

Shuttle Flight Operations Manual

Volume 6
Guidance, Navigation, and Control Hardware

Flight Operations Directorate
Crew Training and Procedures Division

Preliminary
June 15, 1981



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

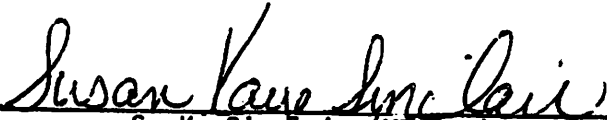
FLIGHT OPERATIONS DIRECTORATE

PRELIMINARY

OFT SHUTTLE FLIGHT OPERATIONS MANUAL
Volume 6 - Guidance, Navigation and Control Hardware

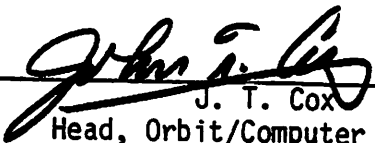
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Preface

The purpose of this manual is to provide Orbiter Guidance, Navigation, and Control (GNC) hardware information for reference by flight operations personnel, primarily the flight crew. The text and diagrams should be considered functional in their level of detail. Guidance, Navigation, and Control hardware outputs to software are shown, but there is no description of software processing in this volume. The reader is referred to Shuttle Flight Operations Manual (SFOM) Volume 7 for software processing of GNC hardware data.

A previously published Preliminary version of this volume (Volume 6A) should be discarded. Basic and Final versions of this volume are planned.

Comments and questions on content and format should be addressed to CG6/Susan K. Sinclair, telephone (713) 483-5348.

ACKNOWLEDGMENTS

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SECTION 1
GNC HARDWARE

1.1 INTRODUCTION

Guidance, Navigation, and Control (GNC) hardware provides sensed data and manual guidance commands to GNC software, and responds to effector commands from GNC software in order to effect vehicle and trajectory control. The GNC sensors and the physical data they sense are:

- Rate Gyro Assembly (RGA) - vehicle rotation rates about three body axes.
- Accelerometer Assembly (AA) - vehicle accelerations along two body axes.
- Inertial Measurement Unit (IMU) - vehicle orientation in inertial space and accelerations along inertial axes.
- Star Tracker (S TRK) - vehicle orientation with respect to stars.
- Tacan - vehicle position with respect to a ground-based tacan station.
- Microwave Scanning Beam Landing System (MSBLS) - vehicle position with respect to ground-based equipment placed near landing runway.
- Radar Altimeter (RA) - vehicle altitude above the ground.
- Air Data Transducer Assembly (ADTA) - air temperature and pressures of air in freestream and disturbed by vehicle.

The GNC hardware providing manual guidance commands and those commands are:

- Rotational Hand Controller (RHC) - vehicle motion about a body axis.
- Translational Hand Controller (THC) - vehicle motion along a body axis.
- Rudder pedals - vehicle motion about the yaw body axis in atmospheric flight.
- Speedbrake/Thrust Controller (SBTC) - change in vehicle aerodynamic drag or change in main engine throttle level.
- Switches - flight control system or display reconfiguration or aerosurface trim.

The GNC hardware responding to software commands and its responses are:

- Aerosurface servo amplifier - aerosurface actuator positioning and hydraulic reconfiguration.
- Ascent Thrust Vector Control (ATVC) - main engine and Solid Rocket Booster (SRB) actuator positioning and hydraulic reconfiguration.

Each of the types of GNC hardware named on the previous page, with the exception of ATVC, is covered in a section of this volume. The ATVC is described in Volume 8 of the SFOM. In addition, the Crew Optical Alignment Sight (COAS), although supported by GNC software, is considered to be a crew system, and as such, is covered in Volume 12 of the SFOM.

1.2 FUNCTIONAL DESCRIPTION

The function, description, interfaces, and performance data are given for each of the GNC hardware types. Because this volume is intended for use by operations personnel, the diagrams and descriptions are simplified and functional and do not represent true electrical wiring or hardware components. For example, the commands Multiplexer-Demultiplexers (MDM's) issue to the hardware to commence data transfer have been omitted and the lines between the MDM's and hardware do not represent the actual number of wires present in the Orbiter. Switches and lights which interface only with software are not diagrammed or described; rather, they are listed in a table in an appendix for quick reference.

SECTION 2 ACCELEROMETER ASSEMBLIES

2.1 INTRODUCTION

There are four body mounted Accelerometer Assemblies (AA) on the Orbiter. The AA's are mounted in the forward avionics bays (ref. appendix A). Each AA contains two single-axis Honeywell accelerometers positioned such that one senses lateral accelerations along the Y-axis and one senses normal accelerations along the Z-axis. Lateral and normal accelerations from the AA's are used in flight control feedback loops to provide stability augmentation during ascent and entry. Current plans are to turn the AA's off during the on-orbit phase and reactivate them for sensor self-test prior to deorbit.

2.2 HARDWARE DESCRIPTION

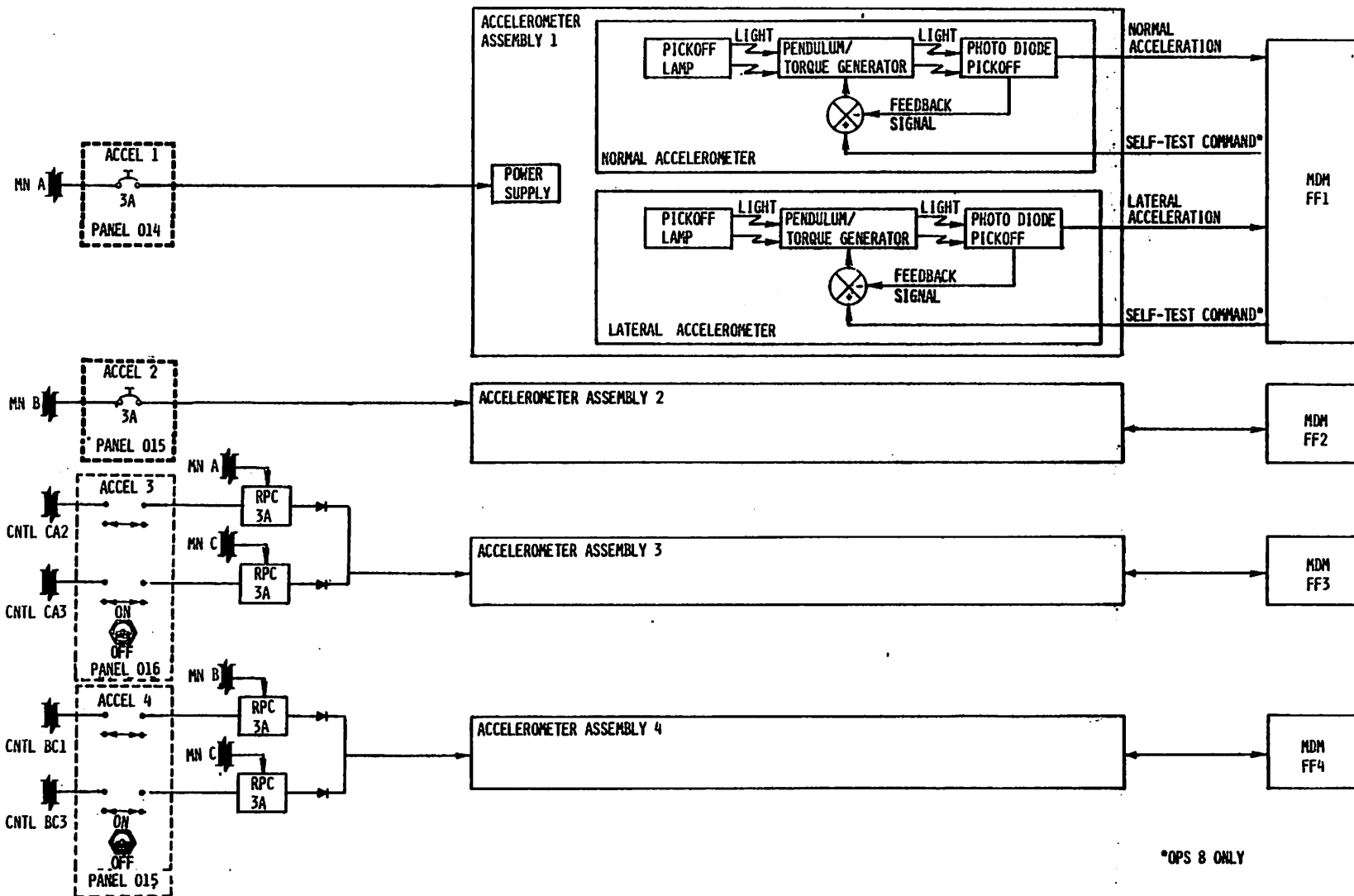
Power flow for each AA is depicted in figure 2-1. AA 1 and AA 2 receive main bus power through circuit breakers, and AA 3 and AA 4 receive main bus power through the use of switches and remote power controllers.

The single-axis accelerometers within an AA function identically and have identical components; therefore, the functional description traces the elements and interaction of those elements for one single-axis accelerometer. The only difference between a lateral and a normal accelerometer is its positioning within the assembly.

A Honeywell single-axis accelerometer consists of a quartz fiber suspension and pendulum, a photo diode pickoff, a one-turn torque generator and a dc power supply (fig. 2-2). A thin coat of silver is vapor-deposited over the length of the suspension and pendulum, providing a conducting surface. The base of the pendulum is positioned in a permanent magnetic field such that current flowing in the pendulum circuit acts as a one-turn torque generator. The optical pickoff consists of a miniature tungsten filament lamp and a silicon junction photo diode.

The pendulum assembly is mounted in a hermetically sealed aluminum housing. The housing is filled with a low viscosity silicon oil to control the dynamic characteristics of the accelerometer.

When zero acceleration exists, the null position is defined such that the base of the pendulum coincides with the photo diode pickoff slot and zero differential voltage exists at the output of the photo diodes. The pendulum deflects from the null position when acceleration is applied. Light unbalance on the two halves of the photo diode results in a differential voltage output to the dc amplifier. Polarity of voltage depends upon which direction the pendulum moves. The signal from the amplifier is fed back to the pendulum one-turn torque generator, in the proper polarity, to rebalance the pendulum at an offset position. When the acceleration is removed, the amplifier and pendulum are returned to the null position.



*OPS 8 ONLY

Figure 2-1.- Accelerometer assembly diagram.

The torque generator also provides the capability to generate an output signal in proportion to the magnitude of an external signal, a self-test command.

2.3 PERFORMANCE DATA/LIMITATIONS

Maximum Output

Normal	$\pm 4 \text{ g}$
Lateral	$\pm 1 \text{ g}$

Warmup time	5 min
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Power Requirement

Low	2.30 W
Nominal	2.80 W
High	3.07 W

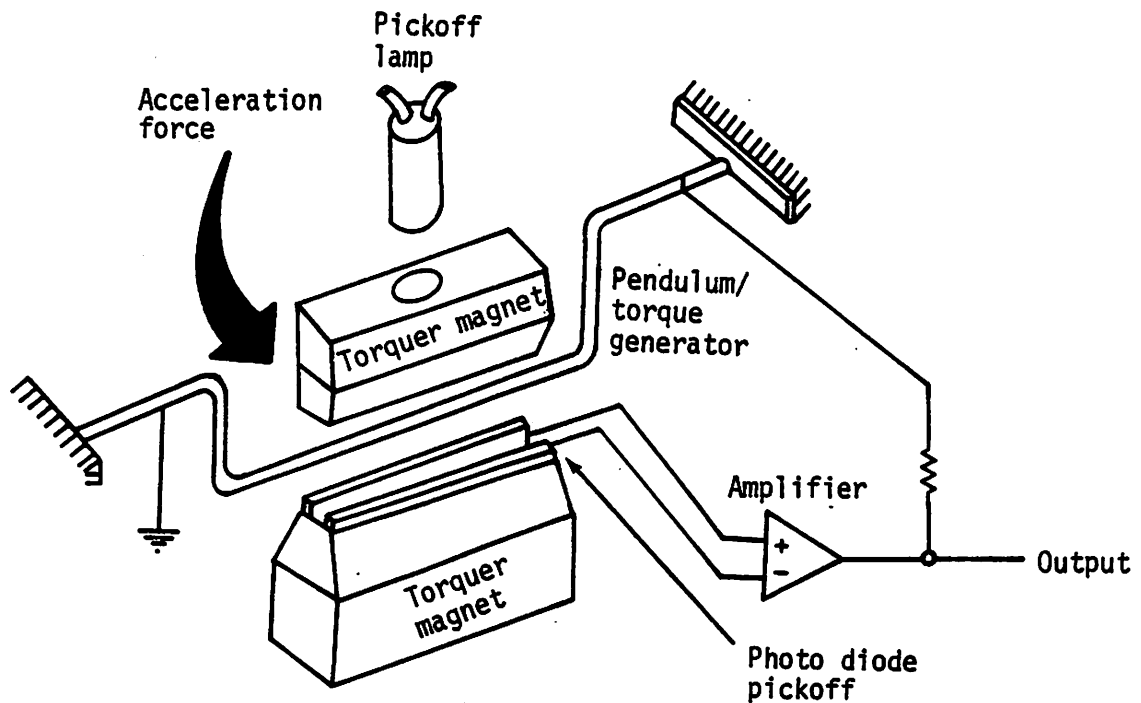


Figure 2-2.- Accelerometer assembly.

SECTION 3 RATE GYRO ASSEMBLIES

3.1 INTRODUCTION

The Orbiter is equipped with four Rate Gyro Assemblies (RGA's) located on the aft bulkhead. RGA's 1 and 2 are located on the left and right side of the bulkhead facing the aft end of the Orbiter. RGA's 3 and 4 are located side by side at the bottom of the bulkhead in the wing well facing the payload bay (appendix A). Each assembly consists of three single degree-of-freedom rate gyros positioned to sense rates about the roll, pitch, and yaw body axes. The Orbiter rate gyros provide the sensed roll, pitch, and yaw body rates to flight control, where the sensed rates act as damping feedback which provides stability augmentation of the vehicle during the ascent and entry flight phases. Current plans are to turn the RGA's off during the on-orbit phase and reactivate them for sensor self-test prior to deorbit.

3.2 HARDWARE DESCRIPTION

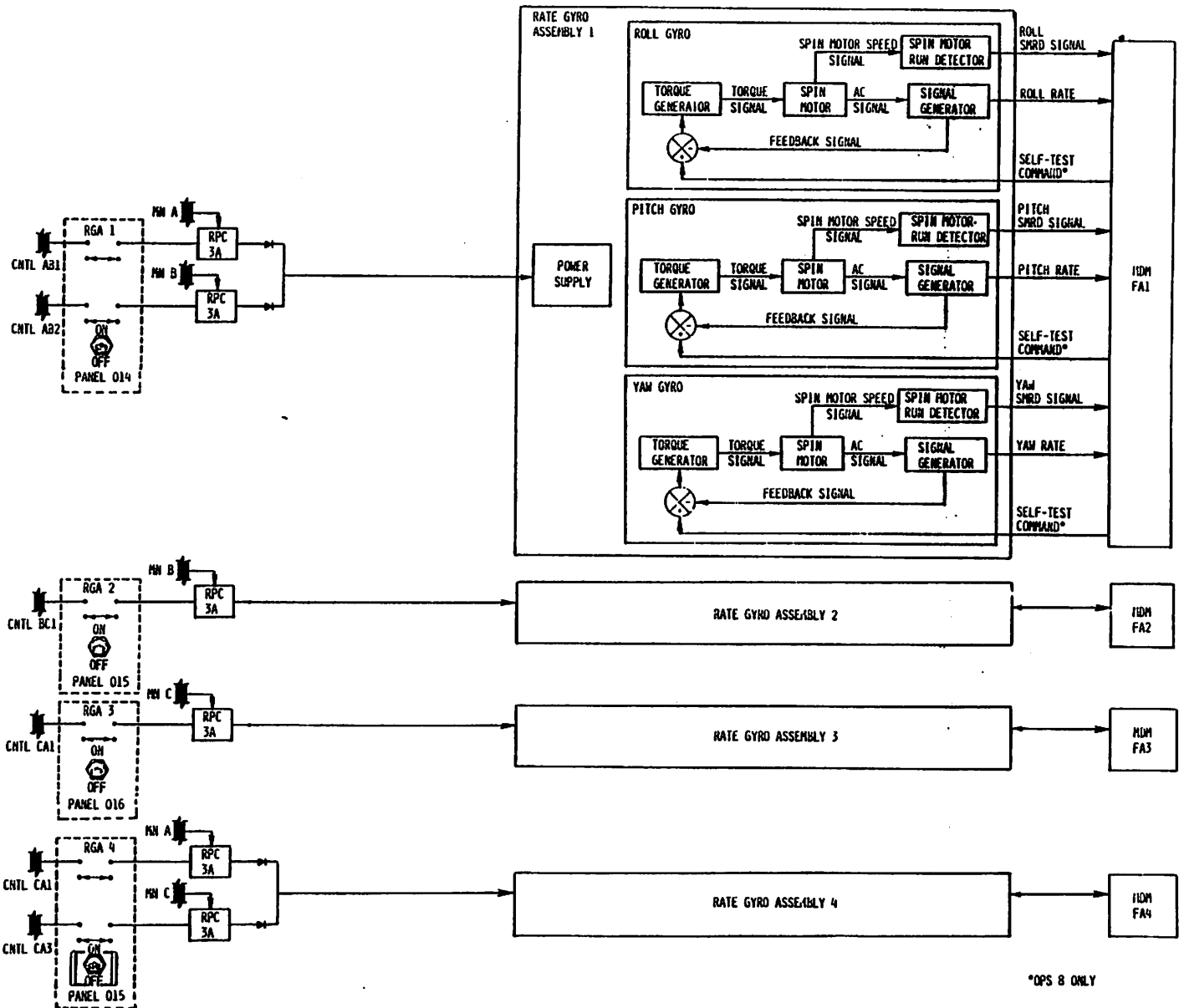
Power flow for each RGA is depicted in figure 3-1. All RGA's receive main bus power through the use of switches and RPC's. RGA 1 and RGA 4 receive redundant main bus power.

The rate gyros within each assembly are identical with respect to operation and hardware components. The only difference between the roll, pitch, and yaw gyros is their positioning within the assembly. The following description covers one single degree-of-freedom rate gyro.

The major elements of a rate gyro consist of the gyro wheel, gimbal assembly, signal generator, and Spin Motor Run Detector (SMRD) circuit.

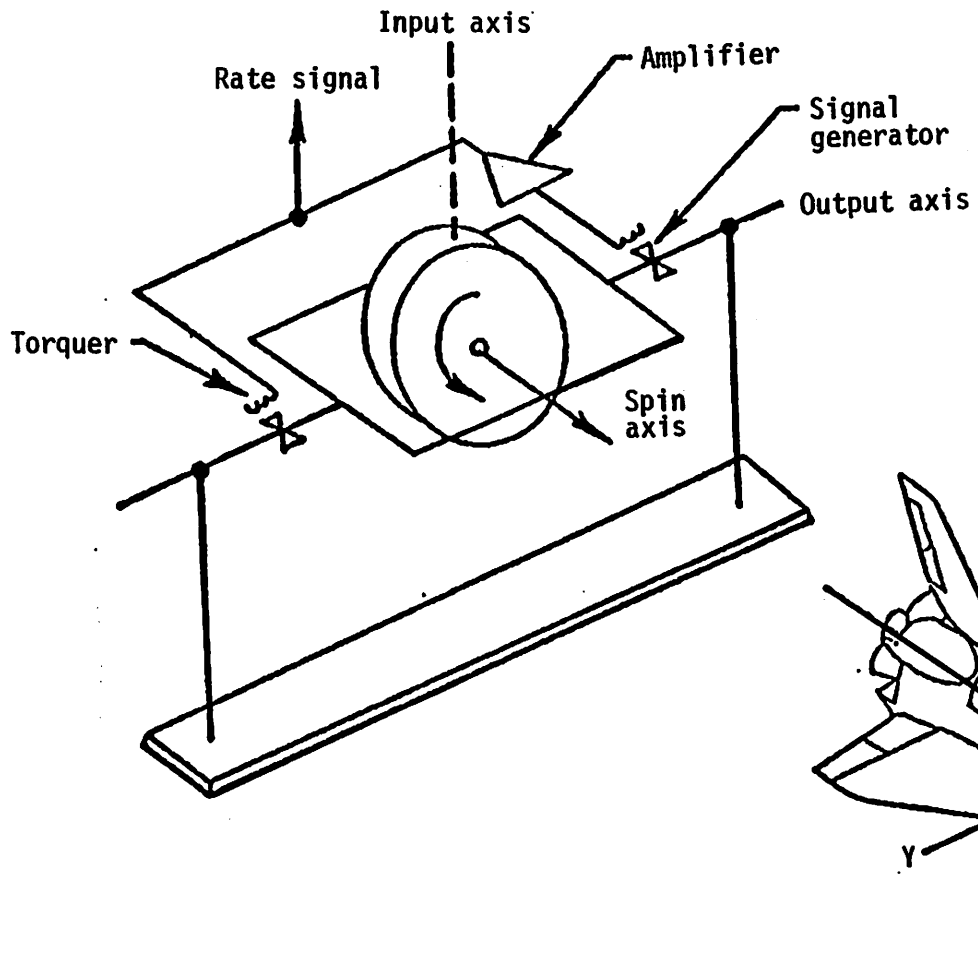
The rate gyro is a floated, single degree-of-freedom rate gyro. When the gyro wheel is running at synchronous speed (24,000 rpm), movement of the vehicle about the input axis triggers movement of the gimbal about the output axis (gimbal precession) (fig. 3-2). As the gyro wheel precesses, torque is developed. The torquer cancels gimbal precession and thus measures input rates accurately without permitting excessive gimbal displacement. The precession rate of the gimbal assembly is directly proportional to the rotational rate of the gyro case. The signal generator provides an output voltage proportional to the angle of gimbal rotation. The torque generator provides the capability to torque the gimbal about the output axis in proportion to the magnitude of an externally applied current, a self-test command.

The Orbiter rate gyros are equipped with a SMRD circuit which detects an underspeed or overspeed of the spin motor. The SMRD circuit will indicate an invalid signal at 98 percent or 102 percent of the spin motor synchronous speed. The SMRD circuit is the rate gyro Built-In Test Equipment (BITE).



*OPS 8 ONLY

Figure 3-1.- Orbiter RGA diagram.



3-3

Figure 3-2.- Rate gyro, in yaw orientation.

3.2.1 Performance Data/Limitations

Maximum gyro output	± 20 deg/sec pitch, yaw rate
	± 40 deg/sec roll rate
Warmup time	5 min
Power requirements	29 W at sync speed
	42 W during spin-up

3.3 SOLID ROCKET BOOSTER RATE GYRO ASSEMBLIES

3.3.1 Introduction

The two Solid Rocket Boosters (SRB's) are each equipped with three RGA's. Each SRB RGA contains two single degree-of-freedom rate gyros; one is positioned to sense pitch rates and the other is positioned to sense yaw rates. The SRB RGA pitch and yaw rates are used in flight control feedback loops to assist in SRB thrust vector control and to provide stability augmentation during the ascent flight phase until SRB separation. The SRB RGA's are mounted on the forward ring within the forward skirt of the SRB attach point (ref. appendix A).

3.3.2 Hardware Description

Power flow for the SRB RGA's is depicted in figure 3-3. Two RGA's on each SRB are powered from the separate SRB buses which receive their power from two Orbiter main buses. The third RGA on each SRB receives power hardwired directly from the Orbiter.

The single degree-of-freedom rate gyros contained in the SRB RGA's have the same functional components as those contained in the rate gyros that comprise the Orbiter RGA's (ref. section 3.1). The only hardware difference between the Orbiter RGA's and the SRB RGA's is the additional roll gyro within the Orbiter RGA's.

