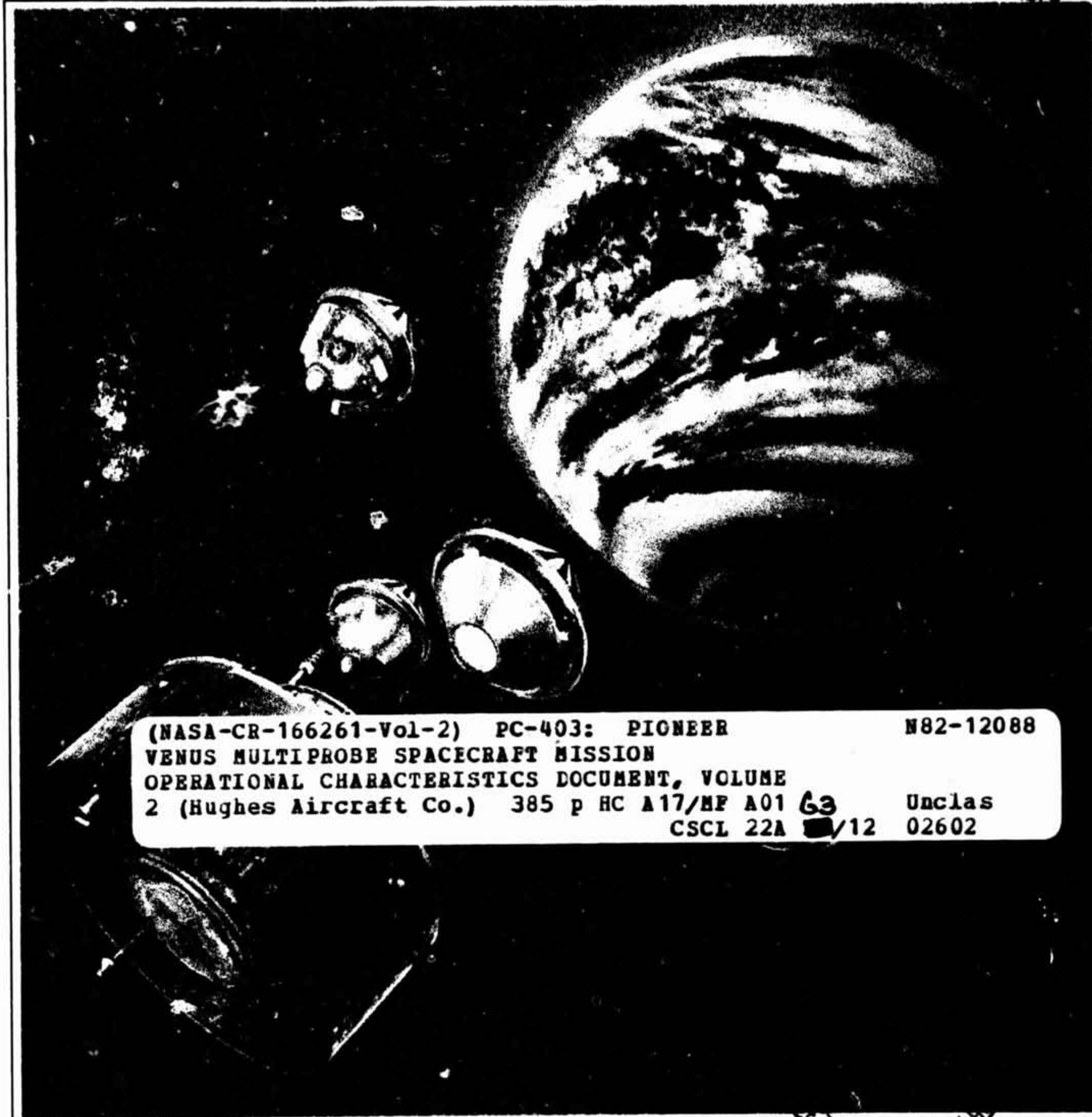

PC-403 — VOLUME II OF III
PIONEER VENUS MULTIPROBE SPACECRAFT MISSION OPERATIONAL CHARACTERISTICS DOCUMENT

MAY 1978

CONTRACT NO. NAS 2-9366 • HS 507-7517 • HUGHES REF NO. D8821

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HUGHES AIRCRAFT COMPANY
SPACE AND COMMUNICATIONS GROUP
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3.5 DATA HANDLING SUBSYSTEM

3.5.1 Subsystem Description. The data handling subsystem contains all the telemetry processing capability on the spacecraft. The subsystem processes analog, serial digital and bilevel telemetry data from the scientific instruments and spacecraft subsystems for transmission to earth. The subsystem provides timing, clock and status signals; data sampling and formatting; convolutional encoding; and biphase modulation for the spacecraft. A functional block diagram for the subsystem is presented in Figure 3.5.1-1 (Appendix C).

The subsystem consists of eight (8) Data Input Modules (DIMs), two (2) redundant PCM Encoders (PCMEs), two (2) redundant Telemetry Processors (TPs). On the spacecraft equipment shelf, these units are arranged as shown in Figure 3.5.1-2. All the data handling subsystem units, except the DIMs, are connected to the switched loads bus. The DIMs receive secondary power from each PCME. Each DIM is power strobed ON just prior to processing a telemetry input, and upon completion, the DIM returns automatically to the standby mode. Discrete and quantitative commands are used to control the functions of all the subsystem units. Figure 3.5.1-3 shows the major cross-strapping between the elements of the subsystem.

The data handling subsystem receives all telemetry data inputs through the eight (8) DIMs and multiplexes these inputs into a PCM/PSK square wave subcarrier that is sent to the spacecraft transmitters. Each DIM is a 32-channel random access commutator with a single input control line and a single Pulse Amplitude Modulated (PAM) output data line. The DIMs provide user-dedicated read envelopes and a common gated read clock to all users of serial digital telemetry; and a 1 milliampere precision current pulse source of a nominal 294 microseconds duration for users of resistive transducers (i.e., conditioned analog channels). The 1 milliampere precision current pulse source is developed in each PCME and provided on a single line to each DIM. Analog data (conditioned or non-conditioned) is sampled, buffered and gated to the output data line as a single PAM pulse; serial digital data is gated to the output data line as 8-bit serial words; and bilevel data is sampled in parallel 8-bit bytes and also gated to the output data line as 8-bit serial words. The ON/OFF control of each individual DIM is through the PCM ENCODER DIM CONTROL quantitative command, i.e., PCMQ1 for PCME1 and PCMQ2 for PCME2. This command is sent to the PCME in the case of a failure where a DIM does not automatically return to standby after being used to process a telemetry input. The ON/OFF status of each DIM is not telemetered because it can be determined from the sense of the telemetry data. The DIMs provide the standardized telemetry interface with all the scientific instruments and spacecraft subsystem users.

The PCME accepts the PAM analog and serial data from all the DIMs, processes and synchronizes the data and generates a non-return-to-zero-level pulse-code-modulated (NRZ-L/PCM) output bit stream to each TP. The PCME performs an eight bit analog-to-digital (A/D) conversion on the analog data and regenerates the digital data. Information from the TP to select the telemetry data channel required by the selected telemetry format is relayed by the PCME to the DIMs. For routing to channels that require a conditioning current, the PCME provides a precision 1 milliampere current pulse source to each DIM. The PCME receives a quantitative command to control the ON/OFF status of the DIMs, as mentioned above. Commanding a DIM ON enables the PCME data input line and also enables the DIM to be power strobed ON via the control line. A discrete ON/OFF command is also received by the PCME to control the power status of the unit, i.e., PCM ENCODER 1 ON/2 OFF (PCM19 or PCMA9), PCM ENCODER 2 ON/1 OFF (PCM29 or PCMB9) and PCM ENCODERS OFF (PCM1Ø or PCMAØ). The telemetry ON/OFF status is provided by DPCM1S for PCME1 and DPCM2S for PCME2.

The TP is the main unit in the data handling subsystem. The TP contains the master spacecraft clock that generates all the timing signals required by the subsystem, the scientific instruments and other spacecraft subsystems. The TP provides the 24-bit spacecraft time code, 4096 second clock, clock signals (i.e., 32,768 Hz and 2048 Hz), telemetry synchronization signals (i.e., major frame rate, minor frame rate and telemetry word rate), and the bit rate status signals. A data minor frame consists of 64 telemetry words consisting of eight bits each (512 bits total). There are 64 minor frames in a major frame. A subcommutated format also consists of 64 telemetry words, except that each word in the subcommutated format appears only once in a unique word position in the minor frame. Therefore, it takes one major frame to complete a subcommutated format. The Multiprobe spacecraft has assigned to it: 4 pre-programmed minor frame formats, one (1) programmable minor frame format and three (3) pre-programmed subcommutated formats, as identified in Table 3.5.1-1. The telemetry data words required in these formats are sequentially addressed by the TP and are sent from the DIMs through the PCME. The TP receives the telemetry data by addressing the PCME, and conditions it for transmission to the spacecraft communications subsystem.

The data processing in the TP includes convolutionally encoded or uncoded data and biphase modulation of the data onto the 16,384 Hz square wave subcarrier. The functions of the TPs are configured by the TELEMETRY PROCESSOR CONTROL quantitative command, i.e., TPCQ1 for TP1 and TPCQA for TP2. Minor frame format word 3 gives the telemetry status of the TPs.

TABLE 3.5.1-1

MULTIPROBE TELEMETRY FORMATS

Pre-Programmed Minor Frame Formats:

1. Bus Engineering
2. Bus Entry
3. ACS
4. Command Memory Readout

Pre-Programmed Subcommutated Formats:

1. Subcom A
2. Subcom B
3. Subcom C

Programmable Minor Frame Format:

"Programmable"

3.5.2 Unit Descriptions. The following sections provide detailed descriptions of the units within the data handling subsystem.

3.5.2.1 Data Input Module. The DIM receives analog, serial digital and bilevel data from the scientific instruments and spacecraft subsystems and routes these data to the TP via the PCMB. The DIM receives control signals, the 1 milliampere precision current pulse source and power from the PCMB. The DIM provides a read clock and read envelopes to users of serial digital data; and relays the precision current pulse source to users of conditioned analog and bilevel channels. The main components of the DIM are the multiplexer, Manchester decoder and control logic, read envelope and clock generator, and power control. In the following sections, these components are described.

3.5.2.1.1 Multiplexer. The multiplexer receives the 32 telemetry channel inputs from the users. Each input is protected against damage from overvoltages as large as +50 volts and -30 volts. The multiplexer is implemented by using eight (8) 4-channel input multiplexers which are controlled by two (2) 4-channel switches that each provide a one-out-of-four decode. Current switches are also contained in the multiplexer that operate synchronously with the multiplexer input switches. The purpose of the current switches is to commutate the 1 milliampere precision current pulse source into the selected multiplexer channel. Six (6) precision current pulse source inputs are provided, with each input allocated to a unique 4-channel input multiplexer.

