

## Multifunction Electronic Display System (MEDS)

MEDS allows onboard monitoring of orbiter systems, computer software processing, and manual control for flight crew data and software manipulation. (For MCDS information, see appendix F.)

MEDS has three types of hardware: four IDPs, 11 multifunction display units (MDUs), 4 analog-to-digital converters (ADCs), and 3 keyboard units, which together communicate with the GPCs over the DK 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 vehicle system operation with keyboards in conjunction with the IDPs. 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.

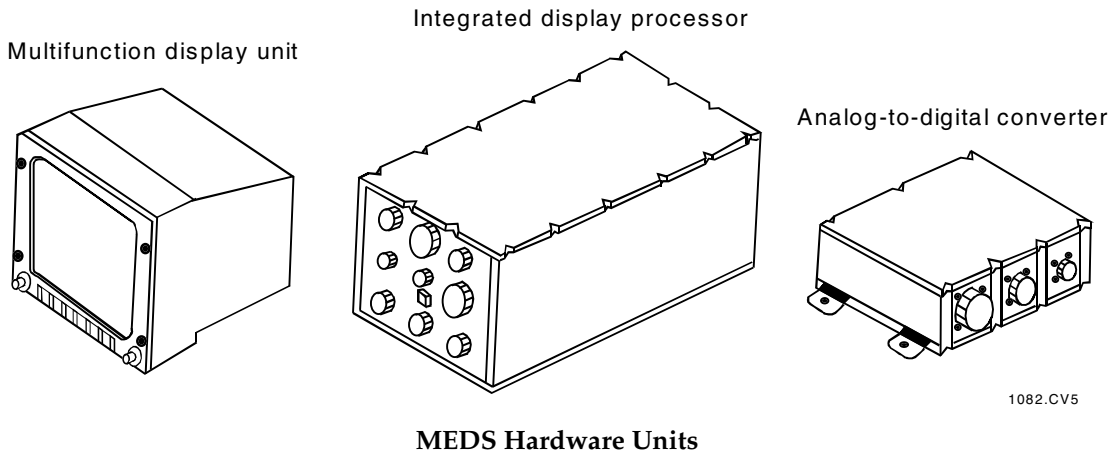
## Integrated Display Processor (IDP)

The IDP is the interface between MEDS and the GPCs. It formats data from the GPCs and ADCs for display on the MDUs. Also, it accepts operator inputs from switches, edgekeys, and keyboards. In addition to all of these functions, the IDP monitors its own status and the status of other MEDS LRUs. It has both hardware built-in test equipment (BITE) and software self-tests.

On the GPC side, each IDP is connected to flight-critical data buses 1 through 4 and one DK bus, in addition to the panel switches and the keyboards. In general, it can display flight instrument and subsystem data on more than one crew station (left, right, aft). On the MEDS side, each IDP controls a 1553B data bus that allows the IDP to interface with the MDUs and a pair of ADCs.

IDPs require 28 V dc that is supplied by a main bus (IDP –main A/FPC1, IDP2 –main B/FPC2, and IDP3 and 4 – main C/FPC3). The IDP power switches are located on panels C2 and R12. These switches also power their respective CRT MDUs. Cooling is provided through forced-air ducting.

The IDPs are in the forward cockpit beneath panels to the left of the commander and to the right of the pilot. An IFM capability is available to swap a forward IDP with the aft IDP.



### Multifunction Display Unit (MDU)

The MDU is a full color, flat panel, 6.7-inch-square, active matrix liquid crystal display. Its primary function is to drive the variety of MEDS color displays that are readable in the sunlight.

Similar to the IDP, the MDU has built-in tests to provide various test coverage for the processor, functions, and hardware.

Six edgekeys are located below the display on the bezel of the MDU. A brightness control knob and an ON/OFF switch are also located on the bezel on either side of the edgekeys. The edgekeys are used to navigate through the MEDS menu system and to perform MEDS specific activities, not to interact with the rest of the DPS system (i.e., clearing DPS fault messages, item entries, etc.).

There are 11 MDUs: CDR 1 and 2 on panel F6; CRT 1, 2, and 3; MFD 1 and 2 on panel F7; PLT 1 and 2 on panel F8; CRT 4 on panel R12; and AFD 1 in the aft station.

In general, each MDU has two ports (primary and secondary) that are connected to two IDPs via a 1553B data bus. Only one IDP commands an MDU at a given time, but both IDPs monitor the status of the MDU. The exception is the CRT MDUs, which use only their primary port. Their secondary port is not connected to any data bus. Thus, they are connected only to a single IDP and indirectly to only one DK data bus. Operationally, the CRT MDUs are dedicated to the DPS display. This configuration maintains a one-to-one relationship between a DK bus, an IDP, and its CRT MDU. While in the autonomous mode, the MDU continues to run and monitors its two ports for an operating IDP.

The MDUs are controlled by the power knob on the display bezel and a circuit breaker on panel R14. However, the CRT MDUs do not have a circuit breaker; they are powered by their respective IDP power switches. Main A powers MFD 2 and PLT 1. Main B powers CDR 2 and MFD 1. Main C powers CDR 1, PLT 2, and AFD 1. The brightness control knob, located to the right of the edgekeys, controls the illumination of the menus and display.

MDUs are cooled via forced-air cooling ducts.

The MDUs on the forward portion of the flight deck have a left and right group that correspond to the flight instrument display switches found on panel F6 (CDR side) and F8 (PLT side). The left side (CDR crew station) consists of CDR 1, CDR 2, MFD 1, CRT 1, and CRT 3. The right side (PLT crew station) consists of CRT 2, PLT 1, PLT 2, and MFD 2. The aft crew station consists of AFD 1 and CRT 4. CRT 4 is slightly tilted to improve readability.

An MDU IFM capability is available.

### Analog-to-Digital Converter (ADC)

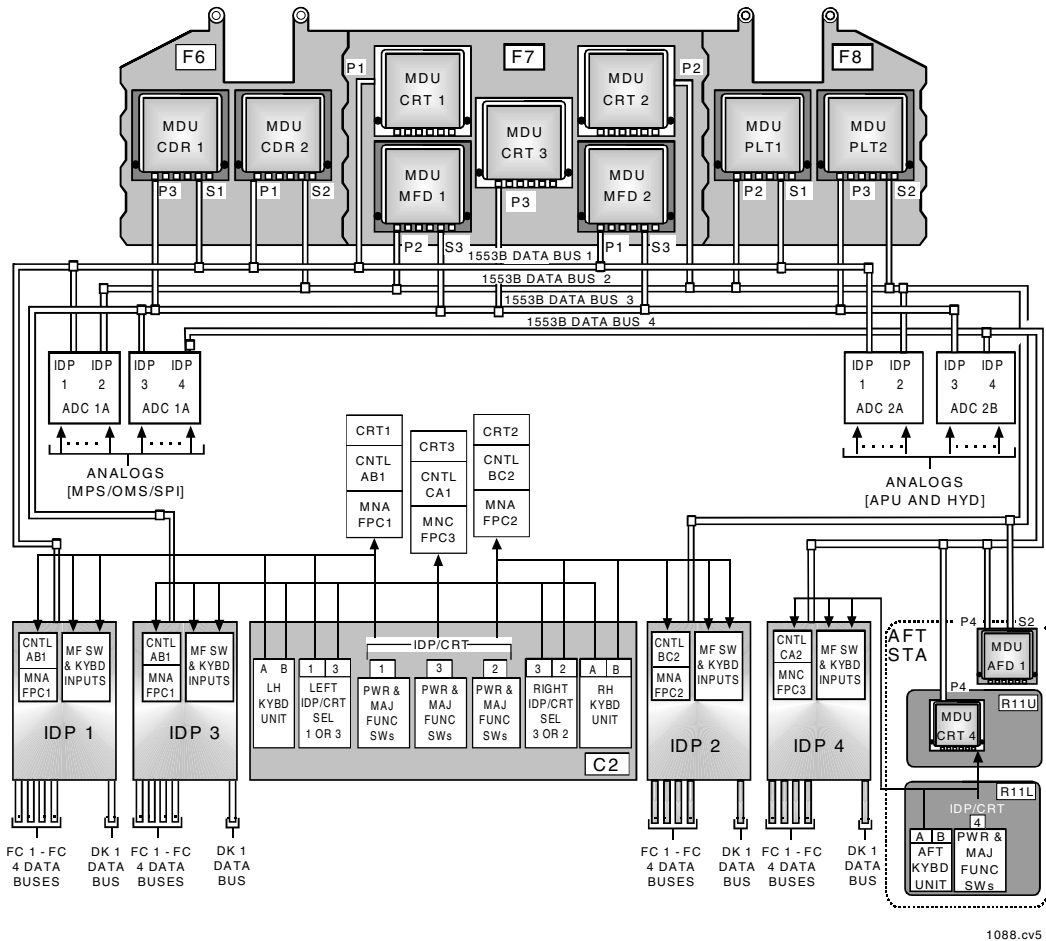
The ADCs convert analog MPS, HYD, APU, OMS, and SPI subsystem data into 12-bit digital data to be used by the IDP to generate the displays on the MDUs. MEDS includes four ADC units (1A, 1B, 2A, 2B). ADCs 1A and 1B convert the analog signals from the MPS, OMS, and SPI meters. ADCs 2A and 2B convert the signals from the APU and HYD meters. Each ADC maintains communication with two IDPs simultaneously (the "As" with IDP 1 and 2 and the "Bs" with IDP 3 and 4). The ADC software performs a continuous self-test.

ADC 1A and 2A are powered by main A via a single circuit breaker on panel R15, while 1B and 2B are powered by main B via a single circuit breaker on panel R15.

### Keyboards

Three identical keyboards are located on the flight deck: one each on the left and right sides of the flight deck 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 IDPs. Only one set of contacts on the aft station keys is actually used, because this keyboard is wired to communicate with only the aft IDP.

There are 10 numeral keys, 6 letter keys (used for hexadecimal input), 2 algebraic keys, a decimal key, and 13 special function keys. Using these keys, the flight crew can ask the GPC more than 1000 questions about the mission and condition of the vehicle.



### MEDS Data Bus Network

IFMs are available to swap out keyboards and replace individual keys as failures occur.

Each of the four IDPs responds to computer commands, transmits data, executes its own software to process keyboard inputs, and sends signals to drive displays on the MDUs. The IDPs store display data, generate the displays, update and refresh on-screen data, check keyboard entry errors, and echo keyboard entries to the DPS display shown on the MDU.

#### MEDS Data Bus Network

Each IDP has its own dedicated 1553B data bus that connects it to MDUs and two ADCs.

#### 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.

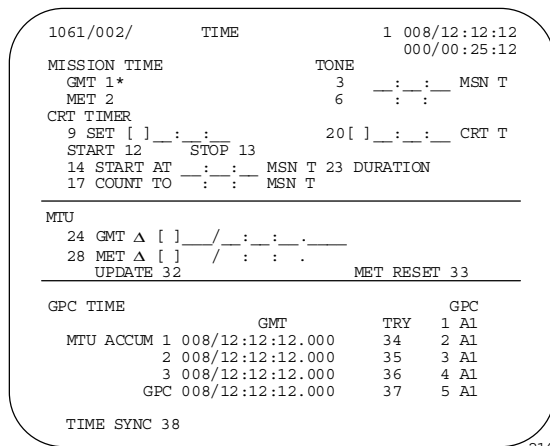
The MTU outputs serial digital time data (GMT/MET) on demand to the GPCs through the accumulators. The GPCs use this information for reference time and indirectly for time-tagging GNC and systems management

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 MTU, 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.

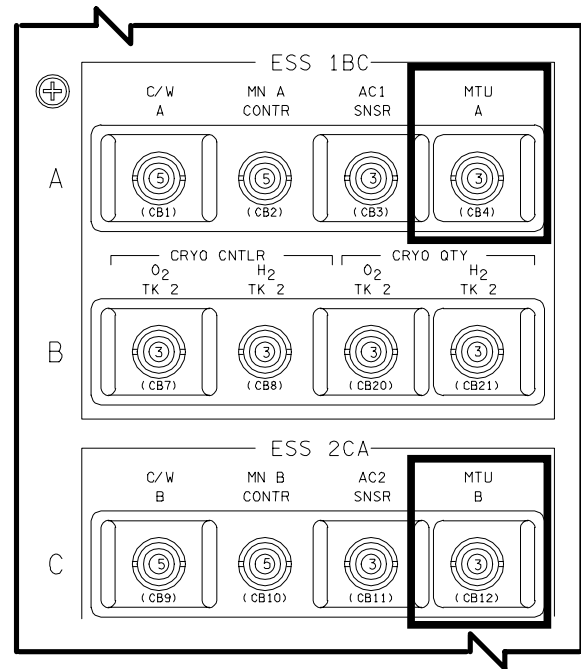


TIME Display (SPEC 2)

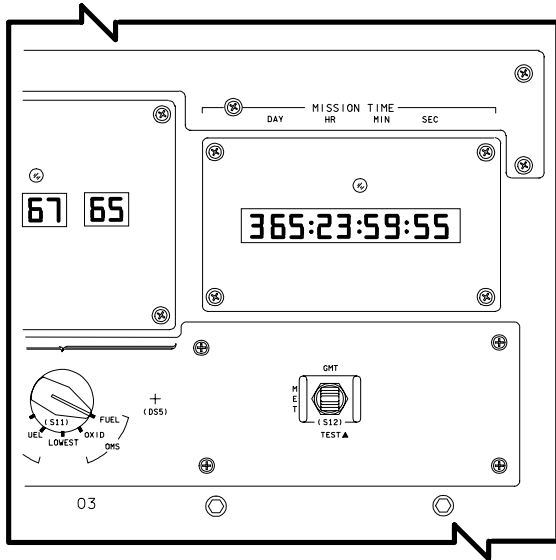
The MTU is redundantly powered by the ESS 1BC MTU A and ESS 2CA MTU B circuit breakers on panel O13. The MASTER TIMING UNIT switch on panel O6 controls the MTU. When the switch is in AUTO, and a time signal from one oscillator is out of tolerance, the MTU automatically switches to the other oscillator.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

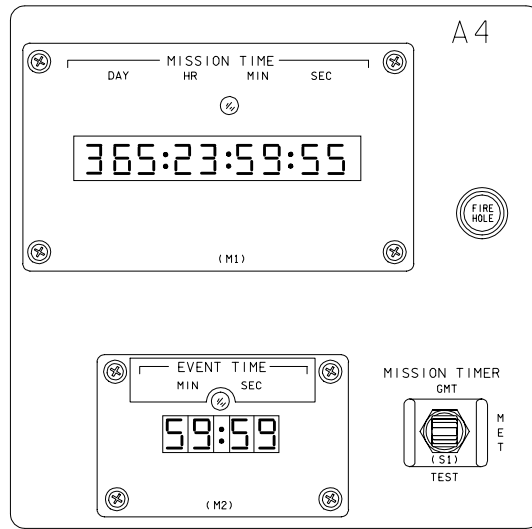
The MTU is located in crew compartment middeck avionics bay 3B and is cooled by a water coolant loop cold plate. The hardware displays associated with the master timing unit are the mission and event timers. MISSION TIME displays are located on panels O3 and A4. They can display either GMT or MET in 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.



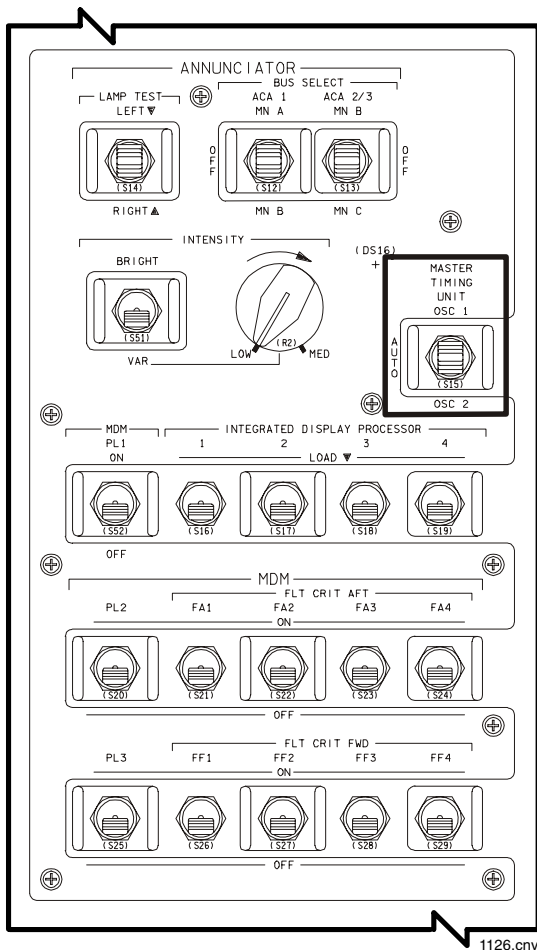
ESS 1BC MTU A and ESS 2CA MTU B Circuit Breakers on Panel O13



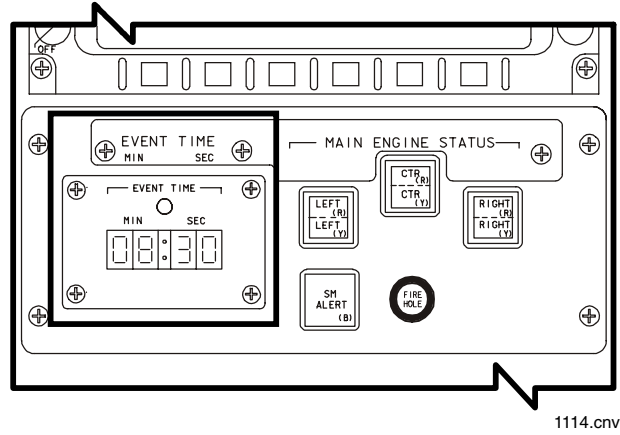
**MISSION TIME Display and Switch on Panel O3**



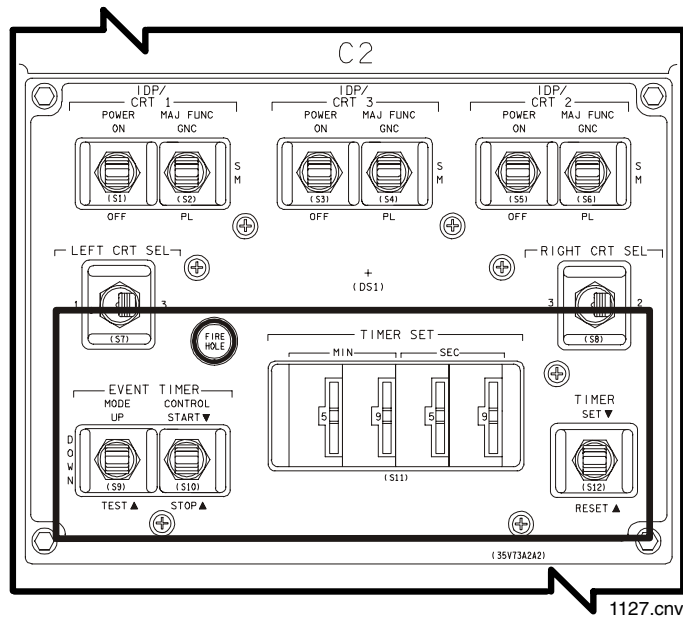
**MISSION TIME and EVENT TIME Displays and MISSION TIMER Switch on Panel A4**



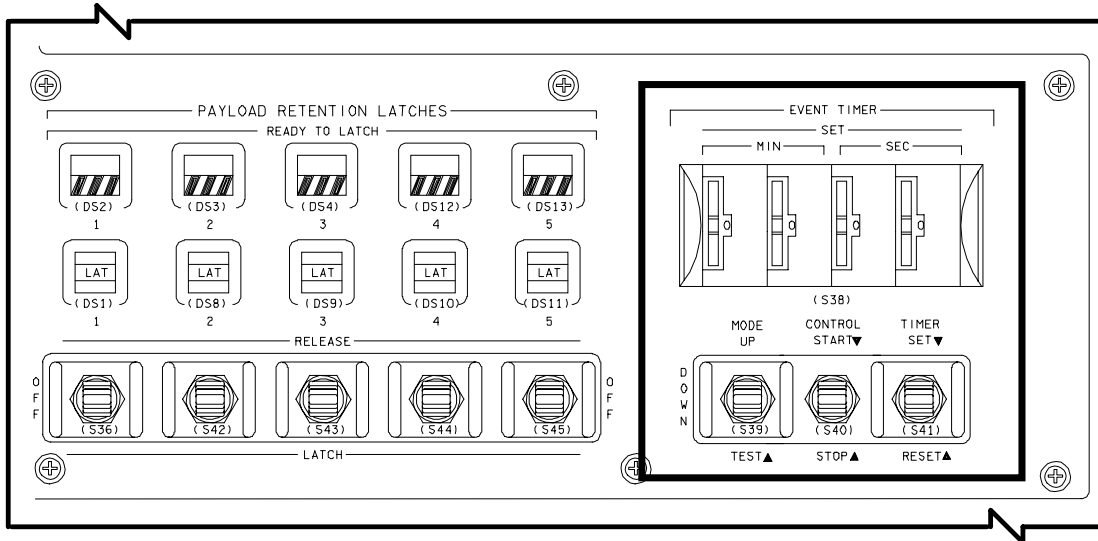
**MASTER TIMING UNIT Switch on Panel O6**



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.

Because 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.

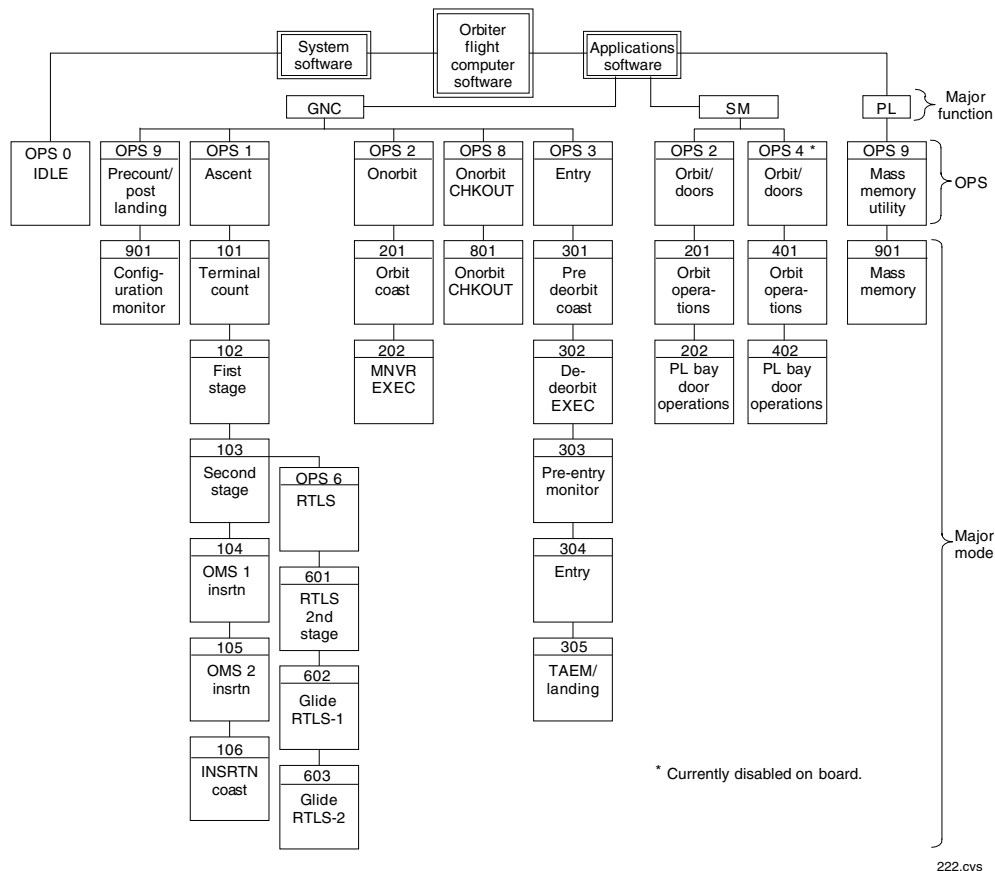
One of the system software functions is to manage the GPC input and output operations, which includes assigning computers as commanders and listeners on the data buses and exercising the logic involved in sending commands to these data buses at specified rates and upon request from the applications software.

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

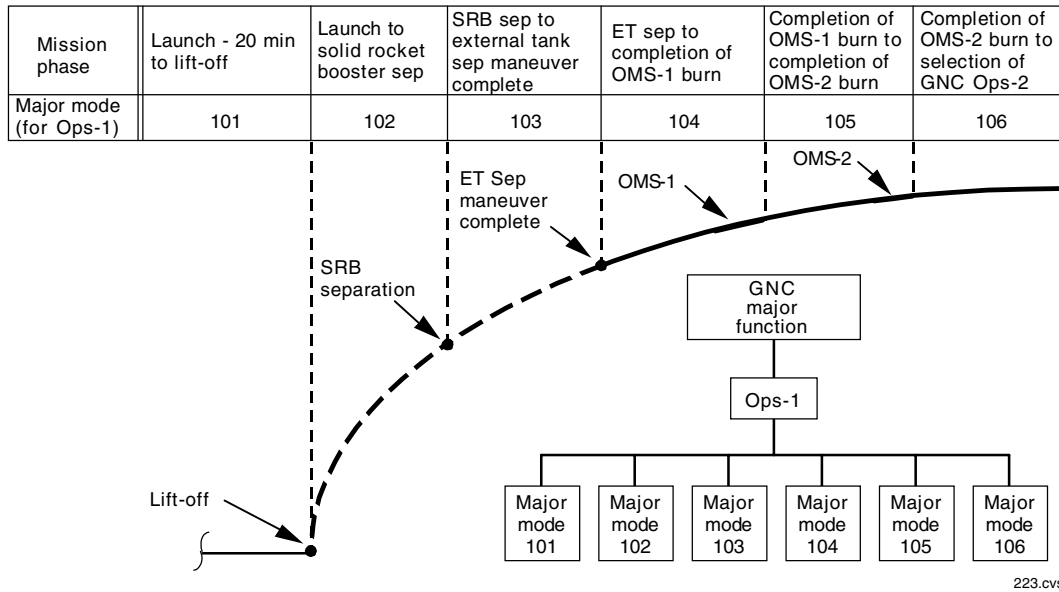
means that none of the GPCs are loaded with PL software. It is only used in vehicle preparation at KSC, and is also a simplex major function. Note that software to support payload operations is included as part of the SM GPC memory configuration.