3.3.3 Performance Data/Limitations

Maximum gyro output	± 10 deg/sec pitch rate
	± 10 deg/sec yaw rate
Warmup time	5 min
Power requirements	19 W at sync speed
	34 W during spin-up

SECTION 4 INERTIAL MEASUREMENT UNIT

4.1 INTRODUCTION

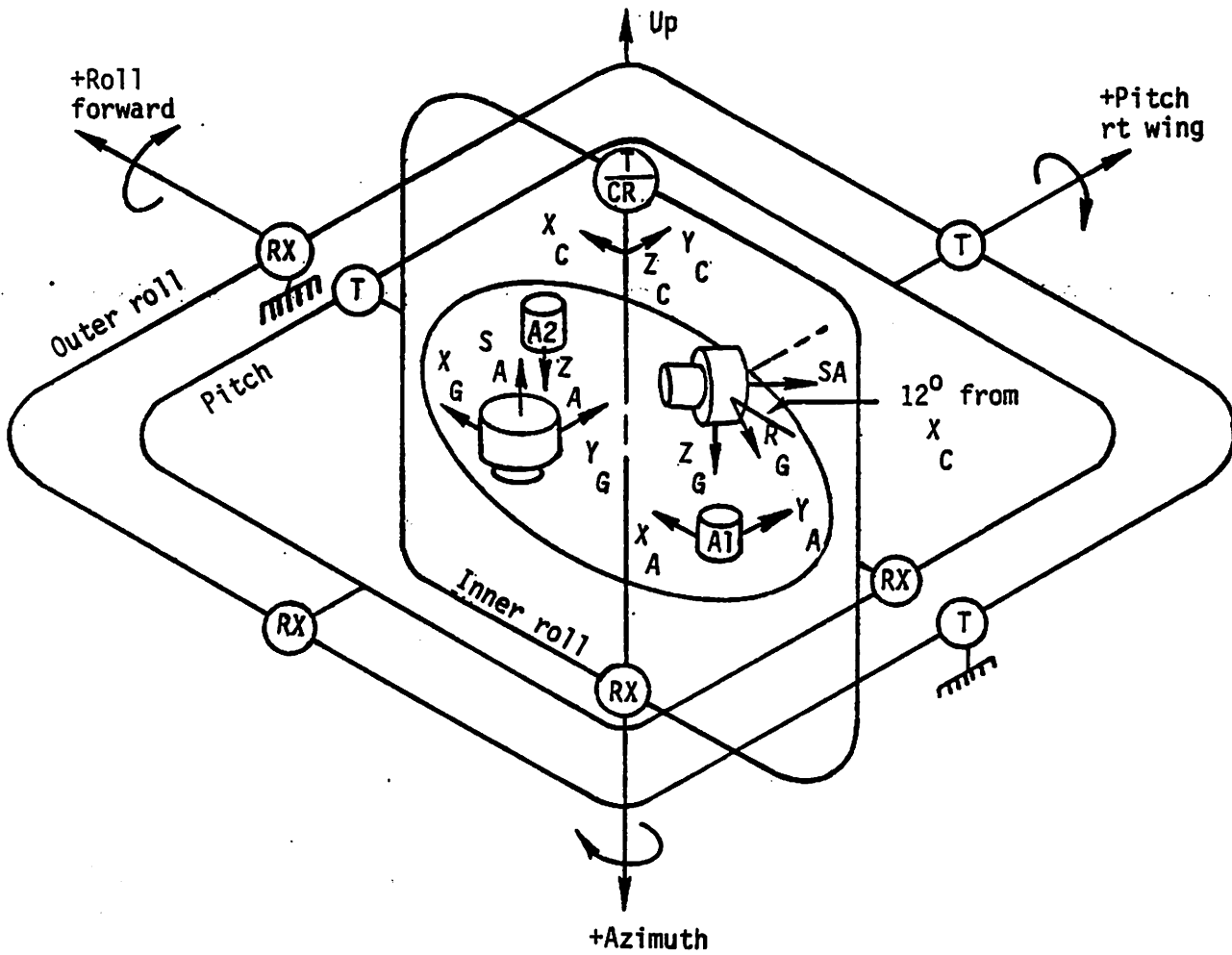
The Inertial Measurement Unit (IMU) provides attitude and velocity data to guidance, navigation, and flight control during all phases of the Orbiter mission. Three functionally independent IMU's are mounted on the navigation (NAV) base inside the pressure hull, forward of the flight deck (appendix A).

4.2 HARDWARE DESCRIPTION

Each IMU is an all-attitude, four-gimbal, inertially stabilized platform with associated platform electronics, power supplies, Built-in Test Equipment (BITE), and input/output circuitry. The Outer Roll (OR) gimbal rotates about a case-supported pivot. The cluster (fig. 4-1), consisting of two gyros and two accelerometers, is attached to the azimuth (AZ) gimbal. The OR gimbal is redundant to the Inner Roll (IR) gimbal and is driven from error signals (sin 1X IR) generated from disturbances to the IR gimbal. The azimuth (Z) gyro is mounted with its spin axis horizontal, and the roll (Y)/pitch (X) gyro is mounted with its spin axis vertical. The X, Y, and Z signals are resolved into roll, pitch, and yaw coordinates to provide gimbal stabilization. The other redundant (ωR) gyro axis signal is closed on itself through a rate capture loop to serve as verification of the X and Y outputs. The attitude outputs come from the one-speed (1X) and eight-speed (8X) resolver outputs on the gimbals. It should be noted that the 1X resolver output represents the true gimbal mechanical angle, whereas the 8X resolver output represents eight times the angle and provides greater angle resolution. Resolver analog outputs (1X and 8X) are converted to digital $\tan \theta$ (X, Y, Z, R) angles, and then a $\tan \theta$ to θ converter computes the actual gimbal angles θX , θY , θZ , θR . Also, the redundant rate (ωR) is converted from analog to digital and output through the input/output electronics with the gimbal angles.

Each IMU contains a single axis accelerometer sensing accelerations along the Z axis, and a dual axis accelerometer sensing accelerations along the X and Y axes. The X, Y, and Z accelerometer voltages are converted to pulses representing velocity increments (both + and -) in the Capacitance Reset Integrator (CAPRI). These pulses are then accumulated in 16 bit counter registers which are initially zero, overflow to zero, and continue counting. The IMU CAPRI can be operated in either high or low gain scale factor. High gain CAPRI scale factor results in 10 times more velocity pulse accumulations for a given acceleration input than does low gain. Most ground operations utilize high gain, while flight operations normally use low gain. Accumulated velocity (X, Y, Z ACCUM VEL) is then output through input/output electronics.

The IMU gimbals may be slewed (large angle repositioning) or gyro pulse torqued (small angle repositioning) in the positive or negative direction under command inputs from IMU software. These commands are converted to



GYRO INPUT AXES-XG, YG, ZG, RG
 ACCELEROMETER SENSING AXES-XA, YA, ZA
 CLUSTER COORDINATES-XC, YC, ZC

- Ⓣ GIMBAL TORQUER
- ⓇX GIMBAL ANGLE RESOLVER
- ⓈCR COORDINATE RESOLVER

Figure 4-1.- The IMU cluster and coordinate system.

appropriate slew or torque voltages and applied to the correct gyros to provide the required gimbal repositioning.

The IMU hardware BITE is designed to test sections of hardware by monitoring system parameters for proper operation. The BITE indicators which are output in the mode/status output word are shown below.

IMU hardware mode/status word bit definition:

BITS															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
															NOMINAL STATUS

Bit Definition

- 1 = IMU GOOD
- 2 = I/O FAIL
- 3 = A/D FAIL
- 4 = PLATFORM FAIL
- 5 = POWER CONTROLLER FAIL
- 6 = DC/DC 1 FAIL
- 7 = FILTER/DC 2 FAIL
- 8 = RX CURRENT FAIL
- 9 = POWER COND OVERTEMP
- 10 = TRANS 1 FAIL
- 11 = TRANS 2 FAIL
- 12 = ACCEL SCALE FACTOR (GAIN) HIGH
- 13 = VERT GYRO LOW GAIN LOOPS CLOSED
- 14 = VERT GYRO HIGH GAIN LOOPS CLOSED
- 15 = AZ GYRO LOW GAIN LOOPS CLOSED
- 16 = AZ GYRO HIGH GAIN LOOPS CLOSED

The IMU's are redundantly powered (fig. 4-2) from the three main dc buses. The IMU ON/OFF toggle switches apply control voltage to Remote Power Controllers (RPC), which in turn provide dc main bus power to the IMU's.

Each IMU is cooled by cabin air circulated within the IMU casings through an IMU-dedicated cooling system (fig. 4-3). Three fans serve all three IMU's, and an IMU-dedicated heat exchanger maintains cool air flow. The three IMU fans are each powered by three-phase ac power from buses AC 1, AC 2, and AC 3, using ON/OFF toggle switches. Nine circuit breakers provide discrete phase protection for each ac bus.

Critical temperatures are maintained by automatically controlled heaters in three locations: on the cluster (160° F), on the inner roll gimbal (150° F), and in the CAPRI (150° F). Temperature sensors on the platform and CAPRI circuits monitor the temperatures and provide ready and safe discrete outputs (see next section for values). A pressure sensor mounted within the IMU housing provides a pressure good discrete (see next section for value).

4-4

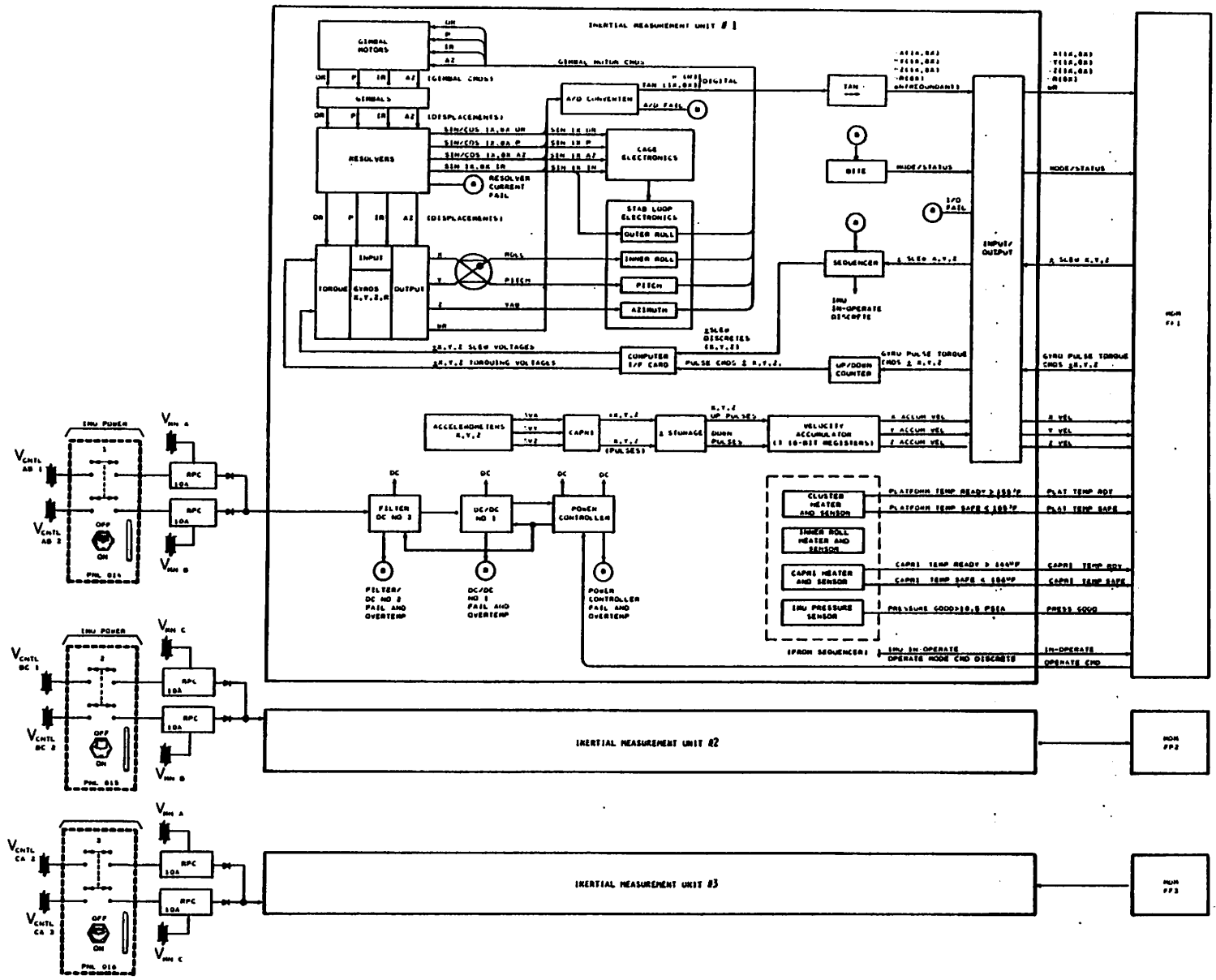


Figure 4-2.- Inertial measurement unit.

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6-GNC

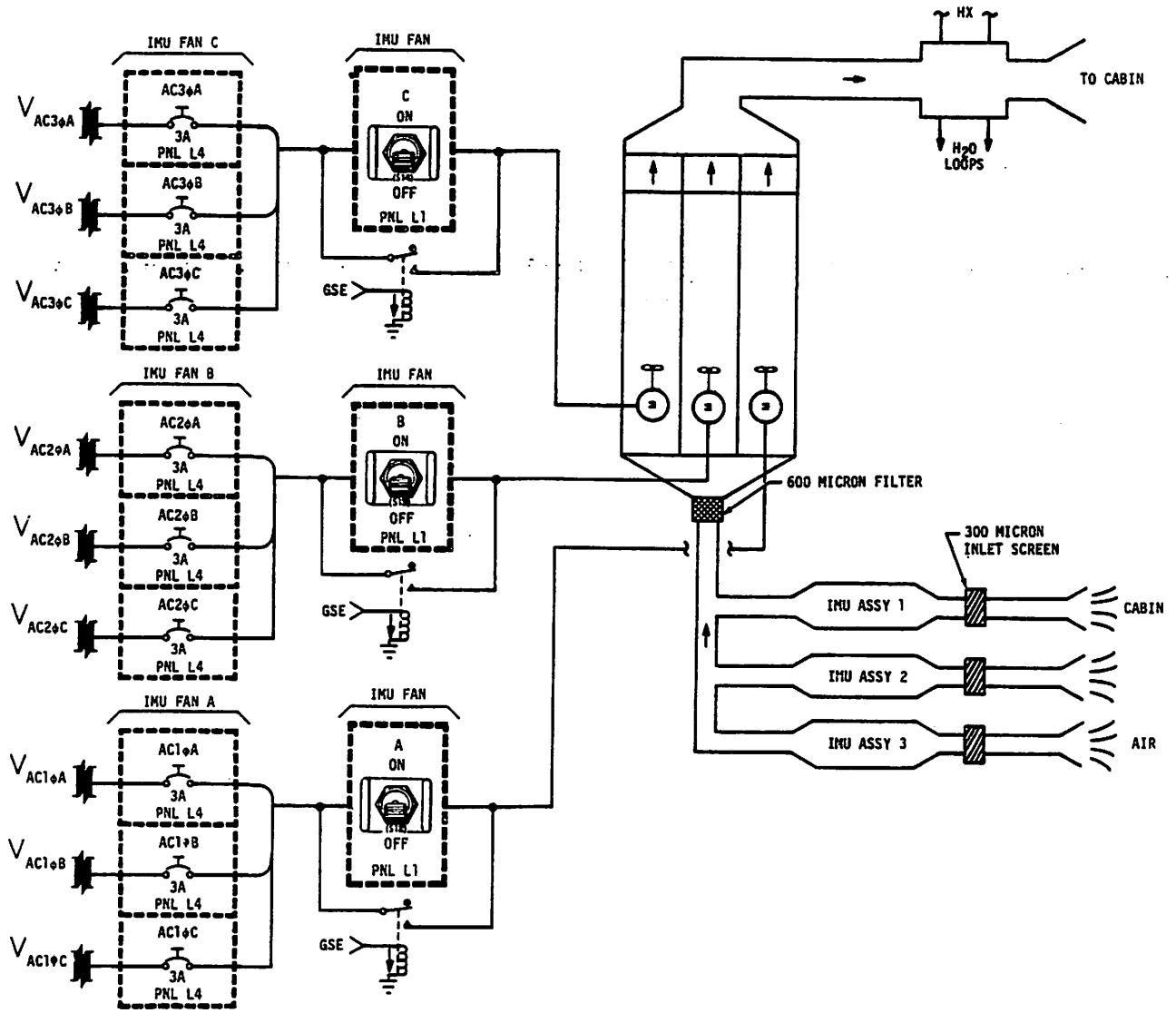


Figure 4-3.- The IMU air circulation.

Upon receipt of the IMU operate mode command discrete from the Data Processing System (DPS) (fig. 4-2), the IMU goes through a runup sequence culminating in the output of the IMU IN OPERATE discrete.

4.3 PERFORMANCE/DATA LIMITATIONS

Power	Warmup mode	150 W max
	Standby mode (temperature stabilized)	75 W max, 50 W nominal
	Operate mode	180 W max, 140 W nominal
Warmup time		30 min nominal
		120 min maximum
Operate time		38 sec startup sequence from receipt of operate mode command to output of in operate discrete.
Heater power		
	Cluster heater elements	<ul style="list-style-type: none"> ● 39.3 W ● 26.2 W ● 55.7 W
	Inner roll heater elements (2)	37.5 W each
	CAPRI heater element	17.0 W
Discretes -		
	Platform temp ready	> 155° F
	Platform temp safe	< 165° F
	CAPRI temp ready	> 144° F
	CAPRI temp safe	< 156° F
	Pressure good	> 10.5 psia

SECTION 5 STAR TRACKER SUBSYSTEM

5.1 INTRODUCTION

The Star Tracker (S TRK) is an electro-optical tracking device used while in orbit to obtain precise line of sight determination of stars and Sun-illuminated targets of greater than +3.0 magnitude. There are two S TRK's located forward of the crew compartment on the Shuttle. They are mounted on an extension to the NAV base which allows their alignment to be precisely calibrated with respect to the IMU's (fig. 5-1). The use of the S TRK's is dependent upon at least one IMU being in reasonably good alignment. Once two stars have been identified and located, any required modification to IMU alignments can be made.

5.2 HARDWARE DESCRIPTION

The two S TRK's, located in the star tracker well, are enclosed by the Thermal Protection System (TPS) and structure (fig. 5-2). Each S TRK has a door assembly for protection during ascent and entry. The doors are each driven by a two-motor differential drive.

The S TRK unit and subassemblies that make up the entire unit are shown in figure 5-3, they include:

- The light shade assembly, through a series of baffles, protects the lens from shadows and glare inside the shade. It also serves as a mount for the Bright Object Sensor (BOS) and shutter mechanism which are used to protect S TRK optics.
- A BOS is mounted on the S TRK light shade assembly. This sensor is installed so the field of view of the sensor extends beyond the S TRK field of view. The purpose of the BOS is to sense those objects coming into the S TRK field of view that are bright enough to cause damage to the S TRK optics. The BOS will protect against objects approaching at rates up to 10 deg/sec by closing a mechanical shutter.
- The protective window provides a seal that protects the electronics assembly and adapter plate from foreign matter and allows the S TRK assembly to be pressurized.
- The adaptor plate provides a common mount for the S TRK light shade and electronics assembly
- The electronics assembly contains the optics and electronics to process the optical data and convert it to usable digital data.

5.3 PERFORMANCE DATA

S TRK field of view size	10° square
Object brightness magnitude limits	+3.0 to -7.0
Object size limits	< 8 arc minutes

Tracking rate limits

0 deg/sec to 0.2 deg/sec
 0.2 deg/sec to 0.5 deg/sec

Accuracy error

< 1 arc minute
 > 1 arc minute - software limitation

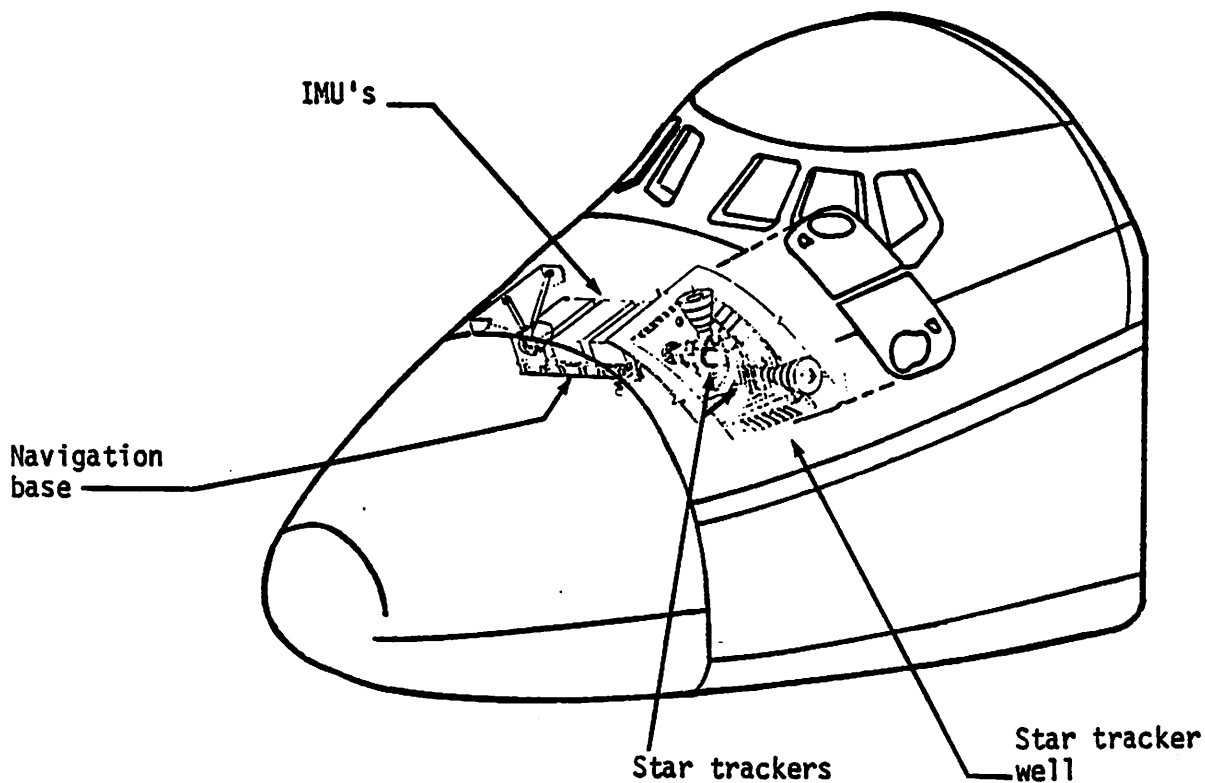


Figure 5-1.- Star trackers location.

5-3

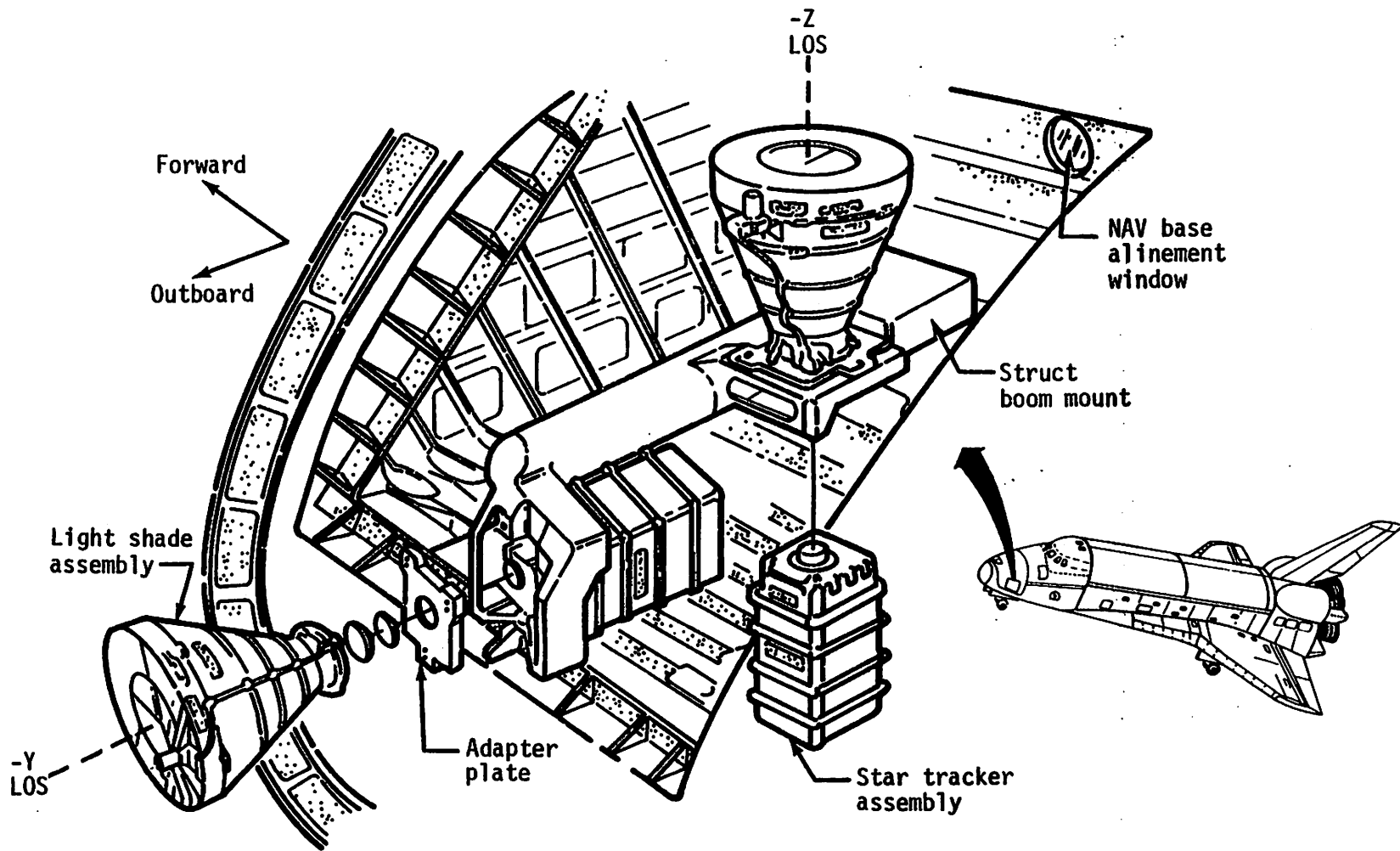


Figure 5-2.- Star tracker well.