3.5.2.1.2 Manchester Decoder and Control Logic. The Manchester decoder in the DIM receives a 10-bit Manchester coded channel address word formatted by the PCME. It decodes the address word and generates a two-phase bit clock and NRZ serial data. These signals are provided to the control logic. The control logic provides the proper coding to the multiplexer to select the desired channel by selecting the 4-channel multiplexer and channel within the multiplexer. Programming pins are used in the unit connector to choose the appropriate distribution of analog, serial digital and bilevel channels for the DIM. The control logic provides the read clock and read envelope outputs to the user's from the mode (i.e., programming) selected for the DIM and the channel address word.

3.5.2.1.3 Read Envelope and Clock Generator. The read envelope and clock generator circuit provides the control signals required for serial digital data transfer from the users. The circuit consists of a one-out-of-sixteen decoder matrix that generates the sixteen read envelope signals and a clock amplifier that provides buffering of the gated read clock signal from the control logic. The read envelope signals are generated in synchronization with the sampling of each 8-bit serial digital word. Up to sixteen serial data channels may be accommodated by wiring the data line to the appropriate input channel (i.e., channels 0 through 15).

3.5.2.1.4 Power Control. The DIM is turned on and off by a variable width pulse on the control line from the PCME. Pulses of 2 milliseconds and 230 microseconds will turn the DIM ON and a 36-millisecond pulse will turn OFF the DIM. The DIM is power-strobed as a means of minimizing power dissipation during idle or non-interrogate times. Power for the unit is provided by +15 volt and -15 volt regulated outputs and ground from the PCME that are inputted to power switches. The power switches apply the +15 volts, -15 volts, and ground to the internal electronics when an address word is detected on the control line. When there are no further pulses on the control line, the Manchester decoder senses this and sends a signal to the power control circuitry to return the DIM to the standby condition.

3.5.2.2 PCM Encoder. The PCME accepts PAM analog and digital data from the DIMs and formulates an NRZ-L/PCM (Non-Return to Zero level/Pulse Code Modulation) output data stream to the TPs. The main functional components of the PCME are the multiplexer, comparator and A/D converter, Manchester decoder and associated logic, DIM decoder, and power supply. These functions are described in the following sections.

3.5.2.2.1 Multiplexer. The multiplexer receives the PAM data input from each of the eight (8) DIMs along with a reference ground. The multiplexer consists of a differential commutator that differentially multiplexes the PAM data and reference ground from each DIM to the comparator. A distributor commutates a precision 1.000 milliampere ±0.5 percent reference current (294 microseconds) to the selected DIM for signal conditioning of transducer resistive inputs. The precision current source is outputted from the multiplexer to each DIM on a dedicated line.

3.5.2.2.2 Comparator and A/D Converter. The comparator consists of a unity gain differential amplifier followed by a precision voltage comparison circuit. The output of the comparator goes to the A/D converter. The differential input from the multiplexer is converted into a single-ended signal by the differential amplifier in the comparator. The treatment of the data, as analog or digital, is controlled by the A/D bit in a 20-bit instruction and address word supplied by the TP. For analog inputs, the comparator compares the input signal to a known reference. The reference is provided by a digital-to-analog feedback circuit in the A/D converter consisting of a binary voltage weighted resistor ladder, switches and a precision -5.120 vdc reference supply. The output of the comparator is encoded into 8-bit digital words by the A/D converter which employs a successive approximation technique. To process digital data, the register and switches are forced to half scale for the entire word time so that the ladder is generating a constant +2.56 volt reference. Thus, the A/D converter functions as a fixed threshold detector for making one-zero decisions on the incoming digital data.

3.5.2.2.3 Manchester Decoder and Associated Logic. The Manchester decoder receives a 20-bit instruction and address word from the TP for three (3) times in succession. The decoder generates a coherent bit clock from the incoming 20-bit words, that provides timing for the bit counter circuit. In addition, the coherent bit clock enables the serial transfer of the instruction and address portion (minus 8-bit sync code) of the 20-bit word into a 12-bit shift register. The 11 instruction and address bits (i.e., A/D bit, 5 DIM address bits and 5 channel address bits) of the 20-bit word constituting the first interrogate subcycle are parallel transferred into an 11-bit holding register by the 12th bit in the shift register. The 5-bit channel address is parallel transferred during the 2nd interrogate subcycle into the address generator where it is converted into a 10-bit word required by the DIMs consisting of a 5-bit sync followed by the channel address.

3.5.2.2.4 DIM Decoder. The DIM decoder provides the channel address information to each DIM on a dedicated output. The DIM decoder circuit receives parallel DIM address bits from the holding register to select the DIM output line, the serial 10-bit channel address word from the address generator to select the DIM channel and power control commands from the power control circuit to turn on and off the DIMs. The ON/OFF control pulses to the DIMs go out on the same lines as the 10-bit channel address word. The power control circuit receives the PCM ENCODER DIM CONTROL quantitative command (PCMQ1 for PCME1 and PCMQ2 for PCME2) and provides a pulse width modulated technique to control the DIMs. Command execution is synchronized to the beginning of the minor frame.

3.5.2.2.5 Power Supply. The PCME has an internal power supply that operates from the +28 volt switched loads bus and is commandable ON and OFF. A series regulator provides regulation of the input bus voltage and an electric conversion unit (ECU) generates all the secondary voltages required by the PCME, including the power supplied to the DIMs. The PCME power supplies are commanded ON and OFF by three discrete commands, i.e., PCM ENCODER 1 ON/2 OFF (PCM19 or PCMA9), PCM ENCODER 2 ON/1 OFF (PCM29 or PCMB9), and PCM ENCODERS OFF (PCM1∅ or PCMA∅). The ON/OFF status is provided to telemetry as DPCM1S for PCME1 and DPCM2S for PCME2.

3.5.2.2.6 Internal Command Response. The PCME receives both quantitative and discrete commands from the CDMs. The following sections describe the internal response of the PCME to the different commands received.

3.5.2.2.6.1 PCM ENCODER DIM CONTROL Quantitative Command. Power control for the DIMs is processed by the DIM power control circuit in the PCME. The 16-bit quantitative command (i.e., bits 25 through 40 of the uplink command format) (PCMQ1 for PCME1 or PCMQ2 for PCME2) is stored in a 16-bit shift register, and the verification pulse at the end of the quantitative command is ignored. Each pair of bits in a given command word contain the power ON/OFF information for a DIM. Power control for the DIMs is implemented using a pulse width modulation technique. Command execution is synchronized to the beginning of a minor frame by using the second negative transition of the minor frame signal following receipt of a command to trigger three (3) one-shots whose periods represent the power ON/OFF states of a DIM. The proper pulse is gated to the DIM address line as a function of the information contained in the command word. A code of "01" or "11" will generate a 36-millisecond pulse which will turn a DIM OFF. A code of "00" or "10" will turn a DIM ON; a "00" code generates a 230 microsecond pulse, and a "10" code generates a 2 millisecond pulse.

3.5.2.2.6.2 PCM Encoder ON Discrete Command. The PCM Encoder ON command (i.e., PCM19 or PCMA9 for PCME 1; PCME29 or PCMB9 for PCME 2) is a discrete command routed through an input buffer to the latch which controls the PCME power. This command sets the latch; a voltage is fed back from the regulator to keep the latch set and PCME power ON. The ON command to a PCME simultaneously turns OFF the other PCME.

3.5.2.2.6.3 PCM Encoder OFF Discrete Command. The PCM Encoder OFF command (i.e., PCM1Ø or PCMAØ) is a discrete command routed to an input buffer and to the latch which controls the PCME power. This command will reset the latch and thus turn PCME power OFF. The OFF command turns off both PCMEs at the same time.

3.5.2.3 Telemetry Processor. The TP controls all functions of the data handling subsystem. The TP requests telemetry data from the DIMs through the PCME, organizes the data into telemetry formats and transmits a PCM/PSK subcarrier to the spacecraft transmitters. All spacecraft timing is derived from the master clock contained in the TP.

The major functional components of the TP are timing, input interface, output interface, controller and power supply. In the following sections, each of these components are described.

3.5.2.3.1 Timing. A 2^{20} (1,048,576) Hz crystal oscillator with a 50 ppm stability is provided in the TP as a timing reference for the scientific instruments, spacecraft subsystems and TP. The crystal oscillator is used as the frequency standard for the timing block. A countdown chain in the timing block provides buffered 32,768 Hz, 2048 Hz and word rate signals to users.

The operating telemetry bit rate of the TP is selected by sending the TELEMETRY PROCESSOR CONTROL quantitative command (i.e., TPCQ1 for TP1 or TPCQA for TP2). Bits 29 through 32 of the uplink command format are coded to select the desired bit rate, as defined in PC-455 (Reference: Paragraph 1.5.1). This 4-bit code is sent to the timing block from the controller which receives it from the command input logic (part of input interface). A change to the bit rate is implemented at the beginning of the next minor frame following receipt of the quantitative command. The timing block also transmits a signal twice the selected bit rate to the controller.

The countdown chain provides a word rate start signal to the controller to start the processing of a telemetry word. The controller completes the processing of one word in less than 3.9 milliseconds and goes into an idle state with the control logic strobed off to conserve power. The controller is reactivated by a new word rate start signal from the timing block. The telemetry word retrieved from a DIM during the current processing cycle is transmitted during the next telemetry word time.

The bit rate status signals (i.e., four (4) output signals giving the logic coding for the operating bit rate) are sent to the scientific instrument users from the timing block.

3.5.2.3.2 Input Interface. The input interface component consists of the command input logic block and the

PCM input logic block. All input information is buffered through standard input buffers and all serial inputs are stored in shift registers which are interrogated by the controller.

The command input logic block receives the 16-bit (i.e., bits 25 through 40 of the uplink command format) TELEMETRY PROCESSOR CONTROL quantitative command (TPCQ1 or TPCQA) from the COM (i.e., COM 3 for TP1 and COM 4 for TP2), and stores it in a shift register. After the command has been completely received by the TP, a flip-flop is set in the command input logic block by the quantitative command verification pulse. The output of the flip-flop is sent to the controller. During internal word time zero (i.e., first word of internal minor frame to be transmitted in next telemetry word time as a TP output), the controller senses the state of the flip-flop and transfers the contents of the shift register into the controller's Random Access Memory (RAM). As a result, the command will be acted upon in the next telemetry word time, which is the time of the first word of the minor frame outputted by the TP. If two (2) or more quantitative commands are sent in the period of a minor frame, only the last transmitted command will be processed at the beginning of the next minor frame.

The PCM input logic block receives PCM data inputs from whichever of the two (2) PCMEs is ON. The PCM interrogate logic block sends a telemetry channel address to the PCME and as a result, 8 bits of data are transferred to the PCM input logic block. The returning data is clocked in using a 32,768 Hz clock generated within the PCM interrogate logic block. The input data is stored in a shift register in the PCM input logic block within one telemetry word time slot, and is transferred to the data output logic block for output at the selected bit rate during the next telmetry word time slot.

3.5.2.3.3 Output Interface. The output interface component contains the PCM interrogate logic block, the data output logic block. All outputs are bufferred through standard output buffers. The real time outputs of the data output logic block to the transponders which are required to be telemetry word rate synchronous, consist of a two (2) register pair located within the block. These are: 1) an internal register that is updated by the controller, and 2) an external register that receives the contents of the internal register by a synchronous transfer using the telemetry word rate clock.