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**





### 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 DPS display, called a major mode display or base page, 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 DPS 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.

Because 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.

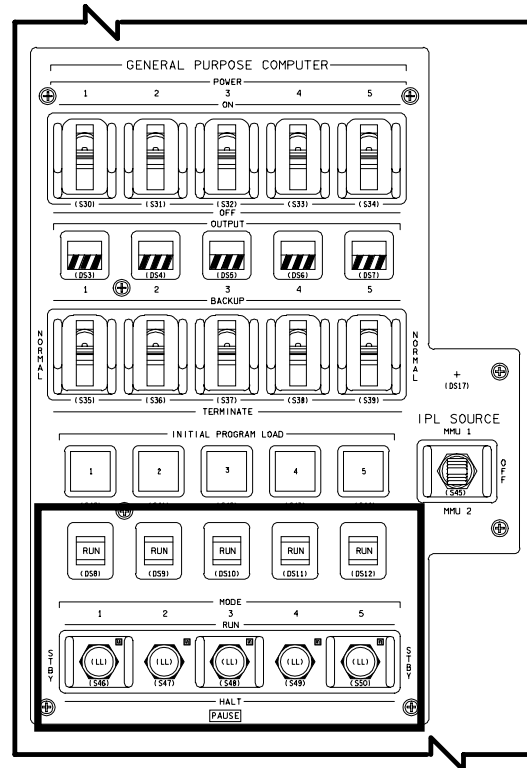
The BFS, like PASS, consists of system software and applications software. System software in the BFS performs basically the same functions as it does in PASS. These functions include time management, PASS/BFS interface, MEDS interface, input and output, uplink and downlink, and engage and disengage 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 GPCs 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 IDPs and updates its own GNC parameters accordingly.

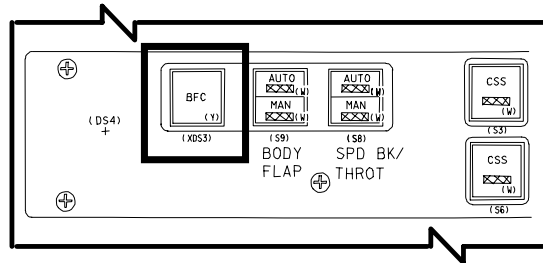
The BFS GPC controls its own instrumentation/PCMMU data bus. The BFS GPC requirements strictly forbid use of the ICC data bus to monitor or to transmit status or data to the other GPCs. The mass memory data buses are not used except during initial program load, which uses the same IPL SOURCE switch on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

The BFS 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 BFS lights are illuminated and stay on until the BFS is disengaged.

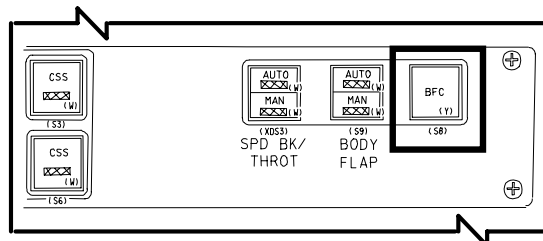
Since the BFS does not operate in a redundant set, its fail votes from and against other GPCs are not enabled; thus, the *GPC STATUS* light matrix on panel O1 for the BFS GPC does not function as it does in PASS. The BFS can illuminate its own light on the *GPC STATUS* matrix if the watchdog timer in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

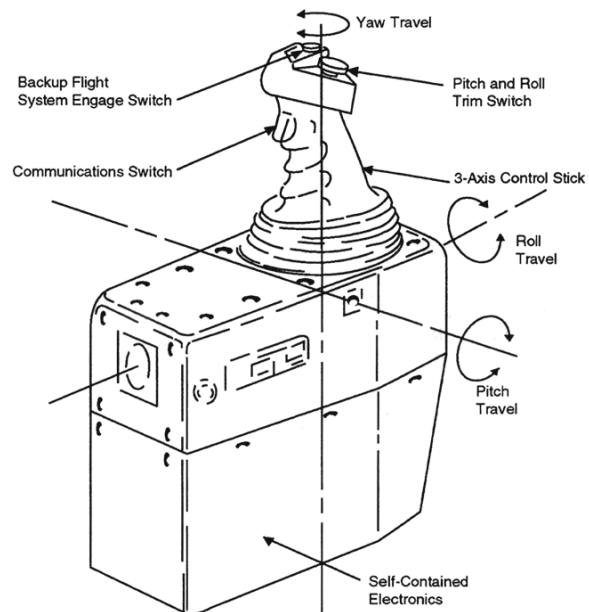
When the BFS is engaged, the BFS lights on panels F2 and F4 are steadily illuminated, the BFS's *OUTPUT* talkback indicator on panel O6 turns gray, all PASS GPC *OUTPUT* and *MODE* talkback indicators on panel O6 display barber-pole, the BFS controls the IDPs selected by the *BFC CRT SELECT* switch on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



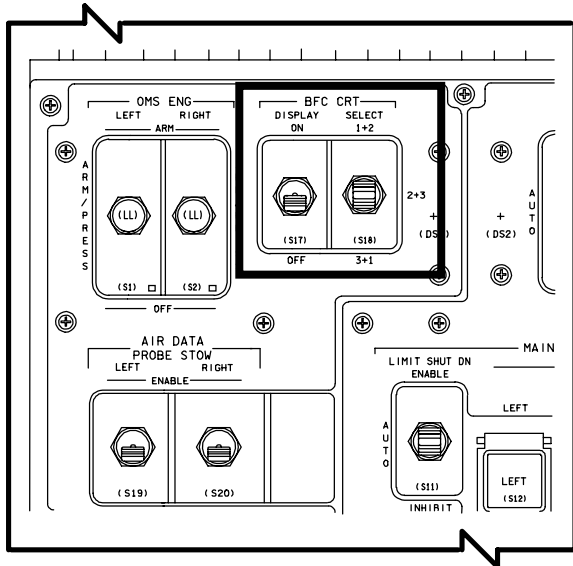
**BFC Light on Panel F2**



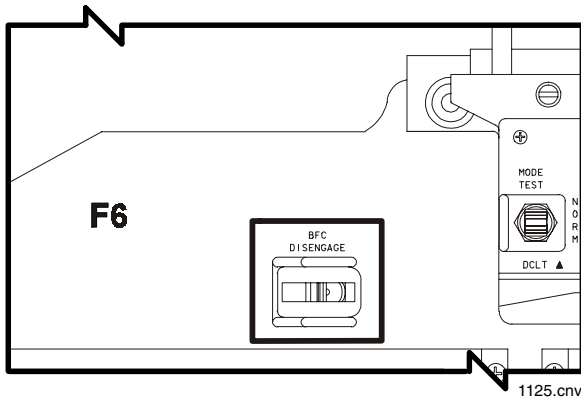
**BFC Light on Panel F4**



**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 IDP 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 IDP 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 BFS that resets the engage discrettes 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: BFS 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 IDPs.

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 Trajectory display, whereas PASS supplies attitude errors to the attitude director indicators; however, when the BFS is engaged, the errors on the Trajectory display are blanked, and attitude errors are supplied to the attitude director indicators.

## MEDS

### IDP Software

The IDP software manages the edgekey menu system, generates the graphical displays, and emulates the DEU for the DPS displays. It also processes data from the flight-critical, display/keyboard, and 1553 data buses, in addition to the switches and the keyboards.

The IDP only receives data on the flight-critical buses. It is able to process data simultaneously on two different flight-critical buses for flight instrument displays on different MDUs. The IDP communicates on the display/keyboard buses on a two-way command/response basis. The IDP receives data over the DK bus for updating the DPS displays. The IDP sends crew inputs and MEDS health status information to the GPC when polled by it.

The IDP also processes the following panel switches: IDP load switch, IDP/CRT select switches (left and right), and the major function switches. The IDP validates keystrokes made on the keyboard for syntax. If at least one of the MDUs controlled by the IDP is displaying the DPS display, the keystrokes will be validated, echoed, and included in the poll response of the IDP to the GPC.

### MDU Software

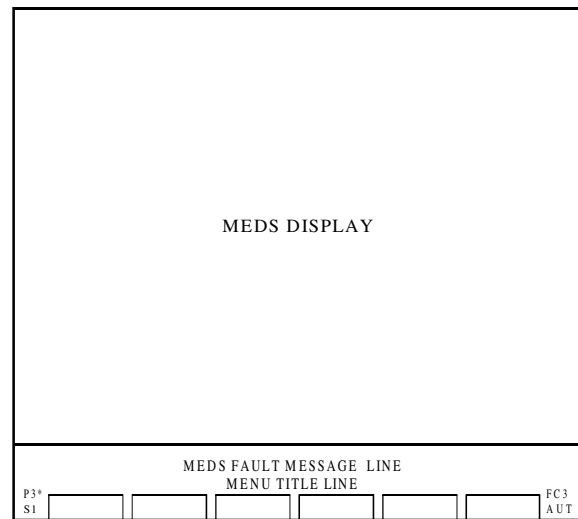
The MDU function (MDUF) software is responsible for drawing the displays on the MDU and providing built-in test capability (BITE).

### MEDS Generic Screen Format

Each MDU screen follows a generic screen format. The top portion of the screen is denoted as the MEDS display format. The lower portion contains the MEDS internal configuration information. A horizontal cyan line separates the two portions. The upper portion is blank or displays the selected MEDS display. At the bottom, the legends for the edgekeys are displayed in the six boxes that are aligned with their respective edgekeys. The color of the boxes and the labels normally are cyan, unless they correspond to the current MEDS display, in which case they are white. A blank edgekey legend means no option is available for that edgekey. If the edgekey is pressed, the IDP ignores it. The menu title is displayed above the edgekey boxes and legend. The MEDS fault message line is the line above the menu title. Any MEDS-generated messages are displayed in white on this line. Any GPC generated messages are displayed on the DPS display in orange (above the cyan horizontal line).

MEDS configuration information is displayed to the left and the right of the menu bars. The information to the left indicates which MDU port is selected and which IDP is connected to each MDU port. "P" indicates primary port and "S" indicates the secondary port. The numbers next to the P and S indicate the IDP that is connected to that port of the MDU. An asterisk indicates which port (and thus which IDP) is selected to command the MDU. The information displayed to the right of the menu bars indicates the port select configuration and

flight-critical data bus selected for that MDU. The flight-critical data bus selected is the number displayed next to "FC." The port reconfiguration mode is displayed below the flight critical data bus information. "AUT" is displayed when automatic port reconfiguration capability has been selected and "MAN" is displayed when manual reconfiguration capability has been selected. Each MDU retains its current configuration through a power cycle (except for the menu, which reverts to the menu associated with the display on the MDU).



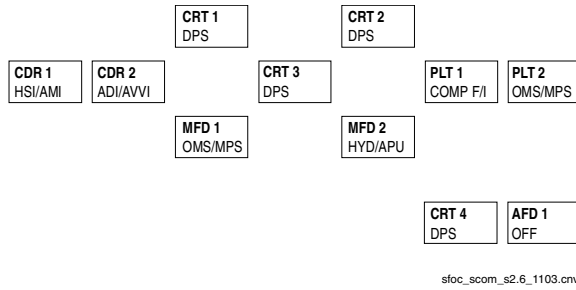
### MEDS Generic Screen Format

### MEDS Displays

The user may view all flight instrument and subsystem status information via the various MEDS displays.

### *Flight Instruments*

The ascent and entry flight instruments have been divided into three separate displays: ADI/AMI, HSI/AVVI, and COMP ADI/HSI. The composite ADI/HSI consists of the ADI, AMI, AVVI, and the upper portion of the HSI. For orbit, only the ADI is used; therefore, there is a display that consists of only the ADI. The ADI on the ascent/entry flight instrument displays will work on orbit. The ADI, HSI, AMI, and AVVI work as described in Section 2.7, Dedicated Display Systems.



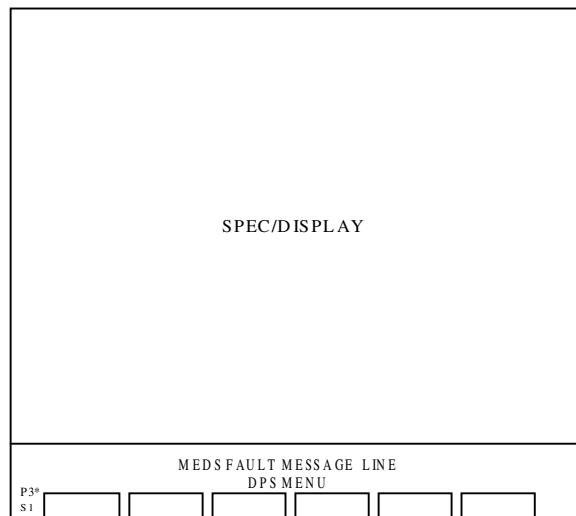
**Typical Ascent MEDS Layout**

**DPS Display**

The MEDS DPS display shows the DPS displays to the crew. The IDP emulates the old "CRT" system using data it obtains over the DK bus. The DPS display allows the crew to interact with the GPCs by entering commands via the keyboards to monitor a variety of systems data.

The GPC fill portion of the DPS display is covered in detail later in this section.

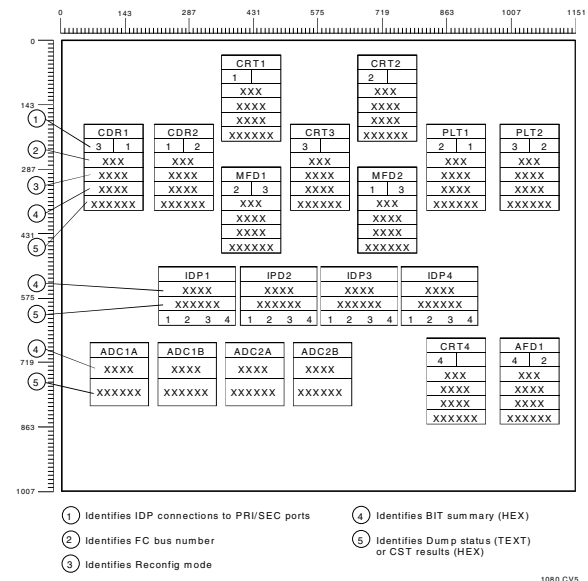
In the MEDS-driven portion, a green outlined box with a number inside of it has been added just below the scratch pad line and centered horizontally. The number represents the IDP that is commanding the MDU. Colored keyboard bars were also added to indicate which keyboards are currently active for an IDP. These keyboard bars appear and disappear, depending on the positions of the Left and Right IDP/CRT Select switches; they are described in the Operations section of this chapter.



**DPS Display**

**MEDS Maintenance Display**

The MEDS maintenance display provides an overview of the current configuration of the MEDS system as viewed by the commanding IDP of the MDU. The MEDS maintenance display shows all of the MEDS LRUs as a box. The forward MDUs are arranged on the display the same way as they are arranged in the forward flight deck. Displayed below them are the four IDPs. The ADCs and the aft MDUs are displayed graphically below the IDPs. Each of the LRUs commanded by the current IDP has a blue background for its box. Each LRU box provides information about its configuration, status, and/or comprehensive self-test (CST) results.



**MEDS Maintenance Display**

The MDU boxes provide information on the port configuration, flight-critical bus selection, and status of the MDU. The first row in the box indicates the name of the LRU. The second row denotes the IDPs that are connected to the primary and secondary ports. The third row displays the flight-critical bus selected, if that MDU is displaying a flight instrument display; otherwise, it is blank. The fourth row indicates if the MDU is in the AUTO or MANUAL reconfiguration mode. This reconfiguration mode is also displayed on the MDUs with which the IDP is communicating but not commanding (no blue background). The fifth row indicates the operational BITE summary in

hex. If one or more bits in the BITE summary are off nominal, the entire BITE summary shows red. The sixth row indicates the dump status (text) or CST results (hex). If one or more bits in a CST result are off nominal, the entire CST result is displayed in red. If a CST has not been performed, the CST results display NO-CST in white. The last row of the box contains the version number of the software loaded in the MDU; e.g., V 0400.

The IDP boxes provide information on the flight-critical bus selection and status of the IDP. The first row in the box indicates the name of the LRU. The second row denotes the operational BIT summary in hex. If one or more bits in the BIT summary are off nominal, the entire BIT summary is red. The third row indicates the dump status (text) or CST results (hex). If one or more bits in a CST result are off nominal, the entire CST result is displayed in red. If a CST has not been performed, the CST results display NO-CST in white. The fourth row indicates which flight-critical data buses currently are being supported. The buses are displayed in reverse video. The last row contains the version number of the software loaded in the IDP; e.g., V 0300.

The ADC boxes provide information on the status of the ADC. The first row in the box indicates the name of the LRU. The second row denotes the operational BITE summary in hex. If one or more bits in the BITE summary are off nominal, the entire BITE summary is red. The last row indicates the dump status (text) or CST results (hex). If one or more bits in a CST result are off nominal, the entire CST result is displayed in red.

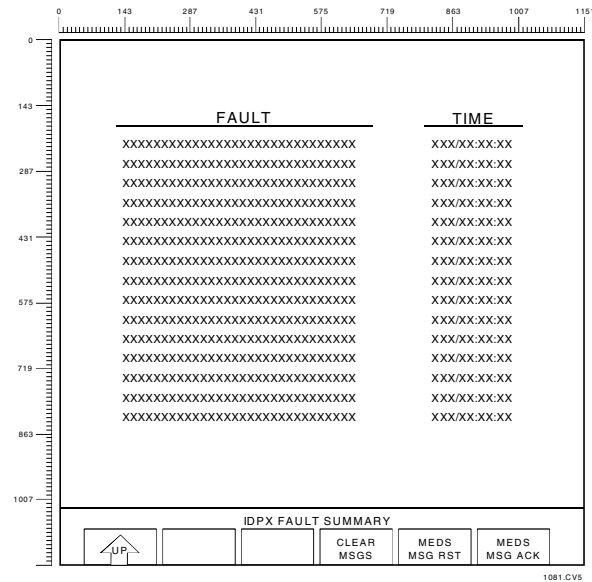
### MEDS Fault Summary Display

The MEDS fault summary display is the MEDS equivalent of the GPC fault summary (SPEC 99). The display lists the past 15 MEDS fault messages and the time of annunciation by the current IDP.

### Edgekey Menu System

The user accesses the edgekey menu system to control the MEDS system. The MEDS edgekey operations are organized by function and are displayed in the proper hierarchy. In general,

edgekeys call up an additional menu, select a MEDS configuration, select a particular MEDS display, and initialize internal tests of the MDUs, ADCs, and IDPs. Except for the top menu (the main menu), the first edgekey (on the left) is the up arrow, which allows the user to go up to the next level. The main menu allows the user to select the flight instrument menu, subsystem status menu, the DPS display, and the MEDS maintenance display and its menu.



**MEDS Fault Summary Display**

Throughout the various menus, the user can select MEDS MSG ACK or MEDS MSG RESET. These edgekey operations are single-stroke keys. The MEDS MSG ACK works the same as the keyboard ACK key. The first time that it is pressed, the MEDS fault messages goes static. Subsequent pressings of the edgekey scroll through the remaining MEDS fault messages. The MEDS MSG RESET clears the MEDS fault message line just like the MSG RESET key works for the DPS displays.

The flight instrument menu allows the user to select either ascent/entry or orbit displays, in addition to clearing the MEDS fault message line. Under the ascent/entry submenu, you can select the ADI/AVVI display, the HSI/AMI display, the COMP ADI/HSI display, the data bus select menu, or scroll through the MEDS fault messages using the MEDS MSG ACK. Under the orbit menu, the only selections are the ADI, data bus select menu, and the MEDS MSG ACK. The data

bus select menu maintains the current flight instrument MEDS display, but allows the user to choose flight-critical 1 through 4.

The subsystem status menu allows the user to access the MEDS displays to view the OMS, MPS, HYD, APU, and SPI information that was available previously on the analog meters. The user may swap between these various subsystem displays with just a single press of the appropriate edgekey. This menu allows the user to port select on the MDU in case the current commanding IDP has a problem with an ADC. This submenu also allows the user to select MEDS MSG ACK.

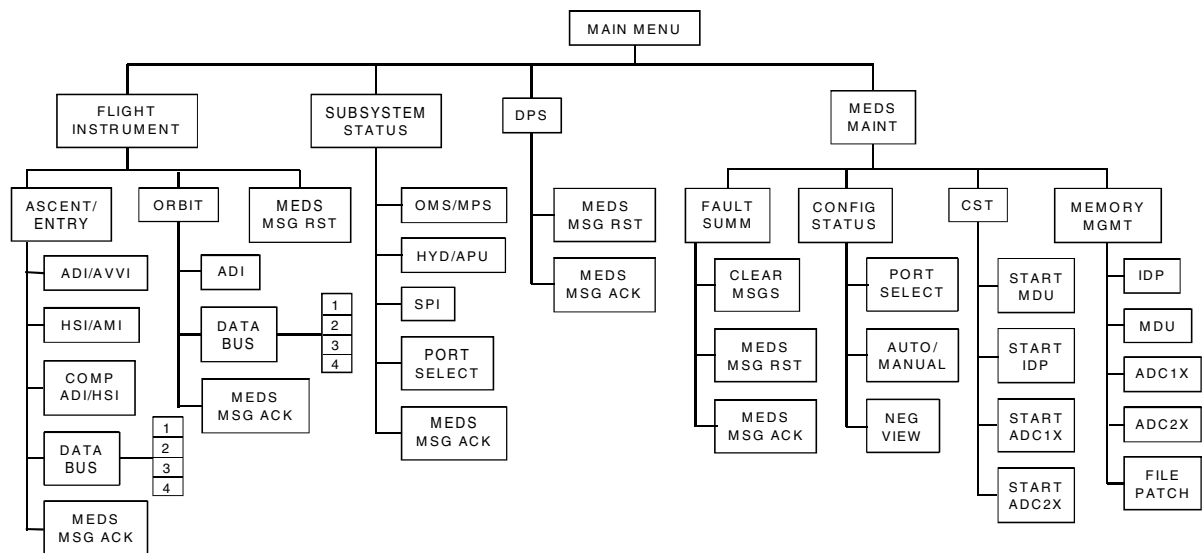
After selecting the DPS menu, the DPS display shows automatically. The edgekey options are the MEDS MSG ACK and MSG RESET.

After selecting the MEDS maintenance menu, the MEDS maintenance display is displayed automatically. From this menu, the user can select any of the following submenus: fault summary, configuration status, CST, or memory management.

After selecting the fault summary option, the MEDS fault summary display is shown. With this submenu, the user can clear the MEDS fault messages, similar to a SPEC 99 PRO but for MEDS. The options to MEDS MSG RESET and ACK are also included on this menu.

The configuration status submenu allows the viewer to port select to the alternate IDP, change its reconfiguration mode to either AUTO or MAN, or change the viewing mode. The viewing mode can be changed only for the Hosiden MDUs (all flight MDUs are Hosiden). The negative viewing mode enhances the readability of the aft MDUs. When negative viewing is selected, 'NEG VIEW' is displayed above the flight-critical bus selection and reconfiguration mode on the MEDS status area of the MDU.

The CST submenu lets the user activate the CST for the current MDU, the commanding IDP, and the associated ADC1X and ADC2X for the commanding IDP. The CST is a test of the hardware and the functional use of the MEDS LRU. It has both interactive and noninteractive parts for the IDP and MDU. The ADC CST is not interactive. During the IDP CST, other MDUs being commanded by this IDP will blank and display the message IDP CST INITIATED. The results of the CST are displayed on the MEDS maintenance display.



**MEDS Edgekey Menu Hierarchy**



The memory management menu has several options. The edgekey menu tree does not display the submenus for each of the possible selections. In general, the memory management menu allows the user to dump the EEPROM and/or RAM for the ADC, MDU, and IDP to the MSU, load IDP or MDU programs from the MSU, load an IDP program load from EEPROM, and patch files on the MSU. Currently, no crew procedure references these memory management functions.

### MEDS Fault Messages

Each IDP has various messages that it can announce. Each MEDS error can be broken down into seven categories (A through G, with A being the most severe). The IDP generates a MEDS fault message for the categories that warrant crew notification. The other categories cause the IDP to notify the ground, archive the method other than a MEDS fault message.

MEDS fault messages for an IDP are displayed on all commanded MDUs that are showing the DPS display. If none of an IDP's commanded MDUs has a DPS display, the IDP will select the MDU with the highest ranking that is available for the MEDS fault messages.

### Operations

The crew interfaces with the five GPCs via the four IDPs and their MDUs. This section first discusses crew operations using PASS, and then discusses crew operations using the BFS.

### IDP Load Switch

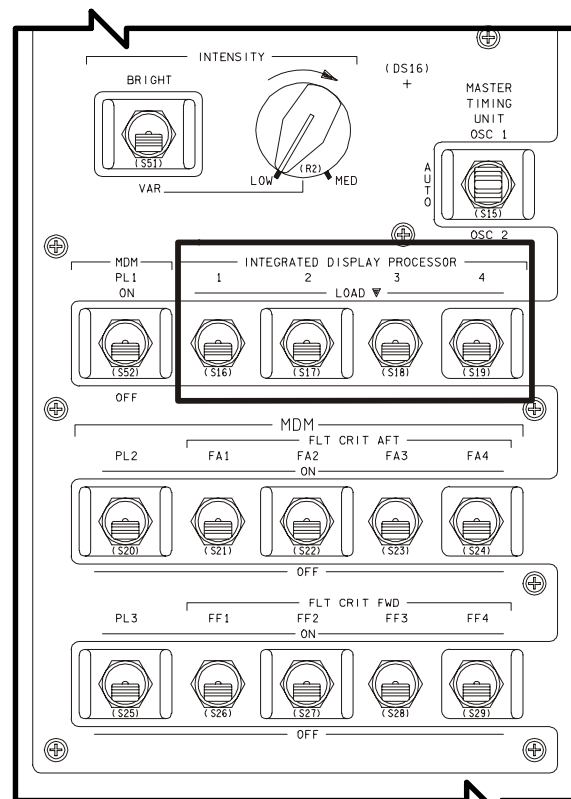
The IDP load switch, located on panel O6, is used to load the critical format information for the DPS displays. The critical formats form a skeleton that the IDP uses and fills with GPC-provided data. When the IDP load switch is toggled and a GPC is running an ops mode that supports the load (SM OPS 2 or 4, PL OPS 9, or post-IPL OPS 0), the IDP receives the GPC information and stores only the critical format information in the EEPROM (other information is sent that was used by the old CRT system).