5-4

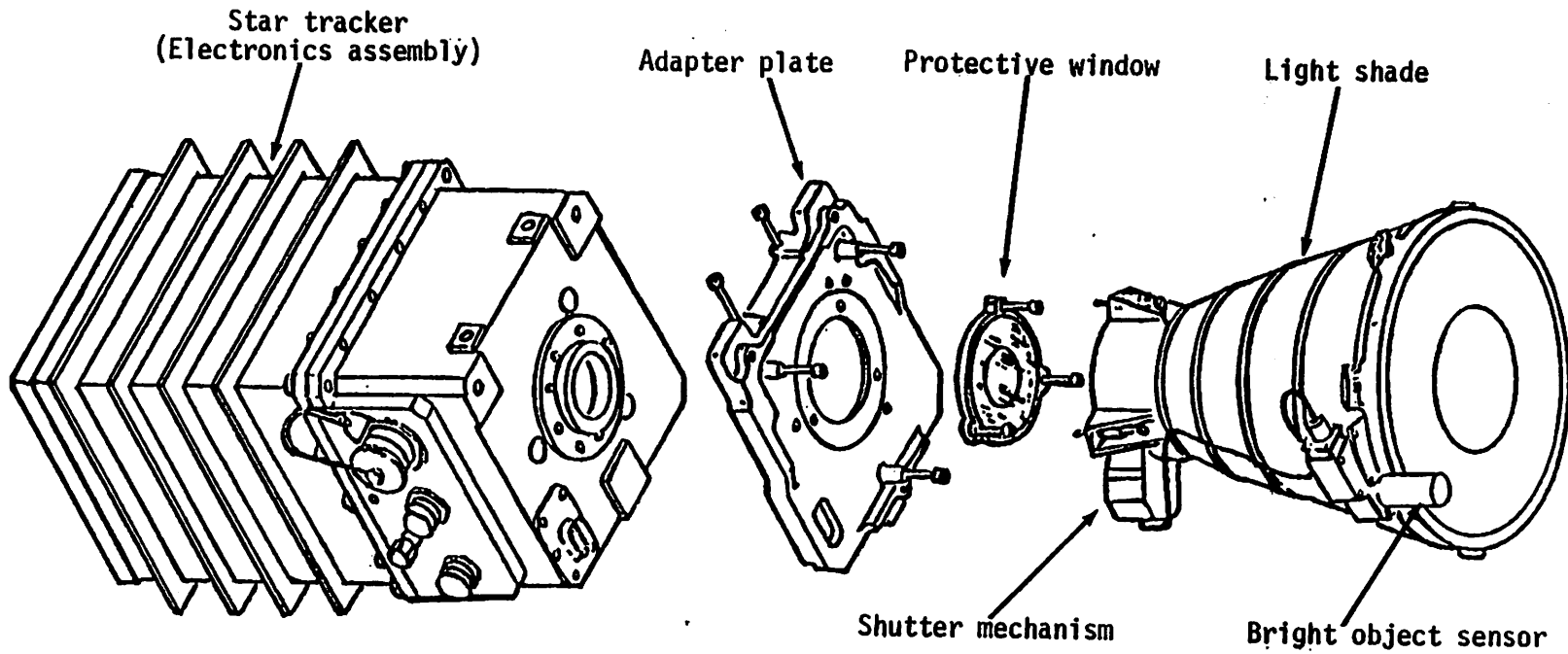


Figure 5-3.- Complete star tracker unit.

SECTION 6 TACAN

6.1 INTRODUCTION

The tacan unit is the airborne portion of a global navigation system. The tacan is a receiver/transmitter operating in the L-band with data computational capability that determines the slant range and magnetic bearing to a ground beacon. In addition, the ground station periodically transmits a coded station identification signal from which the tacan generates a corresponding audio signal called an ID tone.

There are three tacans on the Orbiter located in the forward avionics bays. Each tacan has two antennas, one upper and one lower, located on the upper and lower portions of the vehicle nose (see appendix A for locations). The tacan antenna selection can be made either automatically by computer control or manually by a select switch (fig. 6-1).

The tacan range and bearing data are used to update and increase the accuracy of the navigation state vector during the entry and Terminal Area Energy Management (TAEM) flight phases. After transformation to the runway coordinate system, the range and bearing data are also displayed on the Horizontal Situation Indicator (HSI).

6.2 HARDWARE DESCRIPTION

The three tacans operate simultaneously on one of the 252 L-band channels with nearly omnidirectional antenna coverage. All three tacans may be channeled to the same station or each tacan may be channeled to a station independent of the remaining two tacans.

The channel selection is accomplished via the tacan control head on panel 07. The control head allows manual select, X/Y mode, manual or auto antenna selection, and one of three operating modes - RCV (Receive), T/R (Transmit/Receive), or GPC (General Purpose Computer).

If the RCV mode is selected, the tacan will process only bearing data. The T/R mode processes both range and bearing data. This mode utilizes a manual channel selection while the antenna selection is either manual or automatic. The final tacan mode is the GPC mode which allows the computer to control both the channel and the antenna selection (see SFQM Vol. 8 for details). All power may be removed from the tacan by turning the power switch to OFF.

Components of the tacan hardware include a data processor, power oscillator/modulator, and receiver. The data processor decodes all command signals and produces the signals which are needed to control other modules in the receiver/transmitter. In addition, the data processor decodes the selected channel frequency and sends the data to the receiver and frequency synthesizer. Finally, the data processor sends a transmitter trigger pulse to initiate transmitter pulses. The transmitter

6-2

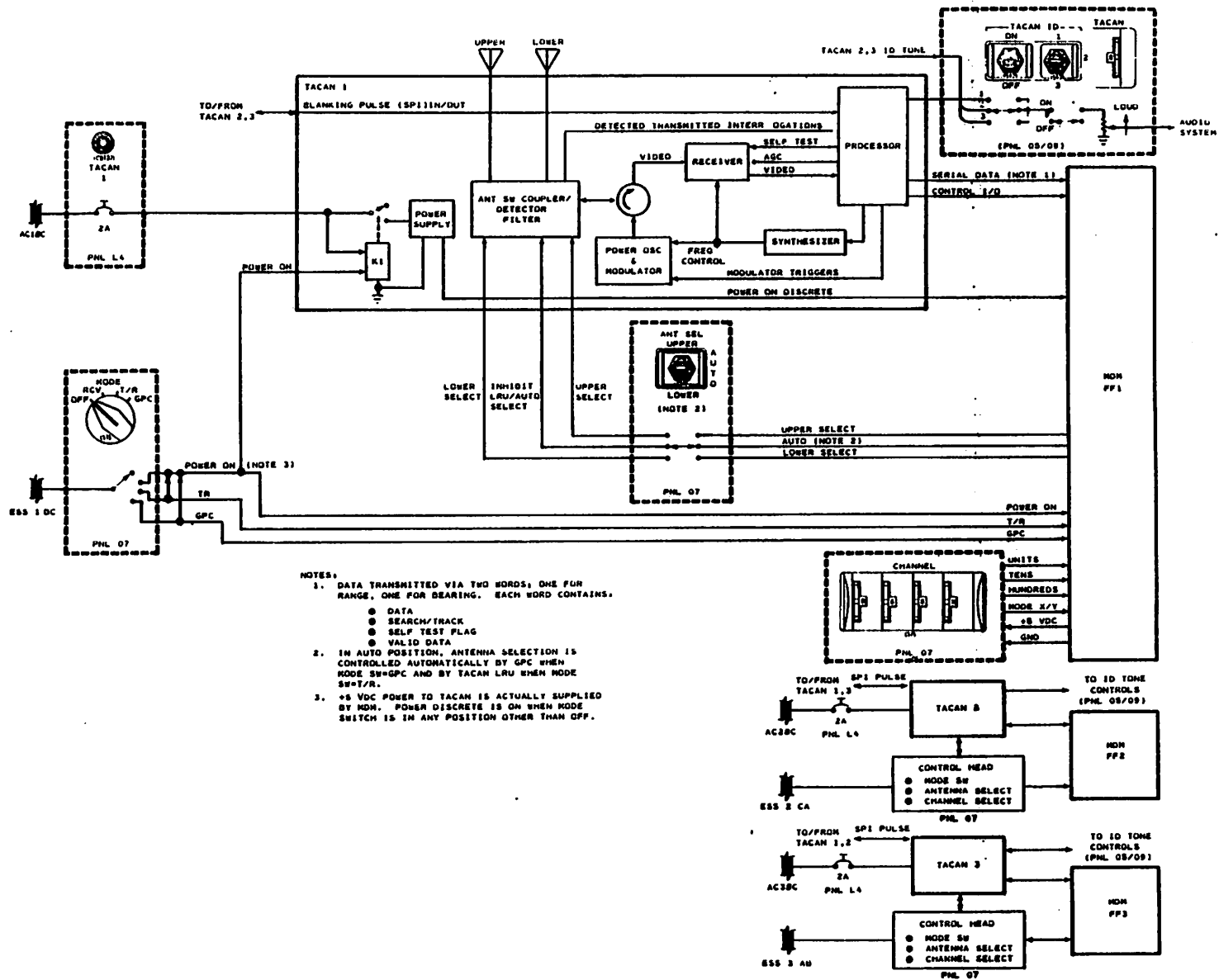


Figure 6-1.- Tacan diagram.

6-GNC

rf signals are applied directly through the coupler/filter switch using either internal or external antenna switching.

The transmitted signal is generated by the power oscillator/modulator which pulses a continuous wave from the frequency synthesizer at a frequency determined by the data processor. The pulsed output signal from the power oscillator/modulator is applied through the circulator and coupler-filter switch to the antennas. The transmitting frequency depends on the selected operating mode and channel, and is one of 126 frequencies.

The receiver amplifies the received rf pulses, performs frequency conversions, and detects the envelope of the converted signal. The signal is amplified and demodulated to obtain the composite received video signal, and is applied to the data processor for processing. The data processor decodes the pulses to recognize valid pulse pairs and times a counter to provide bearing computations. In addition, an internal blanking pulse, which is designed to blank out the receiver and other tacans, is generated. The receiver also composes the signals into a serial data word.

Bearing measurements are accomplished by comparing the phase of the bearing modulation of the main and auxiliary reference pulse groups with the positive inflection of the 15 Hz amplitude modulation.

Range computations are accomplished by operating in two modes, a range search mode and a range track mode. Range measurements are computed by measuring the elapsed time between the transmission of interrogation pulses and the reception of valid reply pulses, and then subtracting known system delays.

6.3 PERFORMANCE DATA

Range	400 n. mi. maximum
Warmup time	≤ 2 min @ 25° C $\pm 5^{\circ}$ C
	≤ 6 min @ -55° C
Power	165 W
	115 V ac, 400 Hz

SECTION 7 MICROWAVE SCANNING BEAM LANDING SYSTEM

7.1 INTRODUCTION

The Microwave Scanning Beam Landing System (MLS or MSBLS) is the airborne portion of an instrument landing system with decoding and data computation capabilities. The MLS determines the slant range and angular displacement in azimuth and elevation in relation to the ground system instrumentation at the landing site. There are three MLS's on the Orbiter located in the forward avionics bays. Each MLS has a dedicated antenna located on the forward portion of the nose that is utilized for both transmitting and receiving (appendix A). The range, azimuth, and elevation data are used by navigation to update and increase the accuracy of the state vector in the approach and landing flight phase. They are also used by area navigation to compute other parameters for display on the horizontal situation indicator. Azimuth and range data are used after touchdown for vehicle steering and rollout guidance.

7.2 HARDWARE DESCRIPTION

Power flow manual controls are shown in figure 7-1. The ground stations, one for elevation/azimuth, operate on a frequency (Ku-band) corresponding to a channel number selected using the thumbwheels on panel 08.

The MLS consists of two major subassemblies, the rf assembly and the decoder assembly. The rf assembly operates in the Ku-band, transmitting and receiving data in rf video form. These data are routed to the decoder assembly for processing and conversion to digital format for use by the computer.

The ground station transmits a Distance Measuring Equipment (DME) solicit pulse to which the onboard transmitter responds with a DME interrogation pulse. The ground equipment then responds by transmitting return pulses which the decoder decodes to determine range, azimuth, and elevation.

- Range: It is a function of the elapsed time between interrogation pulse transmission and signal return.
- Azimuth: The pulses are returned in pairs. The spacing between the two pulses in a pair identifies the pair as azimuth and indicates which side of the runway the Orbiter is on. The spacing between pairs of pulses defines the angular position from runway centerline.
- Elevation: The spacing between the two pulses in a pair identifies the pair as elevation. The spacing between pairs of pulses defines the angular position of the Orbiter above the runway.

7-2

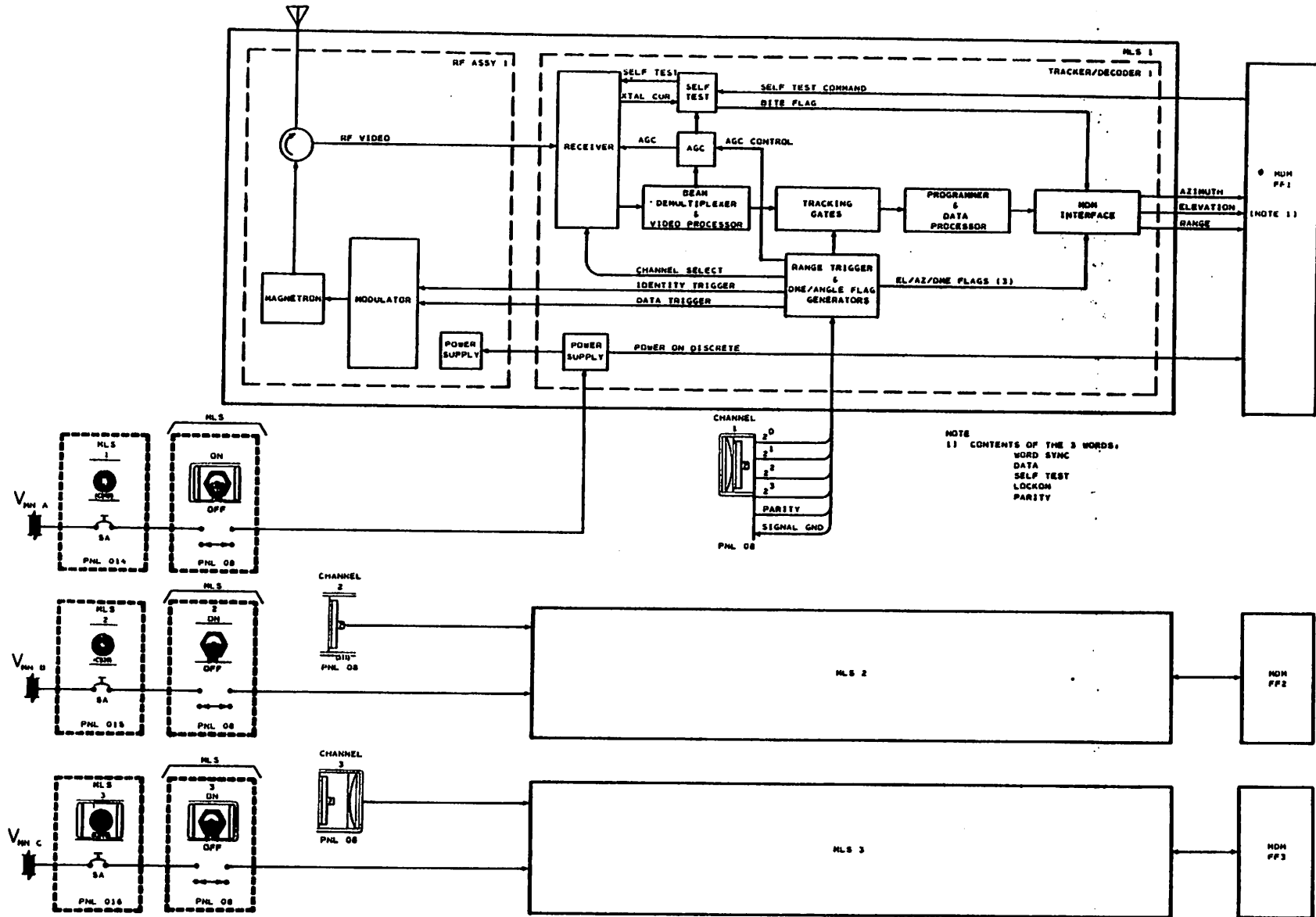


Figure 7-1.- Microwave scanning beam landing system diagram.

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7.3 PERFORMANCE DATA/LIMITATIONS

DME range	20 n. mi. maximum
Azimuth antenna pattern	$\pm 13.5^\circ$ wide, 23° high
Elevation antenna pattern	40° wide, 29° high
Accuracy (1σ)	
Range	± 50 ft
Elevation	$\pm 0.1^\circ$
DME output power	2 kW
DME velocity	2000 ft/sec maximum
Power usage	100 W
Warmup time	Not specified

SECTION 8 RADAR ALTIMETER

8.1 INTRODUCTION

The Radar Altimeter (RA) is an airborne, low altitude terrain tracking and altitude sensing system. The RA will provide a continuous indication of the vehicle's altitude at altitudes less than 5,000 ft. This altitude is displayed on the Altitude/Vertical Velocity Indicator (AVVI). In addition, the RA determined altitude is used by guidance during the approach and landing phase of the flight.

The two RA's onboard the Orbiter are located in forward avionics bays 1 and 2. Each RA has an associated transmitting and an associated receiving antenna. The antennas are located on the underside of the Orbiter nose.

8.2 HARDWARE DESCRIPTION

Each RA uses two antennas, one for transmitting and one for receiving (fig. 8-1). The antenna beam width is a 40° cone, centered around the Z-axis. For optimum performance, the isolation between the transmitting and receiving antennas must be greater than 85 dB, while the isolation between the receiving antennas of the two sets must be greater than 70 dB. The two RA's are capable of operating simultaneously, because each altimeter is not susceptible to nonsynchronous pulse interference, at the center frequency, of as much as 70 dB higher than the return signal being tracked.

The altitude range information is derived by a tracking loop which locks on the leading edge of the reflected ground return pulse and compares the received pulse with a timed ramp voltage which was initiated simultaneously with the transmitted pulse. Altitude range signals are analog voltages proportional to the elapsed time required for return of the ground pulse, which is a function of height and distance from the nearest terrain. The tracking loop remains locked to the return pulse from the nearest terrain during altitude change rates up to 200 ft/sec. This allows tracking of mountain or cliff sides ahead of or adjacent to the vehicle if these obstacles are nearer than the ground below, and it provides a warning of rapid changes in absolute altitude.

The transmitter module generates the rf pulses radiated by the transmitting antenna. It contains the Pulse Repetition Frequency (PRF) generator, the modulator, and the transmitter cavity oscillator.

The cavity oscillator produces rf pulses with a carrier frequency of 4300 MHz. The rf pulse output from the oscillator cavity passes to the transmitting antenna for radiation toward the ground.

The superheterodyne receiver module receives the returning rf pulses from the receiving antenna. The solid state local oscillator in the receiver

8-2

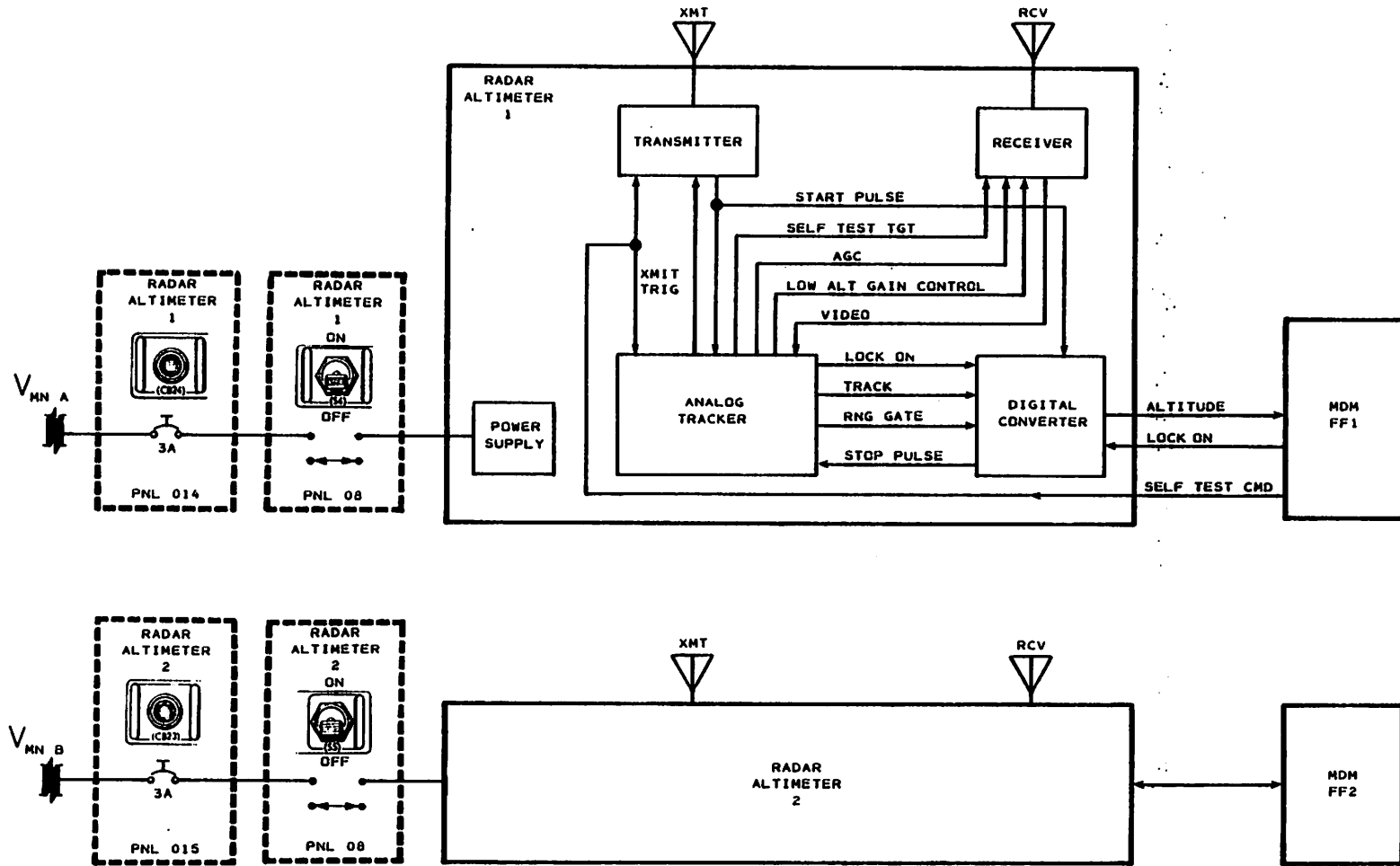


Figure 8-1.- Radar altimeter diagram.

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module is similar to the transmitter cavity oscillator and supplies a continuous-wave 4300 MHz signal to the balanced mixer at a 2.0 mW power level. The phase relationship of the returning rf signal and the local oscillator input determines the amplitude and polarity of the video output pulse.

The zero center frequency Intermediate Frequency (IF) amplifier utilizes five stages of amplification. Use of these amplifiers reduces the power consumption, and at the same time provides the required gain. Gain control is applied to the IF amplifier so that the output remains relatively constant over the flight environment for use by the tracking circuitry.

The range computer consists of a precision ramp generator, gating circuitry, a double operational integrator output circuitry, and control logic. The tracker section maintains a precision leading edge track of the return pulses and provides necessary gain control voltages to the video amplifier.

The basic function of the digital section is to provide an altitude output of zero to 5000 ft. This is based on the radar or absolute altitude above the terrain. The digital section includes the time digital converter, digital output, and an output register. The digital module provides input switching and an interface for associated digital equipment, as well as providing the altitude.

The RA switch on panel 08 is a two-position ON/OFF switch. When the switch is in the ON position, power is applied to the Receiver/Transmitter (R/T) and allows a power present discrete to return from the R/T to the Multiplexer/Demultiplexer (MDM). Software control of the RA is limited to throughputting the self-test command.

Two circuit breakers on panels 014 and 015 supply main bus A and B power to the RA's.

