2.6 DATA PROCESSING SYSTEM (DPS)

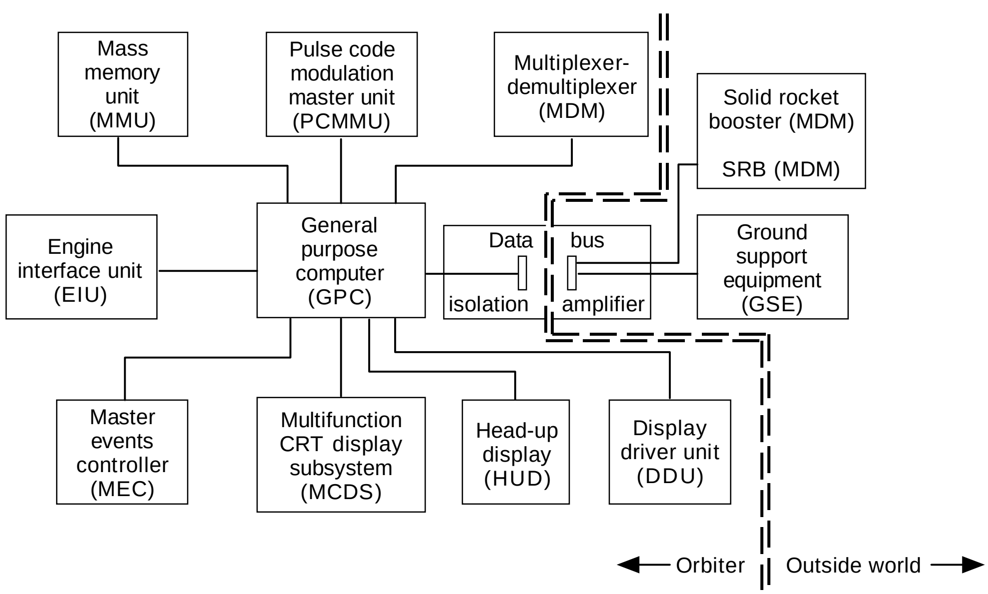
CONTENTS

Description

The DPS, consisting of various hardware components and self-contained software, provides the entire shuttle with computerized monitoring and control. DPS functions are:

- Support the guidance, navigation, and control of the vehicle, including calculations of trajectories, SSME burn data, and vehicle attitude control data.
- Monitor and control vehicle subsystems, such as the electrical power system and the environmental control and life support system.
- Process vehicle data for the flight crew and for transmission to the ground, and allow ground control of some vehicle systems via transmitted commands.
- Check data transmission errors and crew control input errors; support annunciation of vehicle system failures and out-of-tolerance system conditions.
- Support payloads with flight crew/software interface for activation, deployment, deactivation, and retrieval.
- Process rendezvous, tracking, and data transmissions between payloads and the ground.

The DPS hardware consists of five general-purpose computers (GPCs), two mass memory units (MMUs) for large-volume bulk storage, and a network of serial digital data buses to accommodate the data traffic between the GPCs and vehicle systems. The DPS also includes 20 orbiter and 4 SRB multiplexers/demultiplexers (MDMs) to convert and format data from the various vehicle systems, 3 SSME interface units to command the SSMEs, 4 multifunction CRT



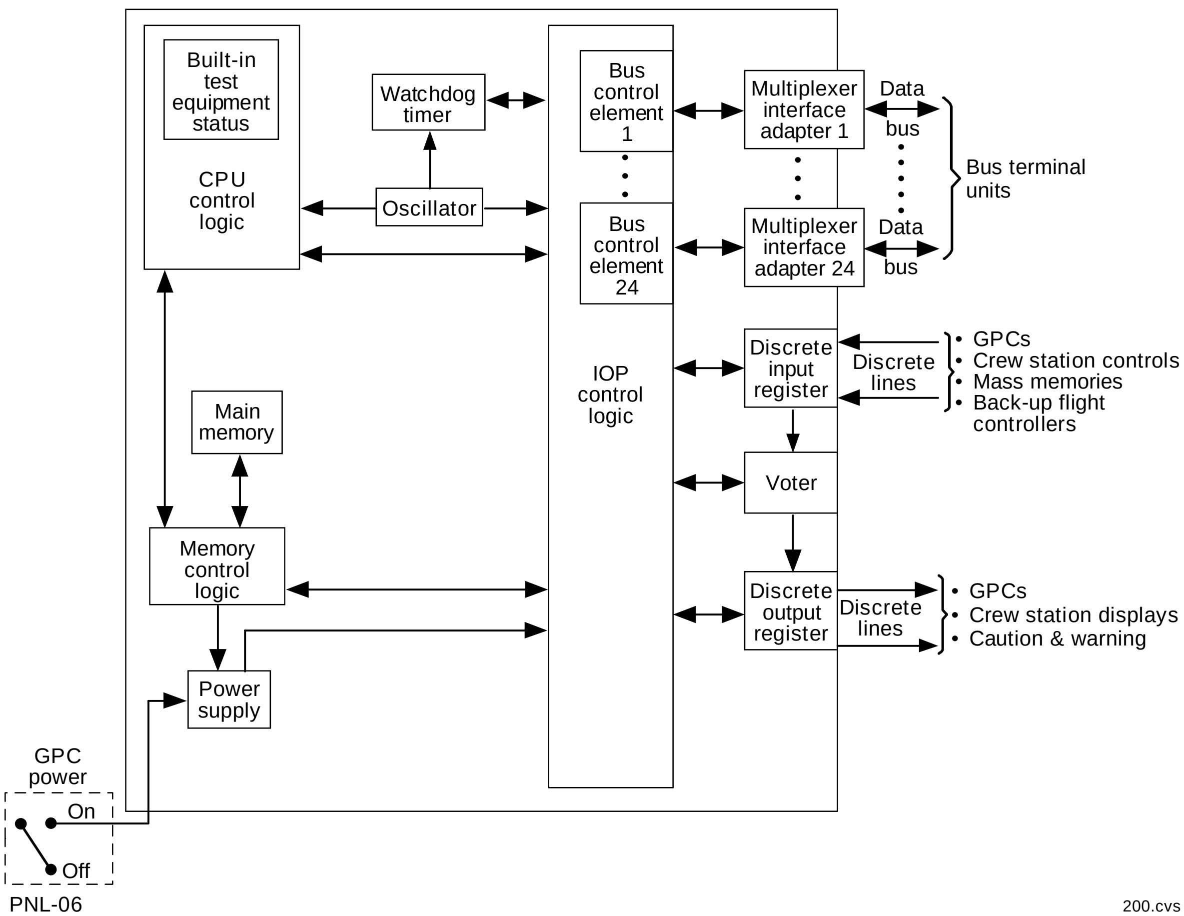
Data Processing System Interfacing Hardware

display systems used by the flight crew to monitor and control the vehicle and payload systems, 2 data bus isolation amplifiers to interface with the ground support equipment/launch processing system and the SRBs, 2 master events controllers, and a master timing unit.

DPS software accommodates almost every aspect of space shuttle operations, including orbiter checkout, prelaunch and final countdown for launch, turnaround activities, control and monitoring during launch, ascent, on-orbit activities, entry, and landing, and aborts or other contingency mission phases. A multicomputer mode is used for the critical phases of the mission, such as launch, ascent, orbit, entry, landing, and aborts.

General Purpose Computers (GPCs)

The orbiter has five identical IBM AP-101S GPCs. The GPCs receive and transmit data to and from interfacing hardware via the data bus network. GPCs also contain the software that provides the main on-board data processing capability. Up to four of the systems may run identical software. The fifth system runs different software, programmed by a different company, designed to take control of the vehicle if an error in the primary software or other multiple failures cause a loss of vehicle control. The software utilized by the four primary GPCs is referred to as PASS (primary avionics software system); the fifth GPC is referred to as BFS (backup flight system).



General Purpose Computer Functional Block Diagram

GPCs 1 and 4 are located in forward middeck avionics bay 1, GPCs 2 and 5 are located in forward middeck avionics bay 2, and GPC 3 is located in aft middeck avionics bay 3. The GPCs receive forced-air cooling from an avionics bay fan. (There are two fans in each avionics bay, but only one is powered at a time.)

CAUTION

If both fans in an avionics bay fail, the computers will overheat within 25 minutes (at 14.7 psi cabin pressure) or 17 minutes (at 10.2 psi) after which their operation cannot be relied upon. An operating GPC may or may not survive for up to an additional 30 minutes beyond the certifiable thermal limits.

Each GPC consists of a central processing unit (CPU) and an input/output processor (IOP) stored in one avionics box. The boxes are 19.55 inches long, 7.62 inches high, and 10.2 inches wide; they weigh approximately 68 pounds. The main memory of each GPC is volatile (the software is not retained if power is interrupted), but a battery pack preserves software contents when the GPC is powered off. The memory capacity of the GPCs is 256 k half-words, but only the lower 128 k half-words are normally used for software processing.

The CPU controls access to GPC main memory for data storage and software execution and executes instructions to control vehicle systems and manipulate data.

The IOP formats and transmits commands to the vehicle systems, receives and validates response data transmissions from the vehicle systems, and maintains the status of interfaces with the CPU and the other GPCs.

The 24 data buses are connected to each IOP by bus control elements (BCEs) that receive, convert, and validate serial data in response to requests for available data to be transmitted or received from vehicle hardware.

For timing, each GPC contains an oscillator that sends signals to internal components to regulate operations. The GPC also uses the oscillator to maintain an internal clock to keep track of Greenwich mean time (GMT) and mission elapsed time (MET) as a backup to the timing signal from the master timing unit (MTU).

Each GPC contains a watchdog timer. The watchdog timer is an incrementing clock register in the GPC that is reset about once every second by a signal from the CPU. If the register ever overflows, then a problem exists and is annunciated by a self-fail indication from that GPC. The PASS set does not utilize this hardware feature since it operates in synchronization with each of its GPCs to ensure proper functioning. Since the BFS operates essentially standalone relative to the PASS set synchronization, the BFS mechanization does utilize the watchdog timer function to serve as a check on its operation.

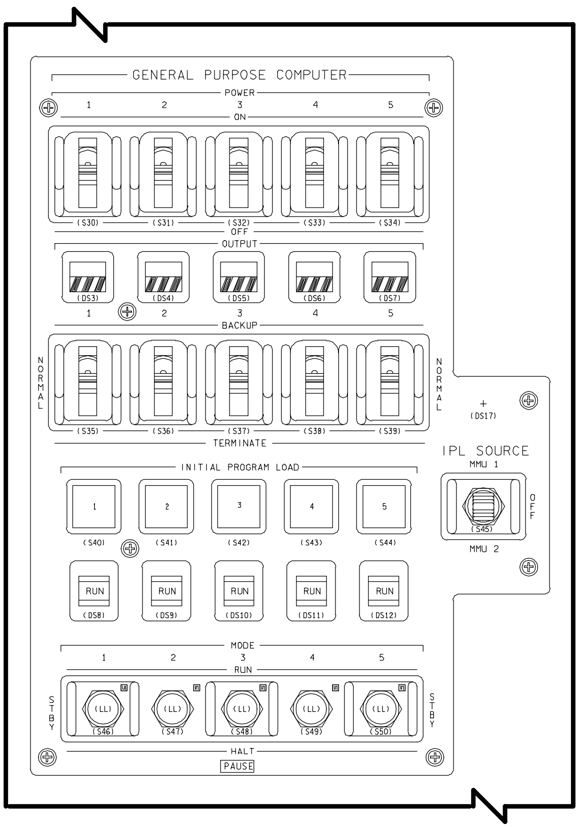
The PASS GPCs use a hardware "voter" to monitor discrete inputs from the other GPCs. Should a GPC receive a fail vote from two or more of the other GPCs, it will cause the GPC to annunciate a self-fail indication that also causes the GPC to inhibit any fail votes of its own against the other GPCs.

GPC Controls

The *GENERAL PURPOSE COMPUTER* hardware controls are located on panel O6. Each of the five GPCs reads the position of its corresponding *OUTPUT* and *MODE* switches and INITIAL *PROGRAM LOAD* pushbuttons from discrete input lines that go directly to the GPC. Each GPC has *OUTPUT* and MODE talkback indicators on panel O6 that are driven by GPC output discretes.

Each GPC has a *GENERAL PURPOSE COMPUTER POWER* switch on panel O6. Positioning a switch to ON enables power from three essential buses, ESS 1BC, 2CA, and 3AB. The essential bus power controls remote power controller (RPCs), which permit main bus DC power from the three main buses (MN A, MN B, and MN C) to power the GPC. There are three RPCs for each GPC; thus, any GPC will function normally, even if two main or essential buses are lost. Each computer uses 560 watts of power.

Each *GENERAL PURPOSE COMPUTER OUTPUT* switch on panel O6 is a guarded switch with *BACKUP*, *NORMAL*, and *TERMINATE* positions. The switch provides a hardware override to the GPC that precludes that GPC from outputting on the flight-critical buses. The switches for the PASS GNC GPCs are positioned to *NORMAL*, which permits them to output. The backup flight system switch (GPC 5) is positioned to *BACKUP*, which precludes it from outputting until it is engaged. The switch for a GPC designated on-orbit to be a systems management (SM) computer is positioned to *TERMINATE*, since the GPC is not to command anything on the flight-critical buses.



GENERAL PURPOSE COMPUTER
Hardware Controls

The talkback indicator above each *OUTPUT* switch on panel O6 indicates gray if that GPC output is enabled and barberpole if it is not.

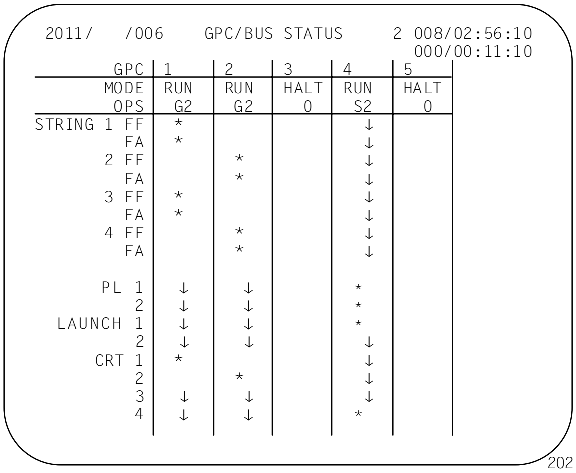
Each GPC receives *RUN*, *STBY*, or *HALT* discrete inputs from its *MODE* switch on panel O6, which determines whether that GPC can process software. The *MODE* switch is lever-locked in the RUN position. The *HALT* position initiates a hardware-controlled state in which no software can be executed. A GPC that fails to synchronize with others is either powered *OFF* or moded to *HALT* as soon as possible to prevent the failed computer from outputting erroneous commands. The talkback indicator above the *MODE* switch for that GPC indicates barberpole when that computer is in *HALT*.

In *STBY*, a GPC is also in a state in which no PASS software can be executed, but it is in a software-controlled state. The *STBY* mode allows an orderly startup or shutdown of processing. It is necessary, as a matter of procedure, for a PASS GPC that is shifting from *RUN* to *HALT* or vice versa to be temporarily (more than 3 seconds) in the *STBY* mode before going to the next state. The *STBY* mode allows for an orderly software cleanup and allows a GPC to be correctly initialized (when reactivated) without an initial program load. If a GPC is moded to *RUN* or *HALT* without pausing in STBY, it may not perform its functions correctly. There is no *STBY* indication on the talkback indicator above the *MODE* switch.

The *RUN* position permits a GPC to support its normal processing of all active software and assigned vehicle operations. Whenever a computer is moded from *STBY* to *RUN*, it initializes itself to a state in which only system software is processed (called OPS 0). If a GPC is in another operational sequence (OPS) before being moded out of *RUN*, that software still resides in main memory; however, it will not begin processing until that OPS is restarted by flight crew keyboard entry. The *MODE* talkback indicator always reads *RUN* when that GPC switch is in *RUN*, and no failures exist.

Placing the backup flight system GPC in *STBY* does not stop BFS software processing or preclude BFS engagement; it only prevents the BFS from commanding the payload buses used by BFS systems management software.

The PASS GPC/BUS STATUS display (DISP 6) indicates the current mode of each PASS GPC in the common set. The display does not differentiate between *STBY* and *HALT*; only *RUN* or *HALT* is displayed (GPC MODE).



GPC/BUS STATUS Display (DISP 6)

The *INITIAL PROGRAM LOAD* pushbutton for a GPC on panel O6 activates the initial program load command discrete input when depressed. When the input is received, that GPC initiates an initial program load (IPL) from the MMU specified by the *IPL SOURCE* switch on panel O6. The talkback indicator above the MODE switch for that GPC indicates *IPL*.

During non-critical periods in orbit, only one or two GPCs are used for GNC tasks, and another is used for systems management and payload operations.

A GPC on orbit can also be "freeze-dried"; that is, it can be loaded with the software for a particular memory configuration and then moded to *HALT*. Before an OPS transition to the loaded memory configuration, the freeze-dried GPC can be moded back to RUN and the appropriate OPS requested.

NOTE

Because all BFS software is loaded into the BFS GPC at the same time, the BFS GPC is sometimes referred to as being freeze-dried on orbit when it is placed in *HALT*. The BFS GPC can be moded to *RUN* prior to entry and will begin processing entry software following the OPS 3 request without having to access a mass memory unit. The term freeze-dry or freeze-dried is most often used with respect to the PASS GPCs.

GPC Modes of Operation

GPC modes of operation are redundant set, common set, and simplex. Redundant set operations refer to the mode in which two or more GPCs are concurrently receiving the same inputs, executing the same GNC software, and producing the same outputs. This mode uses a maximum amount of intercomputer communications, and the GPCs must maintain a high level of synchronization (called redundant set synchronization).

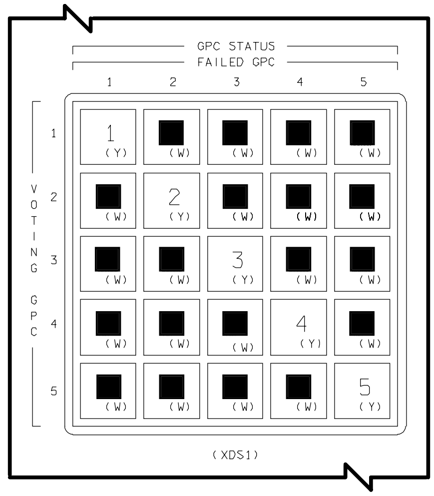
During redundant set operations, each GPC outputs only certain portions of its total software output to its interfacing hardware. Therefore, although each GPC "thinks" it is performing all its operations, only the GPC responsible for supporting a specific group of hardware will be able to actually transmit its data and commands. The redundant set GPCs compare all calculations to ensure that individual outputs are the same.

Common set operations occur when two or more GPCs communicate with one another while they are performing their individual tasks. They do not have to be performing the same major function (although they can be), but they do maintain common set synchronization. Any GPC operating as a member of the redundant set is also a member of the common set.

A simplex GPC is in *RUN*, but not a member of the redundant set. Systems management and payload major functions are always processed in a simplex GPC.

GPCs running together in the same GNC OPS are part of a redundant set performing identical tasks from the same inputs and producing identical outputs. Therefore, any data bus assigned to a commanding GNC GPC (except the instrumentation buses because each GPC has only one dedicated bus connected to it) is heard by all members of the redundant set. These transmissions include all CRT inputs and mass memory transactions, as well as flight-critical data. If one or more GPCs in the redundant set fail, the remaining computers can continue operating in GNC. Each GPC performs about 1.2 million operations per second during critical phases.

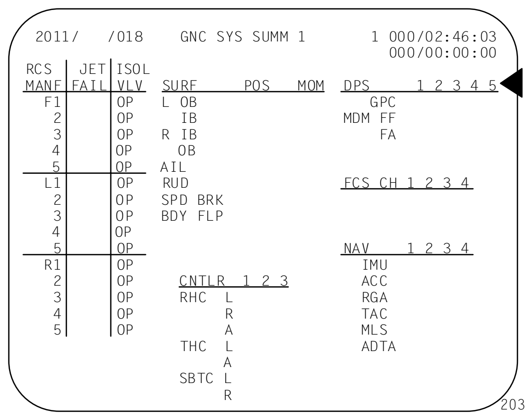
Each computer in a redundant set operates in synchronized steps and cross-checks results of processing hundreds of times per second. Synchronization refers to the software scheme used to ensure simultaneous intercomputer communications of necessary GPC status information among the PASS computers. If a GPC operating in a redundant set fails to meet any redundant synchronization point, the remaining computers will immediately vote it out of the redundant set. If a GPC has a problem with one of its multiplexer interface adapter receivers during two successive reads of response data, or does not receive data while other members of the redundant set do receive data, the GPC with the problem will fail-to-sync. A failed GPC is either powered OFF or moded to HALT as soon as possible by the crew.



GPC STATUS Matrix on Panel 01 (W=white; Y=yellow)

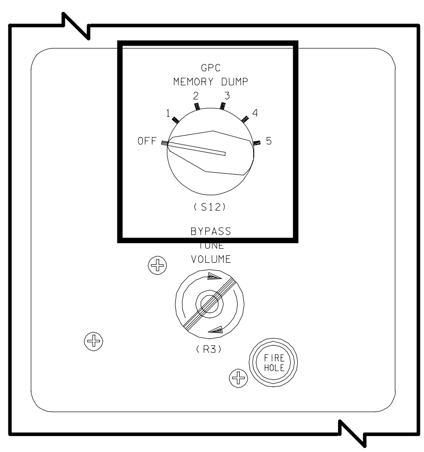
GPC Failure Indications

GPC failure votes are annunciated in a number of ways. Each GPC has discrete output lines for fail votes against each of the other GPCs that go to the other GPCs and the GPC status matrix. A GPC FAIL detection will cause a class 2 GPC fault message with illumination of the *MASTER ALARM*. Error indications may be displayed on DISP 18 GNC SYS SUMM 1 and DISP 6 GPC/BUS STATUS displays.



DPS Parameters on GNC SYS SUMM 11 Display (DISP 18)

The GPC *STATUS* matrix (sometimes referred to as the GPC fail CAM) on panel O1 is a 5-by-5 matrix of lights. Each light corresponds to a GPC's fail vote against another GPC or itself. For example, if GPC 2 sends out a failure vote against GPC 3, the second white light in the third column is illuminated. The off-diagonal votes are votes against other GPCs. The yellow diagonal lights from upper left to lower right are self-failure votes. Whenever a GPC receives two or more failure votes from other GPCs, it illuminates its own yellow light and resets any failure votes that it made against other GPCs (any white lights in its row are extinguished). Any time a yellow matrix light is illuminated, the GPC caution and warning light on panel F7 is illuminated, in addition to MASTER ALARM illumination, and a GPC fault message is displayed on the CRT.



