# **Systems Management Training Manual**

**SM TM 2102** 

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# **Section 1: Introduction**

The successful performance of a complicated space flight depends heavily on the use of a computerized system for controlling and monitoring the entire space vehicle. On the Space Shuttle the computerized system consists of two groups of applications software: SM and guidance, navigation, and control (GNC). These two groups of applications software are called major functions. The Shuttle software has a third major function called payload but at this time the payload major function contains no applications software. This workbook will cover the SM applications software (see the SM software overview, figure 1-1, and the SM structure, figure 1-2).







Figure 1-2.– Systems management structure.

SM is a major function of applications software which monitors and provides interfaces to the crew on Orbiter support systems, payloads, and the remote manipulator system (RMS). The SM structure consists of three primary functions: basic SM processes, special/mission selectable processes, and display and uplink controlled processes. Basic SM processes acquire data from the various vehicle and payload subsystems and monitor this data to provide fault detection and warning in the event of a vehicle or payload anomaly. Special processes and mission selectable processes provide specialized computations and processing sequences to determine and control the status and performance of various vehicle subsystems and payloads. Display and uplink controlled processes provide functions which can be used to initiate, alter, or terminate certain processing within basic SM processes and special processes. Some of these functions provide the onboard capability to modify certain tables used by SM processes.

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All three primary functions of SM require systems software support with respect to input data acquistion, and outputs from the general purpose computer (GPC) to external hardware. The backup flight system (BFS) GPC has its own specialized systems software called the backup operating system (BOS). SM software is active during all mission phases.

Fault detection and annunciation (FDA) and scaling/ displaying provide information on vehicle subsystem health and status through automatic fault detection, performance data readouts, and configuration status displays. Subsystem management of the vehicle is then accomplished by user assessment of this information provided by SM and subsequent user actions to affect vehicle configuration. SM also performs special computations and sequences called special processing (SP) which provide additional information and provide assistance in the maintenance of vehicle subsystems. SM, through SP, controls selected functions onboard the vehicle, such as turning pumps off and on, etc. In addition to monitoring the vehicle subsystems, SM provides the capability for the user to update parameters which control SM processing.

# Section 2: Systems Management Software

### **GPC Software Overview**

In order to understand how SM software fits into the overall GPC software, the student must be familiar with the software configuration of the GPCs. In this section we will review these software configurations. The software within each primary avionics software system (PASS) GPC is divided into two parts, system software (SS/W) and applications software (GNC, SM, or payload).

The SS/W is common to all PASS GPCs, regardless of what applications software is present. SS/W deals with running the GPCs themselves, as opposed to applications software, which runs the vehicle systems. It provides timing, display support, input/output, sync, etc. Additionally, it is capable of functioning with or without applications software's being present in the GPC.

The applications software consists of the various major function/operations sequence (OPS) combinations. These combinations can be one of eight varieties which determine the GPCs memory configuration (MC). These are:

MC	OPS	Function
1	GNC OPS 1 and 6	ASCENT AND RTLS GNC
2	GNC OPS 2	ORBIT GNC
3	GNC OPS 3	ENTRY GNC
4	SM OPS 2	ORBIT SM
5	SM OPS 4	ORBIT SM
6	PL OPS 9	ORBIT VEHICLE UTILITIES
8	GNC OPS 8	ORBIT FLIGHT CONTROL C/O
9	GNC OPS 9	PRELAUNCH and POSTLANDING

Notice that only one MC (MC1) contains more than one OPS and that only because there would be insufficient time to load in GNC OPS 6 when it is needed. Going from one MC to another with a GPC requires that new software be brought (overlaid) into the GPC from the mass memory units (MMUs).

Applications software within a GPC is divided into two parts, the OPS itself and the major function base (MFB). The MFB is that part of memory which is not overlaid when a transition is made to a new MC that is of the same major function ( for example SM OPS 2 to SM OPS 4). The MFB carries to the new MC that intelligence from the old MC that must be passed along for proper applications software functioning. Line replaceable unit (LRU) failure status, state vector, and FDA limit changes are some examples of the intelligence resident in the MFB.

To illustrate how the GPC overlays take place let's take GPC 4 through a typical flight scenario.

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Preflight, the SS/W is loaded into GPC 4 via a process known as the inital program load (IPL). Then GNC OPS 9 is added via overlay with an OPS 901 PRO:



A box around a software segment indicates that it was overlaid during that step.

Next, GPC 4 is taken to MC1 for launch with a GNC OPS 101 PRO. Notice that the MFB is not overlaid in the transition, only OPS 1 and 6:



After the ascent phase, GPC 4 is taken to SM OPS 2 (which is MC4) with an SM OPS 201 PRO. In this case, both the MFB and the SM OPS 2 are overlaid:



Finally, GPC 4 is taken to GNC OPS 3 (MC3) for entry and then back to GNC OPS 9 (MC9) postlanding:



The source of an overlay can be either the MMU or another GPC. For example, in the entry transition for GPC 4, the MFB could come from a GNC GPC while the OPS could come from the MMU.

The BFS is different from the PASS in that all of its software is present within the computer all of the time. This includes SS/W, SM, and GNC OPS 1, 3, and 6. Therefore, no overlays are required.

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### **Ascent and Entry**

During the ascent and entry phases of the mission the SM program is loaded into the BFS GPC with the BFS program. Activation of the BFS program also activates the BOS data acquisition for SM and enables the scaling/display function. The FDA function is always enabled. When the BFS is in run it has control of the payload buses. It is through these payload buses that the BFS SM special processes operate. In BFS, SM is always considered to be in OPS 0 which is different from PASS OPS 0 (see the BFS SM display summary, figure 2-1).

# Orbit

During the orbit phase of the mission SM is available in the PASS OPS 2 and 4. PASS SM OPS 2 and 4 are basically the same. The primary difference is that they will contain different payload capabilities. In general, a Shuttle mission will only require SM OPS 2. However, if all the required payload capabilities cannot be put in the OPS 2 software then it will be split between SM OPS 2 and 4.

Onorbit SM software is executed in a common set GPC, which is usually GPC 4. For an outline of all onorbit displays see figure 2-2, the SM major mode transitions and display summary. For a description of all SM displays see the Data Processing System (DPS) Dictionary.

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Figure 2-1.– BFS SM display summary.



### Figure 2-2.– SM major mode transitions and display summary (PASS).

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# Section 3: SM Command and Data Interfaces

The SM GPC receives commands (CMDs) from the ground or directly by the crew via the multifunction cathode-ray tube (CRT) display system (MCDS). Uplinked CMDs from the ground go through either the Ku-band or S-band signal processor to the network signal processor (NSP). The uplinked CMDs are then sent to the flight forward multiplexer/demultiplexers (FF MDMs) and on to the GN&C GPCs via the flight-critical buses. The GN&C GPC recognizes that the command is for SM and sends it to the SM GPC via the intercomputer channel (ICC) data bus.

Once a CMD is at the SM GPC, it is acted upon internally or sent out over one of two payload buses to either an Orbiter system or a payload. Orbiter systems CMDs are sent to the systems via the payload (PL) MDMs. Data is returned in the reverse direction to the SM GPC or through the operational instrumentation (OI) MDMs to the pulse-code modulation master unit (PCMMU) and on to the SM GPC for processing and also to the ground through the NSP.

Detached payload CMDs are routed to the PL MDM, the payload signal processor (PSP), the payload interrogator (PI), and then to the detached payload. Data from the detached payload is then routed back in the reverse direction, to the SM GPC and also to the payload data interleaver (PDI).

Attached payload CMDs are routed to either the flex MDMs or, in the case of a payload assist module (PAM), to the sequence control assembly (SCA) and then to the payload. Data from the payload is then routed back in the reverse direction to the SM GPC and like detached payloads, to the PDI.

Data sent to the PDI is then sent to the PCMMU. Data sent to the PCMMU can be sent back to the SM GPC and/or the NSP and then to either the S-band or Ku-band signal processor for downlink to the ground. The SM command and data flow is illustrated in figure 3-1.





# Section 4: Basic SM Processes

Basic SM processes acquire data from the various vehicle and payload subsystems and monitor this data to provide FDA in the event of a vehicle or payload anomaly.

# **Fault Detection Annunciation**

SM software contains the computer application program that provides a partial backup capability to the Orbiter alarm system (additional alarm backup functions reside in the GNC GPC). This backup capability in SM is provided by FDA.

The FDA is a software module within the SM software that detects and initiates annunciation of out-oftolerance subsystem conditions. Warnings provided are class 2 and class 3, which are the backup caution and warning (C&W) and alert systems, respectively. A third minor alarm class contained in the SM software module, class 0 limit contained in the SM software module,

class 0 limit sensing, provides the following indications if an out-of-limits condition is detected ( $\uparrow$ ,  $\downarrow$ , H, or L). The processes involved in the FDA function include the following: precondition processing, limit sensing, false alarm avoidance, and fault annunciation output.

Precondition processing is the capability to provide configuration-dependent limit sensing. A parameter may have one, two, or three limit sets available for limit sensing. Limit sets 2 and 3 each have a corresponding logical statement; i.e., a logical combination of up to four discretes or limit-sensing analogs, which defines the configuration for which that limit set is used. If one of the logical conditions is not met, the software defaults to limit set 1. PASS SM and BFS SM software both have numerous examples of precondition processing as outlined on pages 5-12 through 5-19.

Capability exists to limit sense analog parameter values, single-precision floating point parameters, and discrete parameters. The limit sense test compares the parameter value with one set of two limits, either simple or multiple. A simple limit set for an analog parameter is one highlimit and one low-limit constant value. A multiple set is a set which contains two or three simple limit sets, from which one set is selected by preconditions. Alarm class 2 limit sets are simple limit sets only, whereas alarm class 0 and 3 limit sets may be simple or multiple. The capability exists to change limit-sense values by keyboard input on the table maintenance specialist function (SPEC) (PASS SM SPEC 60) or via table maintenance block update (TMBU) commands from the ground.

False alarm avoidance is the capability to change the time a parameter must be out of limits in order to trip an alarm. If a parameter has been out of a limit set for N consecutive software samples, a fault annunciation, as specified for that parameter, is enabled. The parameter will not annunciate again the out of limits for at least N times. The in- and out-of-limits count will be reinitialized by one of the following: the parameter value has been within limits N consecutive times, or a different limit set is selected by preconditions. The value of N is an integer constant, called the filter value, as specified for each parameter and can be changed by a keyboard entry via the table maintenance SPEC or TMBU command.

For example, if a parameter has a filter value of 2 and a software process rate of once a second then that parameter will annunciate an alarm after being out of limits 2 seconds. If a parameter has a filter value of 2 and a

software process rate of 0.5 times a second (once every two seconds) then that parameter will annunciate an alarm in 4 seconds.

Fault annunciation output from SM is defined as follows:

- Class 2 backup C&W Backup C&W light, master alarm (MA), and fault messages.
- Class 3 alert Alert light, alert tone, and fault messages.
- Class 0 No annunciation, preconditioning, or special purpose limit sensing; status characters (or) for out-oflimits conditions only (<sup>↑</sup>, ↓ H, or L).

SM is a major part of the crew warning system. SM software monitors a large number of parameters associated with the backup C&W system and the SM alert system.

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The SM software (see figure 1-1) contains an FDA table made up of a large and changing number of parameters (from flight to flight). The job of the SM software is to monitor these parameters and alert systems software if an out-of-limits condition is found. If an out-of-limits condition is found, SM software sets the out-of-limits flag and tells SS/W what fault message to use and what the alarm class will be. Then SS/W generates the appropriate message, alarm, and tone.