8.3 PERFORMANCE DATA

Altitude	0-5000 ft
Delta altitude	2000 ft/sec maximum
Input power	47 W/28 V dc
MTBF	2500 hr
rf output	100 W peak @ 8.5 kHz PRF
Speed	2000 kn maximum (ground)
Accuracy: (1σ)	0-10 ft ± 1.5 ft 10-65 ft ± 2.5 ft 65-5000 ft $\pm 3\%$ single reading ± 10 ft
Cooling	convection
Weight	4.5 lb
Warmup	≤ 3 min @ -55° C ambient

SECTION 9 AIR DATA SYSTEM

9.1 INTRODUCTION

There are two deployable air data probes, one on the left side and one on the right of the Orbiter. When stowed, the probes are in the forward compartment underneath the Orbiter skin (appendix A). Each probe contains ports (holes) which sense four pressures: PS (static), PaC (total), PaL (alpha lower), and PaU (alpha upper). In addition, each probe has a total temperature head, which contains dual sensors to measure temperature resistance, and three heater elements to prevent ice and/or moisture build-up. Pressures and temperatures sensed by the probe go to four independent Air Data Transducer Assemblies (ADTA's): The left probe is connected to ADTA's 1 and 3; right probe to ADTA's 2 and 4. Logic circuitry within each ADTA processes the pressures, temperature, and also performs internal hardware status checks for output to the Data Processing System (DPS). The pressures are used in software calculations to determine other air data parameters used by guidance, navigation, and flight control during the TAEM, approach, and landing phases of atmospheric flight.

9.2 HARDWARE DESCRIPTION

9.2.1 Air Data Probes

The air data probes are independently deployed by placing the air data probe switch to the desired position (fig. 9-1). A deploy request results in closures of the dual series relays in the Forward Motor Control Assemblies (FMCA's), thus allowing three-phase ac power to the probe motors. The motors, through differential gearing, are mechanically linked to an actuator which rotates the probe outward so that it faces forward. When the probe is fully deployed, the arm of the actuator trips the deploy limit switches within the probe assembly. Closure of the deploy limit switches is fed back (inverted) to the deploy driver logic, thus opening the relays and removing power from the motors. The stow limit switches immediately open upon deploy request.

Positioning the air data probe switches to DEPLOY/HEAT allows one set of series relays in the Forward Power Control Assemblies (FPCA's) to close. When the probe is fully deployed, the same signal used to open the motor relays is also utilized to close a second set of series relays in the FPCA's, thus allowing power to the heaters.

Stowing the probes is accomplished in a similar manner. A second switch, AIR DATA PROBE STOW, must be in the ENABLE position to allow the operation of the STOW position of the probe switch. The only other difference for stowing is that two phases of the motors are reversed. The status of each limit switch, deployed or stowed, is transmitted to the Multiplexer/Demultiplexers (MDM's).

There is redundancy in the electronics and probe motors to ensure operation in the event of failures. Only one of the two motors is required to deploy or stow a probe. Other redundancy is provided in series relays in the FMCA so that if a driver fails closed, the other driver will open the path and remove motor power. The addition of the enable/inhibit switch allows power to be removed from the stow circuits in the INHIBIT position to eliminate the possibility of a single limit switch failure causing actuator damage.

9.2.2 Air Data Transducer Assembly

Pressures sensed at the ports are transmitted via pneumatic lines to the two ADTA's associated with the probe. The two resistance measurements from the probe temperature head are hardwired to an ADTA. ADTA's receive power through circuit breakers (fig. 9-2), which set a power-on discrete to the MDM. Under processor control, calibration constants are extracted from each transducer memory based on the sensed values. The sensed pressures, also under processor control, are converted to digital data by the Analog to Digital (A/D) converter and read by the processor. Probe total temperature is converted to voltage via the bridge and then converted to digital data by the A/D converter. The processor applies various algorithms to produce a linearized set of pressures and temperature. A clock generator provides the gating functions of reading the transducers and A/D converter.

Internal status checks and monitoring are performed by the processor each cycle as part of the Built-in Test Equipment (BITE) circuitry. The processor performs reasonability checks on other components (e.g., power supply) and on the received pressures and temperature. In the event of an out-of-tolerance condition, a fail bit is set in the ADTA mode/status word. At the end of each computational cycle, PS, PoL, PoU, PoC, temperature, and the mode/status word are transferred to the output circuit and the next cycle begins.

In addition to performing continuous BITE tests, each ADTA can be commanded to do a high or low self-test. The self-test request from the MDM is validated in the processor and causes two actions. First, a set of constants, high or low values, are output from the processor for PS, PoU, PoL, PoC, and temperature. Secondly, the processor performs comparison checks on the sensed pressure measurements and compares them to a threshold. An out-of-tolerance condition results in a fail bit being set in the mode/status word. As is the case during continuous operation, the self-test results are transferred to the output circuit and finally to the MDM.

The bit definition of the mode/status word is shown on the following page. Bit 1, ADTA GOOD, is set to 1 if any of the bits 5, 6, 7, 8, 9, 10, 11, 12, and 13 are set to 1. It requires three consecutive fail bits (≈ 120 msec) to set bit 1 to 0; it then requires 16 consecutive "no fail" bits (≈ 640 msec) to reset bit 1 to 1. Bit 14 only applies during a request for self-test. If the processor determines that a valid self-test command does not exist (i.e., bit 14=0) then self-test will not occur.

9-5

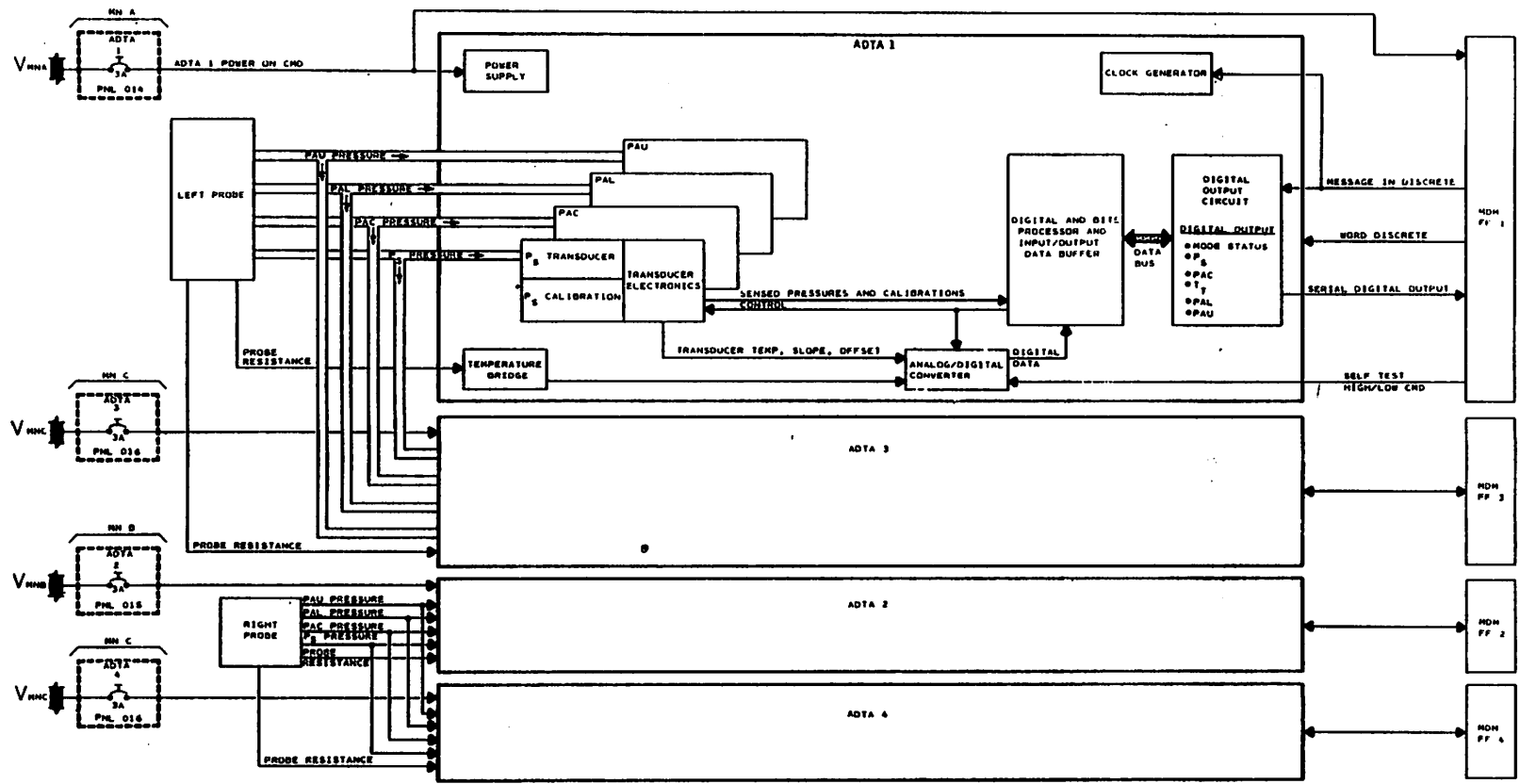


Figure 9-2.- The ADTA diagram.

ADTA mode status word bit definition:

Bits															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0

Nominal status
(no self-test)

Bit definition

- 1 = ADTA GOOD (1 = GOOD, 0 = FAIL)
- 2 = SPARE, ALWAYS 0
- 3 = HIGH TEST MODE (1 = ON)
- 4 = LOW TEST MODE (1 = ON)
- 5 = P α L TRANSDUCER GOOD (1 = GOOD, 0 = FAIL)
- 6 = P α J TRANSDUCER GOOD (1 = GOOD, 0 = FAIL)
- 7 = P α C TRANSDUCER GOOD (1 = GOOD, 0 = FAIL)
- 8 = PS TRANSDUCER GOOD (1 = GOOD, 0 = FAIL)
- 9 = A/D CONVERTER GOOD (1 = GOOD, 0 = FAIL)
- 10 = ELECTRONICS GOOD (1 = GOOD, 0 = FAIL)
- 11 = TEMPERATURE CIRCUIT GOOD (1 = GOOD, 0 = FAIL)
- 12 = SUM CHECK GOOD (1 = GOOD, 0 = FAIL)
- 13 = POWER SUPPLY GOOD (1 = GOOD, 0 = FAIL)
- 14 = SELF-TEST DISCRETE INPUTS GOOD (1 = GOOD, 0 = FAIL)
- 15 = SPARE, ALWAYS 0
- 16 = SPARE, ALWAYS 0

9.3 PERFORMANCE DATA/LIMITATIONS

- Performance envelope
 - Altitude -1000 to 100,000 ft
 - Mach number 0.2 to 3.5
 - Angle of attack -5 $^{\circ}$ to 25 $^{\circ}$
 - Maximum temperature 850 $^{\circ}$ F
- Probe deploy time
 - 2 motors 15 sec
 - 1 motor 30 sec
- Maximum probe actuator load 375 lb/ft 2
- ADTA warmup time 2 sec
- ADTA operating temperature 35 $^{\circ}$ to 100 $^{\circ}$ F
- Power
 - Probe heaters 1300 W per probe
 - ADTA 64 W

SECTION 10 CONTROLLERS

10.1 INTRODUCTION

Manual control of the vehicle is provided via the various controllers. The three Rotational Hand Controllers (RHC's) are used to provide manual roll, pitch, and yaw inputs to the flight control system. The two Translational Hand Controllers (THC's) provide manual lateral, longitudinal, and vertical translational inputs to the flight control system. The two Rudder Pedal Transducer Assemblies (RPTA's) generate an electric signal which is proportional to the displacement of the rudder pedal. This electric signal is used to control the position of the rudder during the final stages of the entry flight phase. The two Speed Brake Thrust Controllers (SBTC's) are used to control the vertical stabilizer mounted speedbrake during the entry flight phase. Additionally, the pilot's SBTC can be used for manual throttle control of the Space Shuttle Main Engines (SSME's) during the ascent phase.

10.2 ROTATIONAL HAND CONTROLLER

The two RHC's located at the pilot's and the commander's stations are usable during all mission phases (ascent, entry, and on-orbit). The RHC located at the aft station is usable only during the on-orbit flight phase. As stated earlier, the RHC's are used to provide manual roll, pitch, and yaw rotational inputs to the flight control system.

10.2.1 Hardware Description

The RHC has a BFS ENGAGE switch, a TRIM switch, and a COMM switch (fig. 10-1).

The BFS ENGAGE switch is used to engage the Backup Flight System (BFS) and is a momentary thumb-operated switch. The BFS ENGAGE switch is inactive in the aft station.

The TRIM switch is used to introduce a constant rate of Orbiter movement about the body pitch or roll axis. (If an increased rate is desired, the switch is actuated again in the same direction. The Orbiter movement is proportional to the length of time the switch is actuated.) If a rate decrease is desired, or if it is desired to totally remove the rate, the TRIM switch must be actuated in the opposite direction. The TRIM switch at the aft station RHC is inactive.

The COMM switch is a "push-to-talk" switch. When the switch is depressed, the radio transmitters are enabled. The transmitters remain in operation as long as the switch is depressed.

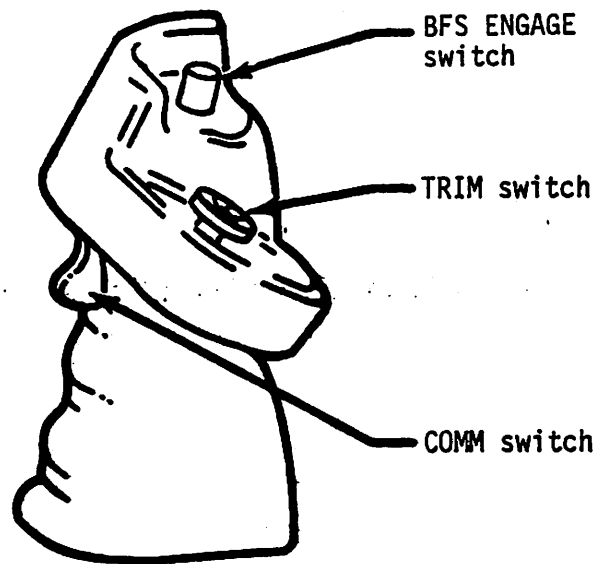


Figure 10-1.- The RHC switches.

The power flow and MDM channelization for each RHC is depicted in figure 10-2. Each RHC is redundantly powered by two main power buses which supply power to a DDU. Each main power bus has an associated circuit breaker. The output of the DDU is controlled by a flight controller power switch. Each DDU contains three power supplies, and each power supply powers one RHC transducer channel for each of the pitch, roll, and yaw axes. The pitch, roll, and yaw output signals for each transducer channel of one RHC are sent over the same flight forward MDM.

10.2.2 Performance Data/Limitations

Mechanical hard stop deflection:	Pitch ± 24.30 Roll ± 24.30 Yaw ± 14.30
Mechanical soft stop deflection:	Pitch ± 19.50 Roll ± 19.50 Yaw $\pm 10^{\circ}$
Maximum signal output:	Pitch 5.103 V dc Roll 5.103 V dc Yaw 5.148 V dc

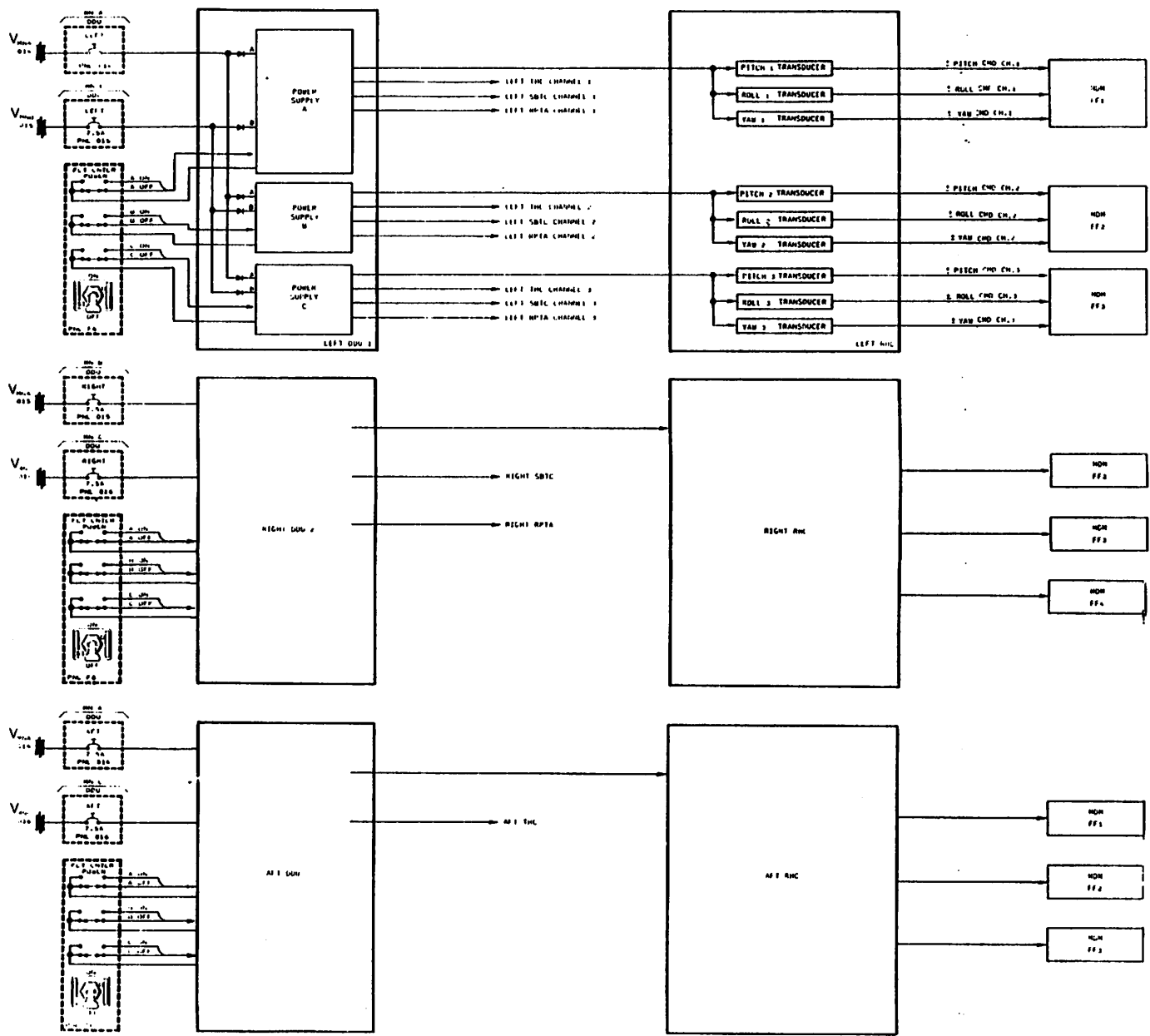


Figure 10-2.- The RHC diagram.

10-3

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10.3 TRANSLATIONAL HAND CONTROLLERS

The two THC's are located at the commander's station and at the aft station. As mentioned earlier, the THC is used for manual lateral, longitudinal, and vertical translational inputs to the flight control system. The commander's THC can be used for the orbit insertion, on-orbit, and deorbit flight phases. The aft station THC can be used only during the on-orbit flight phase.

10.3.1 Hardware Description

The THC rotates about the vertical and lateral axes and translates along the longitudinal axis as shown in figure 10-3.

The power flow and MDM channelization for each THC is depicted in figure 10-4. Each THC is redundantly powered by two main power buses which supply power to a DDU. Each main power bus has an associated circuit breaker.

A flight controller power switch controls the power output of the DDU. Each DDU contains three power supplies, and each power supply powers one THC channel for each of the positive and negative longitudinal, lateral, and vertical axes. The output signals of the axes for each channel of a THC are sent over the same flight forward MDM.

10.3.2 Performance Data/Limitations

THC displacement:	0.45 in. in each axis
Voltage output:	0 or 5 V dc in each axis

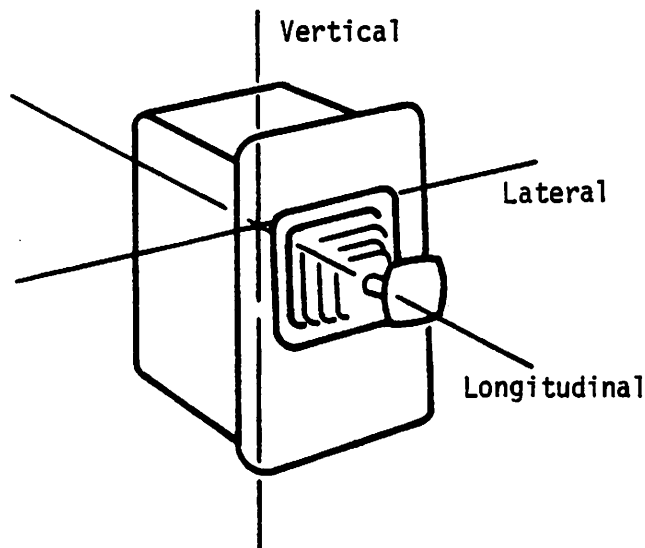


Figure 10-3.- Axes of THC control.

10-5

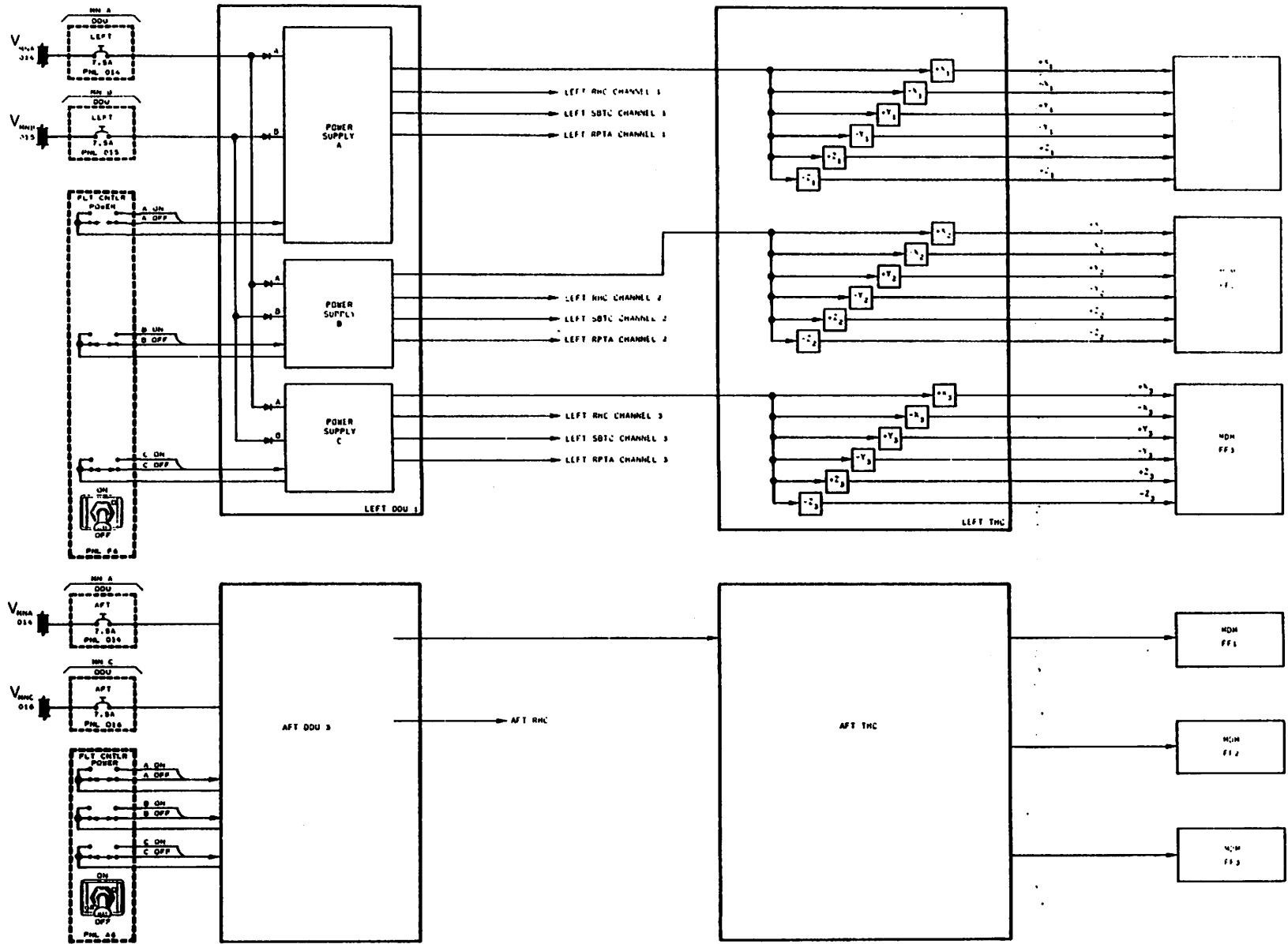


Figure 10-4.- The THC diagram.

10.4 RUDDER PEDAL TRANSDUCER ASSEMBLY

The two RPTA's on the Orbiter are located at the commander's station and at the pilot's station. The RPTA generates an electrical output signal which is proportional to the rudder pedal displacement. This signal controls the position of the rudder during the final stages of the entry flight phase.

10.4.1 Hardware Description

The RPTA is a black box with a set of triple redundant transducers and a mechanical input arm, as depicted in figure 10-5. When the left rudder pedal is depressed, the input lever on the RPTA rotates downward from the null position for left rudder deflection. When the right rudder pedal is depressed, the input lever on the RPTA is rotated upward from the null position to produce a right rudder deflection. The two RPTA's are mechanically linked together.

