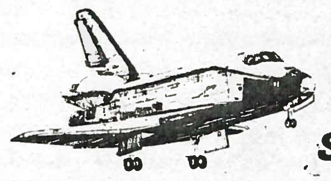


SPACE SHUTTLE ORBITER

BACKUP FLIGHT SYSTEM

USER'S GUIDE

Rockwell International

Space Transportation &
Systems Group

TABLES

1.0 INTRODUCTION

1.1 PURPOSE

The Backup Flight System (BFS) User's Guide provides information concerning the operations and capabilities of the BFS. This information is intended to provide basic reference material that can be used as follows:

1. As a supplemental aid during varied training programs.
2. To supplement available information used for BFS flight readiness testing and verification.
3. To provide system orientation to the potential BFS user.
4. To aid in the preparation and impact assessment of CR's.

1.2 SCOPE

The BFS User's Guide provides an overview of BFS software capabilities, including descriptions of the backup system services (BSS), backup operating system (BOS), guidance, navigation, and control (GN&C) operations, and those operations classified as systems management/special processes and payload support (SM/SP&PL) and sequencing. Also included is information relative to the orbiter's cabin controls (switches, etc.) as they affect operation of the BFS. Relative emphasis is placed on the material provided for the BFS orbiter cabin cathode-ray tube (CRT) displays and their attendant hardware and software interfaces.

This is a reference document. Where conflicts occur between this document and a program requirements document (PRD), the PRD will prevail.

1.3 APPLICABLE DOCUMENTS

The following documents form the basis for the information used to generate this document:

PRD's

BFS Overview	MG038100
Backup Systems Services	MG038101
Guidance and Navigation	MG038104
Flight Control	MG038105
GN&C Hips and Interfaces	MG038106
Systems Management, Special Processes, and Payload	MG038119
Sequencing	MG038120

No.	Title
ICD-3-0068-3	Primary Avionics Software System (PASS) and Backup Flight System (BFS) Software Interface
STS 83-0020	Space Shuttle Orbiter Operational Flight Level C Functional Subsystem Software Requirements (FSSR) Displays and Controls
SOD 79-0002	Shuttle System Data Interfaces Book, Orbiter 102

2.0 BFS OVERVIEW

2.1 BFS PURPOSE

The purpose of the BFS is: (1) provide basic GN&C protection against generic primary flight system (PFS) software errors, which could cause a loss of control of the vehicle, and (2) provide capabilities during ascent and descent not executed by the PFS. In addition, some limited on-orbit capabilities are provided to the system during reconfiguration periods (on-orbit-to-deorbit) and in case of primary system failure. For the latter case, a flight control attitude hold mode is provided. The above capabilities are delegated to one of the five general-purpose computers (GPC's) on the Shuttle orbiter vehicle (nominally GPC 5).

2.2 PFS/BFS HARDWARE CONFIGURATION OVERVIEW

The only BFS unique hardware are the three backup flight controllers (BFC's). The BFC's effect switchover of flight critical bus control authority from PFS to BFS via hardwired commands to the GPC's in response to a manual BFS engage command from the crew.

The BFS is essentially a multi-sensor, single-string system. Its operational flight program (OFP) can be resident in any one of the five GPC's. As a result, data buses and discrete input/output (I/O) interfaces have the same capability as for the PFS. When the BFS is not engaged, the required sensor data are obtained by listening to data requested by the PFS as well as transfer data obtained directly from the PFS.

2.3 BFS CAPABILITIES

The BFS provides the capability to control and fly the vehicle, when engaged, during the ascent and descent mission phases of the Space Transportation System (STS).

The BFS, operating as a single-computer backup system, provides the following functions in one computer memory load:

1. Navigation
2. Guidance
3. Flight control
4. Fault detection and annunciation
5. Systems management (SM)

6. Load capability for the 64 Kbps telemetry format

7. Uplink via the network signal processor (NSP)

8. Auxiliary power unit (APU) quantity gauging

9. Flash evaporator and NH_3 boiler activation/deactivation

10. Non-GN&C caution and warning (C&W) backup in the pre-engaged state; total C&W capability in the engaged state

11. S-band antenna management

12. Payload bay door control

13. Launch data bus interface processing

14. Intact abort (RTLS, ATO, and AOA)

15. Appropriate initializations for the preceding functions

16. Downlist

17. Fast ET separation (subsequent to STS-1)

18. Table maintenance block update

19. Sequencing during nominal ascent, entry, and intact aborts

20. Payload support if required for mission

Prior to BFS engagement, the required sensor data and crew input data to perform the above functions are obtained by listening to the PFS commanded data on the flight critical (FC) and display and keyboard (DK) data buses. The PFS also transfers data to the BFS as defined by the primary avionics software system (PASS)/BFS interface control document (ICD) (see Section 1.3) for the purpose of the BFS tracking the PFS and BFS initialization and sequencing.

During pre-engagement, the BFS is compatible with the PFS related common functions such as I/O profile, GN&C, and sequencing. The data processing for these functions is performed in order to determine the state of the vehicle, e.g., moding indicators, vehicle position and velocity state vector, guidance commands, control errors, and effector commands. The BFS state-of-the-vehicle is determined with the same sensor and crew inputs as that for the PFS; however, the BFS OFP employs different and independent operating and application programs. Limited, but adequate capability to monitor the performance of the BFS relative to that of the PFS is provided through telemetry and crew interface.

Upon BFS engagement, the BFS OFP performs appropriate engagement initialization. Maximum usage of the pre-engagement BFS state is made to ensure smooth vehicle control and guidance transition during BFS engagement. The BFS is thereafter independent of the PFS and provides total vehicle control capability to the crew station.

The BFS functional requirements are the same as those of the PFS with some key exceptions. The significant exceptions are listed below:

1. Redesigned operating system to preclude the occurrence of a generic PFS software error from affecting BFS performance.

2. Multi-sensor with a simple redundancy management single-string system.

3. Limited on-orbit capabilities, e.g., attitude control and SM fault detection and annunciation (FDA).

4. Reduced GN&C functional requirements, e.g.:

   a. No preflight or on-orbit IMU calibration and alignment.

   b. Microwave scanning beam landing system (MSBLS) data are not processed for any purpose.

   c. Radar altimeter data are processed for display only.

   d. Ascent guidance until main engine cutoff (MECO) is the only automatic guidance phase. All other guidance is accomplished with man-in-the-loop.

   e. Guidance command computation during entry is inhibited below an altitude of 2,000 feet.

   f. Controlled stick steering (CSS) landing is similar to Orbiter 101 backup flight control system (BFCS).

5. Reduced systems management/special processes functional requirements.

6. A launch data bus interface that includes protocol for general memory read/write only.

7. Limited contingency abort capability (Fast SEP, MM 102 only).

2.4 PFS/BFS INTERFACE AND INTERACTIONS

The interfaces between the PFS and BFS, as indicated in the PASS/BFS ICD, include the following:

1. Data Bus and Discrete Signal Interface

   The signal interface between systems involves the process of listening to and/or inhibiting conflicting signals. The BFS is capable of monitoring all signals required for vehicle control during normal primary system operation. Additionally, all BFS flight critical data bus command signals are inhibited during operation of the primary system. Conversely, all primary system flight critical data bus command signals are inhibited upon BFS engagement.

2. Shared Display Buses and Line-Replaceable Units (LRU's)

   The display interface between systems is the display of parameters through the CRT's, the dedicated display units (DDU's), and the surface position indicator (SPI). The BFS provides CRT display information on the single forward display selected for backup by the crew in the pre-engage mode. Subsequent to engagement, the BFS provides display information on two selected forward CRT's. The primary system provides the display information to the DDU's and SPI in the pre-engage mode because it has control of the flight critical data buses. Subsequent to engagement, the BFS drives the DDU's and SPI. The BFS also drives the aft-station CRT.

3. Control of the Uplink Function

   The control of the network signal processors (NSP) for receipt of uplink data is accomplished by the primary system before engagement of the BFS. BFS assumes NSP control subsequent to BFS engagement. Note that BFS processes all uplink commands destined for payload buses (PL1 and PL2) during the ascent and descent phases of operation.

4. Transition Between the Primary and Backup Guidance, Navigation, and Flight Control Systems

   The transition from the primary to the backup system can occur during ground checkout and during the ascent and descent modes. If the BFS has been engaged during the ascent or descent modes, there will be no dynamic switchback to the primary. However, the BFS can accommodate a switchback to the primary during the on-orbit mission phase as well as during ground checkout.

2.5 BFS SOFTWARE STRUCTURE

The BFS OFP is structured by the following three major functional areas:

1. BSS
2. GN&C
3. SM/SP&PL and sequencing

These functional areas accomplish the BFS capabilities within the constraints associated with the PFS/BFS interface, interactions, and operational mission time lines.

2.6 FUNCTIONAL SUMMARY

The following provides a summary of the salient functional features of the BFS:

1. Compatible with PFS prior to BFS engagement.
2. Functionally independent of the PFS following switchover to the BFS (BFS engagement).
3. Activated by a single, manual-switchover action by depressing the engage button on either rotation hand controller (RHC).
4. A multi-sensor, single-string system for GN&C functions and for the sequencing function.
5. Performs nonredundant SM/SP functions.
6. The BFS OFP is mechanized to utilize one of the five GPC's with one GPC memory load for ascent and descent operations.

3.0 BFS CAPABILITIES OVERVIEW

3.1 OPERATIONAL SEQUENCES (OPS) AND MAJOR MODES (MM) DESCRIPTION

The BFS has four OPS; i.e., OPS 0, 1, 3, and 6. The BFS provides no support to the capability of the PFS OPS 2 operational sequences. However, it supports a limited on-orbit capability. This on-orbit capability can be performed during the end of OPS 1 (MM 106) or the beginning of OPS 3 (MM 301). Figure 3.1-1 shows an overview of the BFS OPS sequencing with major modes transitions. The detailed requirements of OPS 0 are specified in the BFS Overview PRD. These of OPS 1 and 3 are specified in the SEQ, SM/SP&PL and GN&C PRD's (see Section 1.3).

3.1.1 OPS 0

This operational sequence is an important part of the GPC startup type of initialization. An overview of OPS 0 is given below:

1. OPS 0 is the major mode used to start minor cycle (40 milliseconds) operations subsequent to initial program load (IPL) or system reset.

2. Outputs on the flight critical buses are inhibited during OPS 0.

3. Control of the payload buses is established as follows: When BFS is not engaged, payload bus control is dependent upon the BFS GPC mode RUN-HALT-STANDBY switch. In STANDBY, PASS controls. In RUN, BFS controls. When BFS is engaged, BFS provides payload bus control regardless of the mode switch position.

4. Outputs on other buses are dependent upon the same conditions and constraints that apply to outputs during OPS 1, 3, and 6.

5. Inputs on all buses are dependent upon the same conditions and constraints that apply to inputs during OPS 1, 3, and 6.

6. BOS initializes the job schedule to its tape build mass memory unit (MMU) content status prior to the first minor cycle of BFS OPS 0.

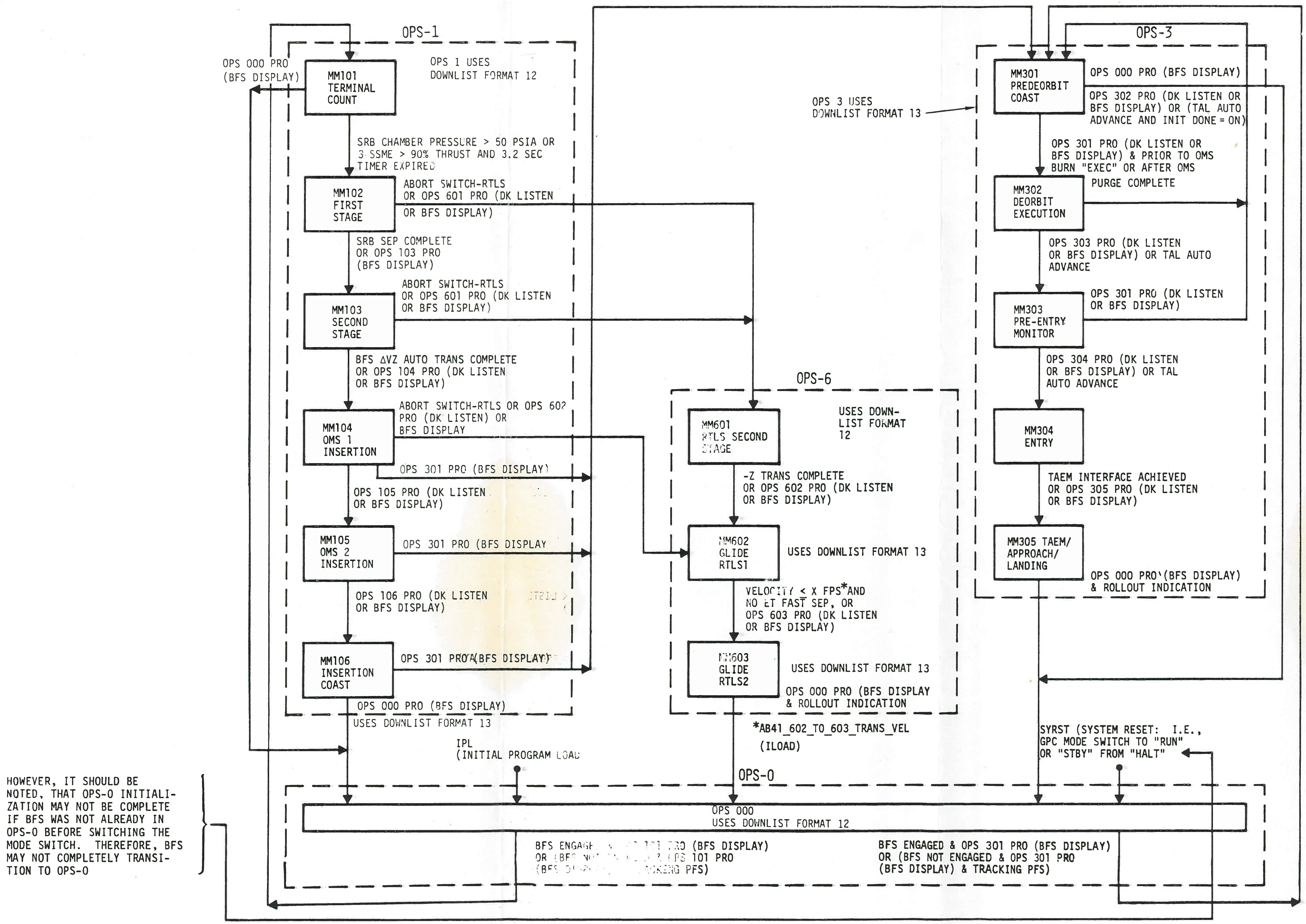


Figure 3.1-1. BFS OPS Sequence/Major Mode Transition Chart

7. OPS 0 Processing:

	BSS	GN&C	SM/SP&S
a.	Data bus configuration	GN&C application controller	Backup events controller
b.	Disengage pass tracking		SM/SP&S application controller
c.	GPC memory and fault summary displays		SM
d.	Uplink (if NSP inputs are available)		Special processes (except antenna management and flash evaporator/ammonia boiler)
e.	Downlist (ascent format)		RCS quantity monitor
f.	One shot PASS data transfer (prior to MM 101 selection, only via keyboard entry on GPC memory CRT display)		

3.1.2 Ascent, Descent, and RTLS Operational Sequences and Major Modes

The mission phases for the Shuttle are defined by operational sequences containing an ordered subset for each sequence. The subsets are defined as major modes. There are four operational sequences: ascent, OPS 1; orbital, OPS 2; descent, OPS 3; and RTLS, OPS 6. The BFS is involved in OPS 1, 3, and 6. If the BFS is utilized during ascent to achieve an orbit, the vehicle will remain in an attitude-hold mode, which is the only BFS GN&C function required on-orbit. Table 3.1.2-1 associates the major modes utilized in each operational sequence with the BFS mechanized functions.

