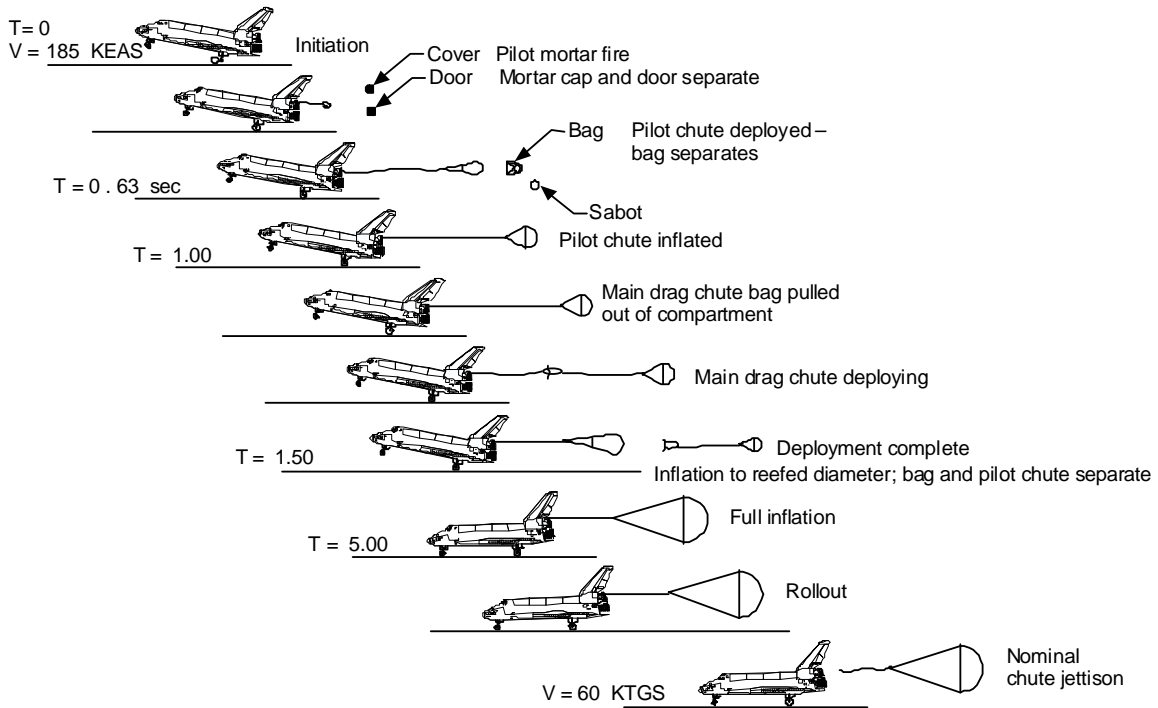
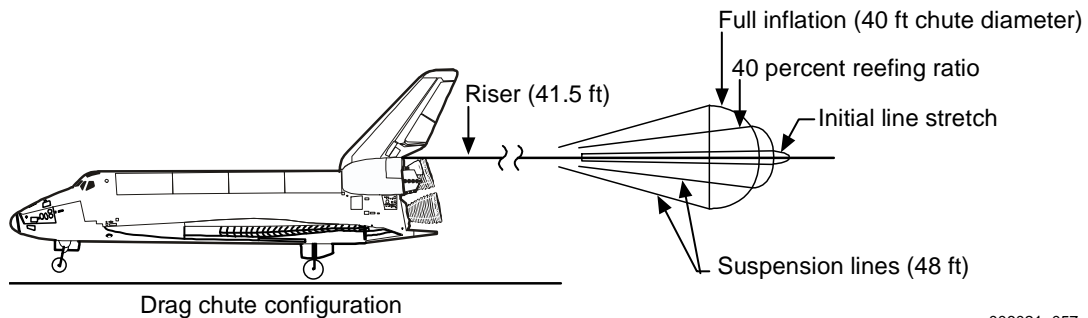


Figure 6-6. Drag chute deploy sequence

One second after the ARM and DPY PBIs are pushed, a pyro fires pushing the drag chute compartment door open and deploying the pilot chute. The pilot chute then inflates and pulls the main chute out of the compartment.