GPC MEMORY DUMP Switch on Panel M042F

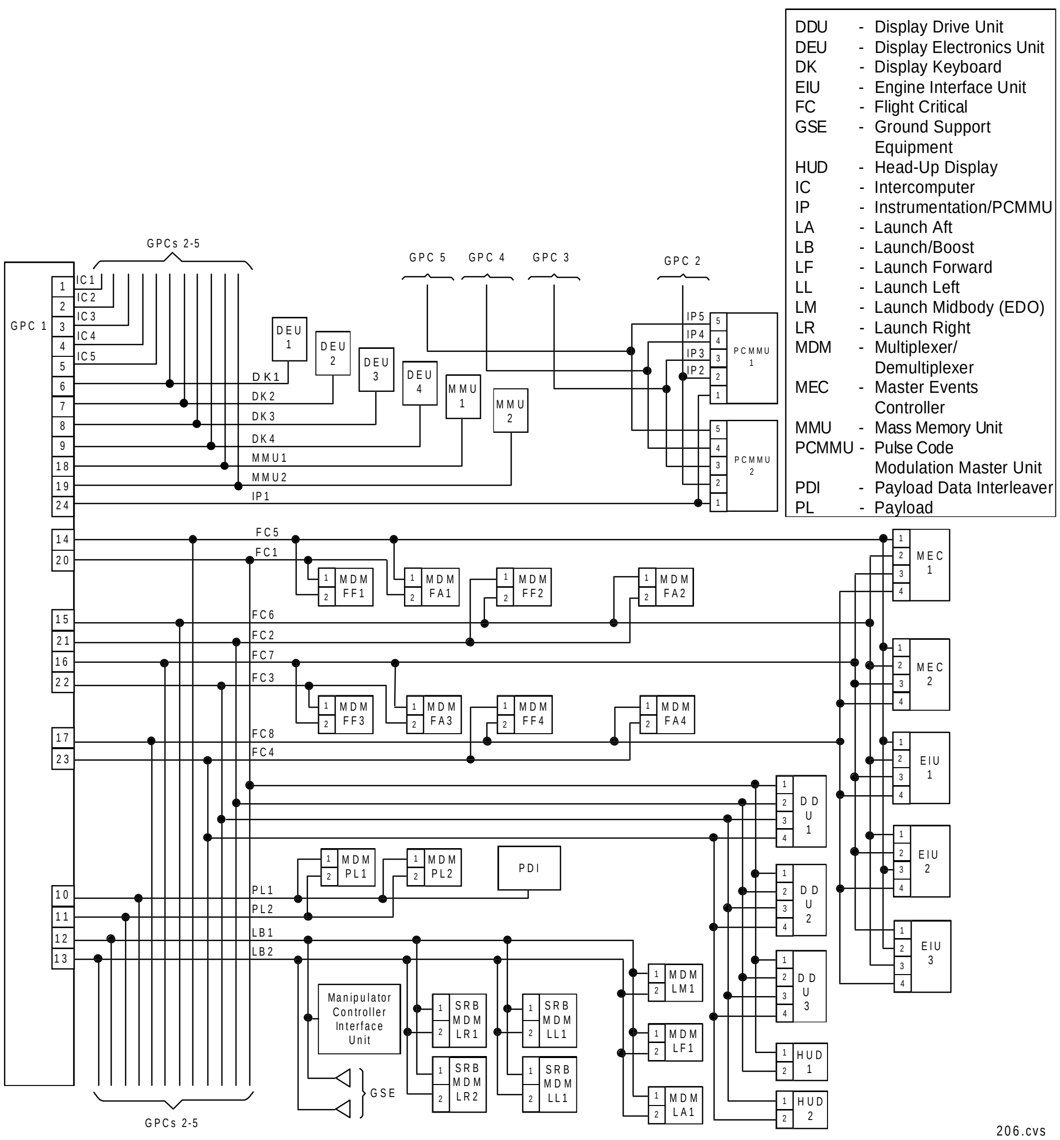
A failed GPC's memory contents can be dumped by powering ON, switching the computer to *TERMINATE* and *HALT*, and then selecting the number of the failed GPC on the GPC *MEMORY* DUMP rotary switch on panel M042F. The GPC is then moded to *STBY* to start the dump. After 2 to 8 minutes, the dump is stopped by moding the GPC to *HALT* and the output to *NORM*. This process is referred to as a hardware-initiated, standalone memory (HISAM) GPC memory dump.

Data Bus Network

The data bus network supports the transfer of serial digital commands and data between the GPCs and vehicle systems. The network is divided into seven groups that perform specific functions:

1. Flight-critical (FC) data buses that tie the GPCs to the flight-critical multiplexer/demultiplexers (MDMs), display driver units, head-up displays, engine interface units, and master events controllers

2. Payload data buses that tie the GPCs to the payload MDMs and the payload data interleaver (PDI), and possibly mission-dependent flex MDMs or sequence control assemblies



Data Bus Network

3. Launch data buses that tie the GPCs to ground support equipment, launch forward, launch aft, launch mid, and SRB MDMs, and the manipulator controller interface unit (MCIU) used by the remote manipulator system

4. Mass memory data buses for GPC/ MMU transactions

5. Display/keyboard data buses for GPC/display electronics unit transactions

6. Instrumentation/pulse code modulation master unit (PCMMU) data buses

7. Intercomputer communication data buses.

Although all data buses in each group except the instrumentation/PCMMU buses are connected to all five GPCs, only one GPC at a time transmits commands over each bus. However, several GPCs may receive data from the same bus simultaneously.

Each data bus, with the exception of the intercomputer communication data buses, is bidirectional; that is, data can flow in either direction. The intercomputer communication data bus traffic flows in only one direction (a PASS software constraint, not a hardware restriction).

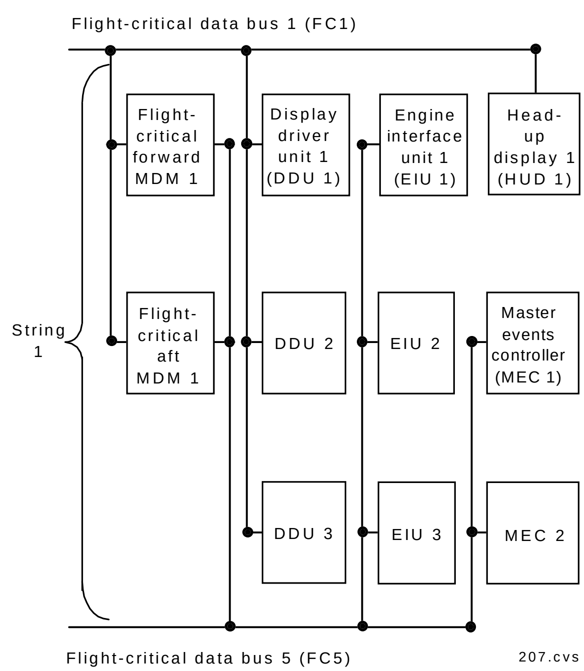
Flight-Critical Data Buses

There are eight FC data buses directed into groups of two, referred to as an FC string. Each FC string can be commanded by a different GPC. Multiple units of each type of GNC hardware are wired to a different MDM and flight-critical bus. FC1, 2, 3, and 4 connect the GPCs with the four flight-critical forward (FF) MDMs, the four flight-critical aft (FA) MDMs, the three display driver units, and the two head-up displays. The other four, FC5, 6, 7, and 8, connect the GPCs to the same four FF MDMs, the same four FA MDMs, the two master events controllers, and the three main engine interface units.

A string is composed of two FC data buses: one from the first group (FC1, 2, 3, or 4) and one from the second group (FC5, 6, 7, or 8). Vehicle hardware is segmented into these groups to facilitate GPC command of these components for redundancy, to allow for nominal mission operations in the event of a loss of one string caused by a GPC or MDM failure, and to allow for safe return to Earth in the event of the loss of a second string.

String 1 consists of FC data buses 1 and 5, MDMs FF1 and FA1 and their hard-wired hardware, controls, and displays, the three engine interface units, the two master events controllers, the three display driver units, head-up display 1, and their associated displays. This distribution of hardware is fixed and cannot be changed. The other three strings are defined in a similar manner.

During ascent and entry, when there are four PASS GNC GPCs in the redundant set, each is assigned a different string to maximize redundancy. All flight-critical hardware units are redundant, and the redundant units are on different strings. The string concept provides failure protection during dynamic phases by allowing exclusive command of a specific group of vehicle hardware by one GPC, which can be transferred to another GPC in case of failure. All or part of one string can be lost, and all avionics functions will still be retained through the other strings.



Components of String 1

With four PASS GNC GPCs in a redundant set, each GPC is responsible for issuing commands over the string assigned to it; that is, it is the commander of that string. The other GNC GPCs will monitor or listen on this string. When the string's commanding GPC sends a request for data to the hardware on the string, all the other GNC GPCs will hear and receive the same data coming back on the string. This transaction (one commanding GPC and multiple listening GPCs) is occurring in parallel with the other three strings. Therefore, all GNC GPCs will get a copy of all of the data from all four strings. Once all the data are received from the string, the GPCs then agree (or disagree) that the data are consistent.

Payload Data Buses

Two payload data buses interface the five GPCs with the two payload MDMs (also called payload forward MDMs), which interface with orbiter systems and payloads. A PDI is connected to payload data bus 1. Additionally, on some flights, one or two flex MDMs and/or sequence control assemblies connect the payload data buses to communicate with other payload equipment.

Each payload MDM is connected to two payload data buses. Safety-critical payload status parameters may be hard-wired; then these parameters and others can be recorded as part of the vehicle's system management, which is transmitted and received over two payload buses. To accommodate the various forms of payload data, the PDI integrates payload data for transmission to ground telemetry. PDI configuration commands and status monitoring is accomplished via payload data bus 1.

Launch Data Buses

Two launch data buses are used primarily for ground checkout and launch phase activities. They connect the five GPCs with the ground support equipment/launch processing system, the launch forward (LF1), launch mid (LM1), and launch aft (LA1) MDMs aboard the orbiter, and the two left and right SRB MDMs (LL1, LL2, LR1, and LR2). Launch data bus 1 is used on orbit for interface with the remote manipulator system controller by the SM GPC.

Mass Memory Data Buses

Each of two MMUs interfaces with its data bus via a multiplexer interface adapter, which functions just like the ones in the GPCs. Each data bus is connected to all five GPCs. Each MMU is connected to only one mass memory data bus.

In addition, each MMU has a separate discrete line called the "ready discrete" that goes to each of the GPCs. If the discrete is on, it tells the GPC the mass memory unit is ready for a transaction. When the discrete is off, the MMU is either busy with another transaction or is powered off.

Note that all MMU operations and transmissions to the GPCs are on an on-demand basis only. There is no insight into the state of the MMU (other than the ready discrete) unless a specific transaction is requested. This includes the status of the MMU's built-in test equipment (BITE), which is only updated for MMU read or write.

Display/Keyboard Data Buses

The four display electronics unit keyboard (DK) data buses, one for each display electronics unit, are connected to each of the five GPCs. The computer in command of a particular display/keyboard data bus is a function of the current *MAJOR FUNC* switch setting of the associated CRT, current memory configuration, GPC/CRT keyboard entries, and the position of the backup flight control CRT switches. (These topics are discussed in more detail under "Operations.")

Instrumentation/Pulse-Code Modulation Master Unit (PCMMU) Buses

The five instrumentation/PCMMU data buses are unique in that each GPC has its own individual data bus to two PCMMUs. All the other data buses interface with every GPC.

Flight controllers monitor the status of the vehicle's onboard systems through data transmissions from the vehicle to the ground. These transmissions, called downlink, include GPC-collected data, payload data, instrumentation data, and onboard voice. The GPC-collected data, called downlist, includes a set of parameters chosen before flight for each mission phase.

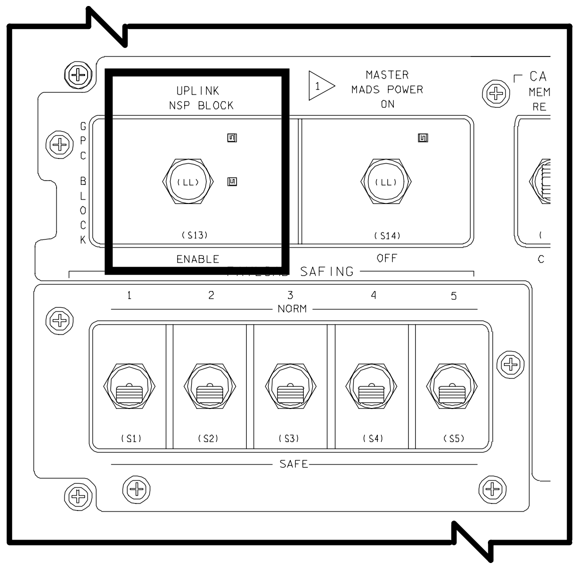
The system software in each GPC assimilates the specified GNC, systems management, payload, or DPS data according to the premission-defined format for inclusion in the downlist. Each GPC is physically capable of transmitting its downlist to the current active PCMMU over its dedicated instrumentation/PCMMU data bus. Only one PCMMU is powered at a time. It interleaves the downlist data from the different GPCs with the instrumentation and payload data according to the telemetry format load programmed in the PCMMU. The resulting composite data set, called the operational downlink, is transmitted to one of two network signal processors (NSPs). Only one NSP is powered at a time. In the NSP, the operational downlink is combined with onboard recorded voice for transmission to the ground. The S-band and Ku-band communications systems transmit the data either to the space flight tracking and data network remote site ground stations or through the Tracking and Data Relay Satellite (TDRS) system to Mission Control.

Uplink is the method by which ground commands originating in Mission Control are formatted, generated, and transmitted to the orbiter for validation, processing, and eventual execution by onboard software. This capability allows ground systems to control data processing, change modes in orbiter hardware, and store or change software in GPC memory and mass memory.

From Mission Control consoles, flight controllers issue commands and request uplink. The command requests are formatted into a command load for transmission to the orbiter either by the STDN sites or by the TDRS system. The S-band or Ku-band transponder receivers aboard the orbiter send the commands to the active NSP. The NSP validates the commands and, when they are requested by the GPCs through a flight-critical MDM, sends them on to the GPC. The GPCs also validate the commands before executing them. Those GPCs listening directly to the flight-critical data buses then forward uplink commands for those GPCs not listening to the FC buses over the intercomputer communication data buses.

The PCMMU also contains a programmable read-only memory for accessing subsystem data, a random-access memory in which to store data, and a memory in which GPC data are stored for incorporation into the downlink.

To prevent the uplink of spurious commands from somewhere other than Mission Control, the flight crew can control when the GPCs accept uplink commands, and when uplink is blocked. The *GPC BLOCK* position of the *UPLINK* switch on panel C3 inhibits uplink commands during ascent and entry when the orbiter is not over a ground station or in TDRS coverage.



UPLINK Switch on Panel C3

Intercomputer Communication Data Buses

There are five intercomputer communication (IC) data buses. The following information is exchanged over these buses for proper DPS operation: input/output errors, fault messages, GPC status matrix data, display electronics unit major function switch settings, GPC/CRT keyboard entries, resident GPC memory configuration, memory configuration table, operational sequences, master timing unit, time, internal GPC time, system-level display information, uplink data, and state vectors.

All GPCs processing PASS software exchange status information over the IC data buses. During launch, ascent, and entry, GPCs 1, 2, 3, and 4 are usually assigned to perform GNC tasks, operating as a redundant set, with GPC 5 as the backup flight system. Each of the PASS GPCs acts as a commander of a given IC data bus and initiates all data bus transactions on that data bus.

The four PASS GPCs are loaded with the same software. Interconnecting the four IC buses to the four PASS GPCs allows each GPC access to the status of data received or transmitted by the other GPCs so that identical results among the four PASS GPCs can be verified. Each IC bus is assigned to one of the four PASS GPCs in the command mode, and the remaining GPCs operate in the listen mode for the bus. Each GPC can receive data from the other three GPCs, pass data to the others, and perform any other tasks required to operate the redundant set.

Multiplexers/Demultiplexers (MDMs)

The MDMs convert and format (demultiplex) serial digital GPC commands into separate parallel discrete, digital, and analog commands for various vehicle hardware systems. The MDMs also convert and format (multiplex) the discrete, digital, and analog data from vehicle systems into serial digital data for transmission to the GPCs. Each MDM has two redundant multiplexer interface adapters (MIAs), each connected to a separate data bus. The MDM's other functional interface is its connection to the appropriate vehicle system hardware by hard-wired lines.

There are 20 MDMs aboard the orbiter; 13 are part of the DPS, connected directly to the GPCs and named and numbered according to their location in the vehicle and hardware interface. The remaining seven MDMs are part of the vehicle instrumentation system and send vehicle instrumentation data to the PCMMUs. (They are termed operational instrumentation (OI) MDMs.)

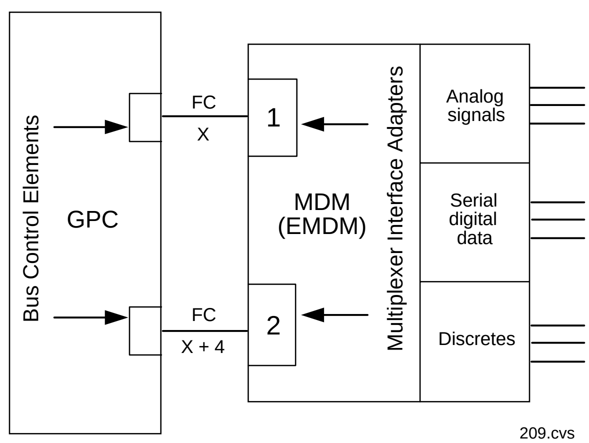
The DPS MDMs consist of flight-critical forward (FF) MDMs 1 through 4, flight-critical aft (FA) MDMs 1 through 4, payload (PL) MDMs 1 and 2, and GSE/LPS launch forward (LF1), launch mid (LM1), and launch aft (LA1). One or two flex MDMs (FMDMs) may also be connected to the PL data buses, depending on the payload needs for a particular flight.

Of the seven operational instrumentation MDMs, four are located forward (OF1, OF2, OF3, and OF4), and three are located aft (OA1, OA2, and OA3).

Also recall, there are four SRB MDMs; i.e., SRB launch left (LL) MDMs 1 and 2 and launch right (LR) MDMs 1 and 2.

The system software in the redundant set GPC activates a GNC executive program and issues commands to authorized buses and MDMs to request a set of input data. Each MDM receives the command from the GPC assigned to command it, acquires the requested data from the GNC hardware wired to it, and sends the data to the GPCs.

Each FC data bus is connected to a flight forward and flight aft MDM. Each MDM has two MIAs, or ports, and each port has a channel through which the GPCs can communicate with an MDM; however, the GPCs can interface on the FC data buses with only one MIA port at a time. Port moding is the software method used to control the MIA port that is active in an MDM. Initially, these MDMs operate with port 1; if a failure occurs in port 1, the flight crew can select port 2. Since port moding involves a pair of buses, both MDMs must be port moded at the same time. The control of all other units connected to the affected data buses is unaffected by port moding. Port moding is a software-only process and does not involve any hardware changes.



GPC/MDM Interfaces

Payload data bus 1 is connected to the primary MIA port of payload MDM 1, and payload data bus 2 is connected to the primary port of payload MDM 2. Payload data bus 1 is connected to the secondary MIA port of payload

MDM 2, and payload data bus 2 is connected to the secondary port of payload MDM 1. Which bus is used to communicate with each MDM is controlled by port moding.

The two launch data buses are also connected to dual launch MDM multiplexer interface adapter ports. The flight crew cannot switch these ports; however, if an input/output error is detected on LF1 or LA1 during prelaunch, an automatic switchover occurs.

The hardware controls for the MDMs are the *MDM PL1*, *PL2*, *PL3*, *FLT CRIT AFT*, and *FLT CRIT FWD* power switches on panel O6. These *ON/OFF* switches provide or remove power for the four aft and four forward flight-critical MDMs and PL1 and PL2 MDMs. The *PL3* switch is unwired and is not used. There are no flight crew controls for the SRB MDMs.

Each MDM is redundantly powered by two main buses. The power switches control bus power for activation of a remote power controller (RPC) for each main power bus to an MDM. The main buses power separate power supplies in the MDM. Loss of either the main bus or MDM power supply does not cause a loss of function because each power supply powers both channels in the MDM. Turning off power to an MDM resets all the discrete and analog command interfaces to subsystems.

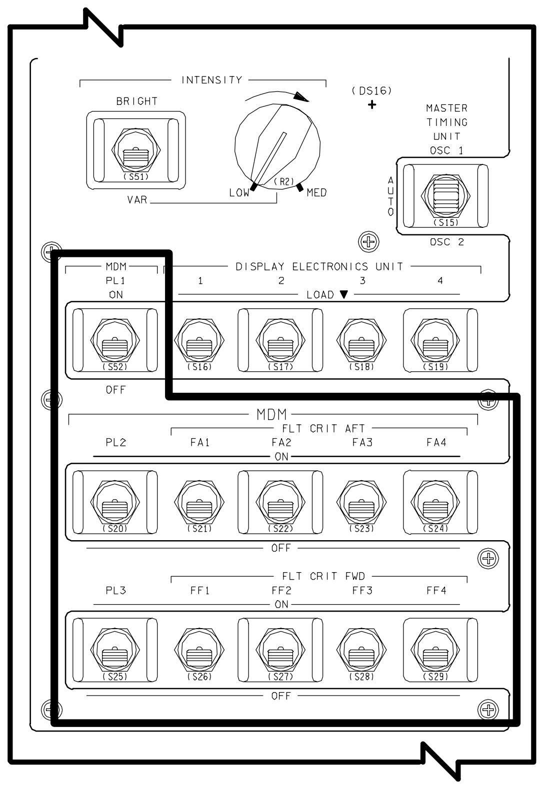
The SRB MDMs receive power through SRB buses A and B; they are tied to the orbiter main buses and are controlled by the master events controller circuitry. The launch forward, mid, and aft MDMs receive their power through the preflight test buses.

The FF, PL, LF, and LM MDMs are located in the forward avionics bays and are cooled by water coolant loop cold plates. LA and FA MDMs are in the aft avionics bays and are cooled by Freon coolant loop cold plates. MDMs LL1, LL2, LR1, and LR2 are located in the SRBs and are cooled by passive cold plates.

Module (or card) configuration in an MDM was dictated by the hardware components to be accessed by that type of MDM. A flight-critical forward and aft MDM are not interchangeable. However, flight-critical MDMs of the same type may be interchanged with another and the payload MDMs may be interchanged.

Each MDM is 13 by 11 by 7 inches and weighs about 38.5 pounds. MDMs use less than 80 watts of power.

Enhanced MDMs (EMDMs) were installed in OV 105. EMDMs will be installed in the other vehicles only as MDMs require replacement. The presence of EMDMs is transparent to the crew except in the case of an MDM OUTPUT message. With MDMs, the message means there is a problem with an MDM or a GPC. An MDM OUTPUT message with EMDMs means it is most likely a GPC problem. Crews flying with a combination of MDMs and EMDMs will receive assistance from flight controllers in interpreting an MDM OUTPUT message.



MDM Power Switches on Panel 06

Mass Memory Units

There are two mass memory units (MMUs) aboard the orbiter. Each is a coaxially mounted, reel-to-reel read/write digital magnetic tape storage device for GPC software and orbiter systems data.

Computing functions for all mission phases requires approximately 600,000 half-words of computer memory. The orbiter GPCs are loaded with different memory configurations from the MMUs. In this way, software can be stored in MMUs and loaded into the GPCs when actually needed.

To fit the required software into the available GPC memory space, programs are subdivided into eight memory configurations corresponding to functions executed during specific flight and checkout phases. Thus, in addition to the central memory in the GPCs themselves, 34 million bytes of information can be stored in each of the two MMUs. Critical programs and data are loaded in both MMUs and protected from erasure.

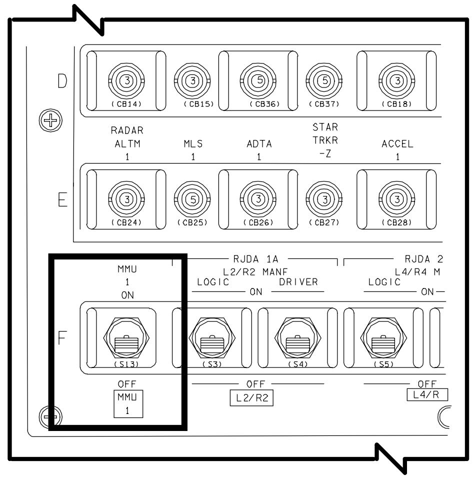
The principal function of the MMU, besides storing the basic flight software, is to store background formats and code for certain CRT displays and the checkpoints that are written periodically to save selected data in case the systems management GPC fails.

Operations are controlled by logic and the read and write electronics that activate the proper tape heads (read or write/erase) and validate the data.