All backup C&Ws are class 2. Only those SM backup C&W alarms that are produced by FDA can be changed and displayed in engineering units. These limits are accessed through the SM table maintenance SPEC (PASS SM SPEC 60) or via TMBU command. The remaining backup C&W alarms, produced by the GNC program, are accessed through the GPC mass memory read/write procedure. A backup C&W out-of-tolerance condition will trigger a C&W MA, light the backup C&W alarm light on panel F7, and display a message on the fault message line and fault summary page. GNC-detected class 2 C&W limit violations also drive an additional command out the flight MDM to annunciate a hardware C&W condition.

The SM alert program is another portion of the SM program and operates similarly to the backup C&W system. The alert program is designed to inform the crew of a situation that may be leading up to a C&W, or a situation which may require additional procedures. The alert program was intended to be used for parameters that are not as critical as those covered by hardware C&W. However, there are exceptions to this now: fuel cell delta volts, fuel cell end cell heater fail on, etc. The alert program is different from the backup C&W system in that it has subroutines that accomplish precondition steering and can compare up to three limit sets for a parameter. The precondition steering selects which set of limits is in effect, as discussed earlier. When an SM alert parameter exceeds its limits, the SM light is illuminated, a discrete is sent to the primary C&W system to turn on the alert tone, and the SS/W displays a message on the fault message line and the fault summary page.

SM also contains the capability to perform scaling on all data acquired in order that the parameter values and states may be displayed in calibrated engineering units.

In comparison to the PASS SM software, the BFS SM software has several limitations:

- A reduced number of alert parameters
- Only 5 BFS displays compared to over 30 PASS SM displays
- Only one value for the N-counter filter associated with false alarm avoidance (N = two samples)
- The limit sense capability is not adjustable, except by TMBU
- A reduced number of precondition processes

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## **Precondition Processing**

Precondition steering is a software function that selects limit sets for FDA. The difference between PASS and BFS preconditioning is that the PASS has one large block of software that performs all preconditioning as opposed to the BFS SM software which has small subroutines that perform each preconditioning function.

#### **BFS SM Precondition Processing**

The BFS SM software contains the following preconditioning processing functions:

- FC STACK T fuel cell stack cool out temperature The three fuel cells stack cool out temperature parameters have multiple limits for FC STACK T high. These variable upper limits depend on the power output of the
- fuel cell (see page 5-15, fuel cells total current and power computation), and an SM alert, class 3 alarm, is generated when these limits are exceeded. This precondition processing is the same in the SM PASS software except that the PASS also has variable lower limits.

Precondition (power output)	SM alert limit High limit (deg F)
<3.5 kW output	212
3.5 - 7.5 kW output	222
>7.5 kW output	238

• APU SPEED - auxiliary power unit (APU) turbine speed -The three APU speeds shall have two upper alarm limits, depending upon whether or not the cockpit switch setting for APU speed is high or normal. There is only one lower limit. If the APU speed is set to normal, an SM alert, class 3 alarm, is generated if the speed violates 112 percent, and a backup C&W, class 2 alarm, is generated if the APU speed is set to high and the speed violates 122 percent. This precondition processing is not in the PASS SM software.

- Inertial measurement unit (IMU) fan preconditioning -Since only one of three IMU fans is on at a time, the three IMU fan speed measurements are preconditioned so as to FDA only the fan which is turned on. This precondition processing is different in the PASS SM software, see page 4-4.
- Gearbox lube oil pressure preconditioning The three gearbox lube oil out pressure measurements are preconditioned so that the FDA alarm is inhibited when the APUs are off. An APU shall be regarded as off if its turbine speed is less than 40 percent. A time delay of 10 seconds shall elapse after each precondition change before limit testing begins. This precondition processing is the same in the PASS SM software.
- Power reaction storage and distribution (PRSD) fuel cell power (FCP) reaction valve preconditioning Each of the three reaction valves (REAC VLV) discretes for the SM SYS SUMM 1 display is derived from the oxygen (O<sub>2</sub>) and hydrogen (H<sub>2</sub>) valve positions. An open display indicator will reflect that both the O<sub>2</sub> and H<sub>2</sub> valves are open. A closed display indicator will reflect that either one or both valves are closed. This precondition processing is the same in the PASS SM software.
- Partial pressure O<sub>2</sub> (PPO2) During the postlanding BFS transition to OPS 0, the backup C&W (class 2) lower limit on PPO2 is lowered from 2.7 to 2.4. This precondition processing is not in the PASS SM software.

- Tire pressure monitoring Each of the six Orbiter tires contains two pressure sensors. The output from these sensors is displayed on the BFS THERMAL display SMO. If any of these 12 sensors detect a tire pressure below 50 pulse code modulation (PCM) counts (256 psi), an SM class 3 FDA/annunciation will occur. Since the crew cannot take protective actions once touchdown has occurred, these tire pressures sensors are inhibited for FDA when the LANDING GEAR DOWN discrete is activated. This precondition processing is not in the PASS SM software. This process is scaled and displayed in OPS 0, 1, 3, and 6; but the FDA is performed in OPS 3 and 6 only. Tire pressures are also available onorbit in SM OPS 2 and 4 via HYD THERMAL display (SPEC 87).
- SM brake pressure monitoring There are two brake skid/control modules for each of the four main gear tires, left outboard, left inboard, right outboard, and right inboard for a total of eight modules. Each of these 8 modules contains 2 brake pressure sensors for a total of 16 sensors. The output from these sensors is displayed to the BFS THERMAL display (SMO). If any of the 16 sensors detect a brake pressure above 180 psia,
- an SM class 3 FDA/annunciation will occur. Preconditioning inhibits the 16 brake pressure sensors from FDA when the LANDING GEAR DOWN discrete is activated. The landing gear deploy sequence is performed approximately 10 seconds from touchdown. The FDA is inhibited prior to touchdown due to the hydraulic spike caused by main gear touchdown. This hydraulic spike would cause alarms if the FDA were not inhibited. This precondition processing is not in PASS SM software. This process is scaled and displayed in OPS 0,1,3, and 6 but the FDA is performed in OPS 3 and 6 only.

However, for the first flight, Space Transportation System (STS) 26, all 16 sensors will not be working. The 16 sensors are divided into 8 A sensors and 8 B sensors. For the first flight, the eight B sensors will not be on the vehicle and, therefore, will not be on the BFS THERMAL display (SM0).

#### **PASS SM Precondition Processing**

The PASS SM software uses precondition processing to perform the following operations:

- APU OIL OUT P Preconditioning sets two low alarm limits for APU OIL OUT P, one for when the APU is OFF (P = 0) and one for when the APU is ON (P = 25).
- CRYO TANK PRESSURE Preconditioning sets to low alarm limits for cryo 02 and cryo H2 tank pressures, one for when the cryogenic heaters are in ON or AUTO and a different limit for when the heaters are OFF. This preconditioning process was added prior to STS-26. In the past we only had one low limit for cryo pressure and this limit was too low to protect us from operating the heaters when the cryo was below its critical pressure. The cryo heaters are designed to work in a single-phase fluid, and if the pressure gets too low, pockets of gas will form in the tanks. This new preconditioning raises the low pressure limit so that we will be warned if the tank pressure goes below the cryo's "critical pressure," and we will be warned earlier about tank leaks.

#### **CRYO TANK P LOWER LIMITS**

	O <sub>2</sub> tank P	H <sub>2</sub> tank P			
HTR OFF	HTR ON or AUTO	HTR OFF	HTR ON or AUTO		
575	740	165	189.8		

The upper limit for  $O_2$  tank pressure is always 960 psia, and the upper limit for  $H_2$  tank pressure is always 283 psia.

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- EVAP TEMP HI LOAD INBD DUCT Preconditioning sets
- two low alarm limits for this parameter, one for when the HI LOAD DUCT HTR is ON (T = 150) and one for when the HI LOAD DUCT HTR is OFF (no low limit).
- FC STACK T Fuel cell stack cool out temperature The three fuel cells have variable upper and lower SM alerts depending on the fuel cells power outputs (see Page 5-15, Fuel Cell Total Current and Power Computation).

Precondition (power output)	SM ale (d	ert limits deg F)
	Low	Hỉgh
<3.5 kW output	180	212
3.5 - 7.5 kW output	190	222
>7.5 kW output	198	238

- FREON FLOW Preconditioning sets two low alarm limits for the Freon flow depending on the position of the FLOW PROP VLV. If the valve is in INTERCHANGER the low limit is 1950 lb/hr, and if the valve is in PAY-LOAD the low limit is 1300 lb/hr.
- FREON LOOP PL HX FLOW Preconditioning sets two low alarm limits for the Freon flow through the payload heat exchanger (HX) depending on the position of the FLOW PROP VLV. If the valve is in INTER-CHANGER the low limit is 187.5 lb/hr, and if the valve is in PAYLOAD the low limit is 500 lb/hr.
- H<sub>2</sub>O LOOP ICH FLOW Preconditioning allows any position of the H<sub>2</sub>O loop pump switch to be selected (ON, GPC, OFF) and still have the same low limit for the H2O LOOP ICH FLOW (550 lb/hr).
- H<sub>2</sub>O LOOP PUMP OUT P AND PUMP OUT ΔP Preconditioning allows the C&W SM alert system to give

different alarms depending on the switch position the  $H_2O$  loops are in.

	PUMPOUT P PUMPOUT $\Delta \dot{P}$				
	Low	High	Low H	igh	
Loop 1 pump switch ON or GPC and either pump com- manded ON	50	70	33	46	
Loop 1 pump switch OFF	20	None	None	5	
Loop 1 pump switch GPC and neither pump running	20	None	None	5	
Loop 2 pump switch ON or GPC and pump commanded ON	o 50	75	33	46	
Loop 2 pump switch OFF or GPC and pum not commanded ON	p 20	None	33	46	

- HUMID SEP Preconditioning sets up variable SM alert alarm indications for the two different switch positions of the two humidity separators (ON and OFF).
  - If both humidity separators are OFF preconditioning generates an alarm.
  - If any humidity separator is ON but not operating at the correct speed an alarm is generated.
  - If either humidity separator is OFF but the speed indication is still good, an alarm will be generated.

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- HYD CIRC PMP P Each of the three hydraulic systems has two limit sets depending on whether the CIRC pump is ON or OFF. If the CIRC pump is on or commanded on by the GPC, an SM alert will be generated if the HYD CIRC PMP P drops below 100 psi. If the CIRC pump is OFF or commanded OFF by the GPC, an SM alert will be generated if the HYD CIRC PMP P is above 100 psi.
- IMU fan Preconditioning sets up variable SM alert alarm indications for the different switch positions of the IMU fans.
  - If all three fans are OFF, preconditioning selects limits that generate an alarm.
  - If any IMU fan is on but not operating at the correct speed, an alarm will be generated.
  - If any IMU fan is OFF but still has a good speed indication, an alarm will be generated.
- W/B BLR T Preconditioning sets two upper limits for the water spray boiler temperature (W/B BLR T) depending on the switch position of the BOILER CNTLR PWR/HTR (A, OFF, or B). If the switch is in A or B the upper limit is 120°, and if the switch is in OFF the upper limit is 209°.
- W/B REG P and W/B TANK T Preconditioning sets two SM alert alarm limits for these parameters depending on the switch position of the BOILER CNTLR PWR/HTR. If the switch position is in A or B these parameters have set upper and lower limits. If the switch is in OFF these parameters do not have any limits.