The power flow and MDM channelization for each RPTA is depicted in figure 10-6. Each RPTA is redundantly powered by two main power buses which supply power to a DDU. Each main power bus has an associated circuit breaker.

A flight controller power switch controls the power output of the DDU. Each DDU contains three power supplies, and each power supply powers one RPTA transducer channel. The output signal for each channel is sent over a separate flight forward MDM.

10.4.2 Performance Data/Limitations

RPTA lever displacement:	0° - 30°
Output signal (varies linearly with the lever displacement):	0° - 22.5°
Voltage output	0 - 5 V dc

10.5 SPEEDBRAKE THRUST CONTROLLER

The two SBTC's on the Orbiter, located at the commander's and pilot's stations, are used to control the position of the vertical stabilizer mounted speedbrake during the entry flight phase. Additionally, the pilot's SBTC can be used for manual throttle control of the SSME's during the ascent phase.

10-7

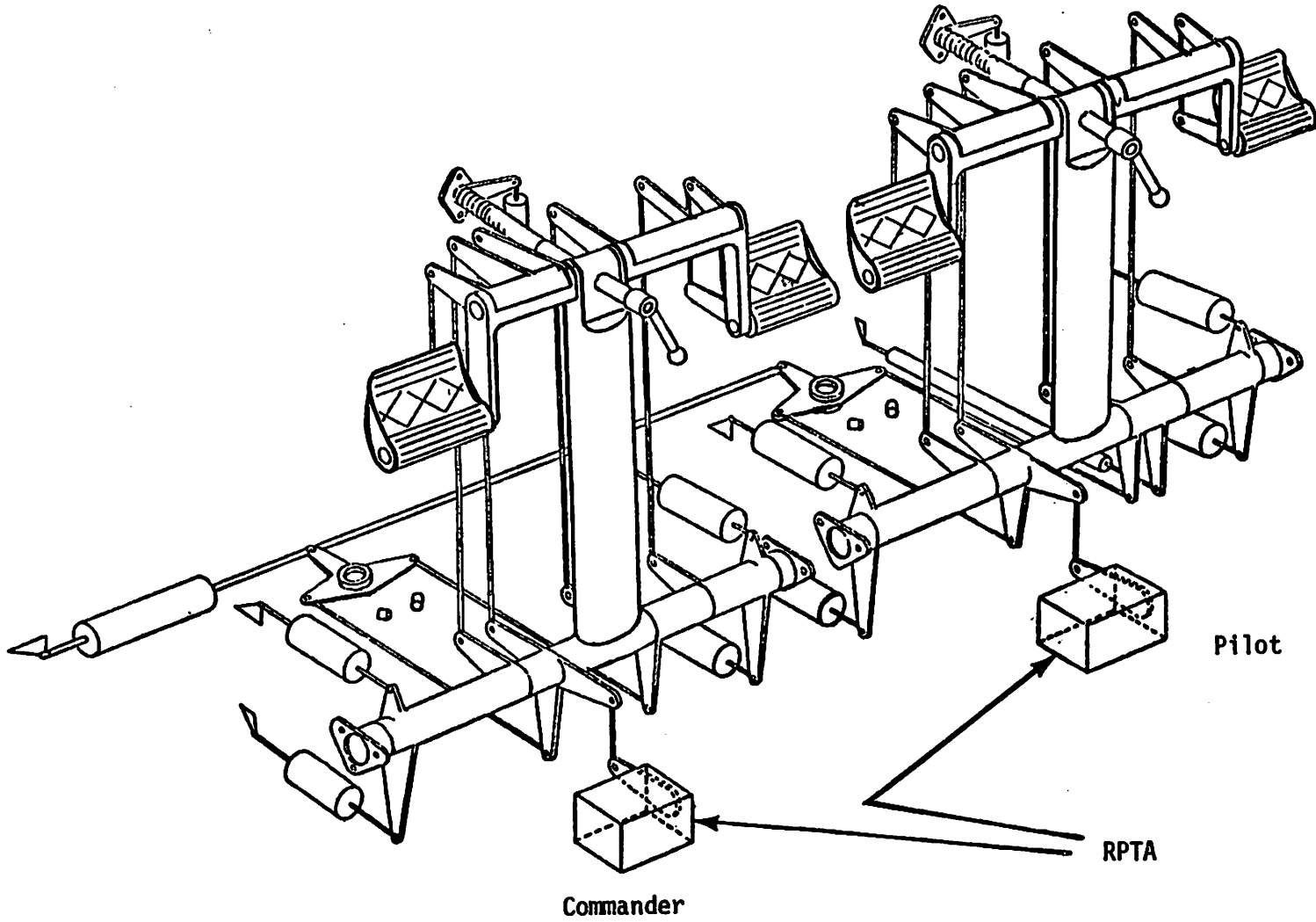


Figure 10-5.- Rudder pedal transducer assembly.

10-8

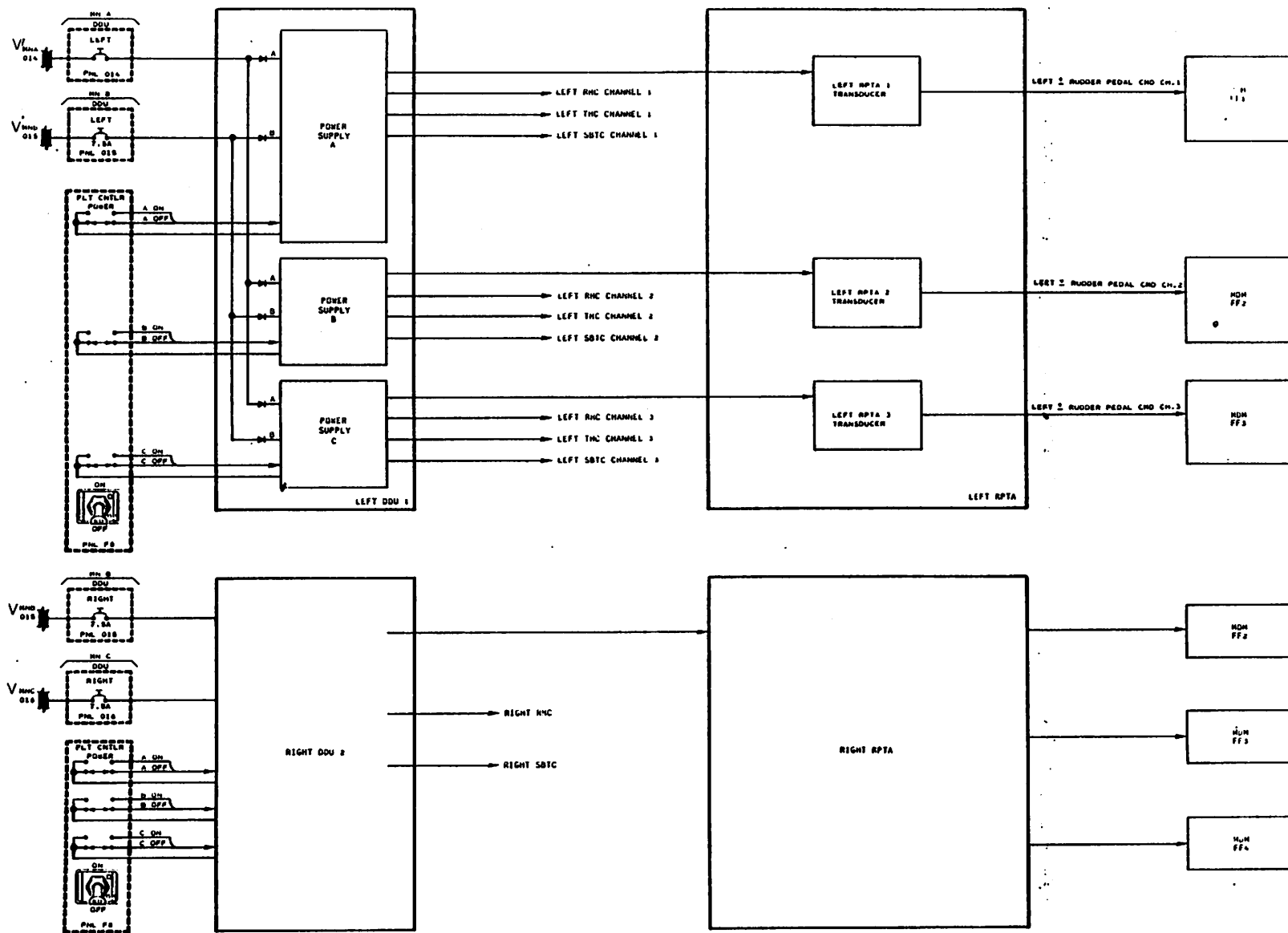


Figure 10-6.- The RPTA diagram.

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10.5.1 Hardware Description

The lever and cockpit mounting configuration of the SBTC makes the control suitable for left-hand use only. A takeover switch located at the thumb position is used to gain manual control of the speedbrake.

For manual control, when the lever is rotated forward to the stop, the speedbrake is commanded completely closed. The lever rotated completely backward to the stop yields a speedbrake full open command. Alternatively, during ascent these two settings correspond to a 100 percent throttle command (full forward) and to a 65 percent throttle command (full backward) (fig. 10-7).

The power flow and MDM channelization for each SBTC is depicted in figure 10-8. Each SBTC is redundantly powered by two main power buses which supply power to a DDU. Each main power bus has an associated circuit breaker.

A flight controller power switch controls the power output of the DDU. Each DDU contains three power supplies, and each power supply powers one SBTC transducer channel. The output signal for each channel is sent over a separate flight forward MDM.

10.5.2 Performance Data/Limitations

SBTC lever displacement:	60°
Maximum voltage output (lever at back stop):	5.4 V dc

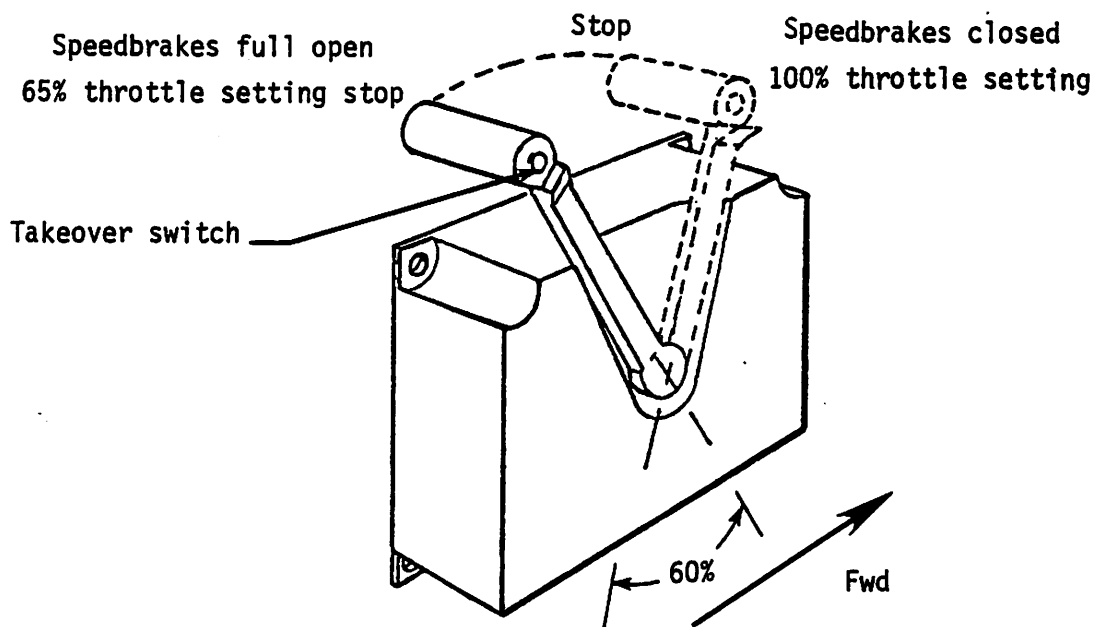


Figure 10-7.- Speedbrake thrust controller use.

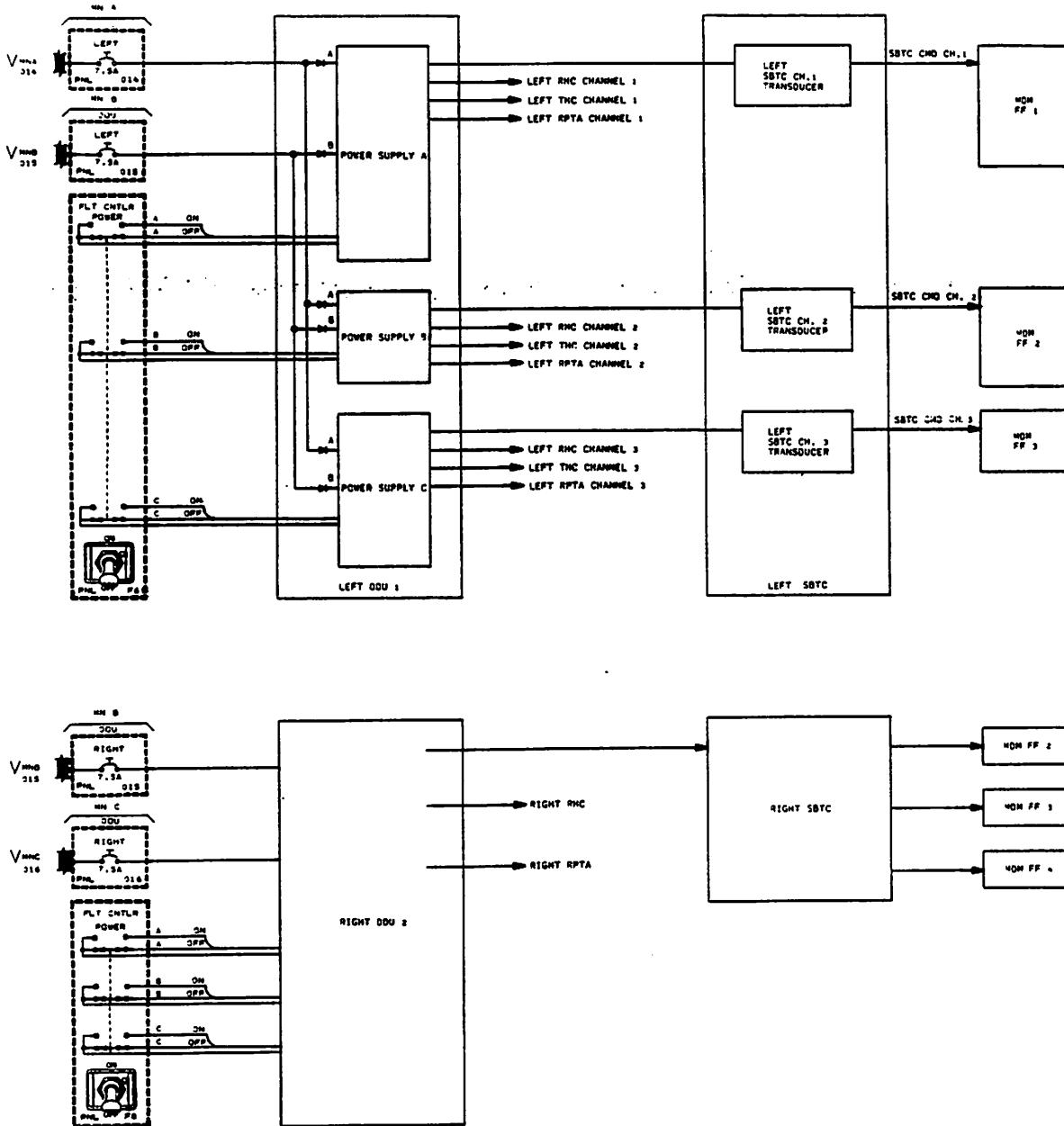


Figure 10-8.- The SBTC diagram.

SECTION 11 AEROSURFACE SERVO AMPLIFIERS AND ACTUATORS

The Orbiter has seven aerodynamic control surfaces - four elevons, rudder, speed brake, and body flap. Each surface is driven by a complex system of aerosurface servoamplifiers and actuators. Included in this system are four elevon actuators, rudder actuator, speed brake actuator, body flap actuator, and four Aerosurface Servoamplifiers (ASA's). Operation of this system requires external power, supplied through FCS channel and ASA power switches; hydraulic power, supplied using three redundant hydraulic systems; and input/output interfaces, utilizing the flight aft MDM's. The overall system is shown in figure 11-1. The following explains the actuator and ASA hardware.

11.1 ACTUATORS

11.1.1 Elevon Actuators

Each elevon actuator consists of a primary actuator (power spool) with a position and primary ΔP transducer, a secondary power spool, four servovalves and four isolation valves with secondary ΔP transducers. Attached to each elevon is a primary power spool from one of the four elevon actuators. This power spool uses hydraulic pressure to supply the force necessary to move the surfaces. Monitoring the primary power spool are two LVDT's - one for measuring elevon position and another for measuring elevon hinge moment. Signals from both LVDT's are sent to the ASA's as position feedback and primary ΔP . The hydraulic flow going to the primary power spool is controlled by the secondary power spool which acts as a hydraulic valve. Four servovalves control the hydraulic flow going to the secondary power spool. Each servovalve receives a position error command from one of the four ASA's and drives to send a hydraulic command to the secondary power spool. Each hydraulic command is monitored by an LVDT which sends secondary ΔP signals to the ASA. A hydraulic command may be isolated by opening the isolation valve which routes the flow away from the secondary power spool.

11.1.2 Rudder and Speed Brake Actuators

The rudder/speed brake panels move in response to both rudder and speed brake commands. To accomplish this, the output of the rudder actuator and speed brake actuator is combined in a mixer gearbox and sent via two parallel torque shafts to four rotary gear actuators which are attached to and move the rudder/speed brake panels. The rudder and speed brake actuators are identical, consisting of a differential gearbox, three hydraulic motors, triplex power spool, four servovalves and four isolation valves with secondary ΔP transducers. The differential gearbox combines the output of three redundant hydraulic motors and supplies a rotation command to the mixer gearbox. The hydraulic motors receive hydraulic pressure from the triplex power spool which is similar to the secondary power spool in the elevon actuator. Control of the triplex power spool is identical to the

elevon actuators using four servovalves with isolation valves and secondary ΔP monitoring.

11.1.3 Body Flap Actuator

The body flap actuator consists of four rotary gear actuators, differential gearbox, three hydraulic motors, three power actuators, and three sets of enable, up, and down solenoids. The body flap is attached using four rotary gear actuators which receive rotational commands via torque shafts from a differential gearbox. Combined in the differential gearbox are outputs of three hydraulic motors. These motors are controlled by hydraulic pressure sent from the power actuators. The power actuators are hydraulic valves that are controlled by three solenoids, an enable, up, and down. The enable solenoid is used only to route hydraulic flow to the up and down solenoids allowing them to control power spool movement.

11.2 ASA'S

Each of the four ASA's has seven channels - one for each of the aerosurfaces. The four elevon, rudder, and speed brake channels are identical except for the addition of primary ΔP in the elevon channels. These channels consist of position command and feedback processing, a servovalve driver, redundant channel equalization, fault detection, override/bypass command processing, and isolation servovalve driver. Each channel receives a position command from flight control via a flight aft MDM and position feedback from an LVDT in the primary actuator. The two are summed along with signals from redundant channel equalization and primary ΔP (elevons only) to form a position error command. The position error command is amplified in the servovalve driver and sent to the actuator servovalves. Any discrepancies between an actuator's four servovalves are found by monitoring secondary ΔP 's. Redundant channel equalization provides compensation for small discrepancies by adding a bias to that channel's position command. Fault detection removes large discrepancies by sending an isolation command to the isolation valve driver which opens the appropriate isolation valve in the actuator. The isolation valve driver may also be manually commanded to bypass via a GPC read/write, or override an isolation command via the FCS channel switch.

The body flap channel consists of three servovalve drivers and position feedback with ASA four having only position feedback. The servovalve drivers receive on/off commands for one of the three body flap solenoids and transmit the signal to the actuators. Position feedback from the actuator is transmitted through the ASA to the GPC.

SECTION 12 DEDICATED DISPLAYS

12.1 INTRODUCTION

The Orbiter GNC dedicated displays include the Attitude Director Indicators (ADI), Horizontal Situation Indicators (HSI), Alpha/Mach Indicators (AMI), Altitude/Vertical Velocity Indicators (AVVI), Surface Position Indicator (SPI), and the G-meter. These displays serve three main functions:

- Allow manual control of the vehicle
- Provide monitoring of auto guidance
- Provide display of flight critical displays

This section presents the physical displays (front views only) and defines their hardware interfaces, including signal interface and power. Parameter definitions, moding, and controls are inherently tied to the dedicated display software, and therefore are described in SFOM Volume 7, Applications Software.

12.2 HARDWARE DESCRIPTION

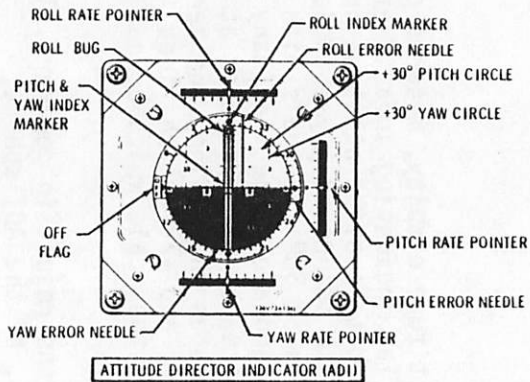
Appendix A shows the location of the dedicated displays in the forward and aft crew stations. The displays are shown in figure 12-1 and hardware interfaces in figure 12-2. Brief descriptions of each display are provided below.

12.2.1 Attitude Director Indicator

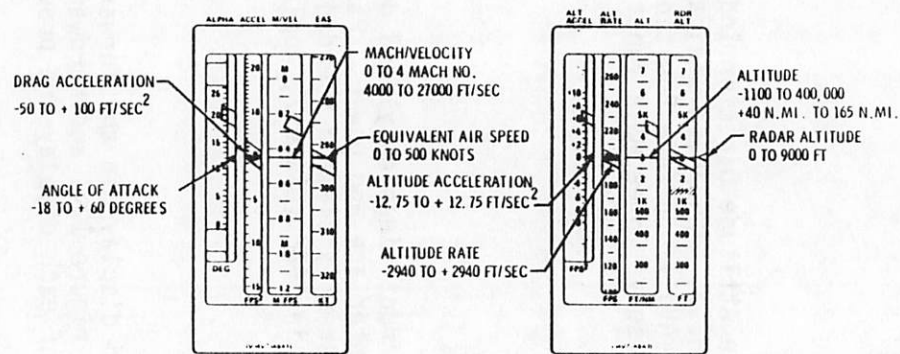
The ADI consists of a gimballed sphere for attitude display, metered pointers for rate and error display, and an OFF flag indicating invalid attitude data. The sphere is painted and gimballed to provide attitude in a pitch/yaw/roll Euler sequence; thus gimbal lock occurs at a yaw angle of 90° . The pitch markings include great circles at 30° intervals with submarkings as shown along the zero yaw line and along the imaginary 15° , 45° , 315° , and 345° yaw lines. Yaw is indicated by minor circles at 30° intervals from -270° to $+90^\circ$, with submarkings as shown along the zero pitch line and along the imaginary $\pm 15^\circ$, $\pm 45^\circ$, and $\pm 75^\circ$ pitch lines. Roll angle is read where the roll "bug" intersects the scale which bounds the sphere.

Positive pitch, yaw, and roll Orbiter rotations result in downward, left, and counterclockwise rotations, respectively, of the ADI sphere.

The ADI OFF flag is spring-loaded to pop into view whenever any of the six attitude driver commands (sine and cosine of pitch/yaw/roll) are invalid or "missing". The ADI ball will continue to drive when the flag appears except in one case: on-orbit, when data is missing. In that case, the ball remains static.