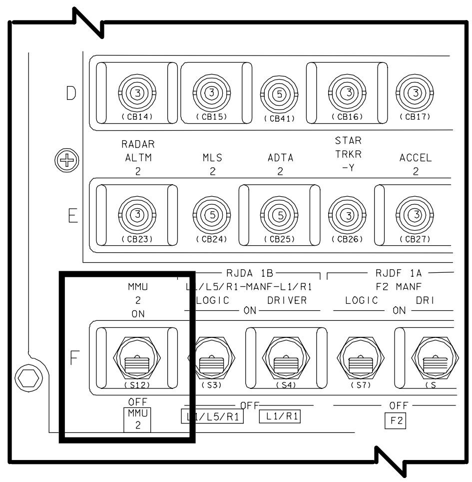
Each MMU interfaces with its mass memory data bus through MIAs that function like the ones in the GPCs. Each mass memory data bus is connected to all five computers; however, each MMU is connected to only one mass memory data bus. All MMU operations are on an on-demand basis only.

The power switches are located on panel O14 for MMU 1 and panel O15 for MMU 2. The *MMU 1* switch on panel O14 positioned to ON allows control bus power to activate an RPC, which allows MNA power to MMU 1. The *MMU 2* switch on panel O15 positioned to ON operates in a similar manner with MNB power. An MMU uses 20 watts of power in standby and 70 watts when the tape is moving.

MMU 1 is located in crew compartment middeck avionics bay 1, and MMU 2 is in avionics bay 2. Each unit is cooled by water coolant loop cold plates. Each MMU is 7.6 inches high, 11.6 inches wide and 15 inches long and weighs 25 pounds.



MMU 1 Power Switch on Panel 014



MMU 2 Power Switch on Panel 015

Multifunction CRT Display System

The multifunction CRT display system allows onboard monitoring of orbiter systems, computer software processing, and manual control for flight crew data and software manipulation.

The system is composed of three types of hardware: four display electronics units (DEUs), four display units (DUs) or CRTs, and three keyboard units, which together communicate with the GPCs over the display/keyboard data buses.

The system provides almost immediate response to flight crew inquiries through displays, graphs, trajectory plots, and predictions about flight progress. The crew controls the vehicle system operation through the use of keyboards in conjunction with the display units. The flight crew can alter the system configuration, change data or instructions in GPC main memory, change memory configurations corresponding to different mission phases, respond to error messages and alarms, request special programs to perform specific tasks, run through operational sequences for each mission phase, and request specific displays.

Three identical keyboards are located on the flight deck: one each on the left and right sides of the flight deck center console (panel C2) and one on the flight deck at the side aft flight station (panel R11L). Each keyboard consists of 32 momentary double-contact pushbutton keys. Each key uses its double contacts to permit communication on separate signal paths to two DEUs. Only one set of contacts on the aft station keys is actually used because this keyboard is wired to communicate with only the aft display electronics unit.

There are 10 number keys, six letter keys (used for hexadecimal inputs), two algebraic keys, a decimal key, and 13 special function keys. Using these keys, the flight crew can ask the GPC more than 1,000 questions about the mission and condition of the vehicle. (Keyboard operations are discussed in detail later in this section.)

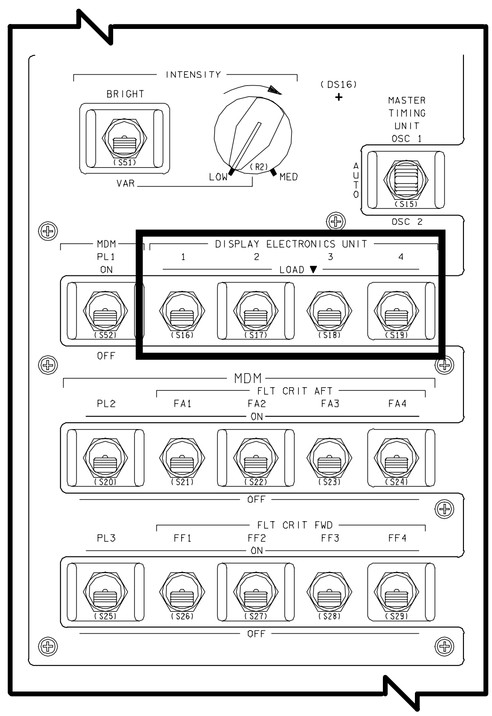
Each of the four DEUs responds to computer commands, transmits data, executes its own software to process keyboard inputs, and sends signals to drive displays on the CRTs (or display units). The units store display data, generate the GPC/keyboard unit and GPC/display unit interface displays, update and refresh on-screen data, check keyboard entry errors, and echo keyboard entries to the CRT.

There are three CRTs on flight deck forward display and control panel F7 and one at the side aft flight deck station on panel R11L. Each CRT is 5 by 7 inches.

The display unit uses a magnetic-deflected, electrostatic-focused CRT. When supplied with deflection signals and video input, the CRT displays alphanumeric characters, graphic symbols, and vectors on a green monochrome phosphorous screen activated by a magnetically controlled beam. Each CRT has a brightness control for ambient light and flight crew adjustment.

The DEUs are connected to the display/keyboard data buses by MIAs that function like those of the GPCs. Inputs to the DEU are from a keyboard or a GPC.

Positioning the *DISPLAY ELECTRONICS UNIT 1, 2, 3, 4* switches on panel O6 to LOAD initiates a GPC request for a copy of DEU software stored in mass memory before operations begin. If the GPC software in control of the CRT is designed to support a DEU load (or IPL) request, then information is sent from the mass memory to the GPC and then loaded from the GPC into the DEU memory.



DISPLAY ELECTRONICS UNIT
Switches on Panel O6

It is possible to do in-flight maintenance and exchange CRT 4 with CRT 1 or 2. CRT 3 cannot be changed out because of interface problems with the orbiter jettison T-handle. Also, either individual keys or the entire forward keyboard can be replaced by the aft keyboard. The DEUs are located behind panels on the flight deck. DEUs 1 and 3 are on the left, and DEUs 2 and 4 are on the right. DEU 4 can replace any of the others; however, if DEU 2 is to be replaced, only the cables are changed because 2 and 4 are next to each other.

The display electronics units and display units are cooled by the cabin fan system. The keyboard units are cooled by passive heat dissipation.

Master Timing Unit

The GPC complex requires a stable, accurate time source because its software uses Greenwich mean time (GMT) to schedule processing. Each GPC uses the master timing unit (MTU) to update its internal clock. The MTU provides precise frequency outputs for various timing and synchronization purposes to the GPC complex and many other orbiter subsystems. Its three time accumulators provide GMT and mission elapsed time (MET), which can be updated by external control. The accumulator's timing is in days, hours, minutes, seconds, and milliseconds up to 1 year.

The MTU is a stable, crystal-controlled frequency source that uses two oscillators for redundancy. The signals from one of the two oscillators are passed through signal shapers and frequency drivers to the three GMT/MET accumulators.

The MTU outputs serial digital time data (GMT/MET) on demand to the GPCs through the accumulators. The GPCs use this information for reference time and indirectly for time-tagging GNC and systems management processing. The MTU also provides continuous digital timing outputs to drive the four digital timers in the crew compartment: two mission timers and two event timers. In addition, the MTU provides signals to the PCMMUs, COMSECs, payload signal processor, and FM signal processor, as well as various payloads.

The GPCs start by using MTU accumulator 1 as their time source. Once each second, each GPC checks the accumulator time against its own internal time. If the time is within tolerance (less than one millisecond), the GPC updates its internal clock to the time of the accumulator, which is more accurate, and continues. However, if the time is out of tolerance, the GPC will try the other accumulators and then the lowest numbered GPC until it finds a successful comparison.

The PASS GPCs do not use the MET that they receive from the master timing unit because they compute MET on the basis of current GMT and lift-off time.

The TIME display (SPEC 2) provides the capability to observe the current MTU and GPC clock status, synchronize or update the MTU and GPC clocks, and set CRT timers and alert tone duration and timers.

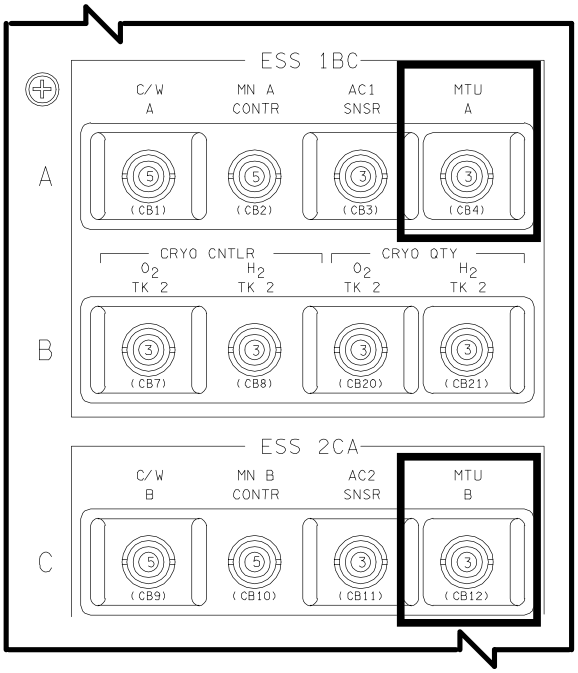
```
1061/002/        TIME                   1 008/12:12:12
                                          000/00:25:12
MISSION TIME                  TONE
  GMT 1*                        3    __:__:__ MSN T
  MET 2                         6      :  :
CRT TIMER
  9 SET [ ]__:__:__            20[ ]__:__:__ CRT T
  START 12     STOP 13
  14 START AT __:__:__ MSN T 23 DURATION
  17 COUNT TO   :  :   MSN T
------------------------------------------------------
MTU
  24 GMT Δ [ ]___/__:__:__.____
  28 MET Δ [ ]   /  :  :  .
     UPDATE 32                     MET RESET 33
------------------------------------------------------
GPC TIME                                       GPC
                     GMT              TRY    1 A1
  MTU ACCUM 1 008/12:12:12.000        34     2 A1
            2 008/12:12:12.000        35     3 A1
            3 008/12:12:12.000        36     4 A1
          GPC 008/12:12:12.000        37     5 A1

  TIME SYNC 38
                                                  214
```

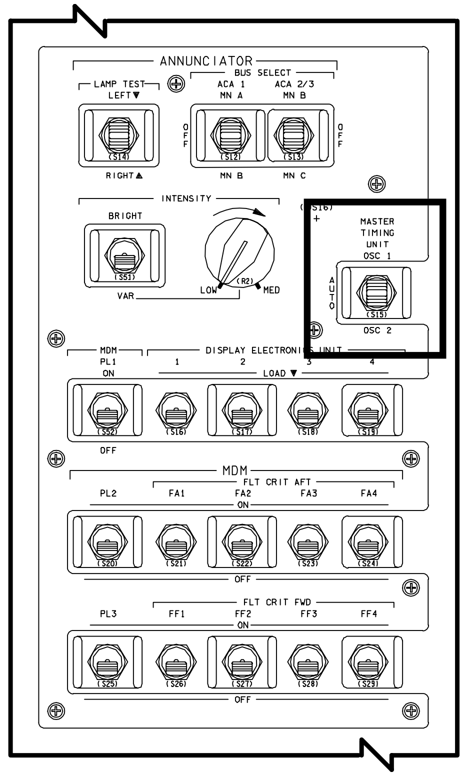
TIME Display (SPEC 2)

The MTU is redundantly powered by the ESS 1BC MTU A and ESS 2CA MTU B circuit breakers on panel O13. The MASTER TIMING UNIT switch on panel O6 controls the MTU. When the switch is in AUTO, and a time signal from one oscillator is out of tolerance, the MTU automatically switches to the other oscillator. For nominal operations, the MTU is using oscillator 2 with the switch in AUTO. The OSC 1 or OSC 2 position of the switch manually selects oscillator 1 or 2, respectively.

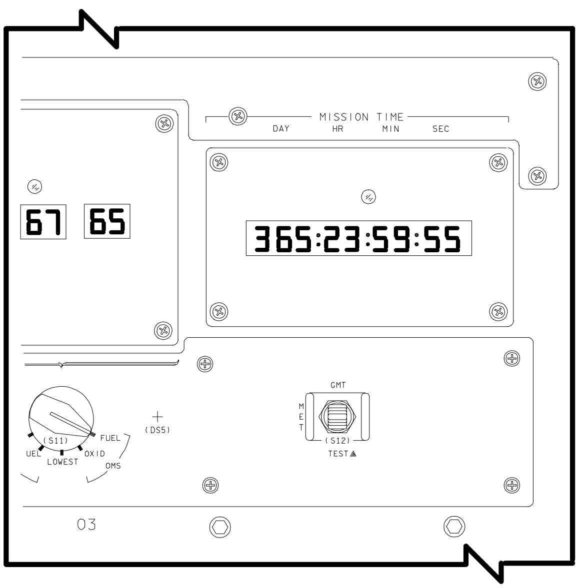
The MTU is located in crew compartment middeck avionics bay 3B and is cooled by a water coolant loop cold plate. The hardware displays associated with the master timing unit are the mission and event timers. MISSION TIME displays are located on panels O3 and A4. They can display either GMT or MET in response to the GMT or MET positions of the switch below the displays. The forward EVENT TIME display is on panel F7, and it is controlled by the EVENT TIME switches on panel C2. The aft EVENT TIME display is on panel A4, and its EVENT TIME control switches are on panel A6U.



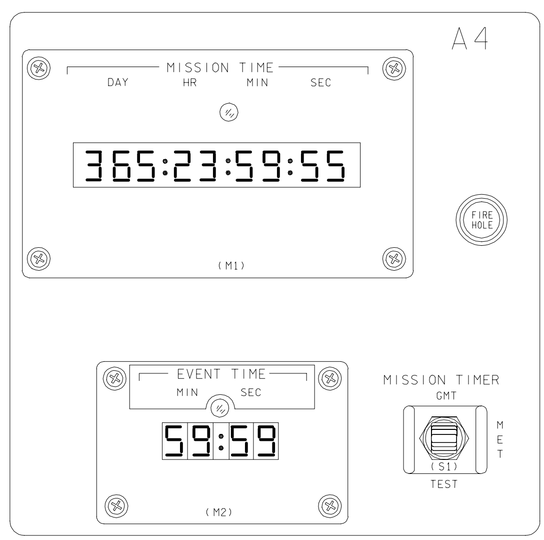
ESS 1BC MTU A and ESS 2CA MTU B Circuit Breakers on Panel O13



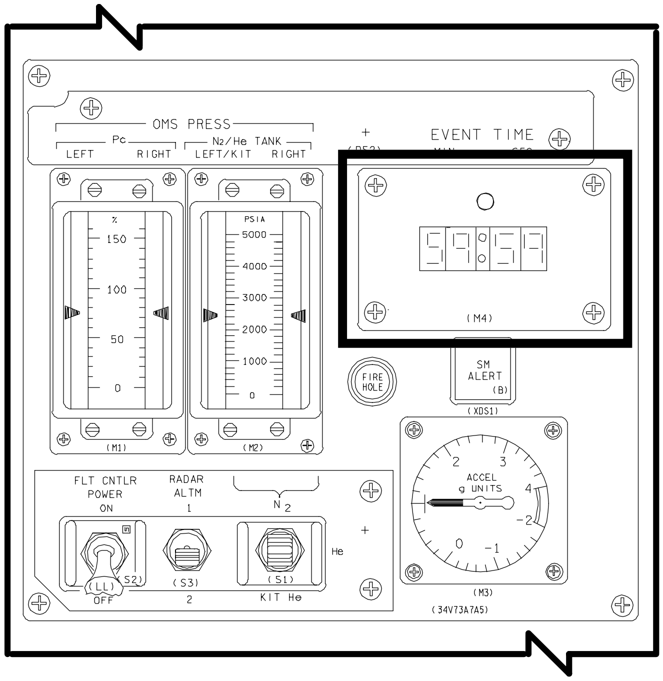
MASTER TIMING UNIT Switch on Panel O6



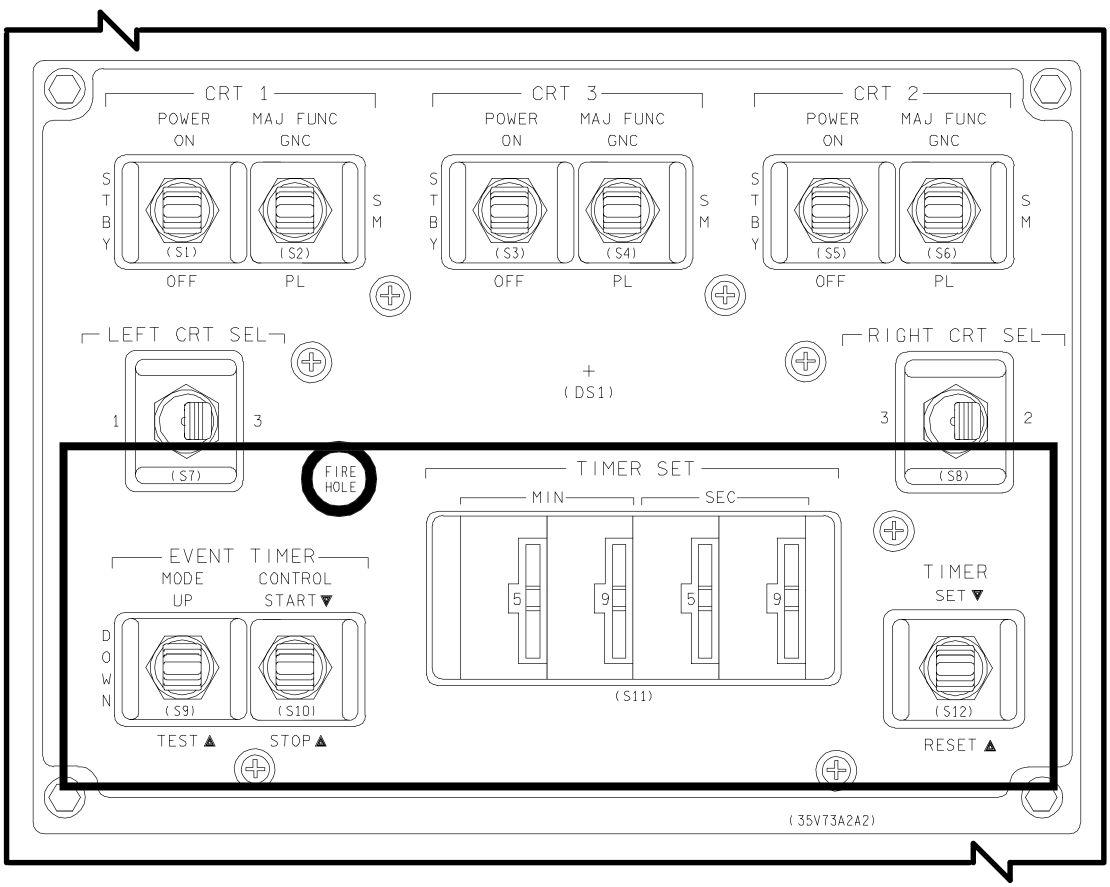
MISSION TIME Display and Switch on Panel O3



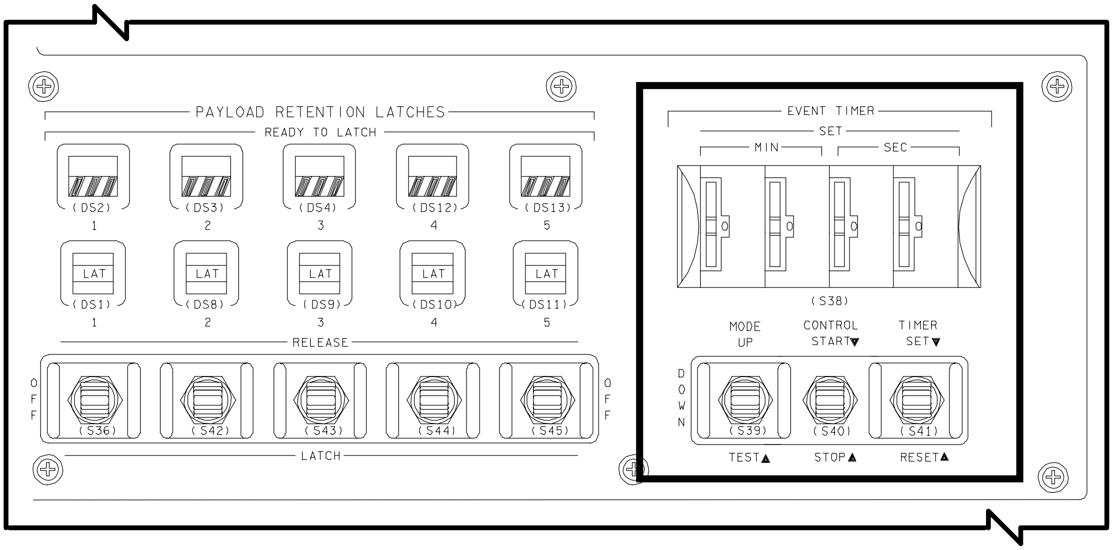
MISSION TIME and EVENT TIME Displays and MISSION TIMER Switch on Panel A4



EVENT TIME Display on Panel F7



EVENT TIMER Switches and TIMER SET Thumbwheels on Panel C2



EVENT TIMER Switches on Thumbwheels on Panel A6U

Software

Primary Avionics Software System (PASS)

The PASS (also referred to as primary flight software) is the principal software used to operate the vehicle during a mission. It contains all the programming needed to fly the vehicle through all phases of the mission and manage all vehicle and payload systems.

Since the ascent and entry phases of flight are so critical, four of the five GPCs are loaded with the same PASS software and perform all GNC functions simultaneously and redundantly. As a safety measure, the fifth GPC contains a different set of software, programmed by a company different from the PASS developer, designed to take control of the vehicle if a generic error in the PASS software or other multiple errors should cause a loss of vehicle control. This software is called the backup flight system (BFS). In the less dynamic phases of on-orbit operations, the BFS is not required. The information provided below describes how the PASS software relates to the DPS and the crew. Much of the material is common between PASS and BFS; therefore, only BFS differences are discussed immediately after the PASS discussion.

DPS software is divided into two major groups, system software and applications software. The two groups are combined to form a memory configuration for a specific mission phase. The programs are written in HAL/S (high-order assembly language/shuttle) specifically developed for real-time space flight applications.

System software is the GPC operating system software that controls the interfaces among the computers and the rest of the DPS. It is loaded into the computer when it is first initialized. It always resides in the GPC main memory and is common to all memory configurations. The system software controls GPC input and output, loads new memory configurations, keeps time, monitors discretes into the GPCs, and performs many other DPS operational functions.