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# **Section 5: Special/Mission-Selectable Processes**

Special processes and mission-selectable processes (MSPs) provide specialized computations and processing sequences to determine and control the status and performance of various vehicle subsystems and payloads. Table 5-1 contains a list of all the SM special processes, MSPs, and their software locations. The table shows us that different SM special/mission-selectable processes will be available depending on the flight phase and the corresponding GPC software that is functioning. There are three categories of special processing software:

- 1. BFS SM special processing
- 2. PASS SM special processing
- 3. Both BFS and PASS SM special processing

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### Table 5-1.– SM special/mission-selectable processing.

	BFS SM	PASS SM	Both BFS and PASS SM
Special processes	V		
Cabin pressure monitor	X	-	-
Flash EVAP/NH <sub>3</sub> boiler ACT/DEACT	X	-	-
Freon pump power management	Х	-	-
Fuel cell auto purge sequence	-	Х	-
Hydraulic fluid onorbit temperature control sequence	-	Х	-
0 <sub>2</sub> /N <sub>2</sub> quantity computation	-	X	-
Recorder tape position	-	Х	-
Standby water coolant loop temperature control	-	Х	-
Remote manipulator system control	-	Х	-
Antenna management	-	-	Х
APU fuel quantity computation	-	-	X
Fuel cell end cell heater monitor	-	-	X
Fuel cells total current and power computation	-	-	X
Hydraulic water boiler quantity	-	-	Х
Payload bay door sequence	-	-	X
Mission-selectable processes Spacelab serial interface function	-	x	-
SSUS sequence control process	-	Х	-
IUS GNC data transfer	-	Х	-
Payload control supervisor sequence control	-	Х	-
Standard GNC data transfer	-	-	Х

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### **Special Processing**

#### **BFS SM Special Processing**

The BFS has the following SM software special processes:

- Cabin pressure monitor
- Flash evaporator/ammonia boiler activation/ deactivation
- Freon pump power management

These processes are only in the BFS SM software. There are other special processes that are in both the PASS and

BFS and they will be discussed later (see page 5-12).

**Cabin Pressure Monitor (Backup dP/dT)**. The cabin pressure monitor is used to determine the cabin pressure change rate. The change rate will be displayed on the BFS SM SYS SUMM 1 display, and if out of limits, a class 3 alarm and CRT message will be issued.

The cabin pressure monitor is initiated anytime the BFS GPC is in standby or run. This means that the backup dP/dT calculation is available no matter what OPS mode the BFS is in. The cabin pressure monitor will be scheduled to run in OPS 0 on the pad, in OPS 1 during ascent, and OPS 3 or 6 during entry, and it will operate both pre- and postengaged. This process is also available in BFS OPS 0 onorbit by simply taking the BFS GPC to standby. The process generates the cabin pressure change rate using cabin pressure readings over a 30-second time period. This change rate is sent to the BFS SYS SUMM 1 CRT display. This change rate is also compared to a high limit value (I-load, nominal -0.12 psi/min). If the change rate exceeds this limit for two consecutive cycles of the program, fault annunciation for that parameter will be enabled. The process shall monitor the input parameter and perform the calculation at least once every five major cycles (for this SM process a major cycle is performed once a second). Therefore, after the first calculation an updated backup dP/dT calculation will be performed every 5 seconds.

	XXXX/XXX/078 SM S	SYS SUMM 1	XX X DD	D/HHINNISS	
	EMERGENCY	1	BE2 DD	U/ HHI MMI SS	
	SMOKE 1/A 2/B AV BAY 1 XX, XS XX, XS	DC VOLTS	1/A XX. XS. X	2/B 3/C	
	2 XX. XS XX. XS	MAIN		ŷ. ŷs ŷŷ. ŷs	
		BC	$\hat{\mathbf{x}}$ $\hat{\mathbf{x}}$ $\hat{\mathbf{x}}$ $\hat{\mathbf{x}}$ $\hat{\mathbf{x}}$	X. XS XX. XS	
		ESS CA	XX.XS X XX.XS X	X.XS XX.XS X.XS XX.XS	
	PRESS XX. XS	AC			
	FAN $\Delta P$ X. XXS X. XXS		XXXS XXXS	XXXS XXXS XXXS XXXS	
	HX OUT T XXXS O2 FLOW XX.XS XX.XS	AMPS O A	XXXS XX.XS X	XXXS XXXS X.XS XX.XS	
	N2 FLOW XX. XS XX. XS	0 B	XX.XS X	X. XS XX. XS	
	IMU FAN AXS BXS CXS	FUEL CELL	PĤĴŽŶŜ		
	SS1 XXXS XXXS XXXS	REAC VLV	XXS	XXS XXS	
	SS2 XXXS XXXS XXXS SS3 XXXS XXXS XXXS	EXIT T		XXXS IXXXS XXXS XXXS	
	TOTAL AMPS XXXXS	COOL P PUMP	XXXS XXS	XXXS XXXS XXS XXS	
		I		· (XX	)
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#### Figure 5-1.– SM SYS SUMM 1 display.

#### Flash Evaporator/Ammonia Boiler Activation/

**Deactivation**. The active thermal control system (ATCS) contains two Freon loops which operate simultaneously throughout the mission. The flash evaporator and the ammonia boiler are two of the heat sinks that provide cooling to these Freon loops during different portions of the mission (ground support equipment (GSE) and the radiators also provide cooling to the Freon loops).

The flash evaporator requires a vacuum in which to operate. Therefore, this BFS SM process activates the flash evaporator during ascent at major mode (MM) 103 transition and solid rocket booster (SRB) separation, and deactivates it during entry at MM 305 transition (603 for return to launch site (RTLS)). The flash evaporator has three controllers, which regulate the water flow. Only one controller is used at a time, and it can service both evaporators. When the Orbiter reaches the appropriate phase during ascent, commands are issued to all three flash evaporator controllers. But only the controller with its respective panel switch in the GPC position will be activated. The commands are terminated during the appropriate phase during entry or RTLS.

The ammonia boiler is not nominally activated by the software during entry, but the GPC has the capability to turn it on for RTLS, transatlantic abort landing (TAL), and abort once around (AOA) aborts as cooling requirements dictate. For an RTLS this BFS SM process activates the ammonia boiler (if switch is in GPC) during entry at MM 602 transition. For a TAL, AOA, or a situation in which radiator cooling is not available, the ammonia boiler is activated during entry by this BFS SM process when the specified altitude (usually 120,000 ft) is reached in MM 304 or at MM 305 transition, whichever occurs first. If the Orbiter is above the MM 305 transition, activation of the ammonia boiler causes the flash evaporator system to shut itself down by way of its own undertemp shutdown logic. There are two ammonia systems, each with a controller to regulate the ammonia flow. Both systems operate independently and service both Freon loops (only one system is used at a time; i.e., like the flash evaporator system, only one controller has its switch in the GPC position).

Each controller for the flash evaporator and the ammonia boiler has a panel switch with an ON, OFF, and GPC position. When the controllers are in the GPC position, this BFS SM process automatically controls these systems (see figure 5-2, panel L1).

Both the flash evaporator and the ammonia boiler are initialized to OFF in OPS 1. In OPS 3 or 6, the flash evaporator is initialized to ON, and the ammonia boiler is initialized OFF. In OPS 0 the flash evaporator is initialized OFF. Also, in OPS 0 the ammonia boiler is initialized OFF unless the OPS transition is from OPS 3 (MM 305) or OPS 6 (MM 603), in which case it is initialized ON. This was done to allow ammonia boiler activation on the ground.



Figure 5-2.– Panel L1.

**Freon Pump Power Management**. The Freon pumps power management special process when enabled provides for automatic reconfiguration of the Freon pumps during a failure that results in the main bus volts, dropping below 20 volts direct current (VDC). The backup flight computer is used to perform this special processing requirement during the ascent phase, (MMs 101 to 106). If the BFS goes to OPS 0 or any other OPS besides 101 through 106, the pump ON commands will be terminated.

The present power profile requirement dictates that for the ascent phase, Freon loops 1 and 2 will have their respective pump A operating. The Freon pump A, loop 1, is powered from main A, and Freon pump A, loop 2, is powered from main C. During ascent, this special process monitors the voltage of main buses A and C. The associated measured value is obtained from the Orbiter instrumentation data. If the measured value of main A voltage falls below 20.0 VDC, the GPC issues the Freon coolant loop (FCL) 1 pump B-ON command. When the bus voltage is restored, the FCL 1 pump B-ON command is terminated. If the measured value of main C voltage falls below 20.0 V, the GPC issues the FCL 2 pump B-ON command. When the bus voltage on main C is restored, the FCL 2 pump B-ON command is terminated.

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### **PASS SM Special Processes**

- Fuel cell auto purge sequence
- Hydraulic fluid onorbit temperature control sequence
- O<sub>2</sub>/N<sub>2</sub> quantity computations
- Recorder tape position
- Standby water coolant loop temperature control

These are the SM processes that are only in the PASS SM OPS 2 and 4 software. There are other special processes that are in both the BFS and the PASS, and they will be discussed later (see page 5-12).

#### Fuel Cell Auto Purge Sequence

The fuel cell auto purge sequence is used during the orbit phase to maintain fuel cell operating efficiency. The auto purge sequence is available in PASS SM OPS 2 and 4 software. The fuel cells are normally purged 2 minutes every 8 hours in order to minimize the drop in fuel cell efficiency. The fuel cell auto purge sequence is provided to release the crewmembers' attention to purge activity and permit the performance of other functions. The auto purge program turns on the purge line heaters, provides for sequential purging of each fuel cell, and then turns off the purge line heaters. This auto sequence does not allow OPS transitions. If an auto purge is started in OPS 2 or 4, the Orbiter software should remain in that OPS until the purge is completed. Any change in OPS modes will result in all the auto purge commands, being cancelled. One possible result of an OPS transition during a purge could

be a frozen purge line since the purge line heaters are commanded off when an OPS transition occurs.

To purge the fuel cells, the crew selects the GPC position for the purge control heaters. The fuel cells to be purged are selected and the respective purge valve switch is positioned to GPC. To start the purge sequence, the crewmember selects and holds the momentary START position of the PURGE SEQ START switch until verification of GPC ON event indication which will occur only if one or more purge valve switches are in GPC. If the procedure is done incorrectly and the software detects that the auto purgeon line signal has been lost after the GPC auto sequence has been initiated, an "FC PURGE SEQ" fault summary message (FSM) will occur. Upon satisfying the start conditions, the GPC issues the purge control heaters ON commands and begins monitoring the O<sub>2</sub>/H<sub>2</sub> vent line heater temperatures. This sequence allows a maximum time of 27 minutes for the vent lines to reach the proper temperature. If the temperatures are below the specified limits, after 27 minutes have elapsed, the crew receives a CRT message "FC PURGE TEMP FAIL," a class 3 alarm is generated, and the sequence stops the purge.

After the vent temperatures have reached the prescribed limits, the GPC determines which fuel cell is selected for purging and issues O<sub>2</sub>/H<sub>2</sub> purge valve open commands for the selected fiel cells. The fuel cells are purged sequentially 1, 2, then 3, if their purge switches are in the GPC position. A flow computation is performed to verify that the valves have opened. If a valve fails to open a CRT message, "FC PURGE" and a class 3 SM alert are generated; commands are issued to close the valves but the purge heaters will remain on to permit the next selected fuel cell to be purged. When the valves open, the selected fuel cell is purged for a minimum of 2 minutes. The purge valves are then commanded closed. Another flow computation is performed to verify that the valves have closed. If a valve fails to close, a CRT message "FC PURGE" and a class 3 SM alert are generated, all purge valve open commands are terminated, and the purge vent line heater ON commands remain for 30 minutes to bake out the lines. When the valves close, the sequence proceeds to the next selected fuel cell to be purged.

