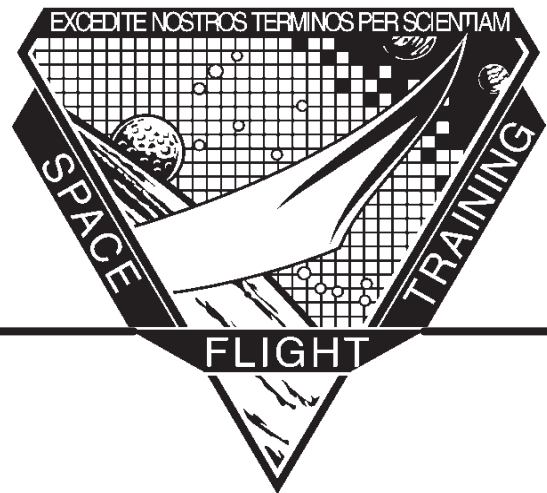
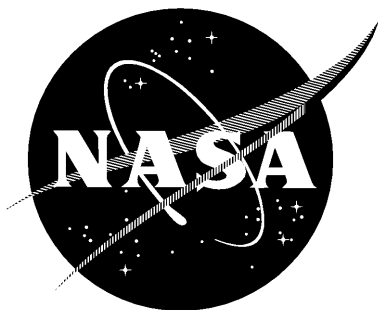


DPS Overview 21002 Workbook



**Mission Operations Directorate
Space Flight Training & Facility Operations
DPS/NAV Training Department**

February 1999



National Aeronautics and
Space Administration

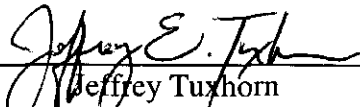
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DPS Overview

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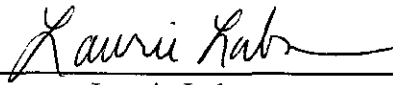
February 1999

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Foreword

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

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Preface

The purpose of this workbook is to provide an overall understanding of the Data Processing System (DPS) and to prepare you to take the DPS 21005 lesson, which is the followup lesson to Crew Software Interface (CSI) Computer Based Training (CBT) lesson, CSI 21057. If you have not read the CSI 21002 workbook, please do so before continuing with this training manual. This workbook builds on the material learned in the CSI workbook and lesson. Many concepts used in this book are introduced in the CSI workbook and lesson.

This workbook also examines key hardware elements important to understanding DPS in addition to the important DPS software concepts, including Operational Sequence (OPS) transitions, memory configurations, Initial Program Load (IPL), and common set and redundant set operations. Also introduced are the four Primary Avionics Software System (PASS) system-level DPS display pages: GPC MEMORY, GPC/BUS STATUS, DPS UTILITY, and TIME SPEC.

Section 1

Introduction

Performance Objectives

As a result of studying this section, the student will be able to do the following:

- State the purpose of the Data Processing System (DPS)
- Identify the three parts of the DPS

Suggested Reference Documents

- a. The Crew Software Interface Training Manual (CSI 21002) is a prerequisite for this manual.
- b. DPS Hardware and Software Training Manual (DPS HW/SW 21002) supplements this training manual
- c. The DPS Dictionary describes every SPEC and DISP page in the Primary Avionics Software System (PASS) and Backup Flight System (BFS) in detail.
- d. The Space Shuttle Systems Handbook (SSSH) has detailed drawings of all hardware components. In particular, drawing 8.1 gives an overview of how various hardware is connected to the General Purpose Computers (GPCs).

Overview

The DPS forms the heart of the space shuttle orbiter; the majority of orbiter systems are controlled directly or indirectly by the DPS. The DPS

- Performs Guidance, Navigation, and Control (GNC) tasks, which are necessary to fly the orbiter
- Performs Systems Management (SM) tasks that monitor various orbiter systems, such as life support, thermal control, communications, and payload operations
- Manages and filters orbiter system data (telemetry) for transmission to the Mission Control Center (MCC), and enables MCC to remotely command many of the orbiter systems

Questions

1. The _____ directly or indirectly controls the majority of the orbiter systems.
2. List and describe three functions of the DPS.

Section 2

DPS Overview

Performance Objectives

As a result of studying this section, the student will be able to do the following:

- Name the functions of DPS for all phases of flight
- State the purpose of the PASS
- State the purposes of the BFS
- Identify the function of the Mass Memory Units (MMUs)
- Describe how flight-critical redundancy is accomplished

Overview

The introduction describes the DPS as “the heart of the space shuttle orbiter.” This is literally correct, for the shuttle could not fly without computer control. All commands, such as External Tank separation (ET SEP), jet firings, Main Engine Cutoff (MECO), communications, and other events, are so complex and time critical that only through the use of computers are they possible. Because of the varying tasks the shuttle computers must perform, they are called general purpose computers. (Even manual flying of the orbiter would not be possible without the computers.)

The shuttle uses five GPCs. These computers (IBM AP101S) have semiconductor (volatile) memories. Since removing power from these GPCs will erase all memory contents, a rechargeable Battery Backup Unit (BBU) maintains the GPC memory contents when it is powered off. The BBU charges whenever power is applied to the GPC.

Four of the five GPCs make up the PASS, which was developed by International Business Machines (IBM). As the name “primary” implies, the PASS GPCs are used throughout the mission to fly the shuttle as well as provide life support, thermal control, communications, and payload activities.

The fifth GPC contains the BFS, which was developed by Rockwell International. The BFS software was developed by a company other than the PASS developer to back up PASS in the event PASS should fail and to additionally protect against a generic software flaw with PASS. In the event that PASS should fail, the BFS was designed to take control of the vehicle and allow the crew to safely return to Earth.

During the ascent and entry phases of flight, all four PASS GPCs are responsible for flying the orbiter. The flying capability of PASS is more sophisticated than that of the BFS; however, even with its limitations, BFS is more than sufficient. The BFS is “listening” to PASS so that in the event it is engaged, it can continue to control the orbiter where PASS left off. The BFS exceeds PASS by performing limited SM functions that PASS cannot perform during ascent and entry. In fact, the BFS is routinely used during these times to monitor orbiter systems. Examples of BFS SM tasks during ascent and entry include managing antenna pointing for communications, monitoring life support and electrical systems, and regulating thermal control.

Because of the criticality of dynamic flight, the BFS is required; however, during the orbit phase, the BFS is not used and is “put to sleep.” The PASS GPCs are able to handle all orbit activities. Since the orbiter is in an orbit in space, the danger of PASS’s failing is not life threatening, as it would be in dynamic flight. When activated, BFS is able to take control of the orbiter should the need arise. On orbit, the crew and mission control have more time to do the necessary preparations either to recover PASS or to enable the BFS to fly the orbiter.

When orbit is achieved, the ascent software is no longer needed. Therefore, new software is loaded into the PASS GPCs, and the BFS is “put to sleep.” When a GPC enters the sleep state, it uses minimum power (from 560 down to 56 watts), which is just enough to maintain its memory contents (exclusive of the BBU). The nominal on-orbit configuration is as follows: two GPCs are responsible for flying the orbiter and one GPC performs all SM tasks as well as some payload activities. The third PASS GPC is “put to sleep” with orbit GNC software, thus providing another software source. Software may be obtained from two sources: other GPCs and the MMUs.

There are two MMUs onboard the orbiter. These are tape-driven machines from which the GPCs obtain their software. On each of these MMUs reside three copies of PASS software and two copies of BFS software. Redundancy, you will learn, is the name of the game in space shuttle flight.

Most equipment on the shuttle that is critical to flight has different levels of redundancy; for example, two, three, or four levels deep. Various hardware black boxes (called Bus Terminal Units (BTUs)) exchange data back and forth between the GPCs and other flight-critical devices such as sensors, navigational equipment, and aero surfaces. This flight-critical equipment is distributed among the GPCs to maximize redundancy.

To elaborate further on what is meant by redundant capability, flight-critical capability is accomplished by allowing each PASS GPC to control part of the total command capability. Flight critical BTUs (hardware) are distributed by software such that during ascent/entry, each PASS GPC controls 25 percent of the total command capability. This type of hardware grouping is referred to as a flight-critical string (or simply “string”). The GPC that is responsible for issuing commands over a particular string is called the commander.

Since the PASS GPCs are running redundantly, they should all be receiving identical inputs and generating identical outputs (through data on the flight-critical strings). If the inputs or outputs differ, then a problem with one or more GPCs or hardware on the string exists. To detect such problems, each redundant GPC monitors or listens to the remaining strings that the GPC is not commanding. These GPCs are called listeners. This provides each GPC with data inputs from all the flight-critical strings. Remember though, that only a given string’s commander can output or transmit commands on that string. The ability to designate which GPC will command which string is a software function under crew control. All redundantly processing GPCs are both commanders (for specific strings) and listeners (on the other strings).

This workbook and the DPS lessons that follow will introduce and teach you how to interact with the GPCs and give you a feel for how to manage DPS redundancy. Many of the concepts above are discussed in more detail in the following sections.

Questions

1. Identify some of the functions that PASS supports.
2. What are the purposes of the BFS?
3. Describe the MMUs onboard the orbiter.

Section 3

Overview of DPS Hardware Concepts

Performance Objectives

As a result of studying this section, the student will be able to do the following:

- Identify the seven types of data buses used in DPS operations
- Discuss the difference between multiplexers and demultiplexers
- Define a “string”
- Identify the GPC hardware controls

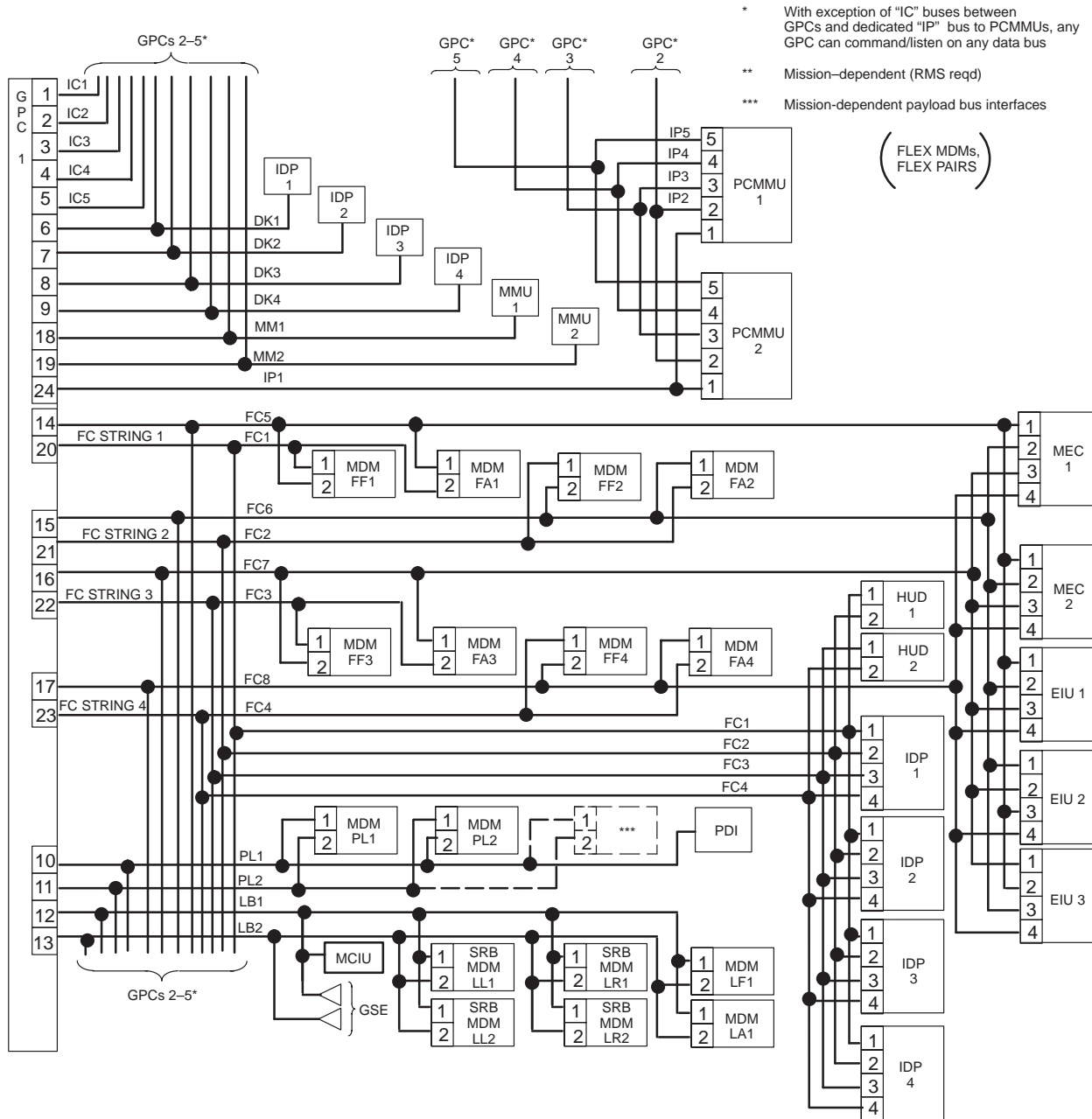
Data Buses and Bus Terminal Units

Serial digital data are exchanged between the GPCs and other electronic devices by data buses (see Figure 3–1). The data bus physically consists of a pair of insulated wires that are twisted together then electrically shielded. The electronic devices the GPCs communicate with are generically referred to as BTUs. Certain BTUs, the Integrated Display Processors (IDPs), appear twice in the data bus diagram. This is because the IDPs replaced multiple types of display hardware including flight instruments and DPS displays. The data for these displays are provided over different data buses, as noted below.