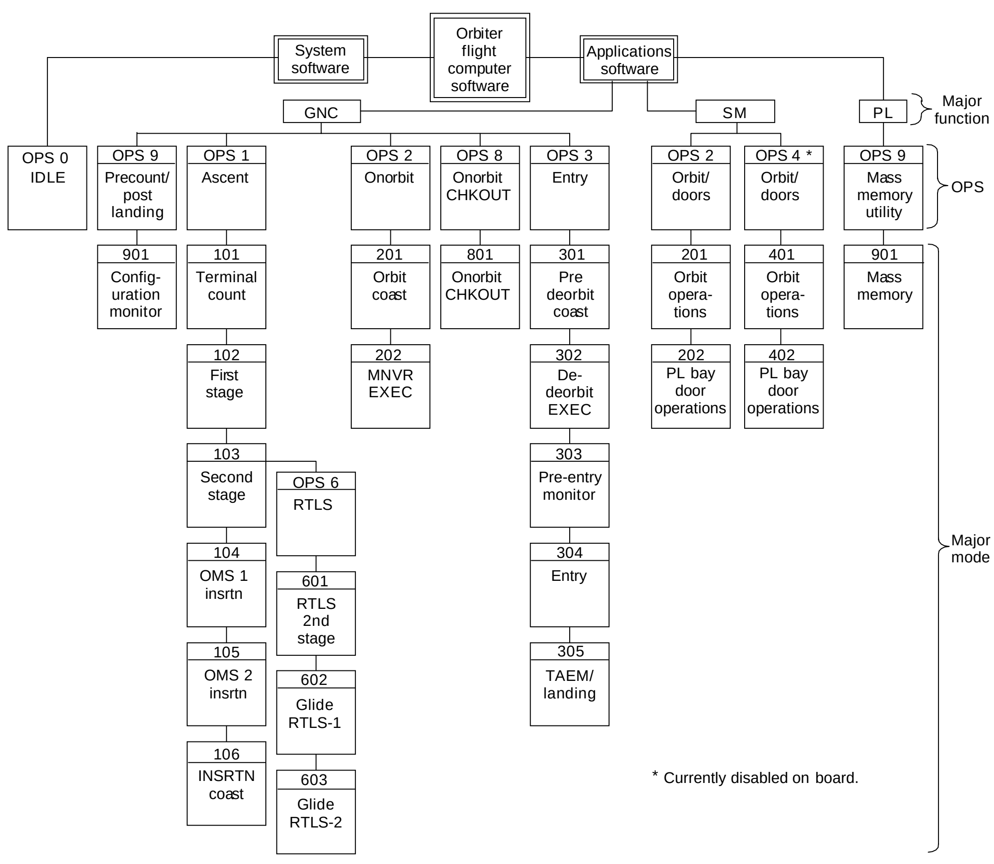
The system software consists of three sets of programs. The flight computer operating system (FCOS) (the executive) controls the processors, monitors key system parameters, allocates computer resources, provides for orderly program interrupts for higher priority activities, and updates computer memory. The user interface programs provide instructions for processing flight crew commands or requests. The system control program initializes each GPC and arranges for multi-GPC operation during flight-critical phases.

One of the system software functions is to manage the GPC input and output operations, which includes assigning computers as commanders and listeners on the data buses and exercising the logic involved in sending commands to these data buses at specified rates and upon request from the applications software.

The applications software performs the functions required to fly and operate the vehicle. To conserve main memory, the applications software is divided into three major functions:

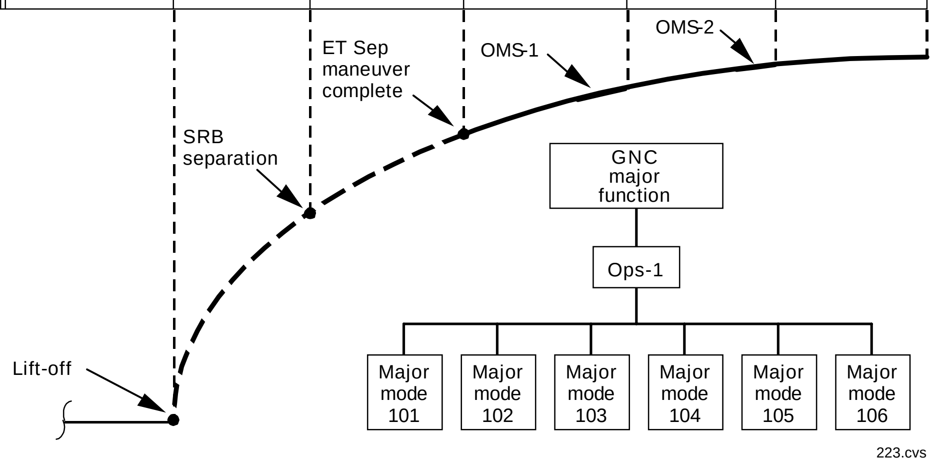
- ***Guidance, navigation, and control (GNC)***: specific software required for launch, ascent to orbit, maneuvering in orbit, entry, and landing. This is the only major function where redundant set synchronization can occur.
- ***Systems management (SM):*** tasks that monitor various orbiter systems, such as life support, thermal control, communications, and payload operations. SM is a simplex major function; only one GPC at a time can actively process an SM memory configuration.
- ***Payload (PL)***: this major function currently contains mass memory utility software. The PL major function is usually *unsupported* in flight, which means that none of the GPCs are loaded with PL software. It is only used in vehicle preparation at KSC, and is also a simplex major function. Note that software to support payload operations is included as part of the SM GPC memory configuration.

Major functions are divided into mission phase oriented blocks called operational sequences (OPS). Each OPS of a major function is associated with a particular memory configuration that must be loaded separately into a GPC from the MMUs. Therefore, all the software residing in a GPC at any given time consists of system software and an OPS major function; i.e., one memory configuration. Except for memory configuration 1, each memory configuration contains one OPS. Memory configuration 1 is loaded for GNC at launch and contains both OPS 1 (ascent) and OPS 6 (RTLS), since there would be no time to load in new software for a return to launch site (RTLS) abort.



Orbiter Flight Computer Software

Mission phase	Launch - 20 min to lift-off	Launch to solid rocket booster sep	SRB sep to external tank sep maneuver complete	ET sep to completion of OMS-1 burn	Completion of OMS-1 burn to completion of OMS-2 burn	Completion of OMS-2 burn to selection of GNC Ops-2
Major mode (for Ops-1)	101	102	103	104	105	106



Major Modes

During the transition from one OPS to another, called an OPS transition, the flight crew requests a new set of applications software to be loaded in from the MMU. Every OPS transition is initiated by the flight crew. When an OPS transition is requested, the redundant OPS overlay contains all major modes of that sequence.

Major modes are further subdivisions of an OPS, which relate to specific portions of a mission phase. As part of one memory configuration, all major modes of a particular OPS are resident in GPC main memory at the same time. The transition from one major mode to another can be automatic (e.g., in GNC OPS 1 from precount MM 101 to first stage MM 102 at lift-off) or manual (e.g., in SM OPS 2 from on-orbit MM 201 to payload bay door MM 202 and back).

Each major mode has an associated CRT display, called a major mode display or OPS display, that provides the flight crew with information concerning the current portion of the mission phase and allows flight crew interaction. There are three levels of CRT displays. Certain portions of each OPS display can be manipulated by flight crew keyboard input (or ground link) to view and modify system parameters and enter data. The specialist function (SPEC) of the OPS software is a block of displays associated with one or more operational sequences and enabled by the flight crew to monitor and modify system parameters through keyboard entries. The display function (DISP) of the OPS software is a group of displays associated with one or more OPS. These displays are for parameter monitoring only (no modification capability) and are called from the keyboard. Display hierarchy and usage are described in detail later in this section.

Backup Flight System

Even though the four PASS GPCs control all GNC functions during the critical phases of the mission, there is always a possibility that a generic software failure could cause loss of vehicle control. Therefore, the fifth GPC is loaded with the BFS software. To take over control of the vehicle, the BFS monitors the PASS GPCs to keep track of the current state of the vehicle. If required, the BFS can take over control of the vehicle upon the press of a button. The BFS also performs the SM functions during ascent and entry because the PASS GPCs are all operating in GNC. BFS software is always loaded into GPC 5 before flight, but any of the five GPCs could be made the BFS GPC if necessary.

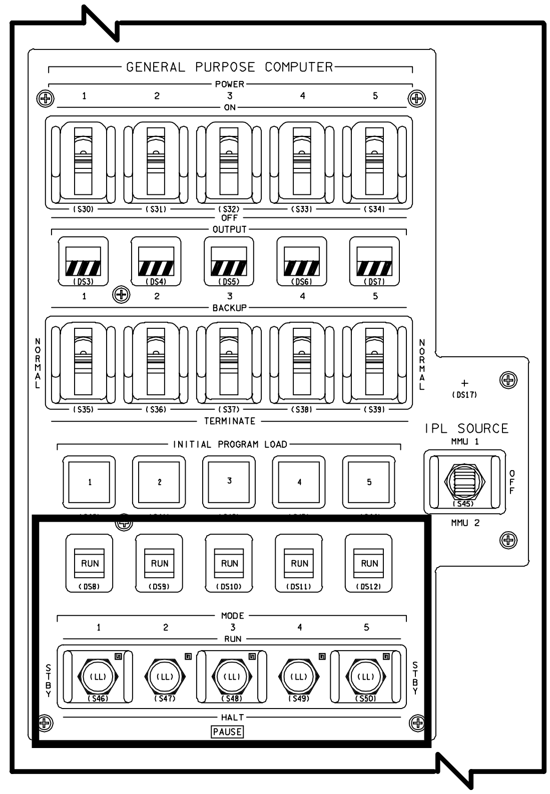
Since the BFS is intended to be used only in a contingency, its programming is much simpler than that of the PASS. Only the software necessary to complete ascent or entry safely, maintain vehicle control in orbit, and perform SM functions during ascent and entry is included. Thus, all the software used by the BFS can fit into one GPC and never needs to access mass memory. For added protection, the BFS software is loaded into the MMUs in case of a BFS GPC failure and the need to IPL a new BFS GPC.

The BFS, like PASS, consists of system software and applications software. System software in the BFS performs basically the same functions as it does in PASS. These functions include time management, PASS/BFS interface, multifunction CRT display system, input and output, uplink and downlink, and engage and disengage control. The system software is always operating when the BFS GPC is not in *HALT*.

Applications software in the BFS has two different major functions, GNC and systems management, but all its applications software resides in main memory at one time, and the BFS can process software in both major functions simultaneously. The GNC functions of the BFS, designed as a backup capability, support the ascent phase beginning at MM 101 and the deorbit/entry phase beginning at MM 301. In addition, the various ascent abort modes are supported by the BFS. The BFS provides only limited support for on-orbit operations via MM 106 or MM 301. Because the BFS is designed to monitor everything the PASS does during ascent and entry, it has the same major modes as the PASS in OPS 1, 3, and 6.

The BFS SM contains software to support the ascent and entry phases of the mission. Whenever the BFS GPC is in the *RUN* or *STBY* mode, it runs continuously; however, the BFS does not control the payload buses in *STBY*. The SM major function in the BFS is not associated with any operational sequence and is always available whenever the BFS is active.

Even though the five general-purpose computers and their switches are identical, the *GENERAL PURPOSE COMPUTER MODE* switch on panel O6 works differently for a GPC loaded with BFS. Since *HALT* is a hardware-controlled state, no software is executed. The *STBY* mode in the BFS GPC is totally different from its corollary in the PASS GPCs. When the BFS GPC is in *STBY*, all normal software is executed as if the BFS were in *RUN*; the only difference is that BFS command of the payload data buses is inhibited in *STBY*. The BFS is normally put in *RUN* for ascent and entry, and in *STBY* whenever a *PASS* systems management GPC is operating. If the BFS is engaged while the *MODE* switch is in *STBY* or *RUN*, the BFS takes control of the flight-critical and payload data buses. The *MODE* talkback indicator on panel O6 indicates RUN if the BFS GPC is in *RUN* or *STBY* and displays barberpole if the BFS is in *HALT* or has failed.



GENERAL PURPOSE COMPUTER MODE Switches and Talkbacks on Panel O6

Pre-engage, the BFS is synchronized with the PASS set using flight-critical I/O so that it can track the PASS and keep up with its flow of commands and data. Synchronization and tracking take place during OPS 1, 3, and 6. During this time, the BFS listens over the flight-critical data buses to the requests for data by PASS and to the data coming back. The BFS depends on the PASS GPCs for acquisition of all its GNC data and must be synchronized with the PASS GPCs so that it will know when to receive GNC data over the FC buses. When the BFS is in sync and listening to at least two strings, it is said to be tracking PASS. As long as the BFS is in this mode, it maintains the current state vector and all other information necessary to fly the vehicle in case the flight crew needs to engage it. When the BFS GPC is tracking the PASS GPCs, it cannot command over the FC buses but may listen to FC inputs through the listen mode. The BFS uses the MTU (like PASS) and keeps track of GMT over the flight-critical buses for synchronization. The BFS also monitors some inputs to PASS CRTs and updates its own GNC parameters accordingly.

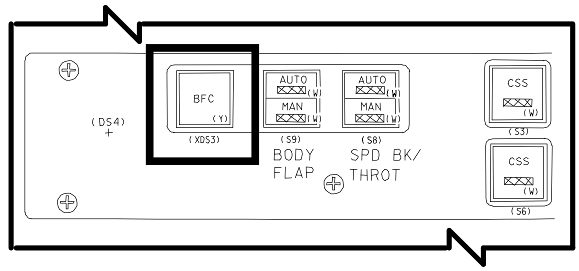
The BFS GPC controls its own instrumentation/ PCMMU data bus. The BFS GPC requirements strictly forbid use of the IC data bus to monitor or to transmit status or data to the other GPCs. The mass memory data buses are not used except during initial program load, which uses the same IPL SOURCE switch on panel O6 as used for PASS IPL.

The BFC lights on panels F2 and F4 remain unlighted as long as PASS is in control, and the BFS is tracking. The lights flash if the BFS loses track of the PASS and goes standalone. The flight crew must then decide whether to engage the BFS or try to initiate BFS tracking again by an I/O RESET on the keyboard. When BFS is engaged and in control of the flight-critical buses, the BFC lights are illuminated and stay on until the BFS is disengaged.

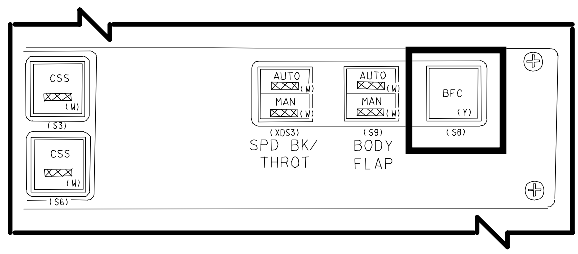
Since the BFS does not operate in a redundant set, its fail votes from and against other GPCs are not enabled; thus, the *GPC STATUS* light matrix on panel O1 for the BFS GPC does not function as it does in PASS. The BFS can illuminate its own light on the *GPC STATUS* matrix if the watchdog timer in the BFS GPC times out when the BFS GPC does not complete its cyclic processing.

To engage the BFS, which is considered a last resort to save the vehicle, the crew presses a *BFS ENGAGE* momentary pushbutton located on the commander's and pilot's rotational hand controllers (RHCs). As long as the RHC is powered, and the appropriate *OUTPUT* switch on panel O6 is in *BACKUP*, depressing the *ENGAGE* pushbutton on either RHC engages the BFS and causes PASS to relinquish control. There are three contacts in each *ENGAGE* pushbutton, and all three contacts must be made to engage the BFS. The signals from the RHC are sent to the backup flight controller, which handles the engagement logic.

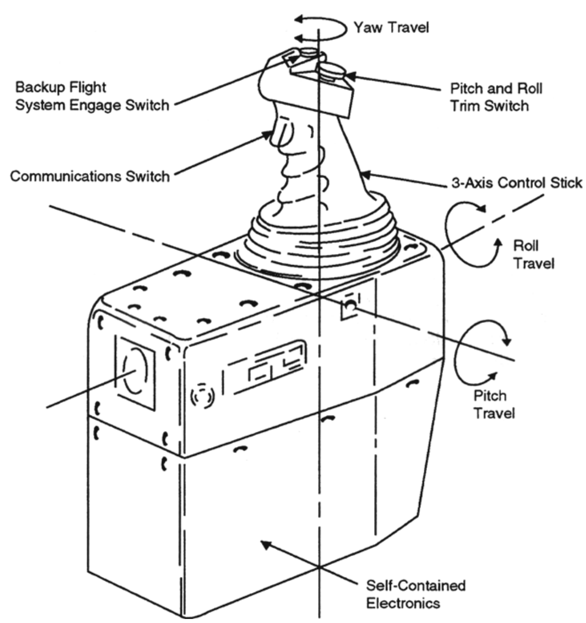
When the BFS is engaged, the BFC lights on panels F2 and F4 are steadily illuminated, the BFS's *OUTPUT* talkback indicator on panel O6 turns gray, all PASS GPC *OUTPUT* and *MODE* talkback indicators on panel O6 display barber-pole, the BFS controls the CRTs selected by the *BFC CRT SELECT* switch on panel C3, big X and poll fail appear on the remaining PASS-controlled CRTs, and all four *GPC STATUS* matrix diagonal indicators for PASS GPCs are illuminated on panel O1.



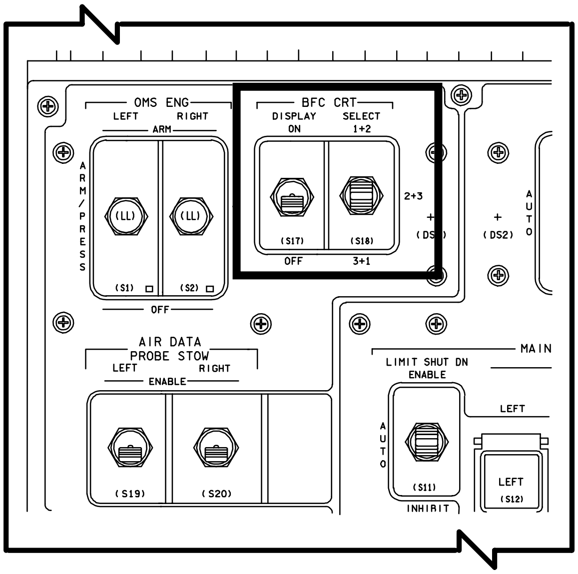
BFC Light on Panel F2



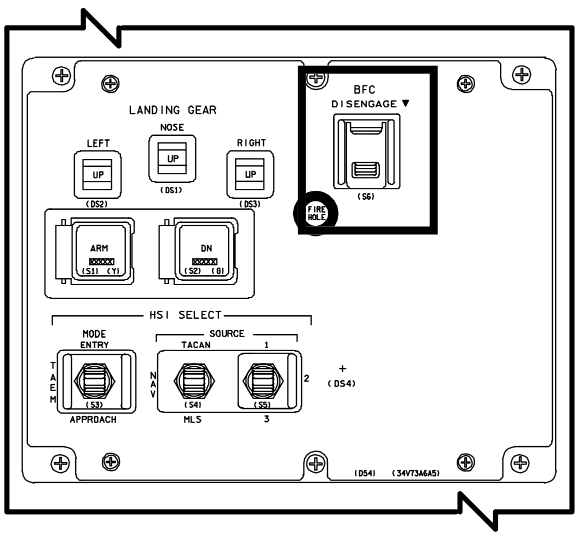
BFC Light on Panel F4



Rotational Hand Controller



BFC CRT DISPLAY and SELECT Switches on Panel C3



BFC DISENGAGE Switch on Panel F6

When the BFS is not engaged, and the *BFC CRT DISPLAY* switch on panel C3 is positioned to ON, the BFS commands the first CRT indicated by the *BFC CRT SELECT* switch. The *BFC CRT SELECT* switch positions on panel C3 are *1 + 2*, *2 + 3*, and *3+1*. When the BFS is engaged, it assumes control of the second CRT as well.

If the BFS is engaged during ascent, the PASS GPCs can be recovered on orbit to continue a normal mission. This procedure takes about 2 hours, since the PASS inertial measurement unit reference must be reestablished. The BFS is disengaged after all PASS GPCs have been hardware-dumped and reloaded with PASS software. Positioning the *BFC DISENGAGE* switch on panel F6 to the *UP* position disengages the BFS. The switch sends a signal to the BFCs that resets the engage discretes to the GPCs. The BFS then releases control of the flight-critical buses as well as the payload buses if it is in *STBY*, and the PASS GPCs assume command.

After disengagement, the PASS and BFS GPCs return to their normal pre-engaged states. Indications of the PASS engagement and BFS disengagement are as follows: BFC lights on panels F2 and F4 are out, BFS's *OUTPUT* talkback on panel O6 displays barberpole, all PASS *OUTPUT* talkback indicators on panel O6 are gray, and BFS releases control of one of the CRTs.

If the BFS is engaged, there is no manual thrust vector control or manual throttling capability during first- and second-stage ascent. If the BFS is engaged during entry, the speed brake can be positioned using the speed brake/throttle controller, and the body flap can be positioned manually. Control stick steering (CSS) by either the commander or pilot is required during entry.

Pre-engage, the BFS supplies attitude errors on the CRT trajectory display, whereas PASS supplies attitude errors to the attitude director indicators; however, when the BFS is engaged, the errors on the CRT are blanked, and attitude errors are supplied to the attitude director indicators.

Operations

The crew interfaces with the five GPCs via four CRTs and various dedicated display instruments. This section first discusses crew operations using PASS, and then discusses crew operations using the BFS.

CRT Switches

Switches on panel C2 designate which keyboard controls each forward display electronics unit. When the LEFT CRT SEL switch is positioned to 1, the left keyboard controls the left CRT 1; if the switch is positioned to 3, the left keyboard controls the center CRT 3. When the *RIGHT CRT SEL* switch on panel C2 is positioned to 2, the right keyboard controls the right CRT 2; if positioned to 3, it controls the center CRT 3.

Thus, flight crew inputs are made on the keyboards, and data are output from the GPCs on the CRT displays.

NOTE

If the *LEFT CRT SEL* and *RIGHT CRT SEL* switches are both positioned to 3, keystrokes from both keyboards are interleaved.

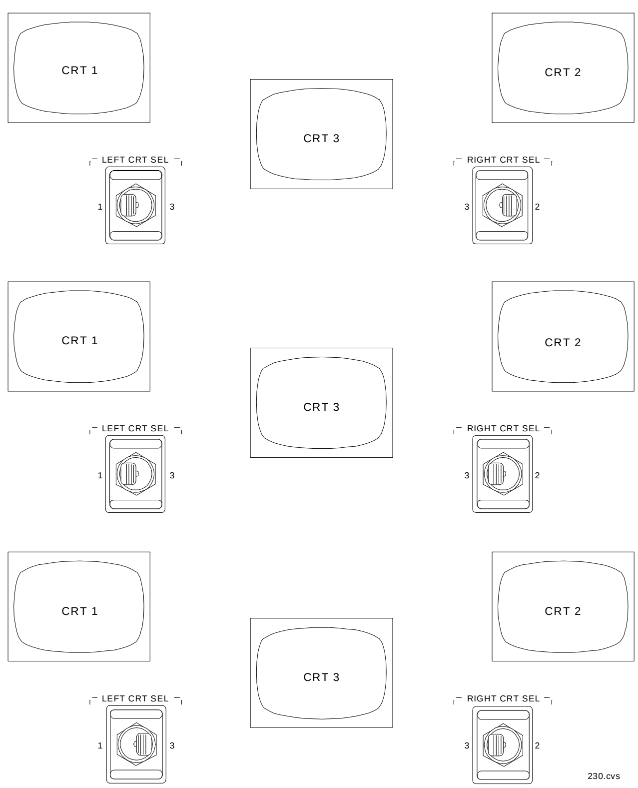
The aft station panel R11L keyboard is connected directly to the aft panel R11L display electronics unit and CRT (or DU); there is no select switch.

Each CRT has an associated power switch. The *CRT 1 POWER* switch on panel C2 positioned to STBY or ON allows control bus power to activate remote power controllers and sends MN A power to CRT 1. The *STBY* position warms up the CRT filament, only. The ON position provides high voltage to the CRT. The *CRT 2 POWER* switch on panel C2 functions the same as the *CRT 1* switch, except that CRT 2 is powered from MN B. The *CRT 3 POWER* switch on panel C2 functions the same as the *CRT 1* switch, except that CRT 3 is powered from MN C. The *CRT 4 POWER* switch on panel R11L functions the same as the *CRT 1* switch, except that CRT 4 is powered from MN C. The respective keyboards receive 5 volts of ac power to illuminate the keys. Each DEU/DU pair uses about 290 watts of power when on and about 20 watts in standby.