The main drag chute does not immediately deploy to its full open position. Instead, the main chute is reefed to 40 percent of its full open capability, in order to reduce the opening shock on the vehicle and crew (Figure 6-7). After approximately 3.5 seconds, two redundant reefing line cutters on the chute allow it to fully open. The pilot chute also separates from the main chute at this time.

During nominal rollout, the drag chute is jettisoned at a ground speed of  $60 \pm 20$  knots. The chute will not be jettisoned below a ground speed of 40 knots because of the increased probability that the drag chute risers will contact the engine bells, possibly causing damage. The drag chute is jettisoned with the JETT PBI on Panel F3 (Figure 6-5) or Panel F4.



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**Figure 6-7. Drag chute deploy configuration**



## QUESTIONS

Answers provided in Appendix B

1. True or False: If hydraulic system 1 is not available, hydraulic system 2 can release the MLG and NLG uplock hooks.
2. True or False: Each landing gear has an extension booster pyrotechnic actuator that fires to ensure landing gear deployment.
3. True or False: The primary supply of hydraulic pressure to each MLG brake assembly is hydraulic systems 1 and 2.

## 7.0 ORBITER WINDOW SYSTEM

### 7.1 OBJECTIVES

Upon completion of this section, the student should be able to

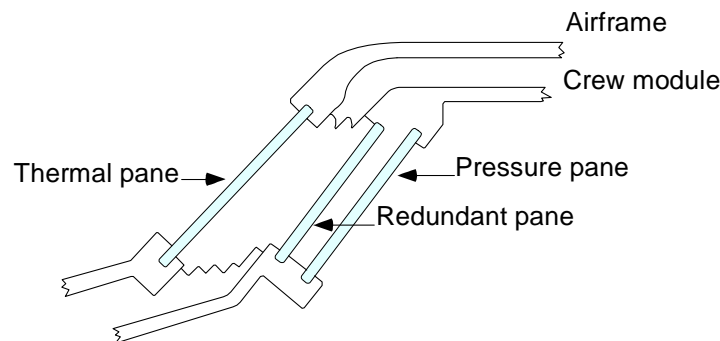
- List the three panes of a typical orbiter window assembly
- State the function of each pane in a typical orbiter window assembly

### 7.2 SYSTEM OVERVIEW

The orbiter window system consists of 11 windows: 6 forward windows, 2 overhead windows, 2 rear windows, and 1 side hatch window. The forward windows provide front, left, and right side visibility from the commander and pilot flight deck stations. The overhead and rear windows provide overhead and payload bay visibility from the aft flight deck station, and the side hatch window provides port side visibility from the middeck.

### 7.3 ORBITER WINDOW ASSEMBLY

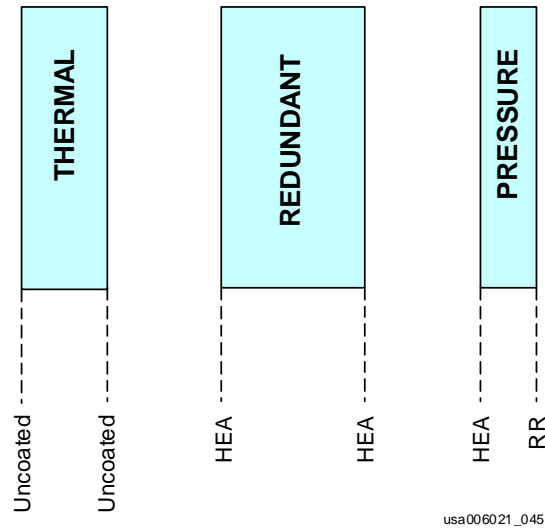
Figure 7-1 shows the three panes that are used in most of the orbiter window assemblies. The outermost pane is referred to as the thermal pane. The thermal pane is made of fused silica and is attached to the fuselage structure. This pane is designed to withstand the heat of reentry. It is not designed to maintain crew compartment pressure.



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**Figure 7-1. Orbiter window assembly**

The middle pane of the window assembly is called the redundant pane. It is made of either fused silica or high strength tempered aluminosilicate glass, depending upon the window location. The redundant pane is attached to the crew module structure and is a redundant pressure seal to the pressure pane. It is coated on both sides with a High Efficiency Antireflectance (HEA) coating that protects the crew against radiation. The redundant pane will not provide thermal protection if the thermal pane is damaged.