There are seven groups of data buses used in DPS operations:

- Flight–Critical (FC) buses (eight) communicate with devices critical to flying the orbiter both on orbit and in the atmosphere and providing flight instrument data to the IDPs and Heads Up Displays (HUDs).
- Payload (PL) buses (two) perform payload control and SM functions.
- Mass Memory (MM) buses (two) link the GPCs to the MMUs, which are magnetic tape devices that provide the GPCs with software.
- Intercomputer Communication (ICC or IC), buses (five), support GPC–to–GPC synchronization schemes which allow communications between the GPCs.
- Display/Keyboard (DK) buses (four) communicate with the IDPs, which in turn drive the DPS displays on the Multifunction Display Units (MDUs). PASS can support up to three active DK buses at any given time.
- Instrumentation/Pulse (IP) Code Modulation Master Unit buses (five) communicate between the Pulse Code Modulation Master Units (PCMMUs) and the GPCs. The PCMMU is used as an interface between DPS and other orbiter systems not critical to flying the orbiter.

- Launch Data Buses (LDBs or LBs) (two) communicate prelaunch with the Ground Support Equipment (GSE), the Solid Rocket Booster (SRB) Multiplexer/Demultiplexer (MDM), and the launch MDMs. On orbit, an LDB is used to control the Remote Manipulator System (RMS), which is the robotic arm carried in the payload bay.



Computer Data Bus Network

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Figure 3-1. Computer data bus network

Multiplexer/Demultiplexers

There is a special group of BTUs called MDMs (see Figure 3–2). Multiplexing takes many streams of data and combines them into one. Demultiplexing is the opposite function. It takes a single stream of data and splits it into several streams of data. The orbiter MDMs act as gateways between the data bus and the various types of equipment in the orbiter. Data flowing through the MDMs can be analog signals, serial digital data, or discrete data, depending upon the equipment connected to the MDM. It is the MDM's function to format the data to and from the GPC.

Multiplexer Interface Adapters (MIAs), commonly referred to as ports, are used to connect the MDMs to the data buses. MDMs can be categorized in different groups; the three groups most important to DPS operations are Flight–Critical Forward (FF), Flight–Critical Aft (FA), and Payload Forward (PF), also referred to as PL MDMs.

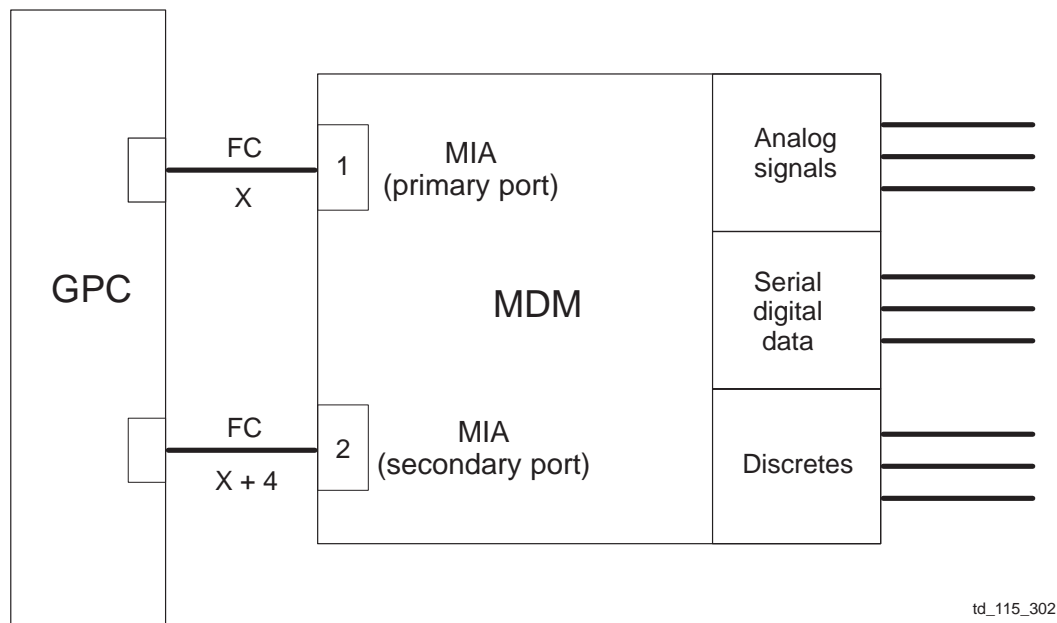
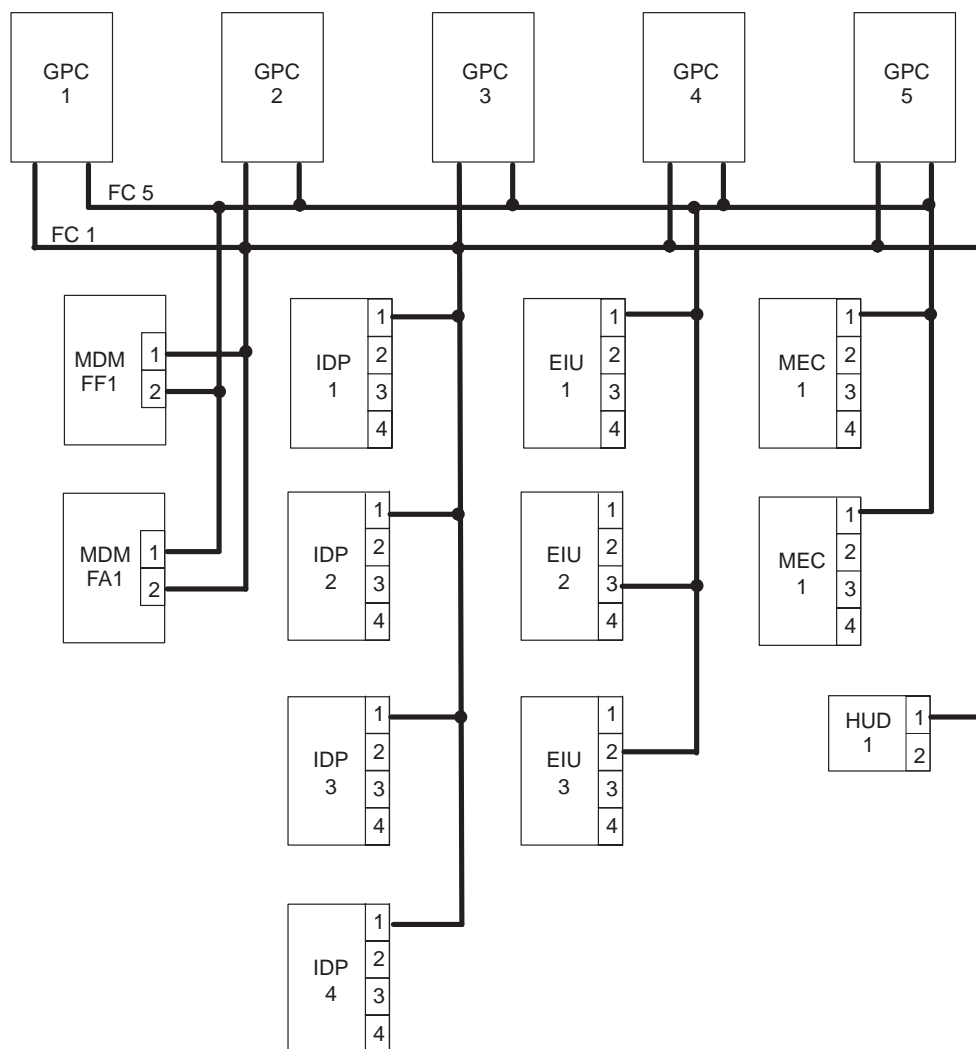


Figure 3–2. Special BTUs, multiplexer/demultiplexer

Flight–Critical Strings

The term “string” refers to all the flight–critical hardware connected to a pair of FC data buses (including one FF MDM and one FA MDM) for the purpose of redundancy (see Figure 3–3). Functionally, the purpose of separating flight–critical vehicle hardware into strings is to maximize redundancy by distributing GPC control of these hardware components. This redundancy allows nominal mission operations in the event of a loss of one string due to the loss of a single GPC. There are four strings defined this way; during ascent and entry flight phases, each string is commanded by a different PASS GNC GPC. The command capability (through software) for a string can be transferred by the crew to another GNC GPC in case of a failure. All GPCs processing GNC software have the ability to listen on all the strings.



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Figure 3–3. String 1

GPC Hardware Controls

The hardware controls for each of the five GPCs are located overhead of the commander's seat on panel O6 (Figure 3-4).

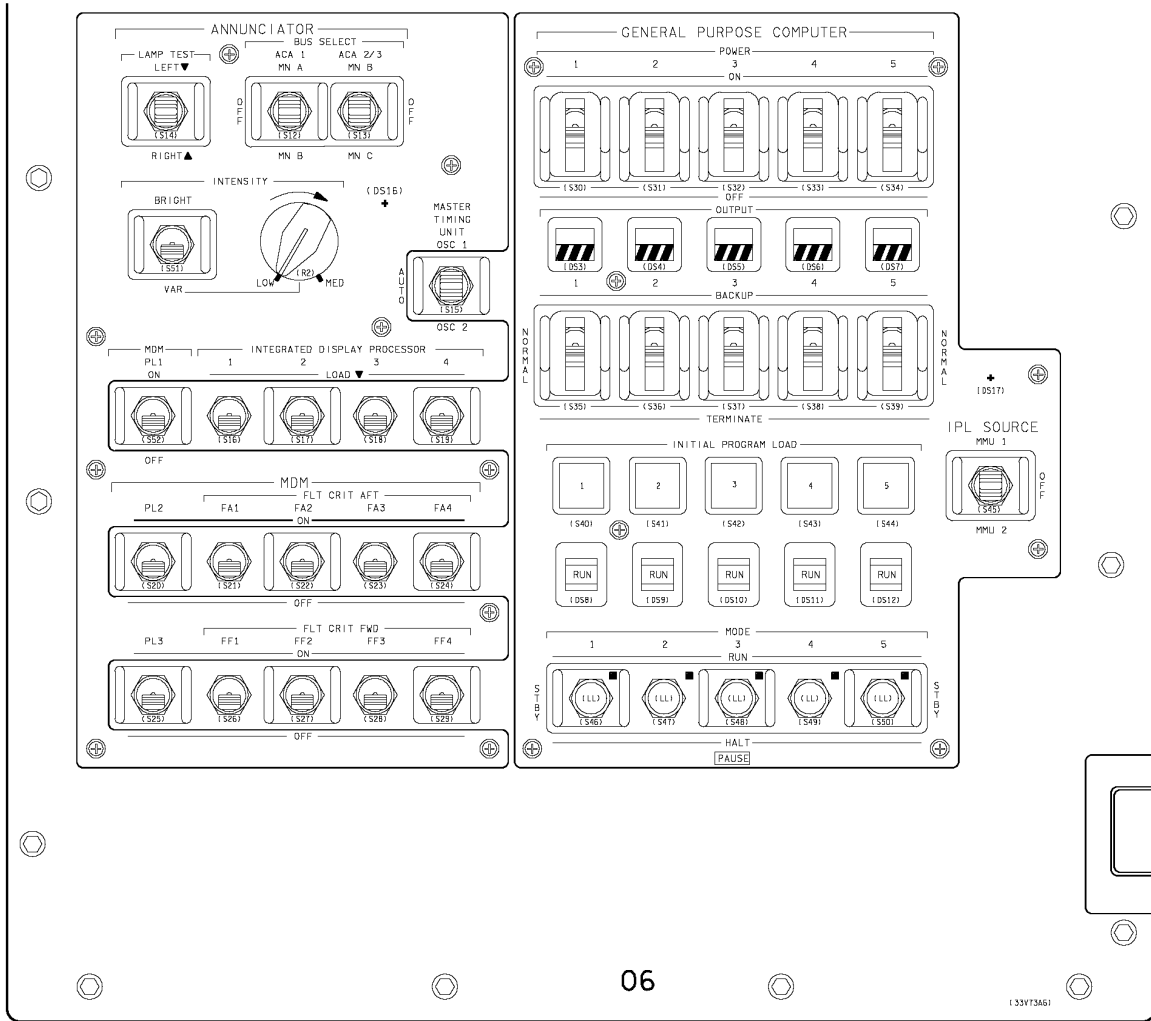


Figure 3-4. Panel O6

POWER Switch

The POWER switch is located in the uppermost GPC row (see Figure 3–4) on panel O6. When ON, power is supplied from three main electrical buses, providing three redundant power sources for each GPC.

The GPCs have volatile memories, which means that a GPC will lose all memory contents upon loss of power. As a measure of protection for this type failure, each GPC has its own rechargeable battery, a BBU. Its function is to generate enough power to maintain the memory contents when the GPC is powered off (but not enough to run the GPC). The BBU charges whenever power is applied to the GPC.

OUTPUT Switch and Talkback

The primary purpose of the OUTPUT switch is to provide hardware control of a GPC’s ability to transmit over Flight Critical (FC) data buses. The switch has three positions: NORMAL, TERMINATE, and BACKUP. In NORMAL, the GPC has the hardware ability to transmit over the flight criticals, whereas the TERMINATE position inhibits this ability. Since the GNC GPCs are responsible for flying the orbiter, they have their OUTPUT switches in NORMAL. On orbit, the SM GPC has its OUTPUT switch in TERMINATE, since it is not supposed to command anything on the flight criticals. The BACKUP position is used to tell the backup flight controller (BFC) hardware which GPC is the BFS (reference Section 4). The BFC consists of three hardware modules that provide four basic DPS functions:

- Routing of the GPC HALT discrete
- Enabling the crew selection of a DPS display for either BFS usage or GPC Initial Program Load (IPL) (see Initial Program Load, page 4–9)
- Enabling or inhibiting a GPC’s ability to transmit over the FC data buses (through the OUTPUT switch)
- Implementing the BFS engage and disengage processes

When the output switch associated with the BFS is in BACKUP, its transmission over the flight criticals is inhibited unless the BFS is engaged. Should the crew engage the BFS, the BFC gives control of the vehicle to the BFS.