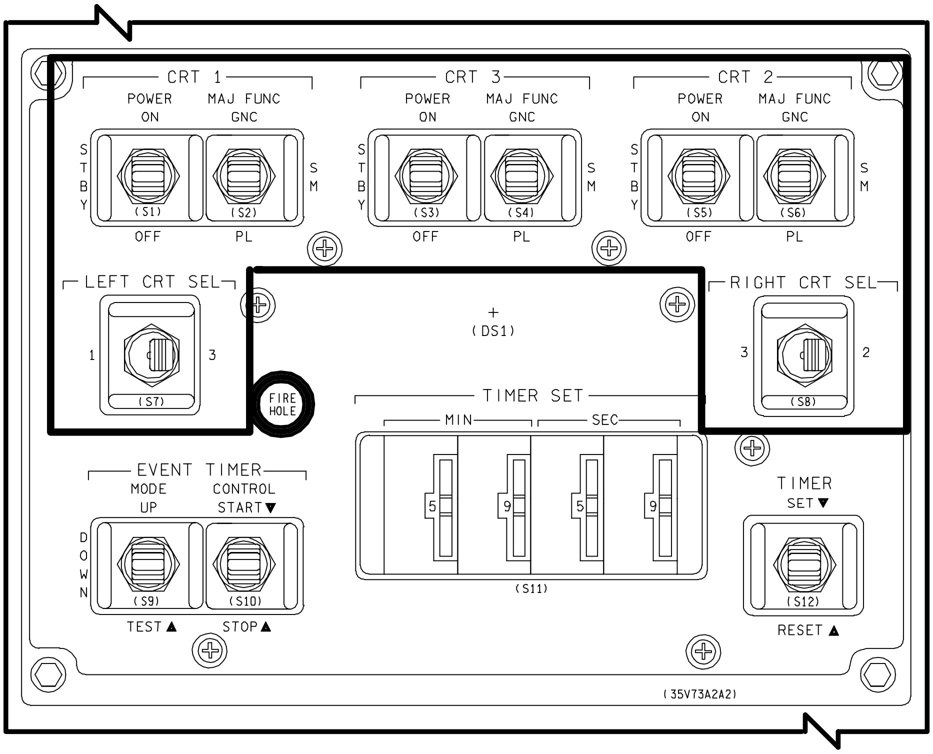
NOTE

Crewmembers should always check that keyboard information is accepted on the proper CRT prior to executing the item.

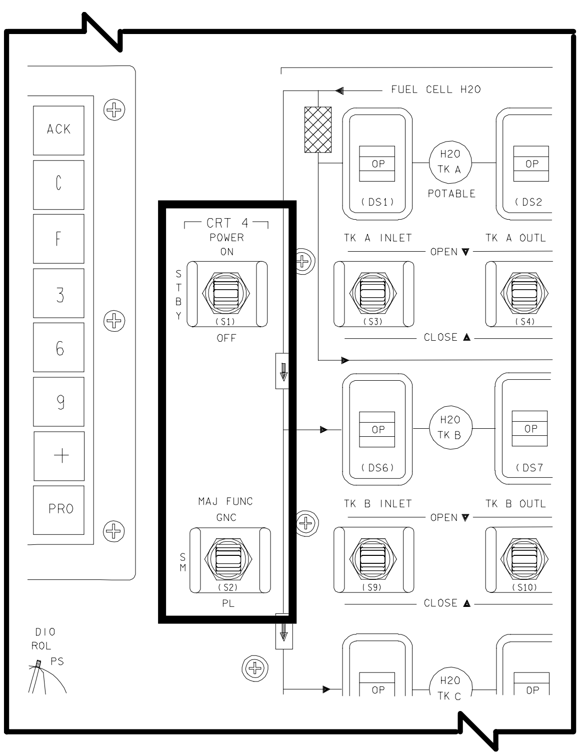
Each CRT has an associated *MAJ FUNC* switch. The *CRT 1, 3, 2, MAJ FUNC* switches on panel C2 tell the GPCs which of the different functional software groups is being processed by the keyboard units and what information is presented on the CRT. The *CRT 4 MAJ FUNC* switch on panel R11L functions in the same manner. This three-position toggle switch allows the crew access to the *GNC*, *SM*, or *PL* software on a desired CRT. The GPC loaded with the desired major function applications software will then drive this CRT. Each major function accesses an independent set of display data and functional software.



Possible CRT/Keyboard Assignments in the Forward Flight Station



CRT Switches on Panel C2



CRT 4 POWER and MAJ FUNC Switches on Panel R11L

Display Hierarchy

CRT display organization consists of three levels of crew software displays within any given major function. The display types parallel the different types of modules used in the GPC software. The established display hierarchy within applications software is operational sequences (OPS), specialist functions (SPEC), and display (DISP) functions. Each has a type of CRT page associated with it.

The OPS is the highest level of crew software control within a major function. Each memory configuration contains one or more OPS. Each OPS allows the crew to accomplish an associated mission phase task. Several operational sequences are defined, each covering some portion of the mission. For example, OPS 1 contains ascent software, OPS 2 contains on-orbit software, and OPS 3 contains entry software.

Each operational sequence is further divided into major modes. Each major mode has an associated display that allows direct crew interface with the software. These are OPS pages, and are also referred to as major mode pages.

Specialist functions (SPECs) are second in the hierarchy. A SPEC allows crew execution of other activities in conjunction with a particular OPS. SPEC displays, like major mode displays, allow direct crew interface with the software. Each SPEC has an associated display that will overlay the major mode display when called. When a SPEC is called, its display rolls in on top of the major mode display, which is still active underneath. The SPEC provides access to an associated portion of the software located in the GPC. Some SPECs are contained in systems software, whereas others are resident in the applications load. A SPEC can be associated with a major function or an OPS, but the systems software SPECs can be obtained in most OPS and major functions. (The list of SPECs and their availability can be found in the DPS Dictionary.)

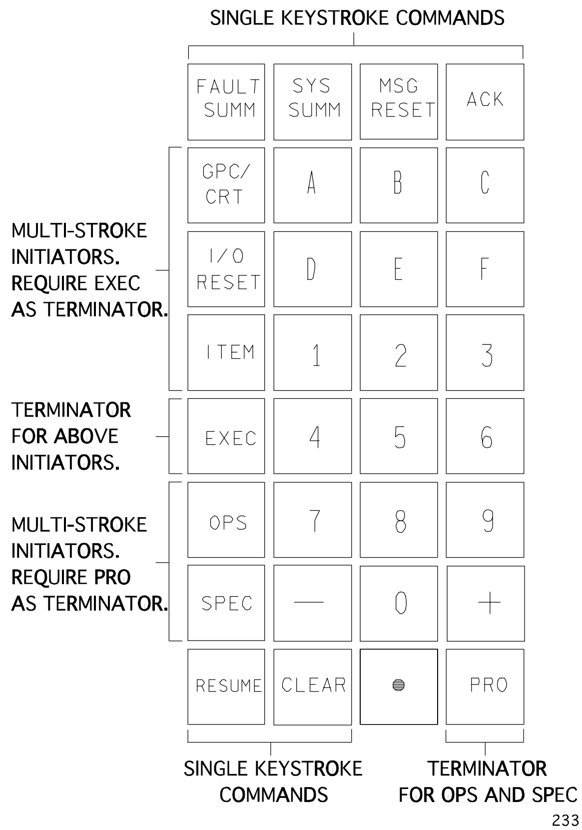
Display functions (DISPs) are the lowest level of software. Each DISP has an associated display that presents the status of a predefined set of parameters. Unlike major mode displays or SPECs, a DISP cannot initiate a change in software processing because DISP displays do not permit direct crew interface with the software. They provide information only.

When called, a DISP will overlay the major mode display and the SPEC, if one is active. Both the SPEC and the major mode display are overlaid, and access to them can be easily regained. The method of terminating the processing of SPECs and DISPs will be discussed later.

The Keyboard

Each keyboard is composed of a 4 x 8 matrix of 32 pushbutton keys. This matrix consists of:

- Sixteen alphanumeric keys: 0 through 9 and A through F, for a hexadecimal numbering system
- Two sign keys (+ and -) serving the dual roles of sign indicators and delimiters. A delimiter is used to separate discrete keyboard entries from their associated data.
- One decimal point key for use in entering data with decimal notation
- Thirteen special function keys: some of these keys are single stroke commands, and some are keys that start or finish a multi-stroke command sequence. A key that starts a command sequence is a command initiator and requires a command terminator key to be depressed to tell the DEU the keyboard entry is complete.



Multifunction CRT Display System Keyboard Unit Found on Panels C2 and R11L

Each of these keys is discussed below.

ACK acknowledges receipt of a fault message on the fault message line by causing the message to become static and by extinguishing the SM ALERT light and software-controlled tones. If multiple messages are indicated on the CRT, each subsequent press of the ACK key will bring up the next oldest unacknowledged message and clear out the last acknowledged one.

MSG RESET operates as a single keystroke command that clears both the currently annunciated fault message and the buffer message indicator (if any) from the fault message line. The fault message line is the second to the last line on the CRT. Depressing this key will also extinguish all software-driven caution and warning annunciators, software-controlled tones, and the SM ALERT light. An ILLEGAL ENTRY message can only be cleared with the MSG RESET key.

SYS SUMM is used to invoke the SYS SUMM display. The particular display called is determined by the selected major function and active OPS.

FAULT SUMM is used to invoke the FAULT display. It operates as a single keystroke command. The FAULT display can be accessed in every major function and OPS.

GPC/CRT initiates a multistroke keyboard entry, allowing the selection of a particular GPC to drive a DEU/DU set.

I/O RESET attempts to restore a GPC's input/output configuration to its original status prior to any error detection. It is a command initiator and requires a terminator keystroke.

ITEM is used as a multi-keystroke command initiator for changing the value of defined parameters or implementing configuration changes on a given display (OPS or SPEC).

EXEC acts as a multi-keystroke terminator to command the execution of the action specified on the scratch pad line. It is the terminator for the initiators above it (GPC/CRT, I/O RESET, and ITEM keys). EXEC may also be a single keystroke command to enable an OMS burn.

OPS serves as a multi-keystroke initiator to load a desired OPS load from mass memory into one or more GPCs. It is also used to transition from major mode to major mode within an OPS.

SPEC acts as a multi-keystroke initiator to select a defined SPEC or DISP display within a given OPS. In addition, this key provides the capability to freeze a display on the CRT. A single depression of the SPEC key freezes the display so it may be statically viewed. The display will remain frozen until another key (other than ACK, MSG RESET, or another SPEC) is entered.

PRO (Proceed) serves as a terminator to the OPS and SPEC keys. The completed command sequence initiates the selection of a desired OPS, SPEC, or DISP display.

RESUME is used to terminate a displayed SPEC or DISP. CRT control is restored to the underlying display upon depression of this key.

CLEAR clears the last echoed keystroke from the bottom line (scratch pad line) of the CRT. For each depression, one additional keystroke is removed, proceeding from right to left. After a command sequence is completed, a single depression of the CLEAR key will erase the static command from the scratch pad line.

Display Selection Procedures

The crew can select a variety of CRT displays. Some of the different ways to select an OPS display and its available SPEC and DISP displays are as follows:

- Selection of the major function is done by placing the MAJ FUNC switch (on panel C2) associated with the CRT in use in the GNC, SM, or PL position.

- An OPS is loaded from the MMU via a three-step keyboard entry. A new OPS is called from mass memory by its first major mode. The OPS is loaded into the GPC that is currently driving the DEU/DU on which the keyboard entry is done. Once the OPS is loaded, access is provided to major modes in that OPS. Major mode displays are advanced by the same keyboard command. The steps for selecting an OPS display are as follows:

    1. *Depress the OPS key*.

    2. *Key in the three numbers of the desired OPS*. The first digit defines the OPS and the next two digits specify the major mode.

    3. *Depress the PRO key*. Once the OPS is loaded into one or more GPCs, that software can be accessed at any time through any CRT in the proper major function.

Selection of a major mode does not involve a mass memory access. Advancing major modes is done by the same keyboard command as loading an OPS. The first digit will be the same as the OPS number, but the last two digits specify the major mode. For example, to go to GNC MM 202, enter OPS 2 0 2 PRO.

Within each OPS, certain SPEC and DISP displays are available. The steps for selecting a SPEC or a DISP are as follows:

1. *Depress the SPEC key*. The SPEC key is used in calling both SPEC and DISP displays.

2. *Key in the SPEC or DISP number omitting all leading zeros*. SPEC and DISP numbers have three digits. They are differentiated by their numbering scheme. The display is a DISP only if the first digit is a 9, or if the last digit is a 6 through 9. To illustrate the method for keying in SPEC and DISP numbers, DISP number 106 would be keyed in as "106"; SPEC number 034 would be keyed "34"; DISP number 066 would be keyed "66"; and SPEC number 001 would be keyed "1."

3. *Depress the PRO key*.

OPS and Major Mode Transitions

Transitions from major mode to major mode or to another OPS are accomplished by either automatic transitions or proper command entry.

- Automatic transitions: Some major mode transitions occur automatically, usually as a function of some mission event. Examples of automatic transitions are between major modes 101 and 102 (SRB ignition) and between major modes 102 and 103 (SRB separation). Selection of an RTLS abort also results in an automatic OPS transition.

- Command entry: Proper command entry (OPS XXX PRO) is almost always used to transition from one OPS to another. In most cases, it is also a legal transition operation for proceeding from one major mode to the next (e.g.; 301 to 302).

Display Sequencing, Overlaying, and Retention

Certain rules have been established for proceeding from one display to another. These can be categorized into treatment of proper display sequencing, the overlaying of current displays by new displays, and the display retention hierarchy.

SPEC and DISP Displays

The hierarchy of overlaying SPECs and DISPs makes sense if one remembers that a SPEC allows crew interaction and control of specialized operations, whereas a DISP provides display information only. Both SPECs and DISPs overlay the current major mode display when called.

A SPEC need not be previously selected in order to call a DISP. If a DISP is on the CRT, and another SPEC or DISP is called, the current DISP is terminated. The terminated DISP can only be viewed again by entering its calling command once more.

If a SPEC is selected, and a DISP is called to overlay it, the SPEC is retained underneath the DISP. If another SPEC is then selected, the underlying SPEC as well as the DISP over it is terminated. The terminated SPEC can only be viewed again if it is recalled.

The RESUME key is used as a single keystroke entry to terminate the SPEC or DISP currently being displayed and to restore the underlying display. If the display being terminated is a DISP, CRT control will be restored to the underlying SPEC, or to the OPS display if no SPEC has been selected. If a SPEC display is terminated, CRT control is restored to the major mode display. It is advisable to press RESUME after viewing any SPEC or DISP to avoid confusion and to decrease the possibility of attempting to retain more SPEC displays than the software allows. Also, certain ground command functions may not be possible when corresponding SPECs are active or underlying a DISP. The RESUME key cannot be used to transition from one major mode display to another or to page backwards through major mode displays.

Display Retention Hierarchy

- Major mode transitions: Both SPECs and DISPs are retained during a major mode transition. If a SPEC or DISP is overlaying the major mode display, the new major mode display can't be seen until the overlaying displays are terminated with the RESUME key.

- Major function change: OPS and SPEC displays on the CRT screen are retained within their major function when major function positions are switched. When the crew returns to the first major function, the SPEC last viewed will appear on the screen. Depression of the RESUME key will restore the underlying OPS. If no SPEC had been selected, return to a major function would restore the last major mode display. DISP displays are not retained at major function switch transitions.

- OPS transition: SPECs, DISPs, and major mode displays are not retained through an OPS transition, since this involves loading an entirely new module of applications software in the GPC. The SPECs may be called again if they are available in the new OPS.

Standard Display Characteristics

Standard Display Features

Two discrete brightness intensities for displayed characters are designated "bright" and "overbright." The bulk of all material is displayed in the "bright" intensity. Special messages and special characters, such as parameter status indicators, are displayed in "overbright" to direct the crew's attention during their display scan.

Certain words and messages are designed to flash on and off. Fault messages will flash, indicating a message that needs to be acknowledged. Command initiators are designed to flash until the command is completed, and an incorrect keyboard entry will result in a flashing "ERR" to the right of the erroneous entry.

Formatting Similarities

OPS number: The four-digit field in the upper left corner of the first line designates the number of the OPS display being processed. The first digit represents the OPS; the next two digits indicate the major mode. The last digit is always a "1," and it is not used when making keyboard entries.

SPEC number: Directly to the right of the OPS number is a three-digit field. This field displays the number of the SPEC overlaying the OPS. This field is blank if no SPEC is selected.

DISP number: The last field in the upper left corner represents the DISP number. It is a three-digit field. This field is blank if no DISP is currently being displayed.

Display title: Centered on the top line of the display is the title of the display. Portions of some titles are dynamic and will specify the mission phase.

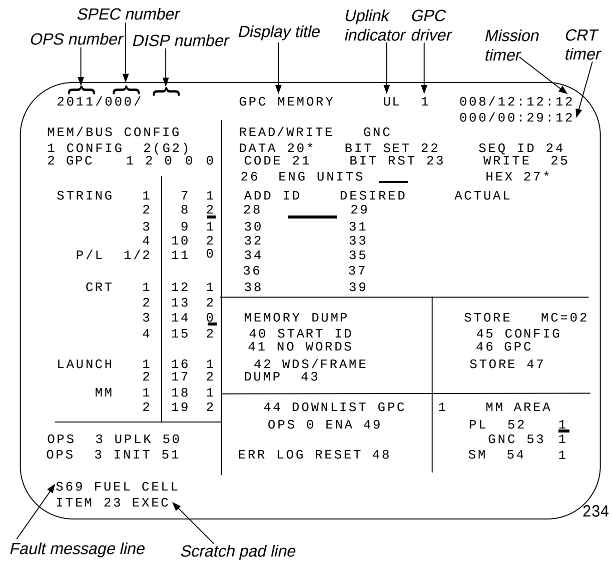
Uplink indicator: Directly to the right of the display title is a two-space field. When an uplink to the GPC is in progress, a flashing "UL" will be displayed. Otherwise this field is blank.

GPC driver: To the right of the uplink indicator is a one-digit field. A number in this field indicates the particular GPC (1, 2, 3, 4, or 5) that is commanding the CRT.

GMT/MET clock: This field displays time in days, hours, minutes, and seconds (DDD/HH: MM:SS). The field is updated every second. The time displayed may be either GMT or MET selectable via a keyboard entry to the SPEC 2 TIME display.

CRT timer: Directly below the GMT/MET clock is a CRT timer field also displayed in days, hours, minutes, and seconds (DDD/HH:MM: SS). This field is also updated every second, and can be set via a keyboard entry to the TIME SPEC display.

Fault message line: The second line from the bottom is reserved for fault messages. Illegal keyboard entry messages and systems fault messages are displayed on this line. In the case of system faults, a number in parentheses to the far right on this line indicates the number of fault messages that have not been viewed and acknowledged (further discussion of fault messages is covered in a later section).



Formatting Conventions Common to All Displays

Scratch pad line: The bottom line of the display echoes keyboard entries made by the crew. Command initiators (OPS, SPEC, ITEM, GPC/CRT, and I/O RESET) will flash on the scratch pad line until the command is terminated. The keystrokes remain on the scratch pad line in a static mode until (a) a new command is initiated, (b) the CLEAR key is depressed, or (c) the MAJOR FUNC switch position is changed. Keyboard syntax errors detected by the DEU will result in a flashing "ERR" on the scratch pad line following the keyboard entry.

Specially Defined Symbols

These symbols include an asterisk and a set of parameter status indicators. Parameter status indicators are displayed in "overbright" intensity for quick recognition. These special symbols are defined as follows:

M: This symbol indicates missing data. It is displayed directly to the right of the affected parameter. The parameter value may be blanked, or the last value received by the GPC may be displayed. If data are missing for a parameter that has no numerical value associated with it, then an M is used to indicate the parameter status.

H: This symbol indicates that a parameter is off-scale high. This indicates a transducer limit has been reached, and the scale is registering its highest possible value. The actual parameter being measured may, in fact, be higher than the recorded data, but the instrument in use does not have the capacity to measure the value. Off-scale high indicators do not appear on the display until several (normally two) consecutive readings have verified this finding. This symbol is displayed to the right of the data affected.

L: This symbol indicates off-scale low parameters. This means that the parameter value displayed is the lowest possible reading due to transducer limitations. The actual value of the parameter may exceed the displayed value, but the range of the hardware is not defined to evaluate this reading. As with the "H," the off-scale low indicator is not displayed until a set number of consecutive readings have verified this status.

Up arrow: This symbol, displayed to the right of the affected parameter, indicates a parameter driven out-of-limits high. The value displayed is a true reading but has equaled or exceeded the operational high limit established by the software. The fault detection and annunciation (FDA) software keeps track of the low and high limits for each parameter and annunciates any violation of these limits to the crew by displaying the appropriate "up arrow" or " down arrow" next to the parameter on the appropriate display.

In the case where the transducer limit is the same as the operational limit, the "H" symbol overrides the "up arrow" symbol. Several (normally two) consecutive readings verify this status before the "up arrow" symbol is displayed.

Down arrow: This symbol indicates that a parameter value is equal to or less than the operational low limit. The value displayed is outside the software limits placed upon the parameter. When the software limit established is the same as the transducer limit, the "L" symbol takes precedence over the "down arrow" symbol. A set number of consecutive readings verifies this indication before the "down arrow" is displayed.

In addition, the down arrow is used to indicate a discrete state that does not agree with the nominal state. For example, a high pressure gas supply valve state reading "closed" when its position is normally "open" would drive the "down arrow" symbol.

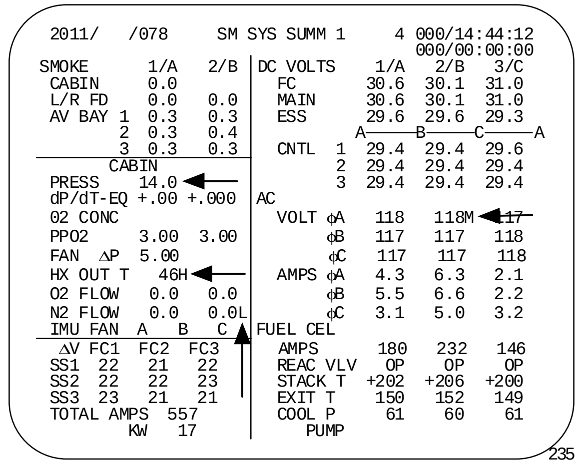
The down arrow is also used to indicate that a hardware unit has been declared failed by a GPC.

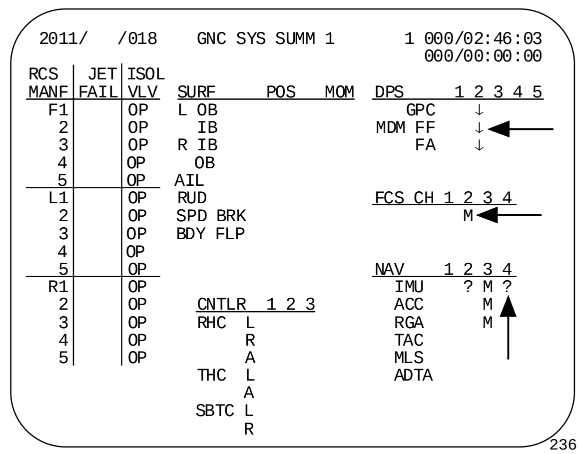
?: This symbol indicates a redundancy management dilemma. That is, if two hardware units measuring the same parameter disagree, and the software cannot isolate which of the two is failed, a "?" will be displayed in both places.