Primary timing and control of the PCME is accomplished by the Manchester coded (biphase) address and instruction format provided by the PCM interrogate logic block. The address and instruction format consists of a 20-bit word sent at 2^{16} (65,536) bits per second. This 20-bit word contains an 8-bit sync pattern plus 1 bit used to shift the remaining 11 bits into a holding register. The first data bit instructs the PCME as to whether the requested telemetry data is analog or digital, the next five (5) data bits select the DIM that is to be interrogated and the last five (5) bits represent the channel address of the selected DIM. This 20-bit word is sent three (3) times in order to provide the proper timing for the PCME.

The data output logic block is responsible for synchronizing the output data with the selected telemetry bit and word rates. Data to be sent to the transponder is loaded into a temporary internal shift register during the telemetry word time slot it is received from the PCME. At the start of the next telemetry word time slot, it is transferred into an external shift register which is serially clocked at the selected bit rate. The data may be convolutionally encoded, sent directly to the biphase modulator, or commanded off by use of the coding within the TP CONTROL quantitative command. When the data is convolutionally encoded, the convolutional encoder is reset after the last bit of the third sync word (i.e., 24th bit of the minor frame) is shifted into the encoder. Data out of the convolutional encoder is clocked into the biphase modulator at 16,384 Hz in order to provide coherence with the subcarrier. After the data is biphase modulated, it is buffered to the spacecraft interface levels and sent to the transponder. The data output logic block also provides the 4096 second clock output to the command processor and the major and minor frame rate signals to the scientific instruments and spacecraft subsystems, as seen in Figure 3.5.1-1.

3.5.2.3.4 Controller. The controller is the core of the TP. Telemetry minor frame and subcommutated formats and control signals are stored within Programmable Read Only Memories (PROMS) contained in the controller. The timing, input interface and output interface functions are linked to the controller by a data bus over which data and control signals are sent. The controller also performs arithmetic and logic manipulations with data and stores pertinent data in the RAM.

Upon TP power turn-on (via TLH19 or TLHA9 for TP1; TLH29 or TLHB9 for TP2), the controller executes an initialization routine. The commandable functions initialize to the states shown in Table 3.5.2.3.4-1. After initialization, the controller goes into the idle state and waits for the telemetry word rate start signal from the timing block. Upon receipt of the telemetry word rate start signal, contents of internal registers are transferred to the external data registers that interface with units outside the TP. This assures that the output interface will be synchronous with the selected telemetry word rate. The spacecraft time code update is the first routine executed after receipt of the telemetry word rate start signal. The time code is incremented as a function of bit rate, i.e., at the highest bit rate (2048 Hz), the increment is 1/256 second and at the lowest bit rate (8 Hz), the increment is 1 second.

If a new command has been received by the command input logic block and the internal telemetry word time slot is telemetry word zero, the command is transferred onto the data bus and stored within the RAM for later access. If, however, the

Direct Memory Access (DMA) bit is set in the TP CONTROL quantitative command, the command is processed as a direct memory access command, i.e., the command is being used to configure the programmable format. At this point, the internal registers that control bit rate select and TP output functions are loaded so that the external registers can be loaded at the next telemetry word time slot, which will be telemetry word zero of the next minor frame. If the current telemetry word is the last telemetry word of a major frame, the three (3) most significant time code words (i.e., three 8-bit words) are sampled and stored for later readout. Next, the various bits which represent minor frame rate, major frame rate, and the 4096 second rate are masked out of the counters which are stored in the RAM and are transferred via the data bus to the data output logic block.

The controller forms a 10 bit address for the minor frame format memory composed of 4 bits for the commanded format type and 6 bits for the contents of the telemetry word counter. A 12-bit word is then retrieved from the minor frame format memory. Four (4) bits of this word serve to classify this word into one of six types.

First, the "normal" type, which is the most prevalent, signifies that the remaining 8 bits are a DIM address and are to be sent to the PCME. The returning commutated telemetry word is placed in an internal register which will be transferred to an external output register at the next telemetry word time slot.

The second type of format word is the subcommutated word. Within the space that would normally be the DIM address bits, there are two (2) bits to indicate the subcom type. These two (2) bits are connected to the 6 bits of minor frame count to form an 8-bit address for the subcom format memory which is similar to the minor frame format memory. The 12-bit word retrieved from the subcom format memory is treated similarly to the 12-bit word retrieved from the minor frame format memory.

Revision

The third type of format word is the internal word. Five (5) of the eight (8) remaining bits are used to indicate an internal status word stored in the RAM to be outputted during the next telemetry word time slot.

The fourth type of format word is the sync word where the actual sync code is stored in the remaining 8 bits of the 12-bit format word.

The fifth format word type is the programmable format word which contains a scratch-pad memory address used to fetch the programmed DIM and channel number.

The sixth format word type is the RAM-read word. When this word is encountered, the minor frame count is used as an address to fetch a word from the scratch-pad and insert it into the data stream.

TABLE 3.5.2.3.4-1

TP INITIAL CONDITIONS

PARAMETER	INITIAL CONDITIONS
Bit Rate	16 Bits Per Second
Frame Format	Orbiter Engineering Format
Convolutional Encoder	ON
Data	ON
Subcarrier	ON
Time Code Word	4 Minutes 16 Seconds prior to Full Scale Clock Reading
Minor Frame Word	63
Minor Frame Number	63

3.5.2.3.5 Data Transfer: DIM to Telemetry Processor. The Telemetry Processor calls for data from a DIM by first initiating an interrogate cycle within the PCM Encoder. This interrogate cycle takes place entirely within the "busy" time segment of controller activity shown in Figure 3.5.2.3-1. The telemetry processor sends a 20-bit Manchester coded address from its PCM interrogate logic to the PCM Encoder's Manchester decoder circuitry. The 20-bit code is sent three successive times to create three subcycles as seen in Figure 3.5.2.3-2. However, the 20-bit address code is not usually the same for the first subcycle as it is for the second and third subcycles.

The first 20-bit address code consists of an 8-bit sync pattern, plus one bit to shift the remaining 11 data bits into a holding register:

```
0 0 0 0 0 0 0 0 1 X X X X X X X X X X X
  MSB           ↑ ↑ └────────────┘   LSB
(or 20th)       | |DIM Select  └─────────┘
  LSB           | |            DIM Channel
 └──────────────┘ |              Select
   Introduction   |
     Pattern      |A/D Bit
                  |
             Shift Bit
```

The 11 data bits consist of an A/D bit which indicates the type of telemetry data required, i.e., analog or digital; 5 DIM select bits (only 3 of the 5 are relevant to the Pioneer Venus Program which uses 8 DIMs); and 5 DIM channel select bits. The second and third 20-bit address codes differ from the first code only in that the DIM channel select bits are always coded as channel 16 (10000). All other bits are identical. In the event that channel 16 of a given DIM is being interrogated, then all bits of all three 20-bit address codes will be the same.

The second and third 20-bit address codes are generated for timing purposes only. Their DIM channel select bits are coded to channel 16 because channel 16 (as well as channels 17 through 31) doesn't create a read envelope which could cause a loss of synchronization, if a read envelope had already been generated during the first subcycle.

In the first interrogate subcycle, the PCM encoder's Manchester decoder circuitry receives the 20-bit address code serially shifted with MSB first. As the address code bits enter the Manchester decoder circuitry, they are used to create clocking signals. The Manchester decoder circuitry accumulates the data into a 12-bit shift register. The first 8 bits, i.e., the logical zeroes (sync pattern) pass straight through the register. The 12th LSB bit of the code, i.e., the logic "1" following the sync pattern, triggers the parallel transfer of the following 11 data bits to an 11-bit holding register. Upon data transfer, the 12-bit shift register is immediately reset.

Instantly after the 11-bit holding register receives the data, the 5 DIM select bits and the 5 DIM channel select bits are decoded by the PCM encoder's DIM decoder circuitry and address generator circuitry, respectively. This is possible because the contents of the 11-bit holding register, excluding the A/D bit, are hard-wired to the DIM decoder circuitry and the address generator circuitry.

The DIM decoder uses 3 of the 5 DIM select bits to activate an address line to the selected DIM. The address generator uses the 5 DIM channel select bits to encode a 10-bit address code. The 10-bit address code consists of a 5-bit sync pattern followed by the 5 DIM channel select bits, MSB first:

$$\underbrace{\overset{\text{MSB}}{0}\ 0\ 0\ 0\ 1}_{\text{Sync Pattern}}\ \underbrace{X\ X\ X\ X\ \overset{\text{LSB}}{X}}_{\text{DIM Channel Select}}$$

The address generator also receives a delayed 5-bit DIM select code for the DIM previously interrogated. This delayed 5-bit code is used to inhibit or enable the sending of a fill address which is generated in the address generator. The 5-bit DIM select code comes from a 6-bit holding register within the PCM encoder. However, the 5 DIM select bits from the 6-bit holding register and the fill address generated by the address generator are of minor importance with respect to the Pioneer Venus Program. In the Pioneer Venus Program, the fill address is derived directly from the 2nd 20-bit address code of the iterrogation cycle. It should be noted that the A/D bit is one of the delayed 6 bits from the 6-bit holding register. The A/D bit must be delayed for one subcycle period to properly instruct the PCM encoder's A/D converter circuitry.

At the midway point of the LSB of the 1st 20-bit interrogate subcycle (as seen in Figure 3.5.2.3-2), the first 10-bit address code generated by the address generator is serially shifted (MSB first) from the PCM encoder's DIM decoder to the selected Manchester decoder circuitry.

In the 2nd interrogate subcycle, the PCM encoder's Manchester decoder circuitry receives the 2nd 20-bit address and generates clocking signals. The data bits are processed in the same manner as in the 1st interrogate subcycle; but the 10-bit address code that is generated by the address generator will serve the purpose of the fill address.

At the MSB of the 3rd 20-bit interrogate subcycle, the fill address leaves the PCM encoder's DIM decoder and goes to the DIM's Manchester decoder. The fill address is used by the DIM to create clocking signals which will allow an 8-bit word of data to be clocked from the DIM to the PCM encoder.

If conditioned data is being sampled, a 1.000 mA precision current output (see Figure 3.5.2.3-2) is also sent from the PCM encoder to the selected DIM within 4 microseconds after the fill address leaves the PCM encoder. If serial digital data is being sampled, then the 50% rise time point of the read envelope (see Figure 3.5.2.3-3) would occur within the same 4 microseconds time span as the leading edge of the precision current output pulse. The read envelope and read clock (also in Figure 3.5.2.3-3) are sent to users by the DIM to transfer data into the DIM.

Within 24 microseconds after the 2nd MSB of the fill address leaves the PCM encoder, an 8-bit telemetry data word is clocked from the DIM (see Figure 3.5.2.3-2) to the PCM encoder.