The OUTPUT talkback (tb) reflects the GPC’s ability to transmit over FC buses. While influenced by the OUTPUT switch, this tb is not controlled solely by the OUTPUT switch. A grey tb indicates the ability to transmit, whereas a barberpole (a diagonal black and white striped pattern) indicates inhibited ability to transmit (for the output tb, the barberpole position is actually half barberpole and half gray; this is to distinguish the output tb from GPC MODE tb at a glance). Nominally, PASS is controlling the orbiter and BFS is not engaged. The GNC GPCs will have gray tb’s, and the BFS will have a barberpole tb. If the BFS is successfully engaged, the PASS tb’s will “go” or “flip to” barberpole while the BFS GPC (the one now in control) has a gray tb.

In summary, the OUTPUT switch, by means of hardware circuitry, provides the GPCs with either the ability or inability to transmit over the flight criticals. If the switch is in NORMAL, then the GPCs have the hardware ability to transmit over the flight criticals. If the OUTPUT switch is in TERMINATE, the GPC is hardware inhibited to transmit over the flight criticals, regardless of what the software demands.

MODE Switch and Talkback

The purpose of the MODE switch is to control a GPC's software processing state. The transitions to the various positions (RUN, STANDBY, and HALT) of the MODE switch generate different responses in PASS and BFS. The MODE tb provides feedback to the crew by indicating RUN, barberpole, or IPL.

PASS

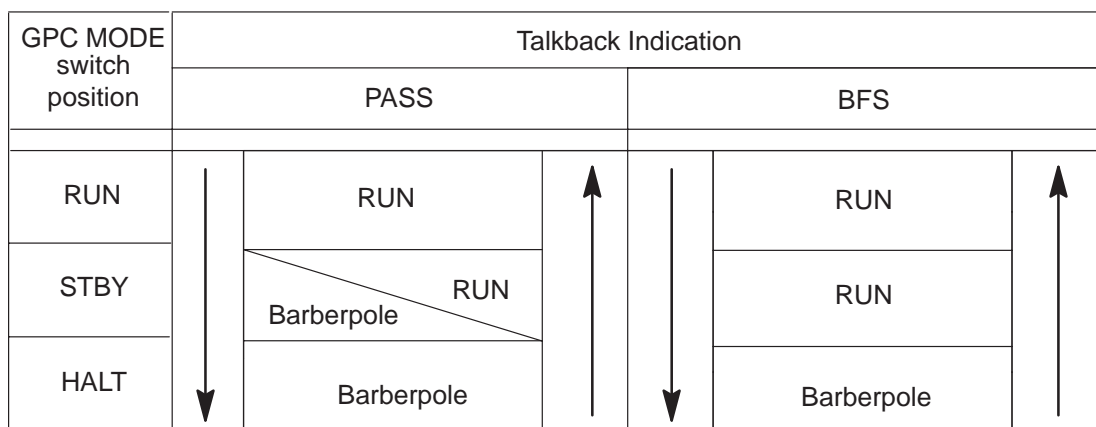
In the RUN position, the GPC supports normal software processing (system and application software). The GPC will reflect RUN on its MODE tb. When a GPC is moded from RUN to STANDBY, the GPC stops processing PASS software and performs an orderly shutdown. The GPC is now in a software-controlled state and is monitoring the movement of the MODE switch. A barberpole tb reflects completion of the orderly shutdown. The OUTPUT tb also goes from gray to barberpole because the GPC can no longer transmit over the FC buses. Placing the MODE switch in HALT puts the GPC in a hardware-controlled state, where no software processing occurs. The hardware monitors a few switches, including the MODE switch and the IPL controls (discussed below). The MODE tb remains barberpole: therefore, whenever a GPC is taken from RUN to HALT, it is necessary to pause in STANDBY and wait for the tb to go from RUN to barberpole. This ensures that the GPC has performed its orderly shutdown and that, barring any failures, the GPC can be restarted.

When the MODE switch is moved from HALT to STANDBY, the GPC goes into a software controlled state and is reinitialized. The MODE tb changes from barberpole to RUN when this process is complete. It is important to pause in STANDBY before going to RUN to allow the reinitialization process to be completed. Even though the tb indicates RUN, there is no PASS software executing in STANDBY. Moding from STANDBY to RUN will start PASS system software (OPS 000) processing, and the MODE tb will remain RUN. The OUTPUT tb will go from barberpole to gray. Subsequent OPS transitions are required to initiate any application software processing.

BFS

Complete BFS software processing occurs whether the MODE switch is in RUN or STANDBY; the difference is that in STANDBY, the BFS cannot command the PL data buses pre-engaged. During ascent and entry, all four PASS GPCs are processing GNC. The BFS is performing limited SM functions such as antenna management over the PL data buses. Once on orbit, placing the BFS in STANDBY allows the PASS SM GPC to command over the PL data buses. Whether in RUN or STANDBY, the MODE tb will remain in RUN. When the BFS is taken to HALT, the BFS is in a hardware-controlled state and behaves the same as PASS, with its tb's barberpole.

Figure 3-5 provides a summary of GPC MODE switch and tb state for PASS and BFS. Note that the tb pattern seen in PASS depends upon the direction the MODE switch is moved.



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Figure 3-5. Talkback indications associated with GPC MODE switch positions (arrows show direction of switch motion)

IPL Hardware Controls

An IPL is the process in which a GPC is loaded (from the MMUs) with either PASS systems software or all of BFS's software. To perform this process, two IPL hardware controls are used: an IPL SOURCE SELECT switch and an IPL pushbutton for each GPC.

The IPL SOURCE SELECT switch is used to reserve an MMU for IPL transactions. Either MMU 1 or MMU 2 is used. While an MMU is selected for an IPL, that MMU should not be used for other transactions, such as OPS transitions. It is important to return this switch to OFF when not performing an IPL.

The IPL pushbutton is used to initiate the IPL process for a given GPC. More details are discussed in the IPL section of this workbook and in the DPS 21005 and DPS FAM 21006 lessons.

Questions

1. Explain what a “flight–critical string” is and state its purpose.
2. Explain what capability a GPC is given when its OUTPUT switch is in NORMAL.
3. Explain what a barberpole OUTPUT tb means.
4. Explain why it is important to pause in STANDBY when moding a GPC from RUN to HALT.
5. Explain the difference in BFS software processing when its MODE switch is in RUN and when it is in STANDBY (pre–engaged).

Section 4

Overview of DPS Software Concepts

Performance Objectives

As a result of studying this section, the student will be able to do the following:

- Identify and describe the types of software that make up PASS
- State the purpose of memory reconfiguration
- Identify the differences between Menu Option IPL and Default Option IPL

PASS vs. BFS

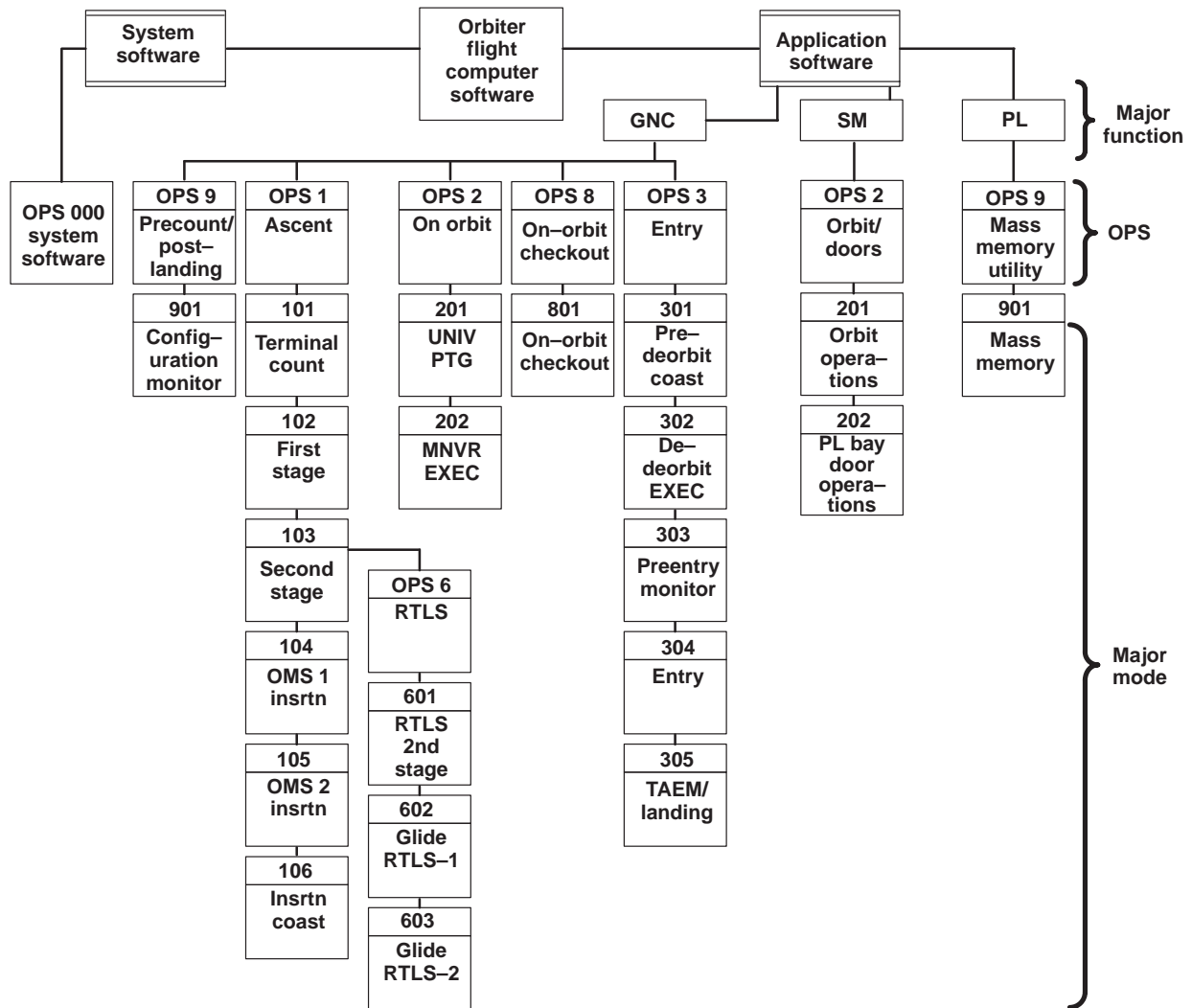
The BFS is an independent software system designed as a backup for PASS. PASS was designed by IBM, whereas BFS was designed by Rockwell International. This independent development ensured that no generic software failures for one system would affect the other. Compared to PASS, the BFS is a more restricted system. Self-contained in a single GPC (usually GPC 5), the BFS is used only during dynamic mission phases. It concurrently monitors PASS GNC GPCs over their flight-critical strings, calculates its own GNC parameters, and performs limited SM functions during ascent and entry. If PASS fails, the BFS can be engaged to take over control of the orbiter.

BFS is in itself an extensive subject. This workbook will provide only a very simplified overview of what BFS is, what it does, and how it compares to PASS. All discussions below refer to PASS unless stated otherwise.

PASS Software Structure

PASS software consists of two types of software: system software and application software. System software runs the GPC. It is responsible for tasks such as GPC-to-GPC communication, loading software from MMUs, and timekeeping activities. Application software is software that runs the orbiter. This includes software that calculates orbiter trajectories and maneuvers, monitors various orbiter systems (such as power, communications, and life support), and supports mission-specific payload operations. The application software is divided into broad functional areas called major functions; in turn, each major function consists of Operational Sequences (OPS), which are loaded into the GPCs for each major phase of flight.

Finally, each OPS has one or more Major Modes (MMs) that address individual events or subphases of the flight. This software structure is reflected graphically in Figure 4–1.