Nominally, the only time the IDP needs to be loaded with critical formats is after an OI flight software change in the GPCs. If a GPC does not

recognize the IDP load request (i.e., it is a GNC computer), an IDP power cycle recovers full capability of the IDP with no loss of its critical formats.

### IDP Switches

Switches on panel C2 designate which keyboard controls each forward IDP. When the LEFT IDP/CRT SEL switch is positioned to 1, the left keyboard controls IDP 1; if the switch is positioned to 3, the left keyboard controls IDP 3. When the RIGHT CRT SEL switch on panel C2 is set to 2, the right keyboard controls IDP 2; if set to 3, it controls IDP 3. Thus, flight crew inputs are made on the keyboards, and data are output from the GPCs on the DPS displays.



**INTEGRATED DISPLAY PROCESSOR  
 Switches on Panel O6**

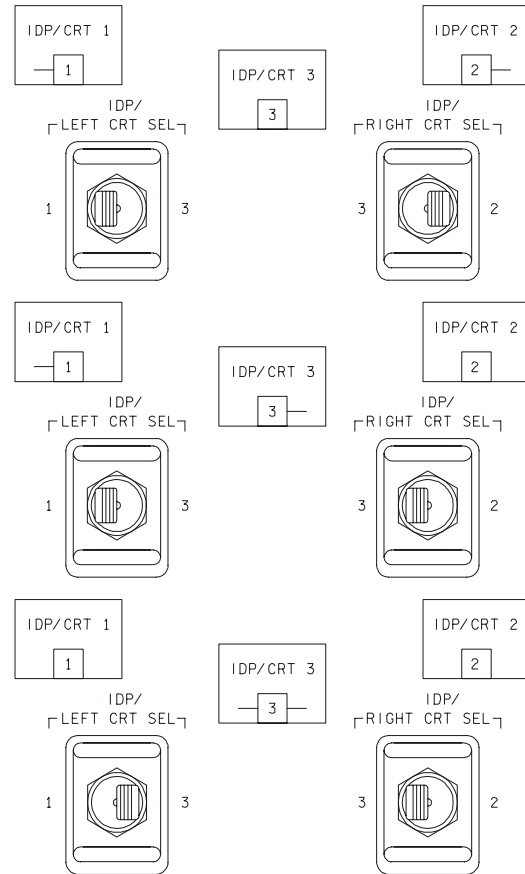
**NOTE**

If the *LEFT IDP/CRT SEL* and *RIGHT IDP/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 IDP; there is no select switch.

These switch positions also drive the MEDS colored keyboard bars. If the *LEFT IDP/CRP SEL* switch is selected to IDP 3 (in other words, the commander's keyboard is talking to IDP 3), a red horizontal bar will be displayed to the left of the box for IDP 3's DPS display. If the switch is moved to IDP 1, the red bar will disappear from IDP 3's DPS display and move to the left of the box on IDP 1's DPS display. The pilot's keyboard bar is yellow and is displayed to the right of the box. Red and yellow were chosen, because the crew already associates the CDR with red and the PLT with yellow for FDF, food, etc. Because the DPS displays can be called up on any MDU, this information is helpful in knowing which IDP a keyboard is talking to and which IDP's DPS display is being displayed. IDP 4's DPS display does not have any keyboard bars displayed, because only the aft keyboard can talk to it.

Each IDP has an associated *MAJ FUNC* switch. The *IDP/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 IDP's DPS display. The *IDP/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 IDP. The GPC loaded with the desired major function applications software will then drive this IDP's DPS display. Each major function accesses an independent set of display data and functional software.



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**Possible IDP/Keyboard Assignments in the Forward Flight Station**

**MDU Configuration**

**Overview**

Nominally, MDUs are configured to their primary ports and are in automatic port reconfiguration mode. CRT MDUs show the DPS (CRT) display. In general, the CDR and PLT MDUs display the flight instruments, while the MFD MDUs display the subsystem displays. This configuration is similar to the current non-MEDS flight-critical data bus configuration.

### **Selecting Alternate MDU Ports**

Automatic port reconfiguration capability allows the MDU to swap automatically to the other port if the MDU loses communication with the currently selected IDP. Manual port reconfiguration capability does not do a port select automatically. The user has to manually reconfigure the MDU onto its alternate port. Operationally, MDUs will always be in auto reconfiguration mode. If an MDU is in manual mode and loses communication with the selected IDP, or if an MDU is in automatic reconfiguration mode and loses communication with the IDPs on both ports, the MDU is in autonomous mode. The MDU blanks the MEDS display and displays the following message: MDU IS AUTONOMOUS. The menu changes to allow the user to reconfigure to automatic port selection, manual primary port, or manual secondary port.

The user can select alternate ports by navigating through the MEDS edgekey menus to either the subsystem menu or the MEDS maintenance menu. The port select option was included in the subsystem menu in case of failure of an ADC. If an ADC that the current IDP com-

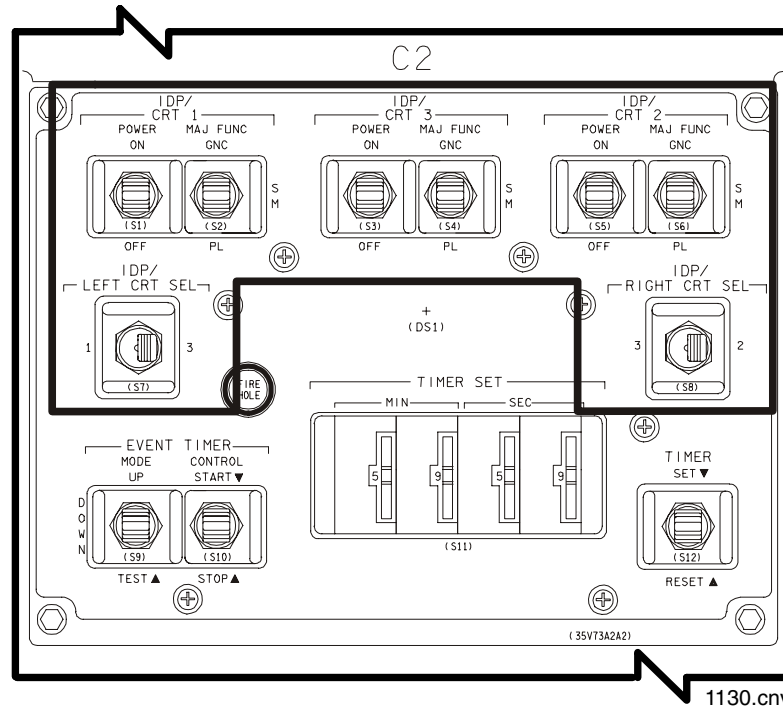
mander is using fails, it cannot display all of the subsystem status information. For the MFD MDUs, CDR 1, and PLT 2, the IDPs on the alternate port were wired so that they will access the other set of ADCs. A port reconfiguration allows recovery of all subsystem status information. (Note that nominally, the MFD MDUs display subsystem status displays.)

### **Recovering from a Disabled Edgekey**

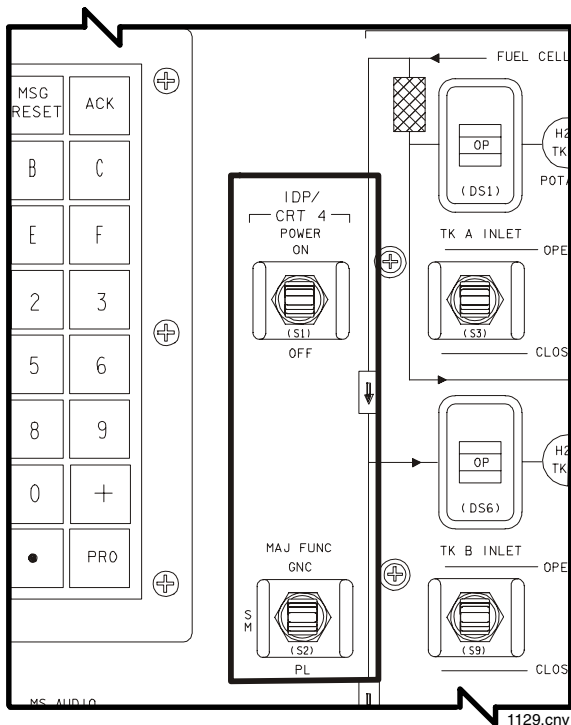
When an edgekey has been disabled, a red "X" appears on the edgekey legend box. An edgekey is disabled when it is pressed continuously for 3 seconds or longer or when MEDS detects that it failed closed. To recover from an accidental edgekey disable, it is necessary to power cycle the MDU via its power knob on the display unit.

### **Selecting Negative Viewing**

The configuration status submenu allows the viewer to change the viewing mode. The viewing mode can be changed only for the Hosiden MDUs. The negative viewing mode enhances the readability of the aft MDUs. When negative viewing is selected, "NEG VIEW" is displayed above the flight-critical bus selection and reconfiguration mode on the MEDS status area of the MDU.



CRT Switches on Panel C2



CRT 4 POWER and MAJ FUNC Switches on Panel R11L

### Display Hierarchy

DPS 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.

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.

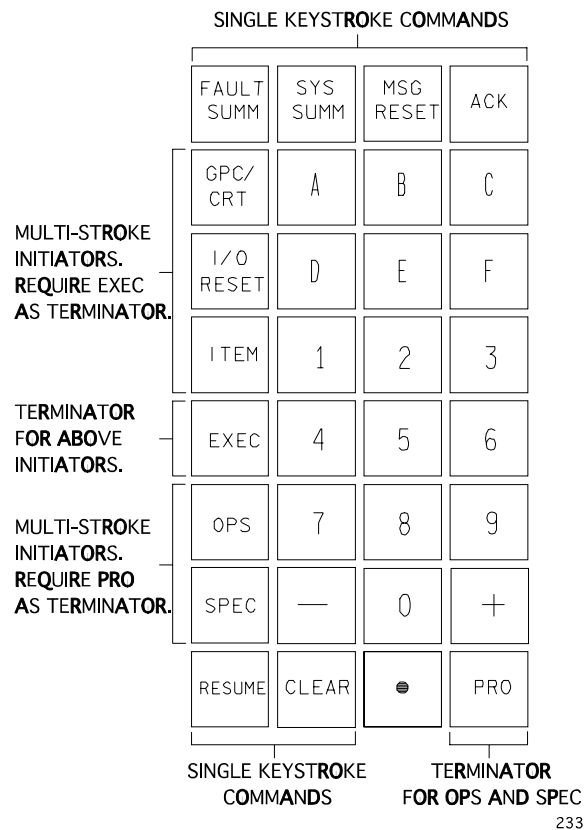
When called, a DISP will overlay the major mode display and the SPEC, if one is active. Both the SPEC and the major mode display are overlaid, and access to them can be easily regained. The method of terminating the processing of SPECS and DISPs will be discussed later.

### 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 IDP the keyboard entry is complete.



### Multifunction Electronic Display System Keyboard Unit 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 DPS display, 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 DPS display. 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 an IDP.

**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 DPS display. 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. The highest level SPEC or DISP is cleared and the underlying display is brought to the forefront upon depression of this key.

**CLEAR** clears the last echoed keystroke from the bottom line (scratch pad line) of the DPS display. 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 DPS displays in numerous ways. 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 IDP 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 IDP on which the keyboard entry is performed. 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 IDP 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 active, 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, 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 completing viewing any SPEC or DISP to avoid confusion and to eliminate locking out certain ground command functions that are inhibited when certain SPECs are active or underlying a DISP; i.e., SM60 and SM62. 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 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," which appears in a yellow font, 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.

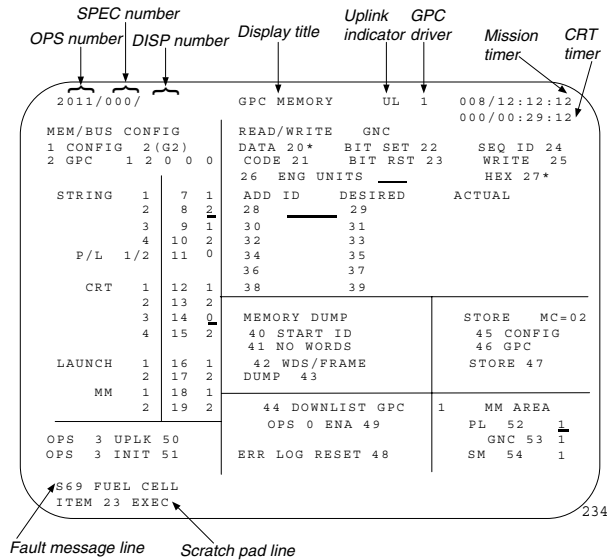
**GPC driver:** To the right of the uplink indicator is a one-digit field. A number in this field indicates the particular GPC (1, 2, 3, 4, or 5) that is commanding the IDP.

**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 IDP 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.

2011/ /078		SM SYS SUMM 1		4		000/14:44:12	
						000/00:00:00	
SMOKE	1/A	2/B	DC VOLTS	1/A	2/B	3/C	
CABIN	0.0		FC	30.6	30.1	31.0	
L/R FD	0.0	0.0	MAIN	30.6	30.1	31.0	
AV BAY	1	0.3	ESS	29.6	29.6	29.3	
	2	0.3					
	3	0.3					
CABIN			CNTL	1	29.4	29.4	29.6
PRESS	14.0			2	29.4	29.4	29.4
GP/dT-EQ	+0.00	+0.000		3	29.4	29.4	29.4
O2 CONC			AC				
PPO2	3.00	3.00	VOLT	ΦA	118	118M	117
FAN ΔP	5.00		ΦB	117	117	118	
HX OUT T	46H		ΦC	117	117	118	
O2 FLOW	0.0	0.0	AMPS	ΦA	4.3	6.3	2.1
N2 FLOW	0.0	0.0L	ΦB	5.5	6.0	2.2	
IMU FAN	A	B	ΦC	3.1	5.0	3.2	
AV FC1	FC2	FC3	FUEL CEL				
SS1	22	21	AMPS	180	232	146	
SS2	22	22	REAC VLV	OP	OP	OP	
SS3	23	21	STACK T	+202	+206	+200	
TOTAL AMPS	557		EXIT T	150	152	149	
KW	17		COOL P	61	60	61	
			PUMP				

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2011/ /018		GNC SYS SUMM 1		1		000/02:46:03	
						000/00:00:00	
RCS	JET	ISOL					
MANF	FAIL	VLV	SURF	POS	MOM	DPS	1 2 3 4 5
F1		OP	L OB			GPC	↓
2		OP	IB			MDM FF	↓
3		OP	R IB			FA	↓
4		OP	OB				
5		OP	AIL				
L1		OP	RUD			FCS CH	1 2 3 4
2		OP	SPD BRK				M
3		OP	BDY FLP				
4		OP					
5		OP					
R1		OP				NAV	1 2 3 4
2		OP				IMU	? M ?
3		OP	CNTLR	1 2 3		ACC	M
4		OP	RHC	L		RGA	M
3		OP	R			TAC	M
4		OP	A			MLS	
5		OP	THC	L		ADTA	
		OP	A				
		OP	SBTC	L			
		OP	R				

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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	↓	↓		*		

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### Specially Defined Symbols on DPS 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 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 IDP 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 certain IDP is determined via a predefined table of assignments. The table is stored in all the common set GPCs' systems software; the crew can manipulate it. 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. The table can be changed via the GPC MEMORY display (SPEC 0). The current GPC driver for an IDP is controlled by the *MAJ FUNC* switch. That is, the position of the *MAJ FUNC* switch (*GNC*, *SM*, or *PL*) determines the GPC with which the IDP communicates. In some cases, a redundant set of GPCs is formed for *GNC*, and the *GNC* IDPs 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 old cockpit configuration consisted of a set of CRTs. The key is still labeled GPC/CRT, although its function is to assign a GPC to command an IDP). The GPC/CRT key allows the crew to reassign an IDP to a different GPC commander. The steps for selecting a GPC to command a given IDP 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 IDP number (1, 2, 3, or 4). No delimiter is needed between the GPC and the IDP numbers.*
4. *Depress the EXEC key.*

An assignment is not executed if the assigned GPC does not have the applications software in memory to support the IDP 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 GPC driver retains the IDP. Thus, if an IDP 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 IDP instead of the invalid GPC. If GPC 4 is the *SM* machine (nominal configuration), it is the only valid GPC to drive an IDP whose *MAJ FUNC* switch is in *SM*.

The payloads major function is usually *unsupported*, which means that none of the GPCs have payload applications software loaded. Any GPC can be assigned to drive an IDP in an unsupported major function. The GPC that was driving the IDP in the previous major function retains the IDP when it is placed in *PL*.

If the keyboard entry specifies a valid GPC, it overrides any assignment made by the software. The keyboard entry assignment remains 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 an IDP from communication with all GPCs. This is done by using "0" for the number of the GPC. The *PASS* set can drive only three of the four IDPs at one time, so at least one IDP is always isolated from *PASS*.

The IDP drives a big X over its *DPS* display to remind the crew that the IDP is not receiving data. The IDP also annunciates a *POLL FAIL* message to inform the crew that the GPC is no longer successfully polling the IDP (not attempting to communicate with the IDP).

### *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; e.g., the current state vector and inertial measurement unit processing. When a GPC transitions 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 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.

A typical NBAT is shown on SPEC 0 GPC MEMORY for GNC OPS 2.

MEM/BUS CONFIG		READ/WRITE		GNC		SEQ ID	
1	CONFIG 3 (G3)	DATA 20*	BIT SET 22	24			
2	GPC 1 2 0 0 0	CODE 21	BIT RST 23	25			
		26	ENG UNITS	HEX 27*			
STRING	1 7 1	ADD ID	DESIRED	ACTUAL			
	2 8 2	28	29				
	3 9 3	30	31				
	4 10 4	32	33				
P/L	1/2 11 1	34	35				
		36	37				
CRT	1 12 1	38	39				
	2 13 2						
	3 14 0						
	4 15 3						
LAUNCH	1 16 0	MEMORYDUMP		STORE MC=02			
	2 17 0	40 START ID		45 CONFIG			
	3 18 1	41 NO WORDS		46 GPC			
MM	1 18 1	42 WDS/FRAME		STORE 47			
	2 19 2	DUMP 43					
OPS 3 UPLINK	50	44 DOWNLIST GPC 1		MM AREA			
OPS 3 INIT	51	OPS 0 ENA 49		PL 52 1			
		ERR LOG RESET 48		GNC 53 1			
				SM 54 1			

sfof\_scom\_s2.6\_238.cnv

### 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.
- The "CRT" portion of the NBAT refers to which GPCs are assigned to command the IDPs over the DK bus (the word CRT remains from the previous CRT cockpit). IDPs 1, 2, 3 are assigned to GPCs 1, 2, 3 respectively, via items 12-14. Since the PASS can only control three IDPs at a time, no GPC is assigned to IDP 4 during entry. Note that IDP 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

Because 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.

2011/001/	DPS UTILITY	1 008/12:12:12	
		000/00:25:12	
MMU ASSIGN	PORT ASSIGN	UL CNTL	
1 2		AUTO 35*	
GNC 1* 2	STRING 1	ENA 36	
SM 3* 4	2	INH 37	
PL 5* 6	3		
OPS 0 7* 8	4		
	P/L 1/2	IPL SOURCE SW	
		MASK 38*	
MMU STATUS	VAR PARAM ID LIST		
1 RDY	25 9ABA	G3 ARCHIVE	
2 RDY	26 9ABB	LOAD 48	
MMU SOURCE/BUS	27 9ABC	RETRIEVE 49*	
GPC/MMU 9*	28 9ABD		
MMU/MMU 10	29 9ABE	GROUND OPS	
GPC/LDB 11	30 9ABF	GSE POLL ENA 50	
CKPT RETRV	31 9ACA	SM GSE INH 51	
ENA 12	32 9ACB	SM C/O ENA 52	
	33 9ACC	GNC C/O ENA 53	
RTC	34 9ACD	BFC C/O ENA 54	
13		ALT PL9 TB 55	
CMD 14			

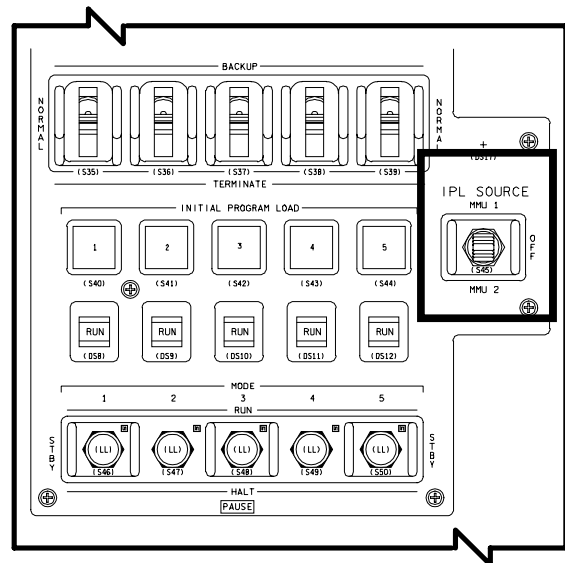
DPS UTILITY Display (SPEC 1)

*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 O6

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 appropriate DPS displays, 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 an IDP's *MAJ FUNC* switch is in GNC, and the SYS SUMM key is pressed, GNC SYS SUMM 1 will appear on that IDP. 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).

RCS		JET	ISOL				1 2 3 4 5				
MANF	FAIL	VLV	SURF	POS	MOM	DPS					
F1		OP	L OB			GPC					
2		OP	IB			MDM FF					
3		OP	R IB			FA					
4		OP	OB								
5		OP	AIL								
L1		OP	RUD			FCS CH	1	2	3	4	
2		OP	SPD BRK								
3		OP	BDY FLP								
4		OP									
5		OP				NAV	1	2	3	4	
R1		OP				IMU					
2		OP	CNTLR	1	2	3	ACC				
3		OP	RHC	L			REG				
4		OP		R			TAC				
5		OP		A			MLS				
			THC	L			ADTA				
				A							
			SBTC	L							
				R							

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

CRYO TK		1	2	3	4	5	MANF1	MANF2
H2 PRESS	211	211	238	238	145L	238	238	
O2 PRESS	834	833	858	858	515L	858	858	
HTR T1	-221	-221	-212	-194	-194			
T2	-221	-221	-212	-194	-194			
AFU	1	2	3					
TEMP EGT	20	15	11					
B/U EGT	16	15	15					
OIL IN	51	59	57					
OUT	56	54	59					
SPEED %	0	0	0					
FUEL QTY	89	88	85					
FMP LK P	15	15	15					
OIL OUT P	24	24	24					
AV BAY								
TEMP	50	88	82					
FAN ΔP	3.59	3.64	3.67					
HYD	1	2	3					
PRESS	65	65	65					
RSVR T	72	72	72					
P	0	0	0					
QTY	55	55	55					
W/B								
H2O QTY	97	94	92					
BYP VLV	BYP	BYP	BYP					
THERM CNTL	1	2						
H2O PUMP P	50	50						
FREON FLOW	2000	2000						
EVAP OUT T	50	50						

075

**PASS SM SYS SUMM 2, available in SM OPS 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 DPS display. Class 3, Alert, triggers the *SM ALERT* light and corresponding tone. A fault message is displayed on 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 IDP. 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

OMS AFT		QTY	L	R	OMS	L	R	
OXID	30.2	30.2			TK P	HE	4070 4070	
FU	30.2	30.2			OXID	258	258	
					FU	260	260	
RCS					N2 TK	P	2260 2260	
FWD	HE	P3048	2968		REG	P	324 324	
TK	P	247	248		P	VLV	CL CL	
QTY		67	67		ENG IN	P		
MANF	1	P	248	242	OXID	258	258	
2	P	248	246		FU	260	260	
3	P	250	246		VLV	1 - 3	0	
4	P	246	246			2	0 - 2	
5								
AFT	HE	P3200	3144		HE	P3216	3160	
L	TK	P	245	249	R	TK	P	251 249
QTY		82	83		QTY		84 84	
MANF	1	P	246	246	1	P	242	246
2	P	246	250		2	P	250	246
3	P	250	250		3	P	246	258
4	P	246	250		4	P	246	242
5					5			

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

XXXX/XXX/078		SM SYS SUMM 1		XX X	DDD/HH:MM:SS	DDD/HH:MM:SS
SMOKE	1/A	2/B	DC VOLTS	1/A	2/B	3/C
CABIN	XX.XS		FC	XX.XS	XX.XS	XX.XS
L/R FD	XX.XS	XX.XS	MAIN	XX.XS	XX.XS	XX.XS
AV/BAY	1 XX.XS	XX.XS	ESS	XX.XS	XX.XS	XX.XS
	2 XX.XS	XX.XS		A	B	C
	3 XX.XS	XX.XS	CNTL	1 XXX.XSXXX.XSXXX.XSX		
				2 XXX.XSXXX.XSXXX.XSX		
				3 XXX.XSXXX.XSXXX.XSX		
PRESS	XX.XS		VOLT	0A XXXS	XXXS	XXXS
dP/dT-EQ	+X.XS	+X.XXSAC	0B	XXXS	XXXS	XXXS
O2 CONC	XXX.XS		0C	XXXS	XXXS	XXXS
PPO2	X.XXS	X.XXS	AMPS	0A XX.XS	XX.XS	XX.XS
FAN ΔP	X.XXS		0B	XX.XS	XX.XS	XX.XS
HX OUT T	XXXS		0C	XX.XS	XX.XS	XX.XS
O2 FLOW	XX.XS	XX.XS	FUEL CELL			
N2 FLOW	XX.XS	XX.XS	AMPS	XXXS	XXXS	XXXS
IMU FAN	AXS	BXS	REAC VLV	XX	XX	XX
AV FC1	FC2	FC3	STACK T	+XXXS	+XXXS	+XXXS
SS1	XXXS	XXXS	EXIT T	XXXS	XXXS	XXXS
SS2	XXXS	XXXS	COOL P	XXXS	XXXS	XXXS
SS3	XXXS	XXXS	PUMP	XXS	XXS	XXS
TOTAL AMPS	XXXXS					(XX)
KW	XXS					

085.cnv

**PASS SM SYS SUMM 1, available in SM OPS 2**



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.

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.