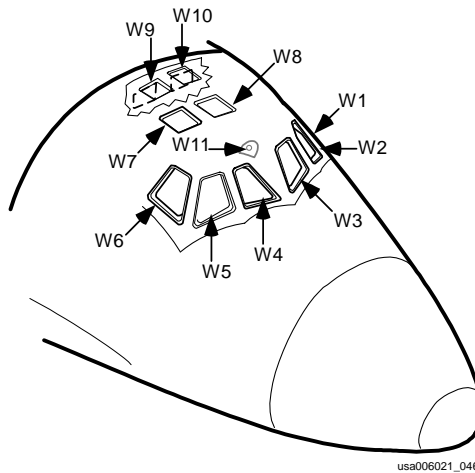
The innermost pane of the window assembly is the pressure pane. This pane is also attached to the crew module. It is composed of either fused silica or aluminosilicate glass, again depending upon the window location, and provides the primary pressure seal for the orbiter. The pressure pane is coated with HEA on the outboard side and an Infrared Reflectance (IR) coating on the inboard side. Figure 7-2 shows the coating arrangement for the window assembly.



**Figure 7-2. Orbiter window coatings**

#### 7.4 WINDOW CONFIGURATION

Figure 7-3 shows the numbering scheme for the orbiter windows. The forward flight deck windows are numbered 1 to 6 starting from the port side. The overhead windows are numbered 7 (starboard) and 8 (port). The rear windows are numbered 9 (starboard) and 10 (port), and the side hatch window is number 11.



**Figure 7-3. Window numbering scheme**

The forward window assemblies, overhead window assemblies, and the side hatch window assembly are each composed of all three panes discussed earlier: a thermal pane, redundant pane, and pressure pane. The rear window assemblies are only composed of two panes: a redundant pane and a pressure pane. Because the payload bay doors provide protection from reentry heating, a thermal pane is not required on these windows.

## QUESTIONS

Answers provided in Appendix B

1. True or False: The innermost pane of a typical orbiter window assembly is called the thermal pane.
2. True or False: The redundant pane of a typical orbiter window assembly acts as a redundant thermal barrier for the thermal pane.

## APPENDIX A - ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AMCA	Aft Motor Control Assembly
AOA	Abort Once Around
ATO	Abort To Orbit
AVS	Active Vent System
BFS	Backup Flight System
DC	Direct Current
DPS	Data Processing System
ECLSS	Environmental Control and Life Support System
EI	Entry Interface
EPS	Electrical Power System
ET	External Tank
FMCA	Forward Motor Control Assembly
GNC	Guidance, Navigation, and Control
GPC	General Purpose Computer
HEA	High Efficiency Antireflection
IDS	Integrated Documentation Services
IR	Infrared Reflectance
JSC	Johnson Space Center
MCA	Motor Control Assembly
MCC	Mission Control Center
MDM	Multiplexer/Demultiplexer
MECO	Main Engine Cutoff
MET	Mission Elapsed Time
MLG	Main Landing Gear
MM	Major Mode
MMCA	Mid Motor Control Assembly
MOD	Mission Operations Directorate
MPS	Main Propulsion System
NASA	National Aeronautics and Space Administration
NLG	Nose Landing Gear
NWS	Nose Wheel Steering
OMS	Orbital Maneuvering System

PASS	Primary Avionics Software System
PBI	Pushbutton Indicator
PDU	Power Drive Unit
PIC	Pyrotechnic Initiator Controller
PLS	Primary Landing Site
psi	Pounds Per Square Inch
RCS	Reaction Control System
RSLs	Redundant Set Launch Sequencer
RTLs	Return to Launch Site
RTV	Room Temperature Vulcanizing Silicone Rubber
SM	System Management
TAL	Transoceanic Abort Landing
TAMS	Training Administration Management System
TIG	Time of Ignition
Vrel	Relative Velocity
WOW	Weight on Wheels

## **APPENDIX B - ANSWERS**

### **Answers to Section 1**

1. c. The function of the PDU differential assembly is to combine the two motor shaft outputs into one shaft input to the gearbox.
2. d. Microswitches turn off the motors once a mechanism reaches its commanded position.
3. False. Dual motor drive time is half as long as single motor drive time.
4. False. Motor control assemblies provide 3-phase AC power to the orbiter's non-continuous AC loads.