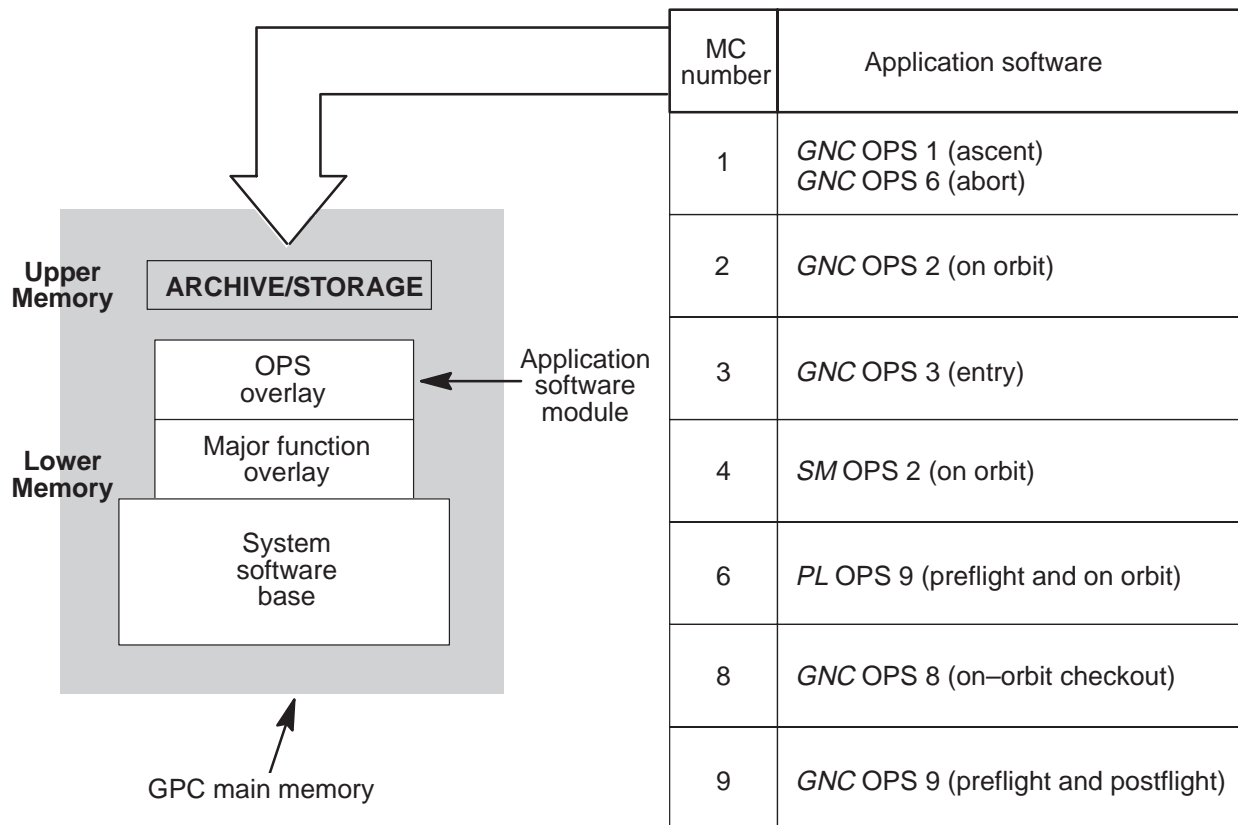
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Figure 4–1. Orbiter flight computer software

As mentioned earlier, it is possible for a GPC to process only its system software (it may or may not have application software loaded in its memory). A GPC in this state is said to be in OPS 000 (which, strictly speaking, is not an operational sequence; however, the term has been in popular use for many years). Note that when a PASS GPC is taken from STANDBY to RUN, it is in OPS 000. However, it is not possible to process application software without system software.

The combination of system and application software which is co-resident in a GPC is referred to as a Memory Configuration (MC). Each MC is assigned a number. There are seven PASS MCs. The GNC MC numbers are easy to remember: the number of the MC is the same as the GNC OPS that it contains (for example, MC 2 contains GNC OPS 2). Except for MC 1, each MC consists of a single OPS from one major function as well as the PASS system software. MC 1 has not only GNC OPS 1 ascent software but also the Return-to-Launch Site (RTL) abort software GNC OPS 6. This is because of the time-critical nature of an RTL abort. With OPS 6 present, the crew need not wait for the loading of this software from the MMUs. MCs are loaded into the GPC on an as-needed basis. The software can come from MMUs or other GPCs.

As seen in Figure 4-2, an MC consists of a system software base and an application software module. The application software module consists of two components: a major function base and an OPS overlay. The major function base contains the software and data that are common to all OPS within a given major function. An example of such data for the GNC major function is the orbiter state vector, which indicates the orbiter's position and velocity. While different OPS use different calculation schemes to determine the state vector, it is constantly maintained by the GNC applications software in the major function base. The OPS overlay consists of the specific flight phase software (for example, OPS 1 ascent: MM 101 – engine ignition, MM 102 – SRB powered flight, and so forth). During OPS transitions, a new major function base, if needed, will be loaded in first, followed by the requested OPS overlay.



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Figure 4-2. Applications software memory configurations

It should be noted that in addition to a GPC's MC, each PASS GPC is loaded with GNC OPS 3 (entry) software in its upper memory location. This software is referred to as the "G3 archive." The purpose of the G3 archive is to improve safety of flight by providing a quick source of entry software in the event of a Transoceanic Abort Landing (TAL) or an Abort-Once-Around (AOA). When this software is activated (through a GNC OPS 3 transition), the software is copied from upper memory into lower memory and processing begins. This process takes about 6 seconds. Each GPC is loaded prelaunch with the MC 3 archive, during the GNC OPS 901 to GNC OPS 101 transition.

It is important to note that the BFS GPC is loaded (through IPL) with all the software it ever needs during a mission. The BFS will never need to access the MMU for software as PASS does.

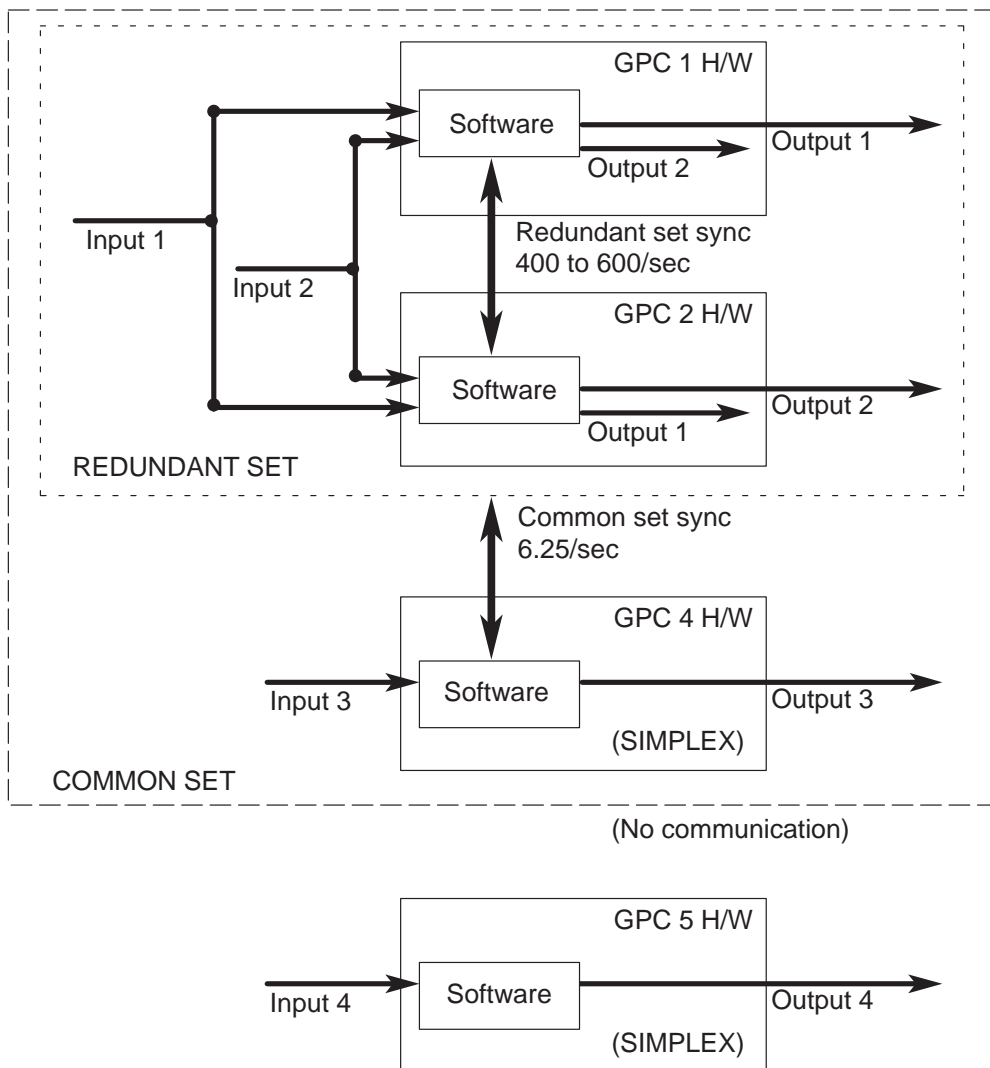
PASS GPC Synchronization

Synchronization is a means by which the GPCs communicate and exchange information with each other.

The Common Set (CS) is the set of all PASS GPCs that are processing PASS software and communicating with one another. Members of the CS can be running identical or different application software. Implemented by system software, CS synchronization involves the exchange of information between GPCs; for example, fault messages, major function switch settings, GPC/CRT key assignments, and time updates. This information exchange occurs over the Intercommunication Communication (ICC) data buses at 6.25 times per second.

The Redundant Set (RS) is a subset of the CS. The RS is made up of PASS GNC GPCs which are simultaneously receiving identical inputs, performing identical calculations, and generating identical outputs. The GNC application software provides for two levels of RS synchronization. The RS GPCs use hardware signals to synchronize their processing tasks; this occurs from 400 to 600 times per second. The RS GPCs also exchange data with each other over the ICC buses approximately 10 times per second. Only GNC GPCs are capable of running redundantly.

A simplex GPC is a single GPC independently processing its software. A simplex GPC may or may not be a member of the CS. For example, an SM GPC is communicating with the other PASS GPCs, so it is in the CS. The BFS is not communicating with PASS, so it is not in the CS.



REDUNDANT SET (RS): Two or more GPCs receive the same inputs, execute the same GNC software, and produce the same outputs at the same time.

COMMON SET (CS): Two or more GPCs share basic status information which they need to know about each other.

SIMPLEX: Any GPC that is running, but not in the RS.

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Figure 4-3. GPC synchronization

If a CS or RS GPC does not maintain synchronization, the other GPCs will vote that GPC out of the CS or RS and log U-Fail votes against the ailing machine. For example, when you take a PASS GPC MODE switch from RUN to STANDBY, that GPC falls out of the CS. The remaining GPCs issue U-Fail votes, saying in effect, “You have failed.” When a GPC receives two or more U-Fail votes, it then votes against itself. This is called an I-Fail vote. The voting status of the GPCs is reflected on the Computer Annunciation Matrix (CAM), located on panel O1 and shown in Figure 4-4 (this is also referred to as the Computer Status Matrix (CSM)). Votes against a given GPC are displayed by lights in that GPC’s column. The rows indicate voting GPCs. I-Fail votes are along the diagonal of the CAM; U-Fail votes are off the diagonal.

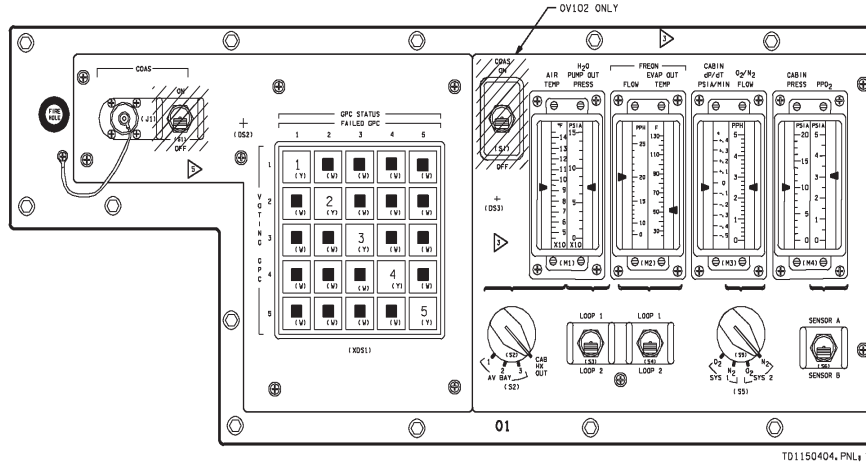


Figure 4-4. Computer annunciation matrix

Commfaults

Anytime a GPC is no longer listening on a given data bus or to a particular BTU, that bus or BTU is said to be commfaulted. The GPC stops listening to any incoming data. However, the GPC will continue to send commands out to the commfaulted device. On Figure 4-5, GNC SYS SUMM 1, the down arrow shows that FF 1 is commfaulted, resulting in the loss of the devices whose data go through these MDMs. One of the typical signatures of commfaulted devices is “M,” as seen on many CRT pages, including System Summaries (SYS SUMMs).

3021/ /018		GNC SYS SUMM 1			1 003/20:34:31 000/00:00:57				
RCS MANF	JETISOL FAIL VLV	SURF	POS	MOM	DPS 1 2 3 4 5				
F1	CLM	L OB	U 1.2	0	GPC				
2	OP	IB	U 1.2	0	MDM FF ↓				
3	OP	R IB	U 1.2	0	FA				
4	OP	OB	U 1.2	0	FCS/CH 1 2 3 4				
5		AIL	0.0		NAV 1 2 3 4				
L1	OP	RUD	0.0		IMU	M			
2	OP	SPD BRK	0.0		ACC	M			
3	OP	BDY FLP	32.7		RGA				
4	OP				TAC	MMM			
5	OP				MLS	MMM			
R1	OP				ADTA	M			
2	OP								
3	OP								
4	OP								
5									
		CNTRLR	1 2 3						
		RHC	L M						
			R						
			A						
		THC	L M						
			A						
		SBTC	L M						
			R						
I/O ERROR FF1 SYS SUM			1234	3/20:33:54(3)					

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Figure 4-5. Commfault of FF 1

Memory Reconfiguration

A memory reconfiguration refers to changing PASS software in the GPCs to meet the needs of a phase of flight. This change involves loading and executing the appropriate MCs into GPCs that are targeted to receive that software. It also includes bus assignments that determine which GPC will command which bus.