Additional general descriptions of the BSS, GN&C, and SM/SP&S functions performed during the major modes are presented in the BFS operational mission timelines and BFS PRD overview paragraphs (see Section 1.3).

3.1.2.1 Ascent Operations

The ascent phase contains all modes and functions necessary to execute a nominal launch or intact aborts.

3.1.2.1.1 MM 101 Terminal Count. This major mode is initiated approximately 20 minutes prior to lift-off. The only requirement for the BFS during this mode is to be able to accept last minute targeting changes. A requirement exists to update inertial measurement unit (IMU) alignment data, based on gyro-compassing information.

3.1.2.1.2 MM 102 First Stage. This major mode contains all functions necessary to guide, monitor, and control the vehicle from solid rocket booster (SRB) ignition to the SRB separation command. There is no closed-loop guidance during this major mode. Navigation is active and generates the vehicle state vector, relative velocity, and altitude. Flight control is accomplished

Table 3.1.2-1. Major Modes Utilized in Each Operational Sequence

MM No.	Operational Sequence
	ASCENT - OPS 1
MM 101	Terminal count
MM 102	First stage
MM 103	Second stage
MM 104	OMS 1 insertion
MM 105	OMS 2 insertion
MM 106	Insertion coast
	ORBIT - OPS 2
	No BFS requirement
	DESCENT - OPS 3
MM 301	Pre-deorbit coast
MM 302	Deorbit execution
MM 303	Pre-entry monitor
MM 304	Entry
MM 305	Terminal area energy management (TAEM) (includes approach and landing)
	RTLS - OPS 6
MM 601	RTLS Second stage
MM 602	Glide RTLS 1
MM 603	Glide RTLS 2

via thrust vector control (TVC) of the main engines and the SRB engines. The sequence of events during this mode is as follows:

1. Lift-off.

2. Vertical rise until tower clear.

3. Tilt maneuver based on pre-programmed pitch and yaw angle histories; these angles are functions of earth-relative velocities. Roll is forced to an I-loaded value, nominally 180 degrees.

4. SRB separation (command) at approximately 120 seconds from lift-off.

Activities included in this MM follow:

1. RCS quantity monitor.

2. MPS helium monitor.

3. SSME operations.

4. BFS FAST SEP initiation.

During this mode, dynamic pressure is implicitly monitored as a function of relative velocity. Resultant throttle commands are issued to limit the maximum value of dynamic pressure.

This major mode can be exited to RTLS second stage major mode (MM 601).

3.1.2.1.3 MM 103 Second Stage. This major mode contains all functions necessary to guide, monitor, and control the vehicle from SRB separation through termination of the -Z translation maneuver. The basic purpose of this mode is to achieve a MECO point commensurate with the desired orbit and the proper impact target for the external tank (ET). During this mode, ATO may be selected, or TAL PRE MECO, or RTLS, perhaps on the basis of an engine failure.

Subject to SRB jettison, closed-loop explicit guidance is initiated. The guidance law is a form of linear tangent guidance. All calculations are performed in M-50 coordinates. During this mode, navigation consists primarily of processing the accelerometer output from the IMU and generating a state vector in M-50 coordinates. Flight control during this mode is accomplished by TVC of the main engines prior to MECO and by the reaction control subsystem (RCS) subsequent to MECO. Throttling is performed during this mode to keep acceleration less than the 3-g limit. The sequence of major events during this mode is as follows:

1. SRB separation (jettison)

2. Four-second attitude hold

3 Closed-loop guidance

4. MECO

5. MPS helium monitor

6. ET separation

7. -Z translation (nominally automatic)

This major mode can be exited to enter RTLS second stage major mode (MM 601) or to progress to TAL (MM 301) via MM 104.

3.1.2.1.4 MM 104 Orbital Maneuvering System (OMS) 1 Insertion. This major mode contains all functions necessary to guide, monitor, and control the vehicle during the first OMS engine burn during the ascent phase. The major purpose of this mode is to place the vehicle onto an intermediate, elliptical trajectory. Guidance during this mode is another form of linear tangent guidance with different constraints than those used in MM 103. Guidance commands in this mode are sent to flight control in the BFS only for display to the crew as attitude errors on the dedicated instruments. Navigational functions are identical to those in MM 103. Flight control is accomplished by the crew providing hand-controller inputs on the basis of error needle displays to the transition digital auto pilot (DAP). The DAP will then nominally command TVC of the OMS engines. If an OMS engine fails, the RCS will provide the necessary control authority.

In the case of an engine failure, the remaining engine is directed through the computed vehicle center of gravity.

The major sequence of events for this mode is as follows:

1. Mode initiation (automatic upon receipt of delta VZ complete; keyboard entry is backup)

2. Closed-loop guidance

3. OMS ignition

4. RCS burn in parallel with OMS if vehicle is in the ATO mode

5. MPS dump

6. OMS termination

7. Vehicle trim to reduce error residual in VGO (RCS engines used)

This major mode can be exited to MM 602 (glide RTLS 1) or MM 301 (TAL).

3.1.2.1.5 MM 105 OMS 2 Insertion. This major mode contains all functions necessary to guide, monitor, and control the vehicle during the execution of the second OMS engine burn. The purpose of this burn is to achieve the final desired circular orbit. All functions are identical to those of MM 104, except that there is no parallel burn.

At the end of this mode, i.e., at OMS termination, the vehicle will be left in an attitude hold. The attitude reference will be the last guidance command. The rotational hand controller will remain enabled.

This major mode can be exited to MM 301 (AOA).

3.1.2.1.6 MM 106 Insertion Coast. This major mode contains all functions necessary to monitor and control the vehicle during coasting flight. Entering this mode terminates the insertion guidance and modes ascent navigation to coasting flight by halting the processing of the accelerometers.

This major mode can be exited to MM 301 or OPS 000.

3.1.2.2 Descent Operations

The descent phase contains all modes and functions necessary to accomplish a deorbit, entry, and landing.

3.1.2.2.1 MM 301 Pre-Deorbit Coast. This mode contains all the necessary functions to prepare the vehicle for the deorbit maneuver. The BFS functions during this mode are dependent upon the primary system aligning the IMU and performing all tasks associated with terminating orbital activity. The BFS will be capable of accepting entry targeting data for initialization purposes via uplink and multifunction CRT display system (MCDS) keyboard inputs. The BFS will perform GN&C computations upon entering MM 301 (simultaneously with the PFS), so that, if necessary, the deorbit burn could be initiated if the BFS were to be engaged prior to the deorbit maneuver.

3.1.2.2.2 MM 302 Deorbit Execution. This major mode contains all functions necessary to monitor, guide, and control the vehicle during the deorbit burn. This mode is initiated by a crew command and a time base set for OMS ignition. The guidance is of a form similar to that used in the insertion OMS burns, with constraints aimed at placing the vehicle on a Keplerian trajectory which is commensurate with the targeted entry point. The navigation and flight control functions are identical to those used in insertion. The mode is terminated subsequent to OMS firing completion by a crew command.

3.1.2.2.3 MM 303 Pre-Entry Monitor. This major mode contains those functions necessary to monitor and control the vehicle from completion of the deorbit burn until atmospheric entry. Crew commands initiate this mode. There is no guidance during this mode because the vehicle is in free fall. The only navigation function is an open-loop computation of time of atmospheric entry. The RCS is used in an attitude-hold, placing the vehicle in an attitude commensurate with entry conditions. The accelerometers are not used during most of this mode. The flight control hydraulic system is periodically exercised during this mode to warm up the system. Five minutes prior to the computed entry point, the mode is terminated by a keyboard entry which calls MM 304.

3.1.2.2.4 MM 304 Entry. This major mode contains all functions necessary to guide, monitor, and control the vehicle from initial entry until the TAEM interface. Guidance is accomplished through use of an analytic drag control scheme. Navigation is performed by a Kalman filter, which is basically a velocity update function until the first true external update is achieved via tactical air navigation (TACAN) information. The first TACAN update must occur prior to 130,000 feet for proper system operation. Prior to the TACAN update, drag is used to compute a course altitude function to stabilize the vertical navigation channel. Flight control is accomplished by the DAP. The autopilot uses RCS initially, until a pressure of approximately 2 psf; at which time the aerosurfaces blend in for pitch and roll control. Because of rudder ineffectiveness at high angles of attack, the RCS is used for yaw control until approximately Mach 3.5, at which time rudder control is blended in with the yaw RCS jets. The BFS will utilize the CSS mode during this major mode, and the pilot will receive guidance information on the dedicated instruments primarily in the form of the error needles on the attitude director indicator (ADI) early in the mode. A temperature control phase, using a predetermined angle of attack schedule, is the first phase of the mode. Range control is accomplished by control of bank angle, and out-of-plane errors are controlled by bank angle reversal. The CRT will display drag/velocity boundaries so that the crew may monitor the performance of the system.

The second phase of entry is the equilibrium glide phase. This is achieved when lifting forces equal gravitational forces and the altitude rates become constant. A constant drag phase exists between Mach 8 and 12. There is an early/late moding of the autopilot, with a transition at approximately Mach 1.5. Prior to Mach 1.5, the vehicle is controlled about the stability axes, taking advantage of aerodynamic instability to maneuver. Subsequent to the early/late moding, the vehicle is flown with coordinated turns as a normal aircraft would operate. One of the last functions that takes place in this mode is the extension of the air data probes. On a velocity cue of approximately 3800 feet per second, the pilot engages a switch to extend the probes. See Section 4.2.9 regarding Item control of this data usage. Termination of the entry mode occurs automatically at the TAEM interface, which is approximately Mach 2.5 and at an altitude of 88,000 feet.

3.1.2.2.5 MM 305 TAEM. This major mode contains all functions necessary to monitor, guide, and control the vehicle from the entry/TAEM interface through a safe landing. TAEM guidance is an energy management scheme, where glide range is controlled by flying to a nominal altitude and dynamic pressure versus range profile. An essential part of TAEM guidance is the prediction of ground track range to the runway threshold. Navigation functions are performed by a Kalman filter using TACAN and air data as external measurements. The flight control is accomplished by the CSS mode of the aerojet DAP. The guidance errors are presented to the pilot via the displays, and his task will be to zero out the various error indications.

Although there are no approach and landing computations in the BFS, as exists in the PFS, it is necessary to define BFS activity during this portion of the flight. The approximate boundary for the approach/landing (A/L) phase is as follows:

1. Altitude 10,000 ft
2. Displacement from runway centerline 1,000 ft
3. Distance to touchdown 6 nmi
4. Flight path angle -24 deg
5. Equivalent airspeed 290 KEAS

Upon reaching this boundary, the PFS will switch to the MSBLS for glide slope information, and the guidance system will compute a transition to the shallow glide slope from the steep slope. The BFS, during A/L, will provide commands as a function of glide slope error, to be displayed on the ADI pitch error needle. Navigation, using TACAN data and targeting information, generates a glide slope, which is displayed on the horizontal situation indicator (HSI). Attitude information on pitch and roll will also be available on the ADI. The altitude/vertical velocity indicator (AVVI) will display barometric altitude, vertical velocity, radar altitude, and vertical acceleration. The alpha/mach indicator (AMI) will display Mach number, angle of attack, equivalent airspeed, and longitudinal acceleration. Flight control functions are identical to those used in the earlier phases of TAEM. At 2,000 feet all guidance computation ceases, and the vehicle is to be landed using visual cues.

3.1.2.3 RTLS Operations

3.1.2.3.1 <u>MM 601 RTLS Second Stage</u>. This major mode contains all functions necessary to monitor, guide, and control the vehicle from crew initiation of an RTLS abort through termination of the ET separation maneuver.

RTLS second stage is exited automatically upon completion of the ET separation maneuver or by an MCDS command (OPS 602 PRO) to transition to glide RTLS 1 major mode.

3.1.2.3.2 <u>MM 602 Glide RTLS</u>. This major mode contains all functions necessary to monitor, guide, and control the vehicle during an RTLS abort. This major mode is nominally entered upon completion of the automatic ET separation maneuver and is nominally exited when a desired relative velocity is achieved.

Glide RTLS 1 is exited automatically upon achieving a predetermined velocity if the ET FAST SEP mode is not selected or by an MCDS command (OPS 603 PRO) to transition to the glide RTLS 2 major mode.

3.1.2.3.3 <u>MM 603 Glide RTLS 2</u>. This major mode contains all of the functions necessary to monitor, guide, and control the vehicle from the end of the glide RTLS 1 major mode to achieving the A/L approximate boundary and to accomplishing A/L and roll-out.

Glide RTLS 2 major mode shall be exited by an MCDS command (OPS 0 PRO) to change to OPS 0.

3.2 BFS GENERAL DESCRIPTION

3.2.1 Backup-System Services (BSS).

The BSS performs a number of important and varied functions for the BFS. The BSS provides the basic timing and dispatch structure in which BFS software executes. The BSS controls all BFS hardware interfaces, both internal and external to the BFS GPC. The BSS provides 12 major functions and the I/O compool. These 12 major functions follow:

1. Backup operating system
2. Data bus I/O
3. MCDS interface
4. Annunciation
5. Dedicated displays
6. Uplink
7. Downlist
8. MTU redundancy management
9. Launch data bus
10. Telemetry format load
11. Payload support
12. Payload bay door processing

The following paragraphs present overviews of the above listed BSS major functions.