### **Answers to Section 2**

1. b. All vent doors are open during ascent.
2. c. During a nominal entry, the vent doors open at  $V_{rel}=2400$  ft/s.
3. b. The crew sends commands to the Active Vent System with item entries on GNC SPEC 51 OVERRIDE.

### **Answers to Section 3**

1. b. Two centerline latches hold the ET doors open during ascent.
2. c. Three uplock latches secure each ET door closed during entry.
3. False. If the pilot is unable to close the ET doors with the Panel R2 switches, he or she should not initiate the automatic closure. Crew initiation of the automatic sequence should be considered a backup closure method during an AOA only.
4. False. During postlanding ET door opening, the pilot must rely on time to determine when the ET doors are in the proper position.

#### Answers to Section 4

1. c. Sixteen centerline latches secure the payload bay doors closed.
2. c. Each payload bay door switch module contains three ready-to-latch microswitches and one closed microswitch.
3. False. The field next to “PBD SW” reflects the position of the PL BAY DOOR control switch on Panel R13.
4. False. The AUTO SEQ column does not show which mechanism is currently being driven. During auto mode operations, a down arrow will be displayed in this column next to a mechanism that causes a payload bay door sequence failure.
5. d. A dilemma will occur and a “PBD CONFIG” message will annunciate. When the port aft bulkhead latches reach the open position, a dilemma will occur because both open microswitches and one closed microswitch will be activated. When the software moves to the next active group (the port door), it will see that the port aft bulkhead latch gang is out of configuration, and a “PBD CONFIG” message will be generated.
6. e. The nominal payload bay door opening sequence will start. When the sequence begins, centerline latches 5-8 and 9-12 will be the first active group. Therefore, a “PBD CONFIG” message will not be generated. Centerline latches 5-8 and 9-12 will be commanded open, and the sequence should proceed nominally.
7. c. A “PBD SEQ FAIL” message will annunciate 40 seconds after the centerline latches are commanded open, because the “A” open microswitch has failed in the “not present” indication.

#### Answers to Section 5

1. True. The forward two radiator panels on each payload bay door are deployable.
2. False. When the radiators are stowed, each deployable panel is secured to the payload bay door by a gang of six latches.
3. False. In order to deploy a single radiator, the PDUs associated with the opposite radiator must be disabled by pulling the appropriate motor control assembly circuit breakers on Panel MA73C.



### **Answers to Section 6**

1. False. If hydraulic system 1 is not available, hydraulic system 2 can only release the NLG uplock hook. There is no backup hydraulic supply for the MLG.
2. False. Only the NLG has an extension booster pyrotechnic actuator that fires to ensure deployment.
3. True. The primary supply of hydraulic pressure to each MLG brake assembly is hydraulic systems 1 and 2.

### **Answers to Section 7**

1. False. The innermost pane of a typical orbiter window assembly is called the pressure pane.
2. False. The redundant pane of a typical orbiter window assembly acts as a redundant seal for the pressure pane.

**APPENDIX C - PLBD MICROSWITCH TABLES**

The PLBD software determines what status will be displayed in the OP/CL column of the PL BAY DOORS display based on the associated microswitch indications. The following PLBD microswitch logic tables (Table C-1 and Table C-2) show which status will be displayed for a specific microswitch configuration.

Microswitch				Onboard CRT output
OP		CL		
A	B	A	B	OP/CL
0	0	0	0	" "
0	0	0	1	" "
0	0	1	0	" "
0	0	1	1	"CL"
0	1	0	0	" "
0	1	0	1	"? "
0	1	1	0	"? "
0	1	1	1	"? "
1	0	0	0	" "
1	0	0	1	"? "
1	0	1	0	"? "
1	0	1	1	"? "
1	1	0	0	"OP"
1	1	0	1	"? "
1	1	1	0	"? "
1	1	1	1	"? "

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**Table C-1. Microswitch logic for payload bay door latches**