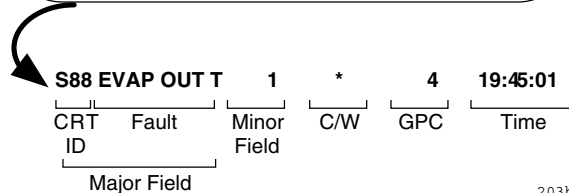
Some illegal keyboard entries are detected by the IDP before being sent to the GPCs. When this occurs, a flashing "ERR" appears immediately to the right of the erroneous entry on the scratch pad line. The crew response is simply to depress the *CLEAR* key. Upon depression of the *CLEAR* key, the "ERR" 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 an IDP-detected error.

2011/ /018		GNC SYS SUMM 1		1 000/02:46:03		000/00:00:00	
RCS	JET	ISOL					
MANF	FAIL	VLV	SURF	POS	MOM	DPS	1 2 3 4 5
P1		OP	L OB			GPC	
2		OP	IB			MDM FF	
3		OP	R IB			FA	
4		OP	OB				
5		OP	AIL				
L1		OP	RUD			FCS CH 1 2 3 4	
2		OP	SPD BRK				
3		OP	BDY FLP				
4		OP					
5		OP				NAV 1 2 3 4	
R1		OP				IMU	
2		OP	CNTRLR 1 2 3			ACC	
3		OP	RHC L			RG	
4		OP	R			TAC	
5		OP	A			MLS	
			THC L			ADTA	
			A				
			SBTC L				
			R				

### 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.



Sample CRT Fault Message

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 IDP's DPS display where the error occurred, rather than on all IDPs like class 2 and 3 errors. To get rid of the class 5 message, a MSG RESET must be done to the IDP where the error occurred. Class 2 backup and class 3 messages are extinguished by a MSG RESET on any IDP.

### *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 IDP. The FAULT display is a DISP available in all OPS. It is selected for viewing by depression of the FAULT SUMM key.

3021/	/099	FAULT		1	006/09:39:31
					000/00:00:00
CRT	FAULT	C/W	GPC	TIME	
ID					

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### **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 DPS display is not necessarily the most recent fault message. Unless the fault message line was cleared with a MSG RESET, the crewmember will not see 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, which 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).

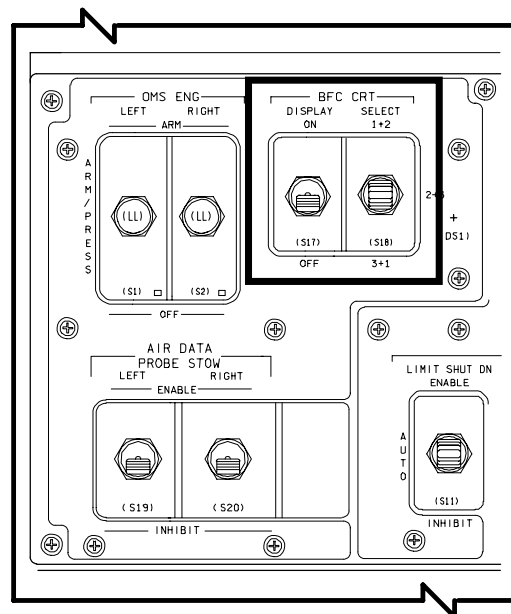
### Crew Software Interface with the BFS

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 IDP 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 IDP(s) specified by the *BFC CRT SELECT* switch is driven by the BFS computer. (The *BFC CRT SELECT* switch controls IDP 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 IDP commanded by the BFS pre-engage. Post-engaged, the BFS also commands a second IDP indicated by the second number. For example, when the *BFC CRT SELECT* switch is in the 1 + 2 position, IDP 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 IDP 1 and IDP 2. During ascent and entry, one forward IDP 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 IDPs 1 and 2. For MEDS flights, IDP 4 is typically assigned to the BFS as well via a GPC/CRT assignment (mission specific). No set of *BFC CRT* switches exists for the IDP 4.



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 an IDP already in the PL major function, the DPS display will be blank except for time and GPC driver fields because the BFS has no software to support this major function.

#### BFS ENGAGE Pushbutton

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.

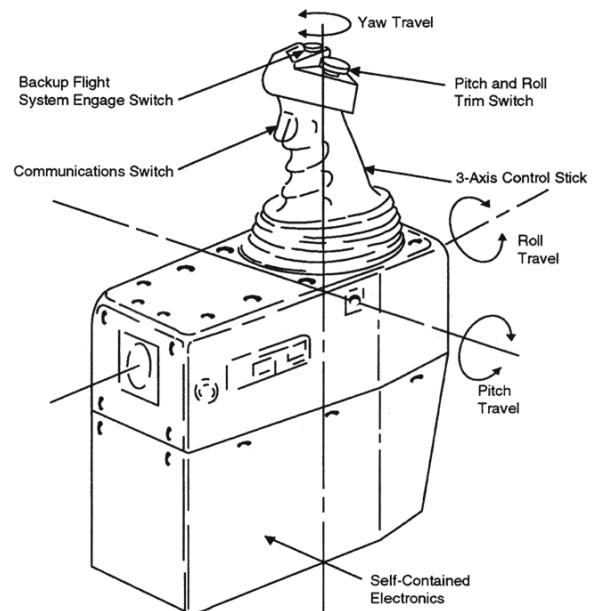
#### Keyboard and Display Differences for the BFS

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 an IDP

to (or isolate an IDP 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 an IDP or to change BFS IDPs. The *BFC CRT DISPLAY* switch allows PASS to automatically begin driving the IDP again when the BFS is turned off. When the BFS is assigned an IDP 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 IDP.

- **The BFS INDICATOR:** When the BFS is commanding an IDP, the BFS indicator will appear on that IDP's DPS display. 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 70L 50L 40L MANF P LH2 46
GO2 OUT T 79L 97L 70L LO2 110
    