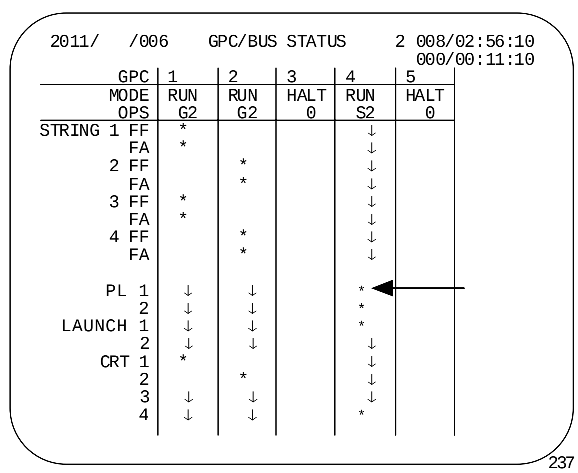
*****: This symbol indicates an active state or the selected item of mutually exclusive items.

Item Operations

Within a given display, certain operations can be performed by the crew. Those items that may be altered are identified by an item number. The item number is a maximum of two digits and is placed in such a way that it is readily identifiable with the parameter or status configuration with which it is associated. When item numbering is obvious, item numbers may be implied and will not appear on the display. Item numbering is sequentially ordered for each display. There are never more than 99 items per display. The two basic types of manipulations that the crew can perform are item configuration change and item data entry.







Specially Defined Symbols on CRT Displays

Item Configuration Change

This operation allows the crew to choose any of a number of options or to initiate a specific action as defined by the particular display format. Typical purposes of this operation include selecting or deselecting an item, initiating and executing an action, and altering software configurations. The procedure used in performing an item configuration change within a selected display is as follows:

1. *Depress the ITEM key.*
2. *Key in the item number.*
3. *Depress the EXEC key.*

Item Data Entry

This operation allows the crew to load data into the software. Typical purposes of this operation include initializing parameters, changing software limits, and specifying memory locations. The procedure used in performing an item data entry is as follows:

1. *Depress the ITEM key.*
2. *Key in the item number.* Item numbers are ordered sequentially (1, 2, 3, . . .) on each display. They are located next to the parameter to which they are assigned. Some item numbers must be inferred by their surrounding item numbers.
3. *Key in a delimiter* ("+" or "-"). A delimiter serves to separate item number codes from their corresponding data. The delimiter whose sign corresponds to the sign of the data should be used, but if no sign is associated with the data, it doesn't matter which delimiter is used. A "[ ]" after the data field indicates that the entry is sign-dependent.
4. *Key in the data.* Data size specifications depend on the format established for that particular data load. Usually, the data size will be indicated with an underline for each digit. As a general rule, leading and trailing zeros need not be entered. Remember that the sign of the delimiter is the sign of the data.
5. *Depress the EXEC key.*

Multiple Data Entries

Multiple item configuration changes cannot be done; however, multiple item data entries can. Multiple data entries can be made with separate command strings, but because this is time-consuming, the software allows more than one data entry to be made with one command sequence. The procedure is the same as described above except step 4 (after data are keyed in). Add step 4a to make more than one item data entry at once.

4a. Key in a delimiter. Consecutive data entries may be loaded by using a delimiter to separate each parameter. Item entries are incremented sequentially so the item number need not be entered for each parameter following the one already entered. Just hit another delimiter, and the next item number will appear, ready to receive its associated data. To skip an item number, hit a delimiter twice. In this way, any amount of item numbers may be skipped until the desired item number is reached.

Both the "+" and the "-" keys may be used interchangeably as delimiters. However, when skipping item numbers, it is a good idea to use the delimiter corresponding to the sign of the next data entry if there is any sign associated with it. Using the sign key corresponding to the next data entry ensures that the GPC receives the proper data entry.

An example of a multiple item data keyboard entry is:

ITEM 7 + 2 + 1 + + 2 + - - 2 EXEC

In this example, Items 7, 8, 10, and 13 have no sign associated with them so the sign of the delimiters doesn't matter. Although there was room for four item entries here, the actual number allowed on the scratch pad line is a function of the size of the data.

This entry will appear on the scratch pad line of the corresponding CRT as:

ITEM (07) + 2 (08) + 1 (10) + 2 (13) - 2 EXEC.

All item operations will be one of these two basic manipulations. However, data size and form will differ for each display.

Remember, only OPS and SPEC displays allow item operations. A DISP display does not.

Special Operations and Displays

GPC/CRT Assignment

GPC assignment to a particular DEU/CRT set is determined via a predefined table of assignments. This table is stored in all the common set GPCs' systems software and can be manipulated by the crew. There is a table for each memory configuration (MC) that is valid when that MC is active (loaded in one or more GPCs), and the particular major function is selected. This table can be changed using the GPC MEMORY display (SPEC 0). The current GPC driver for a CRT is controlled by the *MAJ FUNC* switch. That is, the position of the *MAJ FUNC* switch (*GNC*, *SM*, or *PL*) will determine the GPC with which the DEU communicates. In some cases, a redundant set of GPCs is formed for GNC, and the GNC CRTs are normally split among them. This is done with the predefined table. The table is looked at by the GPCs when they are loaded with the applications software, and that is when the assignments take effect.

Another way to change the current GPC assignment logic is with the GPC/CRT key. The GPC/CRT key allows the crew to reassign a CRT to a different GPC commander. The steps for selecting a GPC to command a given DEU/CRT are as follows:

1. *Depress the GPC/CRT key*.
2. *Key in the desired GPC number* (1, 2, 3, 4, or 5)
3. *Key in the desired CRT number* (1, 2, 3, or 4). No delimiter is needed between the GPC and the CRT numbers.
4. *Depress the EXEC key*.

An assignment is not executed if the GPC being assigned doesn't have the applications software in memory to support the DEU/CRT in its current major function. If the GPC specified by a keyboard entry is not a valid assignment, the reassignment does not occur, and the current GPC driver retains the CRT. Thus, if a CRT is in *GNC*, and an attempt is made to assign a GPC that is not in the redundant set to drive it, a redundant set (or valid) GPC will drive the CRT instead of the invalid GPC. If GPC 4 is the SM machine (nominal configuration), then it is the only valid GPC to drive a CRT whose *MAJ FUNC* switch is in *SM*.

The payloads major function is usually *unsupported*. This means that none of the GPCs have payload applications software loaded in them. Any GPC can be assigned to drive a CRT in an unsupported major function. The GPC that was driving the CRT in the previous major function will retain the CRT when it is placed in *PL*.

If the keyboard entry specifies a valid GPC, it will override any assignment made by the software. The keyboard entry assignment will remain in effect whenever the *MAJ FUNC* switch is in a position supported by that GPC. A new assignment can be made via the keyboard.

The GPC/CRT key can also be used to isolate a DEU from communication with all GPCs. This is accomplished by using "0" for the number of the GPC. The PASS set can drive only three of the four CRTs at one time, so at least one DEU is always isolated from PASS.

The DEU drives a big X over an isolated CRT to remind the crew that the DEU is not receiving data. The DEU also annunciates a POLL FAIL message to inform the crew that the GPC is no longer successfully polling the DEU (not attempting to communicate with the DEU).

Memory Configurations

After a GPC has been IPL'd, the only software resident is the systems software, and the GPC is in OPS 0 when moded to *RUN*. Any applications software is loaded in from the MMU during an OPS transition. There are two levels of applications software: the major function base (MFB) and the OPS overlay. The MFB is that software common to all OPS in a particular major function. For GNC, the MFB contains flight-critical software and data that are retained from one mission phase to another, such as the current state vector and inertial measurement unit processing. When a GPC is transitioned from one OPS to another in the same major function (e.g., from GNC OPS 1 [ascent] to OPS 2 [orbit]), the MFB remains in main memory, and only the OPS overlay is loaded from the MMU and written over the old OPS. Of course, when the major function changes (e.g., when GPC 4 is transitioned from

GNC OPS 1 to SM OPS 2), a new MFB is loaded in from the MMU along with the OPS overlay.

The controls for performing an OPS transition (i.e., loading a new memory configuration into the GPC from the MMU) are on the GPC MEMORY display (SPEC 0), which is also the OPS 0 OPS display. Item 1 determines the memory configuration (CONFIG) to be loaded. Currently, there are eight different memory CONFIGs, besides memory CONFIG 0, which is post-IPL OPS 0 (no applications software loaded).

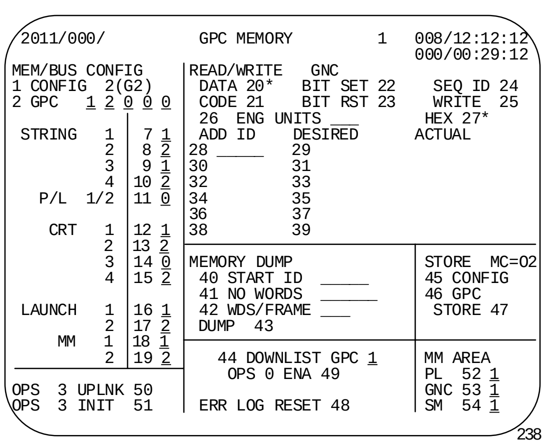
MCC	ABBREV	
1	(G1)	GNC OPS 1 and 6 combined (ascent and aborts)
2	(G2)	GNC OPS 2 (on orbit)
3	(G3)	GNC OPS 3 (entry)
4	(S2)	SM OPS 2 (on orbit)
5	(S4)	SM OPS 4 (on orbit [not used])
6	(P9)	PL OPS 9 (preflight)
No MC 7		
8	(G8)	GNC OPS 8 (on orbit checkout)
9	(G9)	GNC OPS 9 (preflight/postflight)

Memory Configurations

Nominal Bus Assignment Table

Associated with each memory configuration is a nominal bus assignment table (NBAT). It is displayed via items 7-19 on SPEC 0 whenever a memory configuration is entered, and it tells which GPCs are in the target set and which GPCs are to be in command of each data bus. The nominal assignments are already loaded in GPC main memory preflight. However, these bus assignments may be changed any time, including when an OPS transition is performed.

An example of a typical nominal bus assignment table is shown on SPEC 0 GPC MEMORY for GNC OPS 3.



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Sample NBAT Data on GPC MEMORY Display (SPEC 0)

- Items 2-6 determine which GPCs will be in the OPS. They are referred to as the "target" GPCs. In this case, GPCs 1-4 are in a redundant set. If a GPC is not to be in that OPS, a 0 is entered in that GPC's item number, which is one more than the GPC number. (Item 2 is for GPC 1, etc.)

- The commanders of the flight-critical data buses or strings are entered in items 7-10. (String 1 is FF1 and FA1, etc.) In this case, each GPC is set to command its same-numbered string.

- The two PL buses are assigned together. For OPS 1 and 3 they are assigned to GPC 1 via item 11 in case the BFS fails. When the BFS is in RUN (as it is for entry), it commands the PL data buses.

- CRTs 1, 2, 3 are assigned to GPCs 1, 2, 3 respectively, via items 12-14. Since the PASS can only control three CRTs at a time, no GPC is assigned to CRT 4 during entry. Note that CRT assignments are for a particular major function only.

- The launch data buses are assigned via items 16 and 17. Since they have no function during entry, they are deassigned.

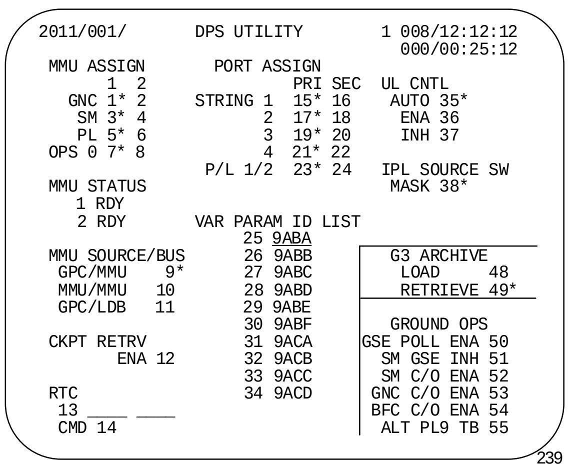
- Items 18 and 19 show that GPC 1 will command mass memory bus 1 for the OPS 3 transition, and GPC 2 will command mass memory bus 2, either if the transaction fails on mass memory bus 1 or if MMU 2 is prime selected on SPEC 1 DPS UTILITY.

MMU Assignment

Since there are two identical MMUs, there must be a method to tell the GPCs which one to use for a particular transaction. This is done on DPS UTILITY SPEC 1 display via items 1 through 8. Only one MMU (and its data bus) is assigned to each major function. A post-IPL OPS 0 GPC also has an MMU assigned to it for requesting freeze-dry software for a memory store. This display is initialized with all assigned to MMU 1, and execution of any of the item numbers causes the appropriate MMU to be assigned.

Note that each of the pairs of item numbers is mutually exclusive.

When a GPC needs to access mass memory, this table tells it which MMU to use. For example, the SM GPC may need to call a roll-in SPEC or take a checkpoint (discussed later). In the case of OPS transitions, if the MMU selected is busy or fails twice, then the other is automatically tried. For a GNC OPS transition where a redundant set is involved, one GPC is assigned to each mass memory bus via items 18 and 19 on SPEC 0 GPC MEMORY. The indicated GPC will command the mass memory bus selected by item 1 or 2 on SPEC 1 DPS UTILITY, then the other GPC will command the next mass memory bus if the first transaction fails. Of course, all GPCs in the redundant set will be listening over both buses and receive the overlay.

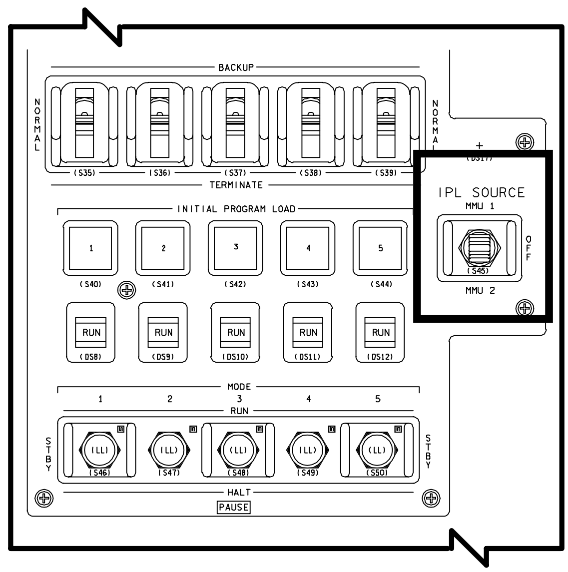


DPS UTILITY Display (SPEC 1)

Software Memory Source Selection

During an initial program load (IPL), an MMU is selected as the software source via the IPL SOURCE switch on panel O6. This switch is a three-position toggle switch that will be either in the MMU 1 or MMU 2 position during the IPL sequence. At all other times, this switch will nominally be in the OFF position.

The controls for selecting the memory source for an OPS transition and the bus over which it is loaded into the GPCs are on SPEC 1 DPS UTILITY (items 9 through 11). The display is initialized with item 9 selected, which is almost always used. As part of the GPC status exchanged at common set sync, each GPC exchanges its current resident memory configuration. When a request is made for a memory configuration, the software determines whether or not another GPC already has the requested OPS or a current major function base. If another GPC already has any of the requested software, the lowest numbered such GPC will be used as a source for the other GPCs. Such a GPC-to-GPC overlay of software will be done over the mass memory data buses. An overlay that is not available from a GPC will be loaded from an MMU. Note that the major function base may come from another GPC and the OPS overlay from mass memory. For transitions to OPS 3, the G3 archive (stored in the upper 128 k of main memory prelaunch) is simply copied to lower memory and executed.



IPL SOURCE Switch on Panel 06

If there is a problem with both of the mass memory data buses, then item 11 may be selected if there is a GPC source for both overlays. In this case, the GPC-to-GPC overlay is done over the launch data buses.

Memory reconfiguration may be forced from an MMU, regardless of other GPC sources, by selection of item 10 on the DPS UTILITY display. In this case, whether both are required or not, both the major function base and the OPS overlay will be loaded from mass memory. This would only be used if the software in a current GPC was suspect for some reason.

If there is no usable GPC source and the selected MMU is off or being used for another memory transaction, the class 3 fault message OFF/ BUSY MMU 1 (2) is initiated. The current status of each MMU is shown on the DPS UTILITY display as either RDY (ready to respond) or BSY (off or currently responding to a GPC command).

Resetting I/O Configurations

When a GPC detects an error or is missing data from a piece of equipment, a fault message will be displayed on the CRTs, the *SM ALERT* light and tone will be activated, and further attempts by the GPC to communicate with the equipment will be terminated. Two common causes of detected errors or missing data are the powering down of equipment or an error in a data transmission. In these two cases, if the equipment is to be powered up, or if the error has been corrected, it is desirable to restore the GPC's data input to the nominal configuration. Restoring input is done through the I/O RESET key in the affected major function. If an I/O RESET is performed only on a GNC GPC, the entire redundant set of GNC GPCs will be restored to nominal I/O configuration. If it is performed on the SM GPC, only the SM GPC's I/O configuration will be restored to nominal. To reset I/O configurations, the procedure is as follows:

- Select desired *MAJ FUNC*.
- Depress the I/O RESET key.
- Depress the EXEC key.

If the powered down equipment has been powered on, or if a problem with a piece of equipment has been fixed, an I/O RESET will resume communication, and it will not cause another fault message annunciation. If the GPC still has a problem communicating with any piece of its assigned equipment, a fault message will reannunciate after an I/O RESET. This termination of attempts by the GPC to communicate with its assigned equipment is called a commfault (i.e., the input element has been bypassed by the GPC) and the resultant loss of input data to applications software is also referred to as a commfault.

Systems Summary Displays

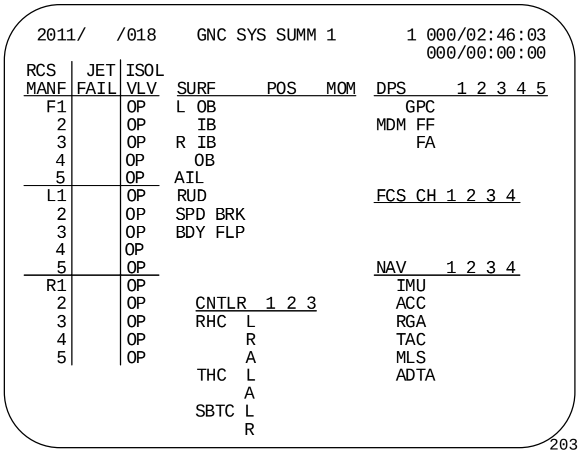
Systems summary displays provide general systems status information that can be accessed quickly to aid immediate diagnosis of a problem. They are designed to support the caution and warning (C/W) matrix located on panel F7. When a C/W alarm occurs, the crew can call a systems summary display that has general information from several systems to pinpoint the problem to a specific system, then continue troubleshooting the problem on system-specific SPECs, DISPs, and hardware panels. The systems summary displays are DISPs and provide information only.

The systems summary displays are major function-specific and are called with the SYS SUMM key. If a CRT's *MAJ FUNC* switch is in *GNC*, and the SYS SUMM key is pressed, then GNC SYS SUMM 1 will appear on that CRT. GNC SYS SUMM 1 is DISP 18 so it may also be called with a SPEC 18 PRO, but it is faster to use the SYS SUMM key.

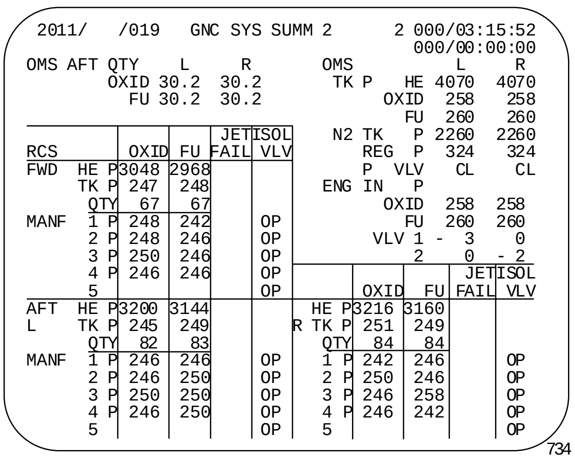
There are four PASS systems summary displays: GNC SYS SUMM 1, GNC SYS SUMM 2, SM SYS SUMM 1, and SM SYS SUMM 2.

The SYS SUMM key is a toggle function in each major function. In SM on-orbit, hitting SM SYS SUMM will cause SM SYS SUMM (DISP 78) to appear on the CRT. If SYS SUMM is depressed again, SM SYS SUMM 2 (DISP 79) will appear, and if SYS SUMM is depressed once more, SM SYS SUMM 1 reappears.

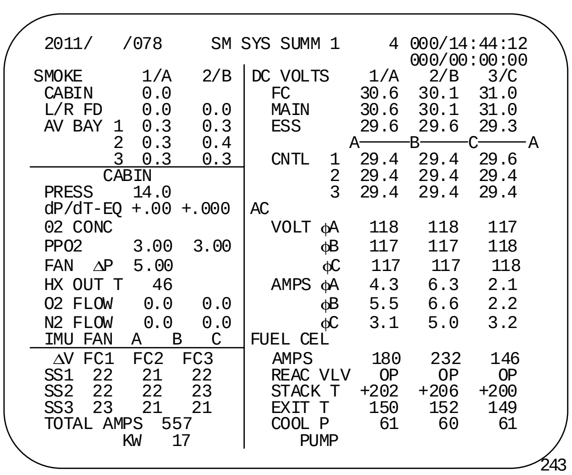
The same toggle function exists in GNC between GNC SYS SUMM 1 (DISP 18) and GNC SYS SUMM 2 (DISP 19).



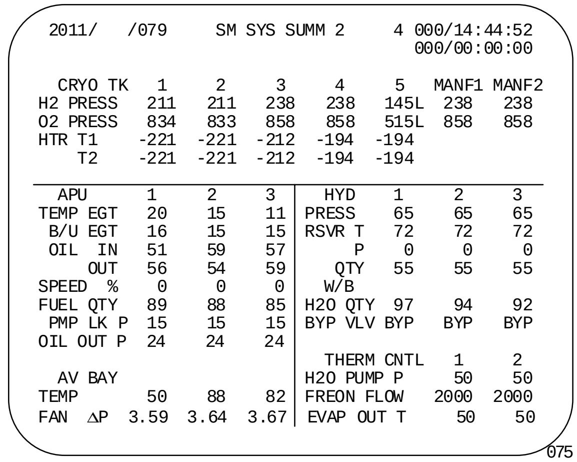
PASS GNC SYS SUMM 2, available in GNC OPS 1, 6, 2, 8 and 3



GNC SYS SUMM 2, available in GNC OPS 2 and 8



PASS SM SYS SUMM 1, available in SM OPS 2



PASS SM SYS SUMM 2, available in SM PS 2

Fault Detection and Annunciation

Five classes of alarms have been established. Class 1, Emergency, has no interface with software. Class 2, Caution and Warning (C/W), is the second highest alarm class. It is divided into primary (hardware-driven) and backup (software-driven) systems. An alarm of the software-driven class will result in the annunciation of the *BACKUP C/W ALARM* light on the C/W matrix on panel F7, the *MASTER ALARM* lights, and an associated tone. In addition, a fault message will be displayed upon the fault message line of the CRT. Class 3, Alert, triggers the *SM ALERT* light and corresponding tone. A fault message is displayed upon the fault message line. Class 5, Operator Errors, is the lowest priority alarm and is caused only by a crew entry error. It results in an ILLEGAL ENTRY fault message being displayed. Class 0, Limit Sense, provides a status indicator (down arrow, up arrow) to the right of the affected parameter on an appropriate CRT. No fault message, tone, or light is triggered.

The output of a fault message to the fault message line results in several indications requiring crew interface. Although generally the crew keyboard responses are similar, the effects of these responses differ for each class alarm.