Microswitch (m/s) Logic for Doors

Set 1 OPEN m/s		Output logic	Set 2 Forward RDY m/s			Output logic	Set 3 AFT RDY m/s			Output logic	Set 4 CLOSE m/s		Output logic
A	B		A	B	C		A	B	C		A	B	
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	1	0	0	1	0
1	0	0	0	1	0	0	0	1	0	0	1	0	0
1	1	1	0	1	1	1	0	1	1	1	1	1	1
			1	0	0	0	1	0	0	0	1	0	0
			1	0	1	1	1	0	1	1	1	0	0
			1	1	0	1	1	1	0	1	1	1	0
			1	1	1	1	1	1	1	1	1	1	1

Set logic from above				Onboard CRT output
1	2	3	4	OP/CL
0	0	0	0	" "
0	0	0	1	" ? "
0	0	1	0	" "
0	0	1	1	" ? "
0	1	0	0	" "
0	1	0	1	" ? "
0	1	1	0	"RDY"
0	1	1	1	" CL"
1	0	0	0	" OP"
1	0	0	1	" ? "
1	0	1	0	" ? "
1	0	1	1	" ? "
1	1	0	0	" ? "
1	1	0	1	" ? "
1	1	1	0	" ? "
1	1	1	1	" ? "

Table C-2. Microswitch logic for payload bay doors

## QUESTIONS

Answer provided on next page.

1. Assuming that no mechanism is being driven, what status will be displayed in the OP/CL column for each of the latch and door microswitch configurations shown below?

2021/XXX/XXX		PL BAY DOORS		XX X	DDD/HH:MM:SS	DDD/HH:MM:SS
AC POWER	ON 1					
	OFF 2	PBD SW - STOP				
AUTO MODE	SEL 3				MICRO-SW STAT	
					LATS DOORS	
					CCOO CRRRO	
CENTER LATCHES	MAN	OP/CL	AUTO		ABAB	ABC
	SEL		SEQ			
5 - 8	4				1000	
9 - 12	5				1100	
1 - 4	6				0100	
13 - 16	7				0011	
STBD						
FWD LATCHES	8				0110	01110
AFT LATCHES	9				0011	11010
DOOR	10					
PORT						
FWD LATCHES	11				1101	11010
AFT LATCHES	12				0111	01001
DOOR	13					
PBD SW BYPASS 14						
				OPEN	15	
				STOP	16	
				CLOSE	17	

## ANSWERS

- The statuses that will be displayed in the OP/CL column are shown on the following PL BAY DOORS display.

2021/XXX/XXX		PL BAY DOORS		XX X	DDD/HH:MM:SS	DDD/HH:MM:SS
AC POWER	ON	1				
	OFF	2	PBD SW - STOP			
AUTO MODE	SEL	3				
				MICRO-SW	STAT	
				LATS	DOORS	
				CCOO	CRRRO	
CENTER LATCHES	MAN	OP/CL	AUTO	ABAB	ABC	
	SEL		SEQ			
5 - 8	4			1000		
9 - 12	5	CL		1100		
1 - 4	6			0100		
13 - 16	7	OP		0011		
STBD						
FWD LATCHES	8	?		0110	01110	
AFT LATCHES	9	OP		0011	11010	
DOOR	10	RDY				
PORT						
FWD LATCHES	11	?		1101	11010	
AFT LATCHES	12	?		0111	01001	
DOOR	13					
PBD SW BYPASS	14					
			OPEN	15		
			STOP	16		
			CLOSE	17		

## APPENDIX D - PROXIMITY SENSORS AND LANDING GEAR DEPLOYMENT

The primary method of landing gear deployment uses hydraulic pressure from system 1 to release the gear uplock hooks. A backup method is provided by two independent pyrotechnic deploy systems that can release the uplock hooks if hydraulic system 1 is not available. They will fire if proximity sensors detect that the gear are still uplocked one second after the crew has initiated deployment.

The orbiter has two proximity sensor electronics boxes (prox boxes). These prox boxes process signals from thirteen proximity sensors on the main landing gear and nose landing gear struts and doors. However, for this discussion, we will only be concerned with the six proximity sensors that affect the landing gear pyro deploy systems.