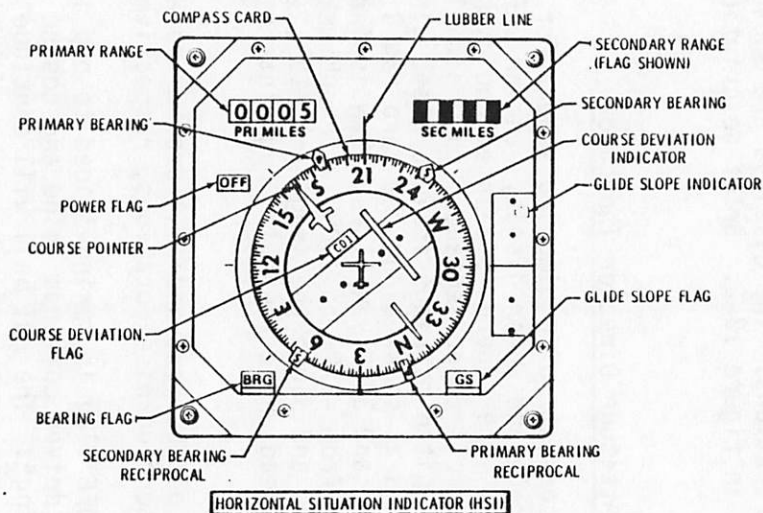


ATTITUDE DIRECTOR INDICATOR (ADI)

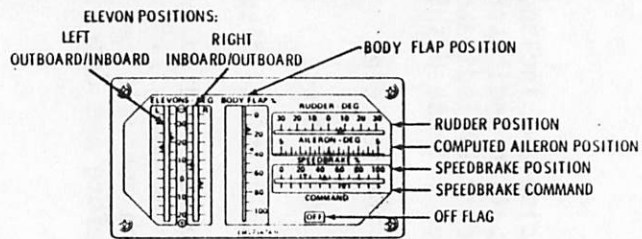


ALPHA/MACH INDICATOR (AMI)

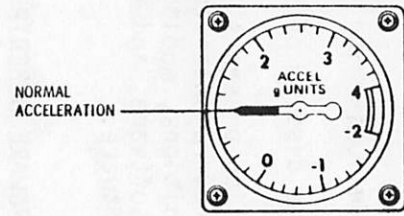
ALTITUDE/VERTICAL VELOCITY INDICATOR (AVVI)



HORIZONTAL SITUATION INDICATOR (HSI)



SURFACE POSITION INDICATOR (SPI)



G-METER

Figure 12-1.- The GNC dedicated displays.

12.2.2 Horizontal Situation Indicator

The HSI display presents a pictorial view of the vehicle with respect to various navigational reference points. The compass card is a circular plate with a 0° - 360° scale against its perimeter. The compass card rotates with respect to the case. Heading angle is displayed where the compass card scale intersects the buffer line.

The course pointer rotates with respect to the compass card and case. Course is indicated by the position of the course pointer on the compass card scale. Primary and secondary bearing and their reciprocals move along the perimeter of the compass card and are read where they intersect the compass card scale. Course deviation is read where the moving CDI bar intersects its scale on the compass card.

Primary and secondary range are displayed digitally in case windows as shown. The glide slope indicator is read where it intersects its fixed scale.

The HSI has validity flags for bearing (BRG), course deviation (CDI), glideslope (GS), power (OFF), and primary/secondary range (barberpoles). The OFF flag appears when power is insufficient or missing, in which case the entire display freezes. The remaining flags can appear alone or in combinations which depend on the failure mode, and portions of the display will go static.

12.2.3 Alpha/Mach Indicator

The AMI provides four flight critical parameters computed from air data or from navigation. ALPHA is displayed using a combination moving scale and pointer. For ALPHA between -4° and $+28^{\circ}$, the scale remains stationary and the pointer moves to the correct reading. For ALPHA less than -4° or greater than $+28^{\circ}$, the pointer stops (at -4° or $+28^{\circ}$) and the scale moves so that the correct reading is adjacent to the pointer. The tape coloration is black on white in the negative region, and white on black in the positive. There are no scale changes throughout the ALPHA scale range of -18° to $+60^{\circ}$.

ACCEL, M/VEL, and EAS are displayed by a moving tape read against a fixed lubber line. The ACCEL tape range is -50 to $+100$ ft/sec^2 , with a scale change at 0 ft/sec^2 . The negative region is white on black; the positive, black on white. M/VEL ranges from Mach 0 to 4 , then from 4000 to $27,000$ ft/sec , with a scale change at Mach 4 . EAS ranges from 0 to 500 knots, with no scale changes.

12.2.4 Altitude/Vertical Velocity Indicator

The AVVI also provides four flight critical parameters. ACT ACCEL is read where a moving pointer intersects a fixed scale. The hardware range is -13.3 to $+13.3$ ft/sec^2 (software limits are ± 12.75 ft/sec^2) with no scale changes. ALT RATE, ALT, and RDR ALT are read where moving tapes intersect a fixed line. ALT RATE ranges from -2940 ft/sec to $+2940$ ft/sec with

scale changes at -740 ft/sec and +740 ft/sec. Negative numbers are white on black; positive are black on white. The ALT scale ranges from -1100 ft to +65 nm, with scale changes at -100 ft, 0 ft, +500 ft, and +100,000 ft and in nm from +40 to +165 nm (ft and nm overlap from +40 nm to +61 nm). The RDR ALT ranges 0 to 9,000 ft, with a scale change at 1500 ft.

12.2.5 Surface Position Indicator

The SPI provides the four elevon surface positions from -35° to +20° (left outboard, left inboard, right inboard, right outboard), body flap position from 0 to 100 percent, rudder position ($\pm 30^\circ$), speedbrake position (0 to 100 percent). The SPI also has a spring-loaded OFF flag.

12.2.6 G-Meter

The G-meter is a fully self-contained mechanical accelerometer and display unit mounted on panel F7. It senses linear acceleration along the Z-body (normal) axis. The range is -2 to +4g.

12.3 PERFORMANCE DATA/LIMITATIONS

The power requirements of the individual displays are summarized in the table below.

<u>Meter</u>	<u>Power Required</u>
ADI	21.5 W
HSI	26.7 W
AMI	38.4 W
AVVI	31.6 W
SPI	TBS W
G-METER	0 W

APPENDIX A
GNC HARDWARE LOCATIONS

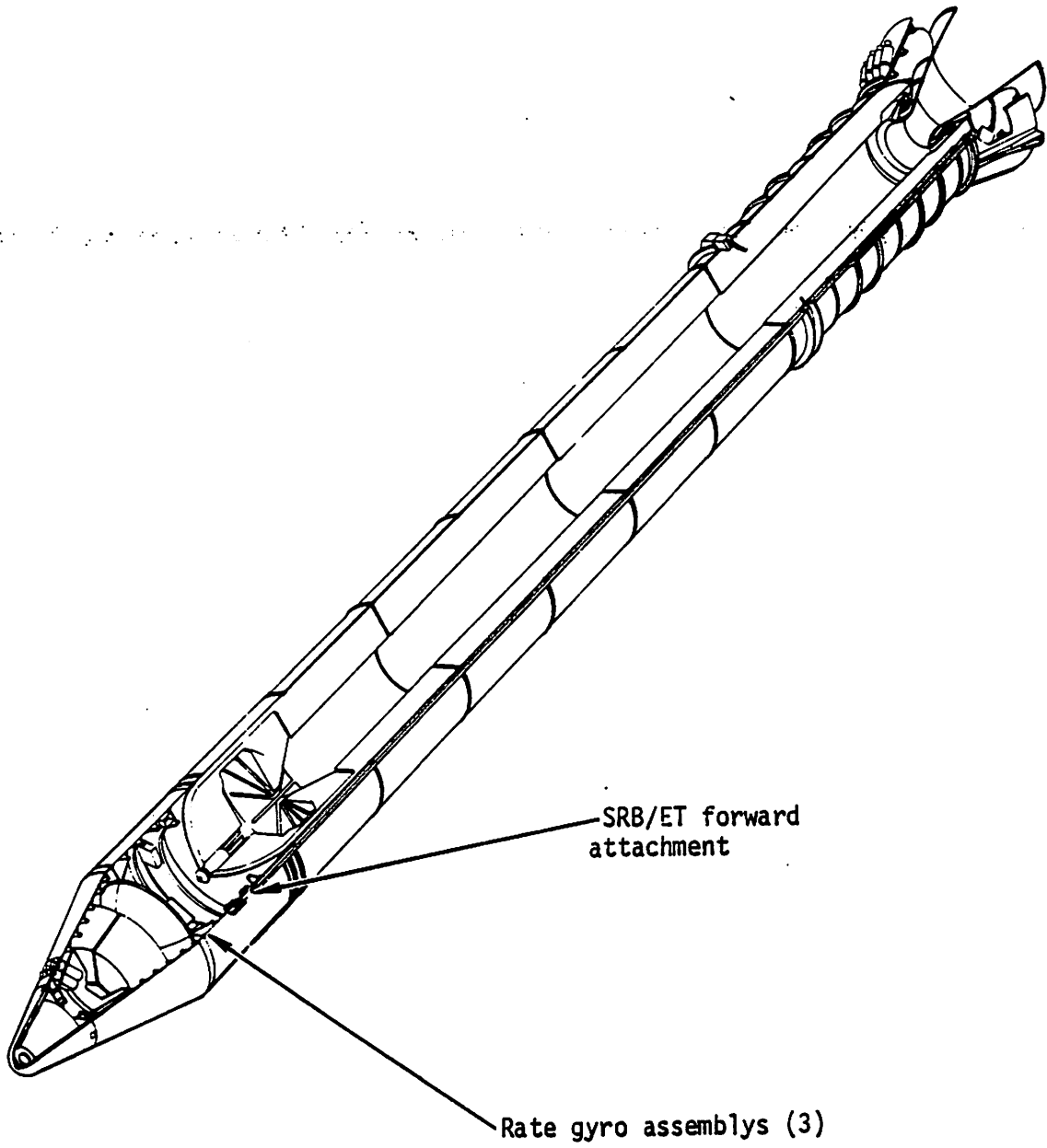
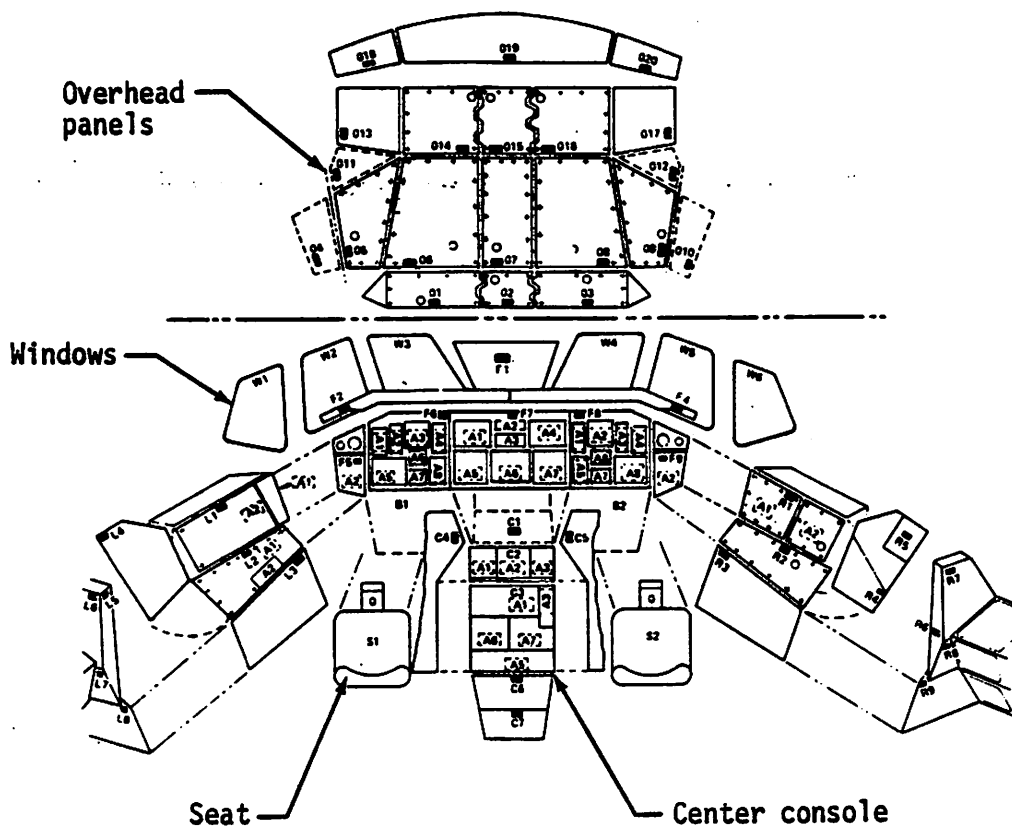
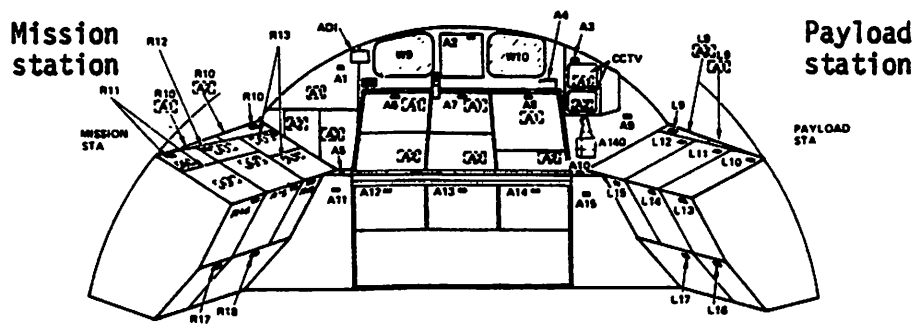


Figure A-1.- The SRB RGA location.

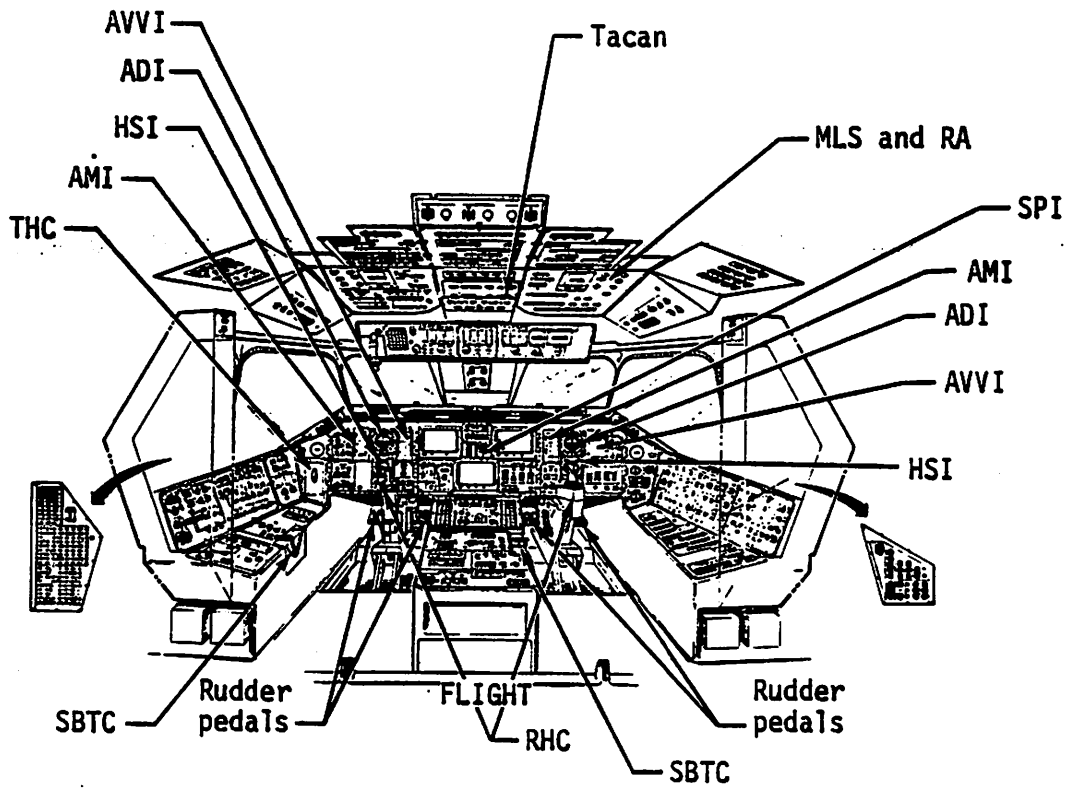


(a) Forward flight deck.

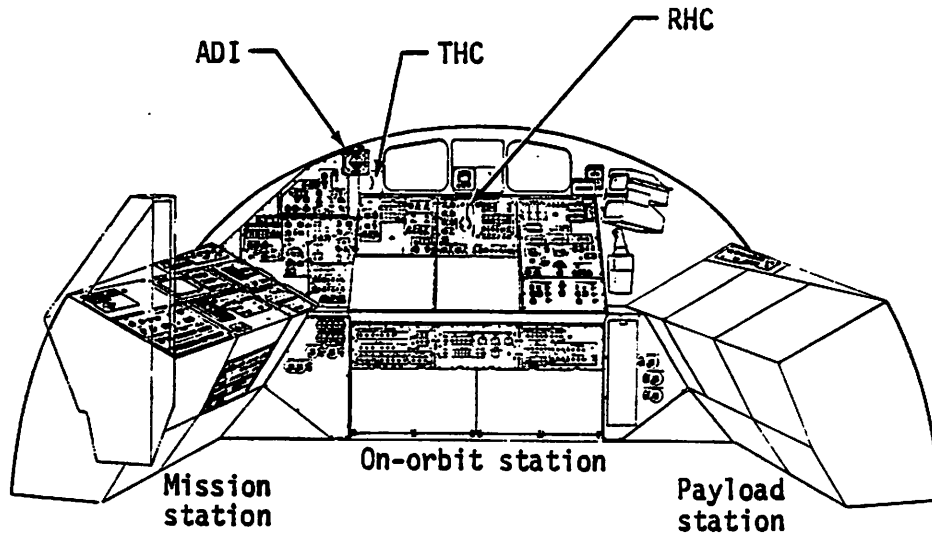


(b) Aft flight deck.

Figure A-2.- Flight deck location codes.



(a) Forward flight deck



(b) Aft flight deck

Figure A-3.- Flight deck GNC displays and controls.

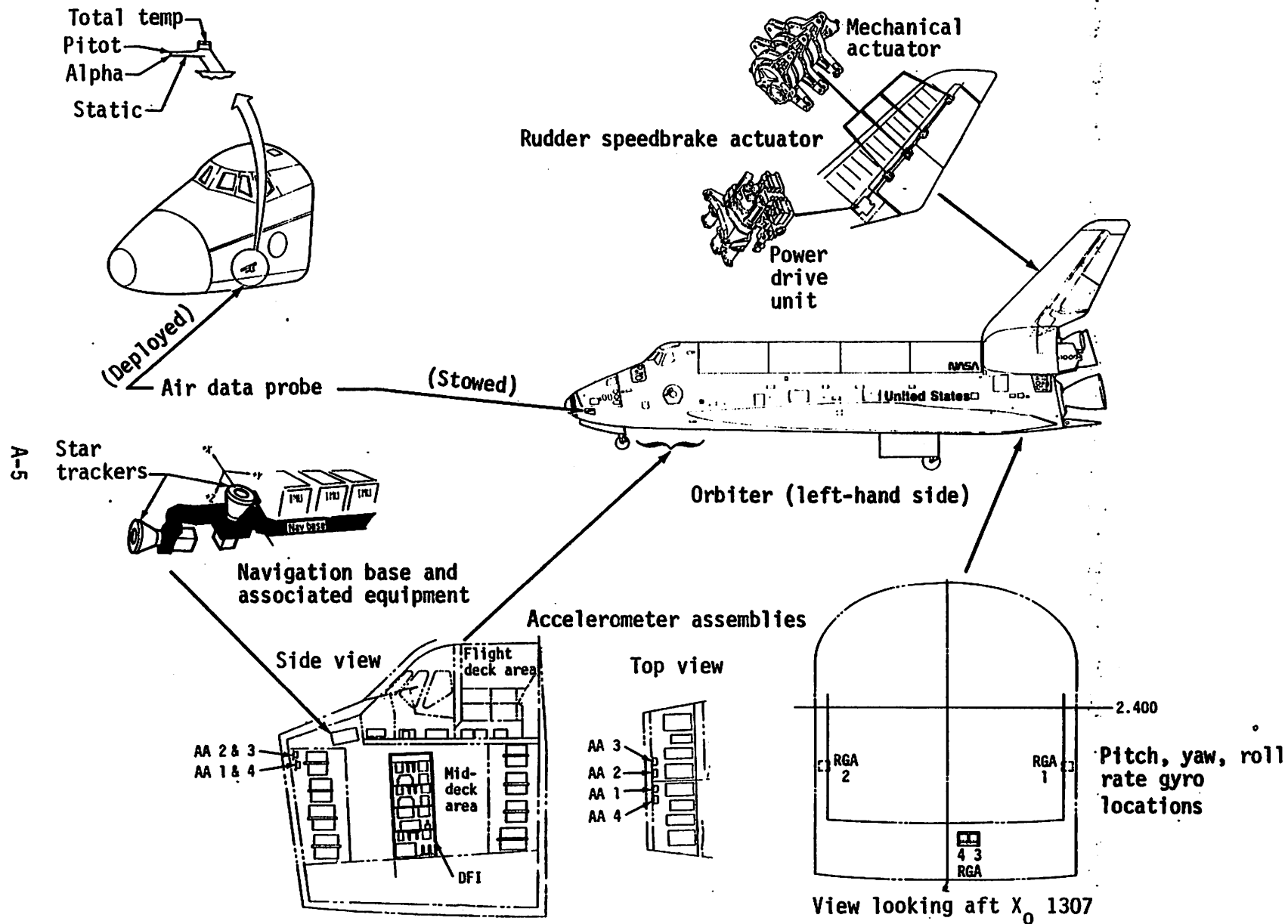


Figure A-4.- The GNC hardware locations.

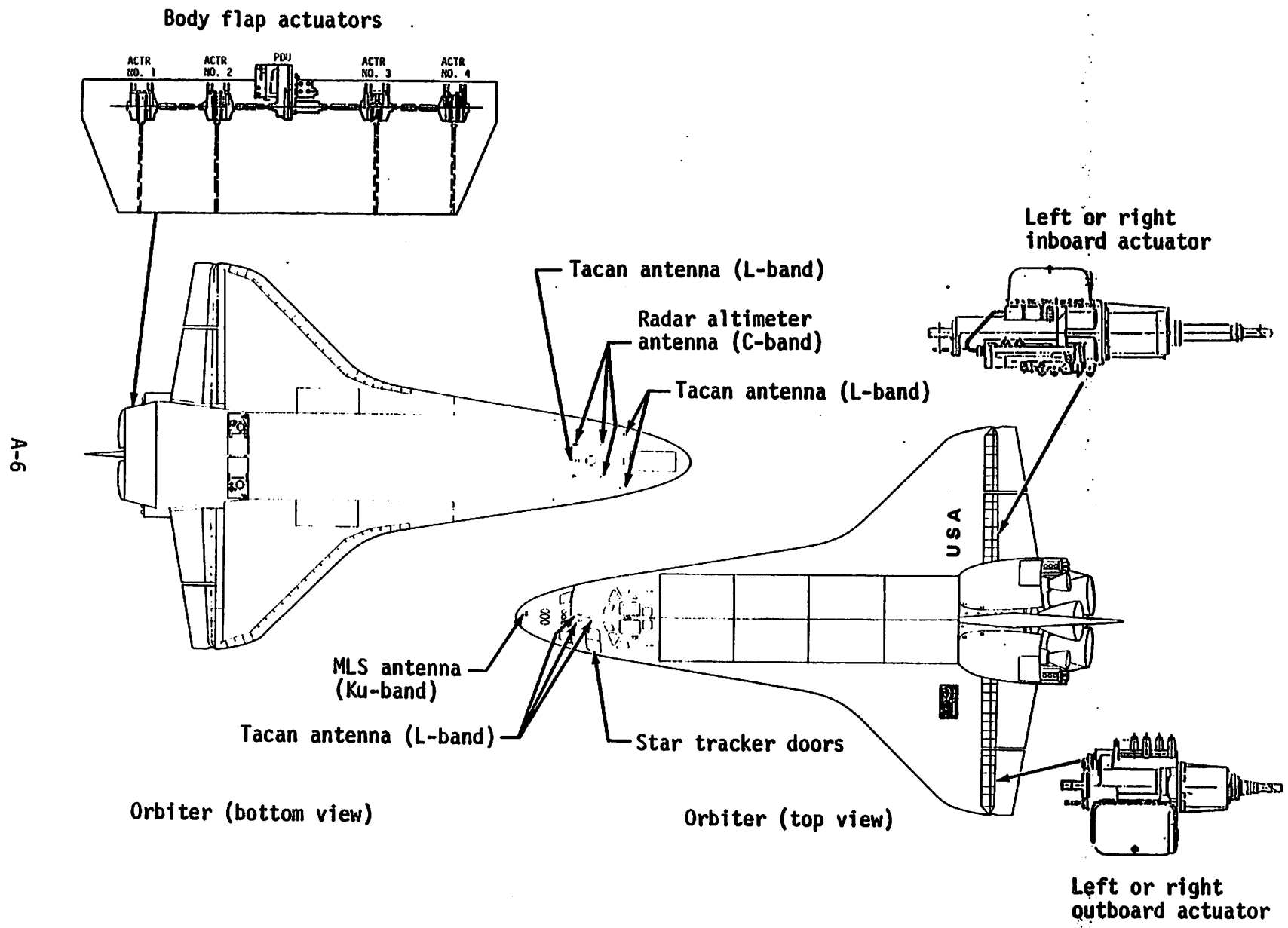


Figure A-5.- The GNC hardware locations.