```

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### BFS Indicator on DPS Display

#### 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 is listening to keyboard inputs made to the PASS controlled IDPs 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.

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 DPS display peculiarities are outlined as follows:

- BFS GNC OPS 0 - BFS MEMORY display: This display is forced to the DPS display 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/FRA ME PASS/BFS XFER ENA 25
DUMP 24

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						
ULL P LH2	42.5	42.7	42.9	MPS PNEU HE P		
LO2	21.1	21.0	20.8	TK	4350	
				REG	798	
				ACUM	760	
GH2 OUT P	70↓	50↓	40↓	MANF P LH2	46	
GO2 OUT T	79↓	97↓	70↓	LO2	110	

**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
RCS				N2 TK	P	2220 2220
FWD HE P	464	1264		REG P		319 319
TK P	248	244		P VLV	CL	CL
	QTY	0	0	ENG IN	P	
MANF	1 P	248	242		OXID	257 258
	2 P	248	244		FU	258 258
	3 P	250	246		VLV	1 - 2 - 2
	4 P	244	244			2 0 0
	5					
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	

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

**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	208 208 206 206 208 207						
O2 PRESS	816 815 814 814 815 815						
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	W/B					
SPEED %	99 102 101	H2O QTY	78 73 78				
FUEL QTY	59 60 62	BYP VLV	BYP BYP BYP				
PMP LK P	14 14 14						
OIL OUT P	42 42 41	THERM CNTL	1 28				
FU TK VLV		H2O PUMP P	23 63				
A T	63 65 62	FRON FLOW	2384 2384				
B T	63 65 62	EVAP OUT T	38 38				
AV BAY	1 2 3						
TEMP	97 97 83						
A4	14 27.439 27.435						
			26.324 31.873 18.48				

**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.

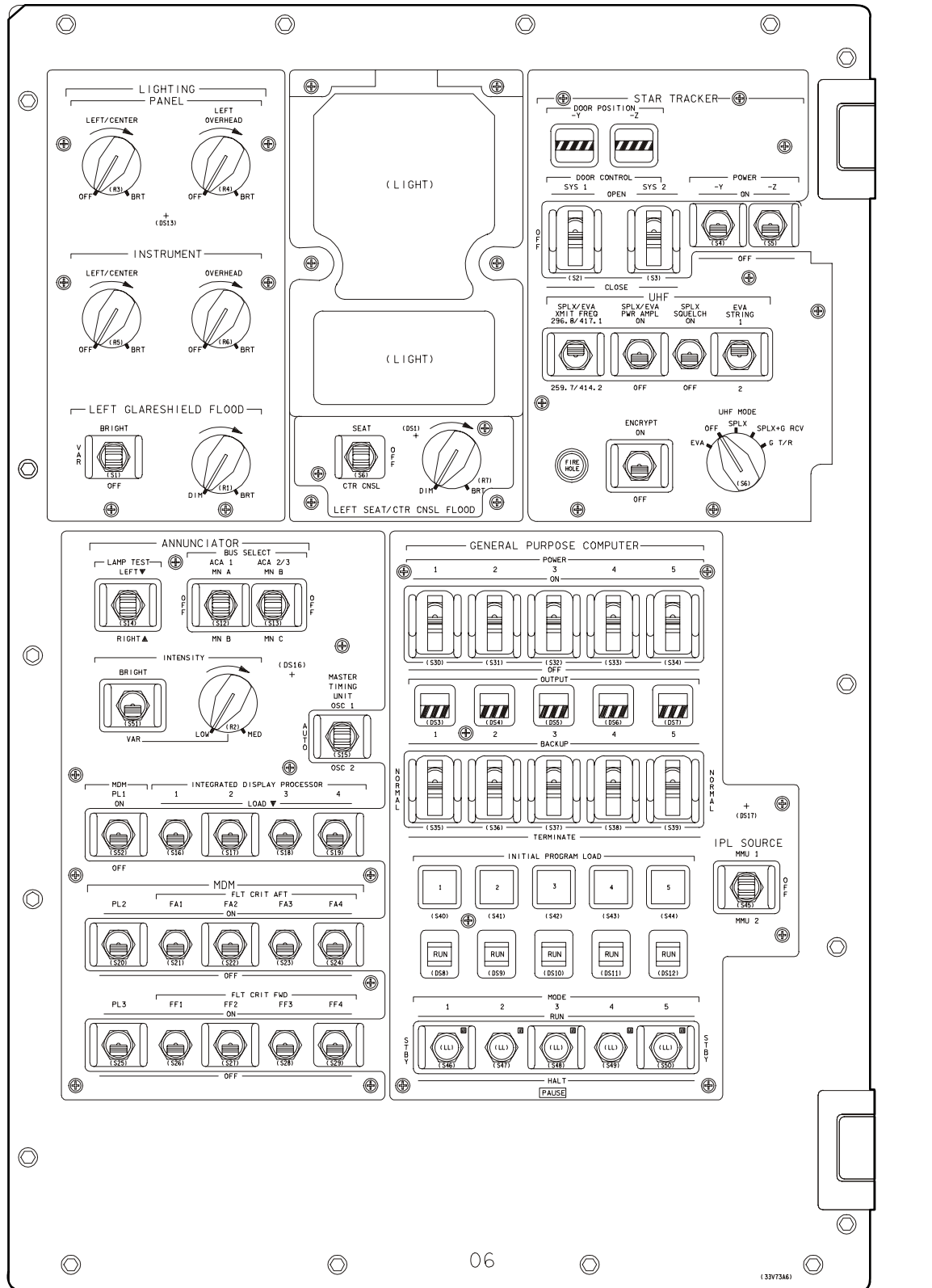
0001/		THERMAL		5		000/00:00:00	
				BFS		000/00:00:00	
HYD SYS TEMP	BDYFLP RD/SB	L OB	L IB	R IB	R OB		
PRIME	+ 99 + 79 + 76 + 79 + 76 + 79						
STBY	1 + 89 + 79 + 79 + 79 + 79 + 79						
BRAKE PRESS							
HYD SYS	1/3	92	92	92	92		
	2/3	92	92	92	92		
HTR TEMP	L/A	R/B	FRON LOOP	1	2		
PRPLT			ACCUM QTY	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			
HYD BLR/HTR		1	2	3			
APU							
GG/FU PMP HTR	H		H	H			
TK/FU LN HTR							
PUMP/VLV							

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

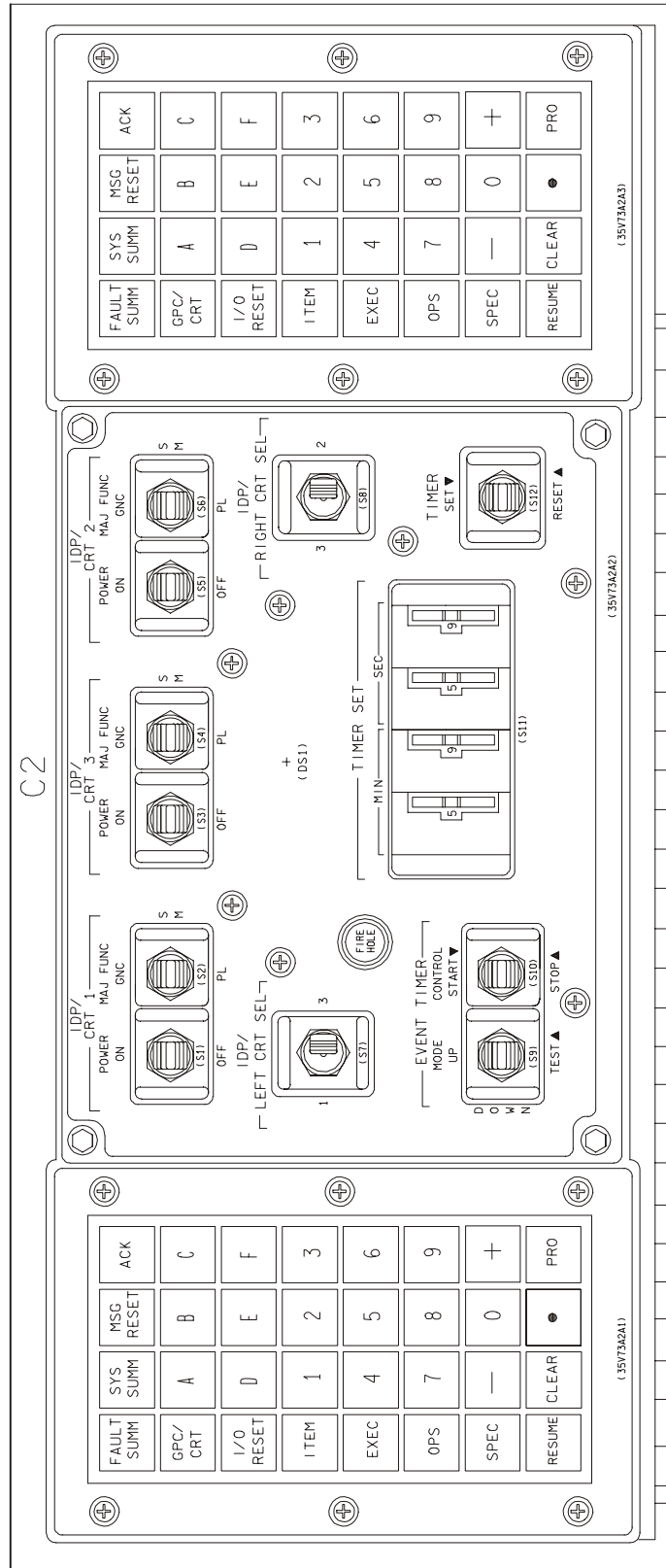
## DPS Summary Data

- The DPS combines various hardware components and self-contained software to provide computerized monitoring and control.
- DPS hardware includes 5 GPCs, 2 mass memory units, a data bus network, 20 MDMs, 4 IDPs, 11 MDUs, 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.
- Two mass memory units provide bulk storage for software and data.
- Four IDPs, 11 MDUs, 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 DPS 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.
- DPS displays relevant to the DPS are: GPC/BUS STATUS (SPEC 6), GPC MEMORY (SPEC 0), DPS UTILITY (SPEC 1), and TIME (SPEC 2).





Panel O6



FLO884A27, PNL# 2

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	↓	↓		*			↓	

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GPC/BUS STATUS (SPEC 6)

2011/001/		DPS UTILITY		1 008/12:12:12 000/00:25:12	
MMU ASSIGN	1 2	PORT ASSIGN	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	

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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				
3	9 1				
4	10 2				
P/L 1/2	11 0				
CRT 1	12 1				
2	13 2				
3	14 0				
4	15 2				
LAUNCH 1	16 1				
2	17 2				
MM 1	18 1				
2	19 2				
OPS 3 UPLNK	50				
OPS 3 INIT	51				

MEMORY DUMP	STORE MC=O2
40 START ID	45 CONFIG
41 NO WORDS	46 GPC
42 WDS/FRAME	STORE 47
DUMP 43	

44 DOWNLIST GPC 1	MM AREA
OPS 0 ENA 49	PL 52 1
	GNC 53 1
ERR LOG RESET 48	SM 54 1

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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		GMT	TRY	GPC	
MTU ACCUM 1	008/12:12:12.000	34	1	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					

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TIME (SPEC 2)

### DPS Rules of Thumb

- Always HALT fail to sync GPCs and reassign their IDPs 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 keyboard 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 does not 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 when not using them or before moving the major function switch.
- 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 IDPs (both PASS and BFS) via PASS IDPs (BFS will DK listen). If you assign BFS to drive an IDP via a BFS keyboard, and a PASS GPC is currently driving the display, dual DK Bus commanders will result, which can cause PASS redundant set breakups.
- Always distribute your IDPs among different GPCs. On orbit, always be sure to minimize SM usage on all IDPs at the same time; if you lose SM, you also lose PASS IDP interface. The same is true if in single GPC GNC OPS, such as in a Group B powerdown.
- 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 IDP/CRT SEL switch should always be checked before making a keyboard entry, and data should always be checked on the 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.

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## 2.7 DEDICATED DISPLAY SYSTEMS

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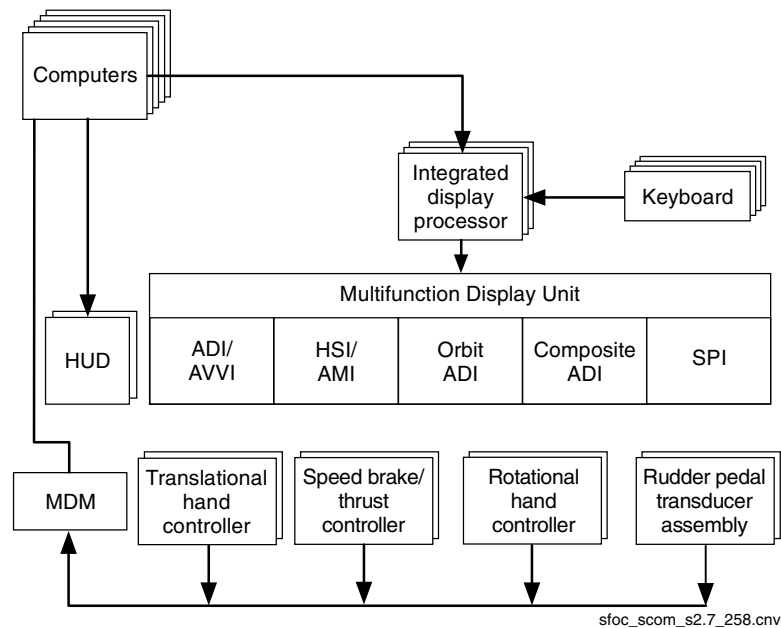
### Description

Dedicated displays provide the flight crew with information required to fly the vehicle manually or to monitor automatic flight control system performance. The data on the dedicated dis-

plays may be generated by the navigation or flight control system software or more directly by one of the navigation sensors. The dedicated displays are located in front of the commander's and pilot's seats and on the aft flight deck panel by the aft-facing windows.

The dedicated displays are:

- Attitude director indicators (ADIs) - on the orbit ADI, ADI/AVVI, and composite flight instrument displays (MEDS) or panels F6, F8, and A1U (non-MEDS)
- Horizontal situation indicators (HSIs) - on HSI/AMI and composite flight instrument displays (MEDS) or on panels F6 and F8 (non-MEDS)
- Alpha/Mach indicators (AMIs) - on HSI/AMI and composite flight instrument displays (MEDS) or on panels F6 and F8 (non-MEDS)
- Altitude/vertical velocity indicators (AVVIs) - on ADI/AVVI and composite flight instrument displays (MEDS) or on panels F6 and F8 (non-MEDS)
- Surface position indicator (SPI) - on SPI display (MEDS) or on panel F7 (non-MEDS)



Dedicated Display and Control System

- Reaction control system activity lights on panel F6
- G-meter on panel F7 (non-MEDS only)
- Head-up display (HUD) on the glare-shield in front of the commander's and pilot's seats

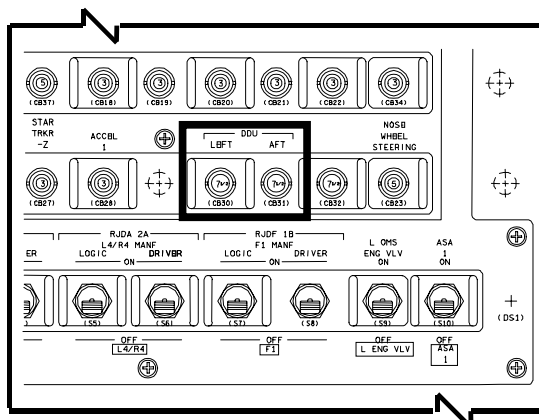
Not all the dedicated displays are available in every operational sequence or major mode. Their availability is related to the requirements of each flight phase.

### Display Driver Unit

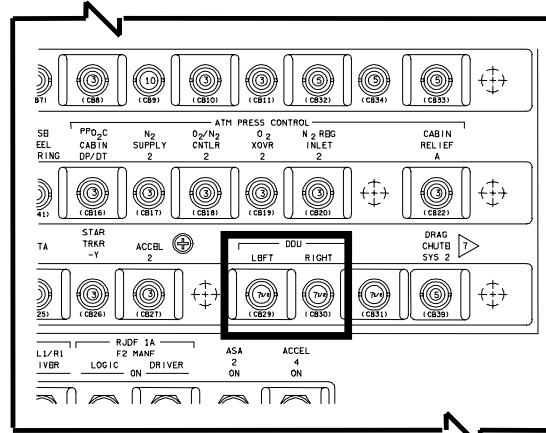
The display driver unit (DDU) is an electronic mechanism that provides dc and ac power for the rotational and translational hand controllers (RHC and THC), the speedbrake thrust controller (SBTC), and rudder pedal transducer assemblies (RPTA).

The orbiter contains three display driver units: one for the commander's station, one for the pilot's station, and one for the aft station.

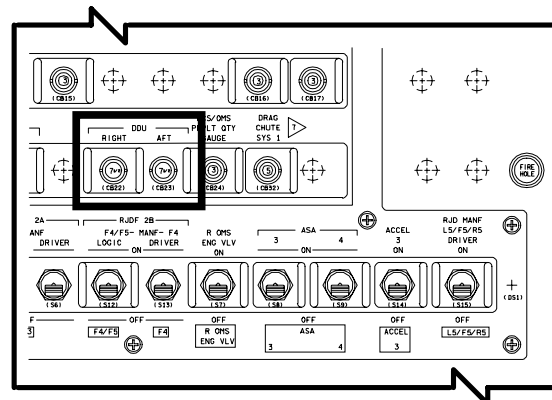
The commander's DDU is powered from the MN A DDU LEFT circuit breaker on panel O14 and the MN B DDU LEFT circuit breaker on panel O15. The pilot's DDU is powered from the MN B DDU RIGHT circuit breaker on panel O15 and the MN C DDU RIGHT circuit breaker on panel O16. The aft flight station DDU is powered from the MN A DDU AFT circuit breaker on panel O14 and the MN C DDU AFT circuit breaker on panel O16.



MN A DDU Circuit Breakers on Panel O14



MN B DDU Circuit Breakers on Panel O15



MN C DDU Circuit Breakers on Panel O16

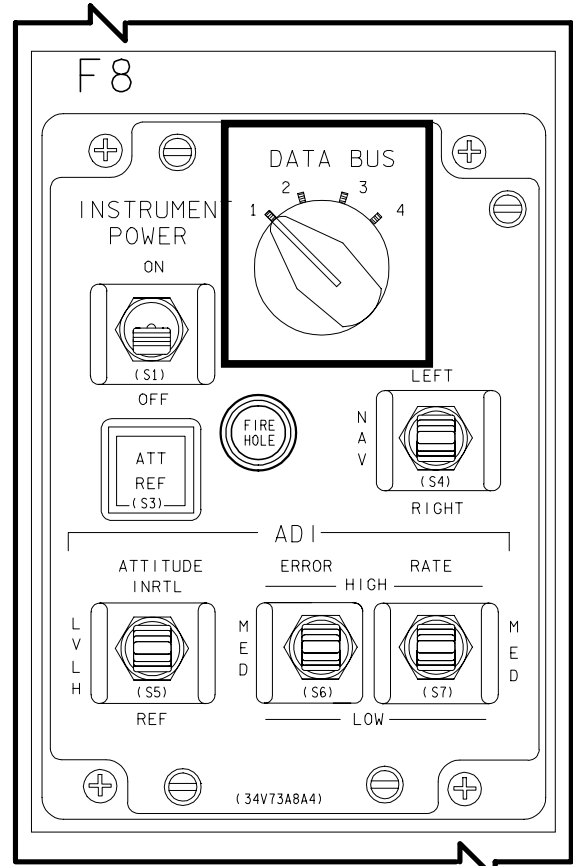
### Non-MEDS

In addition to providing flight control power in the non-MEDS cockpit, the DDU connects the GPCs and the primary flight displays, and powers the ADIs. The DDU receives data signals from the computers and decodes them to drive the dedicated displays. It contains logic for setting flags on the dedicated instruments for such items as data dropouts and sensor failures. The ADIs are powered through power supply D in the DDU.

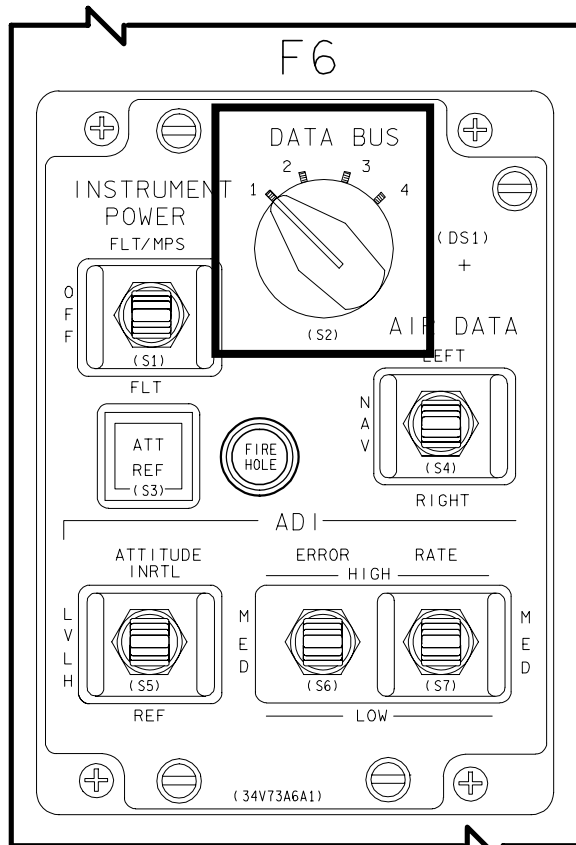
All display parameters, regardless of their origin, are ultimately processed through the dedicated display subsystem operating program (SOP) software (except the G-meter, which is totally self-contained). The display parameters are then routed to the respective displays through either a DDU or multiplexer/demultiplexer (MDM); DDUs

send data to the ADI, HSI, AMI, and AVVI displays; MDMs provide data for the SPI and reaction control system activity lights. In addition, the HUD electronic units generate video symbology for the head-up display.

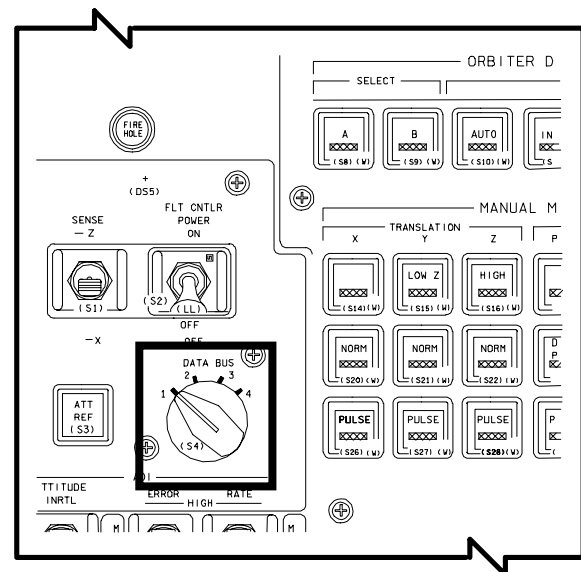
Each DDU has an associated DATA BUS rotary switch. The commander's switch is on panel F6 and the pilot's is on panel F8. The switch for the aft flight station is on panel A6U. Switch positions 1, 2, 3, and 4 allow the flight crew to select any one of four forward flight-critical data buses (FC1 through 4) as the data source for that DDU and its dedicated displays. (Because the flight-critical data buses are assigned to specific orbiter GPCs, the DATA BUS select switch also provides a means of assessing the status of individual computers, if they are assigned to FC1, 2, 3, or 4. See Section 2.6 for detailed data bus information.)



**DATA BUS Switch on Panel F8  
(Non-MEDS)**



**DATA BUS Switch on Panel F6  
(Non-MEDS)**

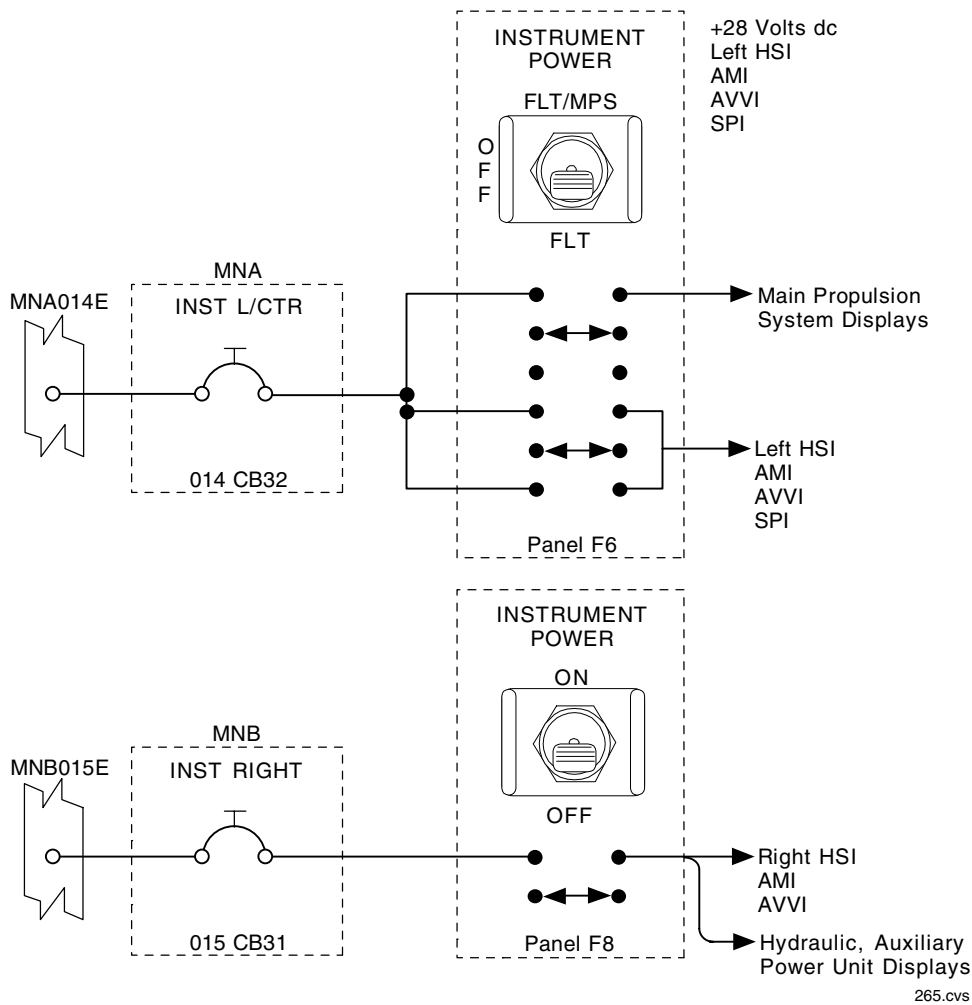


**DATA BUS Switch on Panel A6U  
(Non-MEDS)**



The *INSTRUMENT POWER* switch on panel F6 supplies main bus A power to the commander's HSI, AMI, and AVVI displays, the single SPI, and the main propulsion instruments when positioned to *FLT/MPS*. The *INSTRUMENT POWER* switch on panel F8 supplies main bus B power to the pilot's HSI, AMI, and AVVI displays and the hydraulic and auxiliary power unit displays. The switch on panel F8 is a two-position *ON/OFF* switch.

The reaction control system activity lights receive power from annunciator control assemblies.



**Power for Alpha/Mach Indicator, Altitude/Vertical Velocity Indicator, Horizontal Situation Indicator, and Surface Position Indicator (Non-MEDS)**

**MEDS**

In the MEDS system, the DDU only provides flight control power. The integrated display processors (IDPs) handle all the flight-critical (FC) bus data used to drive the flight instrument displays on their commanded multifunction display units (MDUs).

*Selecting a Flight-Critical Data Bus*

The data bus select menu allows the user to select the FC bus (1 - 4) that will be used for the flight instrument displays for that MDU. This selection was previously done via the rotary switch on panels F6, F8, and A6. The MEDS software follows two rules when a data bus is selected for an MDU.

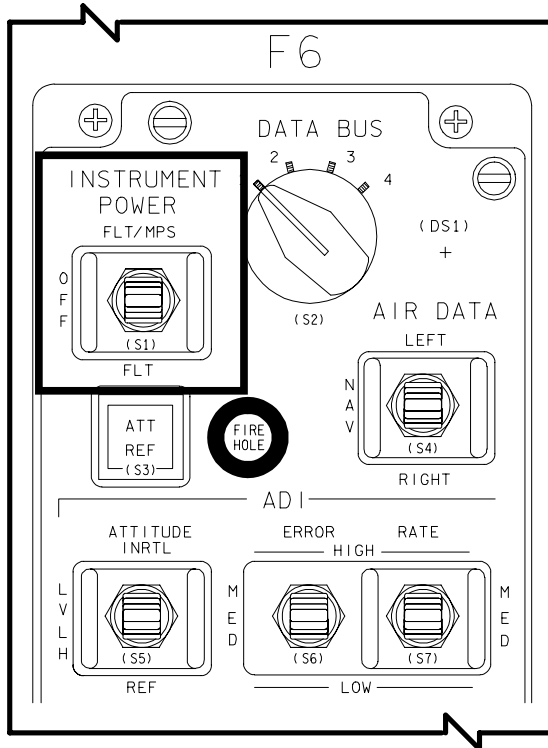
- Each IDP can support up to two different FC data bus selections.
- Each IDP supports only one FC bus selection for each crew station (CDR, PLT, and aft).

If the data bus selected for an MDU violates one of these rules, other MDUs that are displaying flight instrument displays and that are being driven by this same IDP will also change their FC data bus selection.

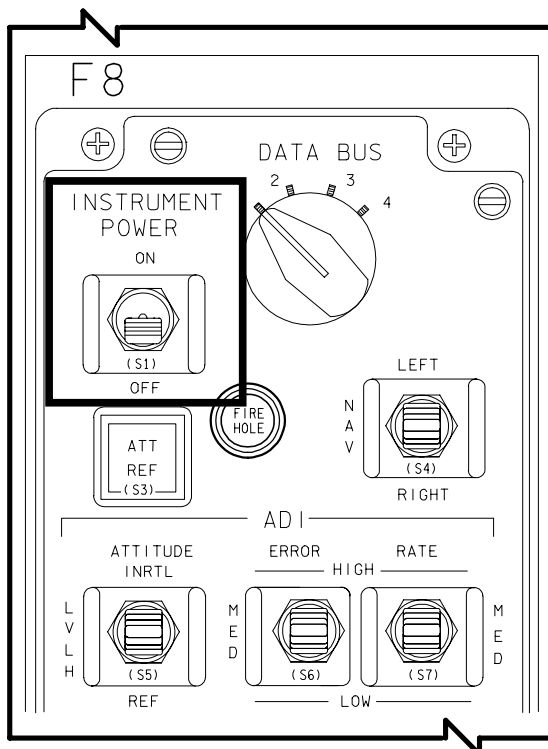
To select a different FC data bus, the user must go to either the ascent/entry flight instrument submenu or the orbit flight instrument submenu. The user can select the DATA BUS option via the edgekeys. The MDU retains the current MEDS display, but a new submenu appears and allows the user to select FC1, 2, 3, or 4 via the edgekey.

**NOTE**

Although all displays indicate a FC bus, it is only meaningful on the flight instrument displays. Additionally, because the FC data buses are assigned to specific orbiter GPCs, the selection of an FC bus to drive a flight instrument display also provides a means of assessing the status of individual computers, if they are assigned to FC1, 2, 3, or 4. See Section 2.6 for detailed data bus information.



**INSTRUMENT POWER Switch on Panel F6  
(Non-MEDS)**



**INSTRUMENT POWER Switch on Panel F8  
(Non-MEDS)**

## Attitude Director Indicator (ADI)

The ADIs give the crew attitude information as well as attitude rate and attitude errors, which can be read from the position of the pointers and needles. The ADI can be viewed on the ADI/AVVI, orbit ADI, and composite flight instrument displays identically.

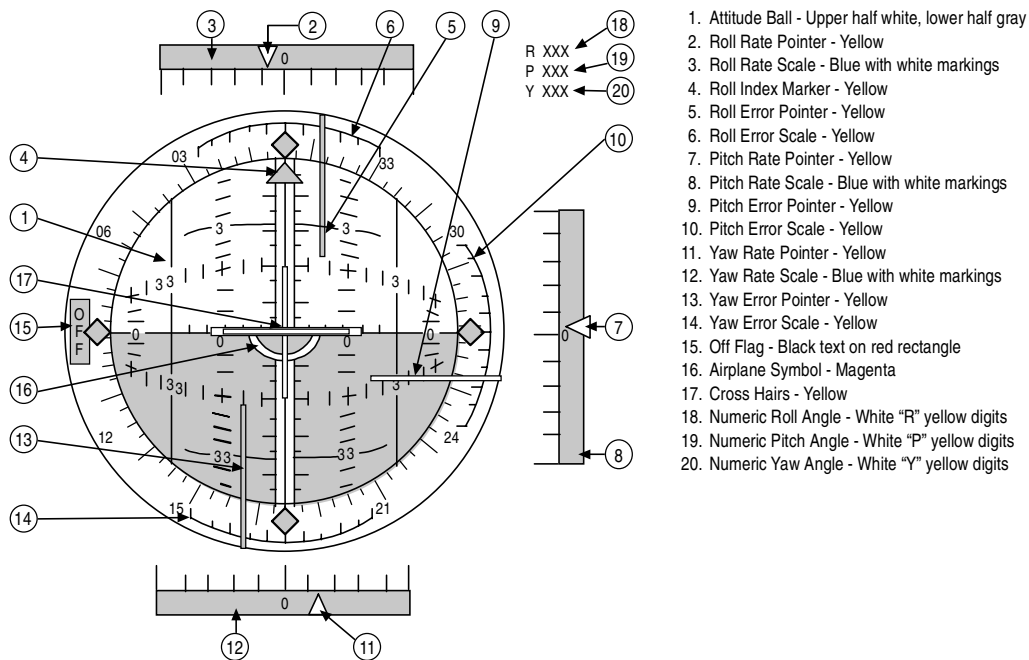
The commander's and pilot's ADIs (supported by IDPs 1, 2, and 3 in MEDS) are supported throughout the mission; the aft ADI (supported by IDP 4 in MEDS) is active only during orbital operations.

The orbiter's attitude is displayed to the flight crew by an enclosed ball (sometimes called the eight ball) that is gimballed to represent three degrees of freedom. The ball, covered with numbers indicating angle measurements (a 0 is added as the last digit of each), moves in response to software-generated commands to depict the current orbiter attitude in terms of pitch, yaw, and roll.

Each attitude director indicator has a set of switches by which the crew can select the mode

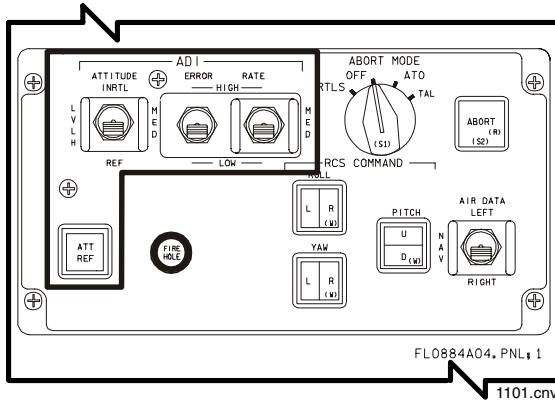
or scale of the readout. The commander's switches are located on panel F6, the pilot's on panel F8, and the aft switches on panel A6U.

The *ADI ATTITUDE* switches determine the unit's frame of reference: *INRTL* (inertial), *LVLH* (local vertical/local horizontal), and *REF* (reference). The *INRTL* position allows the flight crew to view the orbiter's attitude with respect to the inertial reference frame, useful in locating stars. The *LVLH* position shows the orbiter's attitude from an orbiter-centered rotating reference frame with respect to Earth. The *REF* position is primarily used to see the orbiter's attitude with respect to an inertial reference frame defined when the flight crew last depressed the *ATT REF* pushbutton above the *ADI ATTITUDE* switch. The *REF* position is useful when the crew flies back to a previous attitude or monitors an OMS burn for attitude excursions. The switches on panels F6 and F8 are active during ascent, orbital, and transition flight phases but have no effect during entry, the latter part of a return to launch site, or when the backup flight system is driving the attitude director indicators. The switch on panel A6U, like the aft ADI, is operational only in orbit.

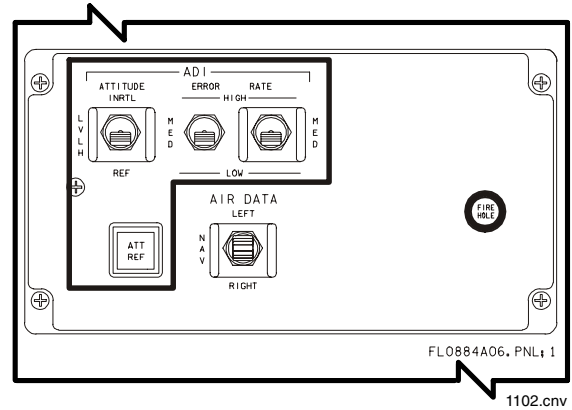


sfoc\_scom\_s2.7\_1108.cnv

Attitude Director Indicator



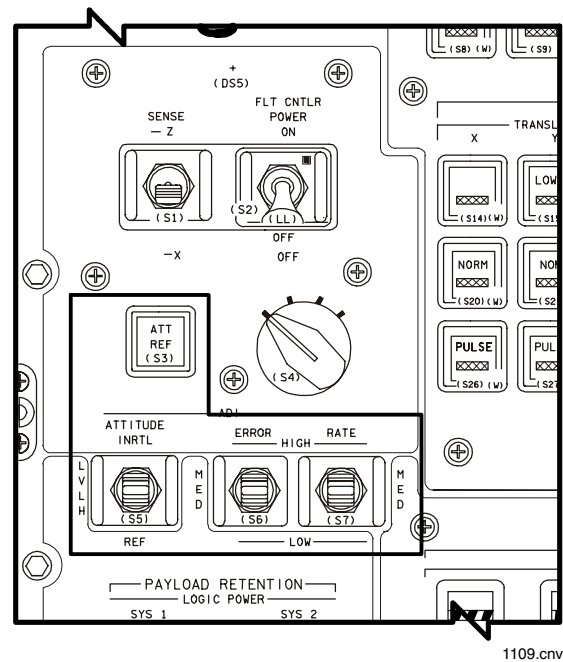
**Commander's ADI Switches and ATT REF Pushbutton on Panel F6**



**Pilot's ADI Switches and ATT REF Pushbutton on Panel F8**

Each attitude director indicator has a set of three rate pointers that provide a continuous readout of vehicle body rotational rates. Roll, pitch, and yaw rates are displayed on the top, right, and bottom pointers, respectively. The center mark on the graduated scale next to the pointers shows zero rates; the rest of the marks indicate positive (right or up) or negative (left or down) rates. The *ADI RATE* switch for each indicator unit determines the magnitude of full-scale deflection. When this switch is positioned to *HIGH* (the coarsest setting), the pointer at the end of the scale represents a rotation rate of 10° per second. When the switch is positioned to *MED*, a full-range deflection represents 5° per second. In the *LOW* position (the finest setting), a pointer at either end of the scale is read at a rate of 1° per second. These pointers are “fly to” in the sense that the rotational hand controller must be moved in the same direction as the pointer to null a rate.