Prox box 1 receives inputs from the NLG DOOR UP, LMG DOOR UP, and RMG UP sensors. Prox box 2 receives inputs from the NLG UP, LMG UP, and RMG DOOR UP sensors. Based on the sensor inputs, each prox box sends output signals to the landing gear pyro deploy systems.

Referring to Figure D-1, you can see that each landing gear has two pyro deploy systems. Each pyro system receives a discrete ("1" or "0") signal from one of the prox boxes. Prox box 1 sends signals to pyro system 1, and prox box 2 sends signals to pyro system 2. For each of the main gear, one of the signals uses normal logic, and the other signal uses reverse logic. Both of the signals being sent to the nose landing gear pyro systems use normal logic. Reverse logic is not available for the nose landing gear.

For the pyro systems that use normal logic, the prox box signal output will be "1" if the proximity sensor detects the gear is still uplocked. For example, when the LMG UP proximity sensor detects the left main gear is uplocked, it sends a 5 V DC signal to prox box 2. Based on this signal, prox box 2 sends a "1" to the left gear's pyro system 2.

For the pyro systems that use reverse logic, the prox box signal output will be "0" when the proximity sensor sends a 5 V DC signal. The proximity sensors associated with reverse logic are the LMG DOOR UP and RMG DOOR UP. For example, when the LMG DOOR UP sensor detects the left door is uplocked, it sends a 5 V DC signal to prox box 1. Because of reverse logic, the prox box now outputs a "0" instead of a "1" to pyro system 1.

If a prox box is lost (either due to a power supply failure or a problem within the box itself), its output will go to "0". Therefore, the main landing gear pyro which receives the reverse logic signal from that prox box will interpret the signal to mean that the gear is still up. This design allows the main landing gear to still have pyro deploy capability in the event of a prox box loss.

Figure D-2 shows a simplified version of the pyro system circuits for normal logic and reverse logic. In order for a pyro system to fire, it must receive three command signals: arm, fire 1, and fire 2. Figure D-2 illustrates where each command originates.

It is important to remember that the reverse logic protects only against failures of the prox boxes and their electrical power supplies. Other electrical failures can disable an entire pyro system, regardless of reverse logic.

The following scenarios demonstrate how the loss of hydraulic systems and prox boxes will affect landing gear deployment.

Scenario #1: Hydraulic system 1 is available, and both prox boxes are powered.

- With hydraulic system 1 available and both prox boxes functioning properly, a nominal hydraulic landing gear deployment will occur.
- When the gear deploys, the proximity sensors will send 0 V DC to their respective prox boxes. The prox box signals with normal logic will send a “0” to the associated pyro systems-preventing the pyros from firing.
- The prox box signals with reverse logic will send a “1” to their associated pyro systems. This signal is inverted to a “0” in the pyro circuitry (refer to Figure D-2), and now those pyro systems are also prevented from firing.

Scenario #2: Hydraulic system 1 is not available, and both prox boxes are powered.

- If hydraulic system 1 is not available and both prox boxes are functioning properly, the main and nose landing gear will each be deployed by two pyro systems.
- When the crew initiates deployment, the proximity sensors will still detect the gear up-sending 5 V DC signals to the prox boxes. The prox box signals with normal logic will send a “1,” causing the associated pyros to fire one second after landing gear deployment is initiated.
- The prox box signals with reverse logic will send a “0”. The pyro circuitry will invert the signal to a “1,” causing those pyro systems to also fire one second after deployment is initiated.

Scenario #3: Hydraulic system 1 is not available, and only one prox box is powered.

- If hydraulic system 1 is not available and only one prox box is functioning, the nose gear and one of the main landing gear will each be deployed by one pyro system, and the other main landing gear will be deployed by two pyro systems.
- For example, if prox box 1 is lost, pyro system 1 on the NLG and RMG will not fire because they use normal logic. Prox box 1 will be sending a “0” signal, and the NLG and RMG pyro circuitry will interpret this to mean that the gear did deploy.
- The LMG will be deployed by both of its pyro systems. The signal from prox box 2 to the LMG pyro system 2 is still good, so that pyro system will fire one second after deployment is initiated. The signal from prox box 1 to the LMG pyro system 1 uses

reverse logic. Therefore, the “0” signal that prox box 1 is sending will be inverted to a “1” in the pyro circuitry, and now the second pyro will also fire one second after deployment is initiated.