The memory/bus configuration table is the tool we use to perform a memory reconfiguration. This table is referred to as the Nominal Bus Assignment Table (NBAT). There are seven NBATs, one per MC, that are maintained as part of CS information. These NBATs, which contain default initial values (I-loads) determined prelaunch, are called by the crew through the GPC MEMORY page (more later in this workbook). The crew can modify the NBATs during various phases of flight, for both nominal and off-nominal situations.

A memory reconfiguration is initiated by an OPS X01 PRO sequence from the keyboard, where X is the number of the new OPS desired. Each OPS transition results in a new MC, which is loaded into the GPCs designated to receive this software (target GPCs). Before each OPS transition, the crew checks the NBAT for the associated MC and makes any changes as required. When the new OPS software starts executing, the memory reconfiguration is complete.

An OPS/mode recall is performed when the crew wishes to invoke a change to the NBAT but does not want to change the MC. They invoke the changed NBAT by recalling the current OPS and MM (OPS XXX PRO), hence the term OPS/mode recall.

Initial Program Load

Before the GPCs can be used, they must first be loaded with system software. This process is called an IPL. There are three identical copies of PASS software and two identical copies of BFS software on each of the two MMUs.

There are two types of IPLs: Menu Option IPL and Default Option IPL. The Menu Option IPL allows the crew to select a specific copy of PASS or BFS software from the MMU by interfacing with a menu on the DPS display. The Default Option IPL always uses copy number 1 of PASS system software. If it is necessary to load any copy of BFS software or the second or third copy of PASS system software, the Menu Option IPL must be used. If a BFS IPL is performed, no further MMU access involving the BFS GPC will be needed, since the BFS is loaded with all the software it needs.

The IPL process is initiated by setting the following switches located on panel O6:

- GPC POWER switch must be ON.
- OUTPUT switch must be in NORMAL.
- MODE switch must be in HALT.

IBM certifies the IPL process only when the GPC is in this configuration. The IPL SOURCE SELECT switch must be set to either MMU 1 or MMU 2. This switch designates the source of the IPL software. The Default Option IPL process begins by depressing the IPL pushbutton (also on panel O6) which loads the bootstrap loader from the MMU into the GPC. The bootstrap loader is a small program that loads the GPC IPL software from the MMU. During the loading of the bootstrap loader, the MODE tb is driven to IPL; once loading is complete, the MODE tb flips to barberpole. The GPC executes the bootstrap loader program when the MODE switch is moved from HALT to STANDBY. This loads the IPL software programs from the MMU. The GPC IPL program acts as the supervisor of the other IPL software programs, including the Self-Test Program (STP) and System Software Loader (SSL). The SSL loads PASS system software copy number 1 from the MMU into the GPC memory. The MODE tb is driven to RUN upon a successful load. Finally, by taking the MODE switch to RUN, the GPC begins executing systems software (OPS 000) and attempts to join the CS (or start a CS if there is none).

Both Menu and Default Option IPLs are covered in depth in DPS FAM 21006, the next lesson in the DPS training flow.

Questions

1. What is the purpose of the system software for PASS?
2. What is the purpose of the application software for PASS?
3. Define PASS GPC synchronization. Describe the three types of synchronization schemes.
4. Describe a commfault.
5. Define memory reconfiguration.
6. Define the types of GPC IPLs and describe their differences.

Section 5

PASS System–Level SPEC Pages

This section of the workbook discusses in detail the four PASS system–level pages: GPC MEMORY, GPC/BUS STATUS, DPS UTILITY, and TIME.

PASS GPC MEMORY Page

The GPC MEMORY page provides the crew with many functions and is available in all MCs and major functions. This is the most widely used page. In flight, this page is displayed in five ways:

- Default page – When the major function switch is in an unsupported major function. (The concepts of supported and unsupported major function are discussed shortly.)
- OPS 000 page – When a GPC is processing only system software.
- Pseudo OPS 000 page – When a GPC goes through OPS 000 during a transition from one MC to another.
- SPEC 0 – A PASS system–level SPEC which is available in all OPS and major modes.
- Major mode page (also referred to as an OPS page): GNC OPS 901.

Note: You may find it helpful to refer to Figure 5–1 (GPC MEMORY page) throughout the following discussion.


```

2011/000/          GPC MEMORY          1 009/12: 45: 34
                                         000/00: 00: 00
MEM/BUS CONFIG | READ/WRITE GNC
1 CONFIG _2(G2) | DATA 20* BIT SET 22 SEQ ID 24
2 GPC 1 0 0 0 0 | CODE 21 BIT RST 23 WRITE 25
                | 26 ENG UNITS HEX 27*
                | ADD ID DESIRED ACTUAL
                | 28 ----- 29 -----
                | 30 ----- 31 -----
                | 32 ----- 33 -----
                | 34 ----- 35 -----
                | 36 ----- 37 -----
                | 38 ----- 39 -----
                |-----|-----|
                | MEMORY DUMP | STORE MC=02
                | 40 START ID  ----- | 45 CONFIG  --
                | 41 NO WORDS  ----- | 46 GPC  _
                | 42 WDS/FRAME  --- | STORE 47
                | DUMP 43 |
                |-----|-----|
                | 44 DOWNLIST GPC 1 | MM AREA
                | OPS 0 ENA 49 | PL 52 1
                | | | GNC 53 1
                | | | SM 54 1
                |-----|-----|
OPS 3 UPLK 50
OPS 3 INIT 51 | ERR LOG RESET 48

```

TD1150501. CRT; 1

Figure 5-1. SPEC 0

The GPC MEMORY page provides two indicators that show what a GPC has in its memory and what it is processing:

- Memory configuration (“MC=”) – Located in the lower right portion of the page (in the STORE section). This indicator reflects the number of the Memory Configuration (MC) currently loaded in this GPC. (The GPC driver indicator, which appears after the title of the CRT page, reflects which GPC is driving the DPS display.)
- Major function indicator – Also referred to as the “OPS Mode Indicator” or “Read/Write Indicator.” The indicator is located in the upper section next to READ/WRITE. It reflects what major function is currently processing in this GPC. When the GPC is in OPS 000 (processing systems software) it reads “000.” Other possibilities are “GNC,” “SM,” and “PL.”

The following indications, along with the DPS display page indicator in the upper left corner, are used to determine what mode the GPC (which is driving this GPC MEMORY page) is in.

- If the SPEC page number = “000” (e.g., “xxx1/000/”, where xxx1 is major mode page number), then this is SPEC 0.

- If the major mode page number = “0001” (e.g., “0001/ / ”) and the major function annunciator = “000,” then this is the OPS 000 page.
- If the major mode page number = “0001” (e.g., “0001/ / ”) and the major function annunciator is “GNC,” “SM,” or “PL,” then this is the default page for an unsupported major function.
- If the GPC MEMORY page appears during an OPS transition, this represents the pseudo OPS 000 page. In this context, GPC MEMORY shows the indications of the OPS 000 page just discussed.

The distinction between default page and OPS 000 page must be understood. A major function is unsupported if there is no GPC processing that major function’s software. When the major function switch for an IDP/CRT is moved to a new position, a search is made to find a GPC in the CS processing under that major function. If a GPC cannot be found, the original GPC retains control of the DPS display but presents the default page on the screen. The default page is used to indicate that the major function switch is currently in an unsupported major function. A GPC processing only systems software is in OPS 000; it will present the OPS 000 version of the GPC MEMORY page. It is important to realize that a GPC displaying a default page is not in OPS 000; the GPC continues to process its major function software.

MEMORY/BUS Configuration Table and NBAT

The left side of GPC MEMORY page is the memory/bus configuration table, popularly called the NBAT.

The purpose of the NBAT is to assign which GPCs are targeted to receive a particular MC (in other words, the target set) and which target GPCs will command which data buses.

As mentioned previously, there are seven PASS MCs; therefore, there are seven NBATs. An NBAT is selected for inspection and editing by using ITEM 1 and the number of the MC desired. An indicator in parentheses displays the applications software in that MC; for example, “G3” refers to GNC OPS 3, while “S2” refers to SM OPS 2.

ITEMs 2–6 (implied item numbering) are used to define the target GPCs for this MC (Figure 5–1). Each of the five GPCs has its own slot. If a GPC is in the target set, its number will appear in its slot. If a GPC is not targeted, a zero will appear in its slot. For example, if GPC 2 is to be assigned to the target set, a “2” will go into slot number 2, using ITEM 3. If we want to turn around and remove GPC 2 from the target set, we enter a “0” into slot 2 through ITEM 3.

The remaining part of the NBAT is set up in three columns. The buses are indicated in the leftmost column. The item numbers listed down the center column are used to make the assignments of GPC commanders for these buses, which appear down the right column. Zeros are used to deassign a bus.

The commanders for the flight–critical strings, PL data buses 1 and 2 (assigned as a pair), the DK data buses (labeled “CRT” on the NBAT), LDBs, and MM data buses are assigned with this section. (The term “CRT” refers to the Cathode–Ray Tube displays that existed prior to the Multifunction Electronic Display System (MEDS). Also note that PASS can support only three DK data buses at a time.)

An important thing to remember concerning NBATs is that the assignments displayed are not necessarily what is currently in effect. (Current information can be seen on SPEC 6, which is discussed in detail below.) NBATs take effect by involving an OPS transition (loading new software) or an OPS/mode recall (no loading of new software) for this MC. An OPS/mode recall is performed by entering an OPS XXX PRO sequence on the keyboard, where XXX is the current OPS and major mode. The purpose of the OPS/mode recall is to implement bus reassignments made in the NBAT without changing MCs.

The most common bus reassignments performed by a crew involve changing commanders for the flight-critical strings; the process of changing string commanders is called restringing. While restringing can be physically performed anytime, current flight rules restrict restringing during some phases of flight.

Before each OPS transition, the crew calls up the NBAT for that MC and checks or sets up the proper target set and bus assignments. The NBAT will then become effective during the OPS transition involving that MC.

READ/WRITE Section

This section allows the crew to modify the contents of a GPC's memory. Changes made in this section will affect the GPC(s) within the selected major function (if the major function is supported) or the GPC driving the DPS display in the case of an OPS 000 machine.

There are four mutually exclusive modes associated with modifying memory:

- CODE mode allows changes to the software coding itself.
- DATA mode allows changes to words located in the DATA areas of memory, which contain variables and parameters used by the software.
- BIT SET allows forcing of individual bits in a memory location to a logical 1.
- BIT RESET allows forcing of individual bits in a memory location to a logical 0.

Apart from the areas of memory affected, CODE and DATA modes operate in an identical fashion. BIT SET operates in style similar to BIT RESET.

To examine a location of memory, an address (hex) is entered in one of the items in the ADD ID (address identification) column; the current contents are displayed in the ACTUAL column, either in hex or engineering units. The format used is controlled by selecting HEX or ENG UNITS mode. The latter takes a three-digit code that indicates whether you want to see fixed or floating point format and whether any of 10 predefined unit conversions are desired. (An option for no unit conversions is also available.)

To examine sequential memory locations, the initial address is entered first, followed by a SEQ ID (ITEM 24). The remaining part of the table below the initial address supplied is filled with the subsequent addresses and their contents.

To actually change data in locations of memory, the desired values are entered under the DESIRED column. In DATA and CODE modes (ITEMs 20 and 21, respectively), the new value to replace the current value is entered. In BIT SET and BIT RESET modes (ITEMs 22 and 23, respectively), a mask word (which indicates which bit positions to force to a 1 or 0, respectively) is entered. The change is initiated by the WRITE command (ITEM 25). Note that in order to perform a WRITE, the HEX mode must be selected.

Before leaving this section, let us elaborate on the BIT SET and BIT RESET modes. Unlike CODE and DATA modes, which replace old words with new words, the BIT modes work on the current value and change only the bits indicated in a mask word. The mask word has logical (binary) 1's where it is desired to change that bit's position, and 0's to leave that corresponding bit's position unchanged. Although the bits are binary in nature (1 or 0), hex (base 16) numbers are used for both the mask word and the contents of a memory location for modification purposes.

The capability to SET and RESET bits is particularly useful in modifying status words used by the software. These status words are often used as a set of on/off flags (1 or 0), where each bit is a flag. We can therefore change specific flags while leaving the remaining flag bits alone. In fact, we do not need to know the current value of the status word. This is especially important when software is constantly updating parts of a status word and the value is continually changing.

STORE Section

The STORE section is used to freeze dry a GPC. A freeze-dried GPC is a GPC which has been loaded with applications software of a particular MC, but the GPC does not process the software; it is simply stored in (lower) memory. The GPC is then moded to STANDBY and then to HALT. After 4.5 minutes, the GPC enters the "sleep mode." In this sleep state, the GPC uses minimum power, which is just enough to maintain its memory contents. The crew's visual cue as to when a GPC goes to sleep is that the GPC's CAM column lights are extinguished. One PASS GPC is freeze-dried when configuring the computers for orbit. This GPC, usually GPC 3, is freeze-dried with G2 in order to provide another source of orbit software in the event of MMU, MM bus, or GPC failures. When the freeze-dried GPC is wakened, it can copy its software into other GPCs. Movement of the MODE or POWER switch will wake up the GPC. Recall that each GPC is loaded with G3 archive; therefore, there are 10 sources of entry software (4 GPCs, 2 MMUs with 3 copies each).

The STORE section loads an MC into a GPC without processing the applications software. In order to use this option, two requirements must be satisfied. The GPC to be freeze-dried must drive the DPS display used to initiate the freeze-dry, and that GPC must be in OPS 000. ITEMs 45 and 46 are used to designate the MC and the GPC to use for the freeze-dry. ITEM 47 initiates the loading of the MC into the designated GPC.