Attitude director indicator rate readings are independent of the selected attitude reference. During ascent, the selected rates come directly from the solid rocket booster or orbiter rate gyros to the attitude director indicator processor for display on the rate pointers. During entry, only the pitch rate follows the direct route to the attitude director indicator display. The selected roll and yaw rates first flow through flight control, where they are processed and output to the attitude director indicator as stability roll and yaw rates. (This transformation is necessary because, in aerodynamic flight, control is achieved about stability axes, which in the cases of roll and yaw differ from body axes.) The rate



**Aft ADI Switches and ATT REF Pushbutton on Panel A6U**

needles strictly display vehicle rate information in all major modes, except while in TAEM (MM 305, 603). For ascent, orbit, and most of entry, the HIGH position represents 10° per second, MED represents 5° per second, and LOW represents 1° per second. During TAEM, the ADI rate needles can be used to help fly the proper HAC profile as long as the rate switch is in MED (see table A).

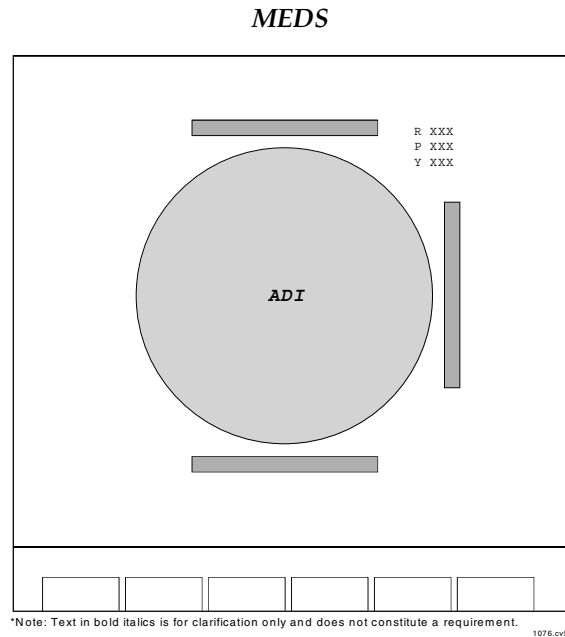
In addition to the rate needles, there are three needles on each attitude director indicator that display vehicle attitude errors. These needles extend in front of the ADI ball, with roll, pitch, and yaw arranged just as the rate pointers are. Like the rate indicators, each error needle has an arc-shaped background scale with graduation marks that allow the flight crew to read the magnitude of the attitude error. The errors are displayed with respect to the body axis coordinate system and, thus, are independent of the selected reference frame of the attitude display.

The ADI error needles are driven by flight control outputs that show the difference between the required and current vehicle attitude. These needles are also “fly to,” meaning that the flight crew must maneuver in the direction of the needle to null the needle. For example, if the pitch error needle points down, the flight crew must manually pitch down to null the pitch attitude error. The amount of needle deflection indicating the number of degrees of attitude error depends upon the position of the *ADI ERROR RATE* switch for each attitude director indicator and the flight phase. For ascent, orbit, and transition, in the *HIGH* position, the error needles represent 10°, *MED* represents 5°, and *LOW* represents 1°. For entry, the needles signify different errors in different phases (see table B).

The *SENSE* switch on panel A6U allows the flight crew to use the aft ADI, rotational hand controller, and translational hand controller in a minus X or minus Z control axis sense. These two options of the aft ADI and hand controllers

correspond to the visual data out of the aft viewing (negative X) or overhead viewing (negative Z) windows.

Each ADI has a single flag labeled *OFF* on the left side of the display whenever any attitude drive signal is invalid. There are no flags for the rate and error needles; these indicators are driven out of view when they are invalid.



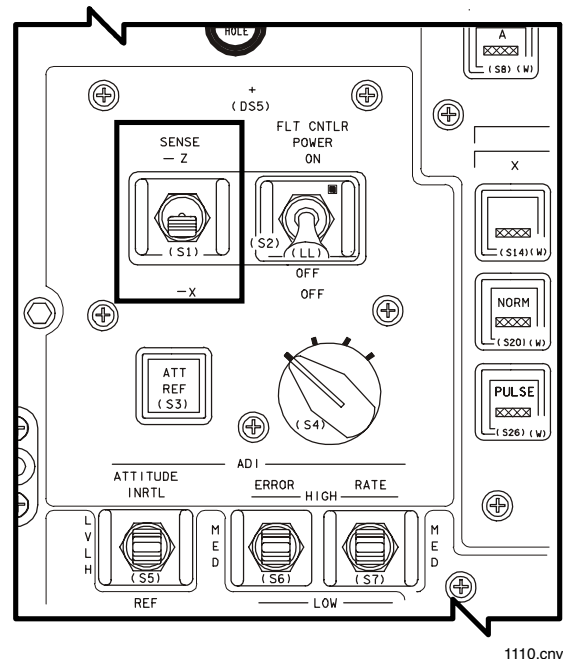
### Orbit ADI Display

The ADI can be viewed on the ADI/AVVI, orbit ADI, and composite flight instrument displays. In addition to the graphical representation of the ADI ball, the MEDS display shows a digital readout of the current roll, pitch, and yaw in degrees.

MISSION PHASE		ROLL	PITCH	YAW
Ascent	(101-106, 601)			
On-orbit	(201, 202, 801)			
Transition/entry	(301-304, 602)	(deg/s)	(deg/s)	(deg/s)
High		10	10	10
Medium		5	5	5
Low		1	1	1
TAEM to HAC intercept	(305, 603)			
High		10 (deg/s)	10 (deg/s)	10 (deg/s)
Medium		Time to HAC intercept (10 sec)	Time to HAC intercept (10 sec)	Time to HAC intercept (10 sec)
Low		1 (deg/s)	1 (deg/s)	1 (deg/s)
HAC intercept to prefinal	(305, 603)			
High		10 (deg/s)	10 (deg/s)	10 (deg/s)
Medium		Stowed	Altitude error (±5000 feet)	Altitude error (±5000 feet)
Low		1 (deg/s)	1 (deg/s)	1 (deg/s)
Prefinal to 7000 ft	(305, 603)			
High		10 (deg/s)	10 (deg/s)	10 (deg/s)
Medium		Stowed	Altitude error (±1000 feet)	Altitude error (±1000 feet)
Low		1 (deg/s)	1 (deg/s)	1 (deg/s)
7000 ft to landing	(305, 603)	(deg/s)	(deg/s)	(deg/s)
High		10	10	10
Medium		5	5	5
Low		1	1	1

(A)  
ADI Rate Switch vs. Full Range Deflection

MISSION PHASE		ROLL	PITCH	YAW
Ascent/	(101-106, 601)			
On orbit	(201, 202, 801)			
Transition	(301, 303)	(Deg)	(Deg)	(Deg)
High		10	10	)
Medium		5	5	10
Low		1	1	5
				1
ENTRY (MM 304, 602)		(Deg)	(Deg)	(Deg)
High		25	10	)
Medium		25	5	2.5
Low		10	1	2.5
				2.5
MM 603 IPH = 4.6				
TAEM (MM 305, 603)		(Deg)	(g's)	(Deg)
High		25	1.25	)
Medium		25	1.25	2.5
Low		10	0.5	2.5
				2.5
IPH ≠ 4,5 WOWLON = 0				
WOWLON = 1				
Rollout (MM 305, 603)		(Deg)	(Deg/s)	(Deg)
High		20	10	)
Medium		5	5	2.5
Low		1	1	2.5
				2.5



SENSE Switch on Panel A6U

(B)  
ADI Error Switch vs. Full Range Deflection

## Horizontal Situation Indicator (HSI)

The HSI displays a pictorial view of the vehicle's position with respect to various navigation points and shows a visual perspective of certain guidance, navigation, and control parameters, such as direction, distance, and course/glide path deviation. The flight crew uses this information to control or monitor vehicle performance. The HSIs are active during the entry and landing and ascent/return to launch site phases. The HSI is available on the HSI/AMI and composite flight instrument displays (MEDS) or on panels F6 and F8 (non-MEDS).

Each horizontal situation indicator provides an independent source to compare with ascent and entry guidance, a means of assessing the health of individual navigation aids during entry, and information needed by the flight crew to fly manual ascent, return to launch site, and entry.

### HSI Ascent Displays

During ascent major modes 102 and 103 (first and second stage) and return to launch site, the horizontal situation indicator provides information about the target insertion orbit. The compass card displays heading with respect to target insertion orbit, and north on the compass card points along the target insertion orbit plane. The heading of the body plus X axis with respect

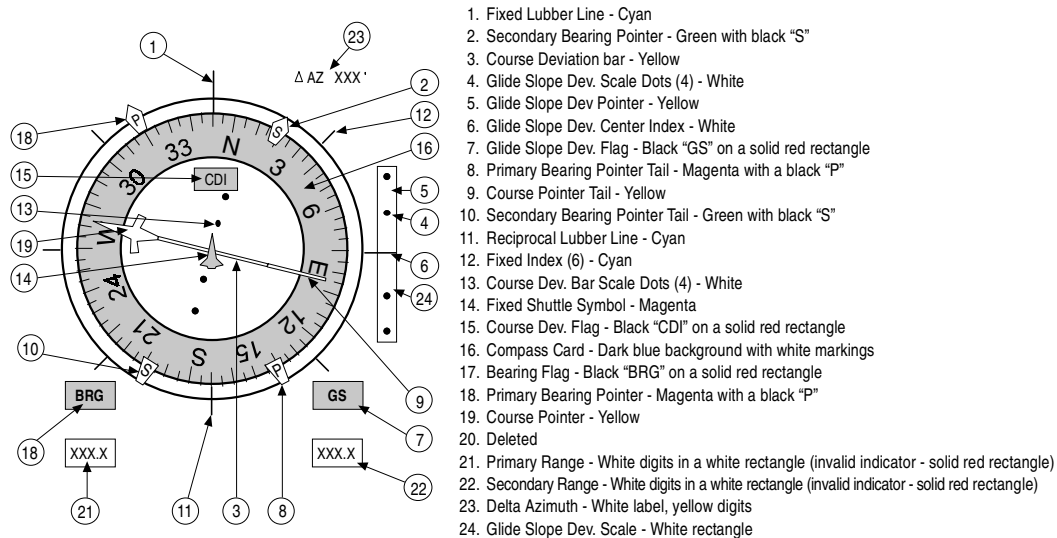
to the target insertion orbit is read at the lubber line.

The course pointer provides the heading of the Earth-relative velocity vector with respect to the target insertion orbit plane. The course deviation indicator deflection indicates the estimated sideslip angle, the angle between the body X axis and the relative velocity vector.

The primary bearing pointer during major modes 102 and 103 (pre-TAL abort) is fixed on the compass card at a predetermined value to provide a turnaround heading in the event of a return to launch site (RTLS) abort. During RTLS major mode 601, or post-TAL abort, MM103, the pointer indicates the heading to the landing site runway. The secondary bearing pointer provides the heading of the inertial velocity vector with respect to the target insertion orbit plane.

### HSI Entry Displays

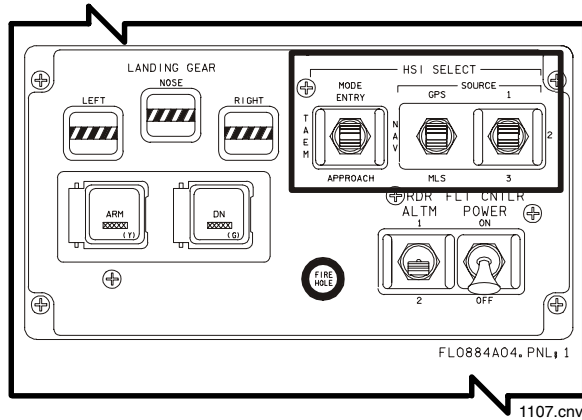
The commander's horizontal situation indicator switches are on panel F6, and the pilot's are on panel F8; however, for MEDS, these switches are the same on both panels. The *HSI SELECT MODE* switch selects the mode: *ENTRY*, *TAEM*, or *APPROACH*. These Area Navigation modes are different from the Guidance phases with virtually identical names (Entry, TAEM, and Approach and Landing). The *ENTRY* position enables HSI mode auto switching from Entry



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## Horizontal Situation Indicator

through Approach. The *HSI SELECT SOURCE* switch selects TACAN, navigation, or microwave scanning beam landing system (MLS); the 1, 2, 3 switch selects one of the three TACAN or MLS units. When the *HSI SELECT SOURCE* switch is positioned to *NAV*, the HSI is supplied with data from the navigation processor, and the 1, 2, 3 switch is not used.



**HSI SELECT Switches on Panel F6  
 and Panel F8**

*SOURCE* switch selects TACAN, navigation, or MLS; the 1,2,3 switch selects one of the three TACAN or MLS units. When the *HSI SELECT SOURCE* switch is positioned to *NAV*, the HSI is supplied with data from the navigation processor, and the 1,2,3 switch is not used.

In *TACAN* or *MLS*, the horizontal situation indicator is supplied with data derived from the unit specified by the 1, 2, 3 switch.

### HSI Display Parameters

Each horizontal situation indicator displays magnetic heading (compass card), selected course, runway magnetic heading, course deviation, glideslope deviation, primary and secondary bearing, primary and secondary range, and flags to indicate validity.

Each horizontal situation indicator consists of a case-enclosed compass card measuring 0° to 360°. At the center of the card is an aircraft symbol, fixed with respect to the case and about which the compass card rotates.

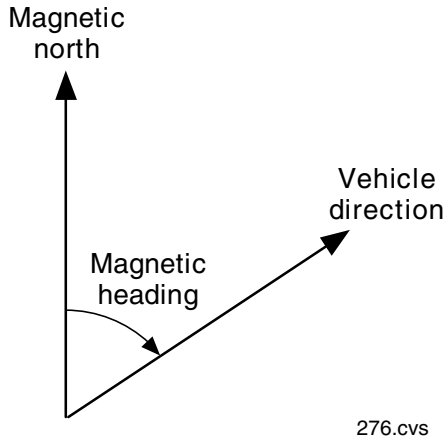
The magnetic heading (the angle between magnetic north and vehicle direction measured clockwise from magnetic north) is displayed by the compass card and read under the lubber line

located at the top of the indicator dial. (A lubber line is a fixed line on a compass aligned to the longitudinal axis of the craft.) The compass card is positioned at 0° (north) when the heading input is zero. When the heading point is increased, the compass card rotates counterclockwise.

The course pointer is driven with respect to the horizontal situation indicator case rather than the compass card. Therefore, a course input (from the display driver unit) of zero positions the pointer at the top lubber line, regardless of compass card position. To position the course pointer correctly with respect to the compass card scale, the software must subtract the vehicle magnetic heading from the runway azimuth angle (corrected to magnetic north). As this subtraction is done continuously, the course pointer appears to rotate with the compass card, remaining at the same scale position. An increase in the angle defining runway heading results in a clockwise rotation of the course pointer.

Course deviation is an angular measurement of vehicle displacement from the extended runway centerline. On the HSI, course deviation is represented by the deflection of the deviation bar from the course pointer line. Full scale on the course deviation scale is ±10° in terminal area energy management and ±2.5° during approach and landing. The course deviation indicator is driven to zero during entry. When the course deviation input is zero, the deviation bar is aligned with the end of the course pointer. With the pointer in the top half of the compass card, an increase in course deviation to the left (right) causes the bar to deflect to the right (left). Therefore, the course deviation indicator is a fly-to indicator for flying the vehicle to the extended runway centerline. Software processing also ensures that the course deviation indicator remains fly to, even when the orbiter is heading away from the runway.





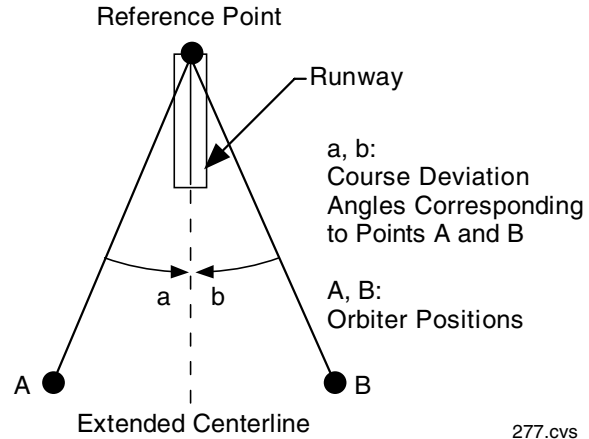
276.cvs

### Horizontal Situation Indicator Heading Geometry

In course deviation geometry, if the orbiter is to the left of the runway, it must fly right (or if the orbiter is to the right of the runway, it must fly left) to reach the extended runway centerline. The corresponding course deviation bar would deflect to the right (or to the left in the latter case). The reference point at the end of the runway is the microwave landing system station. The sense of the course deviation indicator deflection is a function of vehicle position rather than vehicle heading.

Glideslope deviation, the distance of the vehicle above or below the desired glideslope, is indicated by the deflection of the glideslope pointer on the right side of the horizontal situation indicator. An increase in glideslope deviation above (below) the desired slope deflects the pointer downward (upward); the pointer is a fly-to indicator.

The "desired glideslope" is actually only a conceptual term in horizontal situation indicator processing. At any instance, glideslope deviation is really the difference between the orbiter altitude and a reference altitude computed by Area Nav. This reference altitude may be slightly different than the reference altitude computed by Guidance. Also included in the reference altitude equation are factors for a "heavy orbiter" and for high winds.



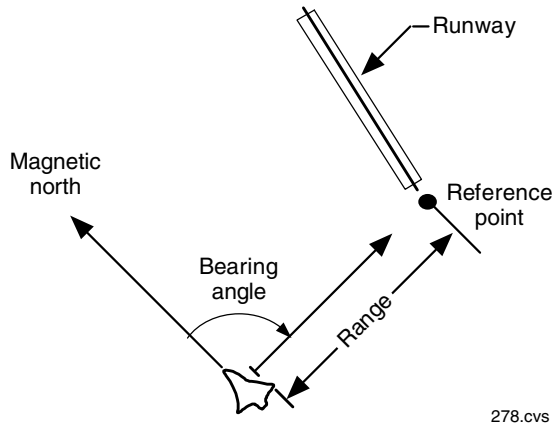
277.cvs

### Course Deviation Geometry

The glideslope indicator computation is not made during entry or below 1,500 feet during approach and landing; therefore, the pointer is stowed, and the glideslope indicator flag is displayed during those intervals.

The primary and secondary bearing pointers display bearings relative to the compass card. These bearings are angles between the direction to true or magnetic north and to various reference points as viewed from the orbiter. For the bearing pointers to be valid, the compass card must be positioned in accordance with vehicle heading input data.

When the bearing inputs are zero, the pointers are at the top lubber line, regardless of compass card position. Like the course pointer, the bearing pointer drive commands are developed by subtracting the vehicle heading from the calculated bearing values. This allows the pointers to be driven with respect to the horizontal situation indicator case but still be at the correct index point on the compass card scale.



### Horizontal Situation Indicator Bearing and Range Geometry

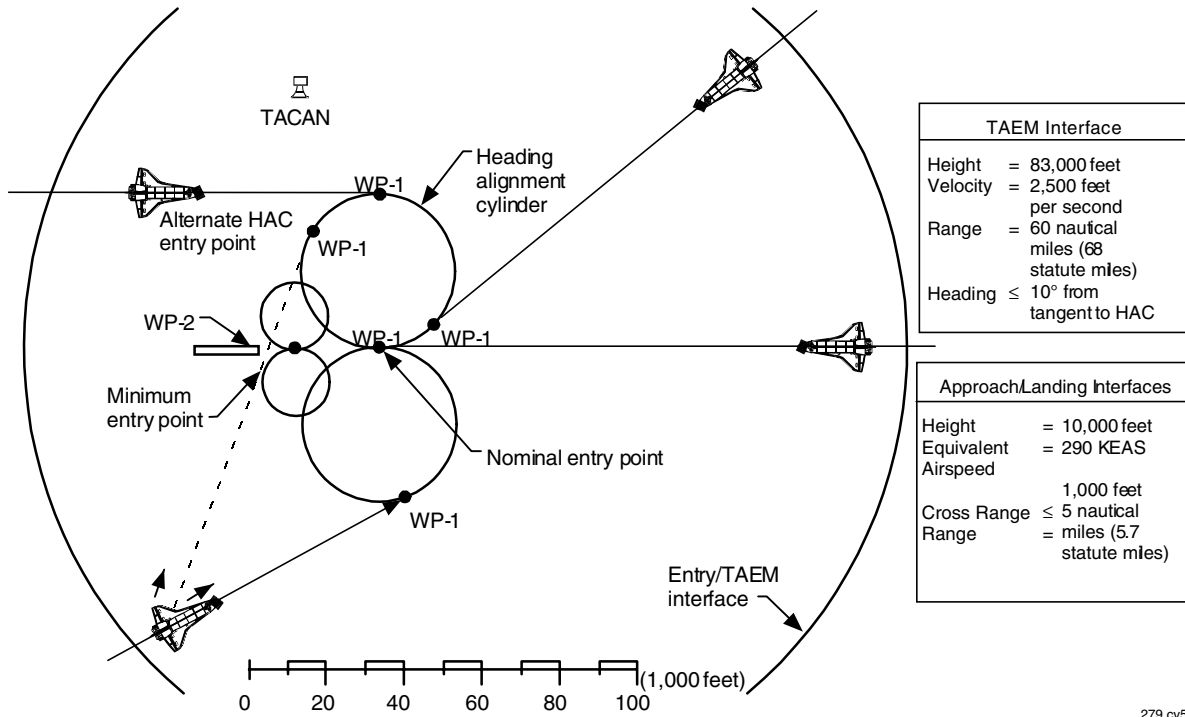
When the bearing inputs are increased, the pointers rotate clockwise about the compass card. The pointer does not reverse when it passes through 360° in either direction.

For example, if the primary bearing is 190°, and the secondary bearing is 245°, the bearing reciprocals are always 180° from (opposite) the pointers. The definition of primary and secondary bearing varies with the flight regime.

The horizontal situation indicator is capable of displaying two four-digit values in the upper left (primary range) and right (secondary range) side of its face. Each display ranges from zero to 3,999 n. mi. (4,602 statute miles). Although their meaning depends on the flight regime, both numbers represent range in nautical miles (n. mi.) from the vehicle to various points relative to the primary and secondary runways.

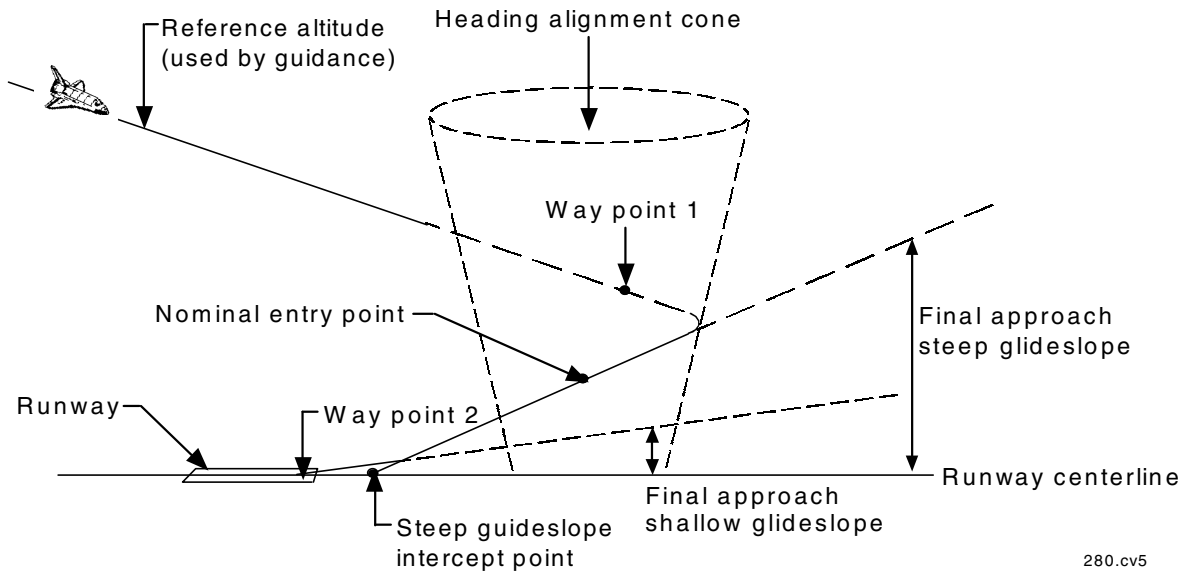
The horizontal situation indicator has four flags – *OFF*, *BRG* (bearing), *GS* (glideslope), and *CDI* – and two barberpole indications that can respond to separate display driver unit commands, identifying invalid data. *OFF* indicates that the entire horizontal situation indicator display is invalid because of insufficient power. *BRG* indicates invalid course, primary bearing, and/or secondary bearing data. *GS* indicates invalid glideslope deviation. *CDI* indicates invalid course deviation data. Barberpole in the range slots indicates invalid primary or secondary range data.

When the *HSI SELECT SOURCE* switch on panel F6 or F8 is positioned to *NAV*, the entire horizontal situation indicator display is driven by navigation-derived data from the orbiter state vector. This makes the horizontal situation indicator display dependent on the same sources as the navigation software (IMU, selected air data, selected navigational aids), but the display is independent of guidance targeting parameters. When the switch is in the *NAV* position, the *SOURCE 1, 2, 3* switch is not processed.



HSI Flight Path Geometry-Top View

279.cv5



HSI Flight Path Geometry-Side View

280.cv5

The *TACAN* or *MLS* position of the *HSI SELECT SOURCE* switch should be used only when *TACAN* or microwave landing system data are available. *TACAN* data are used during entry to update the navigation state, and are usually acquired about 300 n. mi. from the landing site. *MLS* has a range of 20 n. mi. and would be selected after the orbiter is on the heading alignment cone.

The glideslope deviation pointer is stowed when the entry mode is selected, and the off flag is displayed. The glideslope indicator in *TAEM* indicates deviations from the guidance reference attitude  $\pm 5,000$  feet. The glideslope indicator during approach and landing indicates guidance reference altitude  $\pm 1,000$  feet. The glideslope indicator is stowed below 1,500 feet and the off flag is in view.