The PCM encoder receives the PAM or digital data from the DIM, and regenerates the data in non-return-to-zero pulse code modulated (NRZ-L/PCM) form. The PCM encoder uses clocking signals generated from the 3rd 20-bit interrogate subcycle to serially shift the 8-bit telemetry data word (MSB first) to the telemetry processor (see Figure 3.5.2.3-2).

Data which is routed to the transponder is first stored in an internal register of the telemetry processor's data output logic. At the next telemetry word time, the data is transferred to an external register which interfaces directly with the transponder.

3.5.2.3.6 Power Supply. The power supply generates the voltage forms required by the internal TP functions. The power supply provides current limiting, undervoltage detection and shutdown, overvoltage detection and shutdown, negative voltage input clamping, and bus fusing. Power strobing is used to conserve energy. In addition, the power supply provides isolation between the bus return and the signal returns, and buffers the discrete input commands that turn the TP on and off. The TP power supplies receive three (3) discrete commands to control the ON/OFF status of the units, i.e., TP1 ON/2 OFF (TLM19 or TLMA9), TP2 ON/1 OFF (TLM29 or TLMB9) and TPs OFF (TLM1Ø or TLMAØ). The ON/OFF telemetry status of the power supplies is given by DTLM1S for TP1 and DTLM2S for TP2.

3.5.2.3.7 Internal Command Response. The TP receives both quantitative and discrete commands from the COMs to control the configuration and operation of the unit. The following sections describe the internal response of the TP to the different commands received.

3.5.2.3.7.1 <u>TELEMETRY PROCESSOR CONTROL Quantitative Command</u>. The 16-bit quantitative command (i.e., bits 25 through 40 of the uplink command format (TPCQ1 for TP1; TPCQA for TP2) used to configure the TP is stored in a temporary holding register (i.e., external register) in the command input logic block. After the command has been received by the command input logic, a flip-flop is set by the verification pulse. The controller senses the state of the flip-flop during the internal word zero input time and transfer the contents of the temporary holding register into the controller's RAM via the data bus. As a result, the latest TP CONTROL quantitative command will be acted upon at the start of the next minor frame. Information transfer is then accomplished via the data bus to an internal register by a synchronous transfer using the word rate signal. The information bits are decoded and used to control their specified functions.

Bit 36 of the 16-bit quantitative command is used to determine whether a direct memory access (DMA) operation is to take place. If the DMA bit is a logic "1", the TP CONTROL quantitative command is used to configure the programmable format. A logic "0" indicates a normal command. A programmable format command is loaded directly into the RAM, and contains information regarding DIM number, DIM channel, and data type of the telemetry signal(s) to be sampled. The structure of the 16 bits of data for the programmable format command is given in PC-455 (Reference: Paragraph 1.5.1).

The normal command consists of 15 information bits and one spare bit (Bit 37). Bits 25 through 28 are decoded to provide format selection, and bits 29 through 32 are decoded to provide bit rate selection. Bit 38 controls the subcarrier ON/OFF state; bits 39 and 40 control the Convolutional Encoder/Data modes. The status of these three functions are not provided in telemetry.

3.5.2.3.7.2 <u>Telemetry Processor ON Discrete Command</u>. The Telemetry Processor ON command (i.e., TLM19 or

TLMA9 for TP1; TLM29 or TLMB9 for TP2) is a discrete command routed to the input of a latch which controls the TP power. This command sets the latch; a voltage is fed back from the regulator to keep the latch set and the TP power ON. The ON command to a TP is also used to simultaneously turn off the other TP.

3.5.2.3.7.3 Telemetry Processor OFF Discrete Command. The Telemetry Processor OFF command (i.e., TLM1Ø or TLMAØ) is a discrete command routed through an input buffer to the latch which controls the TP power. This command will reset the latch and thus command the TP power OFF. This OFF command simultaneously turns off both TPs.

3.5.3 Operational Description. The following sections describe in detail the operational characteristics of the data handling subsystem.

3.5.3.1 Programmable Format Operations. The TP contains one (1) minor frame format that can be programmed in-flight. Up to eight different analog, serial digital or bilevel words can be inserted into the programmable format by use of the TP CONTROL quantitative command. The primary purpose of this format is to increase the sample rate on single or multiple telemetry channels for spacecraft diagnostic purposes. However, it is also useful for receiving selected telemetry channels during special mission maneuvers and/or events. The following sections describe the organization of the programmable format, the method for loading it, the verification of the format contents and other operational considerations.

3.5.3.1.1 Format Organization. The programmable format is organized into the standard 64 word minor frame format (see Figure 3.5.3.1.1-1) used by the other 15 minor frame formats on the Multiprobe and Orbiter spacecrafts. The first eight words of the 64 words are pre-programmed and cannot be changed. The first seven words (i.e., words 0 to 6) are standard to all 16 minor frame formats and the definition of these words is given in PC-454 (Reference: Paragraph 1.5.2). Word seven is unique to the programmable format. This word contains the full contents of the Random Access Memory (RAM) in the TP. The RAM contains 32 entries consisting of 8-bit words of information; eight of these entries are used to store the DIM address information associated with the eight programmed telemetry words. Section 3.5.3.1.3 will describe the contents of the RAM in detail.

The remaining 56 words in the format are used to program the selected telemetry words. These 56 words can be considered to contain a mini-minor frame that is eight words long and repeated seven times. That is, words 8 to 15, 16 to 23, 24 to 31, etc., all contain identically the same 8 word telemetry format. Each mini-minor frame can be programmed into any combination of telemetry words addressable through a DIM. Internal words, such as spacecraft time code (dynamic and static), format and bit rate status and minor frame count, cannot be selected for the programmable format. The eight words in the mini-minor frame can be all the same, all different, or any intermediate combination. The method for programming the format is explained in the next section.

Figure 3.5.3.1.1-2 shows an example of a programmable format. Bus Voltage Limiter Current (PLIMTI) has been assigned to alternate words in the 8 word format for the mini-minor frame (words 8, 10, 12, 14, 16, 18, etc., to word 62). ATTITUDE MEASUREMENT for ADP1 (ATTM1Z) has been assigned to every eighth word, starting with word 9. ADP status has been assigned to every fourth word, starting with word 11. Finally, PSI* Brightness (A*1BRH) has been assigned to every eighth word, starting with word 13.

3.5.3.1.2 Programming and Starting the Format. The programmable format is configured by the use of those versions of the TP CONTROL quantitative command that are identified as the PROGRAMMABLE FORMAT commands in PC-455 (TPCQ2 and TPCQ3 for TP1; TPCQB and TPCQC for TP2). To initially set up the format, it takes nine (9) transmissions of the quantitative command to the TP. The contents of each command is stored into a different location in the RAM to be used later by the TP in the execution of the format. The order in which the commands are sent is not important because each command contains the RAM address into which the format information is stored.

The structure of the PROGRAMMABLE FORMAT versions of the TP CONTROL quantitative command are given in PC-455 (Reference: Paragraph 1.5.1), but will also be discussed here. Bits 25 through 40 of the uplink command format are used for all quantitative command data. For the PROGRAMMABLE FORMAT commands, bits 33 through 35 are not used and can either be logic "0" or logic "1" bits, but bit 36 must always be logic "1". Bit 36 is used to select TP CONTROL ("0") or PROGRAMMABLE FORMAT ("1") versions of the TP CONTROL command. The RAM addresses (i.e., 23 through 31) are defined in bits 37 through 40 and bits 25 through 32 are used in two different ways, depending on which type of PROGRAMMABLE FORMAT command is sent to the RAM.

The first type of command (TPCQ3 or TPCQC) is used to define whether the selected channels are analog (conditioned or unconditioned) or digital (serial digital or an 8-bit bilevel word). This command must be sent to RAM address 23, and the contents of bits 25 through 32 must define whether the 8 programmed telemetry words are analog or digital. The eight command bits (i.e., 25 through 32) are assigned as follows to the eight telemetry words; bit 25 - word 3, bit 26 - word 4, bit 27 - word 5, bit 28 - word 6, bit 29 - word 7, bit 30 - word 0, bit 31 - word 1 and bit 32 - word 2. A logic "1" denotes an analog telemetry word and a logic "0" denotes a digital telemetry word. In summary, bits 25 through 32 define the type of telemetry word, bits 33 through 35 are not used, bit 36 must be a logic "1" and bits 36 through 40 must be binary 23 where bit 36 is the MSB, to properly transmit this first type of command.

The second type of command (TPCQ2 or TPCQB) is used to load the DIM address information associated with the selected telemetry words into the RAM. RAM addresses 24 through 31 are used to store the binary code for the DIM and the DIM channel that is assigned to the telemetry words to be programmed into the format. Programmed words 0 through 7 are assigned to RAM addresses 24 through 31 respectively. Bits 25 through 27 define the DIM and bits 28 through 32 define the DIM channel. Bits 25 and 28 are the MSBs for the two codes. Therefore, telemetry words 0 through 7 of the mini-minor frame are stored into RAM addresses 24 through 31 respectively. After all the RAM locations are filled and a change is required to a DIM or DIM channel address, only a single command with the corrected DIM information and its associated RAM address has to be sent to the TP, provided the new telemetry word is the same as the old telemetry word it replaces regarding analog or digital categories (otherwise, the corrected first command must precede this single command). The contents of the RAM are permanent for all time that power is applied to the TP.

Once RAM locations 23 through 31 are loaded with the correct information, the programmable format can be selected by using the TP CONTROL version of the TP CONTROL quantitative command. The code for the programmable format is "0011" and it must be inserted in bit locations 25 through 28 of the uplink command format. The other codes in the quantitative command for format, bit rate, DSU control, etc., must be for the current status of the TP if only the format is being changed to the programmable format. The structure for the TP CONTROL version is given in PC-455 (Reference: Paragraph 1.5.1). The programmable format starts at the next minor frame after the format select command is sent.

3.5.3.1.3 Format Verification. The DIM address information loaded into the RAM locations, and consequently the telemetry channels programmed into the format, can only be verified through the use of the format itself. Minor frame telemetry word 7 contains a complete readout of the 32 RAM locations. The first entry in the RAM (location

0) is read out in minor frame 0 of the major frame and all the following RAM locations are read out in the following minor frames. Since there are 64 minor frames in a major frame, the complete RAM readout is accomplished twice in each major frame.

Figure 3.5.3.1.3-1 defines the contents of all RAM locations. Starting with minor frame 24 of the major frame, the eight programmed telemetry words can be verified. If an error is detected, a new command can be sent to the RAM to correct the contents. The command can be sent while the programmable format is in operation.

3.5.3.1.4 <u>Operational Constraints and Considerations</u>. There are a number of constraints and considerations when operating the programmable format. These are as follows:

(a) RAM locations 23 through 31 are random when the TP is first powered on. Therefore, the programmable format should not be commanded into use before loading the desired telemetry words.

(b) RAM locations 0 through 15 are inaccessable by command, so they cannot inadvertently be altered. However, locations 16 through 31 can be accessed by command. Location 16 contains the most significant word of the dynamic time code and therefore, care should be exercised to prevent this word from being changed by sending a command to this location. Locations 17 through 22 are spares but could be used to store information because they are addressable and are read out in the telemetry format.