However, in the present configuration the flow checks mentioned above have been negated (overridden) because of the unreliability of the O<sub>2</sub>/H<sub>2</sub> flow transducers.

The duration of the purge sequence is a changeable constant via the table maintenance function. Its normal value is 2 minutes.

After all the selected fuel cells have been purged, the vent line heaters remain on for 30 additional minutes and then are commanded off by the GPC. The program then recycles back to start and looks for the next fuel cell auto initiation by the crew.

# Hydraulic Fluid Onorbit Temperature Control Sequence

During the onorbit phase, the three hydraulic systems will be subject to periods of prolonged cold. In order to maintain the hydraulic fluids at acceptable operating temperatures, the hydraulic system circulation pumps (circ pumps) will be turned on and the hydraulic fluid will be circulated through the ATCS/hydraulics heat exchanger where heat will be added. The hydraulic fluid onorbit temperature control sequence is the primary mechanism for cycling the circ pumps on and off. This sequence is available only in SM OPS 2 and 4. A transition to any other OPS will result in all sequence commands, being terminated. A transition

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between OPS 2 and 4 will also stop all sequencing commands, but the sequence will start up again without any adverse effects. The circ pump control parameters can be monitored on the HYD THERMAL display (DISP 87).

Another responsibility of this sequence is to maintain the bootstrap accumulator pressure in the three hydraulic systems. The bootstrap accumulators are used to provide head pressure for the hydraulic main pumps. Circ pumps are used onorbit to automatically recharge the accumulators in the event of a pressure decrease in the bootstrap system. The accumulator pressure management software turns on a circ pump if the accumulator pressure for one of the three hydraulic systems is below a predefined low limit of 1960 psi and greater than 32 psi. The 32-psi low limit is to prevent a transducer loss from running a pump unnecessarily. The circ pump will be commanded on for accumulator recharging immediately with no time delay. The software will run the pump until the accumulator pressure timer (a changeable value set at 2 minutes) has

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The hydraulic fluid onorbit temperature control sequence is enabled when the crew selects the GPC switch position for any of the three hydraulic system circ pumps. However, because of a software lockout, the APUs START/RUN switch must be off for this sequence to be enabled. The GPC monitors selected temperature sensors and the accumulator pressures for each hydraulic system under GPC control and commands the circ pumps on or off in the order that each hydraulic system requires activation. Manual ON/OFF positions are also available for the crew to manually cycle the circ pumps (see figure 5-3, hydraulic circ pump switches on panel R2).

elapsed and accumulator pressure is above 1960 psi.

Accumulator pressure management software takes priority over thermal conditioning software. The accumu-

lator pressure management software will turn off any circ pump which the thermal conditioning software has been running. However, accumulator pressure management software may run up to all three circ pumps simultaneously, if required, to recharge more than one bootstrap system. Therefore, even if two circ pumps are manually on, the third system will come on if a hydraulic accumulator pressure below 1960 is detected.

The thermal conditioning software operates the circ pumps onorbit for circulating hydraulic fluid to keep fluid temperatures above low limits and maintain fluid viscosity at acceptable levels for hydraulic main pump startup.



Figure 5-3.- Hydraulic circ pump switches on panel R2.

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The thermal conditioning software will only run one circ pump at a time. If the thermal conditioning software detects any circ pump pressure to be above 100 psi, it will not activate another circ pump. Therefore, if one of the circ pumps has been turned on either manually or by the SM GPC software, it will prevent the other two circ pumps from operating. The software will run pumps consecutively based on a priority system if more than one hydraulic system requires thermal conditioning.

The thermal conditioning software will set a circ pump to come on if one or more of the temperature control sensors in a system falls below the pump turnon limit, (either 0° or -10° F depending on the sensor). The thermal conditioning software features a startup time delay. After a circ pump has satisfied the turnon requirements, the start-

<sup>b</sup> up delay timer will have to expire before the circ pump is actually turned on. The start delay timer is set at 1 minute and is a changeable constant via the table maintenance function. A circ pump will therefore normally be turned on 1 minute after its temperatures fall below the turnon limits. If circ pumps are running consecutively for thermal conditioning, their runs will be separated by the 1-minute startup time delay.

The GPC commands a circ pump off when the following conditions are satisfied: (1) all temperature sensors in a hydraulic system are above the upper turnoff limit of 20°F, (2) a circ pump commanded on for out-of-limit temperatures has been on for a period in excess of a specified circ pump minimum run time (15 minutes for hyd sys 1, 10 minutes for hyd sys 2 and 3) and a second hydraulic system requires circulation, or (3) one of the hydraulic systems has a low accumulator pressure (accumulator pressure low overrides minimum run time and temperature constraints). The sequence is also capable of operation in a timer mode. The thermal conditioning software may be used to cycle two or three circ pumps at regular intervals for specified amounts of time. This is done by changing turnon /off limits for one sensor in each system so that the software thinks all three circ pumps need to run. The startup delay timer and thermal control timer values are then changed to regulate when and for how long the circ pumps will cycle.

Temperature sensor low and high limit values, circ pump pressure low limit values, circ pump start delay time, and circ pump minimum run time are changeable through the table maintenance (TM) constants change capability available on SM SPEC 60.

The following examples are included to help clarify circ

CASE 1:

Circ Pump Control Switch Position

CIRC PUMP

ON GPC GPC

In this configuration neither circ pump 2 or 3 will come on because the circ pump software pressure limit of 100 psi is exceeded by system 1, and the software will not command a second system on.

However, with circ pump 1 on, systems 2 and 3 can be commanded on by the GPC if its accumulator pressure falls below limits, regardless of a system already in operation. Low accumulator pressure is of a higher priority than running two circ pumps simultaneously.

#### CASE 2:

CIRC PUMP 1 2 3

GPC GPC GPC

If circ pump 1 is commanded on for low hydraulic temperatures and system 2 or 3 accumulator pressure begins to drop, then the GPC will command circ pump 1 off and turn 2 or 3 on. The bottom line is that maintaining accumulator pressure takes precedence over low hydraulic temperatures, and running one pump at a time is desired over commanding a second pump on simultaneously.

#### O<sub>2</sub>/N<sub>2</sub> Quantity Computation

**O**<sub>2</sub> **Quantity Computation**. The O<sub>2</sub> quantity computation for the emergency O<sub>2</sub> tank is used during the orbit phase to determine the status of the high pressure O<sub>2</sub> supply. This oxygen source is used as an emergency backup for cabin atmosphere in the event of excessive leakage of cabin pressure and emergency breathing.

The quantity of  $O_2$  gas, in terms of weight, is computed by using the pressure, volume, and temperature (PVT) relationship for the tank. The computation uses the measured tank temperature and the manifold pressure. The result of this computation, in pounds remaining, can be made available on the environmental display (DISP 66) available in SM OPS 2 and 4. However, at the present time the Orbiter does not carry the emergency  $O_2$  tank, but this O<sub>2</sub> computation capability is still available should the tank be put back on the Orbiter.

**N2 Quantity Computation**. The N2 quantity computation for the two system 1 and two system 2 N2 tanks is used during the orbit phase to determine the status of the N2 system. N2 is required to replenish the cabin atmosphere and maintain proper cabin air mixture, and also for pressurization of the water and waste tanks.

The quantity of N<sub>2</sub> gas, in terms of weight, is computed by using the PVT relationship of each tank. The amounts of N<sub>2</sub> of the two system 1 tanks are combined to provide a quantity for system 1, and the same is performed for system 2. The temperature is measured in each tank, and a manifold pressure common to the two tanks in each system is required to perform the computation for each tank. The results of these computations, system 1 supply quantity and system 2, are on the environmental display (DISP 66) available in SM OPS 2 and 4.

#### **Recorder Tape Position Computation**

The recorder tape position computation gives the Orbiter the capability to display the current tape position for the recorders expressed as a percentage of recorder tape length.

Recorder tape position is computed for two operational recorders (RCDR OPS 1 and RCDR OPS 2) and for the payload recorder (RCDR PL) by the recorders themselves. The computation consists of decoding for each recorder of the binary code, as represented by five bits, and of linear scaling conversion to engineering units. This special process then takes these engineering units and calculates

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the tape position as a percentage of the recorder tape length.

The recorder tape position computation is available in PASS SM OPS 2 and 4 and the computed values are displayed on the COMM/RCDR display (figure 5-4). An OPS transition will have no effect on this process because the recorders are doing the calculation of recorder use in engineering units, and this process is simply converting those engineering units to a percent of tape length.

#### Standby Water Coolant Loop Temperature Control

The atmospheric revitalization system (ARS) has two water coolant loops. Loop 1 has two pumps (only one operates at any given time), and loop 2 has one pump. The function of the water coolant loops is to maintain equipment and cabin temperatures throughout the mission.

Only one loop (loop 2) is needed for all phases of flight. For the onorbit phase, only one loop (loop 2) is required for continuous operation with the other loop (loop 1) in the standby mode. To prevent the water in the standby loop from freezing, this sequence will periodically operate the loop 1 pump to circulate the water. Both H<sub>2</sub>O loops have a GPC position and, therefore, can be operated by the standby H<sub>2</sub>O coolant loop temperature control sequence.

In the nominal time line, after the payload bay doors are opened, the crew will place water coolant loop 1 in the

XXX/XXX/076 S-BAND PM XPND MODE SPD SPEC RANGING PREAMP FREQ PWR AMPL OPER STBY	CO XXXS XXXS XXXS XXXS XXXS XXS XXS XXXS	MM/RCDR KU-BAND PA TEMP GMBL TEM SPD SPEC CCTV CNTL UNI CAM OVEF	XX X 1P 2 Y X-TEMP	DDD/HH: DDD/HH: ±XXXS A±XXXS B±XXXS XXXS XXXS XXXS XXXS	MMI SS MM∎ SS
NSP FR SYNC 1 2 FAIL SAFE DATA XMIT RCV UL DATA CODING XMIT RCV RCDR INPUT	XXXS XXXS XXS XXS XXS XXXS XXXS XXXS	GCIL CONF RECORDERS MODE TRK DIR %TAPE TAPE TEMP BITE	OPS 1 XXXXS XXS XXS XXXS XXXX XXXS XXXS XX	OPS 2 XXXXS XXS XXXS XXXS XXXX XXXS XXXS X	XXXS PL XXXS XXS XXS XXS XXXS XXXS XXXS



standby mode by changing the selected pump's panel switch position from OFF to the GPC position. When the payload bay doors are closed, the standby loop is returned to the OFF position.

The sequence operates in SM OPS 2 and 4, and is initiated when OPS 2 or 4 is initiated. Each time either SM OPS becomes active or when an "X" minute expires, commands are issued to all three pumps. Only the pump with its respective switch in the GPC position will turn on. The selected standby pump will operate for "Y" minutes. The computer then terminates the pump ON commands and adds "X" minutes to the Greenwich mean time (GMT). This value is stored and becomes the "X" minute timer. When the current GMT becomes equal to or greater than the stored GMT plus "X" minutes, the computer issues the pump ON commands, and sets the "Y" minute timer. When the "Y" minute timer expires, the pump ON commands are terminated, and a new "X" minute timer value is set. The sequence continues to cycle until the Selected SM OPS is terminated.

The "X" and "Y" minute timers are changeable constants via the TM function. Their values are subject to vehicle attitude. Their values as of January 1, 1988, are 50 hours and 6 minutes, respectively.

The sequence will not verify that the standby pump responds to GPC commands, nor issue any crew alerts if it does not. Crew alerts will be provided by the SM FDA function through its evaluation of water loop temperatures and pump operating performance.