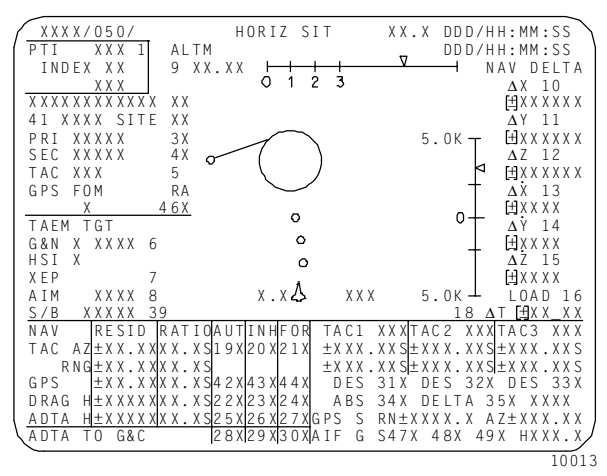
In the entry mode, the compass card heading indicates the magnetic heading of the vehicle's relative velocity vector. In terminal area energy management and approach, the compass card indicates magnetic heading of the body X axis.

In the entry mode, the course deviation indicator is driven to zero with no flag. In terminal area energy management, the course deviation indicator indicates the deviation from the extended runway centerline,  $\pm 10^\circ$ . In approach, the course deviation indicator indicates the deviation from the extended runway centerline,  $\pm 2.5^\circ$ .

In the entry mode, the primary bearing indicates the great circle bearing to the heading alignment cone (HAC) tangency point (way point 1) for the nominal entry point at the selected landing runway. The secondary bearing provides identical data relevant to the secondary landing runway. In terminal area energy management (*TAEM*), the primary bearing indicates the bearing to way point 1 on the selected HAC for the primary runway while the secondary bearing indicates the center of the HAC for the primary runway. In approach, the primary and secondary bearings indicate the bearing to the touchdown point at the primary runway (way point 2).

In the entry mode, the primary range indicates the spherical surface range to way point 1 for the primary runway via the HAC for the nominal entry point. The secondary range

provides identical information relevant to the secondary runway. In *TAEM*, the primary range indicates the horizontal distance to way point 2 on the primary runway via way point 1. The secondary range indicates the horizontal distance to the center of the selected HAC. In approach, the primary and secondary ranges indicate the horizontal distance to way point 2 on the primary runway.



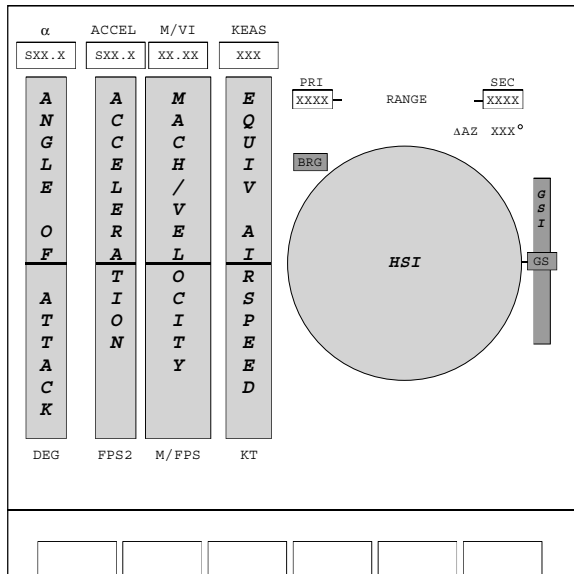
### HORIZ SIT Display (SPEC 50)

The HORIZ SIT display (SPEC 50) allows the flight crew to configure the software for nominal winds or high head winds. The "XEP" item 7 entry determines the distance from the runway threshold to the intersection of the glideslope with the runway centerline or aim point. The high-wind aim point or close in aim point pushes the intercept point closer to the threshold. The distance selected is factored into the computation of reference altitude from which the glideslope deviation is derived.

### MEDS

The HSI can be viewed on the HSI/AMI display and on the Composite flight instrument display. The Composite display cuts off the bottom portion of the HSI. There are a few differences in the mechanical and MEDS versions of the HSI:

- The MEDS displays show a digital IDP calculated  $\Delta$  azimuth (also known as DEL AZ). DEL AZ is discussed in detail in Section 7.3.



\*Note: Text in bold italics is for clarification only and does not constitute a requirement. 1073.cvs

### HSI/AMI Display

- The PRI and SEC range are displayed with a decimal to show tenths of a mile, when applicable. The labels of the PRI and SEC ranges change to 'P-RWY' and 'P-RWY' during entry, 'P-RWY' and 'HAC-C' during TAEM, 'P-RWY' and 'P-RWY' during A/L, and PRI and SEC if the HSI mode flag is invalid or out of range.
- There is no HSI off flag for MEDS.

### Alpha/Mach Indicator

The alpha/Mach indicators consist of four tape meters displaying angle of attack (*ALPHA*), vehicle acceleration (*ACCEL*), vehicle velocity (*M/VEL*), and equivalent airspeed (*EAS*). The AMI is available on the HIS/AMI and Composite flight instrument displays (MEDS) and on panels F6 and F8 (non-MEDS).

*ALPHA* displays vehicle angle of attack, defined as the angle between the vehicle plus X axis and the wind-relative velocity vector (negative wind vector). *ALPHA* is displayed by a combination moving scale and moving pointer. For alphas between 43° to 58° and -4° to -18°, the tape has a yellow background with black markings. For alphas between 58° to 60°, the background color is red. The *ALPHA* tape ranges from -18° to

+60° with no scale changes. The tape has black markings on a white background on the positive side, and white markings on a gray background on the negative side for the nominal range of alpha. In MEDS, below Mach 3.0, a black diamond indicating a maximum lift-over-drag (max L/D) index is displayed. Below Mach 2.5, a green bar depicts the range of allowable max/min alphas.

The *ACCEL* scale displays vehicle drag acceleration, which is acceleration in the normal axis, or total load factor. This is a moving tape upon which acceleration is read at the fixed lubber line. The tape range is -5 to +10 g's. Minus signs are displayed on the *ACCEL* scale also; the negative region has a black background and the positive side has a white background. (Normal acceleration and total load factor are measured in g's.)

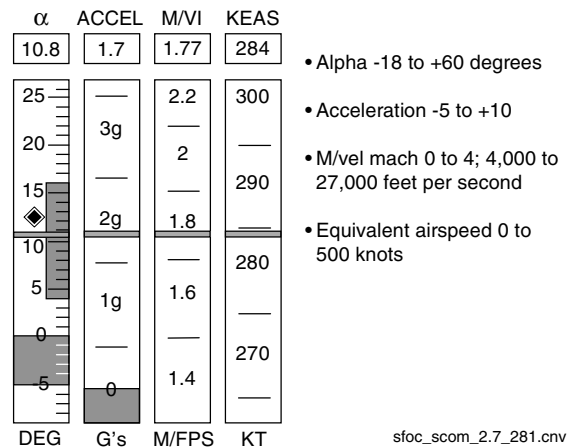
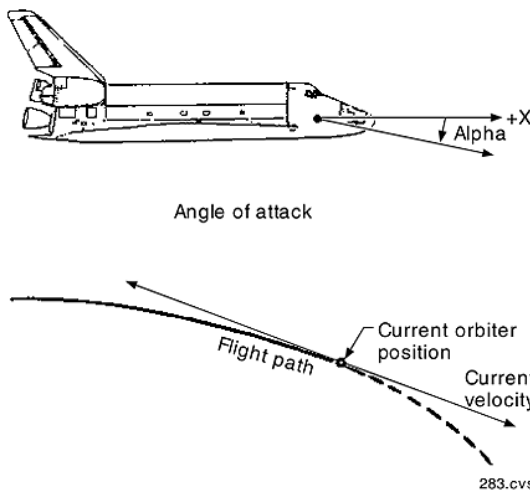
The *M/VEL* scale displays one of the following: Mach number, relative velocity, or inertial velocity. Mach number is the ratio of vehicle airspeed to the speed of sound in the same medium. The relative velocity is in feet per second in relation to the launch site. Inertial velocity is in feet per second and does not consider the rotational speed of the surface. The actual parameter displayed is always Mach number; the tape is simply rescaled above Mach 4 to read relative velocity (MM 102, 304, 305, 602, 603) or inertial velocity (MM 103, 601). The scale ranges from zero to 27, with a scale change at Mach 4.

The *EAS* scale is used to display equivalent airspeed. On the moving-tape scale, equivalent airspeed is read at the fixed lubber line. The tape range is zero to 500 knots, and scaling is 1 inch per 10 knots.

In the non-MEDS cockpit, each scale on the AMI displays an *OFF* flag if the indicator malfunctions, invalid data are received at the display driver unit, or a power failure occurs (all flags appear). The *ACCEL* tape is labeled fps<sup>2</sup>; however, the acceleration is displayed in g's x 10. In MEDS, off indications (empty, red, outlined boxes) are driven if the IDP receives no data, or invalid data for display on the AMI.

HSI Mode	Bearing		Range		Course Deviation (CDI)	Glide Slope Deviation (GSI)	Compass Card (Heading)
	Primary	Secondary	Primary	Secondary			
Entry	Spherical bearing to WP-1 for NEP at <u>primary</u> landing runway	Spherical bearing to WP-1 for NEP at <u>secondary</u> landing runway	Spherical surface range to WP-2 on <u>primary</u> runway via WP-1 for NEP	Spherical surface range to WP-2 on <u>secondary</u> runway via WP-1 for NEP	A valid software zero  (no flag)	GS pointer stowed; flag displayed	Magnetic heading of vehicle relative velocity vector
TAEM	Bearing to WP-1 on selected HAC for primary runway	Bearing to center of selected HAC for primary runway	Horizontal distance to WP-2 on primary runway via WP-2 for selected EP	Horizontal distance to center of selected HAC for primary runway	Deviation from extended runway centerline (full scale = $\pm 10^\circ$ )	Deviation from guidance reference altitude for TAEM (full scale = $\pm 5000$ ft)	Magnetic heading of body X-axis
Approach	Bearing to WP-2 at primary runway	Bearing to WP-2 at primary runway	Horizontal distance to WP-2 on primary runway	Horizontal distance to WP-2 on primary runway	Deviation from extended runway centerline (full scale = $\pm 2.5^\circ$ )	Deviation from guidance reference altitude for A/L (full scale = $\pm 1000$ ft) Not computed below 1500 ft, flag deploys	Magnetic heading of body X-axis

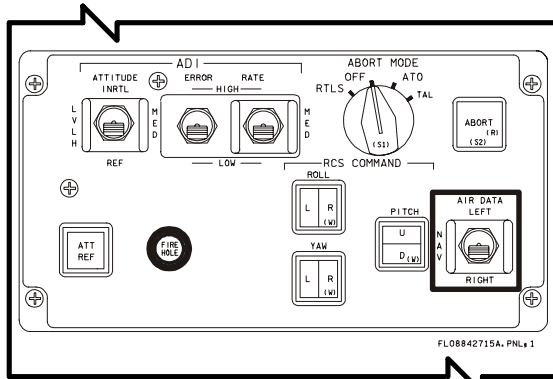
HSI Function Matrix



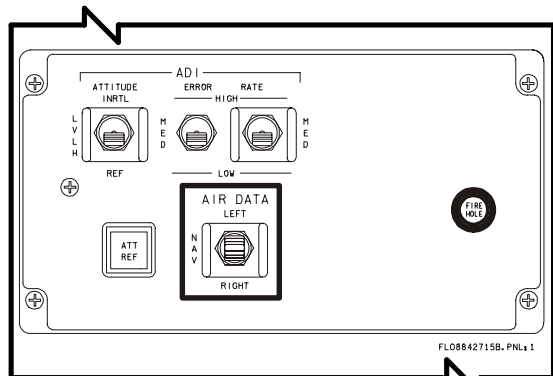
Alpha/Mach Indicator

The *AIR DATA* switch on panel F6 for the commander and panel F8 for the pilot determines the source of data for the alpha/Mach indicator and altitude/vertical velocity indicator. The *NAV* position of the *AIR DATA* switch displays the same parameters (*ALPHA*, *MACH*, and *EAS*) that are sent to guidance, flight control, navigation, and other software users; *ACCEL* comes from navigation software.

The *LEFT* and *RIGHT* positions of the *AIR DATA* switch select data from the left or right air data probe assembly after successful deployment of the left and right air data probes at Mach 5 for *ALPHA*, *M/VEL*, and *EAS* display. However, the data will not be accurate until the velocity is less than Mach 3.5, due to calibration of the probes. *ACCEL* is always derived from navigation software during entry. It is driven to zero during terminal area energy management and approach and landing.



**Commander's AIR DATA switch on Panel F6**



**Pilot's AIR DATA Switch on Panel F8**

**Altitude/Vertical Velocity Indicator**

The altitude/vertical velocity indicators (AVVIs) display vertical acceleration (*ALT ACCEL*), vertical velocity (*ALT RATE*), altitude (*ALT*), and radar altitude (*RDR ALT*). The AVVI is available on the ADI/AVVI and Composite flight instrument displays (MEDS), or panels F6 and F8 (non-MEDS).

The *ALT ACCEL* indicator, which displays altitude acceleration of the vehicle, is read at the intersection of the moving pointer and the fixed scale. The scale range is -10 to +10 ft/sec<sup>2</sup>

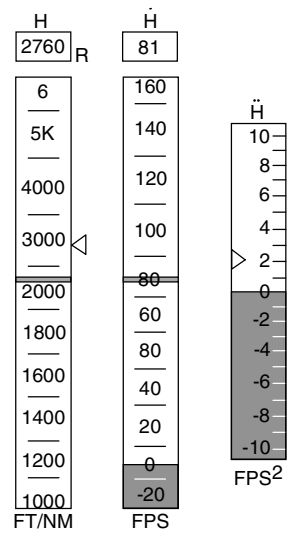
Software limits acceleration values to ±12.75 ft/sec<sup>2</sup>.

The *ALT RATE* scale displays vehicle altitude rate, which is read at the intersection of the moving tape and the fixed lubber line. The scale range is -3,000 to +3,000 feet per second with scale changes at -800 feet per second and +800 feet per second. The negative and positive regions are color-reversed: negative numbers are white on a gray background and positive numbers are black on white.

The *ALT* scale, a moving tape read against a fixed lubber line, displays the altitude of the vehicle above the runway (barometric altitude). The scale range is -1,100 feet to +165 n. mi., with scale changes at 0, 200, 2,000, 30,000, and +100,000 feet. The scale is in feet from -1,100 to +400,000 and in n. mi. from +67 to +165.

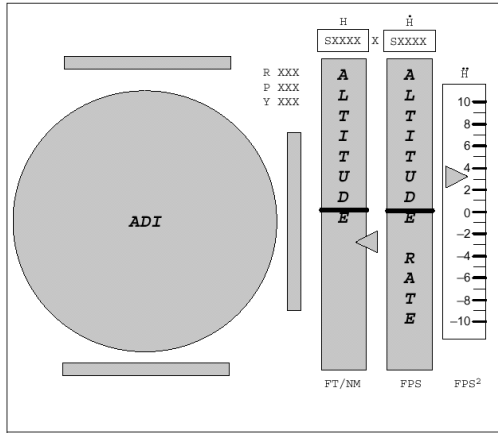
The altitude tape is gray with white markings for altitudes above 2,000 feet. The tape color is yellow for altitudes between 0 and 2,000 feet, and white for altitudes below 0 feet.

With the *AIR DATA* source switch in the *NAV* position, the *ALT ACCEL*, *ALT RATE*, and *ALT* scales are navigation-derived. The *RDR ALT* indicator is controlled by the *RADAR ALTM* switch on panel F6 for the commander and panel F8 for the pilot. *RADAR ALTM* positioned to 1 selects radar altimeter 1; 2 selects radar altimeter 2.



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**Altitude/Vertical Velocity Indicator**



ADI/AVVI Display

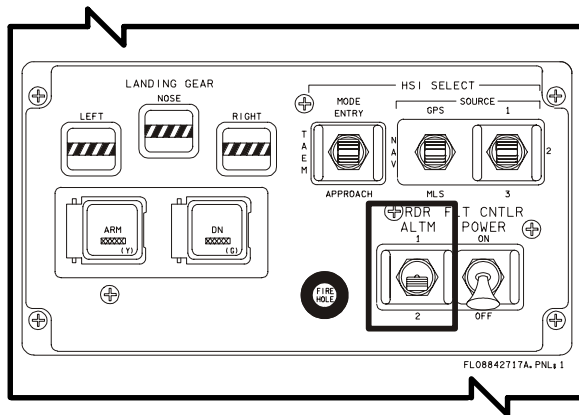
The *AIR DATA* switch is positioned to *LEFT* or *RIGHT* to select the left or right air data probe after air data probe deployment at Mach 5. The *ALT* and *ALT RATE* scales receive information from the selected air data probe. *ALT ACCEL* receives navigation data.

### Non-MEDS

In the non-MEDS system, the altitude and altitude acceleration tapes are swapped. The non-MEDS cockpit also has a dedicated tape to display radar altitude; it is located to the right of the altitude tape. No digital readouts of the tape value are displayed.

### MEDS

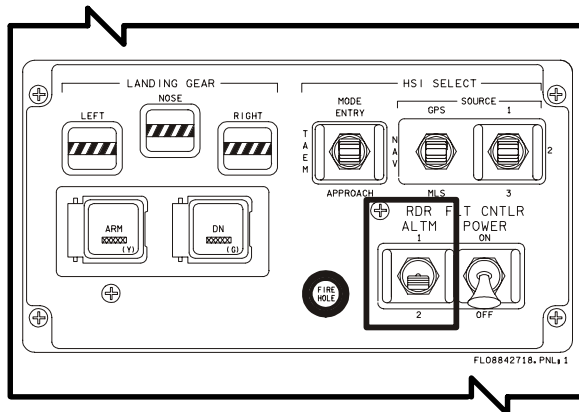
In the MEDS system, a digital readout of each tape value is provided. Also, radar altimeter (RA) data is shown on the altitude tape. When RA is locked on, an "R" appears to the right of the altitude digital, and the digital is driven by the RA data. A floating yellow triangle also appears to the right of the tape at the value of the RA altitude. If no RA is locked on, a "K," indicating thousands of feet, or an "M," indicating nautical miles may appear to the right of the altitude tape digital indicating the units. If the field is blank, no conversion is necessary.



Commander's RADAR ALTM Switch  
on Panel F6

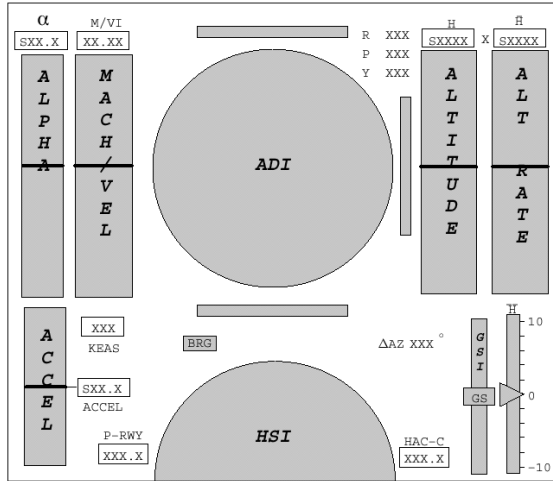
### Composite Flight Instrument Display

The composite ADI/HSI display is only available in MEDS. It contains both the ADI/AVVI and HSI/AMI displays. Due to space constraints, only the top portion of the HSI is shown. Equivalent air speed (EAS) is shown as a digital only (no tape) for most of the flight. On entry, when the vehicle slows to less than Mach 0.9, EAS and Mach swap places, displaying EAS as a tape and digital, and Mach as a digital only.

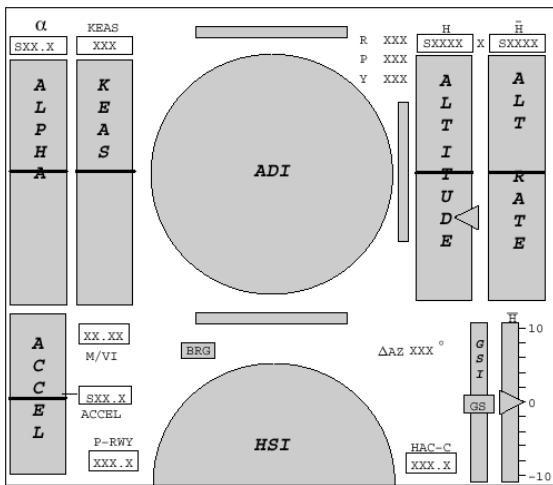


Pilot's RADAR ALTM Switch on Panel F8





COMP ADI/HSI with Mach/Vel Tape



Composite ADI/HSI with EAS tape

### Surface Position Indicator

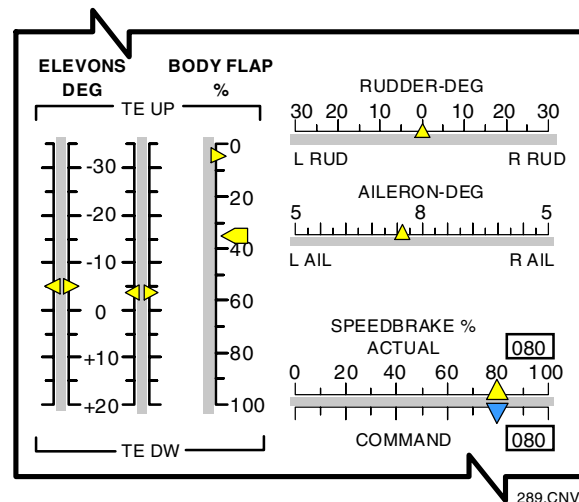
The surface position indicator is a single display that is active during entry and the entry portion of return to launch site. The indicator displays the actual and commanded positions of the elevons, body flap, rudder, aileron, and speed brake. This information is available on the SPI display (MEDS) or panel F7 (non-MEDS).

The four elevon position indicators show the elevon positions in the order of appearance as viewed from behind the vehicle (from left to right: left outboard, left inboard, right inboard, right outboard). The scales all range from +20° to -35°, which are near the software limits to the elevon commands. The pointers are driven by four

separate signals and can read different values, but normally the left pair is identical and the right pair is identical. Positive elevon is below the null line, and negative is above.

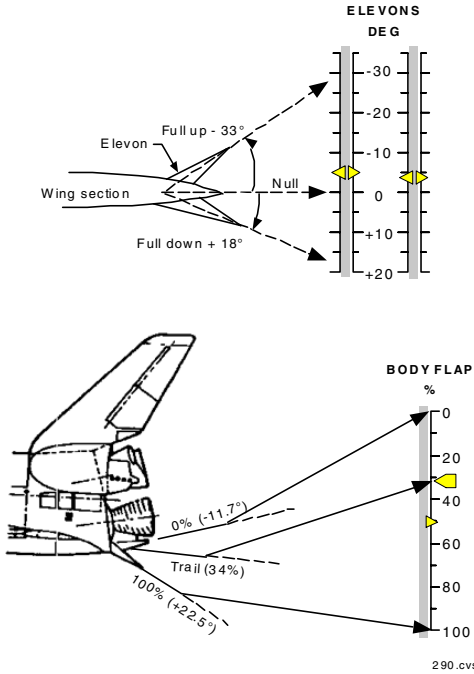
The body flap scale reads body flap positions from zero to 100 percent of software-allowed travel. Zero percent corresponds to full up (-11.7°); 100 percent corresponds to full down (+22.5°). The small pointer at 34 percent is fixed and shows the trail position.

Rudder position is displayed as if viewed from the rear of the vehicle. Deflection to the left of center represents left rudder. The scale is +30° (left) to -30° (right), but software limits the rudder command to ±27.1°.

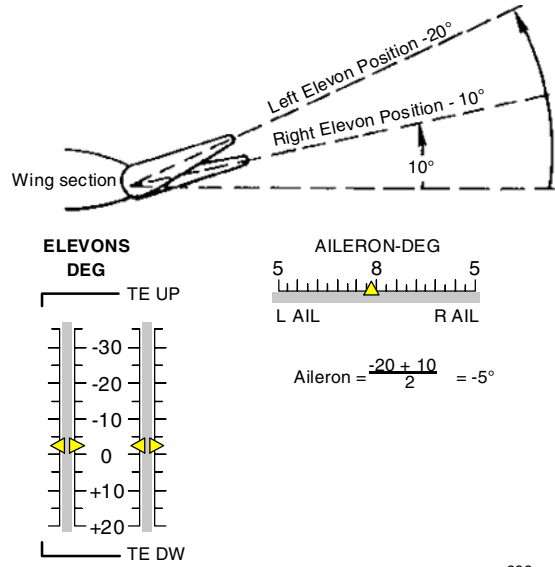


Surface Position Indicator

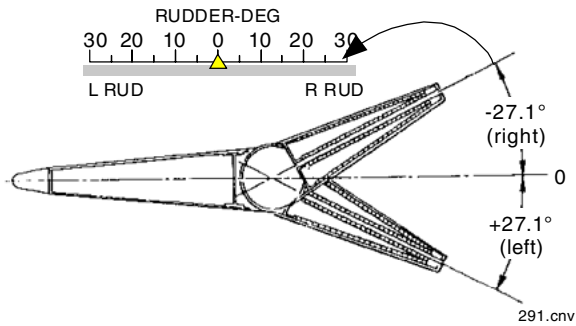
The aileron display measures the effective aileron function of the elevons in combination. Aileron position equals the difference between the average of the left and right elevon divided by two. Deflection of the pointer to the right of center indicates a roll-right configuration (left elevons down, right elevons up) and vice versa. The scale is -5° to +5°, with -5° at the left side. The aileron command can exceed ±5° (max. ±10°), in which case the meter saturates at ±5°.



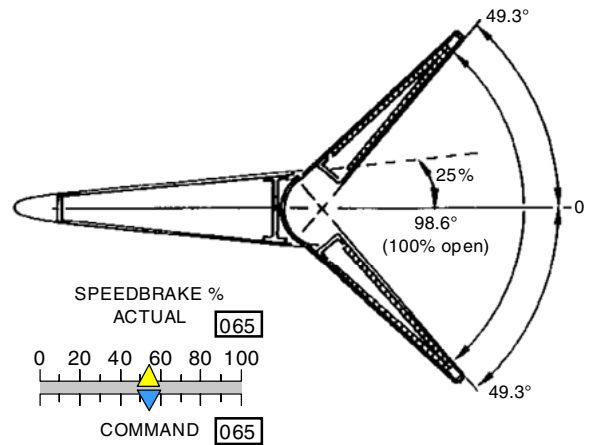
Surface Position Indicator Elevation Travel



Surface Position Indicator Aileron Travel



Surface Position Indicator Rudder Travel



Surface Position Indicator Top View of Open Speed Brake

The speed brake position indicator indicates the actual position on the upper scale and commanded position on the lower scale. The position ranges from zero to 100 percent; zero percent is fully closed, and 100 percent is fully open, which corresponds to 98 percent with respect to the hinge lines.

The speed brake command is scaled identically to position and has the same travel limits. It always represents the speed brake auto guidance command.

#### **Non-MEDS**

The non-MEDS version of the SPI does not have the digital readout for the commanded and actual speed brake settings.

#### **MEDS**

In MEDS, the IDPs get data from analog-to-digital converters (ADCs) 1A and 1B for display on the SPI (see Section 2.6 for more information on IDPs and ADCs). For ADC failures or invalid data cases, the SPI bars will be outlined in red and the triangles will disappear.

### **Flight Control System Pushbutton Indicators**

The flight control system's pushbutton indicators transmit flight crew moding requests to the digital autopilot (DAP) in the flight control software and reflect selection by illuminating the effective DAP state. These indicators are located on panel F2 for the commander and panel F4 for the pilot.