(c) All commands to the TP when loading the RAM should be spaced by one minor frame. If two commands are received in the space of one minor frame, the first command will be ignored.

(d) The contents of the RAM are permanent while the TP is powered. Consequently, the programmable format can be used again after it has been programmed and other minor frame formats have been used in the interim.

3.5.3.2 Telemetry Format and Bit Rate Operations. There are 16 minor frame formats and 13 bit rates that can be commanded into operation on either the Orbiter or Multiprobe spacecrafts. Detailed information about format layout and overhead words for each format is contained in PC-454 (Reference: Paragraph 1.5.2). Either spacecraft will respond to a command containing any telemetry format and any bit rate. However, commonality between the two spacecrafts exists totally only for the bit rates. There are five (5) formats that operate properly on the Multiprobe and 14 on the Orbiter. Consequently, only three (3) formats are common, i.e., the ACS, Command Memory Readout and Programmable formats.

If a telemetry format designed for the Orbiter is commanded into operation on the Multiprobe, the TP will address the DIM channels in accordance with the Orbiter pre-programmed format. As a result, the format will contain data that is meaningless to the ground software which is programmed to receive known telemetry parameters in each word of the commanded format. However, the data can be made useful, if necessary, by using PC-454 (Reference: Paragraph 1.5.2) to compare the differences between the DIM assignments on the two spacecrafts. Therefore, caution should be exercised when commanding telemetry formats to insure that the correct formats are used on each spacecraft.

Information regarding TM data times is shown in Table 3.5.3.2-1.

The formats and bit rates are commanded into operation through the TP CONTROL quantitative command, (TPCQ1 or TPCQA, as explained in PC-455 (Reference: Paragraph 1.5.1). Bits 25 through 28 of the uplink command format are used to code the telemetry formats and bits 29 through 32 are used for the telemetry bit rates. Telemetry verification is through word 3 of all 16 telemetry minor frame formats. The first four (4) bits of this 8-bit word gives the status of the format selected and the remaining four (4) bits gives the status of the bit rate selected. The 4-bit codes in this format word are identical to the codes used to command the format and/or bit rate into operation.

One constraint on the use of this command is that two different quantitative commands should not be sent to the TP in the space of one minor frame time. Since the commands are loaded into a shift register when received and held until the next minor frame, only the last command will be executed.

Another consideration is that the status of the Convolutional Encoder and Data control bits (bits 39 and 40 of the uplink command word) must be inserted in the quantitative command to insure a mode change does not take place, such as commanding OFF the data output of the TP (Reference: Paragraph 1.5.17).

The spacecraft should not be operating in a telemetry format that reads out coast time when any one of the probes' coast timer is being loaded. This may cause an attempt to simultaneously write into and read out of the coast timer, thus jeopardizing valid write-in of the desired coast time (Reference: Paragraph 1.5.18).

TABLE 3.5.3.2-1

PIONEER VENUS TELEMETRY DATA TIMES

BIT RATE (bps)	MINOR FRAME PERIOD (SEC)	MAJOR FRAME PERIOD	MINOR FRAME WORD RATE (bps)
4096	1/8	8 sec	64
2048	1/4	16 sec	32
1024	1/2	32 sec	16
682-2/3	3/4	48 sec	10-2/3
512	1	1 min 4 sec	8
341-1/3	1-1/2	1 min 36 sec	5-1/3
256	2	2 min 8 sec	4
170-2/3	3	3 min 12 sec	2-2/3
128	4	4 min 16 sec	2
64	8	8 min 32 sec	1
32	16	17 min 4 sec	1/2
16	32	34 min 8 sec	1/4
8	64	1 hr 8 min 16 sec	1/8

3.5.3.3 PCM Encoder Operations. The PCMEs are turned ON and OFF by three discrete commands, i.e., PCM ENCODER 1 ON/2 OFF (PCM19 or PCMA9), PCM ENCODER 2 ON/1 OFF (PCM29 or PCMB9) and PCM ENCODERS OFF (PCM1Ø or PCMAØ). When one PCM is commanded ON, the other PCM is simultaneously commanded OFF. This prevents the telemetry data from being scrambled by two PCMEs responding to the instructions from the operating TP.

At initial spacecraft turnon, a Telemetry Processor should be turned ON before the PCM Encoder is turned ON. If, subsequently, the TP is turned OFF and then ON, or the TP's are switched, DIM ON status should be re-established by either a DIM configuration command, or by turning the PCM Encoder OFF and ON again to establish initial conditions (Reference: Paragraph 1.5.18).

3.5.3.4 Spacecraft Time Code Operations. The spacecraft time code consists of a 24-bit code (DCLOK1, DCLOK2 and DCLOK3) that is inserted into the first three 8-bit words of Subcom A of all the 16 minor frame formats. The time code has a resolution of 125 milliseconds and can count time for 24.27 days. At the beginning of each major frame, the time code is updated and frozen for the entire major frame. The major frame, as it exits the TP, is delayed 30.5 microseconds relative to Universal time. The accuracy of the time code is a function of the 50 ppm stability of the TP master oscillator.

The spacecraft time code also appears in the ACS, Engineering and Command Memory Readout formats. The 8 MSBs of the time code (DCLOK1) appears in the Command Memory Readout format, the 8 LSBs (DCLOK3) appear in the ACS format and the 16 LSBs (DCLOK2 and DCLOK3) are in the Engineering format. Originally, these time code entries were intended to be the dynamic time code that is updated on a telemetry word basis by the TP, but through a programming error, these time code words are the same as those in Subcom A. Therefore, it should be recognized that these time code words in the minor frame do not provide any additional time code information.

3.5.3.5 4096 Second Clock Operations. The TP generates a squarewave clock with a period of 4096 seconds that is used as an accurate timing reference by the command processor to start the command memory. When the Stored Command Logic (SCL) within the COMMAND PROCESSOR is commanded into the TIMED START mode, the SCL waits until the next one-to-zero transition of the 4096 second clock and then starts processing the contents of the command memory.

The 4096 second clock is derived in the TP from the 24-bit time code that is inserted into the first three words of Subcom A of all the minor frame formats. The second MSB of DCLOK2 is used as the clock, i.e., the bit that charges state every 2048 seconds. The time code is updated at the beginning of each major frame. Therefore, the occurrence of the 4096 second clock can be resolved to the time of one major frame without any special procedures. At 2048 bps the resolution is 16 seconds. To improve this resolution to one minor frame time, a command can be inserted into the command memory that changes the state or mode of a parameter telemetered in the minor frame. By doing this, the resolution can be improved to 250 milliseconds at 2048 bps.

There are three errors associated with the use of the 4096 second clock that are inherent in the way the clock is implemented in the TP and used by the SCL. The errors are the 125 millisecond resolution in starting the SCL, the bit rate dependance of the clock output in that the 24-bit time code is updated on a word basis, and the stability of the command processor which effects the execution of events when time delays are programmed in the command memory. These errors are discussed in detail in Section 3.6.3.2.3.2.

3.5.4 Command Response. Table 3.5.4-1 presents the command responses for the data handling subsystem. The table lists every command that directly affects the subsystem and the telemetry indication that verifies the proper execution of the command. The mnemonics for each of the command and telemetry parameters are also included.

TABLE 3.5.4-1

COMMAND RESPONSES FOR DATA HANDLING SUBSYSTEM

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	Title	Response	Mnemonic	Indication and/or Remarks
Telemetry Processor Control (TPCQ1 for TP1; TPCQA for TP2) FMT = XXXY (Format Select)	Orbiter Engr (0000) Bus Engr (0001) Bus Entry (0010) Programmable (0011) ACS (0100) Command Memory Readout (0101) Playback (0110) Data Memory Readout (0111) Launch/Cruise (1000) Periapsis A (1001) Periapsis B (1010) Periapsis C (1011) Periapsis D (1100) Periapsis E (1101) Apoapsis A (1110) Apoapsis B (1111)	The format select command selects one of the mission selectable formats. Execution of the selected format change is minor frame synchronous.	Internal Word 3	Format: Orbiter Engineering (0000) Bus Engineering (0001) Bus Entry (0010) Programmable (0011) ACS (0100) Command Memory Readout (0101) Playback (0110) Data Memory Readout (0111) Launch Cruise (1000) Periapsis A (1001) Periapsis B (1010) Periapsis C (1011) Periapsis D (1100) Periapsis E (1101) Apoapsis A (1110) Apoapsis B (1111)
Telemetry Processor Control (TPCQ1 or TPCQA), BR = XXXX (Bit Rate Select)	8 bps (0000) 16 bps (0001) 32 bps (0010) 64 bps (0011) 128 bps (0100) 170-2/3 bps (0101) 256 bps (0110) 341-2/3 bps (0111) 512 bps (1000) 682-2/3 bps (1001) 1024 bps (1010) 2048 bps (1011) 4096 bps (11xx) (where x = don't care bits).	The bit rate select command selects one of 13 mission selectable bit rates. Execution of the selected bit rate change is minor frame synchronous.	Internal Word 3	Bit Rate: 8 bps (0000) 16 bps (0001) 32 bps (0010) 64 bps (0011) 128 bps (0100) 170-2/3 bps (0101) 256 bps (0110) 341-2/3 bps (0111) 512 bps (1000) 682-2/3 bps (1001) 1024 bps (1010) 2048 bps (1011) 4096 bps (11xx) (where x = don't care bits equal to that which was cmded)

TABLE 3.5.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	**Title**	**Response**	**Mnemonic**	**Indication and/or Remarks**
Telemetry Processor Control (TPCQ1 or TPCQA), SUBC = E/D (Subcarrier Control)	Subcarrier ON/OFF ON: 1 OFF: 0	The subcarrier ON/OFF command controls the state of the subcarrier output.	N/A	No telemetry indication; check RF carrier for absence or presence of subcarrier.
Telemetry Processor Control (TPCQ1 or TPCQA), Conv = E/D; Data = E/D (Convolutional Encoder Data)	Convolutional Encoder/Data - Unencoded Data: 11 or 10 Encoded: 01 Data OFF: 00	The convolutional encoder bypass/encode command bypasses or encodes the telemetry data and controls the modulation on the subcarrier prior to transmission.	N/A	No telemetry indication; proper operation with or without convolutional decoder. If data has been commanded OFF, loss of frame sync lock occurs.
Telemetry Processor Control (TPCQ2 or TPCQB), DIM = 0 - 7, (Programmable format; DIM select)	DIM Select (0 to 7) (000 to 111)	Execution of all programmable mode select commands are minor frame synchronous. The DIM and channel select commands select one of eight telemetry signals to be dwelled on. Any combination of up to eight telemetry words can be selected.	N/A	Same as commanded code; appears in RAM playback in minor frame format word 7.
	DIM Channel Select (0 to 31) (00000 to 11111)		N/A	Same as commanded code; appears in RAM playback in minor frame format word 7.