- In this case, brake isol 2 will be opened early to provide NLG deployment redundancy with hydraulic system 2.

Scenario #4: Hydraulic system 1 is not available, and both prox boxes are lost.

- If hydraulic system 1 is not available and both prox boxes are lost, the main gear will each deploy by one pyro system only. Only the pyro systems that use reverse logic will fire.
- Because the NLG pyro systems only use normal logic, they will not fire. In this case, brake isol 2 must be opened early to provide NLG deployment with hydraulic system 2.

Scenario #5: Hydraulic system 1 is available, but one of the prox boxes is lost.

- If hydraulic system 1 is available, but one of the prox boxes is lost, a hydraulic landing gear deployment will occur. However, the pyro system that receives a reverse logic signal from the lost prox box will still fire.
- The pyro systems that receive a normal logic signal will not fire, since they will see the signal that the gear did deploy.

Scenario #6: Hydraulic system 1 is available, but both prox boxes are lost.

- If hydraulic system 1 is available, but both prox boxes are lost, a hydraulic landing gear deployment will occur. However, the pyro systems that receive reverse logic signals will still fire.
- The pyro systems that receive a normal logic signal will not fire, since they will see the signal that the gear did deploy.
- Because the NLG pyro systems only use normal logic, they will not fire. In this case, brake isol 2 will be opened early to provide NLG deployment redundancy with hydraulic system 2.