1. Backup Operating System (BOS)

   BOS provides the structure (960-millisecond major cycle composed of twenty-four 40-millisecond minor cycles) within which the BFS software executes. BOS performs GPC discrete I/O and controls the data bus configuration in response to discrete inputs and keyboard commands. For each minor cycle, BOS extrapolates Greenwich Mean Time (GMT) and mission elapsed time (MET), selects the I/O to be performed, selects the job groups to be dispatched, and phases the input-process-output sequence. BOS provides the initial software response to GPC errors detected by hardware and I/O errors detected by data bus I/O. It also detects other symptoms of system malfunctions. BOS controls system start, restart, and engage/disengage transitions. In the pre-engage state, BOS synchronizes the BFS minor cycles with the PASS I/O profile and provides protection against pollution from PASS.

2. Data Bus I/O

The data bus I/O function consists of all input/output processor (IOP) programs used in controlling the transfer of data to and from the data bus system. The BFS provides an interface with the flight critical (FC) payload (PL), launch/boost data (LB), displays/keyboard (DK), and instrumentation processor (IP) data buses.

3. MCDS Interface

The MCDS interface function provides processing and control of I/O transactions on the DK buses, IPL of the display electronics unit (DEU), display format loading, keyboard input processing, display sequencing, and display parameter output processing/generation. The BFS controls up to four DEU's as a function of the engage/disengage state, BFS CRT switches, IPL source select switch, and GPC/CRT keyboard entries. The BFS also monitors PFS DEU's and responds to selected crew keyboard entries. See Section 4.2.

4. Annunciation

The annunciation function provides annunciation of Classes 0, 2, 3, 4, and 5 faults, using the CRT message line, fault display, and the Shuttle backup caution and warning system. (See Sections 4.2.11 and 8.2.) Annunciation is provided by the BSS for faults detected by both the BSS and application programs. Note Class 0 annunciation involves only an up or down arrow on a CRT display.

5. Dedicated Displays. (Post-engage only)

The dedicated display function is responsible for assembling information and generating the messages required to drive the dedicated display indicators. The specific dedicated display indicators driven by BFS are as follows: (See Section 5.0).

a. Attitude director indicator (ADI)

b. Alpha/mach indicator (AMI)

c. Altitude/vertical velocity indicator (AVVI)

d. Horizontal situation indicator (HSI)

e. Surface position indicator (SPI)

6. Uplink

The uplink function provides the capability of accepting commands transmitted from the ground. These commands are input by the GPC from one of two NSP's. As a function of NSP power status and block normal switch status, NSP input transactions are automatically maintained to ensure receipt of messages from the currently powered-on NSP. The uplink software supports two general types of uplink commands: single-stage command (SSC) and two-stage commands (TSC). SSC's are processed by uplink software upon receipt at the maximum rate of 10 commands per 200 milliseconds. TSC's are buffered and downlisted for preview by the ground. These commands are not executed until receipt of a buffer-execute command from the ground.

7. Downlist

The downlist function collects data, repacks discretes, formulates and controls the proper sequencing of downlist frames, and outputs the downlist data to the pulse code modulator (PCM) master unit. The downlist function automatically provides the ascent and the descent downlist format during the appropriate mission phases.

8. Master Timing Unit (MTU) Redundancy Management (RM)

The MTU RM function provides for selection of an MTU time source and for its use in initialization and maintenance of internal GPC GMT and MET. GMT/MET is initialized from the MTU and is corrected once per major cycle by the MTU RM functions. MTU source selection for GMT/MET correction is performed by a combination of commfault status, past source selection, MTU bite status, and reasonableness tests on the MTU data.

9. Launch Data Bus

The BFS supports a communications interface with the ground (GSE) via the launch data bus (LDB) to provide a general memory (G-MEM) read/write capability. GSE polling is initiated and/or terminated by means of item entries on the GPC memory display.

10. Telemetry Format Load

The telemetry format load function selects, transfers, and verifies automatically the required 64 Kbps format during the mission phases. The load of the 64 Kbps telemetry format random access memory (RAM) of the PCM master unit (PCMMU) is initiated when a PCMMU power switchover is detected.

11. <u>Payload Support</u>

The payload support function provides downlisting of payload analog signals and discretes during ascent and entry phases. Payload command capability is provided by BFS processing of uplink commands for buses PL1 and PL2 during ascent and descent.

12. <u>Payload Bay Door Processing</u>

The payload bay door (PBD) function provides the capability to open the PBD's during orbital insertion phase and to close the doors during pre-deorbit coast. Control and monitoring of the PBD is provided via a cockpit switch and the PBD display. Item entries on the display determine the PBD operations to be performed. The PBD processing provides all necessary sequencing to open and close the door panels and latches in both the auto and manual modes. See Section 4.2.12.

3.2.2 <u>Guidance, Navigation, and Control (GN&C)</u>

A general signal flow diagram of the GN&C is shown in Figure 3.2.2-1. As shown in this figure, GN&C provides the five following major functions:

1. Hardware interface programs
2. GN&C applications controllers
3. Navigation
4. Guidance
5. Flight control

The following paragraphs present overviews of the navigation, guidance, and flight control functions.

3.2.2.1 Navigation

The basic function of the BFS navigation is to provide an estimate of the orbiter state during most of the major modes contained in OPS 1, 3, and 6, i.e., ascent, descent, and RTLS operation sequences, respectively. The orbiter six-element state vector, consisting of the orbiter position and velocity vectors, is estimated based only on IMU data during the ascent operational sequence and is estimated based upon IMU and NAVAID data during the descent and RTLS operational sequences.

The IMU data consist of mid-value selected data from the three IMU's as processed by the IMU hardware interface program.

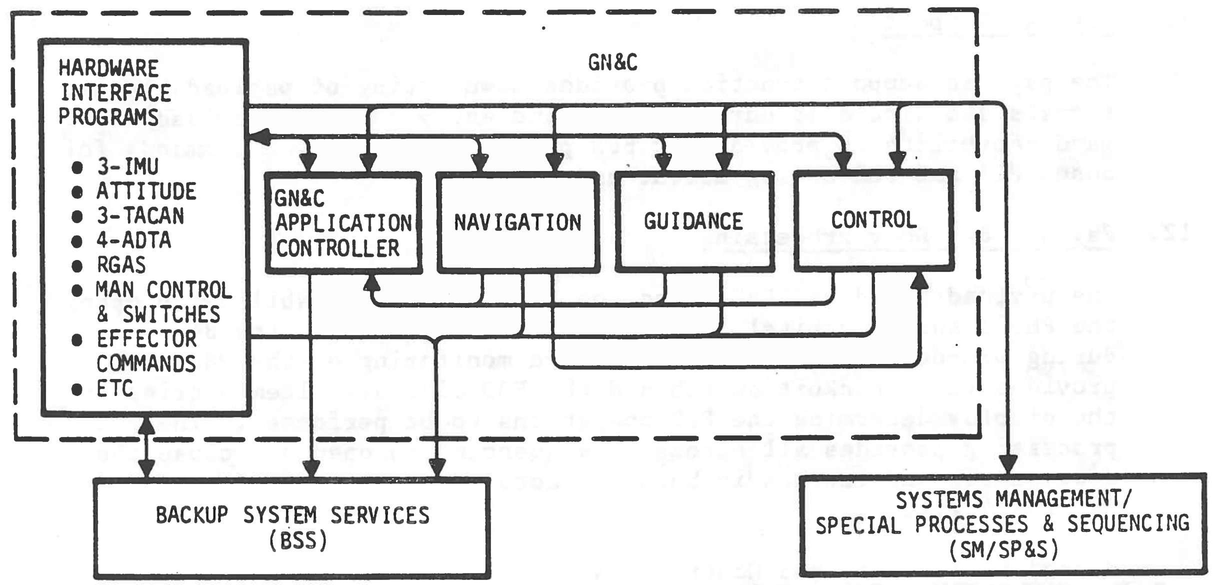


Figure 3.2.2-1. GN&C General Signal Flow Diagram

The navigation aid (NAVAID) data consist of range and bearing from one, two, or three TACAN's; air data transducer assembly (ADTA) barometric-altitude; IMU accelerometer sensed drag; and uplinked or manual state vector corrections. The BFS navigation function employs the same PFS Kalman filtering algorithm in order to achieve optimal IMU-NAVAID navigation.

The BFS navigation function in conjunction with the BFS GN&C application controllers is implemented containing the following major functions:

1. <u>Navigation Control</u>

   It performs the initialization of navigation function parameters and sets up the sequencing of functions to accomplish navigation requirements.

2. <u>Measurement Scheduler</u>

   It selects the appropriate sensor measurements in accordance with selection criteria.

3. Data Handler

   It prepares data for sensor measurement processing.

4. Navigation Reconfiguration

   It initializes state vector and covariance matrix for sensor measurement processing of manual updates and prepares site location data for changing sites.

5. State and Covariance Propagation

   It propagates state and covariance matrix for sensor measurement processing. It also propagates state for user parameter calculations.

6. State and Covariance Update

   It determines and performs state and covariance updates.

7. User Parameter Processing

   It computes state-related parameters for guidance, control, user interface, and SM/SP&S.

The GN&C PRD (MG038104), Paragraph 3.2.2, specifies the detailed navigation program requirements, including those associated with the above major functions and other detailed functions.

3.2.2.2 Guidance

3.2.2.2.1 Ascent Guidance. The BFS guidance system is intended to take over, upon PFS failure, anytime during the ascent phase and to guide the Shuttle to a safe orbit. The basic BFS algorithms and guidance laws are identical to those used for the primary system because the requirements are the same.

First-stage guidance is accomplished by a pre-programmed set of Euler angles that are converted to steering commands as a function of relative velocity. Guidance also monitors relative velocity as a cue in throttling to preclude exceeding a maximum value of dynamic pressure.

Subsequent to SRB separation, second-stage guidance is initiated. The guidance law used assumes optimal fuel usage and flexibility of targeting. Throttling is commanded during the second stage to prevent excessive longitudinal acceleration.

Shortly after MECO, the ET separation occurs, and then the two OMS burns. The insertion guidance law is similar to that used in the second stage.

3.2.2.2.2 <u>Descent Guidance</u>. Deorbit guidance is similar to insertion guidance in that a desired relationship between vertical and horizontal velocities at the target point is a boundary condition. After the OMS burn, which puts the vehicle into a free fall trajectory, guidance computes the time to 400,000 feet, which is the assumed atmospheric entry. Five minutes prior to this time, the crew modes to MM 304, and the vehicle is aligned to the desired initial angle of attack.

During MM 304, guidance is divided into five subphases. Normally, they are ordered: pre-entry, temperature control, equilibrium glide, constant drag, and transition. In MM 304, guidance commands are pre-programmed angle of attack, which is a function of relative velocity. During the pre-entry subphase, a constant attitude is maintained. In temperature control, roll is commanded to fly to two quadratic drag-velocity profiles. Equilibrium glide is a range-stretching subphase in which a drag-velocity profile of approximately $\dot{\gamma} = 0$ is flown, where γ equals the flight path angle. Constant drag is a constant drag regime. Transition utilizes an energy-drag profile to reach the TAEM interface.

The system modes to MM 305 when Mach ≤ 2.5. The TAEM guidance mode uses energy as the driver in attempting to place the vehicle tangent to an imaginary cylinder. The vehicle is then flown around the cylinder until reaching a tangent congruent with the runway centerline. The guidance system then generates error signals in the pitch axis to reflect deviations from a steep glide path (21-to-24 degree range).

Roll commands are also generated as a function of the deviations of the vehicle from the runway centerline. TAEM guidance continues until an altitude of approximately 2,000 feet, where it is terminated.

The BFS is designed to take over during any phase of deorbit and entry and guide the vehicle to a safe landing.

3.2.2.3 Flight Control

The Shuttle BFS flight control system is intended to provide controls capability for safe insertion or return from any point in the mission after lift-off. By intent, its design requirements are very similar to the primary system flight control, the major difference being elimination of automatic options during the return phase. The body flap and speed brake operation is manual or automatic at crew option.

During ascent, the TVC control undergoes three distinct changes. First-stage boost utilizes gimballed thrust from SRB's and SSME's for control and occurs within the sensible atmosphere. Load relief for vehicle structure, as well as for elevons, is provided. Following SRB staging and until MECO, control authority is provided by the SSME's utilizing IMU and orbiter rate gyro signals.

Following MECO, the transition DAP takes control using the gimballed OMS engines for control authority; RCS attitude control is available in case the OMS TVC requests added control authority, or if an OMS fails. Ascent flight control through MECO is automatic, while the transition and descent DAP's accept only manual inputs.

Following MECO in RTLS abort, the mated coast and ET separation DAP (R_DAP) takes control. During mated coast, control is automatic using the RCS jets. During ET separation, control is automatic using the RCS jets and the rudder. Both speed brake and elevons are held at frozen positions.

Control during deorbit burn is again accomplished manually through the transition DAP, and is the three-axis RCS maneuver to entry attitude and hold until MM 304 is initiated at which time the descent DAP is called.

Control throughout the remainder of the flight is via the descent DAP, using a manual CSS mode throughout. The nominal entry and glide return to landing site (GRTLS) entry control are integrated with appropriate switching into this DAP. Reduced/increased gain CSS will be available via a downmoding option. Initially, attitude control is maintained using aft RCS jets only with elevon control blended in. Roll RCS is inhibited at $\bar{q} = 10$, while pitch RCS is inhibited at $\bar{q} = 20$. Yaw RCS jets are used until $M = 1$.

Yaw RCS is terminated automatically at $M < 1$. Terminal area energy management (TAEM) and approach and landing are accomplished via the descent DAP. Decrab and rollout are accomplished manually.

Limited attitude hold capability is provided during MM's 104 through 106 and 301 through 303. This control mode, which is named discrete rate command/attitude hold (DRC/AH), provides a predetermined angular rate about a specified axis with an attitude-hold in that axis when the RHC is in detent. This mode downmodes to acceleration command mode by axis any time the RHC exceeds the softstop. RCS jet firings shall be inhibited when the RHC is returned to within softstop limits in that axis and remain inhibited until the RHC is returned to detent. At that time, the DRC/AH mode shall resume.