TABLE 3.5.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	**Title**	**Response**	**Mnemonic**	**Indication and/or Remarks**
Telemetry Processor Control (TPCQ2 or TPCQB). RAM = 24 - 31 (Programmable format; RAM Address)	RAM Address Location (24 to 31) *(11000 to 11111)*	Addresses for Programmable words 0 to 7.	N/A	No telemetry indication; verification of data above verifies correct address location.
Telemetry Processor Control (TPCQ3 or TPCQC) RXXX = D/A (Programmable format; Digital or Analog Select).	Analog/Digital Data Analog: 1 Digital: 0	This command specifies whether each of the 8 programmable words are analog or digital.	N/A	Same as commanded code; appears in RAM playback in minor frame word 7.
	RAM Address Location (23) (10111)	Address for Analog/Digital data specification.	N/A	No telemetry indication; verification of data above verifies correct address location.
PCM19 PCMA9	PCM Encoder 1 ON/ 2 OFF.	Discrete command which will turn PCM Encoder 1 ON and PCM Encoder 2 OFF.	DPCM1S DPCM2S	PCM Encoder 1 ON/OFF: ON (Logic 1). PCM Encoder 2 ON/OFF: OFF (Logic 0).
PCM29 PCMB9	PCM Encoder 2 ON/ 1 OFF	Discrete command which will turn PCM Encoder 2 ON and PCM Encoder 1 OFF.	DPCM2S DPCM1S	PCM Encoder 2 ON/OFF: ON (Logic 1) PCM Encoder 1 ON/OFF: OFF (Logic 0)
PCM1Ø PCMAØ	PCM Encoders OFF	Discrete command which will turn both PCM Encoders OFF.	N/A	Loss of all Downlink Telemetry.

TABLE 3.5.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	Title	Response	Mnemonic	Indication and/or Remarks
PCM Encoder DIM Control. PCMQ1 PCMQ2	DIM 0 DIM 1 DIM 2 DIM 3 DIM 4 DIM 5 DIM 6 DIM 7 Coding: ON: 00 or 10 OFF: 01 or 11	Quantitative command used to turn OFF a failed DIM. In normal operation, all DIMs are automatically turned ON two minor frames after receipt of the PCM Encoder ON command.	N/A	No DIM telemetry status; correct telemetry from all DIMs in the ON condition. Telemetry from OFF DIMs is indeterminate.
TLM19 TLMA9	Telemetry Processor 1 ON/2 OFF.	Discrete command which will turn Telemetry Processor 1 ON and Telemetry Processor 2 OFF.	DTLM1S	Telemetry Processor 1 ON/OFF: ON (Logic 1)
			DTLM2S	Telemetry Processor 2 ON/OFF: OFF (Logic 0)
TLM29 TLMB9	Telemetry Processor 2 ON/1 OFF.	Discrete command which will turn Telemetry Processor 2 ON and Telemetry Processor 1 OFF.	DTLM2S	Telemetry Processor 1 ON/OFF: OFF (Logic 0)
			DTLM1S	Telemetry Processor 2 ON/OFF: ON (Logic 1)
TLM1Ø TLMAØ	Telemetry Processors OFF.	Discrete command which will turn both Telemetry Processors OFF.	N/A	Loss of all downlink telemetry.

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****                                 ****
****    This Figure is a Foldout.    ****
****                                 ****
****          See APPENDIX C         ****
****                                 ****
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This Figure is a Foldout. See APPENDIX C