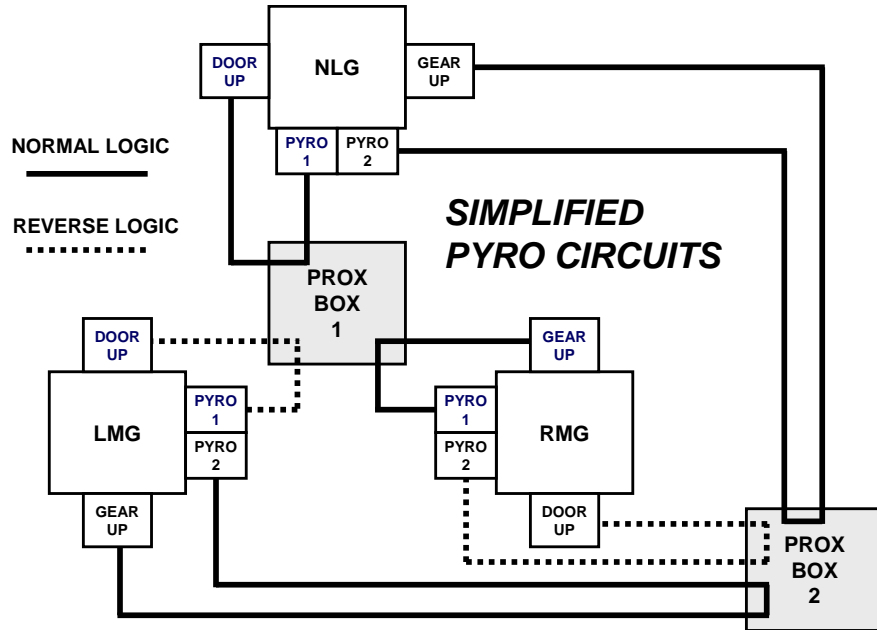


Figure D-1. Simplified pyro circuits

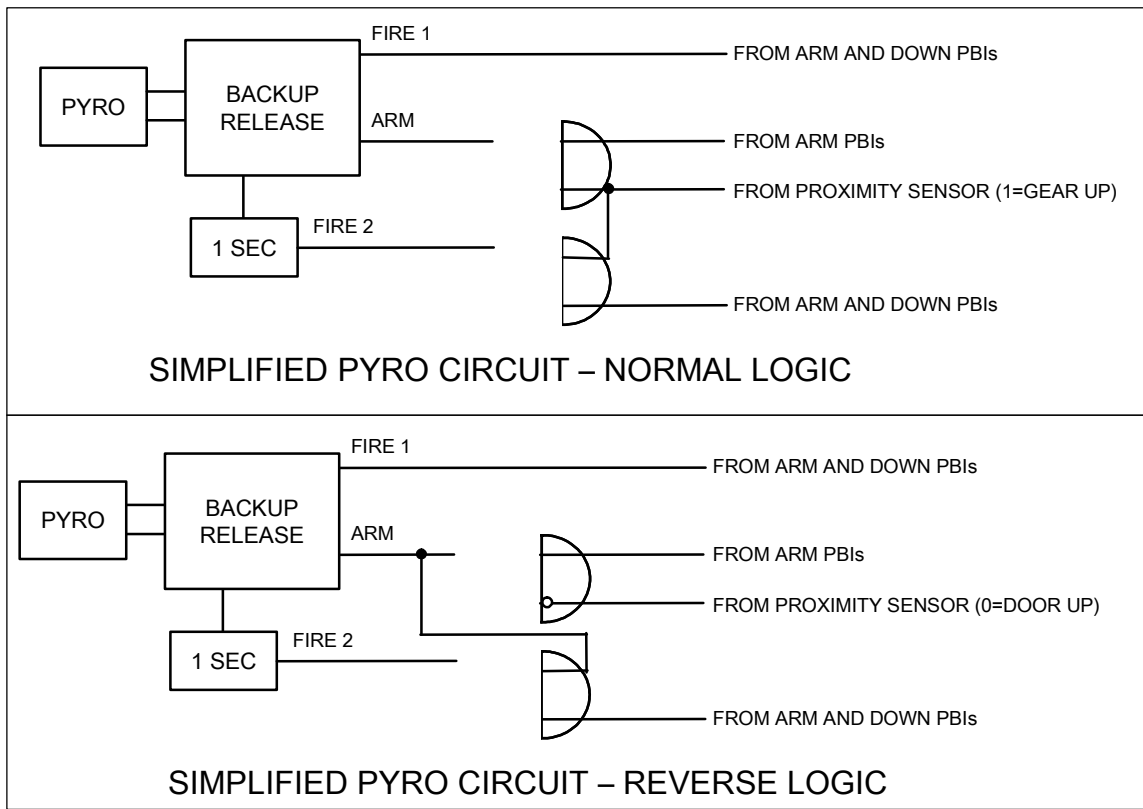


Figure D-2. Simplified pyro circuits: normal logic and reverse logic

## Training Materials Evaluation

Please answer the following questions regarding the lesson that you have just completed. Your feedback allows us to produce more effective training materials.  
*When completed, mail to: Systems Training, DS45.*

**TITLE/LESSON CODE: MECHANICAL SYSTEMS TRAINING MANUAL - MECH SYS 21002**

### SIZE OF AUDIENCE/CLASS:

#### 1. How well did this lesson meet its purpose?

For each statement below, mark one box on the scale:

- a. *The lesson objectives are clearly stated.*
- b. *The lesson objectives are clearly defined.*
- c. *The lesson effectively teaches skills and information.*
- d. *The lesson meets its purpose and objectives.*

Strongly Disagree				Strongly Agree			
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#### 2. How satisfying is the content of this lesson?

For each statement below, mark one box on the scale:

- a. *The information is structured in a logical flow.*
- b. *The content is clear.*
- c. *The content is complete.*
- d. *The level of detail is correct for this information.*
- e. *The amount of information is effective.*
- f. *The graphics contribute to my understanding.*

Strongly Disagree				Strongly Agree			
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<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

#### 3. How appealing was the presentation of this lesson?

For each statement below, mark one box on the scale:

- a. *The overall presentation is appealing.*
- b. *The visuals chosen are appropriate for the lesson.*
- c. *The visuals make the information more interesting.*
- d. *The graphics are legibly reproduced.*
- e. *The audio/visual or print quality is good.*

Strongly Disagree				Strongly Agree			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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#### 4. How valuable is this information?

For each statement below, mark one box on the scale:

- a. *The lesson teaches skills and information I need.*
- b. *The lesson meets my expectations.*
- c. *This information is useful for later reference.*
- d. *I would recommend this lesson to others.*

Strongly Disagree				Strongly Agree			
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**PLEASE WRITE YOUR COMMENTS/QUESTIONS ON THE BACK OF THIS FORM.  
EXPLAIN ANY NEGATIVE ANSWERS IN SPECIFIC TERMS  
THANK YOU IN ADVANCE FOR YOUR ASSISTANCE!**

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