3.2.3 Systems Management/Special Processes and Payload (SM/SP&PL) and Sequencing

A general signal flow diagram of the SM/SP&PL and sequencing is shown in Figure 3.2.3-1. As shown in this figure, the SM/SP&PL and sequencing contains six major functions and the event compool. These six major functions are as follows:

1. Hardware interface program (HIP)
2. SM/SP and sequencing application controllers
3. Sequencing

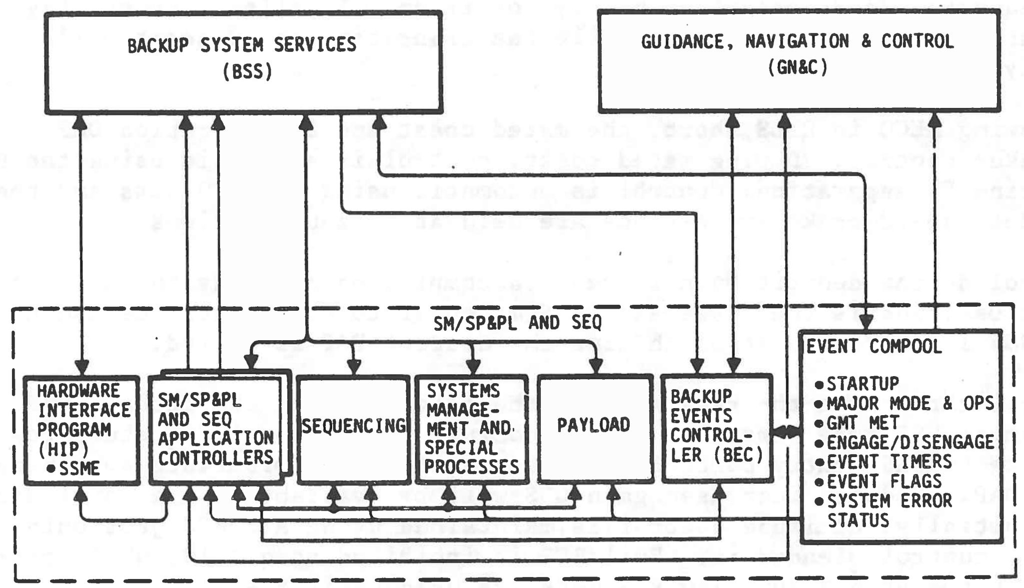


Figure 3.2.3-1. SM/SP&PL and Sequencing General Signal Flow Diagram

4. Systems management and special processes

5. Payload

6. Backup events controller

The following paragraphs present overviews of the SM/SP, sequencing backup events controller, and payload functions.

3.2.3.1 Systems Management/Special Processes

The SM/SP portion of the BFS is composed of two primary groups. The first, or systems management group, consists of the following functions:

1. FDA

2. Scaling and display (SD)

The second or special processes group consists of the following functions:

1. APU fuel quantity gauging

2. S-band antenna management

3. Hydraulic water boiler quantity gauging

4. Fuel cell total current and power calculations

5. Flash evaporator activation/deactivation

6. Ammonia boiler activation

7. Freon pump power management

8. Cabin pressure monitor (dp/dt)

9. Postlanding special process

The SM/SP functions are executed whenever the BFS GPC mode switch is in either the STDBY or RUN mode. The FDA/SD functions will be executed once per major cycle. The data used for FDA is fetched by the BOS I/O from the PCMMU operational instrumentation (OI) buffer. The FDA program performs limit checking of OI data parameters. The parameters, which fail limit checking, are identified to the BSS MCDS interface and annunciation functions. Annunciation to the crew of detected failures is then via the caution and warning panel, the alert tone and alert light, and the message line of the CRT. The crew may, via the MCDS interface software function, call up three displays, which will present a summary of the subsystem status on the BFS CRT. The SM displays are the SM SYS SUMM 1, SM SYS SUMM 2, and the THERMAL displays. Some OI data parameters are processed by the FDA/SD functions during a limited on-orbit period only. This period spans MM 104 through 106, on-orbit OPS 0 and MM 301 through 303. See Sections 4.2.11 and 8.0 for additional detail.

3.2.3.1.1 Payload. The payload portion of the BFS consists of the table-driven processing to provide the following capabilities for processing up to 50 payload support parameters.

1. Fault detection and annunciation (FDA)

2. Scaling of PCM counts to engineering units

3. Display of scaled parameters

4. Downlist of all processed parameters

The FDA capability provides for limit sensing (upper and lower), false alarm avoidance filtering, and fault annunciation via the display interface. All parameters can be linearly scaled to provide their value in engineering units and a status indicator to the display interface. The status indicator provides out-of-limits high or low information and data missing information for each displayed parameter, as required. All processed parameters must be downlisted in 25 downlist words. Discretes may be packed 16 to a downlist word. Note that this downlist requirement places a constraint on the number and type mix of processed parameters, and it may not be possible to achieve processing of the maximum of 50 parameters for certain type mixes.

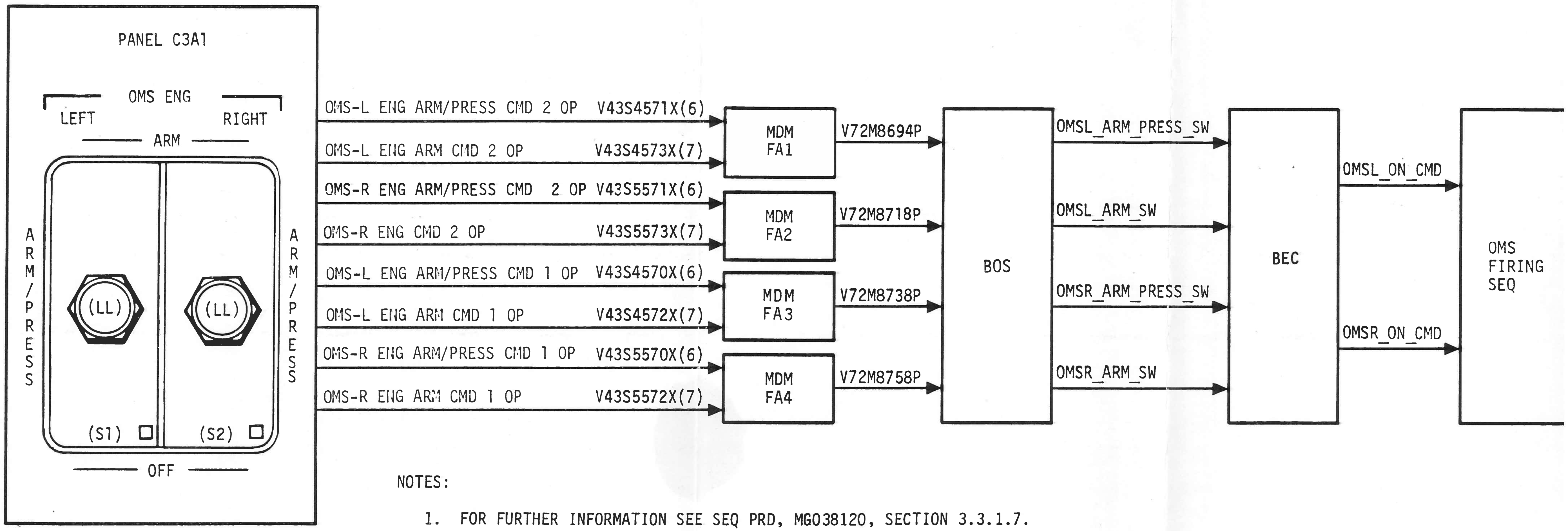
Payload processing will be disabled for all flights except those that require payload support from the BFS. When disabled, the payload display (SPEC 206) will not be available and no parameters will be processed by the payload function.

3.2.3.2 Sequencing

The sequencing portion of the BFS consists of the following sequences and subsequences as shown in Figures 3.2.3.2-1 through 3.2.3.2-5.

1. SRB separation and range safety safing
2. ET separation
3. SSME operations
4. SSME HIP
5. Main propulsion system (MPS) dump
6. OMS engine firing
7. Vent door control
8. RCS quantity gauging
9. Abort control
10. Landing gear isolation valve control
11. Abort OMS-to-RCS interconnect
12. MPS helium pressure monitor
13. Backup events controller (BEC)

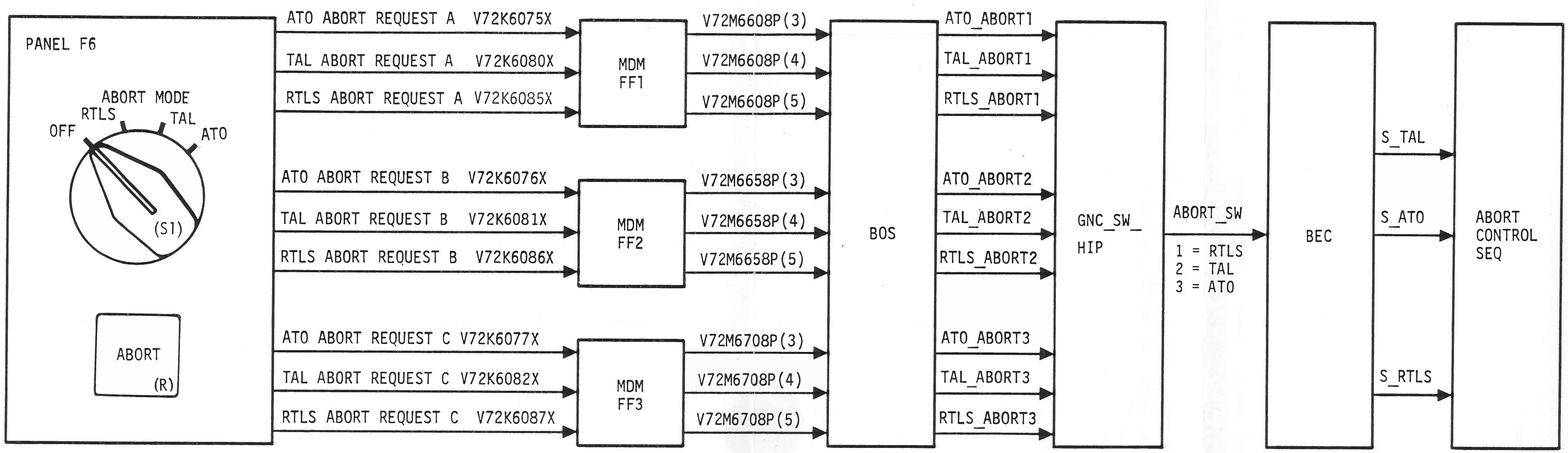
Because engagement can occur at anytime during ascent or descent, each sequencing function is capable of taking control from the primary system at any point in the ascent or descent mission phases.



NOTES:

1. FOR FURTHER INFORMATION SEE SEQ PRD, MG038120, SECTION 3.3.1.7.
2. THE OMS FIRING SEQUENCE LOGIC PERFORMS A LOGICAL OR OF THE OP1 AND OP2 SIGNALS FOR FAILURE DETECTION AND FOR PURGING.

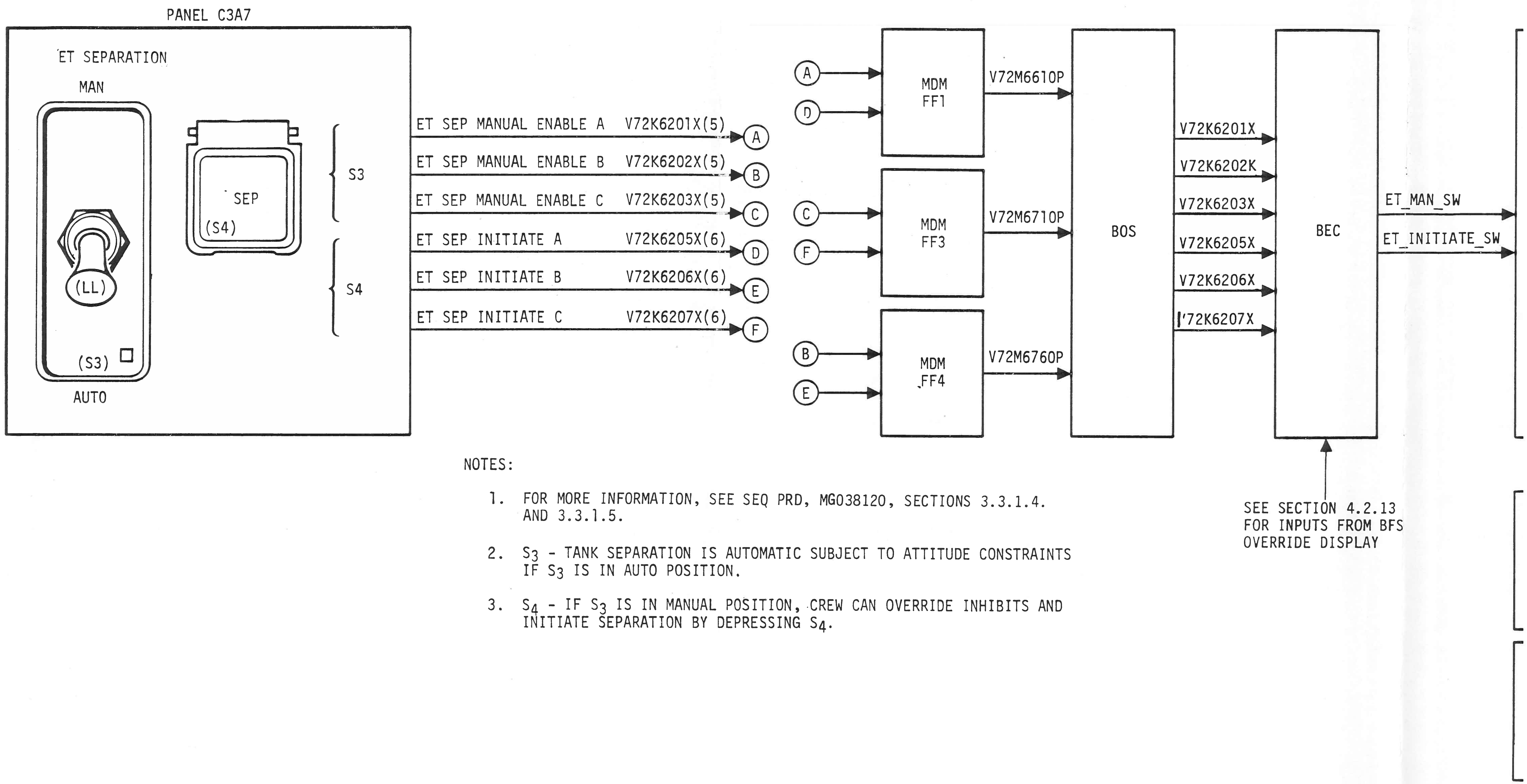
Figure 3.2.3.2-1. OMS Firing Sequence Switch Interface



NOTES:

1. THE SIGNALS S_TAL, S_ATO, AND S_RTLS ARE USED BY THE ABORT CONTROL SEQUENCE TO DETERMINE WHICH BURN VALUES (I-LOAD) TO USE. FOR MORE INFORMATION SEE SEQ PRD, MG038120, SECTION 3.3.1.9