Figure 3.5.1-1

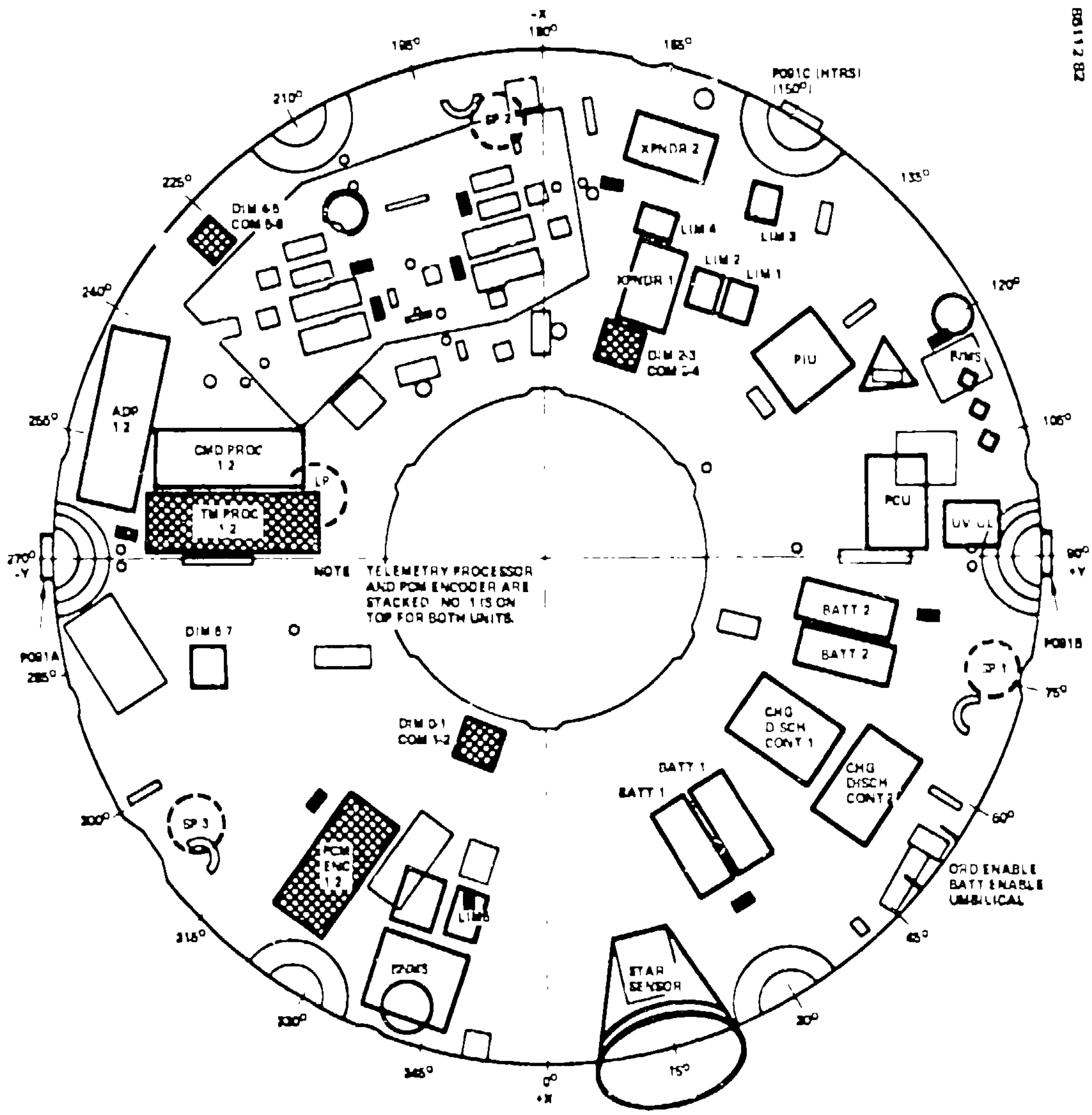

FIGURE 3.5.1-2 SHELF LAYOUT FOR DATA HANDLING SUBSYSTEM

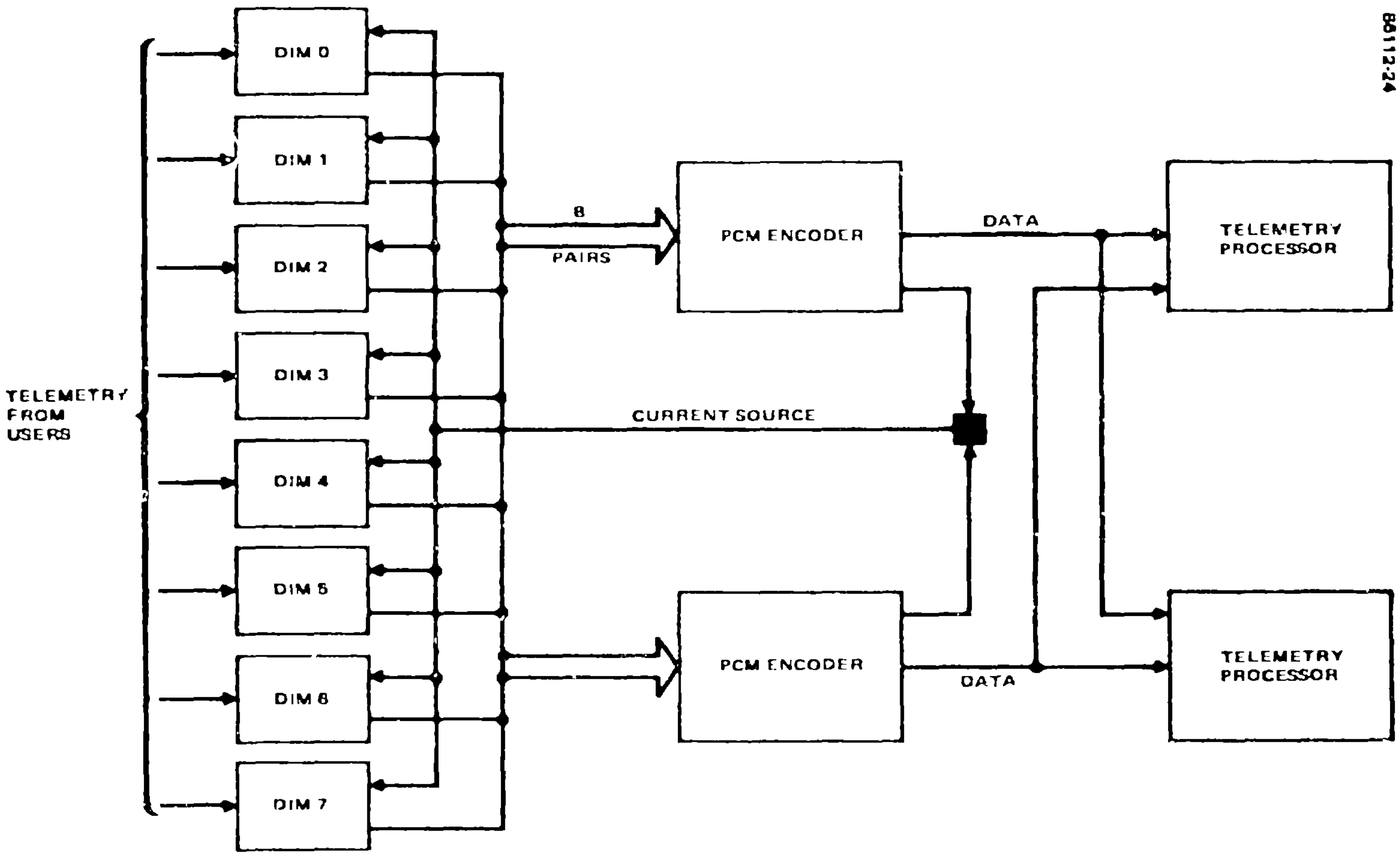

FIGURE 3.5.1-3. MULTIPROBE DATA HANDLING SUBSYSTEM REDUNDANCY BLOCK DIAGRAM

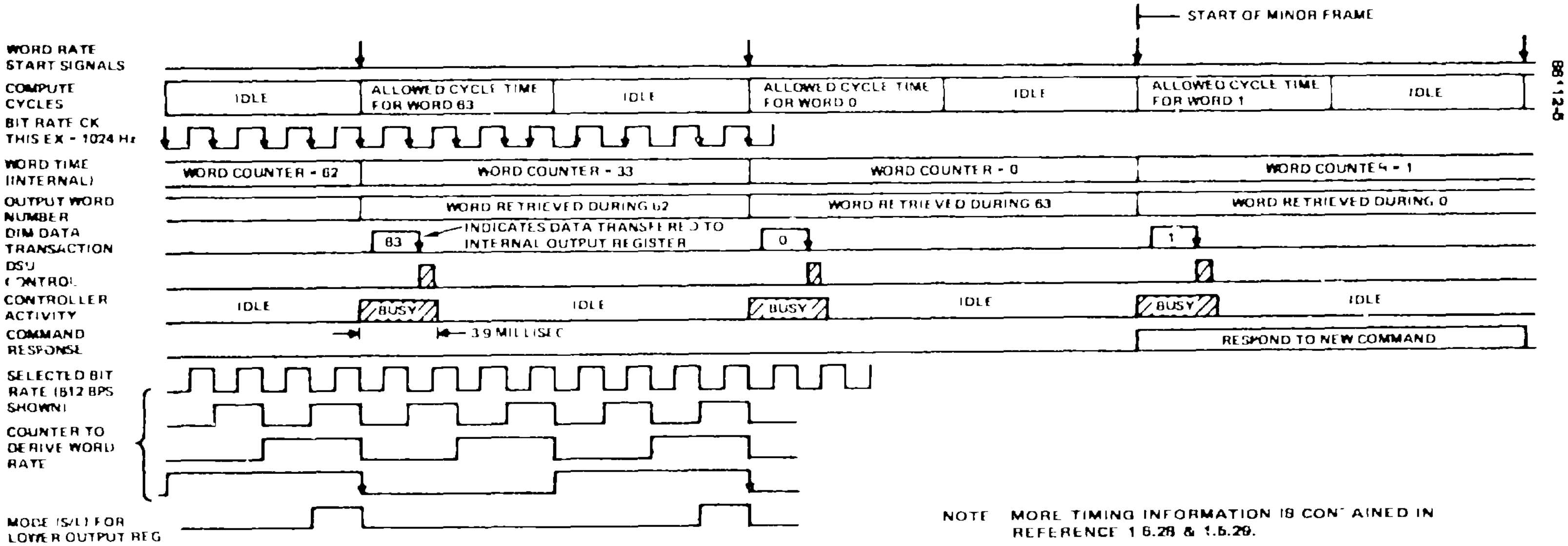

Figure 3.5.2.3-1. Telemetry Processor Timing

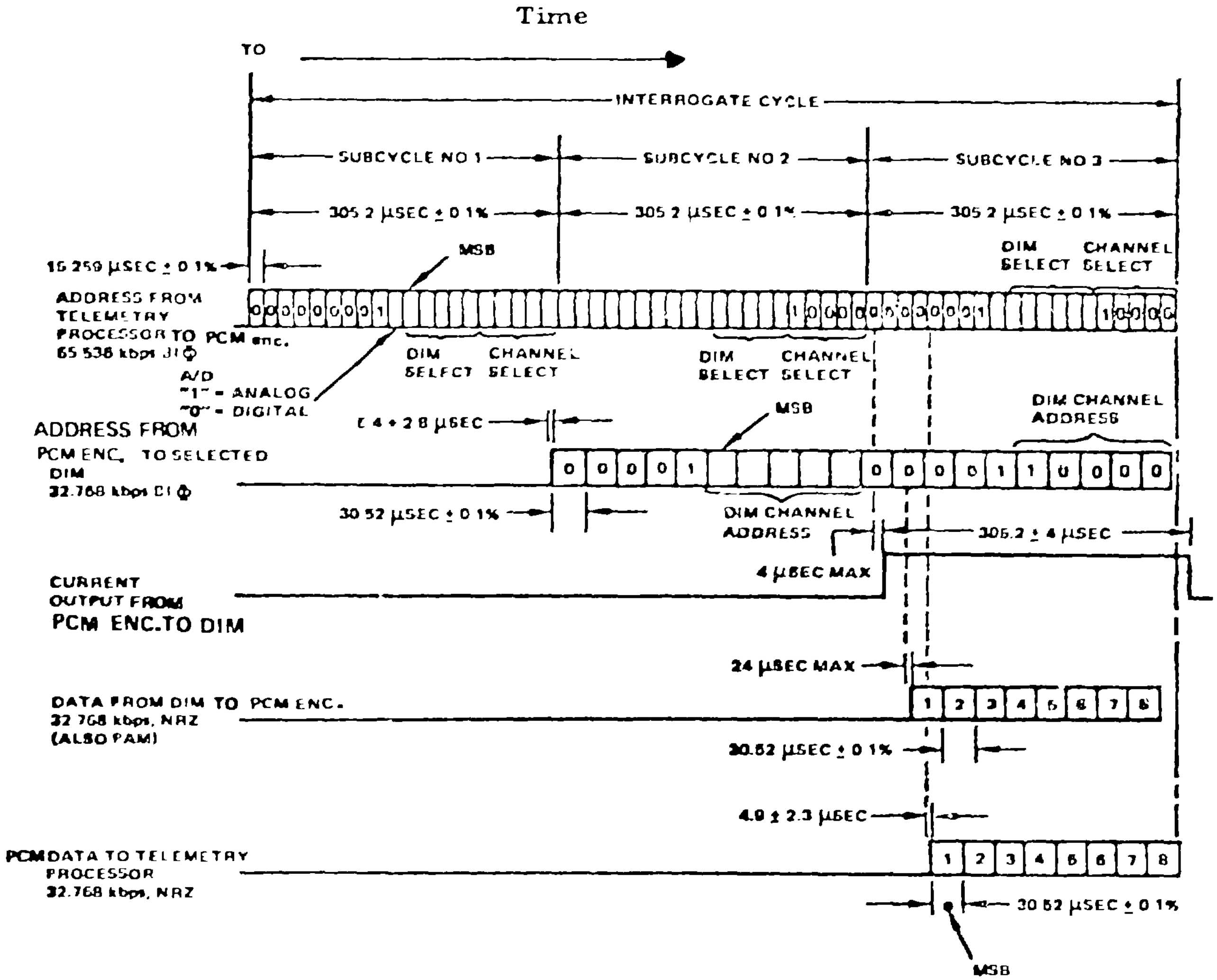

Figure 3.5.2.3-2. PCM Encoder Timing Diagram

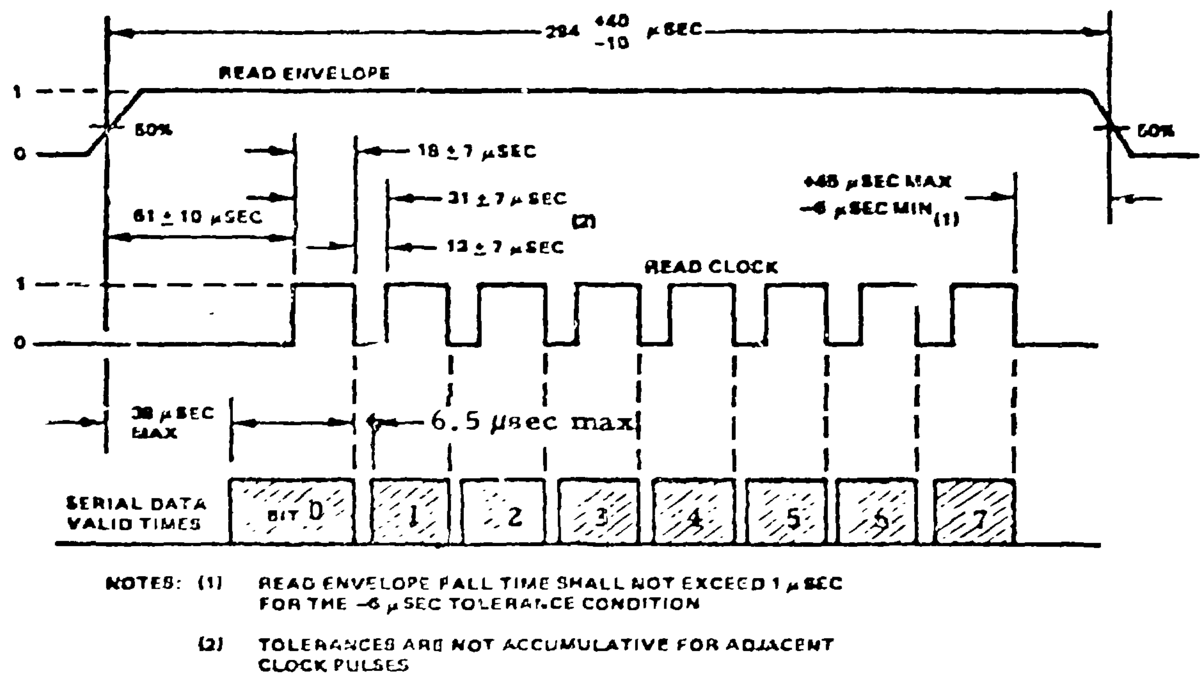

Figure 3.5.2.3-3. DIM Serial Digital Timing Diagram

Revision

NOTE: PW = PROGRAMMABLE WORD

PROGRAMMABLE FORMAT

0 ← FRAME SYNC	1 FRAME SYNC	2 FRAME SYNC →	3 FORMAT BITRATE ID	4 S/C ID SCID	5 SUBCOM A	6 SUBCOM B	7 RAM
8 PW 0	9 PW 1	10 PW 2	11 PW 3	12 PW 4	13 PW 5	14 PW 6	15 PW 7
16 ↓	17 ↓	18 ↓	19 ↓	20 ↓	21 ↓	22 ↓	23 ↓
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48 ↓	49 ↓	50 ↓	51 ↓	52 ↓	53 ↓	54 ↓	55 ↓
56 PW 0	57 PW 1	58 PW 2	59 PW 3	60 PW 4	61 PW 5	62 PW 6	63 PW 7

78648-49X

FIGURE 3.5.3.1.1-1. PROGRAMMABLE FORMAT FOR ONE MINOR FRAME

PROGRAMMABLE FORMAT

0 ← FRAME SYNC	1	2 →	3 FORMAT BITRATE ID	4 S/C ID SCID	5 SUBCOM A	6 SUBCOM B	7 RAM
8 PLIMTI	9 ATTM1Z	10 PLIMTI	11 ADP STATUS	12 PLIMTI	13 A*1BRM	14 PLIMTI	15 ADP STATUS
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