The crew response to a class 2 backup fault message is:

1. *Depress the MASTER ALARM pushbutton indicator*. This will

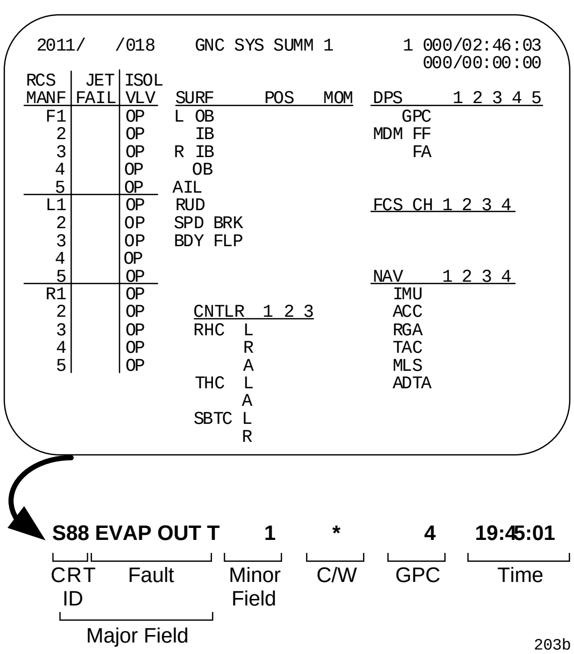
extinguish the *MASTER ALARM* light and caution and warning tone.

2. *Depress the ACK key* (on the keyboard). The fault message will cease flashing. If the crewmember can examine the message while it flashes, this step is unnecessary. Depress the *ACK* key again to look at the next message in a stack if required.

3. *Depress the MSG RESET key*. Depression of this key removes the fault message from the fault message line. In addition, the *BACKUP C/W* light is extinguished. (Hardware-driven lights remain on until the problem is corrected.)

The crew response to a class 3 fault message is:

1. *Depress the ACK key*. This will cause the fault message to become static. Depression of the ACK key will also extinguish the *SM ALERT* light and tone. (The tone duration is set to a crew-selected length and may have stopped before the ACK key is pressed.) Depress the ACK key again to look at the next message in a stack if required.



Sample CRT Fault Message

2. *Depress the MSG RESET key*. This will remove the fault message from the fault message line. If the ACK key had not been depressed, the MSG RESET key would extinguish the SM *ALERT* light and tone.

A class 5 fault message displays a flashing "ILLEGAL ENTRY" on the fault message line. The crew response is simply to depress the *MSG RESET* key. This clears the fault message from the fault message line. The *ACK* key will not clear an "ILLEGAL ENTRY." It will cause messages stacked under the "ILLEGAL ENTRY" display to be acknowledged and cleared.

Some illegal keyboard entries are detected by the DEU before being sent to the GPCs. When this occurs, a flashing "ERR" appears immediately to the right of the erroneous entry on the scratch pad line. The crew response is simply to depress the CLEAR key. Upon depression of the CLEAR key, the "ERR" and the last keystroke will disappear. Subsequent depressions of the CLEAR key will remove single keystrokes, proceeding from right to left. This feature enables the crew to CLEAR back to the portion of the command that was incorrect, correct it, and proceed. This type of error is not identified by class, since it is not GPC-detected and is known simply as a DEU-detected error.

Fault Messages

Fault messages associated with alarm classes 2, 3, and 5 follow a standard format of five fields.

The major field is a 14-character field. The first three characters identify the display on which more information about the annunciated failure can be found. An S or a G, followed by a two digit number, indicates the major function (G for GNC and S for SM) and the number of the SPEC or DISP. If no display is associated with the fault, this field is blank. In the example below, "S88" is the CRT ID and means that information on the fault can be found on SPEC 88 in SM.

The remaining characters identify the problem or subsystem group associated with the fault. In the example, "EVAP OUT T" is the FAULT portion of the major field and indicates a fault in the flash evaporator subsystem.

The minor field is a four-character field that further identifies the fault. It will specify the subdivision, direction, location, parameter, or specific unit of the subsystem or problem identified in the major field. In the example fault message, "1" is the minor field message and means that the temperature sensor 1 is the area in which the fault was detected.

The C/W field is used only with caution and warning class 2 backup messages. An asterisk appears in this column across from the corresponding fault to denote that the condition is a class 2 backup alarm.

The GPC field identifies the GPC that detected this fault. This characteristic aids the crewmember in locating or identifying internal GPC or I/O errors.

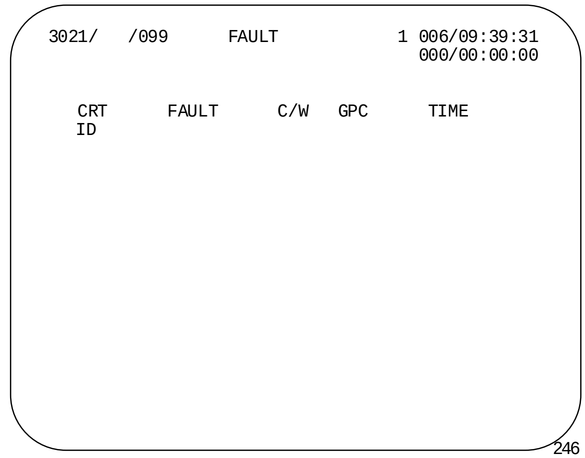
The far right field is the TIME field. This field indicates the time at which the fault occurred. The time is MET and is displayed in hours, minutes, and seconds (HH:MM:SS).

A complete listing of all possible fault messages can be found in the Flight Data File Reference Data Book and in Section 2.2.

A class 5 alarm is annunciated by an "ILLEGAL ENTRY" in the major field, and all other fault message fields are blank. When a class 5 message is received, it is displayed instantaneously on the fault message line of the CRT where the error occurred, rather than on all CRTs like class 2 and 3 errors. To get rid of the class 5 message, a MSG RESET must be done to the CRT where the error occurred. Class 2 backup and class 3 messages are extinguished by a MSG RESET on any CRT.

The Fault Summary Display

A historical summary of class 2 backup and class 3 fault messages is provided via the FAULT display (DISP 99). Class 5 errors are not displayed as they are caused by illegal crew entries to a single DEU. The FAULT display is a DISP available in all OPS. It is selected for viewing by depression of the FAULT SUMM key.



FAULT Display (DISP 99)

The PASS fault summary display consists of up to 15 fault message lines. They appear in reverse chronological order. The oldest message appears on the bottom line. When a new fault message is generated, it appears on the top line. The other messages are pushed down, and the 15th message (the oldest) disappears.

The only difference between the fault messages on the FAULT display and the fault message on the fault message line is the TIME field. On the FAULT display, the time field includes days as well as hours, minutes, and seconds (DDD/HH: MM:SS).

Sometimes, a subsystem failure or malfunction results in the output of several fault messages, some of which may be identical. The fault detection and annunciation logic can prevent the annunciation of identical fault messages. When a fault message is generated, its major and minor fields are compared to those of the top message of the display. If the fields are the same, and if the new fault message has occurred within a 4.8 second window, the new message is inhibited.

The last message displayed on the fault message line of any CRT is not necessarily the most recent fault message. Unless the fault message line was cleared with a MSG RESET, the crewmember will not see any new messages that came in after the flashing or frozen message. In that case, the crewmembers can see if a new message has been annunciated by looking at a two-character field. This field is called the buffer message indicator and is located in the last field on the far right of the fault message line.

The buffer message indicator serves to indicate the number of messages in the fault buffer on the FAULT display since the last MSG RESET. This number includes class 2 backup and class 3 messages only. Class 5 messages and the currently displayed messages are not included in this counter. The number is enclosed by parentheses. If no fault messages are in the stack, this field is blank. To view any of these messages, the crewmember may depress the ACK key to display subsequent messages or look at the FAULT display. A MSG RESET clears both the fault message line and the buffer message indicator.

In addition to using the FAULT SUMM key, the FAULT display may also be selected by the keyboard entry "SPEC 99 PRO." However, this command will clear all fault messages from the FAULT display and the fault message lines. This capability is useful if and when the fault messages displayed are no longer significant (i.e., they are old, or they have been dealt with).

Crew Software Interface with the BFS

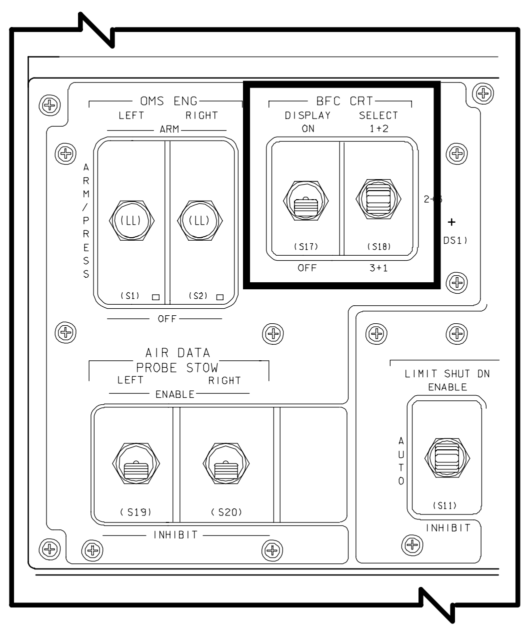
The crew software interface with the BFS is designed to be as much like PASS as possible, but there are some differences. This section covers the differences between the PASS's and BFS's crew and CRT interfaces. If something is not mentioned in this section, it can be assumed to operate the same as the PASS interface.

BFC CRT Switches

Panel C3 contains two switches relevant to BFS operations. The *BFC CRT DISPLAY* switch is a two-position *ON/OFF* switch. In the *ON* position, the CRT(s) specified by the *BFC CRT SELECT* switch is driven by the BFS computer. (The *BFC CRT SELECT* switch controls CRT assignment to the BFS computer.) The switch is read by the GPC only when the *BFC CRT DISPLAY* switch is in the *ON* position. The *BFC CRT SELECT* switch has three positions. In each position, the first digit is the CRT commanded by the BFS pre-engage. Post-engaged, the BFS also commands a second CRT indicated by the second number. For example, when the *BFC CRT SELECT* switch is in the *1 + 2* position, CRT 1 is connected to the BFS GPC *prior* to engaging the BFS. After the BFS is engaged, this switch position allows the BFS computer to command both CRT 1 and CRT 2. In the 2 + 3 position, CRT 2 is commanded by the BFS GPC *prior* to engaging the BFS. Post-engaged, this switch allows CRT 2 and CRT 3 to be supported by the BFS computer. In the 3 + 1 position, CRT 3 is driven by the pre-engaged BFS GPC. Upon engaging the BFS, both CRT 3 and CRT 1 will be assigned to the BFS computer.

During ascent and entry, one CRT will normally be assigned to the BFS via the *BFC CRT SELECT* switch. The nominal position of the switch is the 3+1 position. However, this switch position may be changed at any time, pre-engage or post-engage. If the BFS is engaged with the *BFC CRT DISPLAY* switch *OFF*, the BFS will automatically assume command of CRTs 1 and 2.

No set of *BFC CRT* switches exists for the CRT in the aft station.



BFC CRT DISPLAY and SELECT Switches on Panel C3

BFS Functions of the MAJ FUNC Switch

The *MAJ FUNC* switches on panels C2 and R11L are also functional for the BFS. However, the display data and functional software accessed by the three-position switch are slightly different. The BFS functions of the MAJ FUNC switch are defined as follows:

- *GNC*: Flight critical software including limited guidance, navigation, and control software is contained in this major function. The BFS GNC major function contains only that software necessary for safe orbital insertion and return, including ascent abort logic.

- *SM*: This major function contains limited nonredundant systems management and payload software. There is no room in the BFS for the redundancy management found in PASS. When the *MAJ FUNC* switch is set in the SM position, the THERMAL display is invoked. This display is unique to the BFS.

- PL: This major function is not functional for the BFS. Should the *MAJ FUNC* switch be set in this position, no display change would occur. If the *BFC CRT DISPLAY* switch is turned on, allowing the BFS to drive a CRT already in the PL major function, the CRT will be blank except for time and GPC driver fields because the BFS has no software to support this major function.

BFS ENGAGE Push Button

The BFS ENGAGE pushbutton is located on the commander's and pilot's rotational hand controllers (RHCs). During the dynamic flight phases (ascent and entry), the commander and pilot usually rest a hand on or near the RHC. In this way, BFS engagement can occur as quickly as possible. If the crew delays engagement during these flight phases, they could lose control of the vehicle, or the BFS' navigation calculations could degrade very quickly so that control would be essentially lost after engagement.

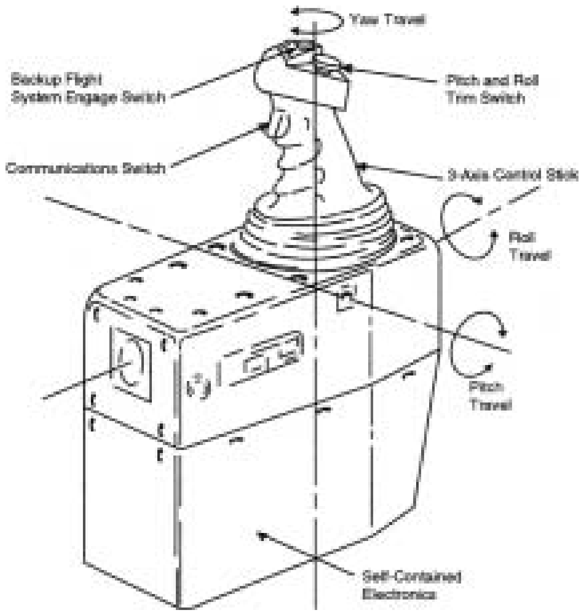
Some force (8 lb) is required to depress this pushbutton to prevent inadvertent engages. While on-orbit, the pushbutton is essentially disabled by reconfiguring the BFS OUTPUT switch. The BFS cannot track PASS while it is in OPS 2 and is moded to HALT on-orbit. If the BFS needs to be engaged on-orbit, the BFS must be "awakened", and the only software that will be of any use is entry and systems management software.

Keyboard and Display Differences for the BFS

The keyboard operates exactly the same way for the BFS as for the PASS. A few additional capabilities need to be mentioned.

- The GPC/CRT key: In addition to the *BFC CRT DISPLAY* switch, this key provides the capability to assign a CRT to (or isolate a CRT from) the BFS GPC. Both methods can be used interchangeably, but as long as the *BFC CRT DISPLAY* switch is working, it is the fastest method of allowing the BFS to drive a CRT or to change BFS CRTs. The *BFC CRT DISPLAY* switch allows PASS to automatically begin driving the CRT again when the BFS is turned off. When the BFS is assigned a CRT with the GPC/CRT key, it is the same as deassigning that screen from PASS with a GPC/CRT 0X EXEC. PASS must be reassigned to resume commanding of that CRT.

- The BFS INDICATOR: When the BFS is commanding a CRT, the BFS indicator will appear on the CRT being commanded. On the second line of every BFS display a three-character space field has been reserved for the message "BFS." This field is located directly below the GPC indicator. The BFS indicator is displayed in the overbright intensity and is intended to prevent possible confusion of a PASS display with a BFS display. Often the BFS display will be identical or very close to the corresponding PASS display.



Rotational Hand Controller

```
1011/   /018    GNC SYS SUMM 1       5 000/02:46:03
                                   BFS 000/00:00:00

      SURF       POS   MDM         DPS     1 2 3 4
      L OB                         MDM FF
        IB                             FA
      R IB                             PL
        OB
       AIL
       RUD                         FCS CH 1 2 3 4
       SPD BRK
       BDY FLP

MPS              L     C     R     NAV  1 2 3 4
 HE TK P        4280  4230  4240  |IMU
    REG P A      784   768   768  |TAC
          B      776   766   770  |ADTA
   dP/dT
                                   MPS PNEU HE P
ULL P LH2       42.5  42.7  42.9          TK   4350
      LO2       21.1  21.0  20.8          REG   798
                                          ACUM  760
GH2 OUT P         70↓   50↓   40↓ MANF P LH2   46
GO2 OUT T         79↓   97↓   70↓          LO2 110
                                                        249
```

BFS Indicator on CRT

BFS Display Sequencing

The BFS is designed to operate in the same manner as the PASS where possible. BFS requirements, however, demanded a distinction be made between BFS pre-engage and BFS post-engage major mode transitions and associated display sequencing.

BFS pre-engage major mode display sequencing is either automatic, or it may be performed in the same manner as that of the PASS. Before the BFS is engaged, the BFS CRT is listening to the PASS CRT across the display/keyboard (DK) buses and updating its software accordingly. This is called DK listening and the BFS can hear PASS item entries, PASS major mode transitions, and PASS GPC/CRT assignments. On the other hand, the PASS doesn't know that the BFS exists, so it never DK listens to the BFS. Therefore, BFS major mode transitions are performed automatically as a function of the major mode transitions performed on a PASS keyboard. If the BFS does not follow the PASS major mode transitions, then the BFS must receive a manual OPS XXX PRO on its CRT.

BFS post-engage major mode display sequencing is the same as that of the PASS. After the BFS is engaged, the BFS GPC is on its own. It no longer listens to the PASS GPCs. Therefore, major mode display sequencing has been designed to be the same as that of the PASS.

Three operational sequences are defined for BFS GNC; one operational sequence is defined for the BFS SM. Transactions to and from these OPS displays differ considerably from the PASS. BFS keyboard and CRT peculiarities are outlined as follows:

- BFS GNC OPS 0 - BFS MEMORY display: This display is forced to the CRT when BFS is not processing either GNC OPS 1 or 3. Nominally, this occurs prior to ascent and again prior to entry. This display corresponds to the PASS GPC MEMORY display and performs the same functions for the BFS. It also performs some of the same functions as PASS SPEC 2, the TIME SPEC, in that time updates can be performed along with selection of GMT or MET to be displayed. GPC MEMORY is the default display for PASS OPS 0, and the BFS MEMORY display is the default display for BFS GNC OPS 0.

- BFS GNC OPS 1 and 6 - Ascent: This OPS must be manually selected via a keyboard assigned to the BFS prelaunch. BFS GNC OPS 1 is available for use during the ascent portion of the mission. The OPS 6 transition is automatic upon abort selection with the ABORT rotary switch and pushbutton, or an OPS 601 PRO may be used.

```
 0001/000/        BFS MEMORY          5 008/12:12:12
                                    BFS 000/00:29:12
         READ/WRITE
          DATA 1*  BIT SET 3   SEQ ID 5
          CODE 2   BIT RST 4   WRITE  6
          7 ENG UNITS         HEX 8*
          ADD ID   DESIRED   ACTUAL
          9 ______ 10
         11        12
         13        14
         15        16
         17        18
         19        20
----------------------------------------------------
MEMORY DUMP                |LAUNCH BUS   1 26   TFL ENA
  21 START ID              |             2 27        29
  22 NUMBER WDS            |    OFF 28*
  23 WDS/FRAME             |
  DUMP 24                  |PASS/BFS XFER ENA 25

BFS TIME UPDATES     UPDATE 38    MISSION TIME
 30 GMT D[ ]___/__:__:__.___       GMT 39
 34 MET D[ ]   /  :  :  .          MET 40
                                                   250
```

BFS MEMORY Display

- BFS GNC OPS 3 - Entry: This OPS must be manually selected from BFS GNC OPS 0 or BFS GNC OPS 1. BFS GNC OPS 3 is available for use during the entry portion of the mission. It is a legal transition to go from the BFS GNC OPS 1 to BFS GNC OPS 3 (for aborts), but nominally, the transition will be from BFS GNC OPS 0. In both cases, the manual keyboard entry "OPS 301 PRO" is required.

The major mode displays for BFS OPS 1, 3, and 6 are similar, if not identical, to their PASS counterparts. A complete listing of PASS and BFS displays can be found in the DPS Dictionary.

BFS Special Operations and Displays

In the pre-engaged mode, the BFS GPC performs BCE and MDM bypasses when PASS data are bypassed, or it sets its own bypasses. The I/O RESET command when made via the BFS keyboard restores those I/O configurations set by the BFS GPC. That is, a BFS "I/O RESET EXEC" restores the bypasses set by the BFS GPC. In addition, the I/O RESET operation attempts to synchronize the BFS with the PASS GPC listen commands so the BFS can track PASS.

Post-engage, the only bypasses set are those detected by the BFS GPC. The "I/O RESET EXEC" command functions to restore those bypasses.

The BFS systems summary displays operate the same way the PASS displays work. The BFS display numbers are the same as their PASS counterparts and some of the displays themselves are identical. However, three of the BFS SYS SUMM displays are unique to the BFS.

- GNC SYS SUMM. The GNC SYS SUMM consists of two DISPs. GNC SYS SUMM 1 is display format and content unique to BFS. It is called via the SYS SUMM key or by the command "SPEC 18 PRO." GNC SYS SUMM 2 is identical to the GNC SYS SUMM 2 display available in the PASS OPS 2 and 8. It is called by the command "SPEC 19 PRO" or by depressing the SYS SUMM key twice.

```
 1011/   /018    GNC SYS SUMM 1       5 000/02:46:03
                                    BFS 000/00:00:00

     SURF       POS   MDM         DPS    1 2 3 4
     L OB                         MDM FF
       IB                             FA
     R IB                             PL
       OB
      AIL
      RUD                         FCS CH 1 2 3 4
      SPD BRK
      BDY FLP

MPS            L     C     R      NAV  1 2 3 4
 HE TK P     4280  4230  4240    |IMU
   REG P A    784   768   768    |TAC
         B    776   766   770    |ADTA
  dP/dT                          ---------------
                                  MPS PNEU HE P
ULL P LH2    42.5  42.7  42.9         TK   4350
      LO2    21.1  21.0  20.8         REG   798
                                      ACUM  760
GH2 OUT P      70↓   50↓   40↓  MANF P LH2   46
GO2 OUT T      79↓   97↓   70↓         LO2  110
                                                   249
```

BFS GNC SYS SUMM 1, available in GNC OPS 1, 6, and 3 (Unique to BFS)

```
 3011/   /019   GNC SYS SUMM 2      5 015/20:25:34
                                  BFS 000/00:26:24
OMS AFT QTY     L      R       OMS          L     R
        OXID 28.6   28.6        TK P   HE 2610   2680
          FU 28.3   28.3              OXID  260   258
    FU INJ T   79     79                FU  267   258
                          JET ISOL  N2 TK    P 2220  2220
RCS         OXID   FU  FAIL VLV        REG   P  319   319
FWD  HE P 1464 1264                    P  VLV   CL    CL
     TK P  248  244                ENG IN    P
      QTY    0    0                     OXID  257   258
MANF  1 P  248  242                       FU  258   258
      2 P  248  244                      VLV 1 -  2   - 2
      3 P  250  246                          2    0     0
      4 P  244  244                                  JET  ISOL
      5                                 OXID   FU  FAIL  VLV
AFT  HE P 2800 2672                HE P 2744 2616
L    TK P  244  249              R TK P  247  247
    QTY     63   63                QTY    62   61
MANF  1 P  244  246                1 P  242  246
      2 P  246  250                2 P  250  246
      3 P  248  250                3 P  246  250
      4 P  246  250                4 P  246  242
      5                            5
                                                   242
```

BFS GNC SYS SUMM 2, available in GNC OPS 1, 6, and 3 (Identical to PASS GNC SYS SUMM 2 except shaded lines)

- SM SYS SUMM. There are two SM SYS SUMM displays. SM SYS SUMM 1 is identical to the PASS SM SYS SUMM 1, while BFS SM SYS SUMM 2 is a unique display. They are called in the same manner as the PASS SM SYS SUMM displays.
- THERMAL. This is a systems summary DISP available as the SM OPS 0 display in BFS. It is forced to the screen anytime the MAJ FUNC switch is placed in the SM position (unless an SM SPEC is called up over it). This display is unique to the BFS. It cannot be obtained with a SPEC key, and it never requires a keyboard entry.

```
 0001/   /078     SM SYS SUMM 1      5 000/03:13:09
                                   BFS  000/00:00:00
SMOKE       1/A   2/B
 CABIN    - 0.9          DC VOLTS     1/A   2/B   3/C
 L/R FD   - 0.4   0.2      FC         31.1  31.1  31.1
 AV BAY 1- 1.2 - 0.0       MAIN       31.0  31.1  31.0
        2- 0.6   0.3       CNTL AB    29.3  29.3  29.3
        3- 0.1 - 0.9            BC    29.3  29.3  29.3
      CABIN                     CA    29.3  29.3  29.3
 PRESS    14.7             ESS        29.8  29.8  29.8
 dP/dT    +.00           AC
    BU/EQ -.00  +.00       VOLT φA     117   117   117
 PPO2     3.02  3.02            φB     117   117   117
 FAN  P   5.79                  φC     117   117   117
 HX OUT T   49             AMPS φA     4.4   4.1   2.7
                                φB     3.9   4.2   3.2
 N2 FLOW   0.0                  φC     2.4   3.2   4.8
 IMU FAN ΔP       4.62   FUEL CELL PH
  ΔV FC1  FC2  FC3         AMPS        172   167   178
 SS1  15   18   18         REAC VLV     OP    OP    OP
 SS2  16   20   11         STACK T    +204  +203  +203
 SS3  22   26   26         EXIT  T     150   150   151
 TOTAL AMPS  510           COOL  P      61    61    61
         KW   15              PUMP
                                                  085
```

BFS SM SYS SUMM 1, available in SM OPS 0 (Unique to BFS)

```
 0001/   /079     SM SYS SUMM 2      5 008/23:29:22
                                   BFS 000/00:00:00
  CRYO TK    1     2     3     4     5   MANF1 MANF2
 H2 PRESS   208   208   206   206   206   208   207
 O2 PRESS   816   815   814   814   814   815   815
 HTR T1    -248  -248  -248  -248  -248
     T2    -248  -248  -248  -248  -248
  APU       1     2     3    HYD      1     2     3
 TEMP EGT  942   942   942  PRESS  3064  3064  3064
  B/U EGT  942   942   942  ACUM P 3080  3080  3080
  OIL  IN  250   250   250  RSVR T  116   153   142
      OUT  264   264   264
  GG BED   511H  511H  511H    QTY   72    74    71
  INJ     1271  1271  1271
 SPEED  %   99   102   101    W/B
 FUEL QTY   59    60    62  H2O QTY  78    73    78
  PMP LK P  14    14    14  BYP VLV BYP   BYP   BYP
 OIL OUT P  42    42    41
 FU TK VLV
       A T  63    65    62    THERM CNTL   1    28
       B T  63    65    62  H2O PUMP P    23    63
  AV BAY     1     2     3  FREON FLOW  2384  2384
 TEMP       97    97    83  EVAP OUT T    38    38
 A4 14        27.439 27.435  26.324  31.873  18.48
                                                  051
```

BFS SM SYS SUMM 2, available in SM OPS 0 (unique to BFS)

BFS Fault Messages

Several crew interface characteristics of fault annunciation in the BFS differ from those in the PASS.