A-7

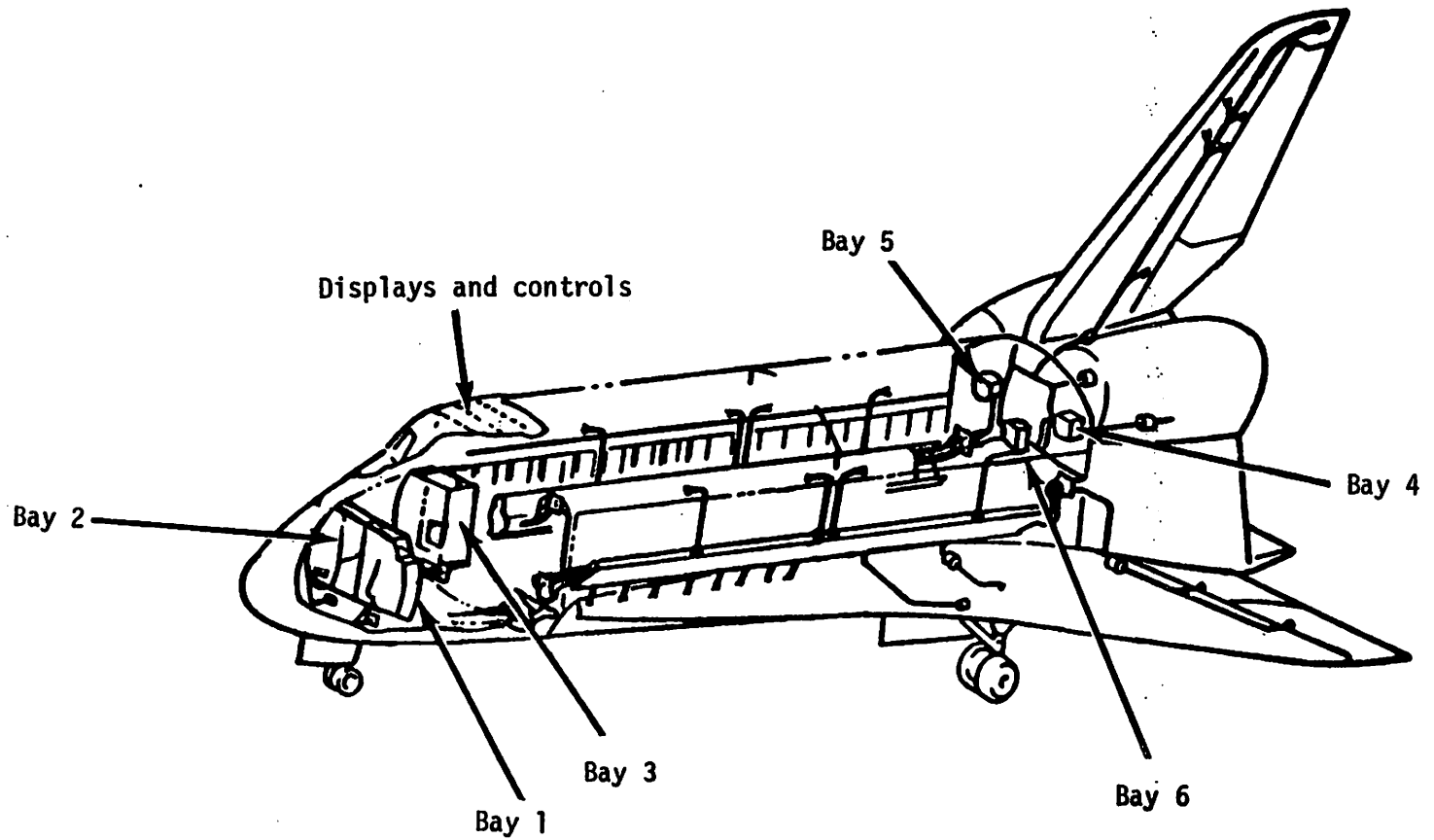


Figure A-6.- Orbiter avionics bays.

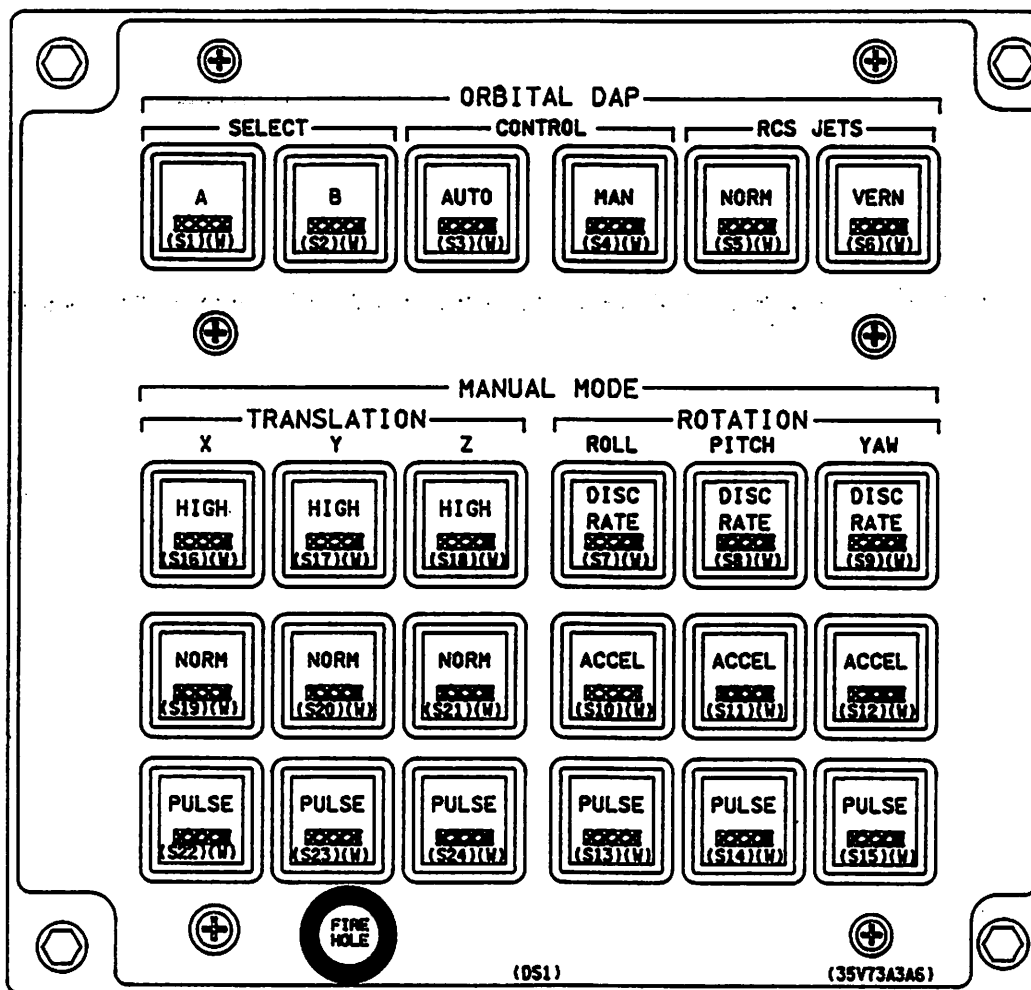


Figure B-1.- ORBITAL DAP and MANUAL MODE controllers.

APPENDIX B
GNC CONTROLS/DISPLAYS POWER/DATA TABLE



TABLE B-1.- CONTROLLERS

Control/display	Panel	Function		Contacts	MDM	Signal power	Circuit breaker			AND RBUES		Light	
							Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
MANUAL MODE ROTATION PITCH ACCEL (fig. B-1)	C3	Causes pitch thruster to fire while RHC is out of detent.	Forward	1 2 19	FF3 FF4 FF3	CA2 BC2					5		
	A6		Aft	1 2 20	FF1 FF2 FF1	AB3 BC3					1		
MANUAL MODE ROTATION PITCH DISC RATE (fig. B-1)	C3	Causes pitch thrusters to fire to attain a predetermined rotation rate while RHC is out of detent.	Forward	1 2 11	FF3 FF4 FF3	CA2 BC2					5		
	A6		Aft	1 2 12	FF1 FF2 FF1	AB3 BC3					1		
MANUAL MODE ROTATION PITCH PULSE (fig. B-1)	C3	Causes roll thrusters to fire for a preset increment when the RHC is deflected.	Forward	1 2 27	FF3 FF4 FF3	CA2 BC2					5		
	A6		Aft	1 2 28	FF1 FF2 FF1	AB3 BC3					1		
MANUAL MODE ROTATION ROLL ACCEL (fig. B-1)	C3	Causes roll thrusters to fire while RHC is out of detent.	Forward	1 2 17	FF3 FF4 FF3	CA2 BC2					5		
	A6		Aft	1 2 18	FF1 FF2 FF1	AB3 BC3					1		
MANUAL MODE ROTATION ROLL DISC RATE (fig. B-1)	C3	Causes roll thrusters to fire to attain a predetermined rotation rate while RHC is out of detent.	Forward	1 2 9	FF3 FF4 FF3	CA2 BC2					5		
	A6		Aft	1 2 10	FF1 FF2 FF1	AB3 BC3					1		

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TABLE B-I.- CONTROLLERS - Continued

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
MANUAL MODE ROTATION ROLL PULSE (fig. B-1)	C3	Causes roll thrusters to fire for a preset increment when the RHC is deflected.	Forward	1	FF3	CA2					5	
			2	FF4	BC2							
	A6	Aft	25	FF3								
			1	FF1	AB3						1	
			2	FF2	BC3							
			26	FF1								
MANUAL MODE ROTATION YAW ACCEL (fig. B-1)	C3	Causes yaw thrusters to fire while RHC is out of detent.	Forward	1	FF3	CA2					5	
			2	FF4	BC2							
	A6	Aft	21	FF3								
			1	FF1	AB3						1	
			2	FF2	BC3							
			22	FF1								
MANUAL MODE ROTATION YAW DISC RATE (fig. B-1)	C3	Causes yaw thrusters to fire to attain a predetermined rotation rate while RHC is out of detent.	Forward	1	FF3	CA2					5	
			2	FF4	BC2							
	A6	Aft	13	FF3								
			1	FF1	AB3						1	
			2	FF2	BC3							
			14	FF1								
MANUAL MODE ROTATION YAW PULSE (fig. B-1)	C3	Causes yaw thrusters to fire for a preset increment when the RHC is deflected.	Forward	1	FF3	CA2					5	
			2	FF4	BC2							
	A6	Aft	29	FF3								
			1	FF1	AB3						1	
			2	FF2	BC3							
			30	FF1								
MANUAL MODE TRANSLATION LVLH (fig. B-1)	C3	Modes the DAP to an LVLH attitude hold.	Forward	1	FF3	CA2					4	
			2	FF4	BC2							
	A6	Aft	9	FF3								
			1	FF1	AB3						3	
			2	FF2	BC3							
			10	FF1								

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TABLE B-I.- CONTROLLERS - Continued

Control/display	Panel	Function		Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
							Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
MANUAL MODE TRANSLATION X NORM (fig. B-1)	C3	Enables the X primary thrusters to be fired as long as the THC is held out of detent.	Forward	1 2 17	FF3 FF4 FF3	CA2 AC2						4	
	A6		Aft	1 2 18	FF1 FF2 FF1	AB3 BC3						3	
MANUAL MODE TRANSLATION X PULSE (fig. B-1)	C3	Enables the X primary thrusters to be fired for a preset increment for each deflection of the THC.	Forward	1 2 25	FF3 FF4 FF3	CA2 BC2						4	
	A6		Aft	1 2 26	FF1 FF2 FF1	AB3 BC3						3	
MANUAL MODE TRANSLATION Y NORM (fig. B-1)	C3	Enables the Y primary thrusters to be fired as long as the THC is held out of detent.	Forward	1 2 19	FF3 FF4 FF3	CA2 BC2						4	
	A6		Aft	1 2 20	FF1 FF2 FF1	AB3 BC3						3	
MANUAL MODE TRANSLATION Y PULSE (fig. B-1)	C3	Enables the Y primary thrusters to be fired for a preset increment for each deflection of the THC.	Forward	1 2 27	FF3 FF4 FF3	CA2 BC2						4	
	A6		Aft	1 2 28	FF1 FF2 FF1	AB3 BC3						3	
MANUAL MODE TRANSLATION Z HIGH (fig. B-1)	C3	Causes both primary and backup Z thrusters to be fired as long as the THC is held out of detent.	Forward	1 2 13	FF3 FF4 FF3	CA2 BC2						4	
	A6		Aft	1 2 14	FF1 FF2 FF1	AB3 BC3						3	

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TABLE B-I.- CONTROLLERS - Continued

Control/display	Panel	Function		Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
							Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
MANUAL MODE TRANSLATION Z LOW (fig. B-1)	C3	Enables the X thrusters to be fired for +Z maneuvers.	Forward	1	FF3	CA2							
				2	FF4	BC2							
	Aft		11	FF3							4		
			1	FF1	AB3								
A6	2	FF2	BC3										
	12	FF1										3	
MANUAL MODE TRANSLATION Z NORM (fig. B-1)	C3	Enables the Z primary thrusters to be fired as long as the THC is held out of detent.	Forward	1	FF3	CA2							
				2	FF4	BC2							
	Aft		21	FF3									4
			1	FF1	AB3								
A6	2	FF2	BC3										
	22	FF1										3	
MANUAL MODE TRANSLATION Z PULSE (fig. B-1)	C3	Enables the Z primary thrusters to be fired for a preset increment for each deflection of the THC.	Forward	1	FF3	CA2							
				2	FF4	BC2							
	Aft		29	FF3									4
			1	FF1	AB3								
A6	2	FF2	BC3										
	30	FF1										3	
ORBITER DAP CONTROL AUTO (fig. B-1)	C3	Modes the DAP to an automatic mode.	Forward	1	FF3	CA2							
				2	FF4	BC2							
				3	FF1	AB2							
	Aft		5	FF3									4
			1	FF1	AB3								
			2	FF2	BC3								
A6	3	FF3	CA3										
	6	FF1										3	
ORBITER DAP CONTROL MAN (fig. B-1)	C3	Modes the DAP to a manual mode.	Forward	1	FF3	CA2							
				2	FF4	BC2							
				3	FF1	AB2							
	Aft		1	FF3									5
			1	FF1	AB3								
			2	FF2	BC3								
A6	3	FF3	CA3										
	2	FF1										1	

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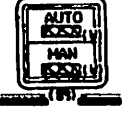


6-GNC

TABLE B-1.- CONTROLLERS - Continued

Control/display	Panel	Function		Contacts	MDM	Signal power	Circuit breaker			RPC		Light			
							Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM		
ORBITER DAP RCS JET NORM (fig. B-1)	C3	Enables the primary RCS jets for rotation and translation firings, and disables the vernier jets.	Forward	1	FF3	CA2									
				2	FF4	BC2									
				3	FF1	AB2									
	A6		Aft	3	FF3						5				
				1	FF1	AB3									
				2	FF2	BC3									
	ORBITER DAP RCS JET VERN (fig. B-1)		C3	Enables the vernier RCS jets for rotational RCS firing and disables the primary jets.	Forward	3	FF1	AB2							
						5	FF3								
1		FF1				AB3									
A6		Aft	2		FF2	BC3									
			3		FF3	CA3									
			6		FF1							1			
ORBITER DAP SELECT A (fig. B-1)		C3	Implements DAP load A settings for the on-orbit gains.		Forward	1	FF3	CA2							
						2	FF4	BC2							
	3			FF1		AB2									
	A6	Aft		1	FF3										
				1	FF1	AB3									
				2	FF2	BC3									
	ORBITER DAP SELECT B (fig. B-1)	C3		Implements DAP load B settings for the on-orbit gains.	Forward	3	FF1	AB2							
						3	FF3								
1			FF1												
A6		Aft	1		FF1	AB3									
			2		FF2	BC3									
			3		FF3	CA3									
					4	FF1									

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TABLE B-I.- CONTROLLERS - Continued





Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
AFT SENSE 	A6	Modes the aft RHC, THC, and ADI to correspond to the operator's viewing direction.	A B C		FF1 FF2 FF3	AB2 CA2 BC2						
BODY FLAP (PBI) BODY FLAP 	F2	Provides an indication to change the body flap control from manual to auto or from auto to manual.	Left	1	FF1	AB1 BC1 CA1					1	
	F4			2 3 11	FF2 FF3 FF1					1		
			Right	1	FF2	BC2 CA2 BC3						
				2 3 30 34	FF3 FF4 FF3 FF4							2 2
FLT CNTLR POWER Left 	F6	Supplies power to left RHC, SBTC, RPTA, and THC.		1 2 3	FF1 FF1 FF1	MNA MNB						
FLT CNTLR POWER Right 	F8	Supplies power to right RHC, SBTC, RPTA.		1 2 3	FF2 FF2 FF2	MNB MNC						

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TABLE B-I.- CONTROLLERS - Continued

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
FLT CNTLR POWER Aft 	A6	Supplies power to aft RHC and THC.	1 2 3	FF3 FF3 FF3	MNA MNC							
PITCH AUTO 	F2	During ascent, modes flight control to auto in all axes.	Left 1 2 3 13	FF1 FF2 FF3 FF1	AB1 BC1 CA1						1	
	F4	During entry, modes flight control to auto in pitch axis.	Right 1 2 3 14	FF2 FF3 FF4 FF3	BC2 CA2 BC3						2	
PITCH CSS 	F2	During ascent, modes flight control to augmented manual in all axes.	Left 1 2 3 15	FF1 FF2 FF3 FF2	AB1 BC1 CA1						1	
	F4	During entry, modes flight control to augmented manual in pitch axis.	Right 1 2 3 16	FF2 FF3 FF4 FF4	BC2 CA2 BC3						2	
PITCH GAIN ENA 	F2	Enables DAP gain switches to charge rate gains for pitch in the DAP's.	Left 1 2 3 17	FF1 FF2 FF3 FF1	AB1 BC1 CA1						1	
	F4		Right 1 2 3 18	FF2 FF3 FF4 FF3	BC2 CA2 BC3						2	




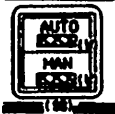
B-9

TABLE B-1.- CONTROLLERS - Continued

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
PITCH TRIM 	L2	Commands an aerodynamic surface deflection rate for pitch.	Left	1	FF1	AB1	BC1					
				2	FF2							
C3	Right		1	FF3	CA2	BC2						
			2	FF4								
RHC		Left	Roll	A	FF1							
				B	FF2							
				C	FF3							
			Pitch	A	FF1							
				B	FF2							
				C	FF3							
			Yaw	A	FF1							
				B	FF2							
				C	FF3							
RHC		Right	Roll	A	FF1							
				B	FF2							
				C	FF3							
			Pitch	A	FF1							
				B	FF2							
				C	FF3							
			Yaw	A	FF1							
				B	FF2							
				C	FF3							
RHC		Aft	Roll	A	FF2							
				B	FF3							
				C	FF4							
			Pitch	A	FF2							
				B	FF3							
				C	FF4							
			Yaw	A	FF2							
				B	FF3							
				C	FF4							
ROLL TRIM 	L2	Commands an aerodynamic surface deflection rate for roll.	Left	1	FF1	AB1	BC1					
				2	FF2							
	C3		Right	1	FF3	CA2	BC2					
				2	FF4							

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TABLE B-1.- CONTROLLERS - Continued

Control/display	Panel	Function		Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
							Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
ROLL/YAW AUTO 	F2	During ascent, modes flight control to auto in all axes.	Left	1	FF1	AB1							
					2	FF2	BC1						
				3	FF3	CA1							
				19	FF1							1	
	F4	During entry, modes flight control to auto in roll/yaw axes.	Right	1	FF2	BC2							
					2	FF3	CA2						
				3	FF4	BC3							
				20	FF3							2	
ROLL/YAW CSS 	F2	During ascent, modes flight control to augmented manual in all axes.	Left	1	FF1	AB1							
					2	FF2	BC1						
				3	FF3	CA1							
				21	FF2							1	
	F4	During entry, modes flight control to augmented manual in roll/yaw axes.	Right	1	FF2	BC2							
					2	FF3	CA2						
				3	FF4	BC3							
				22	FF4							2	
ROLL/YAW GAIN ENA 	F2	Enables DAP gain switches to change rate gains for roll/yaw in the DAP's.	Left	1	FF1	AB1							
					2	FF2	BC1						
				3	FF3	CA1							
				23	FF1							1	
	F4		Right	1	FF2	BC2							
					2	FF3	CA2						
				3	FF4	BC3							
				24	FF3							2	
SPD BK/THROT (PBI) SPD BK/ THROT 	F2	Provides an indication to place the speedbrake or throttling function under software control.	Left	1	FF1	AB1							
					2	FF2	BC1						
				3	FF3	CA2							
				25	FF1							1	
				27	FF2							1	
	F4		Right	1	FF2	BC2							
					2	FF3	CA2						
				3	FF4	BC3							
				26	FF2							2	
				28	FF3							2	

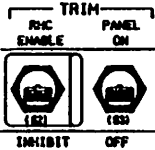
B-11

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TABLE B-I.- CONTROLLERS - Continued

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light		
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY	MDM
THC		Forward	+X	A	FF1								
				B	FF2								
				C	FF3								
			-X	A	FF1								
				B	FF2								
				C	FF1								
		+Y	A	FF1									
			B	FF2									
			C	FF3									
		-Y	A	FF1									
			B	FF2									
			C	FF3									
+Z	A	FF1											
	B	FF2											
	C	FF3											
-Z	A	FF1											
	B	FF2											
	C	FF3											
THC		Aft	+X	A	FF1								
				B	FF2								
				C	FF3								
			-X	A	FF1								
				B	FF2								
				C	FF1								
		+Y	A	FF1									
			B	FF2									
			C	FF3									
		-Y	A	FF1									
			B	FF2									
			C	FF3									
+Z	A	FF1											
	B	FF2											
	C	FF3											
-Z	A	FF1											
	B	FF2											
	C	FF3											
TRIM RHC ENABLE/INHIBIT	F6 F8	Enables the associated RHC trim switch to be active.	Left	1	FF1								
				2	FF2								
			Right	1	FF3								AB1 BC1
				2	FF4								CA2 BC2

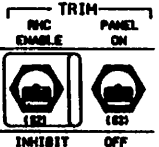



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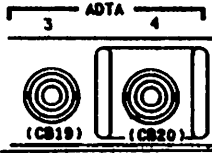
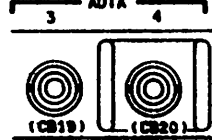
6-GNC

TABLE B-I.- CONTROLLERS - Concluded

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
TRIM PANEL 	F6	Provides power to the associated roll, pitch, and yaw panel trim switches when in the ON position.	Left	1	FF1	AB1						
				2	FF2	BC1						
F8	Right		1	FF3	CA2							
			2	FF4	BC2							
TRIM RHC		Commands a constant vehicle rate about the body pitch and roll axis.	Left	1	FF1	MNA						
			2	FF2	MNB							
	Right		1	FF3	MNB							
			2	FF4	MNC							
YAW TRIM 	L2	Commands an aero-surface rate for yaw.	Left	1	FF1	AB1						
				2	FF2	BC1						
C3	Right		1	FF3	CA2							
			2	FF4	BC2							

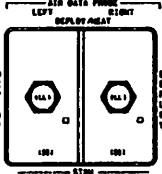
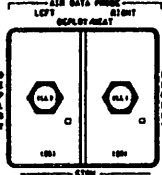
B-13

TABLE B-II.- AIR DATA

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC			Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY	MDM
AIR DATA 1 ADTA 1 	014	Applies power to ADTA 1.		FF1	MNA 014	ADTA 1	014	5					
AIR DATA 2 ADTA 2 	015	Applies power to ADTA 2.		FF2	IMNB 015	ADTA 2	015	5					
AIR DATA 3 ADTA 3 4 	016	Applies power to ADTA 3.		FF3	IMNC 016	ADTA 3	016	5					
AIR DATA 4 ADTA 3 4 	017	Applies power to ADTA 4.		FF4	IMNC 016	ADTA 4	016	5					

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TABLE B-II.- AIR DATA - Continued

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light		
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM	
AIR DATA PROBE LEFT 	C3	o Closes one set of heater relays in FPCA 1 and closes one set of deploy relays in FMCA 1.	Deploy/heat		AB1								
		o Closes one set of deploy relays in FMCA 1.	Deploy		AB1								
		o Closes one set of stow relays in FMCA 1.	Stow		AB1								
		o Provides power to heaters and closes one set of deploy relays in FMCA 1.	Deploy/heat	MDM OF4	AB2								
		o Closes one set of deploy relays in FMCA 1.	Deploy		AB2								
		o Closes one set of stow relays in FMCA 1.	Stow		AB2								
		o Closes one set of heater relays in FPCA 2 and closes one set of deploy relays in FMCA 2.	Deploy/heat		BC2								
		o Closes one set of deploy relays in FMCA 2.	Deploy		BC2								
		o Closes one set of stow relays in FMCA 2.	Stow	MDM OF4	BC2								
		o Provides power to heaters and closes one set of deploy relays in FMCA 2.	Deploy/heat		BC1								
		o Closes one set of deploy relays in FMCA 2.	Deploy		BC1								
		o Closes one set of stow relays in FMCA 2.	Stow		BC1								
AIR DATA PROBE RIGHT 	C3	o Closes one set of heater relays in FPCA 3 and closes one set of deploy relays in FMCA 3.	Deploy/heat		CA1								
		o Closes one set of deploy relays in FMCA 3.	Deploy		CA1								
		o Closes one set of stow relays in FMCA 3.	Stow		CA1								