# Both BFS and PASS SM Special Processes

- Antenna management
- APU fuel quantity computation
- Fuel cell end cell heater monitor
- Fuel cells total current and power computation
- Hydraulic water boiler quantity
- Payload bay door sequence

These are the SM special processes that are in both the BFS software and PASS OPS 2 and 4 software.

#### Antenna Management

The antenna management function, resident in the SM software, is used to automatically control the Orbiter S-band and Ku-band antenna systems.

During the ascent and entry mission phases, the antenna management function program, resident in the BFS, controls the selection of the most effective S-band antenna based on the relative locations and attitude of the Orbiter and the location of a receiving station. During the orbit phase the antenna management function, resident in the PASS SM OPS 2 and 4 software, not only performs S-band antenna selection but, after the Ku-band system has been deployed and activated, the antenna management function also directs the Ku-band antenna angles for Tracking and Data Relay Satellite (TDRS) operation. The Ku-band antenna functions strictly through TDRS while the S-band antenna uses both ground stations and TDRS.

Onorbit the PASS SM antenna management software also provides the GNC flight software with a site-in-view flag that is used to provide uplink block for the Orbiter. This computed site-in-view flag determines acquisition of signal (AOS) and loss of signal (LOS) time periods of the ground stations and of TDRS. Uplink block is used to prohibit unauthorized command sources from reaching the Orbiter. (Note: The uplink block function is not required in the encrypted mode, which is the normal mode of operations.)

Figures 5-5 and 5-6 show how the S-band and Ku-band antenna systems interface with the antenna management software, the SM GPC, and payload MDMs.

S-Band Antenna Management. The antenna management program, depending on the commanded Orbiter transponder mode (TDRS/Space Tracking and Data Network/(STDN)/Space Ground Link Station (SGLS)), automatically selects one of the four S-band phase modulation (PM) antennas plus the forward and aft directivity of the antenna selected. The automatic selection can be overridden by:

- Ground command (provided the GPC antenna command function is inhibited)
- Crew switch selection

One of the two S-band frequency modulation (FM) antennas is selected in the same manner as the S-band PM antenna, with the exception only ground coverage is available. Indications of the antenna selection are visible to the crew on an Orbiter dedicated antenna CRT display, OPS 20X (40X) and by Mission Control Center (MCC) flight controllers via the Orbiter telemetry system.

The antenna management function attempts to make an S-band antenna selection once every 2 seconds.



Figure 5-5.– S-band designated steering.



Figure 5-6.– Ku-band designated steering.

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Ku-Band Antenna Management. The Ku-band antenna management sequence consists of the following functions: selection of target (either TDRS or a satellite to rendezvous with) available for use, computation of antenna pointing angles, and commanding the antenna to the selected target.

These functions shall be performed cyclically. In addition to the above functions, the capability exists to control the auto acquisition sequence of the Ku-band antenna for acquisition of either the selected TDRS (for communications) or the GNC designated target (for rendezvous operations).

Command data for Ku-band antenna management is transmitted via the PL MDM (PF1). The ground has the capability to bias the antenna management line-of-sight vector to compensate for errors in the antenna management processing. By biasing the antenna management line-of-sight vector, the ground can fine tune the selected antenna angles. The crew can override the antenna management antenna selections via a switch throw. Indications of Ku-band antenna selection are visible to the crew on an Orbiter dedicated display OPS 20X (40X) and digital readout. MCC monitors antenna selection via the Orbiter telemetry system.

The antenna management program routes antenna steering data to the Ku-band antenna system once every 2 seconds.

**TDRS**. Antenna management obtains the TDRS state vector and the Orbiter state vector and attitude to make S-band antenna selections and to determine the Ku-band pointing angles.

The state vector referred to above is the location of an object with respect to the latitude, the longitude, and the center of the Earth.

#### **Auxiliary Power Unit Fuel Quantity Calculation**

The purpose of the APU fuel quantity calculation sequence is to calculate the quantity of the hydrazine fuel remaining in each of the three APU fuel tanks. The APU fuel is stored in a diaphragm-type tank with nitrogen used as the pressurant. The PVT method is used to determine the volume of nitrogen, which in turn is subtracted from the volume of the fuel tank to arrive at the quantity of fuel remaining. Fuel tank temperature and pressure are the primary parameters for calculating APU fuel quantity. To back up these parameters, uplink capabilities are provided to select an alternate fuel tank outlet pressure sensor and a best predicted value for fuel tank temperature.

The sequence operates in all OPS modes of the BFS and in PASS SM OPS 2 and 4. The output from the APU fuel quantity calculation is displayed on a meter and on the APU/HYD display (DISP 86) in SM OPS 2 and 4, and on SM SYS SUMM 2 (DISP 79) during all flight phases (BFS and PASS SM).

The APU fuel quantity calculation is active during prelaunch and remains active during all flight phases. Sequence inputs are accessed at a rate sufficient to perform the calculations, once per two major cycles

(2 seconds). Inputs to the sequence are the following for each APU: fuel tank temperature and pressure, fuel tank outlet pressure, and the constants specified in the detail requirements. The mass of nitrogen loaded into each APU tank is calculated prior to each flight by ground software and must be entered into the sequence via uplink in order to produce a correct calculation for APU fuel quantity. Prior to uplinking the actual value for nitrogen, mass I-load values will be used. The sequence is not interrupted due to the detection of invalid data. In the case of invalid data, the sequence issues an "M" to be displayed next to the last good value of the parameters with invalid data and continues to perform the computations.

#### **Fuel Cell End Cell Heater Monitor**

The sequence monitors the fuel cell end cell heaters, two per fuel cell, for proper on/off cycling. The end cell heaters cycle on/off to maintain the end cell temperatures at the desired operating temperature. This special process uses predefined parameters to indicate heater status. These parameters shall be acquired at least once per second and processed at least once per 2 seconds. If a heater cycles on and remains on for longer than 6 minutes, then a class 3 alarm is initiated along with the fault message "FC END HTR."

This sequence is active in all BFS OPS modes and PASS SM OPS 2 and 4. Therefore, this sequence will be functioning during all mission phases. The output from this monitor is available on the FUEL CELLS display (DISP 69) in SM OPS 2 and 4, and on the BFS THERMAL display when the BFS is active. NOTE: For STS-26 FC no. 2 will not have end cell HTRs, and plans are for STS-27 to have three FCs that have no end cell HTR.

#### **Fuel Cell Total Current and Power Computation**

This sequence computes the total current and power of the three fuel cells and performs the fuel cell power preconditioning limit setting for fuel cell stack cool out temperature (stack temp). The fuel cells current and power computation is active during all flight phases to provide the status of the electrical power subsystem. The computation is active in the BFS during all OPS modes and it is active in SM OPS 2 and 4 onorbit.

The total current and power generated by the three fuel cells is computed by respectively summing the current and power (in kW) generated by the individual fuel cells. The measured value of current and voltage for each fuel cell is obtained from the Orbiter instrumentation data. The results of the computations, total current and power, are then made available on the ELECTRIC display (DISP 67) in SM OPS 2 and 4, and the total power load is made available on SYS SUMM 1 (DISP 78) during all flight phases.

The sequence will monitor the input parameters and also process the computed outputs at a rate of once every two major cycles (a major cycle is performed once a second).

The precondition limit setting for each fuel cell is based on the power (in kW) generated by the individual fuel cell. Precondition limit sets for the individual fuel cell are established for three output ranges. The precondition limits sets are made available to FDA to status the fuel cell stack cool out temperature measurement. The three

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power output ranges are defined within two power levels. The power levels are changeable constants via the TM function (SPEC 60). The nominal values for levels 1 and 2 are: less than 3.5 and greater than 7.5 kW, respectively.

NOTE: This SM special process is also referred to as the fuel cell volts-current-temperature (V-I-T) program or the fuel cell performance monitor, not to be confused with cell performance monitor (CPM) which is not a software function.

#### Hydraulic Water Boiler Quantity

The hydraulic water boiler quantity process computes the amount of water remaining in the three water spray boiler (WSB) storage tanks for all flight phases. The WSB is part of the APU/hydraulics system and its purpose is to cool the hydraulic fluid and APU lube oil when the APUs are running. Water is stored in bellows-type tanks, which are pressurized by gaseous nitrogen. The storage tanks supply water to the spray boiler as demanded by the hydraulic fluid and APU lube oil temperatures. As the water is depleted, the amount of water remaining in each tank is computed.

The sequence operates in all OPS modes of the BFS and in PASS SM OPS 2 and 4. The output from the hydraulic water boiler quantity calculation is displayed on a meter and on the APU/HYD display (DISP 86) in SM OPS 2 and 4 and on SM SYS SUMM 2 (DISP 79) during all flight phases (BFS and PASS SM).

The hydraulic water boiler quantity calculation is active during prelaunch and remains active during all flight phases. Sequence inputs are accessed at a rate sufficient

to perform the calculations once per two major cycles (2 seconds). Inputs to the sequence are the following for each WSB: H<sub>2</sub>O tank temperature and pressure and GN<sub>2</sub> tank temperature and pressure. After the GN<sub>2</sub> and H<sub>2</sub>O tanks are loaded, the process computes the initial total GN<sub>2</sub> quantity in the system. This is done by adding the quantity of GN<sub>2</sub> in the GN<sub>2</sub> tank to the GN<sub>2</sub> ullage volume in the H<sub>2</sub>O tank. The GN<sub>2</sub> ullage volume is an I-load value that determines the quantity of H<sub>2</sub>O to which the software initializes (Kennedy Space Center loading is 83 percent and for Vandenburg Launch Site, loading is 94 percent). As water is used and GN<sub>2</sub> is transferred from the GN<sub>2</sub> tank to the H<sub>2</sub>O tank, the process computes the resulting quantity of GN<sub>2</sub> in the H<sub>2</sub>O tank. The total volume of GN<sub>2</sub> in the H<sub>2</sub>O tank is subtracted from the volume of the H<sub>2</sub>O tank to compute the volume and percentage of water remaining.

The process corrects for the GN<sub>2</sub> vented overboard during ascent (there is no venting during entry) by calculating the quantity vented overboard and subtracting this from the initial total computed quantity of GN<sub>2</sub> in the system.

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#### **Payload Bay Door Sequence**

The payload bay doors (PLBDs) are opened onorbit for payload operations and for Orbiter cooling via the radiators. However, if Orbiter cooling problems occur or some other contingency situation arises, the PLBDs can be opened via the BFS computer during ascent and during deorbit backout procedures. Without the SM software (PASS OPS 2, 4, or the BFS software) the PLBDs cannot be opened.

The PLBDs display (figure 5-7) provides auto and manual modes for operating the doors and the latch groups and for monitoring all limit switches status. The BFS PLBD display (SPEC 63) operates exactly as the PASS SM OPS 202 or 402 display.