- The BFS FAULT display. The BFS FAULT display functions in the same manner as the PASS. The BFS FAULT display is composed of 20 fault lines as compared to 15 in the PASS. The C/W field displays an asterisk when the message annunciated is a class 2 backup alarm. The BFS FAULT display provides a history of only class 2 backup and class 3 messages annunciated by the BFS GPC itself.

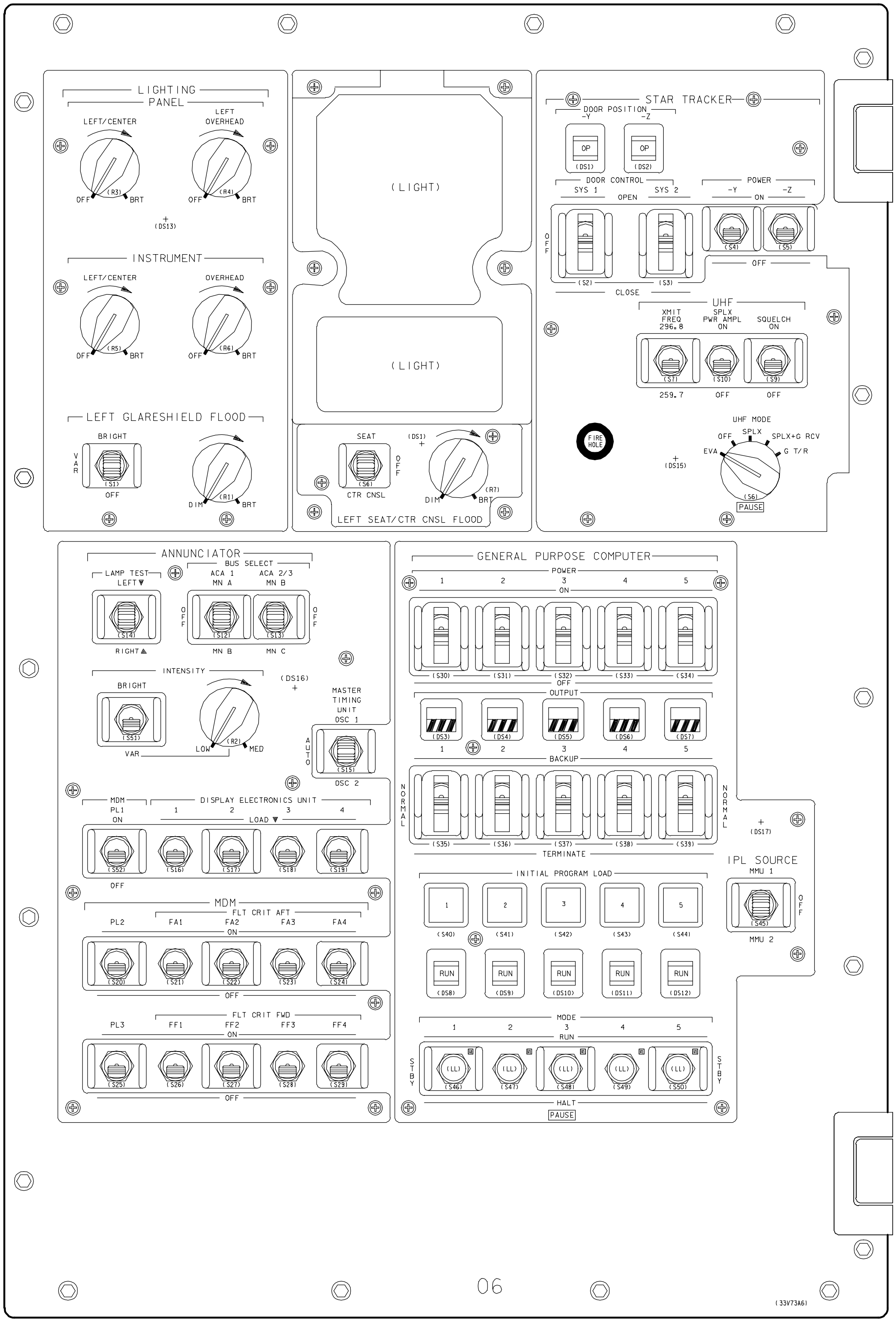
- BFS Unique CRT IDs. In BFS SM, all messages referring to SM SYS SUMM 1 or SM SYS SUMM 2 are indicated by the CRT IDs SM1 and SM2. Fault messages referring to the THERMAL display are indicated by the CRT ID SM0.

```
 0001/           THERMAL          5 000/00:00:00
                                BFS 000/00:00:00
HYD  SYS TEMP BDYFLP RD/SB  L OB  L IB  R IB  R OB
        PRIME  + 99  + 79  + 76  + 79  + 76  + 79
       STBY 1  + 89  + 79  + 79  + 79  + 79  + 79
               BRAKE PRESS
               HYD SYS 1/3 | 92    92    92    92
                       2/3 | 92    92    92    92
HTR TEMP  |  L/A  |  R/B  |FREON LOOP  1    2
 PRPLT    |       |       | ACCUM QTY  34   34
 POD      |       |       | RAD OUT T 109  109
 OMS CRSFD|       |       |H2O SUP  P   0
EVAP      |       |       |TIRE PRESS
 HI   LOAD|       |       |MG    LEFT     RIGHT
 TOP  DUCT|       |       | IB 429  420  418  418
       NOZ|       |       | OB 421  421  416  416
 FDLN     |       |       |NG  397  397  381  381
              |     1     |     2     |    3    |
HYD BLR/HTR   |           |           |         |
APU           |           |           |         |
 GG/FU PMP HTR|H          |H          |H        |
 TK/FU LN  HTR|           |           |         |
 PUMP/VLV
                                                  255
```

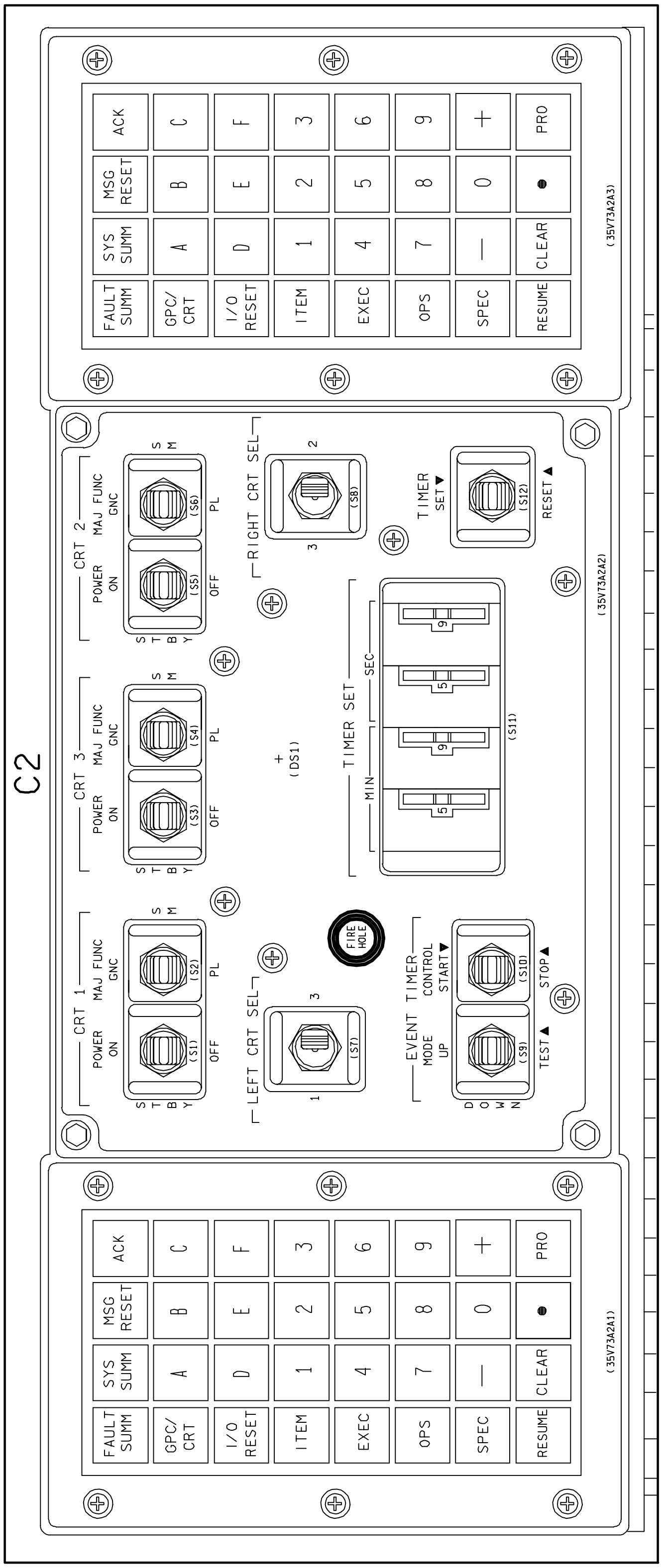
BFS THERMAL, available in SM OPS 0 (unique to BFS)

DPS Summary Data

- The DPS combines various hardware components and self-contained software to provide computerized monitoring and control.
- DPS hardware includes five GPCs, two mass memory units, a data bus network, 20 MDMs, four CRTs, and other specialized equipment.
- Each of the five GPCs consists of a CPU and an IOP stored in one avionics box. During ascent/entry, four of the GPCs are loaded with identical PASS software; the fifth is loaded with different software, the BFS.
- The data bus network transfers data between the GPCs and vehicle systems. There are seven types of data buses: flight-critical, payload, launch, mass memory, display/keyboard, instrumentation/PCMMU, and intercomputer communication.
- The 13 DPS MDMs convert data to appropriate formats for transfer between the GPCs and vehicle systems. OV 105 has all EMDMs.
- Two mass memory units provide bulk storage for software and data.
- Four CRTs (three on panel F7 and one on panel R11L) and associated keyboards provide the means for flight crew interaction with the GPCs.
- The two types of DPS software, system software and applications software, combine to form a memory configuration for a specific mission phase.
- The system software is operating software that always resides in GPC main memory.
- The applications software performs the functions required to fly and operate the vehicle. It is divided into three major functions: guidance, navigation, and control (GNC); systems management (SM); and payload (PL).
- Major functions are divided into mission phase oriented blocks called operational sequences (OPS).
- OPS are further divided into blocks called major modes (MM), which relate to specific portions of a mission phase.
- There are three levels of CRT displays: major mode or OPS, specialist (SPEC), and display (DISP).
- The four PASS GPCs control all GNC functions during ascent/entry mission phases; the fifth GPC is loaded with backup flight system (BFS) software to take over in case of PASS GPC failure.
- The BFS contains a limited amount of software; there are some operational differences between BFS and PASS.
- The BFS is engaged by pushbutton on the rotational hand controller.
- A GPC FAIL detection will display a class 2 GPC FAULT message with illumination of the MASTER ALARM. The GPC STATUS matrix (sometimes referred to as the computer annunciation matrix (CAM)) on panel O1 lights to indicate failure votes; any time a yellow matrix light is illuminated, the GPC caution and warning light on panel F7 also lights.
- Most DPS control switches are located on panels O6 and C2. Others may be found on panels C3, R11L, F2, F4, F6, and F7.
- CRT displays relevant to the DPS are: GPC/BUS STATUS (SPEC 6), GPC MEMORY (SPEC 0), DPS UTILITY (SPEC 1), and TIME (SPEC 2).


LIGHTING PANEL
LEFT/CENTER
LEFT OVERHEAD
OFF (R3) BRT
OFF (R4) BRT
(DS13)
INSTRUMENT
LEFT/CENTER
OVERHEAD
OFF (R5) BRT
OFF (R6) BRT
LEFT GLARESHIELD FLOOD
BRIGHT
VAR
(S1)
OFF
DIM (R1) BRT
(LIGHT)
(LIGHT)
SEAT
(DS1)
(S6)
OFF
CTR CNSL
DIM (R7) BRT
LEFT SEAT/CTR CNSL FLOOD
STAR TRACKER
DOOR POSITION
-Y
-Z
OP
OP
(DS1)
(DS2)
DOOR CONTROL
SYS 1
SYS 2
OPEN
POWER
-Y
-Z
ON
OFF
(S2)
(S3)
CLOSE
(S4)
(S5)
OFF
UHF
XMIT FREQ 296.8
SPLX PWR AMPL ON
SQUELCH ON
(S7)
(S10)
(S9)
259.7
OFF
OFF
FIRE HOLE
UHF MODE
OFF
SPLX
SPLX+G RCV
EVA
G T/R
(DS15)
(S6)
PAUSE
ANNUNCIATOR
LAMP TEST
LEFT▼
(S14)
RIGHT▲
BUS SELECT
ACA 1 MN A
ACA 2/3 MN B
OFF
(S12)
(S13)
OFF
MN B
MN C
INTENSITY
BRIGHT
(S51)
VAR
LOW (R2) MED
(DS16)
MASTER TIMING UNIT
OSC 1
AUTO
(S15)
OSC 2
MDM PL1 ON
DISPLAY ELECTRONICS UNIT
1 2 3 4
LOAD ▼
(S52) (S16) (S17) (S18) (S19)
OFF
MDM
FLT CRIT AFT
PL2 FA1 FA2 FA3 FA4
ON
(S20) (S21) (S22) (S23) (S24)
OFF
FLT CRIT FWD
PL3 FF1 FF2 FF3 FF4
ON
(S25) (S26) (S27) (S28) (S29)
OFF
GENERAL PURPOSE COMPUTER
POWER
1 2 3 4 5
ON
(S30) (S31) (S32) (S33) (S34)
OFF
OUTPUT
(DS3) (DS4) (DS5) (DS6) (DS7)
1 2 3 4 5
BACKUP
NORMAL
(S35) (S36) (S37) (S38) (S39)
NORMAL
TERMINATE
(DS17)
INITIAL PROGRAM LOAD
1 2 3 4 5
(S40) (S41) (S42) (S43) (S44)
IPL SOURCE
MMU 1
(S45)
OFF
MMU 2
RUN RUN RUN RUN RUN
(DS8) (DS9) (DS10) (DS11) (DS12)
MODE
1 2 3 4 5
RUN
STBY
(S46) (S47) (S48) (S49) (S50)
STBY
HALT
PAUSE
O6
(33V73A6)

Panel O6


C2
ACK
C
F
3
6
9
+
PRO
MSG RESET
B
E
2
5
8
0
•
SYS SUMM
A
D
1
4
7
—
CLEAR
FAULT SUMM
GPC/ CRT
I/O RESET
ITEM
EXEC
OPS
SPEC
RESUME
(35V73A2A3)
CRT 2
POWER ON
OFF
(S5)
MAJ FUNC GNC
PL
(S6)
SM
STBY
RIGHT CRT SEL
2
3
(S8)
TIMER SET▼
RESET▲
(S12)
(35V73A2A2)
CRT 3
POWER ON
OFF
(S3)
MAJ FUNC GNC
PL
(S4)
+ (DS1)
TIMER SET
MIN
SEC
(S11)
CRT 1
POWER ON
OFF
(S1)
MAJ FUNC GNC
PL
(S2)
FIRE HOLE
LEFT CRT SEL
1
3
(S7)
EVENT TIMER
MODE UP
DOWN
TEST▲
(S9)
CONTROL START▼
STOP▲
(S10)
(35V73A2A1)

Panel C2

```
 2011/   /006    GPC/BUS STATUS     2 008/02:56:10
                                      000/00:11:10
           GPC | 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     |  ↓   |  ↓   |      |  *   |
                                                  202
```

GPC/BUS STATUS (SPEC 6)

```
2011/001/       DPS UTILITY         1 008/12:12:12
                                      000/00:25:12
 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
                   P/L 1/2  23* 24    IPL SOURCE SW
 MMU STATUS                           MASK 38*
    1 RDY
    2 RDY        VAR PARAM ID LIST
                      25 9ABA
 MMU SOURCE/BUS       26 9ABB        | G3 ARCHIVE
  GPC/MMU    9*       27 9ABC        |   LOAD     48
  MMU/MMU   10        28 9ABD        |   RETRIEVE 49*
  GPC/LDB   11        29 9ABE        |
                      30 9ABF        |  GROUND OPS
 CKPT RETRV           31 9ACA        |GSE POLL ENA 50
        ENA 12        32 9ACB        |  SM GSE INH 51
                      33 9ACC        |  SM C/O ENA 52
 RTC                  34 9ACD        | GNC C/O ENA 53
  13 ____ ____                       | BFC C/O ENA 54
  CMD 14                             |  ALT PL9 TB 55
                                                  239
```

DPS UTILITY (SPEC 1)

```
 2011/000/          GPC MEMORY        1   008/12:12:12
                                          000/00:29:12
MEM/BUS CONFIG        |READ/WRITE   GNC
1 CONFIG  2(G2)       | DATA 20*  BIT SET 22    SEQ ID 24
2 GPC   1 2 0 0 0     | CODE 21   BIT RST 23    WRITE  25
                      | 26  ENG UNITS ___       HEX 27*
 STRING    1  |  7 1  | ADD ID    DESIRED      ACTUAL
           2  |  8 2  |28 _____   29
           3  |  9 1  |30         31
           4  | 10 2  |32         33
   P/L  1/2   | 11 0  |34         35
              |       |36         37
    CRT    1  | 12 1  |38         39
           2  | 13 2  |
           3  | 14 0  |MEMORY DUMP              |STORE  MC=02
           4  | 15 2  | 40 START ID  _____      |45 CONFIG
              |       | 41 NO WORDS  ______     |46 GPC
 LAUNCH    1  | 16 1  | 42 WDS/FRAME ___        | STORE 47
           2  | 17 2  | DUMP  43                |
     MM    1  | 18 1  |                         |MM AREA
           2  | 19 2  |   44 DOWNLIST GPC 1     |PL   52 1
                      |     OPS 0 ENA 49        |GNC  53 1
OPS  3 UPLNK 50       |                         |SM   54 1
OPS  3 INIT  51       | ERR LOG RESET 48        |
                                                     238
```

GPC MEMORY (SPEC 0)

```
 1061/002/       TIME                  1 008/12:12:12
                                         000/00:25:12
 MISSION TIME                 TONE
   GMT 1*                       3   __:__:__ MSN T
   MET 2                        6     :  :
 CRT TIMER
   9 SET [ ]__:__:__           20[ ]__:__:__ CRT T
   START 12     STOP 13
   14 START AT __:__:__ MSN T 23 DURATION
   17 COUNT TO   :  :   MSN T
 ------------------------------------------------------
 MTU
   24 GMT Δ [ ]___/__:__:__.____
   28 MET Δ [ ]   /  :  :  .
      UPDATE 32                     MET RESET 33
 ------------------------------------------------------
 GPC TIME                                   GPC
                        GMT          TRY    1 A1
   MTU ACCUM 1 008/12:12:12.000       34    2 A1
             2 008/12:12:12.000       35    3 A1
             3 008/12:12:12.000       36    4 A1
           GPC 008/12:12:12.000       37    5 A1

   TIME SYNC 38
                                                  214
```

TIME (SPEC 2)

DPS Rules of Thumb

- Always HALT fail to sync GPCs and reassign their CRTs to good GPCs to avoid inadvertent entries (NBATs /restrings, burn targets, etc.).

- Before OPS transitions and restrings, always verify the appropriate NBAT is what you want it to be; never assume that it is correct! Also check the proper major function and GPC switch configuration.

- Make sure you have the correct memory configuration called up before you start making NBAT changes.

- During OPS transitions, keep "hands off" everything, including all switches and CRT entries.

- Clear the Fault Message line as soon as you have seen the message or use the ACK key to display subsequent messages.

- Post BFS engage, check to ensure that all active PASS GPCs have recognized the engage (both MODE and OUTPUT talkbacks are barberpole). If not, take the offending GPC to HALT (or if this doesn't work, power it OFF) immediately to avoid I/O problems on the flight critical strings.

- It is a very good idea to resume SPECs and DISPs from CRTs when not using them or before going to another major function on that CRT.

- It is important to be able to identify GPC failures. The information you provide will affect Mission Control analysis and its ability to plan for subsequent failures (both DPS and non DPS).

- Always hard assign CRTs (both PASS and BFS) via PASS CRTs (BFS will DK listen). You can cause dual CRT commanders if you try to assign BFS to a CRT that a PASS CRT is still driving.

- Always distribute your CRTs among different GPCs. On orbit, always be sure to minimize SM usage on all CRTs at the same time; if you lose SM, you also lose PASS CRT interface. The same is true if in single GPC GNC OPS, such as Spacelab missions.

- When using the GPC MODE switch, always take your hand off between positions. On past missions, there have been problems with the switch being in essentially two positions at the same time. This problem can occur on other orbiter switches too. It is a good idea to always pause slightly in each switch detent to ensure the contacts are made and recognized by the GPCs.

- The CRT SEL switch should always be checked before making a keyboard entry, and data should always be checked on the CRT scratch pad line before it is entered.

- When moding PASS GPCs into the common set (i.e., STBY to RUN), always pause 10 seconds before and after switch throws to avoid a possible fail-to-sync and to ensure proper common set initialization.