Figure 3.2.3.2-2. Abort Mode Switch Interface



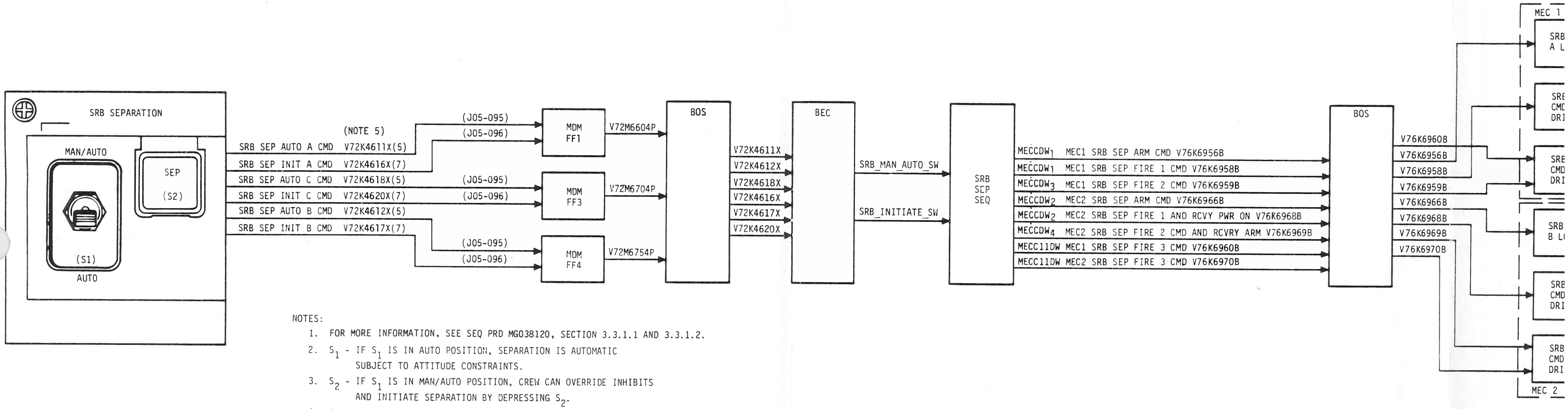
NOTES:

1. FOR MORE INFORMATION, SEE SEQ PRD, MG038120, SECTIONS 3.3.1.4. AND 3.3.1.5.

2. S_3 - TANK SEPARATION IS AUTOMATIC SUBJECT TO ATTITUDE CONSTRAINTS IF S_3 IS IN AUTO POSITION.

3. S_4 - IF S_3 IS IN MANUAL POSITION, CREW CAN OVERRIDE INHIBITS AND INITIATE SEPARATION BY DEPRESSING S_4.

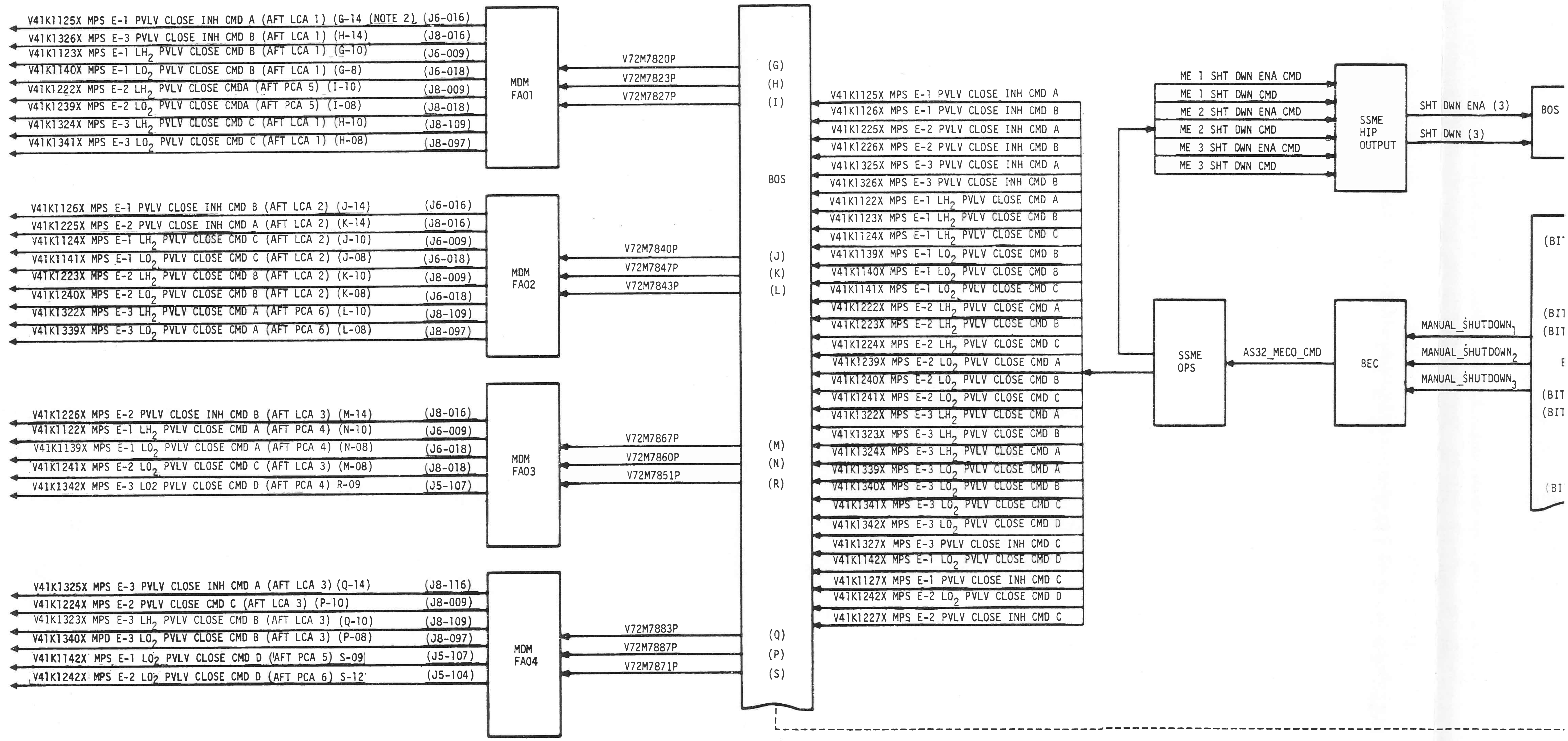
Figure 3.2



NOTES:

1. FOR MORE INFORMATION, SEE SEQ PRD MG038120, SECTION 3.3.1.1 AND 3.3.1.2.
2. S_1 - IF S_1 IS IN AUTO POSITION, SEPARATION IS AUTOMATIC SUBJECT TO ATTITUDE CONSTRAINTS.
3. S_2 - IF S_1 IS IN MAN/AUTO POSITION, CREW CAN OVERRIDE INHIBITS AND INITIATE SEPARATION BY DEPRESSING S_2.
4. S_1 - IF S_1 IS IN MAN/AUTO POSITION, SEPARATION IS AUTOMATIC IN THE ABSENCE OF INHIBITS.
5. NO.'S FOLLOWING DISCRETE MSID'S INDICATE BIT POSITION IN THE APPROPRIATE PARENT WORD USING A 00-15 POSITION CONVENTION, E.G., V72K4611X(5) CONSTITUTES BIT 05 OF PARENT WORD V72M6604P.

Figure 3.2.3.2-4.



V41K1125X MPS E-1 PVLV CLOSE INH CMD A (AFT LCA 1) (G-14 (NOTE 2) (J6-016)
V41K1326X MPS E-3 PVLV CLOSE INH CMD B (AFT LCA 1) (H-14) (J8-016)
V41K1123X MPS E-1 LH2 PVLV CLOSE CMD B (AFT LCA 1) (G-10) (J6-009)
V41K1140X MPS E-1 LO2 PVLV CLOSE CMD B (AFT LCA 1) (G-8) (J6-018)
V41K1222X MPS E-2 LH2 PVLV CLOSE CMDA (AFT PCA 5) (I-10) (J8-009)
V41K1239X MPS E-2 LO2 PVLV CLOSE CMDA (AFT PCA 5) (I-08) (J8-018)
V41K1324X MPS E-3 LH2 PVLV CLOSE CMD C (AFT LCA 1) (H-10) (J8-109)
V41K1341X MPS E-3 LO2 PVLV CLOSE CMD C (AFT LCA 1) (H-08) (J8-097)
MDM FA01
V72M7820P
V72M7823P
V72M7827P
V41K1126X MPS E-1 PVLV CLOSE INH CMD B (AFT LCA 2) (J-14) (J6-016)
V41K1225X MPS E-2 PVLV CLOSE INH CMD A (AFT LCA 2) (K-14) (J8-016)
V41K1124X MPS E-1 LH2 PVLV CLOSE CMD C (AFT LCA 2) (J-10) (J6-009)
V41K1141X MPS E-1 LO2 PVLV CLOSE CMD C (AFT LCA 2) (J-08) (J6-018)
V41K1223X MPS E-2 LH2 PVLV CLOSE CMD B (AFT LCA 2) (K-10) (J8-009)
V41K1240X MPS E-2 LO2 PVLV CLOSE CMD B (AFT LCA 2) (K-08) (J6-018)
V41K1322X MPS E-3 LH2 PVLV CLOSE CMD A (AFT PCA 6) (L-10) (J8-109)
V41K1339X MPS E-3 LO2 PVLV CLOSE CMD A (AFT PCA 6) (L-08) (J8-097)
MDM FA02
V72M7840P
V72M7847P
V72M7843P
V41K1226X MPS E-2 PVLV CLOSE INH CMD B (AFT LCA 3) (M-14) (J8-016)
V41K1122X MPS E-1 LH2 PVLV CLOSE CMD A (AFT PCA 4) (N-10) (J6-009)
V41K1139X MPS E-1 LO2 PVLV CLOSE CMD A (AFT PCA 4) (N-08) (J6-018)
V41K1241X MPS E-2 LO2 PVLV CLOSE CMD C (AFT LCA 3) (M-08) (J8-018)
V41K1342X MPS E-3 LO2 PVLV CLOSE CMD D (AFT PCA 4) R-09 (J5-107)
MDM FA03
V72M7867P
V72M7860P
V72M7851P
V41K1325X MPS E-3 PVLV CLOSE INH CMD A (AFT LCA 3) (Q-14) (J8-116)
V41K1224X MPS E-2 PVLV CLOSE CMD C (AFT LCA 3) (P-10) (J8-009)
V41K1323X MPS E-3 LH2 PVLV CLOSE CMD B (AFT LCA 3) (Q-10) (J8-109)
V41K1340X MPD E-3 LO2 PVLV CLOSE CMD B (AFT LCA 3) (P-08) (J8-097)
V41K1142X MPS E-1 LO2 PVLV CLOSE CMD D (AFT PCA 5) S-09 (J5-107)
V41K1242X MPS E-2 LO2 PVLV CLOSE CMD D (AFT PCA 6) S-12 (J5-104)
MDM FA04
V72M7883P
V72M7887P
V72M7871P
BOS
(G)
(H)
(I)
(J)
(K)
(L)
(M)
(N)
(R)
(Q)
(P)
(S)
V41K1125X MPS E-1 PVLV CLOSE INH CMD A
V41K1126X MPS E-1 PVLV CLOSE INH CMD B
V41K1225X MPS E-2 PVLV CLOSE INH CMD A
V41K1226X MPS E-2 PVLV CLOSE INH CMD B
V41K1325X MPS E-3 PVLV CLOSE INH CMD A
V41K1326X MPS E-3 PVLV CLOSE INH CMD B
V41K1122X MPS E-1 LH2 PVLV CLOSE CMD A
V41K1123X MPS E-1 LH2 PVLV CLOSE CMD B
V41K1124X MPS E-1 LH2 PVLV CLOSE CMD C
V41K1139X MPS E-1 LO2 PVLV CLOSE CMD B
V41K1140X MPS E-1 LO2 PVLV CLOSE CMD B
V41K1141X MPS E-1 LO2 PVLV CLOSE CMD C
V41K1222X MPS E-2 LH2 PVLV CLOSE CMD A
V41K1223X MPS E-2 LH2 PVLV CLOSE CMD B
V41K1224X MPS E-2 LH2 PVLV CLOSE CMD C
V41K1239X MPS E-2 LO2 PVLV CLOSE CMD A
V41K1240X MPS E-2 LO2 PVLV CLOSE CMD B
V41K1241X MPS E-2 LO2 PVLV CLOSE CMD C
V41K1322X MPS E-3 LH2 PVLV CLOSE CMD A
V41K1323X MPS E-3 LH2 PVLV CLOSE CMD B
V41K1324X MPS E-3 LH2 PVLV CLOSE CMD A
V41K1339X MPS E-3 LO2 PVLV CLOSE CMD A
V41K1340X MPS E-3 LO2 PVLV CLOSE CMD B
V41K1341X MPS E-3 LO2 PVLV CLOSE CMD C
V41K1342X MPS E-3 LO2 PVLV CLOSE CMD D
V41K1327X MPS E-3 PVLV CLOSE INH CMD C
V41K1142X MPS E-1 LO2 PVLV CLOSE CMD D
V41K1127X MPS E-1 PVLV CLOSE INH CMD C
V41K1242X MPS E-2 LO2 PVLV CLOSE CMD D
V41K1227X MPS E-2 PVLV CLOSE INH CMD C
ME 1 SHT DWN ENA CMD
ME 1 SHT DWN CMD
ME 2 SHT DWN ENA CMD
ME 2 SHT DWN CMD
ME 3 SHT DWN ENA CMD
ME 3 SHT DWN CMD
SSME HIP OUTPUT
SHT DWN ENA (3)
SHT DWN (3)
BOS
SSME OPS
AS32_MECO_CMD
BEC
MANUAL_SHUTDOWN1
MANUAL_SHUTDOWN2
MANUAL_SHUTDOWN3

Figure 3.2

3.2.3.2.1 <u>SRB Separation and Range Safety Safing</u>. The SRB SEP SEQ scheduler (SSSS) monitors hardware signals to determine the status of SRB separation. If BFS is engaged and separation has not been accomplished by PASS, the SSSS monitors SRB chamber pressure (Pc) for an indicator of thrust tail-off. When thrust tail-off occurs, that is, Pc is less than 50 psia, the SSSS initiates the SRB SEP sequence module and then monitors for the SRB separation command. Note that the SRB SEP sequencer can be initiated by the SSSS at a default value of maximum SRB burn time, which is an I-load parameter, MAX_SRB_BURN TIME.

1. <u>Functional Description</u>. The SRB separation sequencer (SRBSS) operates at 25 Hz. If BFS is engaged, the SRBSS is attached approximately 100 seconds after SRB ignition on the basis of tail-off of the SRB's thrust chamber pressure or an I-loaded default value of maximum SRB burn time. See previous subsection. Separation occurs automatically at a nominal time of 6 seconds after thrust chamber pressure drops below 50 psia, if the vehicle rate parameters and dynamic pressure are within acceptable limits established by I-loads. Failure to meet these criteria results in inhibition of the separation sequence, which can be overriden manually by switches S1 and S2 (AUTO/MAN and SEP) on orbiter panel C3 (see Figure 3.2.3.2-4). Figure 3.2.3.2.1-1 provides a sequential time line for the SRB separation sequencer showing the input and output functions.

2. <u>Hardware and Software Parametric Interfaces</u>. Parametric interfaces for the SRB separation sequencing subsystem are shown in Figure 3.2.3.2.1-2.