The pushbutton indicators are used to command and reflect the status of the pitch and roll/yaw control modes. The *PITCH* and *ROLL/YAW* indicators transmit moding requests to the digital autopilot and indicate the effective state of the pitch and roll/yaw DAP channels by lighting.

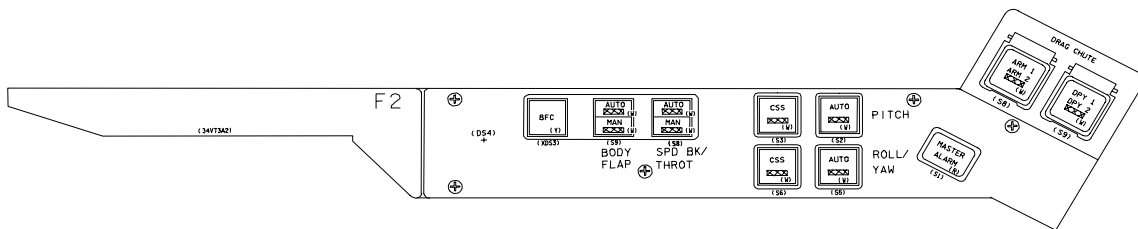
*AUTO* indicates that control is automatic, and no crew inputs are required. *CSS* is control stick steering; crew inputs are required, but are smoothed by the DAP (stability augmentation, turn coordination).

The *SPD BK/THROT* (speed brake/throttle) pushbutton indicator has two separate lights, *AUTO* and *MAN*, to indicate that the DAP speed brake channel is in the automatic or manual mode. The pushbutton light indicator transmits only the *AUTO* request.

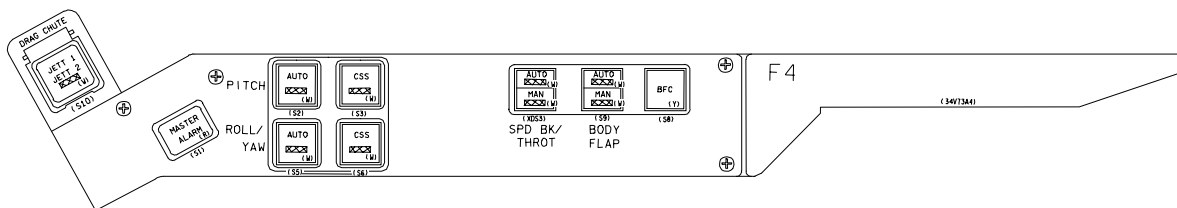
The *BODY FLAP* pushbutton indicator also has separate *AUTO* and *MAN* lights, indicating the state of the body flap channel.

**Entry Flight Control System Mode Pushbutton Indicator Light Logic**

LIGHTS	LEFT/RIGHT LIGHT LOGIC	CAUSES
<i>PITCH AUTO</i>	Both on or both off } Auto, CSS mutually exclusive	<i>PITCH AUTO</i> pushbutton indicator depressed
<i>PITCH CSS</i>		<i>PITCH CSS</i> pushbutton indicator depressed or RHC out of detent in pitch
<i>ROLL/YAW AUTO</i>	Both on or both off } Auto, CSS mutually exclusive	<i>ROLL/YAW AUTO</i> pushbutton indicator depressed
<i>ROLL/YAW CSS</i>		<i>ROLL/YAW CSS</i> pushbutton indicator depressed or RHC out of detent in roll or yaw
<i>SPD BK/THROT</i>		
<i>AUTO</i>	Both on or both off } Auto, man. mutually exclusive	Neither SBTC takeover pushbutton depressed or <i>AUTO</i> pushbutton depressed
<i>MAN</i>		Either SBTC takeover pushbutton depressed
<i>BODY FLAP</i>		
<i>AUTO</i>	Both on or both off } Auto, man. mutually exclusive	<i>AUTO</i> pushbutton indicator depressed
<i>MAN</i>		<i>MAN</i> pushbutton depressed



**Commander's Flight Control System Pushbutton Light Indicators on Panel F2**



**Pilot's Flight Control System Pushbutton Light Indicators on panel F4**

**Reaction Control System Command Lights**

The *RCS COMMAND* lights on panel F6 are active during OPS 104-106 and OPS 602 and 603. Their primary function is to indicate reaction control system (RCS) jet commands by axis and direction; secondary functions are to indicate when more than two yaw jets are commanded, and when the elevon drive rate is saturated.

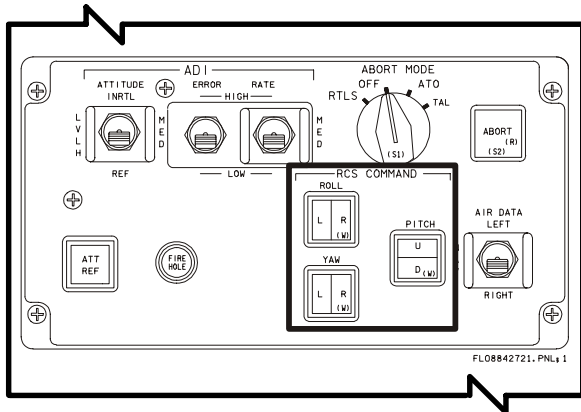
During major modes 301 through 304, until the roll jets are no longer commanded (dynamic pressure exceeds 10 pounds per square foot), the *ROLL L* and *R* lights indicate that left or right roll jet commands have been issued by the

DAP. The minimum light-on duration is extended so that the light can be seen even during minimum-impulse firings. When dynamic pressure is greater than or equal to 10 pounds per square foot, the *ROLL* lights are quiescent until 50 pounds per square foot, after which time both lights are illuminated whenever more than two yaw jets are commanded on.

The *PITCH U* and *D* lights indicate up and down pitch jet commands until dynamic pressure equals 40 pounds per square foot, after which the pitch jets are no longer used. When dynamic pressure is 50 pounds per square foot

or more, the *PITCH* lights, like the *ROLL* lights, assume a new function: both light whenever the elevon surface drive rate exceeds 20° per second (14° per second if only one hydraulic system is left).

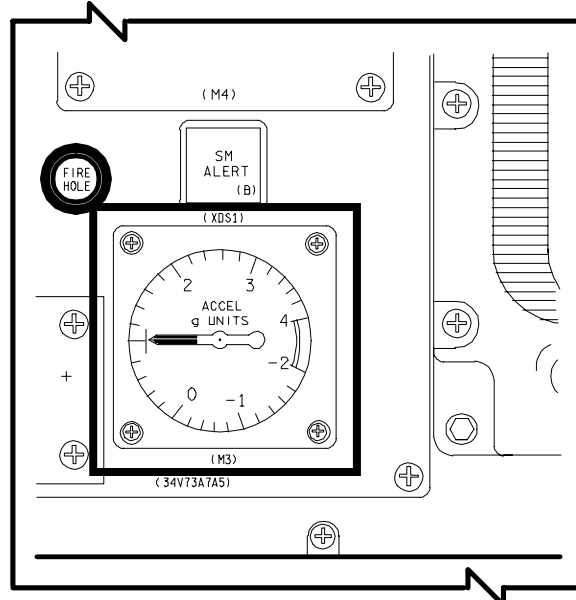
The *YAW L* and *R* lights function as yaw jet command indicators throughout entry until the yaw jets are disabled at Mach 1. The yaw lights have no other functions.



RCS COMMAND Lights on panel F6

### G-Meter (Non-MEDS only)

The g-meter is a self-contained accelerometer and display unit mounted on panel F7. It senses linear acceleration along the Z axis (normal) of the vehicle. A mass weight in the unit is supported vertically by two guide rods and is constrained by a constant-rate helical spring. The inertial force of the mass is proportional to the inertial force of the vehicle and, hence, to the input acceleration, under conditions of constant acceleration. Displacement of the mass is translated to pointer displacement through a rack-and-pinion gear train, the output of which is linear with input acceleration. The display indicates acceleration from -2 g's to +4 g's. The g-meter requires no power and has no software interface. Like all the dedicated displays, it has an external variable incandescent lamp.



G-METER on Panel F7

### Head-Up Display

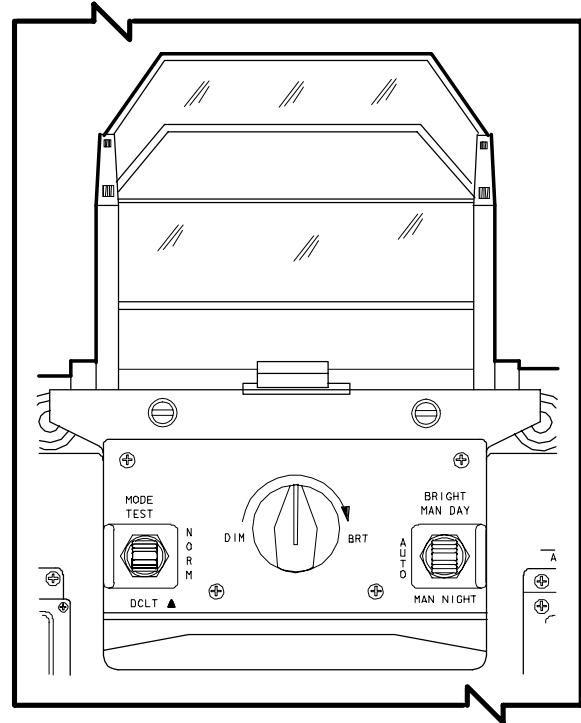
The head-up display (HUD) is an optical miniprocessor that cues the commander and/or pilot during the final phase of entry and particularly in the final approach to the runway. With minimal movement of their eyes from the forward windows (head up) to the dedicated display instruments (head down), the commander and pilot can read data from head-up displays located in the front of them on their respective glareshields. The head-up display presents the same data presented on several other instruments, including the attitude director indicator, surface position indicator, alpha/Mach indicator, and altitude/vertical velocity indicator.

The head-up display allows out-of-the-window viewing by superimposing flight commands and information on a transparent combiner in the window's field of view. Since the orbiter avionics systems are digital, and minimal impact on the orbiter was paramount, the head-up display drive electronics were designed to receive data from the orbiter data buses. The head-up display drive electronics utilize, to the maximum extent possible, the same data that drive the existing electromechanical display devices. The orbiter display device uses a CRT to create the image, which is then projected through a series of lenses onto a combining glass.

Each head-up display is a single-string system, but it is connected to two data buses for redundancy. It is an electronic/optical device with two sets of combiner glasses located above the glareshield in the direct line of sight of the commander and the pilot. Essential flight information for vehicle guidance and control during approach and landing is projected on the combiner glasses and focused at infinity.

The images, generated by a small CRT and passed through a series of lenses, are displayed to the flight crew on the combiners as lighted symbology. The transmissiveness of the combiner allows the crew to look through it and see actual targets like the runway.

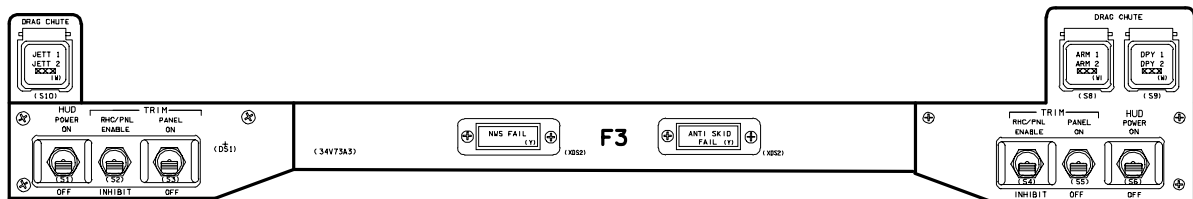
For instance, if the crew is 9,000 feet on the final approach course in a solid overcast, the base of which is at 8,000 feet, the lighted outline of the runway would be displayed on the combiner. However, when the orbiter exits the overcast at 8,000 feet, the lighted outline of the runway would be superimposed on the real runway. As the orbiter proceeds down the steep glideslope, the velocity vector is superimposed over the glideslope aim point. At preflare altitude, flare triangles move up to command the pullout. The pilot maintains the velocity vector symbol between the triangles. After a short period of stabilized flight on the shallow glideslope, the guidance diamond commands a pitch-up until the nose is about 8° above the horizon, which is essentially the touchdown attitude. After touchdown, during the rollout phase, the crew maintains the approximate touchdown attitude, +6° theta (nose above the horizon), until 185 knots equivalent airspeed and then commands a derotation maneuver.



**Head-Up Display and Controls on Panel F6  
(Identical on Panel F8)**

The head-up display has proved to be a valuable landing aid and is considered the primary pilot display during this critical flight phase.

A *HUD POWER ON/OFF* switch located on the left side of panel F3 provides and terminates electrical power to the commander's head-up display on panel F6. A second switch is located on the right side of panel F3 for the pilot's head-up display on panel F8.



**Panel F3**

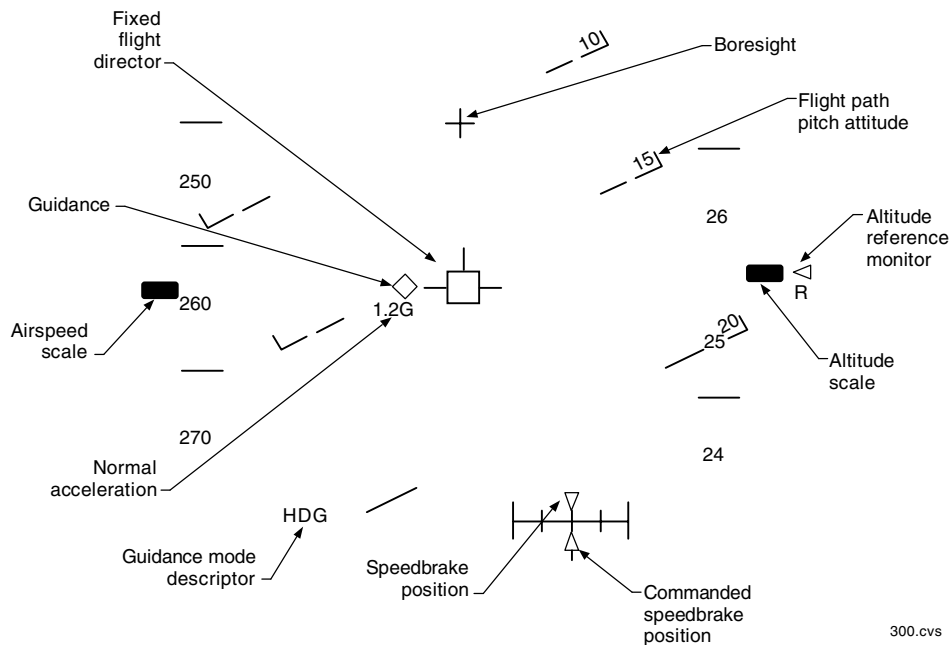
**WARNING**

A generic hardware problem has been identified in several HUD units. At 13 KFT, the flight director symbol is uncaged to become a velocity vector (→). Cycling HUD POWER after this transition may result in erroneous symbol positioning. Flying these false cues would result in landing short of the runway, at a very high sink rate. (Ref: JSC Memo DF6-90-053)

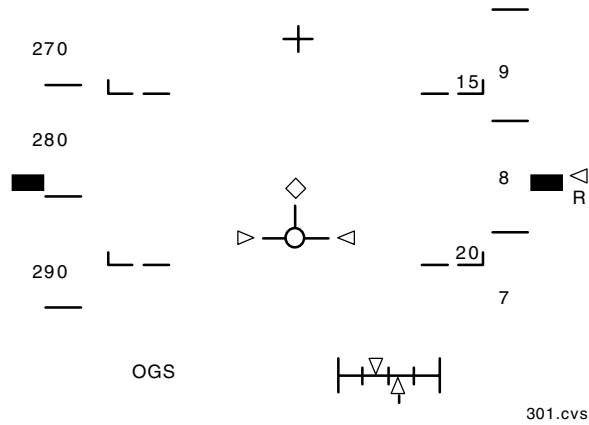
removes the airspeed and altitude tapes (replacing them with digital values) and the horizon/pitch attitude scales, but leaves the horizon line when within FOV. The third declutter level removes all symbology except for the boresight. A fourth declutter attempt will return the HUD to its original form with all symbols displayed.

A three-position *MODE* switch is located below the HUD. In the *NORM* position, automatic sequencing of formats and symbology is provided. The *TEST* position forces up a test display for 5 seconds. Selection of the momentary *DCLT* position initiates a symbol blanking routine. Successive selections of *DCLT* will serially remove display elements in the following order. The first activation removes the runway symbology. The second activation

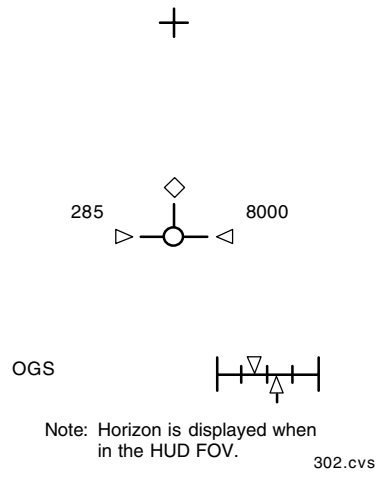
Data displayed on the HUD comes from the GPCs across flight critical (FC) databus 1 or 2 for the CDR's HUD and FC databus 3 or 4 for the PLT's HUD. In MEDS, a HUD databus switch on panel F6 (CDR) or F8 (PLT) controls the data source. In the non-MEDS cockpit, the HUD data source is controlled by the databus rotary knob. For the CDR's HUD, databus select positions 'FC 1' and 'FC 3' use FC 1 to drive HUD data. Positions 'FC 2' and 'FC 4' use FC 2 to drive HUD data. For the PLT HUD, positions 'FC 1' and 'FC 3' use FC 3 to drive HUD data and 'FC 2' and 'FC 4' use FC 4 to drive HUD data.



**Approach and Land Display (TAEM Heading Phase); No Declutter**



**Approach and Land Display (Declutter Level 1)**



**Approach and Land Display (Declutter Level 2)**

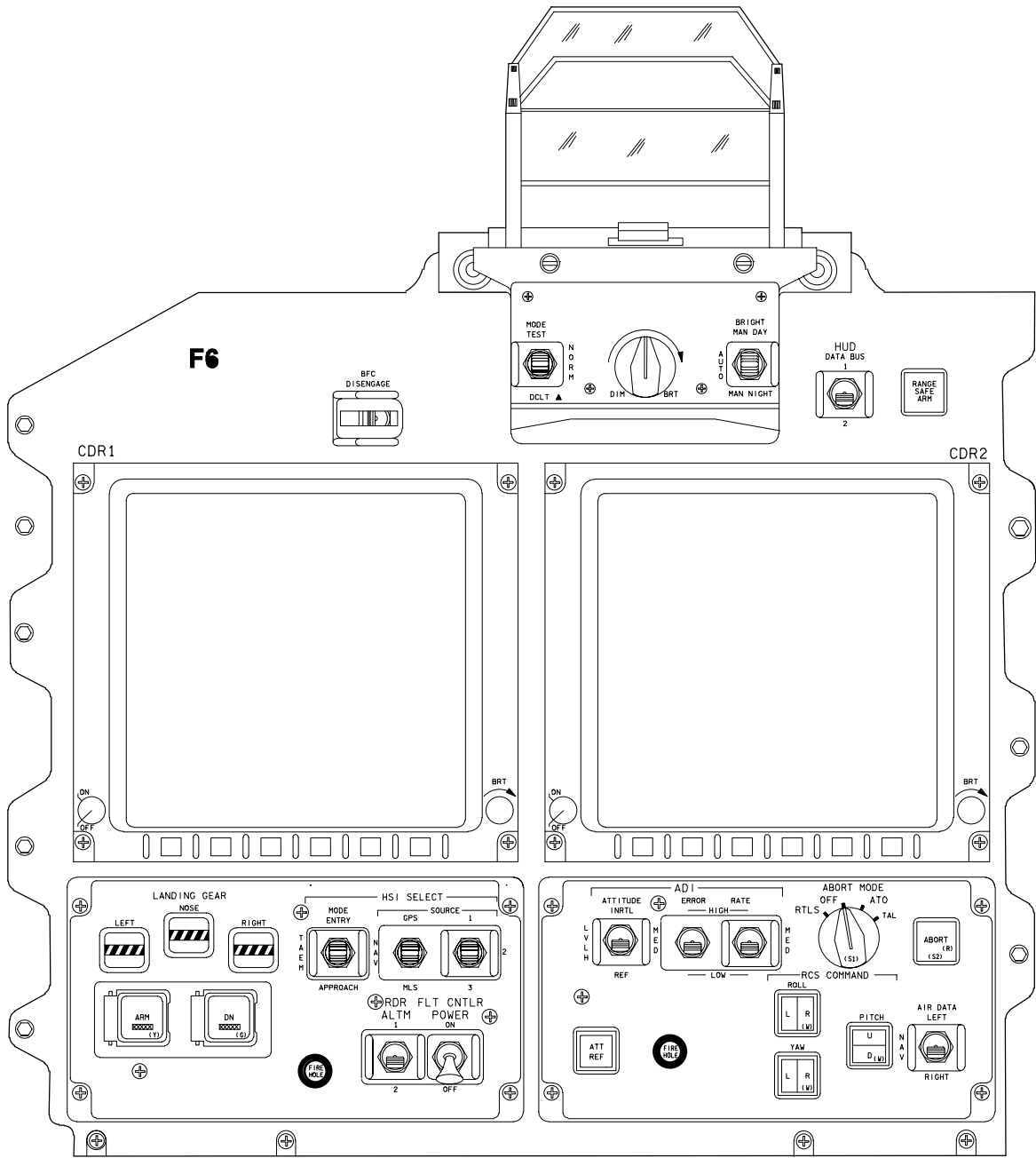


**Approach and Land Display (Declutter Level 3)**



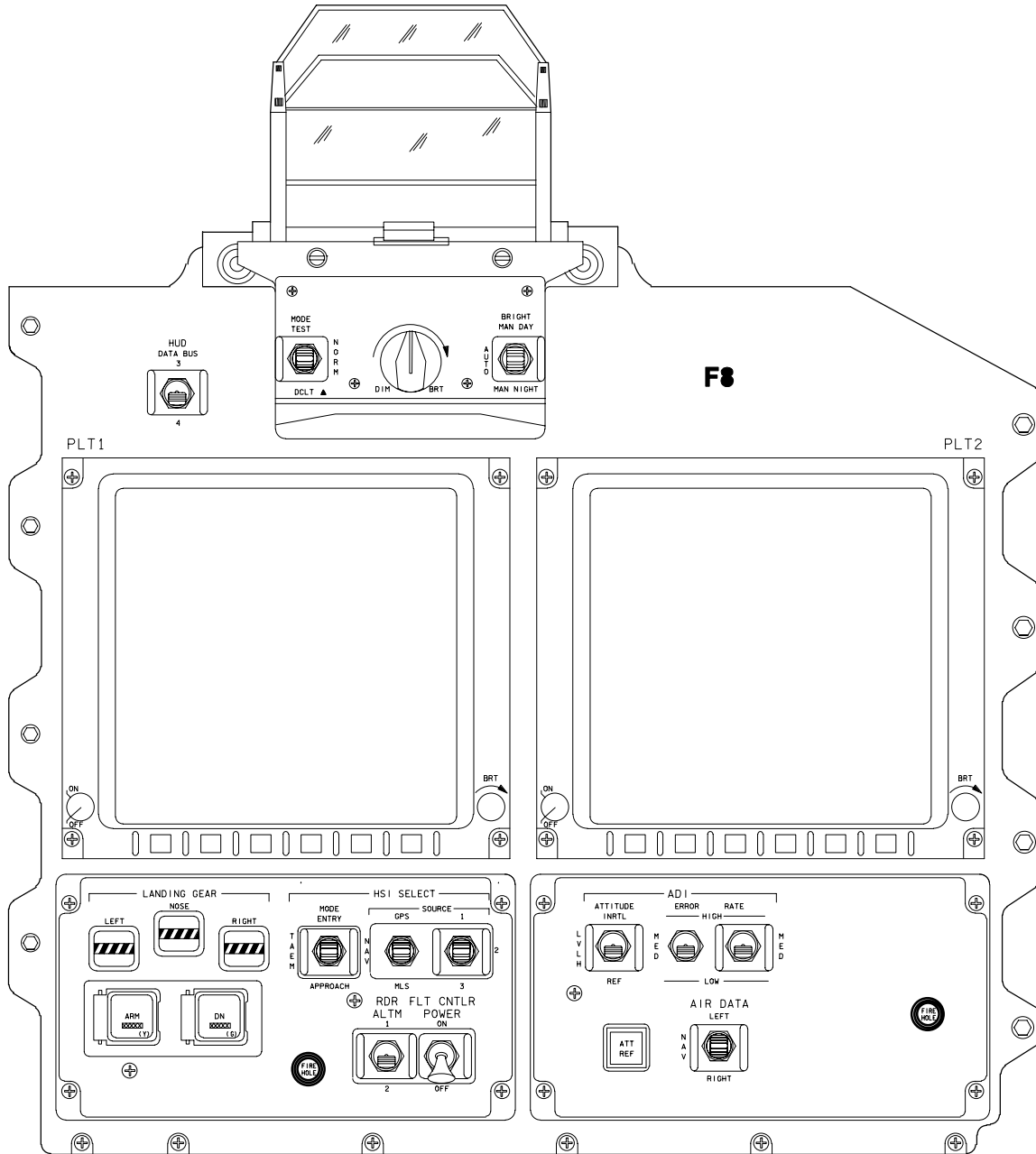
## Dedicated Display Systems Summary Data

- Dedicated displays are located in front of the commander's and pilot's seats and on the aft flight deck panel by the aft-facing window (panels F6, F8, and A1U) for a non-MEDS cockpit, and on the flight instrument and subsystem status displays driven on the 11 multifunction display units (MDU) in a MEDS cockpit.
- Dedicated displays include: attitude director indicators, horizontal situation indicators, alpha/Mach indicators, altitude/vertical velocity indicators, surface position indicator, RCS activity lights, and head-up displays.
- Circuit breakers for dedicated display units are located on panels O14, O15, and O16.
- Power switches for the commander's dedicated displays are on panel F6; for the pilot's displays on panel F8 (non-MEDS).
- The attitude director indicators display orbiter attitude by an enclosed ball gimballed to represent three degrees of freedom.
- The horizontal situation indicators visually display certain guidance, navigation, and control parameters such as directions, distances, and course/glide path deviation.
- The alpha Mach indicator displays angle of attack, acceleration, vehicle velocity, and equivalent airspeed.
- The altitude/vertical velocity indicators display vertical acceleration, vertical velocity, barometric altitude, and radar altitude.
- The surface position indicator displays actual positions of the elevons, body flap, rudder, aileron, and speedbrake. Speedbrake commanded position is also displayed.
- The g-meter is a self-contained accelerometer and display unit on panel F7 (non-MEDS only).
- The head-up display cues the commander and/or pilot during final phases of entry by superimposing flight commands and information on a transparent combiner in the window's field of view. Power switches are located on panel F3.
- The ADI ball is mechanically frozen when the ball is at 270° or 90° in yaw.
- During ascent powered flight (MM 102-103) or RTLS powered flight (MM 601), active displays include the ADI, HSI, AML, and AVVI.
- Post MECO, the ADI is the only active display (MM 104-106).
- During RTLS gliding flight (MM 602-603), all displays are driven as in the nominal TAEM/ approach phases (MM 304, 305).
- On orbit, when in the Flight Control System (FCS) checkout mode (MM 801), all displays can be driven by test software to allow the crew to verify correct operation prior to entry.
- The ACCEL tape on the alpha/Mach indicator, the error and rate needles on the ADI, and the HSI indicate different parameters in different major modes.



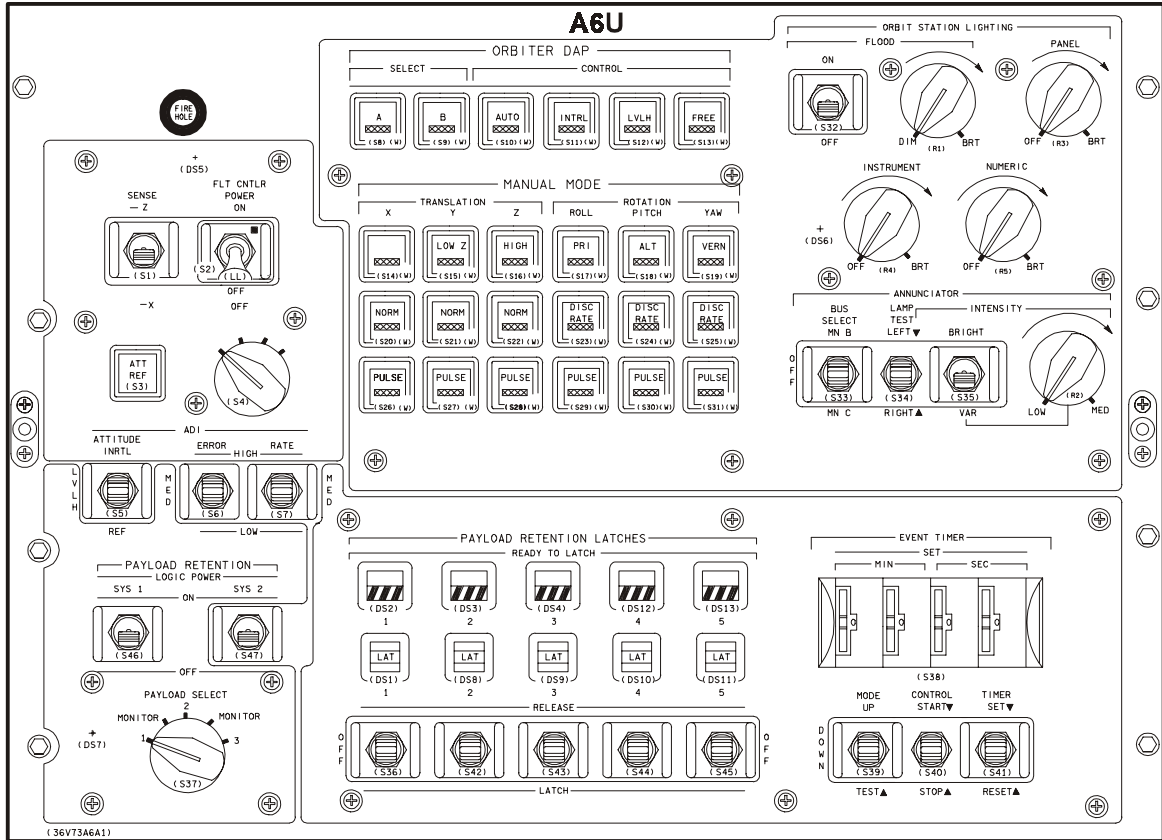
F0884A04, PNL 1

Panel F6



FL0884A06. PNL 1

Panel F8



FL0884A43, PNL 1

Panel A6U

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## 2.8 ELECTRICAL POWER SYSTEM (EPS)

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Fuel Cell System .....	2.8-10
Electrical Power Distribution and Control .....	2.8-20
Operations .....	2.8-30
EPS Caution and Warning Summary .....	2.8-32
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EPS Rules of Thumb.....	2.8-38

### Description

The electrical power system (EPS) consists of the equipment and reactants that produce electrical power for distribution throughout the orbiter vehicle, and fulfill all the orbiter external tank, solid rocket booster, and payload power requirements, when not connected to ground support equipment. The EPS operates during all flight phases. For nominal operations, very little flight crew interaction is required by the EPS.

The EPS is functionally divided into three subsystems: power reactants storage and distribution (PRSD), three fuel cell power plants (fuel cells), and electrical power distribution and control (EPDC).

Through a chemical reaction, the three fuel cells generate all 28-volt direct-current electrical power for the vehicle from launch minus 3 minutes 30 seconds through landing rollout. Prior to that, electrical power is provided by ground power supplies and the onboard fuel cells.

Power is controlled and distributed by assemblies located in the forward, mid, and aft sections of the orbiter. Each assembly is a housing for

electrical components such as remote switching devices, buses, resistors, diodes, and fuses. Each assembly usually contains a power bus or buses and remote switching devices for distributing bus power to subsystems located in its area.

### Power Reactants Storage and Distribution System

The power reactants storage and distribution system stores the reactants (cryogenic hydrogen and oxygen) and supplies them to the three fuel cells that generate all the electrical power for the vehicle during all mission phases. In addition, the subsystem supplies cryogenic oxygen to the environmental control and life support system (ECLSS) for crew cabin pressurization. The hydrogen and oxygen are stored in tanks at cryogenic temperatures (-285°F for liquid oxygen and -420° F for liquid hydrogen) and supercritical pressures (above 731 psia for oxygen and above 188 psia for hydrogen).

The PRSD system components are located in the orbiter midbody underneath the payload bay liner or on a payload bay pallet for 10+ day missions in extended duration orbiter (EDO) vehicles. The system stores the reactants hydrogen and oxygen in double-walled, thermally insulated spherical tanks with a vacuum annulus between the inner pressure vessel and outer tank shell. Each tank has heaters to add energy to the reactants during depletion to control pressure. Each tank is capable of measuring quantity remaining.

The tanks are grouped in sets of one hydrogen and one oxygen tank. The number of tank sets installed depends on the specific mission requirement and vehicle. Up to five tank sets can be installed in the midfuselage under the payload bay liner of OVs-102, -103, -104, and -105. Up to four additional tank sets can be flown on the EDO pallet in the payload bay of OV-102 and -105. OV-105 may be configured at a later date to fly up to four additional tank sets (total of eight additional sets). Switches to control these tanks are already installed.