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2021		PL BAY	DOORS	XX BF	X DDD/HHI S DDD/HHI	MMISS MMISS
AC POW AUTO M	OFF	1X 2X PB 3X	D SW-XX	XXS   MICRO- LATS	SW STAT DOORS	
CENTER L	ATCHES S 5- 8 9-12 1- 4 13-16	AN OP/ EL 4X XX 5X XX 6X XX 7X XX	CLIAUTO SEG SXX SXX SXX SXX	CCOO ABAB XXXX XXXX XXXX XXXX XXXX	CRRRO ABC	
FWD L AFT L DOOR	ATCHES ATCHES	8X XX 9X XX 0X XXX	s x s x s x	XXXX XXXX	XXXXX XXXXX	
FWD L AFT L DOOR	ATCHES 1 ATCHES 1	1X XX 2X XX 3X XX	S X S X S X	XXXX XXXX	XXXXX XXXXX	
PBD SW B	YPASS 14	OP X ST CLO	EN 15X OP 16X SE 17X		ı	( XX)

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Figure 5-7.- PL BAY DOORS display (OPS 202, 402, or BFS SPEC 63). The auto mode provides for automatic sequencing of PLBD operations (see figure 5-8, Payload bay door close auto sequence). Referring to the display, once the **OPEN/CLOSE** selection is initiated the software checks the status of all the PLBD microswitches, and if an improper configuration is detected, the auto sequence stops, PLBD ac power is removed, and a class 3 alarm and message (PLBD CONFIG) are output. If all microswitch feedbacks indicate that the PLBDs and latches are properly configured, then the auto sequence continues and the latches and doors are driven in a predefined sequence top to bottom for OPEN request and bottom to top for CLOSE request. Microswitch status is verified for each step as the auto sequence proceeds, and if any microswitches are invalid (only two out of three ready-to-latch microswitches are required for each door) the sequence holds at that point. PLBD ac power is removed, and a class 3 alarm and message (PLBD SEQ FAIL) are output. The PLBD sequence can be interrupted during execution by terminating the OPEN (CLOSE) request and all functions will halt. Reselection of the OPEN (CLOSE) request continues the sequence. The PLBD OPEN/STOP/CLOSE request can be made on the PLBD display or a switch on panel R13.

A unique feature of the PLBD auto sequence is that once the PLBD display has been called up on a CRT the crew cannot call up another display on that CRT once the auto sequence has been initiated (selection of the OPEN/CLOSE request). If the crew attempts to call up another display they will receive an ILLEGAL ENTRY message on the CRT. Also, the crew cannot terminate the present OPS mode once the auto sequence is initiated without receiving an ILLEGAL ENTRY message. This means that if the crew is using SM OPS 202 to open the PLBDs, doing an SM OPS 201 will be an illegal entry. The manual mode can also be used to operate the PLBDs. The crew will then be able to select any component (items 4 through 13) that they desire to move. Ideally we want to follow the sequence described above for the auto sequence (top to bottom to open, reverse to close). However, in the manual mode we can drive the latches and door motors in any order we like. Of course if we try to drive a door open while the latches are closed, the door will not open.



Figure 5-8. – Payload bay door close auto sequence.

CENTERLINE LATCHES 13-16 9-12 -5-6

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AFT BULKHEAD LATCHES

1-4 PORT

1-4 STED

13 HINDES

- FIXED HINGE

- FLOATING NINGE

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# **Mission-Selectable Processes**

The SM software also provides for the execution control of two types of MSPs in support of payloads: missiondependent processes (MDPs) and mission-unique processes (MUPs). Any combination of MDPs and MUPs may be included in a mission as long as no more than eight MUPs are specified and the total computer resources used for all MSPs are compatible with the resources available.

There is one MUP currently used called the Spacelab serial interface function and there are four MDPs: spinning solid upper stage (SSUS) sequence control process, inertial upper stage (IUS) GNC data transfer, payload control supervisor (PCS) sequence control, and standard GNC data transfer. These processes exist only in PASS SM OPS 2 and

4 software, except for the standard GNC data transfer capability which is also in the BFS software (see table 5-1, page 5-2)

#### **Spacelab Serial Interface Function**

The Spacelab serial data interface function through a serial input/output (I/O) card provides the software interface between the Orbiter SM GPC and the Spacelab computers via the PL MDMs. There are two serial I/O cards, one for each of the two PL MDMs.

These cards interface to the MDM couplers in each Spacelab input/output unit (IOU) (PLD MDM 1 to MDM coupler A and PL MDM 2 to MDM coupler B in each IOU). To control the flow of serial digital data and commands, the PL MDM through the serial I/O card issues three discretes to the Spacelab subsystem (SS) and experiment (EXP) IOU MDM couplers. These three discretes are message in, message out, and word discretes.

The Spacelab serial interface function is active as long as SM software and command and data management subsystem (CDMS) software are processing. As the interface between the Orbiter and Spacelab computers, the Spacelab serial interface function, through its I/O card, has four main purposes:

- 1. Transferring state vector information to the Spacelab computers
- 2. Providing a path for ground uplink commands to the Spacelab computers
- 3. Providing the path for SM GPC commanding, via SPECs, to get to the Spacelab remote acquisition units (RAUs)
- 4. Providing the Spacelab with PASS SM software for fault detection and annunciation.

The Spacelab serial interface function exists only in PASS SM OPS 2 software.

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#### **SSUS Sequence Control Process**

This software function is executed by the SM GPC in conjunction with the deployment of an SSUS, such as a PAM, from the Orbiter. During a nominal SSUS deployment the SM GPC issues two commands to the SSUS, and the basic purpose of the sequence control process (SCP) is to tell the SM GPC when to issue these commands.

Currently PAMs are the only users of the SSUS SCP. There may be up to four PAMs on a given flight. Since there is only one SCP and it can be executed for only one PAM at a time, the SCP must be "initiated" and then "reset" for each PAM to be deployed.

Each PAM normally utilizes three displays to allow

commanding and data monitoring of the SSUS and associated spacecraft. These SM displays are the Deploy SPEC, Monitor display, and the Control SPEC. By doing an "item entry" on the Deploy SPEC (item 1, COUNTDOWN START) the SCP is "called" by the SM software and processed. To "reset" the SCP so that another PAM may be deployed requires another item entry on the Deploy SPEC (item 5, RESET).

After the SCP is initiated, it checks for a valid deploy identification (ID) (a number from 1 to 4), a valid deploy time, displays a countdown to deploy on each PAM display, and then essentially monitors time to determine when to issue its two commands. If the SCP were not active these commands would not be issued and the SSUS would not be deployed automatically. If an SM GPC cannot be activated then the crew does have cockpit switches that will deploy the PAM manually. Normally the crew will verify the correct display ID and deploy time prior to initiating the SCP. If these are incorrect they may be updated by the crew using SM SPEC 60 SM TABLE MAINT, or the ground using a TMBU. The crew will "reset" the SCP as part of the postdeploy procedures.

The SSUS SCP capability exists only for the PASS SM major function (PASS OPS 2 and 4).

#### **IUS GNC Data Transfer**

This function provides the capability to transfer Orbiter GNC state vector and attitude data to the IUS. The PASS SM GPC obtains these GNC data points and through a SPEC item entry (SM SPEC 200) transfers the data, via a PL MDM serial I/O channel, to the communications interface unit (CIU) at a rate of once every 2 seconds. The crew then sends this data to the IUS via a CIU command. The GNC data shall be acquired via the ICC data bus. The two data sets (state vector data and attitude data) shall each be processed as a time-homogeneous data set (snapshot) so that parameters from two different ICC updates for a set are not used in one IUS transfer.



# The IUS GNC data transfer capability exists only for the SM major function (PASS OPS 2 and 4, see figure 5-9).

Figure 5-9.– IUS transfer path.

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#### Payload Control Supervisor Sequence Control

The principle mission of the Space Shuttle is to transport payloads to and from a low Earth orbit. Payloads to be carried in the Shuttle cargo bay include deployable satellites and bay-resident experiments.

Checkout, activation, monitoring, and deployment of payloads are performed with the use of software onboard the Shuttle. This software resides in the PASS SM OPS 2 and 4 software.

Many times, the activation and control of a certain payload can be quite complex, requiring numerous commands and many critical crew work hours. To reduce the number of work hours, a software package which will execute predefined command sequences onorbit has been developed. This package is called the PCS, and it is available as an optional service to payloads. The payload developer should consider using the PCS if the payload requires many commands and a lot of crew time.

The PCS package consists of command sequences, the main purpose of which is to issue commands to a specific payload in order to accomplish the payloads mission objectives. The PCS resides in the PASS SM GPC and uses the same command path from the GPC as the uplink and crew commands use. This command path must be one of the following:

- Attached payloads
  - Through the PL MDM and PSP to the payload
  - Through the PL MDM and directly to the payload

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- Directly to the payload through a payloadprovided bus terminal unit (BTU)
- Detached payloads

Through the PL MDM and PSP, through the PI, and to the payload

These command paths are shown in figure 5-10.



Figure 5-10.– PCS command path.

The PCS function provides the crew with the capability to execute predefined PCS sequences during orbit. These sequences consist of operators which are preprogrammed on the ground and defined on a mission-unique basis. The crew controls and activates PCS sequences via the PCS CONTROL display SPEC 90 (figure 5-11), which has the capability of executing and monitoring up to 10 sequences at a time.

XXXX/090	PCS	CONT	ROL	XX	х	DDD/H	H: MM:	SS	
1 SET XX XXXXXX 2 SEQ XXXX XXXX 3 GMT XXX/XX: XX 7 FIRST STEP 9 HOLD STEP 9 HOLD STEP 9 HOLD STEP ENA 10 HOLD TERM 12 RESUME SEQ UPDATE 14 STEP XXX 15 MASK XXXX 16 HI LIMIT XXX 17 LO LIMIT XXX 18 DELAY XX: XX CURRENT XXX ERROR XXX/X TERM ALL 20 CLEAR TEXT 21	x x x x x x x x x x x x x x x x x x x	SEQ XXXX XXXX XXXX XXXX XXXX XXXX XXXX X	STAT XXXX XXXX XXXX XXXX XXXX XXXX XXXX	NAME XXXXXX		DDD/H G XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXX/X XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX XXXX	H: MM MT X: X: X: X: X: X: X: X: X: X: X: X: X: X: X: X: X: X: X: X	SS XX XX XX XX XX XX XX XX XX XX XX XX X	
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Figure 5-11.– PCS CONTROL display.

#### **Standard GNC Data Transfer**

This function provides the capability to process Orbiter state vector and attitude data, obtained via the ICC data bus from the GNC GPC for outputs to payloads and for the antenna management function discussed on page 5-12. The payload commands are sent via the PL MDM serial I/O card or the PSP function in response to payload processing control indicators. This GNC data transfer may be either cyclic via standard serial interfaces (SSIs) or on demand via SSIs or the PSP and may consist of any one of the following time homogeneous data sets:

- Greenwich true of date state vectors
- Greenwich true of date attitude/attitude rate
- Mean of 1950 (M50) state vector
- M50 attitude/attitude rate

The standard GNC data transfer capability exists in both BFS and PASS SM OPS software.

# Section 6: Display and Uplink Controlled Processes

Display and uplink controlled processes provide functions which can be used to initiate, alter, or terminate certain processing within basic SM processes and special processes. Table 6-1 contains a list of all the display and uplink controlled processes and their software locations. The table shows us that most display and uplink controlled processes are located only in the PASS SM software; the two exceptions to this are located in both the PASS SM software and the BFS software.

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 Table 6-I.- Display and uplink controlled processes.

	BFS SM	PASS SM	Both BFS and PASS SM
PCMMU telemetry format load	-	-	x
SM system summary displays	-	-	x
Checkpoint	-	X	-
Mass memory unit read/write	-	Х	-
Payload data interleaver format load	-	x	-
Payload data uplink processing	-	Х	-
Payload signal processor communications	-	X	-
Remote manipulator system control	-	X	-
Table maintenance SPEC	-	x	-

# Both BFS and PASS SM Display and Uplink Controlled Processes

- PCMMU telemetry format load
- SM systems summary displays

#### **PCMMU Telemetry Format Load**

The PCMMU is the device which accumulates the onboard instrumentation data. This data is made available for downlinking and to GPCs. The PCMMU via a fetch programmable read-only memory (PROM) polls the OI MDMs for information then stores this data in a data random access memory (RAM). This data is now accessible by the GPCs and the formatter for downlinking. Checks are made during this process to determine validity flagging of this data with its status. If the data is flagged invalid on two consecutive reads of an LRU, OI MDM, PDI, or Spacelab, the GPC bypasses the element via FDA, no longer looking for data from the failed LRU.