3. <u>Operational Description</u>. The following provides a brief summary of the events occurring after initiation of the separation sequence:

   Step 1: Issue MEC 1 and 2 master reset. Activate ET/ORB separation camera. Issue commands to MEC to turn power off to SRB and RSS.

   Step 2: Issue SRB separation arm commands to MEC.

   Step 3: Issue MEC ATVC SRB 26V deadface commands. Terminate MEC ATVC SRB IVD power-on commands.

   Step 4: Issue MEC SRB separation arm commands.

   Step 5: Issue MEC SRB separation fire 1, 2, and 3 commands.

Step 6: Terminate the following MEC commands following 4-second delay.

- RSS power off
- SRB power C on
- MEC 1 and 2 SRB sep fire 3 commands
- SRB power A and B on

The following provides a summary of the salient operating characteristics of the SRB separation sequencer.

1. The separations indicate parameters shown in Figure 3.2.3.2.1-3, e.g., V76X9151X, are used by BFS to determine if PFS has completed SRB separation.

2. The separation auto and separation initiate commands are monitored by the BFS BEC (see Figure 3.2.3.2-4) to determine if manual separation has been selected and initiated. If manual separation has been initiated in the BFS pre-engaged mode, BFS will execute the separation sequence if engaged prior to separation completion.

3. If BFS is engaged during the separation sequence, BFS will initiate at STEP 1 above, and complete the sequence.

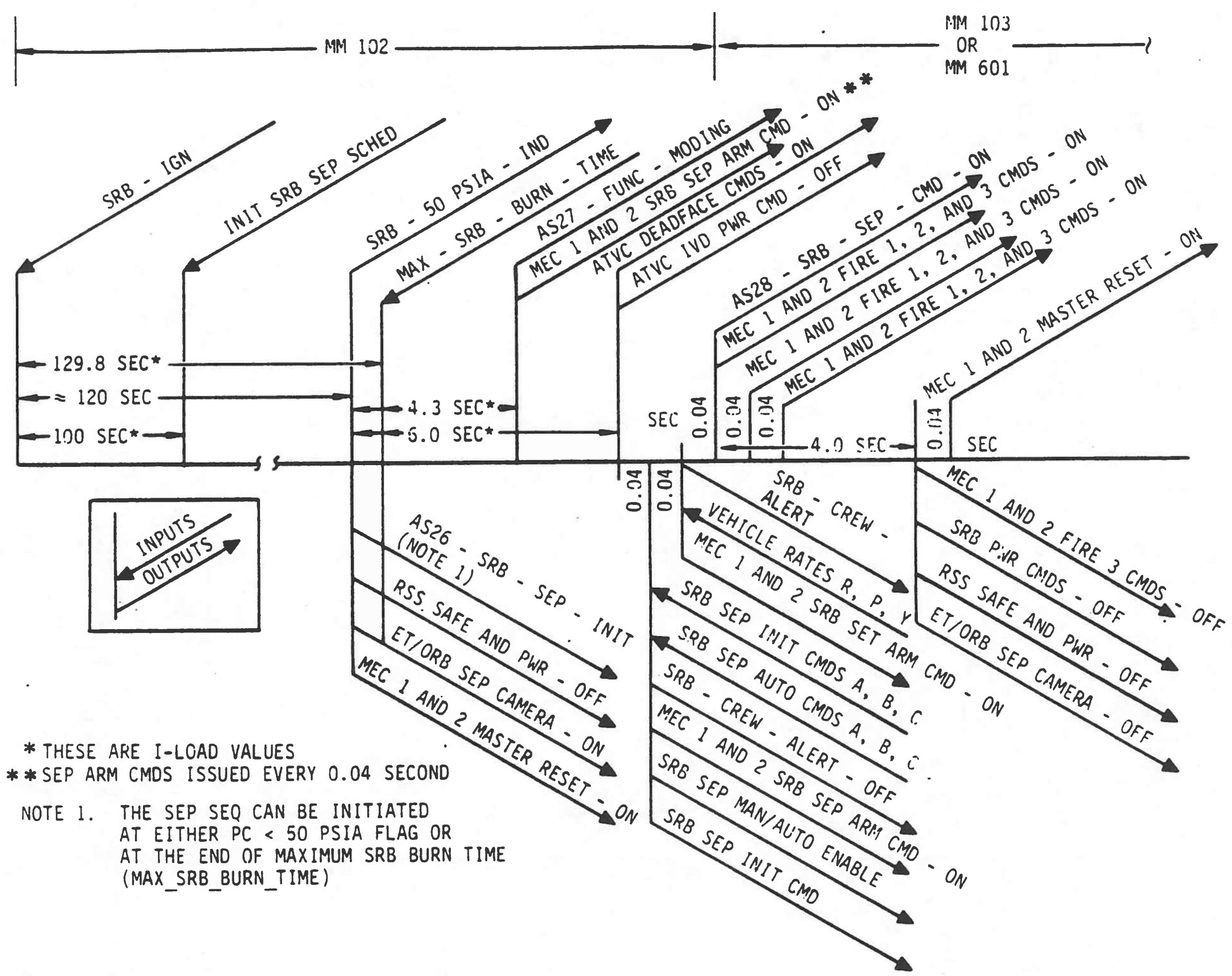
3.2.3.2.2 Restart Effects. If a restart occurs on a non-critical step, the SRB separation sequencer will continue the step.

If a restart occurs at a critical step, e.g., between PIC arm and fire commands, the sequence will step backward to allow a 1.7-second circuit charging time before issuing fire commands.

3.2.3.2.3 Backup Events Controller (BEC). The BEC software mechanization for the BFS is equivalent to the master sequence and control (MSC) function in the PFS. As such, it controls the BFS system major mode transitions and events that occur within each major mode. The BEC monitors and accepts input signals from sequencing, guidance, flight control, BOS, user interface (UI), I/O compool, and PASS transfer data. The resulting system mode/event as determined by the BEC is stored in the event compool for usage by other software functions.

3.3 MASS MEMORY INTERFACE

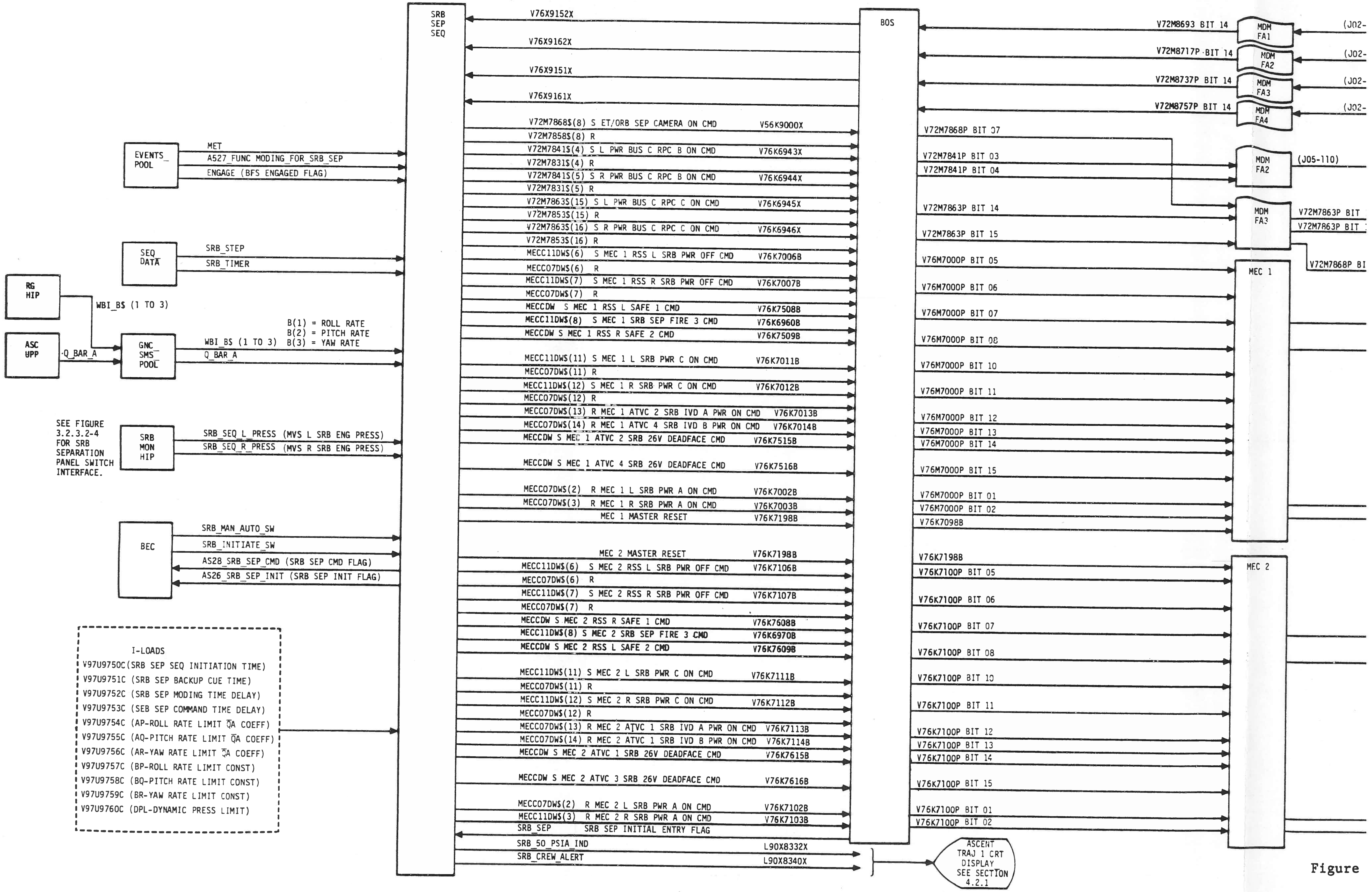
(TBD)



* THESE ARE I-LOAD VALUES
** SEP ARM CMDS ISSUED EVERY 0.04 SECOND

NOTE 1. THE SEP SEQ CAN BE INITIATED AT EITHER PC < 50 PSIA FLAG OR AT THE END OF MAXIMUM SRB BURN TIME (MAX_SRB_BURN_TIME)

Figure 3.2.3.2.1-1. SRB Separation Sequencer Time Line



SRB SEP SEQ
BOS
V76X9152X
V76X9162X
V76X9151X
V76X9161X
V72M7868$(8) S ET/ORB SEP CAMERA ON CMD V56K9000X
V72M7858$(8) R
V72M7841$(4) S L PWR BUS C RPC B ON CMD V76K6943X
V72M7831$(4) R
V72M7841$(5) S R PWR BUS C RPC B ON CMD V76K6944X
V72M7831$(5) R
V72M7863$(15) S L PWR BUS C RPC C ON CMD V76K6945X
V72M7853$(15) R
V72M7863$(16) S R PWR BUS C RPC C ON CMD V76K6946X
V72M7853$(16) R
MECC11DW$(6) S MEC 1 RSS L SRB PWR OFF CMD V76K7006B
MECC07DW$(6) R
MECC11DW$(7) S MEC 1 RSS R SRB PWR OFF CMD V76K7007B
MECC07DW$(7) R
MECCDW S MEC 1 RSS L SAFE 1 CMD V76K7508B
MECC11DW$(8) S MEC 1 SRB SEP FIRE 3 CMD V76K6960B
MECCDW S MEC 1 RSS R SAFE 2 CMD V76K7509B
MECC11DW$(11) S MEC 1 L SRB PWR C ON CMD V76K7011B
MECC07DW$(11) R
MECC11DW$(12) S MEC 1 R SRB PWR C ON CMD V76K7012B
MECC07DW$(12) R
MECC07DW$(13) R MEC 1 ATVC 2 SRB IVD A PWR ON CMD V76K7013B
MECC07DW$(14) R MEC 1 ATVC 4 SRB IVD B PWR ON CMD V76K7014B
MECCDW S MEC 1 ATVC 2 SRB 26V DEADFACE CMD V76K7515B
MECCDW S MEC 1 ATVC 4 SRB 26V DEADFACE CMD V76K7516B
MECC07DW$(2) R MEC 1 L SRB PWR A ON CMD V76K7002B
MECC07DW$(3) R MEC 1 R SRB PWR A ON CMD V76K7003B
MEC 1 MASTER RESET V76K7198B
MEC 2 MASTER RESET V76K7198B
MECC11DW$(6) S MEC 2 RSS L SRB PWR OFF CMD V76K7106B
MECC07DW$(6) R
MECC11DW$(7) S MEC 2 RSS R SRB PWR OFF CMD V76K7107B
MECC07DW$(7) R
MECCDW S MEC 2 RSS R SAFE 1 CMD V76K7608B
MECC11DW$(8) S MEC 2 SRB SEP FIRE 3 CMD V76K6970B
MECCDW S MEC 2 RSS L SAFE 2 CMD V76K7609B
MECC11DW$(11) S MEC 2 L SRB PWR C ON CMD V76K7111B
MECC07DW$(11) R
MECC11DW$(12) S MEC 2 R SRB PWR C ON CMD V76K7112B
MECC07DW$(12) R
MECC07DW$(13) R MEC 2 ATVC 1 SRB IVD A PWR ON CMD V76K7113B
MECC07DW$(14) R MEC 2 ATVC 1 SRB IVD B PWR ON CMD V76K7114B
MECCDW S MEC 2 ATVC 1 SRB 26V DEADFACE CMD V76K7615B
MECCDW S MEC 2 ATVC 3 SRB 26V DEADFACE CMD V76K7616B
MECC07DW$(2) R MEC 2 L SRB PWR A ON CMD V76K7102B
MECC11DW$(3) R MEC 2 R SRB PWR A ON CMD V76K7103B
SRB_SEP SRB SEP INITIAL ENTRY FLAG
SRB_50_PSIA_IND L90X8332X
SRB_CREW_ALERT L90X8340X
ASCENT TRAJ 1 CRT DISPLAY SEE SECTION 4.2.1
EVENTS_POOL
MET
A527_FUNC_MODING_FOR_SRB_SEP
ENGAGE (BFS ENGAGED FLAG)
SEQ DATA
SRB_STEP
SRB_TIMER
RG HIP
ASC UPP
WBI_B$ (1 TO 3)
Q_BAR_A
GNC_SMS_POOL
WBI_B$ (1 TO 3)
Q_BAR_A
B(1) = ROLL RATE
B(2) = PITCH RATE
B(3) = YAW RATE
SEE FIGURE 3.2.3.2-4 FOR SRB SEPARATION PANEL SWITCH INTERFACE.
SRB MON HIP
SRB_SEQ_L_PRESS (MVS L SRB ENG PRESS)
SRB_SEQ_R_PRESS (MVS R SRB ENG PRESS)
BEC
SRB_MAN_AUTO_SW
SRB_INITIATE_SW
AS28_SRB_SEP_CMD (SRB SEP CMD FLAG)
AS26_SRB_SEP_INIT (SRB SEP INIT FLAG)
I-LOADS
V97U9750C(SRB SEP SEQ INITIATION TIME)
V97U9751C (SRB SEP BACKUP CUE TIME)
V97U9752C (SRB SEP MODING TIME DELAY)
V97U9753C (SEB SEP COMMAND TIME DELAY)
V97U9754C (AP-ROLL RATE LIMIT QA COEFF)
V97U9755C (AQ-PITCH RATE LIMIT QA COEFF)
V97U9756C (AR-YAW RATE LIMIT QA COEFF)
V97U9757C (BP-ROLL RATE LIMIT CONST)
V97U9758C (BQ-PITCH RATE LIMIT CONST)
V97U9759C (BR-YAW RATE LIMIT CONST)
V97U9760C (DPL-DYNAMIC PRESS LIMIT)
V72M8693 BIT 14
V72M8717P BIT 14
V72M8737P BIT 14
V72M8757P BIT 14
MDM FA1
MDM FA2
MDM FA3
MDM FA4
V72M7868P BIT 07
V72M7841P BIT 03
V72M7841P BIT 04
MDM FA2
(J05-110)
V72M7863P BIT 14
V72M7863P BIT 15
MDM FA3
V76M7000P BIT 05
V76M7000P BIT 06
V76M7000P BIT 07
V76M7000P BIT 08
V76M7000P BIT 10
V76M7000P BIT 11
V76M7000P BIT 12
V76M7000P BIT 13
V76M7000P BIT 14
V76M7000P BIT 15
V76M7000P BIT 01
V76M7000P BIT 02
V76K7098B
MEC 1
V76K7198B
V76K7100P BIT 05
V76K7100P BIT 06
V76K7100P BIT 07
V76K7100P BIT 08
V76K7100P BIT 10
V76K7100P BIT 11
V76K7100P BIT 12
V76K7100P BIT 13
V76K7100P BIT 14
V76K7100P BIT 15
V76K7100P BIT 01
V76K7100P BIT 02
MEC 2