MEMORY DUMP Section

This section allows the dumping of GPC memory locations to MCC and/or the onboard OPS recorders. The starting address is entered (in hex) in START ID (ITEM 40), the number of words to dump (in decimal) in ITEM 41, and the rate in ITEM 42. The dump itself is initiated with an ITEM 43. The appropriate parameters for a given situation involving a memory dump are found in the Flight Data File (FDF). It is possible to dump all locations of memory. A memory dump is always performed with MCC's coordination.

Other Parts of GPC MEMORY Page

The downlist is information generated by a GPC that is sent to the MCC. Each different type of GPC (GNC, SM, and BFS) generates and sends its own downlist data to MCC. Since GNC GPCs are redundantly processing identical software and generating identical outputs, they are also producing identical downlist. Therefore, sending the downlist of all the RS GPCs is not necessary. Instead, only one RS GPC's downlist is used; ITEM 44 allows us to designate the downlist GPC. This is usually the lowest numbered RS GPC.

If we desire to downlist an OPS 000 GPC, we must enable this with ITEM 49, OPS 0 ENA, which must be entered into the OPS 000 GPC.

ITEM 48, the ERR LOG RESET, clears the error logs generated by the GPCs and used by the MCC to assess the health of the GPCs. An ERR LOG RESET also clears GPC fail votes. Note that it is very important to get MCC concurrence before performing an ERR LOG RESET, as MCC will lose this data upon completion of the command.

OPS 3 UPLK (ITEM 50) and OPS 3 INIT (ITEM 51) were used to provide the capability to uplink MC 3 into a GPC. OPS 3 UPLK enabled and disabled the uplink process. OPS 3 INIT initialized the GPC once the uplink of MC 3 had been completed. Because of the capability of G3 archive, this process has now been disabled.

MM AREA (ITEMs 52, 53, and 54) provides the crew with the capability to access other copies of applications software on the MMUs. These options are major function dependent. For example, suppose copy number 1 of GNC OPS 2 is bad. Copy number 2 may be retrieved by entering ITEM 53+2 EXEC, followed by an OPS 201 PRO. Note that the software copy specified is retrieved for all OPS transitions in that major function.

GPC/BUS STATUS Page (DISP 6)

The GPC/BUS STATUS page (commonly called SPEC 6 (Figure 5-2)) is used to see MC and bus assignments currently in effect for the PASS CS GPCs. This page, which is available in all OPS, has a column for each GPC. The MODE row indicates whether the GPC is running software or is in HALT. (A GPC in STANDBY will be shown here as being in HALT.) The OPS row indicates what software is currently processing for GPCs in RUN or what software was last executing in a halted GPC.

2011/ /006		GPC/BUS STATUS					2 000/02: 34: 35	
		1		2	3	4	5	
MODE		RUN	RUN	HALT	RUN	HALT		
OPS		G2	G2	0	S2	0		
STRING	1	FF	*					
		FA	*				↓	
	2	FF		*			↓	
		FA		*			↓	
	3	FF		*			↓	
		FA		*			↓	
	4	FF	*				↓	
		FA	*				↓	
	PL	1	↓	↓		*		
		2	↓	↓		*		
	LAUNCH	1	↓	↓		*		
		2	↓	↓			↓	
	CRT	1	*				↓	
		2		*			↓	
		3	↓	↓			↓	
		4	↓	↓		*		

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Figure 5-2. GPC/BUS STATUS, SPEC 6

The remaining rows display current information for the flight-critical strings (these are subdivided into FF and FA MDMs), PL, launch, and DK (CRT) data buses. GPCs displaying HALT will have a blank column, since they are not part of the CS. For those in RUN, special symbols are used. An asterisk (*) indicates that the GPC is commanding a particular bus, whereas a blank indicates that GPC is listening to traffic on that bus. A down arrow indicates that the software is bus masking; that is, it is not listening to traffic on that bus. Bus masking can be nominal, as in the case of an on-orbit SM GPC bus masking the flight-critical strings, or it can be off nominal, as in the case of a bus failure. An asterisk followed by a down arrow could indicate a failure or a hardware inhibit of the bus. Therefore, the GPC which is assigned to command this bus is being masked to prevent GPC(s) from listening to traffic on that bus.

It is important to remember how this page and the NBAT differ.

- The GPC/BUS STATUS page (DISP 6) indicates current status based on CS information.
- The NBAT reflects the desired target GPCs and desired bus assignments for a given MC. These assignments are not invoked until an OPS transition or OPS/mode recall is performed. Therefore, the NBAT display does not necessarily reflect what the current assignments are.

DPS UTILITY Page (SPEC 1)

SPEC 1 (Figure 5–3) is available in all OPS. It provides the crew with many DPS–related capabilities.

```

2011/001/          DPS UTILITY          1 000/02: 34: 35
                                     000/00: 08: 35

MMU ASSIGN          PORT ASSIGN
  1  2              PRI  SEC  UL CNTL
GNC 1* 2          STRING 1 15* 16  AUTO 35*
SM  3* 4          2  17* 18  ENA 36
PL  5* 6          3  19* 20  INH 37
OPS 0 7* 8        4  21* 22
                                     IPL SOURCE SW
MMU STATUS          PL 1/2 23* 24  MASK 38*
  1 RDY
  2 RDY
VAR PARAM ID LIST
  25 ABCD
MMU SOURCE/BUS      26 ABCD
GPC/MMU  9*         27 ABCD
MMU/MMU  10         28 ABCD
GPC/LDB  11         29 ABCD
                                     30 ABCD
CKPT RETRV         31 ABCD
  ENA 12           32 ABCD
                                     33 ABCD
RTC               34 ABCD
  13 -----
CMD 14 -----

G3 ARCHIVE
LOAD 48
RETRIEVE 49*

GROUND OPS
GSE POLL ENA 50
SM GSE INH 51
SM C/O ENA 52
GNC C/O ENA 53
BFC C/O ENA 54
ALT PL9 TB 55
( )

```

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Figure 5–3. DPS UTILITY

Port Moding Section

Each of the FF, FA, and payload MDMs have two MIAs, commonly referred to as ports. Each port is connected to a separate data bus, so there are two pathways (a primary and a secondary) by which the GPCs can communicate with an MDM.

Each FC data bus is connected to both an FF and an FA MDM, whereas both PL buses are connected to both payload MDMs. However, these buses can interface with only one MDM at a time. Port moding is a software method that controls which bus is used to communicate with an MDM and hence, which port of an MDM is active.

Initially, all buses are in the primary mode. Figure 5–4 represents string 1. Notice that FC 1 goes to the primary port of the FF 1 MDM, and FC 5 goes to the primary port of FA 1. If a failure occurs at an MDM, it may be related to a port in the MDM. Therefore, the crew would try the secondary port. This is done on SPEC 1, DPS UTILITY, using ITEMS 15 through 24. For example, performing an ITEM 16 EXEC would result in a port mode on string 1; FC 1 now links FA 1 through its secondary port, while FC 5 links FF 1 through its secondary port (Figure 5–5). Port moding takes effect immediately, and an I/O RESET is automatically performed on just that string.

Since port moding always involves both FC (or PL) data buses, both MDMs will be port moded at the same time. It is also important to remember that the control of other units on the string is unaffected by port moding.

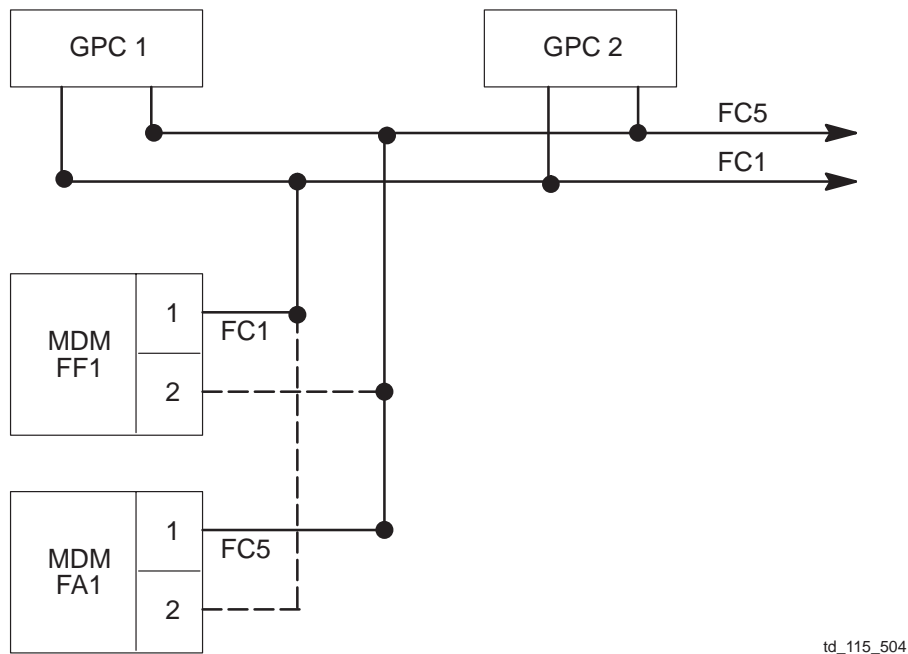
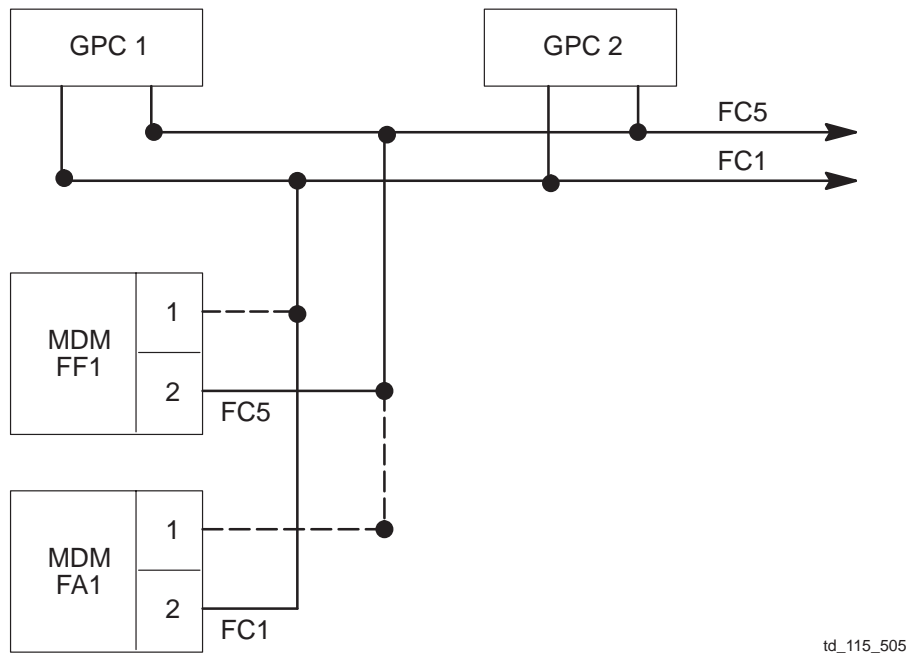


Figure 5–4. String 1 in the primary mode (GPC 1 commanding)



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Figure 5-5. String 1 in the secondary mode (GPC 1 commanding)

MMU-Related Sections

The MMU assignment section assigns the prime MMU for various MMU transactions involving GNC, SM, PL, or OPS 000 GPCs to either MMU 1 (ITEMs 1, 3, 5, and 7, respectively) or MMU 2 (ITEMs 2, 4, 6, and 8, respectively).

Next are the MMU status indicators; for MMUs 1 and 2 we see either RDY if ready or BSY if the MMU is off or busy.

MMU source/bus is used for OPS transitions. It indicates the software source and which data buses are to be used to transport that software to the target GPC(s). The default option (ITEM 9) is GPC/MMU. If a GPC currently has the requested software, it is used as the source of that software. Otherwise, the MMUs are used as the software source. (Obtaining the software from a GPC is much faster than retrieving it from an MMU.) In any case, the MM data buses are used to load software into the GPCs.

If we wish to force the software to come from an MMU regardless of whether or not a GPC is available as a source, ITEM 10 is selected. The software is loaded into the target GPC(s) through the MM buses. Afterwards it will default back to GPC/MMU (ITEM 9). GPC/LDB (ITEM 11) is used if the MM data buses fail. The launch data buses are used as an alternative path to transport the software from a source GPC into the other target GPCs.

Other Sections

The CKPT RETRV ENA (ITEM 12) is used to allow the SM GPC to retrieve a checkpoint during an SM OPS transition.

A checkpoint is a snapshot of SM-related data, such as Caution and Warning (C&W) limits, that are saved to a file on the MMU. The data are changed and updated in the SM GPC as the flight progresses. A checkpoint is periodically taken during the course of a flight to save the data on the MMUs. If a new SM GPC had to be brought up, the use of an accurate checkpoint eliminates the task of the crew and/or the MCC reestablishing all the changes made up to that point in the flight.

The Real-Time Command (RTC) section (ITEMs 13 and 14) allows the crew to send commands through the MDMs directly to various hardware devices. A hex code consisting of an address and command word can be entered through ITEM 13. The command is then sent through ITEM 14. An example of using RTC is to control whether or not voice transmissions are recorded on the OPS recorders (typically, voice is not recorded during crew sleep periods). Almost all RTCs are performed by an uplink through the MCC.

The VARIABLE PARAM ID LIST (ITEMs 25 through 34), which is major function specific, allows up to 10 additional memory location parameters to be included in the downlist for use by the MCC. This is used if the ground wants to look at data that are not usually part of the downlist. Each major function has its own separate variable parameter list which is maintained across OPS transitions.