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
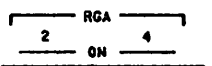

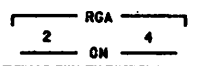
6-GNC

TABLE B-II.- AIR DATA - Concluded

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
		<ul style="list-style-type: none"> o Provides power to heaters and closes one set of deploy relays in FMCA 3. o Closes one set of deploy relays in FMCA 3. o Closes one set of stow relays in FMCA 3. o Closes one set of heater relays in FPCA 2 and closes one set of deploy relays in FMCA 2. o Closes one set of deploy relays in FMCA 2. 	<ul style="list-style-type: none"> Deploy/heat Deploy Stow Deploy/heat Deploy 	MDM OF4	<ul style="list-style-type: none"> CA2 CA2 CA2 BC1 BC1 							
		<ul style="list-style-type: none"> o Closes one set of stow relays in FMCA 2. o Provides power to heaters and closes one set of deploy relays in FMCA 1. o Closes one set of deploy relays in FMCA 2. o Closes one set of stow relays in FMCA 2. 	<ul style="list-style-type: none"> Stow Deploy/heat Deploy Stow 		<ul style="list-style-type: none"> BC1 BC2 BC2 BC2 							




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TABLE B-III.- RATE GYRO ASSEMBLIES

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
RGA 1  (S2) OFF	014	Applies power to RGA 1.	1	FA1	CNTL AB1				MNA APC 1	3		
			2	FA1	CNTL AB2				MNB APC 2	3		
RGA 2  (S2) (S13) OFF	015	Applies power to RGA 2.	1	FA2	CNTL BC1				MNB APC 5	3		
RGA 3  (S2) OFF	016	Applies power to RGA 3.	1	FA3	CNTL CA1				MNB APC 5	3		
RGA 4  (S2) (S13) OFF	015	Applies power to RGA 4.	1	FA4	CNTL CA1				MNA MPC 1	3		
			2	FA4	CNTL CA3				MNC MPC 3	3		

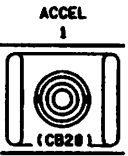
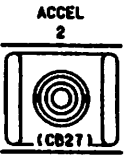


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TABLE B-IV.- IMU

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
IMU 1 	014	Applies power to IMU 1.	1	FF1	CNTL AB1				MNA FPC 1	10		
			2	FF1	CNTL AB2				MNB FPC 2	10		
IMU 2 	015	Applies power to IMU 2.	1	FF2	CNTL BC1				MNC FPC 3	10		
			2	FF2	CNTL BC2				MNB FPC 2	10		
IMU 3 	016	Applies power to IMU 3.	1	FF3	CNTL CA2				MNA FPC 1	10		
			2	FF3	CNTL CA3				MNC FPC 3	10		

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TABLE B-V.- ACCELEROMETER ASSEMBLIES

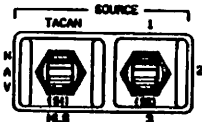
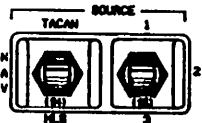
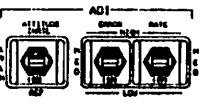
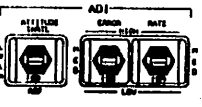
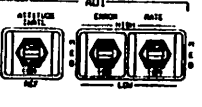
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
ACCEL 1 	014	Applies power to AA 1.	1			Accel 1	014	3				
ACCEL 2 	015	Applies power to AA 2.	1			Accel 2	015	3				
ACCEL 3 	016	Applies power to AA 3.	1	FF3	CNTL CA2				MNA FPC 1	3		
			2	FF3	CNTL CA3			MNC FPC 3	3			
ACCEL 4 	015	Applies power to AA 4.	1	FF4	CNTL BC1				MNB FPC 2	3		
			2	FF4	CNTL BC3			MNC FPC 3	3			

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TABLE B-VI.- DEDICATED DISPLAY


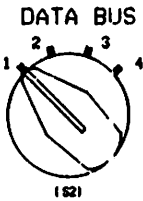
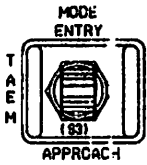
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
HSI SELECT SOURCE 	F6	Determine type of data driving HSI (TACAN/NAV/MLS).	Left	1	FF1	AB2						
	F8			2								
3												
Right	1		FF2	BC2								
	2											
	3											
HSI SELECT SOURCE 	F6	Determine type of data driving HSI (1,2,3).	Left	1	FF1	AB2						
	F8			2								
3												
Right	1		FF2	BC2								
	2											
	3											
ADI ATTITUDE 	F6	Selects attitude reference system for ADI display (INRTL/LVLH/REF).	Left	1	FF1	AB2						
	F8			2								
				3								
	Right		1	FF2	BC2							
			2									
			3									
Aft	1	FF3	CA2									
	2											
	3											
ADI ERROR 	F6	Selects desired scaling for ADI error needles display (HIGH/MED/LOW).	Left	1	FF1	AB2						
	F8			2								
				3								
	Right		1	FF2	BC2							
			2									
			3									
Aft	1	FF3	CA2									
	2											
	3											
ADI RATE 	F6	Selects desired scaling for ADI rate needles displays (HIGH/MED/LOW).	Left	1	FF1	AB2						
	F8			2								
				3								
	Right		1	FF2	BC2							
			2									
			3									
Aft	1	FF3	CA2									
	2											
	3											

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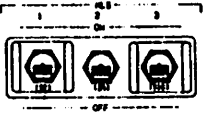
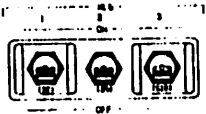
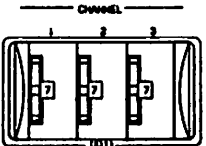
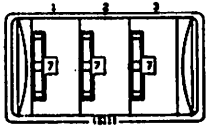
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TABLE B-VI.- DEDICATED DISPLAY - Concluded

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
ATT REF 	F6	Engages attitude reference for ADI.	Left	1	FF1	AB1						
				2								
	F8		Right	1	FF2	BC1						
				2	FF2	BC2						
	A6		Aft	1	FF3	CA1						
				2	FF3	CA2						
DATA BUS 	F6	Selects the data bus that will provide data to the DDU (1/2/3/4).	DDU 1	1		!MNBO15E	DDU left	015E	7.5			
				1			!MNA014E	DDU left	014E			
	F8		DDU 2	1	!MNCO16E	DDU right	016E	7.5				
		1	!MNBO15E	DDU right	015E	7.5						
	A6	DDU 3	1	!MNA014E	DDU aft	014E	7.5					
			1	!MNCO16E	DDU aft	016E	7.5					
HSI SELECT MJDE 	F6	Determines the phase for which HSI data represents (ENTRY/TAEM/APPROACH).	Left	2	FF1	AB2						
				3								
	F8	Right	2	FF2	BC2							
				3								

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TABLE B-VII.- MLS

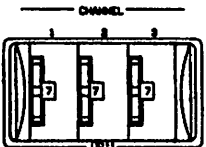
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
MLS 1 	08	ON Applies power to MLS 1. OFF Removes power from MLS 1. ON MLS 1 power on. OFF	1 2 3 4	FF1	VMNA 014 ESS1BC	MLS 1	014	5				
MLS 2 	08	ON Applies power to MLS 2. OFF Removes power from MLS 2. ON MLS 2 Power on. OFF	1 2 3 4	FF2	VMNB 015 ESS2CA	MLS 2	015	5				
MLS 3 	08	ON Applies power to MLS 3. OFF Removes power from MLS 3. ON MLS 3 power on. OFF	1 2 3 4	FF3	VMNC 016 ESS3AB	MLS 3	016	5				
MLS 1 CHANNEL SELECT 	08	Selects channel 0-9 for MLS 1.		FF1	GND							
MLS 2 CHANNEL SELECT 	08	Selects channel 0-9 for MLS 2.		FF2	GND							

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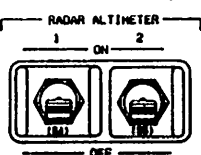
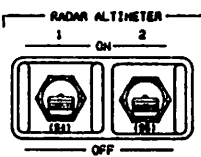
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TABLE B-VII.- MLS - Concluded

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
MLS 3 CHANNEL SELECT 	08	Selects channel 0-9 for MLS 3.		FF3	GND							

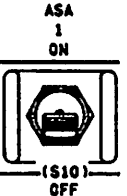

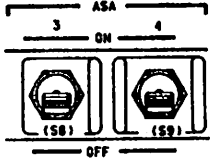
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TABLE B-VIII.- RADAR ALTIMETER

Component	Code	Position	Description	Priority	Failure Mode	Component	Code	Priority	Other	
RADAR ALTIMETER 1 	08	ON	Applies power to RA 1.	1	VMNAR4	Radar altimeter 1	014	3		
		OFF	Removes power from RA 1.	2						
		ON	Applies power to "RA 1 ON."	3	FF1					ESS1BC
		OFF	Removes power from "RA 1 ON."	4						
RADAR ALTIMETER 2 	08	ON	Applies power to RA 2.	1	VMNBR4	Radar altimeter 2	015	3		
		OFF	Removes power from RA 2.	2						
		ON	Applies power to "RA 2 ON."	3	FF2					ESS2CA
		OFF	Removes power from "RA 2 ON."	4						

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TABLE B-IX.- AEROSURFACE SERVOAMPLIFIER/ACTUATORS

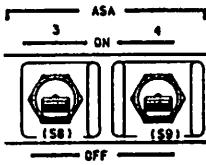
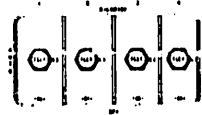
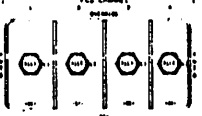
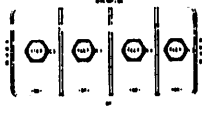
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL. PWR	Amps	ANNUN ASSY	MDM
ASA 1 	014	Applies power to ASA 1 power supply.	2		IFCSCH 1 (2) BC1				MNBAPC5	5		
		Applies power to ASA 1 power supply ASA 1 isolation valve drivers.	1		IFCSCH 1 (1) AB1				MNAAPC4	10		
		Applies power to ASA 1 isolation valve drivers.	3		ICNTLCA1				MNCAPC6	5		
ASA 2 	015	Applies power to ASA 2 power supply and ASA 2 isolation valve drivers.	3		IFCSCH2 (3) CA3				MNCAPC6	5		
		Applies power to ASA 2 power supply.	2		IFCSCH2 (2) BC2				MNBAPC5	10		
		Applies power to ASA 2 isolation valve driver.	1		ICNTLAB2				MNAAPC4	5		
ASA 3 	016	Applies power to ASA 3 power supply.	1		IFCSCH3 (1) AB2				MNAAPC4	5		
		Applies power to ASA 3 power supply and ASA 3 isolation valve drivers.	3		IFCSCH3 (3) CA1				MNCAPC6	10		
		Applies power to ASA 3 isolation valve drivers.	2		ICNTLBC3				MNBAPC5	5		

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TABLE B-IX.- AEROSURFACE SERVOAMPLIFIER/ACTUATORS - Continued

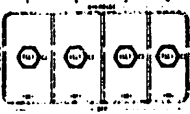
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light		
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM	
ASA 4 	016	Applies power to ASA 4 power supply.	1		FCSCH4 (1) AB3				MNAAPC1	5			
		Applies power to ASA 4 power supply.	3		CNTLBC2				MNBAPC2	5			
		Applies power to ASA 4 isolation valve driver.	2		FSC4 (3) CA2				MNCAPC3	5			
FCS CHANNEL 1 	C3	Override	1	FF1	AB1								
			2	FF2	BC1								
			3	FF3	CA2								
		Auto	1	FF1	AB1								
			2	FF2	BC1								
			3	FF3	CA2								
		Off	1	FF1	AB1								
			2	FF2	BC1								
			3	FF3	CA2								
FCS CHANNEL 2 	C3	Override	1	FF4	BC3								
			2	FF2	BC2								
			3	FF3	CA3								
		Auto	1	FF4	BC3								
			2	FF2	BC2								
			3	FF3	CA3								
		Off	1	FF4	BC3								
			2	FF2	BC2								
			3	FF3	CA3								
FCS CHANNEL 3 	C3	Override	1	FF1	AB2								
			2	FF2	BC1								
			3	FF4	CA1								
		Auto	1	FF1	AB2								
			2	FF2	BC1								
			3	FF4	CA1								
		Off	1	FF1	AB2								
			2	FF2	BC1								
			3	FF4	CA1								

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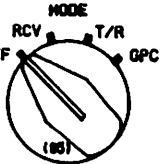
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TABLE B-IX.- AEROSURFACE SERVOAMPLIFIER/ACTUATORS - Concluded

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light		
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM	
FCS CHANNEL 4 	C3	Override	1	FF4	AB3								
			2	FF1	AB2								
			3	FF3	CA2								
		Auto	1	FF4	AB3								
			2	FF1	AB2								
			3	FF3	CA2								
		Off	1	FF4	AB3								
			2	FF1	AB2								
			3	FF3	CA2								

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TABLE B-X.- TACAN

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
		Wafer D <ul style="list-style-type: none"> o Indicates not selected. o Indicates GPC selected. o GPC functional control (to MDM). 	1-3D 4D C-D	FF2 FF2 FF2	GND +5 V							
		Wafer E <ul style="list-style-type: none"> o Indicates not selected. o Indicates T/R selected. o T/R functional control (to MDM). 	1,2,4E 3E C-E	FF2 FF2 FF2	GND +5 V							
TACAN 3 MODE 	07	Selects operational mode for tacan 3. Wafer A <ul style="list-style-type: none"> o Off position. o Power on signal. o Tacan 3. o Signal ground to common. 	1A 2-4A C-A	FF3	AC bus 3-C GND	Tacan 3	L4	3				
		Wafer B <ul style="list-style-type: none"> o Not used. o Tacan 3 GPC selected. o Applies bus power to 4B. 	1-3B 4B C-B	FF3	ESS1BC							
		Wafer C <ul style="list-style-type: none"> o Not used. o Power on. o Applies bus power. 	1C 2-4C C-C	OF4/ LF1	ESS1BC							

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TABLE B-X.- TACAN - Continued

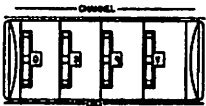
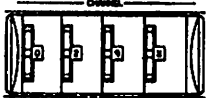
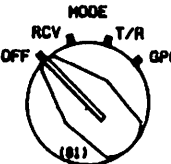
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
		Wafer D <ul style="list-style-type: none"> o Indicates not selected. o Indicates GPC selected. o GPC functional control (to MDM). 	1-3D 4D C-D	FF3 FF3 FF3	GND +5 V							
		Wafer E <ul style="list-style-type: none"> o Indicates not selected. o Indicates T/R selected. o T/R functional control (to MDM). 	1,2,4E 3E C-E	FF3 FF3 FF3	GND +5 V							
TACAN ID (LEFT AUDIO) 	05	1-Selects ID tone from tacan 1. 2-Selects ID tone from tacan 2. 3-Selects ID tone from tacan 3.	1 2 3		ID tone to ON/OFF switch							
		ON-Selected ID tone to tacan volume control. OFF - N/A.	1 2									
TACAN ID (RIGHT AUDIO) 	09	1-Selects ID tone from tacan 1. 2-Selects ID tone from tacan 2. 3-Selects ID tone from tacan 3.	1 2 3		ID tone to ON/OFF switch							
		ON-Selected ID tone to tacan volume control. OFF-N/A.	1 2									

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TABLE B-X.- TACAN - Continued

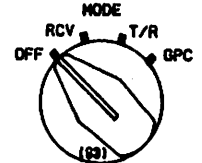
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
TACAN 2 CHANNEL 	07	Selects channel 0-126 for tacan 2 o Units 1,2,4,8. o Tens 10,20,40,80 o Hundreds 100 Selects mode (X,Y).			FF2 0 V dc/ +5 V dc/ FF2 0 V dc/ +5 V dc/ FF2 0 V dc/ +5 V dc/ FF2 0 V dc/ +5 V dc/							
TACAN 3 CHANNEL 	07	Selects channel 0-126 for tacan 3. o Units 1,2,4,8. o Tens 10,20,40,80. o Hundreds 100. Selects mode (X,Y).			FF3 0 V dc/ +5 V dc/ FF3 0 V dc/ +5 V dc/ FF3 0 V dc/ +5 V dc/ FF3 0 V dc/ +5 V dc/							
TACAN 1 MODE 	07	Selects operational mode for tacan 1. Wafer A o Off position. o Power on signal. o Tacan 1. o Signal ground to common.	1A 2-4A C-A		FF1 AC bus 1-C GND	Tacan 1	L4	3				
		Wafer B o Not used. o Tacan 1 GPC selected. o Applies bus power to 4B.	1-3B 4B C-B	FF1	ESS1BC							
		Wafer C o Not used. o Power on. o Applies bus power.	1C 2-4C C-C	OF4/ LF1	ESS1BC							

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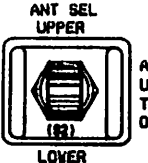
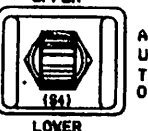
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TABLE B-X.- TACAN - Continued

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
		Wafer D <ul style="list-style-type: none"> o Indicates not selected. o Indicates GPC selected. o GPC functional control (to MDM). 	1-3D 4D C-D	FF1 FF1 FF1	GND +5 V							
		Wafer E <ul style="list-style-type: none"> o Indicates not selected. o Indicates T/R selected. o T/R functional control (to MDM). 	1,2,4E 3E C-E	FF1 FF1 FF1	GND +5 V							
TACAN 2 MODE 	07	Selects operational mode for tacan 2.		FF2	AC bus 2-C	Tacan 2	L4	3				
		Wafer A <ul style="list-style-type: none"> o Off position. o Power on signal. o Tacan 2. o Signal ground to common. 	1A 2-4A C-A		GND							
		Wafer B <ul style="list-style-type: none"> o Not used. o Tacan 2 GPC selected. o Applies bus power to 4B. 	1-3B 4B C-B	FF2	ESS1BC							
		Wafer C <ul style="list-style-type: none"> o Not used. o Power on. o Applies bus power. 	1-C 2-4C C-C	OF4/ LF1	ESS1BC							

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TABLE B-X.- TACAN - Continued

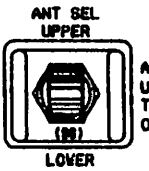
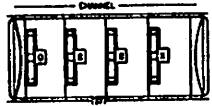
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light		
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM	
TACAN 1 ANT SEL 	07	UPPER - Allows manual selection of upper antenna.	1	FF1									
		LOWER - Allows manual selection of lower antenna.	2	FF1									
		AUTO - Allows GPC selection of antenna when mode switch is in GPC; LRU selection when mode switch is in T/R.	3	FF1									
		UPPER - Antenna sw inhibit.	1A	FF1	+5 V dc								
		AUTO - Antenna sw inhibit.	2A	FF1	ANT sw								
		LOWER - Antenna sw inhibit.	3A	FF1	inhibit								
					+5 V dc								
		UPPER - Upper/lower ANT lock.	1B	FF1	+5 V dc								
		AUTO - Upper/lower ANT lock.	2B	FF1	ANT lock								
		LOWER - Upper/lower ANT lock.	3B	FF1	GND								
TACAN 2 ANT SEL 	07	UPPER - Allows manual selection of upper antenna.	1	FF2									
		LOWER - Allows manual selection of lower antenna.	2	FF2									
		AUTO - Allows GPC selection of antenna when mode switch is in GPC; LRU selection when mode switch is in T/R.	3	FF2									

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TABLE B-X.- TACAN - Concluded

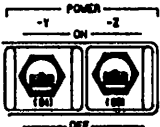
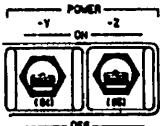
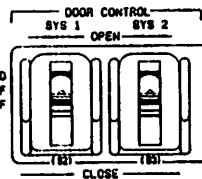
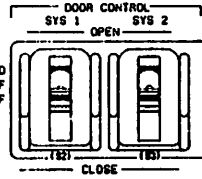
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
		UPPER - Antenna sw inhibit. AUTO - Antenna sw inhibit. LOWER - Antenna sw inhibit.	1A 2A 3A	FF2 FF2 FF2	+5 V dc ANT sw inhibit +5 V dc							
		UPPER - Upper/lower ANT lock. AUTO - Upper/lower ANT lock. LOWER - Upper/lower ANT lock.	1B 2B 3B	FF2 FF2 FF2	+5 V dc ANT lock GND							
TACAN 3 ANT SEL	07	UPPER - Allows manual selection of upper antenna. LOWER - Allows manual selection of lower antenna. AUTO - Allows GPC selection of antenna when mode switch is in GPC; LRU selection when mode switch is in T/R.	1 2 3	FF3 FF3 FF3								
		UPPER - Antenna sw inhibit. AUTO - Antenna sw inhibit. LOWER - Antenna sw inhibit.	1A 2A 3A	FF3 FF3 FF3	+5 V dc ANT sw inhibit +5 V dc							
		UPPER - Upper/lower ANT lock. AUTO - Upper/lower ANT lock. LOWER - Upper/lower ANT lock.	1B 2B 3B	FF3 FF3 FF3	+5 V dc ANT lock GND							
TACAN 1 CHANNEL	07	Selects channel 0-126 for tacan 1. o Units 1,2,4,8. o Tens 10,20,40,80. o Hundreds 100. Selects mode (X,Y),		FF1	0 V dc/ +5 V dc/ 0 V dc/ +5 V dc/ 0 V dc/ +5 V dc/ 0 V dc/ +5 V dc/							
												

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TABLE B-XI.- STAR TRACKER

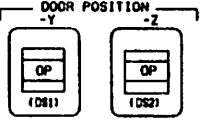
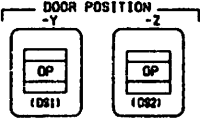
Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL PWR	Amps	ANNUN ASSY	MDM
STAR TRACKER POWER -Y 	06	Supplies power to -Y star tracker.	1	FF3	VMNB	STARTRKR -Y	015	3				
STAR TRACKER POWER -Z 	06	Supplies power to -Z star tracker.	1	FF1	VMNA	STARTRKR -Z	014	3				
STAR TRACKER DOOR CONTROL SYSTEM 1 	06	Activates system 1 door motor for a star tracker whose power switch is on.										
		Open CMD	1	FF3	BC1	F25 fuse		1				
		Close CMD	2	FF3	BC1	F25		1				
		Open CMD	3	FF3	BC2	F26		1				
		Close CMD	4	FF3	BC2	F26		1				
		Open CMD	5	FF1	AB2	F29		1				
		Close CMD	6	FF1	AB2	F29		1				
		Open CMD	7	FF1	AB1	F30		1				
		Close CMD	8	FF1	AB1	F30 fuse		1				
STAR TRACKER DOOR CONTROL SYSTEM 2 	06	Activates system 2 door motor for a star tracker whose power switch is on.										
		Open CMD	1	FF3	BC1	F32 fuse		1				
		Close CMD	2	FF3	BC1	F32		1				
		Open CMD	3	FF3	BC2	F31		1				
		Close CMD	4	FF3	BC2	F31		1				
		Open CMD	5	FF1	CA2	F27		1				
		Close CMD	6	FF1	CA2	F27		1				
		Open CMD	7	FF1	CA1	F28		1				
		Close CMD	8	FF1	CA1	F28 fuse		1				

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TABLE B-XI.- STAR TRACKER - Concluded

Control/display	Panel	Function	Contacts	MDM	Signal power	Circuit breaker			RPC		Light	
						Title	Panel	Amps	CNTL	PWR	Amps	ANNUN ASSY
STAR TRACKER DOOR -Y TALKBACK 	06	Indicates star tracker -Y door status. Barberpole is the lack of power applied to either OP or CL.	OP	1	FF1	FMCA-1 MNA	Fuse	FMCA inter- nal	1			
			CL	2	FF3	FMCA-2 MNB	Fuse	FMCA inter- nal	1			
			OP	1	FF1	FMCA-1 MNA	Fuse	FMCA inter- nal	1			
			CL	2	FF3	FMCA-2 MNB	Fuse	FMCA inter- nal	1			
STAR TRACKER DOOR -Z TALKBACK 	06	Indicates star tracker -Z door status. Barberpole is the lack of power applied to either OP or CL.	OP	1	FF3	FMCA-3	Fuse	FMCA inter- nal	1			
			CL	2	FF1	FMCA-2	Fuse	FMCA inter- nal	1			
			OP	1	FF3	FMCA-3	Fuse	FMCA inter- nal	1			
			CL	2	FF1	FMCA-2	Fuse	FMCA inter- nal	1			

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Shuttle Flight Operations Manual

PRELIMINARY

VOL. 6

Guidance, Navigation,
and Control Hardware

June 1981

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