Figure

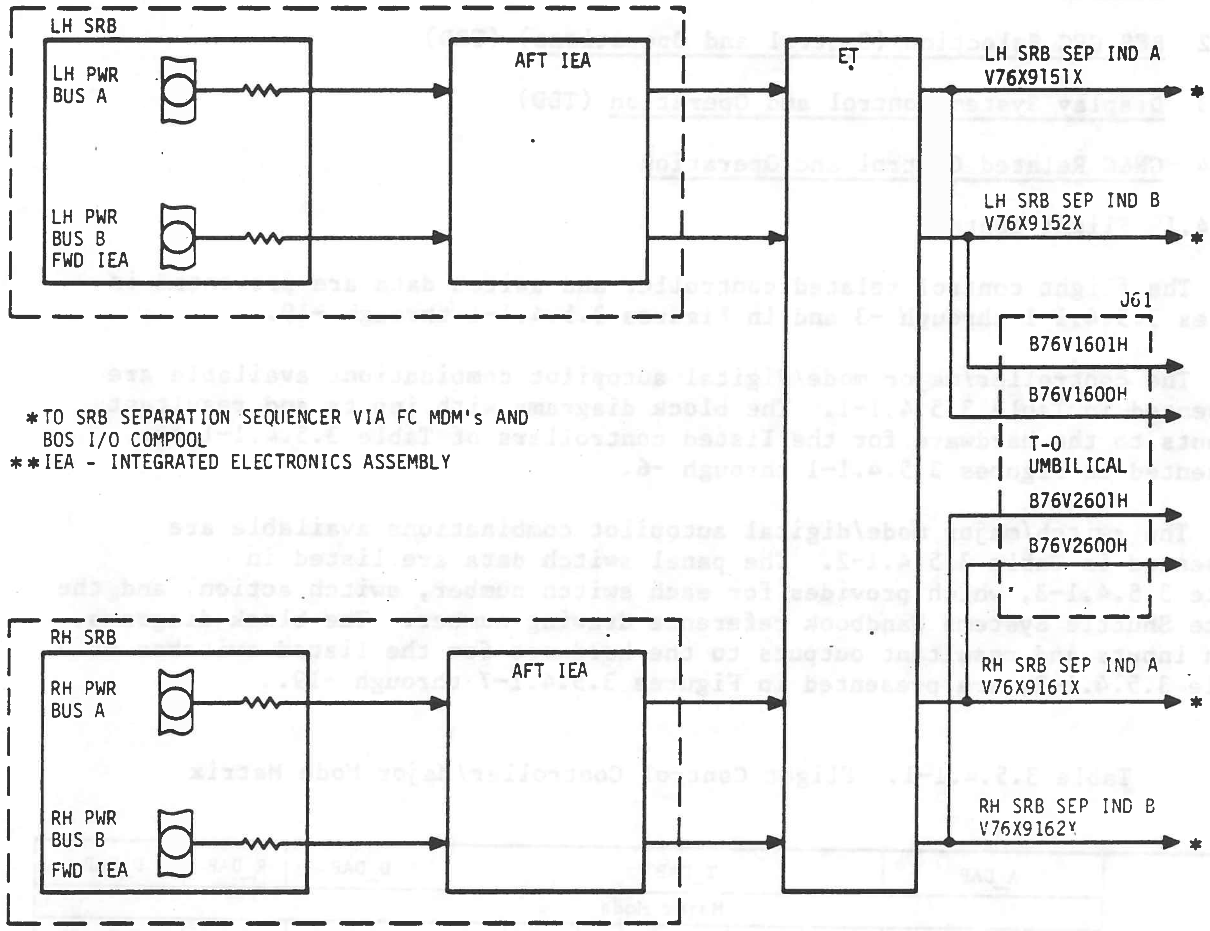


Figure 3.2.3.2.1-3. SRB Separation Indicators

3.4 SYSTEM INITIALIZATION (TBD)

3.5 BFS CREW FUNCTIONAL AND HARDWARE INTERFACES (TBD)

3.5.1 General (TBD)

3.5.2 BFS GPC Selection (Control and Operations) (TBD)

3.5.3 Display System Control and Operation (TBD)

3.5.4 GN&C Related Control and Operation

3.5.4.1 Flight Control

The flight control related controller and switch data are presented in Tables 3.5.4.1-1 through -3 and in Figures 3.5.4.1-1 through -19.

The controller/major mode/digital autopilot combinations available are presented in Table 3.5.4.1-1. The block diagrams with inputs and resultant outputs to the hardware for the listed controllers of Table 3.5.4.1-1 are presented in Figures 3.5.4.1-1 through -6.

The switch/major mode/digital autopilot combinations available are presented in Table 3.5.4.1-2. The panel switch data are listed in Table 3.5.4.1-3, which provides for each switch number, switch action, and the Space Shuttle Systems Handbook reference drawing number. The block diagrams, with inputs and resultant outputs to the hardware for the listed switches of Table 3.5.4.1-2, are presented in Figures 3.5.4.1-7 through -19.

Table 3.5.4.1-1. Flight Control Controller/Major Mode Matrix

	A_DAP			T_DAP						D_DAP		R_DAP	D_DAP	
	Major Mode													
Controller	101	102	103	104	105	106	301	302	303	304	305	601	602	603
LH RHC				X	X	X	X	X	X	X	X		X	X
RH RHC				X	X	X	X	X	X	X	X		X	X
FWD THC				X	X	X	X	X	X					
AFT THC				X	X	X	X	X	X					
LT RPTA										X	X		X	X
RT RPTA	Not supported by BFS													
LT SBTC										X	X		X	X
RT SBTC										X	X		X	X

Table 3.5.4.1-2. Flight Control Switch/Major Mode Matrix

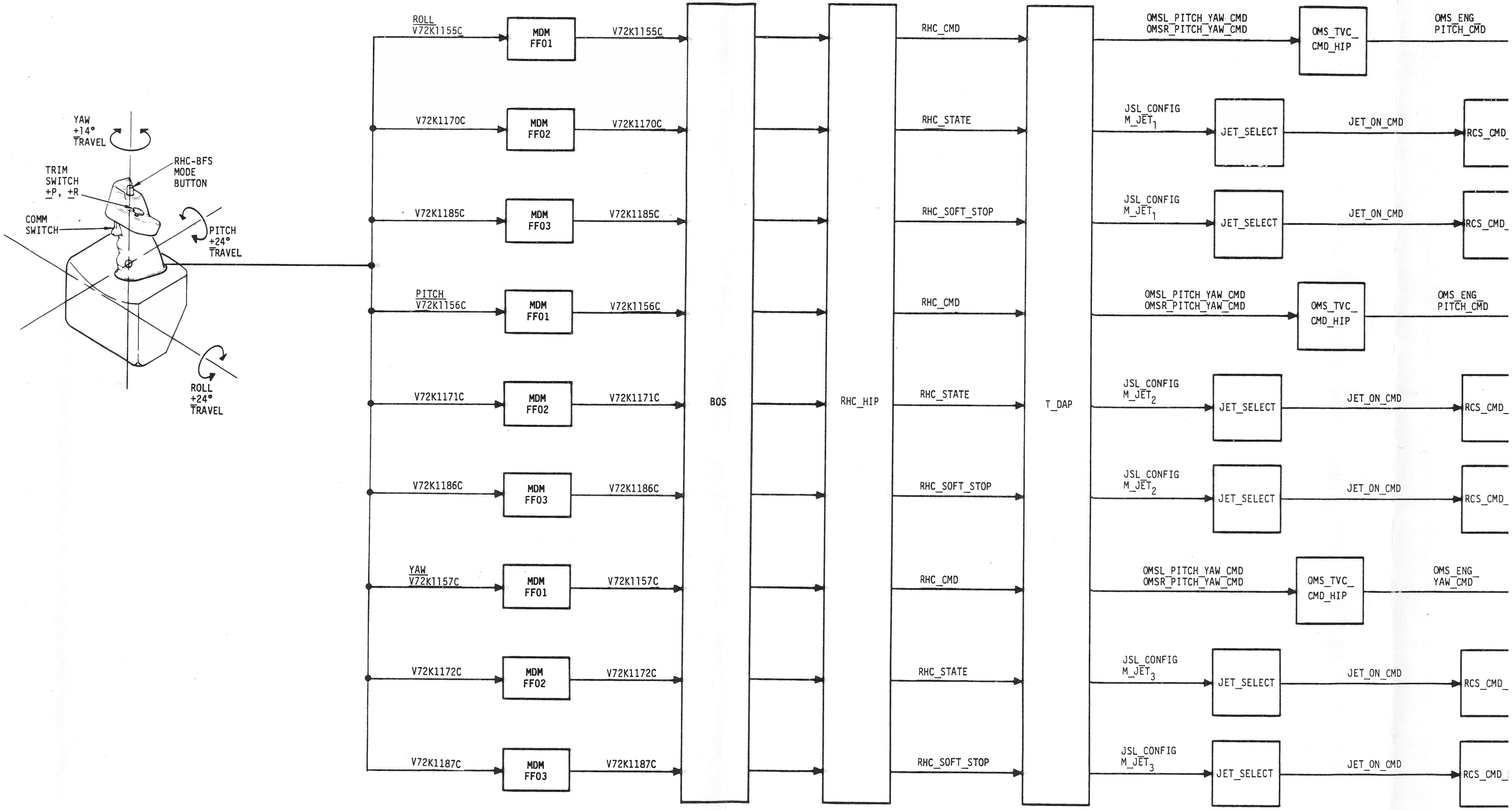
Switch	A_DAP			T_DAP						D_DAP		R_DAP	D_DAP	
	Major Mode													
	101	102	103	104	105	106	301	302	303	304	305	601	602	603
PANEL F2														
PITCH CSS										X	X		X	X
ROLL/YAW CSS										X	X		X	X
SPD BK/THROT										X	X	X	X	X
BODY FLAP										X	X	X	X	X
PANEL F6														
BFC DISENGAGE		X	X	X	X	X	X	X	X	X	X	X	X	X
FLT CNTR POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TRIM RHC										X	X		X	X
TRIM PANEL										X	X		X	X
PANEL F8														
FLT CNTR POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TRIM RHC										X	X		X	X
TRIM PANEL										X	X		X	X
PANEL L2														
TRIM ROLL										X	X		X	X
TRIM PITCH										X	X		X	X
BODY FLAP										X	X		X	X
YAW TRIM										X	X		X	X
PANEL C2														
LEFT CRT SEL	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RIGHT CRT SEL	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CRT 1 POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CRT 2 POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CRT 3 POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CRT 1 MAJ FUNC	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CRT 2 MAJ FUNC	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CRT 3 MAJ FUNC	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PANEL C3														
BFC CRT DISPLAY	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BFC CRT SELECT	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ROLL TRIM										X	X		X	X
PITCH TRIM										X	X		X	X
BODY FLAP										X	X		X	X
YAW TRIM										X	X		X	X
FCS CHANNEL 1	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FCS CHANNEL 2	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FCS CHANNEL 3	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FCS CHANNEL 4	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ET SEP INIT			X								X	X	X	X
SRB SEP INIT		X									X			X

Table 3.5.4.1-3. Flight Control Panel Switch Data

Description	Panel No.	Switch No.	Switch Action*	Drawing No.**
Left CRT select	C2	7	C	8.6
Right CRT select	C2	8	C	8.6
CRT 1 power	C2	1	C	8.6
CRT 2 power	C2	5	C	8.6
CRT 3 power	C2	3	C	8.6
CRT 1 major function	C2	2	C	8.6
CRT 2 major function	C2	6	C	8.6
CRT 3 major function	C2	4	C	8.6
BFC CRT display	C3A1	17	C	8.2
BFC CRT select	C3A1	18	C	8.2
Roll trim	C3A1	15	M	9.17
Pitch trim	C3A1	16	M	9.17
Body flap	C3A1	10	M, C, M	9.17
Yaw trim	C3A7	5	M	9.17
FCS Channel 1	C3A1	6	C	9.15
FCS Channel 2	C3A1	7	C	9.15
FCS Channel 3	C3A1	8	C	9.15
FCS Channel 4	C3A1	9	C	9.15
ET SEP init	C3A7	3, 4	C, M	5.3
SRB SEP init	C3A7	1, 2	C, M	5.3
Pitch CSS	F2	3	M	9.10
Roll/yaw CSS	F2	6	M	9.10
Spd bk/throt	F2	8	M	9.10
Body flap	F2	9	M	9.10
BFC disengage	F6A5	6	M	8.2
Flt cntr power	F6A7	1	C	9.1, 9.17
Trim RHC	F6A7	2	C	9.17
Trim panel	F6A7	3	C	9.17
Flt cntr power	F8A7	1	C	9.1, 9.17
Trim RHC	F8A7	2	C	9.17
Trim panel	F8A7	3	C	9.17
Entry roll mode	L2A1	25	C	9.10
Trim roll	L2A1	8	M	9.17
Trim pitch	L2A1	9	M	9.17
Body flap	L2A1	7	M, C, M	9.17
Yaw trim	L2A1	10	M	9.17