Downlist data, information accumulated by the GPC, is available and stored in a buffer in the PCMMU. This data is accessible by the formatter to be included with the OI telemetry for downlinking.

Telemetry format load (TFL) is the information available for setting up the PCMMU downlink datastream. The PCMMU TFL capability is a PASS SM OPS 2 and 4 process that is accessible via the PCMMU/PL COMM display SPEC 62 (see figure 6-1). The TFLs reside on the MMU and upon request are transferred to the PCMMU, setting up processing of OI telemetry. TFLs are available in two data rates: 128 kilobits per second (kbps) high data rate and 64

( XXXX/062/ SM COM BUFF XXX	PCMMU/PL COMM )	XX X DDD/HH:MM:SS DDD/HH:MM:SS
PCMMU BITE WORD XXXX FMT SEL FXD 1XS PGM 1D 64 XXX 128 XXX 3 SEL 1D XXX LOAD 4 XXXX I/O RESET PCM 5XX		PDI I/O RESET BXX BITE WORD XXXX 9 SEL DECOM X 10 SEL FMT XXX LOAD 11 XXXX 12 SEL INPUT X LOAD 13 DECOM INPUT FMT 1 X XXS 2 X XXS 3 X XXS 4 X XXS
PSP I/O RESET PSP1 6XX PSP2 7XX SYNC BIT XXXS FRAME XXXS LOAD XXXX XXXX	PL INTRG 1 CHANNEL XXXS 2 CHANNEL XXXS PHASE LOCK XXXS ERR ±XXS XMIT PWR XX.XXS PL SIG STR X.XXS	15-FPM XXX DECOM ENA FDA 1 14X 2 15X 3 16X 4 17X 18 TF1 GPC SEL X
		( XX)

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Figure 6-1.– PCMMU/PL COMM display.

kbps low data rate, each having its own formatter within the PCMMU and loaded independently of each other. The formatter then has the capability to request the desired information to be inserted into the downlink telemetry.

Each PCMMU also has a hardcoded high data rate TFL (129). This precludes total loss of data in the event of failures which will not allow access to the loading of TFLs. The PCMMU will retain only its hardcoded TFL in the event of an electrical power interruption.

#### **SM System Summary Displays**

There are two key SM displays, SM SYS SUMM 1 and SM SYS SUMM 2. These displays are available during all flight phases and provide critical systems information in support of the Orbiter.

SM System Summary 1 (see figure 6-2), the first of two summary displays, contains status information on emergency parameters, electrical power and distribution, and basic Orbiter atmospheric conditions. SM System Summary 2 (see figure 6-3), the second of two summary displays, contains status information on cryogenics, APUs, hydraulics, and thermal control subsystems.

The BFS and PASS SYS SUMM 1 displays are the same. The BFS and PASS SYS SUMM 2 displays are slightly different (see the DPS Dictionary).

The SM SYS SUMM 1 display is called up by pushing the SYS SUMM key on an Orbiter keyboard unit (KBU) assigned to either the BFS GPC (ascent or entry) or a PASS SM GPC (orbit). Successive depressions of the SYS SUMM key toggles between the two SYS SUMM displays.

1									
	0001/	/078	SM	SYS SUMM	1 1	5	004/00:	41:18	
	SMOKE CABIN	1/A -0.0	2/B		s	1/A	2/B	_3/C	
	AV BAY 1	-0.0	-0.0	MAIN CNTL	AB	30.6 30.4 28.8	30.6 30.5 28.8	30.6 30.5 28.8	
		BIN 14.7	-0.0	ESS	BC CA	28.8 28.8 29.2	28.8 28.8 29.3	28.8 28.8 29.3	· [
	BU PPO2	00 00 3.13	3.13	VOLT	ФА ФВ	116 116	116 116	116 116	
	HX OUT T	5.83 47 Q.QL	0.OL	AMPS	ФС ФА ФВ	116 2.3 2.4	116 4.3 4.6	116 2.4 2.5	
	NZ FLOW	O.OL A B*	0.0L	FUEL CE	OC LL F	3.7 2H	4.8	3.8	
	ΔV FC1 SS1 18 SS2 18	FC2 F 21 22	C3 21 13	AMPS REAC STACK	VLV	218 0P +206	211 0P +205	213 OP +206	
	TOTAL AME	20 25 642 KW 19	20	EXIT COOL PU	P MP	150 60	149 60	150 60	
	SYS SUMM	1							J

Figure 6-2.– SM SYS SUMM 1 display.

	0010				•	00/0113	5110
	H2 PRE 02 PRE HTR	TK 1 SS 22 SS 95 T1 + 7 T2 + 7	5 2 0 9 5 + 5 +	2 3 25 225 50 950 78 + 10 77 + 9	4 225 950 + 76 + 75		
APU TEMP EGT B/U EGT OIL IN OUT SPEED Y	1 950 850 220 260	2 850 750 215 225	3 80 70 85 80	HYD PRESS RSVR T QTY	1 301 80 80	2 55 95 78	3 62 70 50
FUEL OTY PMP LK I OIL OUT I	73 P 0 P 80	75 0 80	99 0 15	H20 QTY BYP VLV	68 W/B	70 W/B	99 Byp
AV BAY TEMP FAN∆P	90 0.1	90 0.1	90 0. 2	H20 PUM FREON F EVAP OU		70 1500 37	15+ 0+ 78

Figure 6-3.- SM SYS SUMM 2 display.

## PASS SM Display and Uplink Controlled Processes

- Checkpoint
- MMU read/write
- PDI format load
- Payload data uplink processing
- PSP communications
- RMS control
- Table maintenance SPEC
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### Checkpoint

A checkpoint is a record of system parameter values written to the MMUs at a specific instant in time and reserved for later use. Certain SM software control parameters (e.g., FDA status, limit values, constants, noise filter constants, parameter annunciation inhibits, state vectors, etc.) are preloaded, but may be changed during a mission's progress. These changes are maintained in the SM GPC main memory. The most current values of these parameters are lost when the GPC software is overwritten by a new load, or the SM GPC fails. Therefore, a function called checkpoint retrieval (CKPT RETRV) (on SPEC 1) enables or inhibits the retrieval and incorporation of SM checkpoint data from mass memory at SM OPS transitions and OPS mode recalls.

Preparing a checkpoint allows the most recent version of system control data to be written onto the MMUs. The checkpoint section of the MMU is located in a different place from the nominal SM software. The checkpoint write capability currently exists only for the SM major function (PASS OPS 2 and 4), and is performed in conjunction with the SM Table Maintenance display (PASS SM SPEC 60) and the DPS UTILITY display (SPEC 1). Only data that can be changed on SPEC 60 is captured by a checkpoint, and this data will only be retrieved during a checkpoint if enabled on SPEC 1.

#### **MMU Read/Write**

The MMU read/write capability is the most generic use of the MMU and provides the ability to access anything on the MMU except for the IPL software. This process is available in PASS SM OPS 2 and 4, on a display called MASS MEMORY R/W, (PASS SM SPEC 85, see figure 6-4), in payload OPS 9 (PL 9) on the MASS MEMORY R/W display, or by ground uplink to the vehicle.

The display provides the capability to read from the MMU, write to the MMU, dump the MMU to the ground, and to compare a loadblock in one MMU to the same one in the other MMU. After a specific loadblock is selected, it may be read from either MMU into the GPC buffer. The data can then be dumped via downlist or displayed, 39 words at a time, on the MMU R/W display (SM SPEC 85). When a write is done, the changes are made to the displayed data, it is merged into the buffer, and then written to either MMU. The following blocks of software are on each MMU and available for MMU read/write:

- Display text and graphics
- PASS 1
- PASS 2
- PASS 3
- BFS

9011/085/ M SM COM BUFF XXX	ASS MEMOR	Y R∕₩	XX X DDD/HH: MM: SS DDD/HH: MM: SS
DESTRED ACTUAL 1 XXXX XXXX 2 XXXX XXXX 3 XXXX XXXX 4 XXXX XXXX 5 XXXX XXXX 6 XXXX XXXX 6 XXXX XXXX 7 XXXX XXXX 9 XXXX XXXX 10 XXXX XXXX 11 XXXX XXXX 11 XXXX XXXX 12 XXXX XXXX 13 XXXX XXXX 14 XXXX XXXX 16 XXXX XXXX 18 XXXX XXXX 18 XXXX XXXX 18 XXXX XXXX 19 YXYY 19 YXYY 10 XXXX XXXX 11 XXXX XXXX 12 XXXX XXXX 13 XXXX XXXX 14 XXXX XXXX 15 XXXX XXXX 16 XXXX XXXX 18 XXXX XXXX 18 XXXX XXXX 18 YYYY 19 YYYY 19 YYYY 19 YYYY 19 YYYY 19 YYYY 19 YYYY 19 YYYY 19 YYYY 10 YXXX 10 XXXX 11 XXXX XXXX 11 XXXX XXXX 12 XXXX XXXX 13 XXXX XXXX 14 XXXX XXXX 15 XXXX XXXX 16 YXXX XXXX 17 XXXX XXXX 10 XXXX XXXXX 10 XXXX XXXX 10 XXXX XXXXXXX 10 XXXX XXXXX 10 XXXX XXXX 10 XXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	DESIRED 21 XXXX 22 XXXX 24 XXXX 25 XXXX 26 XXXX 26 XXXX 27 XXXX 28 XXXX 29 XXXX 30 XXXX 30 XXXX 31 XXXX 31 XXXX 32 XXXX 33 XXXX 34 XXXX 35 XXXX 36 XXXX 37 XXXX 38 XXXX 38 XXXX	ACTUAL XXXX XXXX XXXX XXXX XXXX XXXX XXXX X	SELECT MMU 1 40X MMU 2 41X 42 S/W SYSTEM X 43 PHASE XXX 44 LOAD BLK XXX 45 OFFSET XXXXX 46 NUMBER XX 47 PATCH ID XXXX 47 PATCH ID XXXX WIOLATE XXX READ LOAD BLK 48X MERGE 49X WRITE LOAD BLK 50X COMPARE 51X STATUS XXXX ERROR CODE X REGISTER A XXXX B XXXX
	CHECKSUM	XXXX XXXX	DUMP VIA DL 52X

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Figure 6-4.– MASS MEMORY R/W display.

- Display electronics unit (DEU)
- Space Shuttle main engine (SSME)
- Test control supervisor (TCS) sequence

The above list shows that there are three copies of PASS software available to the crew. Therefore, if PASS 1 has a software problem onorbit, the crew can access the mass memory and obtain PASS 2 software through a mass memory read. The MMU read/write capability allows us to read or write to any of the above software blocks.

Another user of the MMU read/write capability is the crew text or text uplink memory system (TUMS). The TUMS is available only in PASS SM OPS 2 or 4. The display pages available to this system are numbered from 900 to 999 and are roll-in displays. The text on these displays is written there by MMU read/write via uplink. A use of this system is to allow secure transmission of textual material for Department of Defense (DOD) flights. TUMS can also be used when all audio communications have been lost.

Probably the most common use of the MMU by the SM machine is that of roll-in displays. Since all SM displays cannot be held in mass memory at one time, the roll-in display capability allows the SM machine to use more displays than can fit in memory at one time by reserving two areas of memory (called buffers) that can be used to store displays (a maximum of two at any one time) that have been called in from the MMU (see figure 6-5, MMU roll-in buffers).