The uplink control section (ITEMs 35, 36, and 37) defines how incoming MCC commands uplinked to the orbiter are accepted by PASS. The uplink control section works in conjunction with hardware. In order for the controls on this page to work, the uplink switch on panel C3 must be in ENABLE.

The enable option (ITEM 36) enables uplink at any time. Inhibit (ITEM 37) inhibits any uplink. Auto (ITEM 35) selectively inhibits and enables uplink based on current communication coverage status as determined by the SM GPC.

In the IPL section of this workbook, it was mentioned that when an MMU is selected for an IPL via the IPL SOURCE SELECT switch, that MMU is reserved for the IPL process. ITEM 38, IPL SOURCE SW MASK, provides the capability to software mask this switch's ability to reserve an MMU for IPLs. This mask allows access to an MMU selected by the IPL SOURCE SELECT switch to support OPS transitions and other types of MMU access. This becomes important in the event of an IPL SOURCE SELECT switch failure, where the selected MMU would otherwise be unavailable for anything except IPLs. If an asterisk appears beside ITEM 38, then masking is enabled. No asterisk means the software masking function is disabled. Note that a GPC IPL can occur from the MMU selected for IPL via the IPL SOURCE SELECT switch, regardless of the state of the software mask.

The G3 ARCHIVE section (ITEMs 48 and 49) provides enable/inhibit control of the G3 software overlay to be loaded prelaunch into the GPC's upper memory during the G9 to G1 transition. ITEM 48 is valid only in G9. ITEM 49 is enabled upon successful archive loading and can be toggled off should the need arise to disable archive activation for a G3 OPS transition.

Time Management and the TIME SPEC (SPEC 2)

The TIME SPEC is available in all OPS except GNC OPS 1, 3, and 6. It consists of three major sections, which are covered in this section. The operation of the Master Timing Unit (MTU) also is discussed.

MISSION TIME, CRT TIMER, and TONE Sections

This section of SPEC 2 (Figure 5–6) controls both the mission time and CRT Timers seen in the upper right portion of every PASS page. In addition, this section is used to set crew alarms for various times during a flight. The format for the CRT TIMER and TONE entries is hh:mm:ss where “h” is for hours, “m” is for minutes, “s” is for seconds, and leading zeros need not be entered.

```
2011/002/          TIME          2 000/01: 01: 00
                                000/00: 00: 00
MISSION TIME          TONE
GMT 1                3  ---  ---  ---  MSN T
MET 2*              6
CRT TIMER
9 SET[]__ __STOP 13      20[]__ __ __ CRT T
14 START AT  --  --  --  MSN T  23 DURATION 01
17 COUNT TO  --  --  --  MSN T

-----
MTU
24 GMT Δ[]__ __ / __: __: __ __ __
28 MET Δ[]
UPDATE 32              MET RESET 33

-----
GPC TIME              GPC
                        GMT          TRY
MTU ACCUM 1 | 078/02: 34: 06. 108 | 34 | 1 A1
2 | 078/02: 34: 06. 108 | 35 | 2 A1
3 | 078/02: 34: 06. 108 | 36 | 3 A1
GPC | 078/02: 34: 06. 108 | 37 | 4 A1
                        5 A1

TIME SYNC 38
```

TD1150506. CRT; 1

Figure 5–6. SPEC 2

The MISSION TIME section controls whether Greenwich Mean Time (GMT, ITEM 1) or Mission Elapsed Time (MET, ITEM 2) is shown in the uppermost time display for all PASS DPS display pages. The asterisk indicates which time is being used. Typically, MET is used.

The CRT Timer, once given an initial starting value, will count upwards once a second until the crew commands it to stop. (If the timer reaches 23:59:59, it rolls over to 00:00:00 and continues counting.) By entering a negative starting value for the CRT Timer, the timer will count downwards to zero, after which it will count upwards from zero until commanded to stop.

The CRT TIMER section provides controls for using the CRT Timers, with one timer per major function. A starting value for the CRT Timer can be entered using ITEMS 9, 10, and 11 (implied item numbering). Note the presence of the brackets ([]). Brackets are a reminder that negative or positive values are used to control whether the timer starts counting down to zero or starts counting up. ITEMS 12 and 13 can be used to start and stop the timer, respectively. START AT (ITEMs 14, 15, and 16) can be used in lieu of ITEM 12 to start the timer counting when the mission time reaches a designated time. Finally, when a time is entered in the COUNT TO section (ITEMs 17, 18, 19), the CRT Timer starts to count down to the designated time. It reaches zero when the mission time reaches the entered time. The CRT Timer will then continue counting in a positive direction until commanded to stop.

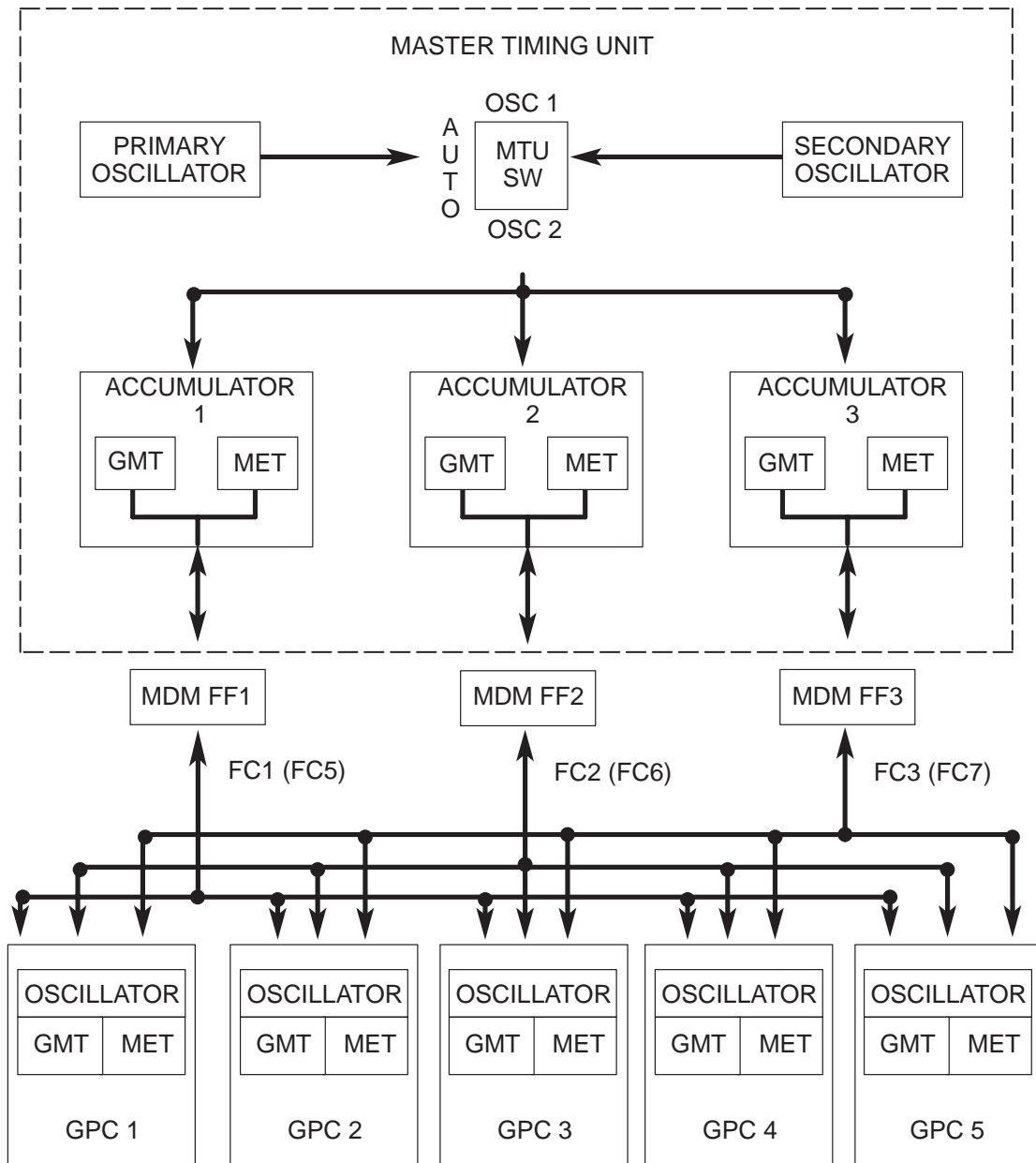
The TONE section allows audio alarms to annunciate at crew-selected times. The alarms are signaled by an SM ALERT TONE and a TIME TONE fault message. For each major function, two alarms can be set based on mission time (ITEMs 3–5 and 6–8) and one based on the CRT Timer (ITEMs 20–22). The DURATION field (ITEM 23) controls the duration of the SM ALERT TONE. The value can range from 0–99 seconds. Note that this changes not only SM ALERT TONE duration associated with the CRT Timers, but also the duration for all SM ALERT TONES.

Master Timing Unit

DPS requires a centralized, stable, and accurate GMT source in order to schedule its processing. The MTU is used as a source by each of the GPCs to update its own internal clocks.

As can be seen from Figure 5–7, the MTU is composed of primary and secondary oscillators, which provide signals to three accumulators. These in turn provide GMT and MET to various systems in the orbiter through the FF 1, FF 2, and FF 3 MDMs. In addition, the GPCs also have oscillators and GMT/MET accumulators, but they are not as accurate as those in the MTU. Time information from all the PASS GPCs as well as from the MTU are part of the CS information transmitted over the ICC buses. Controls for the MTU and how the GPCs use them are found on the TIME SPEC, SPEC 2 (Figure 5–6).

The PASS GPCs use one of the MTU accumulators (or potentially, another GPC) as a time source in a process described next.



td_115_507

Figure 5-7. GPC/MTU operational interface

PASS GPC Time Source Selection Process

The PASS GPCs, which start off using MTU accumulator 1, cyclically stop (approximately once every second) and determine the difference between the accumulator GMT and the GMT from the GPC's internal time. This difference is compared to a predefined value (which is less than a millisecond). If the difference is less than the tolerance, the GPC copies the GMT from the MTU accumulator into its own accumulator and continues to use that MTU accumulator. If the difference exceeds the tolerance, the GPC tries the other MTU accumulators and then the other

GPCs, performing this test until it finds a good time source. If none can be found, the GPC uses its own internal time.

An important point to note concerns how MET is used by DPS. While the MTU has MET accumulators which provide MET to other orbiter systems (such as the event timer), PASS does not use MET from this source. PASS uses a calculated MET, which is derived by subtracting a reference GMT from the current GMT. The reference GMT is usually the GMT of lift-off but can be changed through the TIME SPEC.

MTU Update Section

The MTU section on the TIME SPEC (Figure 5–6) can be used to update the GMT and MET in the GPC as well as the MTU by entering a delta time which adjusts the current time. ITEMS 24–27 adjust the GMT. ITEMS 28–31 adjust the MET. The delta update can be specified in days, hours, minutes, and seconds/milliseconds. (Note the use of implied item numbering.) These deltas can be either positive or negative, as indicated by the brackets ([]) which precede the data fields. Leading zeros need not be entered.

Because of the timing involved with CS synchronization, GMT updates are allowed only for values which do not exceed a delta of 15 milliseconds. A higher value will result in an ILLEGAL ENTRY message. The one exception to this is when there is only one GPC in the CS and it is in OPS 000; any size delta time can be used. There is no limit on the size of the delta update for MET.

ITEM 32 actually performs the update, which takes between 1 and 2 minutes to be incorporated. The software waits for the next whole minute then waits an additional 60 seconds, after which the update is incorporated. All the GPCs and all the accumulators (GPCs as well as MTU) get the update. MTU accumulator 1 is then reselected. Do not perform I/O RESETs or time source selections during this period. Updating the GMT also causes a change in the MET. Updating the MET changes not only the MTU's MET accumulators but also changes the reference GMT used by PASS to calculate the MET.

The MET can be reset to zero by performing an MET RESET (ITEM 33). This change occurs immediately.

GPC Time Source Section

On the bottom part of the TIME SPEC, the current GMT for the three MTU accumulators is displayed as well as the GMT of the lowest number GNC GPC commanding FF1, FF2, or FF3. ITEMS 34–37 are used to get the PASS GPCs to try to use one of these four time sources as their time source. Whenever a time source is changed as a result of a time miscompare or a comm-fault, a TIME MTU fault message will occur.

At the extreme lower right portion of the TIME SPEC, the current time source that the PASS GPCs are using is displayed. “A#” indicates the number of the MTU accumulator being used (for example, A1 = accumulator 1). If a GPC is being used as the time source, it appears as “G#”, where “#” is the number of the GPC.

Time sync (ITEM 38) synchronizes the three MTU accumulators and all GPCs to the time source being used by the selected GPC (the lowest numbered GPC in command of string 1, 2, or 3). Afterwards, the GPCs will try to use MTU accumulator 1 as their time source.