*C = Continuous contact
M = Momentary contact

**OV-102 Space Shuttle Systems Handbook, Volumes I-III, Revision A, 1 May 1979, NASA


YAW
±14°
TRAVEL
TRIM
SWITCH
±P, ±R
RHC-BFS
MODE
BUTTON
COMM
SWITCH
PITCH
±24°
TRAVEL
ROLL
±24°
TRAVEL
ROLL
V72K1155C
V72K1170C
V72K1185C
PITCH
V72K1156C
V72K1171C
V72K1186C
YAW
V72K1157C
V72K1172C
V72K1187C
MDM
FF01
MDM
FF02
MDM
FF03
BOS
RHC_HIP
RHC_CMD
RHC_STATE
RHC_SOFT_STOP
T_DAP
OMSL_PITCH_YAW_CMD
OMSR_PITCH_YAW_CMD
JSL_CONFIG
M_JET1
M_JET2
M_JET3
OMS_TVC_
CMD_HIP
JET_SELECT
JET_ON_CMD
OMS_ENG_
PITCH_CMD
OMS_ENG_
YAW_CMD
RCS_CMD_

Figure

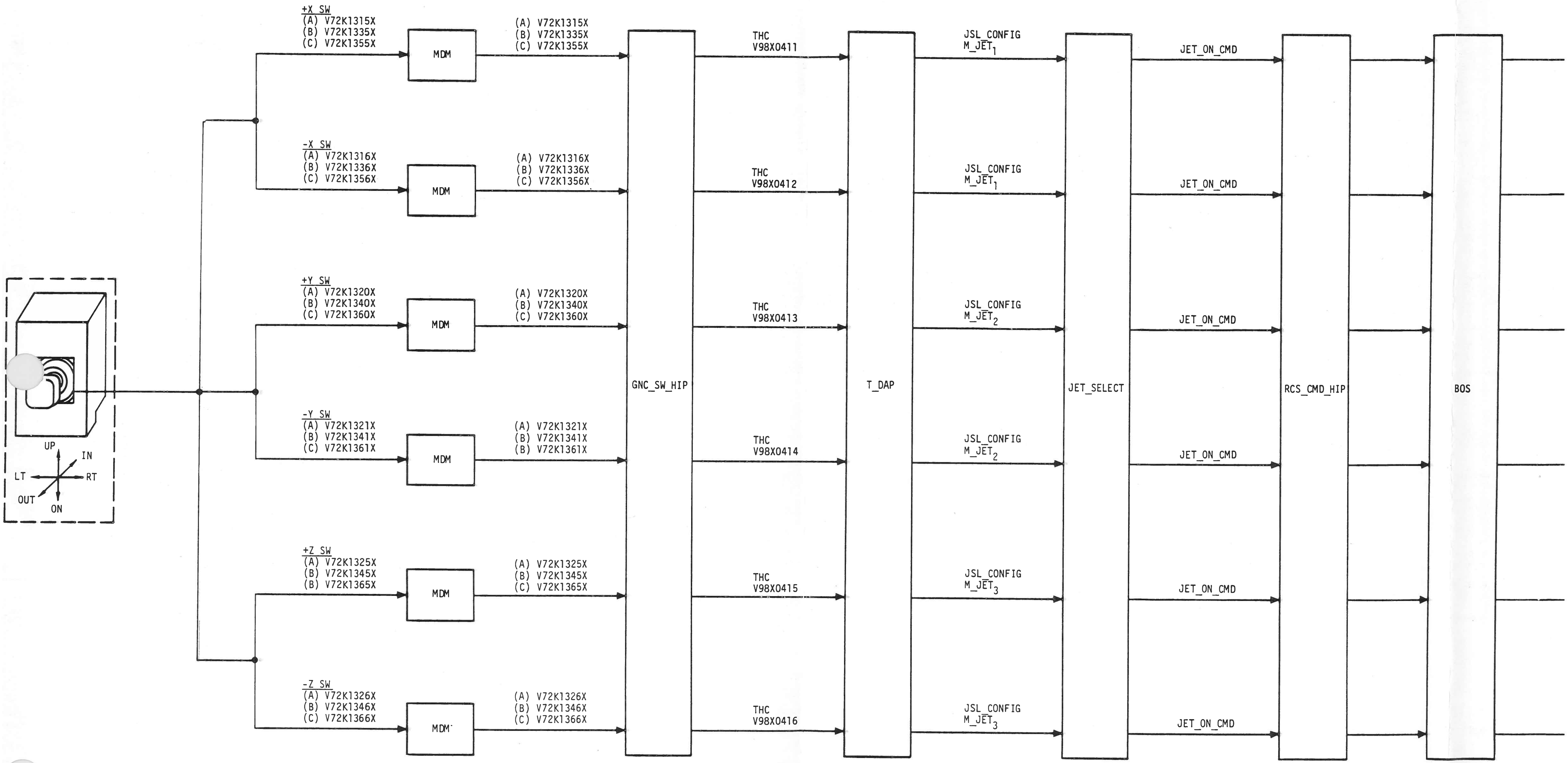


Figure 3.5.4.1-2. Transition DAP Lef

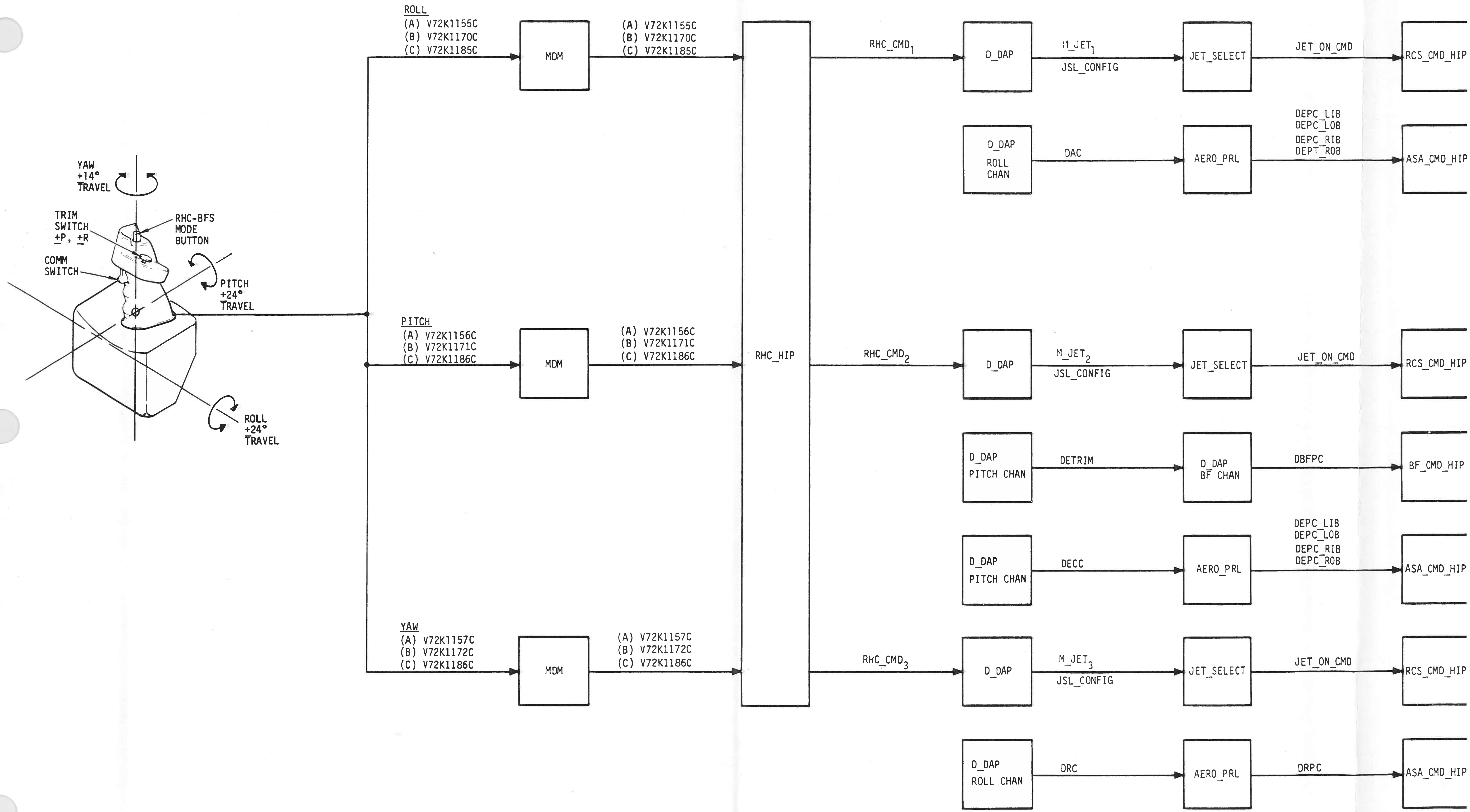

YAW
+14°
TRAVEL
TRIM
SWITCH
+P, +R
COMM
SWITCH
RHC-BFS
MODE
BUTTON
PITCH
+24°
TRAVEL
ROLL
+24°
TRAVEL
ROLL
(A) V72K1155C
(B) V72K1170C
(C) V72K1185C
PITCH
(A) V72K1156C
(B) V72K1171C
(C) V72K1186C
YAW
(A) V72K1157C
(B) V72K1172C
(C) V72K1186C
MDM
MDM
MDM
(A) V72K1155C
(B) V72K1170C
(C) V72K1185C
(A) V72K1156C
(B) V72K1171C
(C) V72K1186C
(A) V72K1157C
(B) V72K1172C
(C) V72K1186C
RHC_HIP
RHC_CMD1
RHC_CMD2
RHC_CMD3
D_DAP
M_JET1
JSL_CONFIG
JET_SELECT
JET_ON_CMD
RCS_CMD_HIP
D_DAP
ROLL
CHAN
DAC
AERO_PRL
DEPC_LIB
DEPC_LOB
DEPC_RIB
DEPT_ROB
ASA_CMD_HIP
D_DAP
M_JET2
JSL_CONFIG
JET_SELECT
JET_ON_CMD
RCS_CMD_HIP
D_DAP
PITCH CHAN
DETRIM
D_DAP
BF CHAN
DBFPC
BF_CMD_HIP
D_DAP
PITCH CHAN
DECC
AERO_PRL
DEPC_LIB
DEPC_LOB
DEPC_RIB
DEPC_ROB
ASA_CMD_HIP
D_DAP
M_JET3
JSL_CONFIG
JET_SELECT
JET_ON_CMD
RCS_CMD_HIP
D_DAP
ROLL CHAN
DRC
AERO_PRL
DRPC
ASA_CMD_HIP

Figure 3.5.4.1-

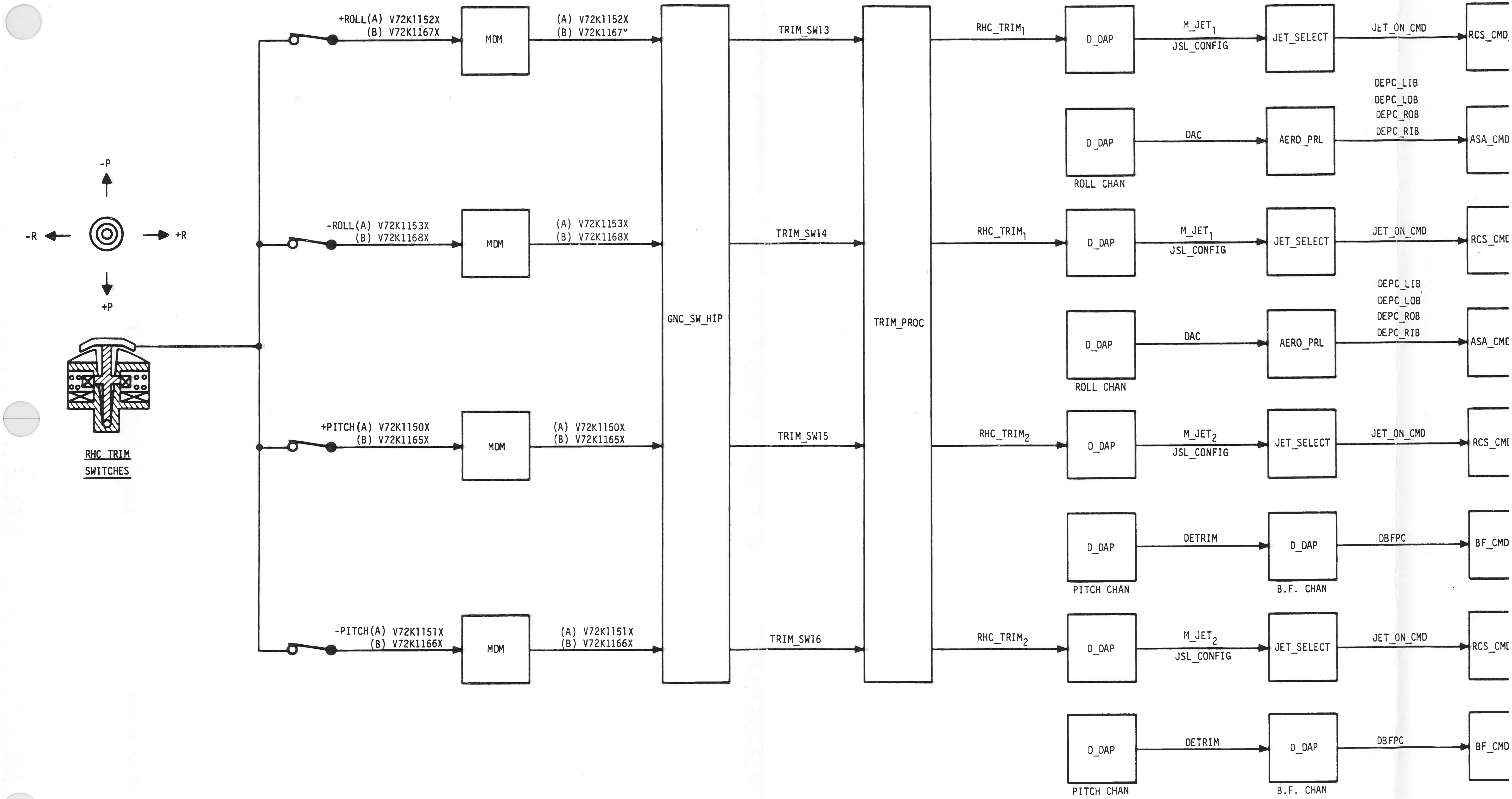


Figure 3.5.4.1-4. Descen