#### **Payload Data Interleaver Format Load**

The PDI is the subsystem which processes selected payload data to either the PCMMU or the SM GPC. This data can be processed for monitoring onboard and/or available for downlinking in the OI telemetry. The PDI consists of a switch matrix allowing for six inputs, four decoms, and a fetch pointer memory (FPM). Input selections, decom, and FPM loading are accomplished via the SM GPC which also performs FDA to determine the status of the PDI.

The PDI decom format load (DFL) and FPM data are stored on the MMU. Upon demand either via keyboard entry or uplink command, data is acquired, verified, and loaded into the applicable unit. Legal format I-loads range from 0 to 31 for the PDI DFLs and 1 to 999 for the FPM.

The PDI format load capability exists in SM OPS 2 and 4 and is accessible via the PCMMU/PL COMM display SPEC 62 (see figure 6-1, page 6-2).



Figure 6-5.– MMU roll-in buffers.

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### **Payload Data Uplink Processing**

Payload data uplink processing is used as a means for the ground or the crew (via payload-specific displays) to communicate with various payloads via the PASS SM GPC. The load is variable in length and consists of from 1 to 33 48-bit command words. These data should include a destination and the number of words to be included in the uplink. These commands include an operations code which directs the data to the proper payload interface. Valid destinations shall include PSP communications, standard serial I/O, and the Spacelab serial data interface.

The payload data uplink processing capability exists in SM OPS 2 and 4.

## **Payload Signal Processor Communication**

The PSP is a device used as an interface between the Orbiter systems and its payloads. The PSP is configurable via the SM GPC, accepting commands, converting these commands into a compatible form to be sent to either the payload via hardline or the PI for radio frequency (RF) transmission. The PSP also has the capability to accept detached payload telemetry via the PI, making this data available to the PDI for processing.

The SM computer communicates with the PSP via its corresponding payload MDM. The SM application has the capability to access five prestored configuration messages, a reinitialize configuration message, and output to the PSP via uplink command. These configuration messages consist of five 16-bit words. The PSP also outputs five 16-bit status words, indicating the units current status available for display and downlist.

The PSP interface function is available in PASS SM OPS 2 and 4 and is accessible via the PCMMU/PL COMM display SM SPEC 62 (see figure 6-1, page 6-2).

### **Remote Manipulator System Control**

The RMS function is performed in PASS SM OPS 2 and 4. It has the capability to monitor and control the RMS for payload deployment and retrieval. The design of the RMS function supports the control of two manipulator arms, but only one arm may be active at a time.

The capability exists, via the Payload Deployment and Retrieval System (PDRS) Control display, SM SPEC 94 (see figure 6-6), to input RMS and payload initialization data; initiate communication between the SM GPC and the RMS manipulator controller interface unit (MCIU); input and monitor RMS auto sequence data; enable and inhibit certain GPC-controlled system checks and safety features; and monitor the state of RMS roll-out mechanism and retention latches.

Another RMS display is the PDRS STATUS display, SM SPEC 96 (see figure 6-7), which provides data on point of resolution commanded and actual rates, positions, attitudes, and RMS faults.

Because the RMS SM software is so lengthy and complex, this training manual only covers the RMS display interfaces. For more information on the RMS software, see the PDRS Nominal Operations Workbook.

XXXX/094/ PI RMS SEL: XXXX RMS PORT 1X STBD 2X I/ 3 PL ID XX 4 END EFF X 1 2 13 XX 14 XX 11	DRS CONTROL PWR XXX O ON 5X OFF 6X AUTO MODES 3 4 L5 XX 16 XX	XX X DDD/HH: MM: SS DDD/HH: MM: SS ENA INH SOFT STOP 7X 8X AUTO BRAKE 9X 10X POS ENC CK 11X 12X 17 START PT XXX
RMS SEL: XXXX RMS PORT 1X STBD 2X J PL ID XX 4 END EFF X 1 2 13 XX 14 XX 1	PWR XXX /O ON 5X OFF 6X AUTO MODES 3 4 L5 XX 16 XX	DDU/HH:MM:SS ENA INH SOFT STOP 7X BX AUTO BRAKE 9X 10X POS ENC CK 11X 12X 17 START PT XXX
STBD 2X I 3 PL ID XX 4 END EFF X 13 XX 14 XX 1	YO ON 5X OFF 6X AUTO MODES 3 4 L5 XX 16 XX	AUTO BRAKE 9X 10X POS ENC CK 11X 12X 17 START PT XXX
$13 \frac{1}{XX} 14 \frac{2}{XX} 11$	AUTO MODES 3 4 L5 XX 16 XX	17 START PT XXX
13 <u>XX</u> 14 <u>XX</u>	15 XX 16 XX	
		LAST PT XXX
OPR ( END POS END A 18 X 中 XXXX 21 P C	MD MODES	INIT ID <u>XX</u>
	<sup>™</sup> XXX CMD CK	25 XXXX
RMS STO/DPLY SHLD X X X X	26 WR RA	ANGE <u>X</u>
RMS LAT/REL/RDY AFT X X X X X MID X X X X X X FWD X X X X X X	AUTO BF	RAKE CK 27X
		( XX)
	TO X (山 XXXX 21 P L XXXX 22 Y E 20 Z 白 XXXX 23 R C RMS STO/DPLY SHLD X X X X RMS LAT/REL/RDY AFT X X X X X X MID X X X X X X FWD X X X X X X	10 Y 田 XXXX 21 P 田 XXX 20 Z 田 XXXX 22 Y 田 XXX 20 Z 田 XXXX 23 R 田 XXX RMS STO/DPLY 26 WR R/ SHLD X X X X X RMS LAT/REL/RDY AUTO BF AFT X X X X X X MID X X X X X X FWD X X X X X X

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#### Figure 6-6. – PDRS CONTROL display.

(	XXXX/XXX/O	96	PC	RS S	TATL	S	XX X	DDD/ HH: MM: SS
	RMS SEL: XX	XX						
	TRANS RATES ROT RATES POSITIONS ATTITUDES	ACT CMD ACT CMD ACT ACT	±xx ±xx ±xx ±xx ±xx ±xx ±xx	X/P (X. XX (X. XX (X. XX (X. XX (X. XX (X. XX (X. X) (X. X) (X. X)	s s s		Y/Y ±XX.XXS ±XX.XX ±XX.XXS ±XX.XXS ±XX.XXS ±XXX.XS	Z/R ±xx. xxs ±xx. xx ±xx. xxs ±xx. xxs ±xx. xx ±xxxxs ±xxxxs ±xxx. xs
			R	MS F	AULT	s		
	JOINTS	SY	SP	ΕP	WP	WY	WR	
	REACH LIMIT ABE - TACH SPA MTR DR MTR PWR <u>CONTROL ERR</u> <u>CK CRT</u> - POS	× × × × × × × × ×	× × × × × × × × ×	× × × × × × × × × ×	× × × × × × × × × × × × ×	****	× × × × × × × × × × × × ×	MCIU MADC X MCPC X ICF X ABE/MCIU X CHECK CRT: END EFF X TEMP CKT X D&C/MCIU X (XX)

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#### Figure 6-7.– PDRS STATUS display.

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#### **Table Maintenance SPEC**

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The Table Maintenance SPEC (figure 6-8), available in PASS SM OPS 2 and 4, is called up by entering SPEC 60 PRO on the CRT. This display provides the capability for the crew to interface directly with software in order to perform the following:

- View and change FDA limits
- View and change FDA filter values
- Inhibit or enable FDA parameter annunciation
- View and change telemetry TM constants
- Initiate a checkpoint
- Inhibit or enable all FDA annunciation

The procedures for using this display are in the Reference Data book.



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Figure 6-8.– SM TABLE MAINT typical display.

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# **Appendix B: Acronyms and Abbreviations**

A		abort once around acquisition of signal	FM	frequency modulation
A	PU	auxiliary power unit	FPM	fetch pointer memory
Δ	RS	atmospheric revitalization system	FCNA	fault summary massage
Δ	TCS	active thermal control system	ECCD	Functional Subsystem Cofficients Demoinements
Â	TO	abort to orbit	LOOK	Functional Subsystem Software Requirements
			GMT	Greenwich mean time
В	FS	backup flight system	GNC	guidance, navigation, and control
B	OS	backup operating system	GPC	general purpose computer
B	TU	bus terminal unit	GSE	ground support equipment
ں <sup>88</sup>	&W	caution and warning	Ца	hudroach
č		checkout		haat auch an san
Č	r C	cargo control	пх	neat exchanger
		command and data management system	1/0	
		communications interfess unit	1/0	input/output
		communications interface unit		intercomputer channel
		cneckpoint	ID .	identification
		command Command	IMU	inertial measurement unit
C	PDS	Computer Program Development	100	input/output unit
~		Specification	IPL	initial program load
		cell performance monitor	IUS	inertial upper stage
C	KI	cathode ray tube		
_			kbps	kilobits per second
D	EU	display electronics unit	KBU	keyboard unit
D	FL	decom format load	kW	kilowatt
D	OD	Department of Defense		
D	PS	data processing system	LOS	loss of signal
			LRU	line replaceable unit
E	XP	experiment		
			M50	Mean of 1950
FC	C	fuel cell	MA	master alarm
FC	CL	Freon coolant loop	MC	memory configuration
FC	CP	fuel cell power	MCC	Mission Control Center
FC	DA	fault detection and annunciation	MCDS	multifunction CRT display system
FC	DF	Flight Data File	MCIII	manipulator controller interface unit
FF	=	flight forward	MDM	multiplayer/demultiplayer
•••				maniplexel/demuniplexel

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MDP MFB MM	mission-dependent process major function base major mode	RTLS	return to launch site
MMU	mass memory unit	SCA	sequence control assembly
MSP	mission-selectable process	SCP	sequence control process
MUP	mission-unique process	SGIS	Space Ground Link Station
	mission anique process	SM	systems management
NSP	network signal processor	SP	special processing
1451	network signal processor		special processing
0-	0,5,4,0,8,0		solid rocket booster
OFT	onorational flight tost		suita rocket booster
	operational instrumentation	55/VV	system soltware
	operational instrumentation	22	subsystem stor doud conict interfecto
OPS	operations sequence	221	standard serial interface
D		2202	spinning solid upper stage
PAM	payload assist module	SIDN	Space Tracking and Data Network
PASS	primary avionics software system	SIS	Space Transportation System
PBI	pushbutton indicator		
РСМ	pulse code modulation	TAL	transatiantic abort landing
PCMML	J pulse code modulation master unit	TCS	test control supervisor
PCS	payload control supervisor	TDRS	Tracking and Data Relay Satellite
PDI	payload data interleaver	TFL	telemetry format load
PDRS	payload deployment and retrieval system	TM	table maintenance
PI	payload interrogator	TMBU	table maintenance block update
PL	payload	TUMS	text uplink memory system
PLBD	payload bay door		
PM	phase modulation	VDC	volts direct current
PPO <sub>2</sub>	partial pressure $O_2$	V-I-T	volts-current-temperature
PRSĎ	power reaction storage and distribution		
PROM	programmable read-only memory	WSB	water spray boiler
psi	pounds per square inch		
PSP	pavload signal processor		
PVT	pressure, volume, and temperature		۱. ۱
	P	•	
RAM	random access memory		
RAU	remote acquisition unit		
RCDR	recorder		
REACV	IV reaction valve		
RETRV	retrieval		
RE	radio frequency		
RMS	remote manipulator system		
CIVIJ	remote manipulator system		

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END

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