Section 6

BFS MEMORY Page

The BFS MEMORY page is a system software display which is always associated with BFS OPS 000 and SPEC 0. This page is similar to the PASS GPC MEMORY page (reference Section 5) but differs somewhat. Please refer to Figure 6-1 throughout the following discussion.

```

001/      /      BFS MEMORY      XX X DDD/HH: MM: SS
                                BFS DDD/HH: MM: SS

READ/WRITE
DATA 1X  BIT SET 3X  SEQ ID 5
CODE 2X  BIT RST 4X  WRITE 6
7 ENG UNITS XXX      HEX 8X
ADD ID   DESIRED    ACTUAL
9 XXXXX 10 XXXX    ±XXXXXXXXXXXX
11 XXXXX 12 XXXX    ±XXXXXXXXXXXX
13 XXXXX 14 XXXX    ±XXXXXXXXXXXX
15 XXXXX 16 XXXX    ±XXXXXXXXXXXX
17 XXXXX 18 XXXX    ±XXXXXXXXXXXX
19 XXXXX 20 XXXX    ±XXXXXXXXXXXX

-----
MEMORY DUMP
21 START ID   XXXXX
22 NUMBER WDS XXXXXX
23 WDS/FRAME  XXX
DUMP 24

LAUNCH BUS   1 26X TFL ENA
              2 27X   29X
              OFF 28X

PASS/BFS XFER ENA 25X

BFS TIME UPDATES
30 GMT Δ[+] XXX/XX: XX: XX_XXX
34 MET Δ[+] XXX/XX: XX: XX.XXX
UPDATE 38

MISSION TIME
GMT 39X
MET 40X      ( XX)

```

TD1150601. CRT 3

Figure 6-1. BFS MEMORY page

READ/WRITE Section

This section allows the crew to modify and view the contents of the BFS memory. (This works the same way as PASS GPC MEMORY page.)

There are four mutually exclusive modes associated with modifying memory:

- CODE mode allows changes to the software coding itself.
- DATA mode allows changes to words located in the DATA areas of memory, which contain variables and parameters used by the software.
- BIT SET allows forcing of individual bits in a memory location to a logical 1.
- BIT RESET allows forcing of individual bits in a memory location to a logical 0.

Apart from the areas of memory affected, CODE and DATA modes operate in an identical fashion. BIT SET operates in style similar to BIT RESET.

To examine a location of memory, an address (hex) is entered in one of the items in the ADD ID (address identification) column; the current contents are displayed in the ACTUAL column, either in hex or engineering units. The format used is controlled by selecting HEX or ENG UNITS mode. The latter takes a three-digit code that indicates whether you want to see fixed or floating point format and whether any of 10 predefined unit conversions are desired. (An option for no unit conversions is also available.)

To examine sequential memory locations, the initial address is entered first, followed by a SEQ ID (ITEM 5). The remaining part of the table below the initial address supplied is filled with the subsequent addresses and their contents.

To actually change data in locations of memory, the desired values are entered under the DESIRED column. In DATA and CODE modes (ITEMs 1 and 2, respectively), the new value to replace the current value is entered. In BIT SET and BIT RESET modes (ITEMs 3 and 4, respectively) a mask word (which indicates which bit positions to force to a 1 or 0, respectively) is entered. The change is initiated by the WRITE command (ITEM 6). Note that in order to perform a WRITE, the HEX mode must be selected.

Before leaving this section, let us elaborate on the BIT SET and BIT RESET modes. Unlike CODE and DATA modes, which replace old words with new words, the BIT modes work on the current value and change only the bits indicated in a mask word. The mask word has logical (binary) 1's where it is desired to change that bit's position, and 0's to leave that corresponding bit's position unchanged. Although the bits are binary in nature (1 or 0), hex (base 16) numbers are used for both the mask word and the contents of a memory location for modification purposes.

The capability to SET and RESET bits is particularly useful in modifying status words used by the software. These status words are often used as a set of on/off flags (1 or 0), where each bit is a flag. We can therefore change specific flags while leaving the remaining flag bits alone. In fact, we do not need to know the current value of the status word. This is especially important when software is constantly updating parts of a status word and the value is continually changing.

MEMORY DUMP Section

This section allows the dumping of the contents of a group of memory locations to MCC and/or the onboard OPS recorders. The starting address is entered (in hex) in START ID (ITEM 21), the number of words to dump (in decimal) in ITEM 22, and the rate in ITEM 23. Note that ITEM 23 WDS/FRAME is provided for you. This is because 32 is the default rate at which a BFS memory dump is performed. The only valid rates which may be entered here are 16, for 16-bit words, or 32, for 32-bit words. The dump itself is initiated with an ITEM 24. The appropriate parameters for a given situation involving a memory dump are found in the FDF. It is possible to dump all locations of memory. A memory dump is always performed with MCC's coordination.

BFS Time Updates and Mission Time

The BFS TIME UPDATES section on the BFS MEMORY page (Figure 6-1) can be used to update the GMT and MET in the BFS by entering a delta time which adjusts the current time. ITEMS 30-33 adjust the GMT. ITEMS 34-37 adjust the MET. The delta update can be specified in days, hours, minutes, and seconds/milliseconds. (Note the use of implied item numbering.) These deltas are either positive or negative, as indicated by the brackets ([]) which precede the data fields. Leading zeros need not be entered.

ITEM 38 actually performs the update. An update to BFS GMT is legal only in GNC OPS 000; an update to BFS MET is legal only in GNC OPS 301. If an update is illegally requested, an ILLEGAL ENTRY is annunciated. If values are entered for either delta GMT or delta MET that do not fall between day 1 and up to (but not including) day 400, an ILLEGAL entry is annunciated, and the delta time values are blanked on the display.

The MISSION TIME section controls whether Greenwich Mean Time (GMT, ITEM 39) or Mission Elapsed Time (MET, ITEM 40) is shown in the uppermost time display. The asterisk indicates which time is being used. MET is the default.

Other Parts of BFS MEMORY Page

PASS/BFS XFER ENA (ITEM 25) is used prelaunch to enable the BFS to receive pertinent initialization data from PASS. Execution of this item causes an "*" to appear.

LAUNCH BUS (ITEMS 26 and 27) allows the BFS to poll launch data bus 1 or 2, respectively, prior to launch and umbilical separation. LAUNCH BUS OFF (ITEM 28) terminates BFS polling. These three items are mutually exclusive. An "*" denotes the current state.

TFL ENA (ITEM 29) allows the BFS to automatically load the PCMMU whenever a PCMMU switchover occurs. The mode comes up enabled and may be disabled/enabled by toggling the item number. The PCMMU receives data from the GPCs and orbiter systems as well as some payload-specific data. It then formats and routes the data to the appropriate destination (e.g., MCC and GPCs). The TFL is the software that enables the PCMMU to format this data for routing.

You may have noticed that there is no NBAT section. The BFS assumes control of the entire vehicle after engaging. There are no other GPCs to share command of buses; the BFS becomes the commander for all buses.

Section 7

Conclusion

This workbook introduced the key hardware and software concepts important to understanding DPS. Introduced were the seven different groups of data buses (FC, PL, MM, ICC, DK, IP, and LDB), focusing in on FC, PL, and ICC buses. Also included were the flight-critical strings, how they can be controlled, and the two flight-critical MDMs they contain. The GPC hardware controls (the POWER, OUTPUT, and MODE switches and the OUTPUT and MODE talkbacks) were introduced and discussed in depth.

For the software side of the DPS, basic differences between PASS and BFS were introduced. Important DPS software concepts covered include OPS transitions, PASS synchronization, MCs, and default IPL. We also introduced the four PASS system-level DPS display pages: GPC MEMORY (SPEC 0), GPC/BUS STATUS (DISP 6), DPS UTILITY (SPEC 1), and TIME (SPEC 2). In particular, the NBAT portion of the GPC MEMORY page is a very important DPS concept, as shown in subsequent DPS workbooks and lessons.

The next lesson is DPS 21005 in the Crew Software Trainer (CST). The instructor will discuss the information provided here in detail, and you will have a chance to practice the concepts discussed here through interaction with the simulator.

Upon completion of this lesson, the next series of lessons in the DPS flow are the three DPS familiarization classes (DPS FAM), starting with DPS FAM 21006. These lessons, which are given in the Single System Trainer (SST), reinforce and expand upon the concepts discussed in this workbook. Pick up a copy of DPS Familiarization 21002 Workbook and read it prior to taking the first lesson.

Appendix A

Acronyms and Abbreviations

ADD ID	Address Identification
AOA	Abort–Once–Around
B/U	Backup
BBU	Battery Backup Unit
BFC	Backup Flight Controller
BFS	Backup Flight System
BTU	Bus Terminal Unit
C&W	Caution and Warning
CRT	Cathode–Ray Tube
CS	Common Set
CSI	Crew Software Interface
CSM	Computer Status Matrix
CST	Crew Software Trainer
DISP	Display
DK	Display/Keyboard (data bus)
DPS	Data Processing System
DPS FAM	Data Processing System Familiarization
ENA	Enable
ERR	Error
ET SEP	External Tank Separation
FA	Flight–Critical Aft (MDM)
FC	Flight Critical (data bus)
FDF	Flight Data File
FF	Flight–Critical Forward (MDM)
GMT	Greenwich Mean Time
GNC	Guidance, Navigation, and Control
GPC	General Purpose Computer
GSE	Ground Support Equipment
HW	Hardware
HEX	Hexadecimal (base 16)
I/O	Input/Output
IBM	International Business Machines

IC, ICC	Intercomputer Communication (data bus)
IDP	Integrated Display Processor
IP	Instrumentation/Pulse Code Modulation Master Unit (data bus)
IPL	Initial Program Load
LB, LDB	Launch Data Bus
MC	Memory Configuration
MCC	Mission Control Center
MDM	Multiplexer/Demultiplexer
MDU	Multifunction Display Unit
MECO	Main Engine Cutoff
MEDS	Multifunction Electronic Display System
MET	Mission Elapsed Time
MIA	Multiplexer Interface Adapter
MM	Major Mode
	Mass Memory (data bus)
MMU	Mass Memory Unit
MTU	Master Timing Unit
NBAT	Nominal Bus Assignment Table
OPS	Operational Sequences
PASS	Primary Avionics Software System
PCMMU	Pulse Code Modulation Master Unit
PF	Payload Forward (MDM)
PL	Payload
PRO	Proceed
PWR	Power
RMS	Remote Manipulator System
RS	Redundant Set
RTC	Real-Time Command
RTLS	Return to Launch Site
SEQ	Sequential
SEQ ID	Sequential Identification
SM	Systems Management
SPEC	Specialist Function
SRB	Solid Rocket Booster
SSSH	Space Shuttle Systems Handbook
SST	Single System Trainer
STBY	Standby
SW	Software

SYS
SYS SUMM

System
System Summary

TAL
tb
TFL

Transoceanic Abort Landing
Talkback
Telemetry Format Load

Appendix B

Answers

Answers to Section 1

1. The DPS directly or indirectly controls the majority of the orbiter systems.
2. Three functions of the DPS are
 - a. Performs GNC tasks necessary to fly the orbiter
 - b. Performs SM tasks that monitor the orbiter systems and some payload functions
 - c. Manages and filters telemetry to the MCC and enables MCC to remotely command many of the orbiter systems

Answers to Section 2

1. Some of the functions that the PASS supports are
 - a. Flying the shuttle
 - b. Providing life support
 - c. Supporting communications
 - d. Assisting with payload activities
 - e. Maintaining thermal control
2. The purposes of the BFS are as follows:
 - a. The BFS was developed to take control of the shuttle and allow the crew to safely return to Earth should the PASS fail.
 - b. During ascent and entry, the BFS provides SM capabilities, which are not supported by PASS.
3. The MMUs onboard the orbiter are tape-driven machines that provide redundant copies of PASS and BFS software for the GPCs. Each MMU houses three copies of each type of software.

Answers to Section 3

1. A flight-critical string refers to all the hardware connected to a pair of FC data buses (including an FF and an FA MDM) for the purpose of redundancy.
2. A GPC is given the hardware capability to transmit over the FC data buses (strings) when its OUTPUT switch is in NORMAL.

3. A barberpole OUTPUT tb is the crew's indication that the GPC is not able to transmit over the flight-critical strings.
4. Pausing in STANDBY is important to allow the GPC to perform an orderly shutdown of its software processing.
5. The BFS is able to transmit over the PL data buses when its MODE switch is in RUN. The BFS cannot transmit over the PL data buses when its MODE switch is in STANDBY (pre-engaged). There is no difference in the software processing.

Answers to Section 4

1. The purpose of the system software for PASS is to run the GPCs. It is responsible for such things as
 - a. GPC-to-GPC communications
 - b. Loading software from the MMUs
 - c. Timekeeping activities
2. The purpose of the application software for PASS is to run the orbiter. This includes software that
 - a. Calculates trajectories and maneuvers
 - b. Monitors orbiter power, communications, and life support systems
 - c. Supports payload operations
3. PASS GPC synchronization is the communication system between GPCs. The three types of synchronization schemes are
 - a. Redundant set (RS): Two or more GPCs receive the same inputs, execute the same GNC software, and produce the same outputs at the same time.
 - b. Common set (CS): One or more GPCs share basic status information which they need to know about each other.
 - c. Simplex: Any GPC that is running, but not in the redundant set.
4. The GPCs listen to the data being transferred along the data buses. When a GPC stops listening to a data bus or a BTU, that data bus or BTU is commfaulted. However, the GPC still sends data to the commfaulted data bus or BTU.
5. Memory reconfiguration is the process of changing PASS software within the GPCs to meet specific flight needs.
6. The Menu Option IPL is designed for crew selection of a specific copy of PASS or BFS software from the MMU. The Default Option IPL defaults to PASS system software copy number 1. If a PASS copy other than the first or any BFS copy of software is needed, the Menu Option IPL must be used.

Appendix C

Suggested Reference Documents

- a. The Crew Software Interface (CSI 21002) Workbook is a prerequisite for this manual.
- b. There are several other training manuals available which offer more detailed information about DPS. We recommend you supplement this training manual with the DPS Hardware and Software Training Manual (DPS HW/SW 21002).
- c. We also recommend DPS Dictionary (part of the Flight Data File (FDF)), which describes in detail every SPEC and DISP page in PASS and BFS.
- d. The SSSH has detailed drawings of all hardware components. In particular, drawing 8.1 gives an overview of how various hardware is connected to the GPCs.