78640-49

FIGURE 3.5.3.1.1-2. EXAMPLE OF PROGRAMMABLE FORMAT FOR ONE MINOR FRAME

Revision

BIT / MINOR FRAME	0 (MSB)	1	2	3	4	5	6	7 (LSB)	COMMENTS
0	ID	X	2 ON	1 ON	0	DSU STATE			ID = 0 FOR BUS AND 1 FOR ORBITER 2 ON AND 1 ON = 1 WHEN SPECIFIED DSU IS ON 3 BITS SHOW DSU IN 1 OF 8 POSSIBLE STATES.
1	TEMPORARY STORAGE USED TO PROCESS USER RATE DATA								MINOR FRAME, MAJOR FRAME AND 4096 SEC RATES ARE PROCESSED AND TRANSFERRED TO THE INTERNAL USER RATE REGISTER (INVALID DATA)
2	FRAME FORMAT				BIT RATE				MOST SIGNIFICANT 8 BITS OF QUANTITATIVE COMMAND
3	DSU COMMAND			DMA	X	S	C	D	LEAST SIGNIFICANT 8 BITS OF QUANTITATIVE COMMAND
4	0	0	WORD COUNTER						6-BIT COUNTER
5	0	0	MINOR FRAME COUNTER						6-BIT COUNTER
6	DSU STATE			0	0	0	0	0	3 BITS TO SHOW DSU IN 1 OF 8 POSSIBLE STATES.
7	DYNAMIC TIMECODE WORD 0								LEAST SIGNIFICANT WORD OF 4 DYNAMIC TIMECODE WORDS (8 BITS)
8	DYNAMIC TIMECODE WORD 1								THIRD WORD OF 4 DYNAMIC TIMECODE WORDS (8 BITS)
9	DYNAMIC TIMECODE WORD 2								SECOND WORD OF 4 DYNAMIC TIMECODE WORDS (8 BITS)
10	STATIC TIMECODE WORD 1								LEAST SIGNIFICANT WORD OF 3 STATIC TIMECODE WORDS.
11	STATIC TIMECODE WORD 2								SECOND WORD OF 3 STATIC TIMECODE WORDS
12	STATIC TIMECODE WORD 3								MOST SIGNIFICANT WORD OF 3 STATIC TIMECODE WORDS
13	FORMAT INFORMATION								LEAST SIGNIFICANT 8 BITS OF 12-BIT FORMAT WORD (INVALID DATA)
14	S/C ID		MINOR FRAME COUNT						SPACECRAFT ID = 00 FOR BUS AND 10 FOR ORBITER 6 BITS FOR MINOR FRAME COUNT
15	0	0	0	0	FORMAT INFORMATION				MOST SIGNIFICANT 4 BITS OF 12-BIT FORMAT WORD
16	DYNAMIC TIMECODE WORD 3								MOST SIGNIFICANT WORD OF 4 DYNAMIC TIMECODE WORDS (8 BITS)
17	SPARE								WILL INITIALIZE WITH ALL BITS = 0
18	SPARE								WILL INITIALIZE WITH ALL BITS = 0
19	SPARE								WILL INITIALIZE WITH ALL BITS = 0
20	SPARE								WILL INITIALIZE WITH ALL BITS = 0
21	SPARE								WILL INITIALIZE WITH ALL BITS = 0
22	SPARE								WILL INITIALIZE WITH ALL BITS = 0
23	PW3 TYPE	PW4 TYPE	PW5 TYPE	PW6 TYPE	PW7 TYPE	PW0 TYPE	PW1 TYPE	PW2 TYPE	SPECIFIES TYPE OR PROGRAMMABLE WORDS 0-7 ANALOG = 1 AND DIGITAL = 0
24	DIM NO			CHANNEL NO					PROGRAMMABLE WORD 0
25	DIM NO			CHANNEL NO					PROGRAMMABLE WORD 1
26	DIM NO			CHANNEL NO					PROGRAMMABLE WORD 2
27	DIM NO			CHANNEL NO					PROGRAMMABLE WORD 3
28	DIM NO			CHANNEL NO					PROGRAMMABLE WORD 4
29	DIM NO			CHANNEL NO					PROGRAMMABLE WORD 5
30	DIM NO			CHANNEL NO					PROGRAMMABLE WORD 6
31	DIM NO			CHANNEL NO					PROGRAMMABLE WORD 7

NOTE: X SIGNIFIES UNUSED BIT WHICH MAY BE IN LOGIC 0 OR 1 STATE

IN WORD 3
- S = SUBCARRIER ON/$\overline{\text{OFF}}$
- C = CONVOLUTIONAL ENCODER BYPASS/$\overline{\text{ENCODE}}$
- D = DATA ON/$\overline{\text{OFF}}$

FIGURE 3.5.3.1.3-1. RAM CONTENTS

3.6 COMMAND SUBSYSTEM

3.6.1 Subsystem Description. The command subsystem contains all the command processing capability on the spacecraft. The subsystem provides the capability to decode, process and distribute ground commands to spacecraft subsystems and scientific instruments as well as store commands for later execution. Firing pulses are also provided for pyrotechnic devices. Commands may be either discrete or quantitative. A functional block diagram of the subsystem is presented in Figure 3.6.1-1 (Appendix C).

The subsystem consists of two (2) redundant Command Processors (CPs), seven (7) Command Output Modules (COMs) and two (2) Pyrotechnic Control Unit (PCUs). On the spacecraft equipment shelf, these units are arranged as shown in Figure 3.6.1-2. The two (2) CPs are connected to the essential bus and are not capable of being commanded off. All seven (7) COMs receive secondary power from each CP. The associated COM is power strobed on prior to the issuance of a command output. After the command is issued, the COM turns itself off. The PCU receives control power from the essential bus and squib driver power from a lower voltage tap from the spacecraft batteries to minimize essential bus voltage drops during pyrotechnic device firings. Figure 3.6.1-3 shows the major cross-strapping between the elements of the subsystem.

Real-time ground-generated commands are transmitted via the RF uplink to the spacecraft receivers. Each receiver is connected to a single CP, i.e., there is no cross-strapping. A specific receiver/CP combination is selected by transmitting the RF carrier frequency associated with the receiver in the desired pair. On either the Multiprobe spacecraft or Orbiter spacecraft, there is a unique RF carrier frequency assigned to each receiver. The uplink format is PCM/FSK/PM and the command subcarrier output to the CP is PCM/FSK. The tone frequency for a logic "1" is 250 Hz and for a logic "0" is 100

Hz, and the command bit rate is 4 bits per second.

The uplink command format is 48 bits long and is detailed in the lower portion of Figure 3.6.1-1. This format provides the capability to address either the Multiprobe spacecraft or Orbiter spacecraft, to address either CP, to process real-time commands or store the commands in memory for later execution, to store time delays in memory and to distribute two types of commands to spacecraft users, namely discrete and quantitative commands. A 48-bit preamble of alternating logic "1" and logic "0" tones (250 Hz and 100 Hz respectively) is required once prior to sending a single command or multiple contiguous commands to the spacecraft.

The two CPs are cross-strapped such that the output of the FSK demodulator portion of each CP can be processed by either CP. By using the address bit in the uplink command format, either CP can be selected to process the transmitted uplink command. The FSK demodulator verifies the 13 bit sync code prior to sending the transmitted command to the central command processing portion (Figure 3.6.1.-3) of the real-time processor of either CP. In the central portion, the spacecraft address, the CP address and the poly code are verified before the command is routed to the addressed COS or to the command memory. The polycode is used to detect errors in the 28 information bits (i.e., bits 13 through 40) of the command format.

The subsystem contains two command memories (one in each CP), each of which can store 128 entries. Each entry, which can be a discrete or quantitative command or a time delay, is 24 bits long and is contained in bit locations 17 through 40 of the command format. Once the command sequence is loaded into memory, the sequence can be executed by sending a real-time start command, closure of the spacecraft separation switch or by use of the 4096 second clock from the Telemetry Processor. The 4096 second clock is used as an accurate time reference to start the memory at a later time. Time delays from 125 millisecond to 291 hours can be loaded into each slot of the command memory. The command resolution and time delay resolution for the memory is 125 milliseconds. Commands issued from the memory are executed within 125 microseconds, not including delays such as mechanical relay response time. Timing in the CP permits nearly concurrent processing of commands from the memory and RF uplink. RF uplink commands to one CP and memory commands from the other CP must not address the same COM within 62.5 milliseconds to avoid loss of both commands.

The CP routes all commands to the individual COMs for distribution to the users. Each COM can supply 64 discrete commands and 4 quantitative commands. Different subsystem and scientific instrument users are assigned to the seven (7) COMs. Almost all commands are redundant, so the primary command is sent to one COM and the redundant (or back-up) command to a different COM.

The subsystem also provides the firing pulses for all pyrotechnic devices on the spacecraft through two PCUs. Each PCU receives the standard discrete command output from the COMs and current amplifies these pulses to the level required to actuate the pyro device. Each PCU contains six (6) squib drivers each of which can provide a minimum of 5 amps firing current to three (3) squibs. Each PCU is divided into two equal redundant halves so that pyrotechnic devices with redundant squibs can be fired simultaneously.

3.6.2 Units Descriptions

3.6.2.1 Command Processor. The CP is the main element in the command subsystem. The CP receives a PCM/PSK subcarrier from the transponder in the communications subsystem and relays control signals to the COMs to provide both discrete and quantitative commands to subsystem and scientific instrument users. A shift register memory is provided in the CP which holds a maximum of 128 entries so that commands and time delays can be stored and then executed at a later time.

When essential bus power is applied to the CP initially, the unit will turn-on without generating any spurious commands. It takes from 0 to 60 seconds for the CP to become operational after the essential bus power is applied, due to the cyclic fuse in the CP (Refer to Section 3.6.2.1.7). When power is applied to the CP, the SCL remains OFF until commanded ON; receivor reverse logic configuration will be random.

The major functional components of the CP, as shown in Figure 3.6.2.1-1, are the FSK demodulator, stored command logic, receiver reverse logic, real time processor, telemetry logic, output control logic and power supply. In the following sections, these components are described.

3.6.2.1.1 FSK Demodulator. The FSK demodulator provides the interface with the communication subsystem for uplink real-time command processing. Each CP contains a single FSK demodulator that is connected by a three wire interface to a single transponder; there is no cross-strapping between transponders and demodulators. The FSK demodulator is selected by frequency-selection of the spacecraft transponder connected to it. Either of the two redundant CPs can be selected for processing the output of either of the redundant FSK demodulators by use of the address bit in the uplink command format; i.e., there is cross-strapping between the FSK demodulators and the central command processing portions of the real-time processor of each CP. The central portion of the CP provides power from the essential bus and a 1024 Hz timing signal to the FSK demodulator.

The input FSK command subcarrier is converted to a return-to-zero (RZ) data output, a bit timing clock and a sync code verification pulse. These three signals are used internally in the CP and are also cross-strapped to the redundant CP. The FSK command subcarrier consists of tone frequencies of 100 Hz and 250 Hz, representing logic zero and logic one data respectively. The bit rate of the FSK input is 4 bits per second. The demodulator also receives a transponder in-lock signal from the transponder that indicates when the transponder is phase-locked to an uplink carrier. If this signal is a logic zero (i.e., no carrier), the demodulator is inhibited from detecting the uplink sync pattern, and consequently, the sync code verification pulse output to the CPs will be a logic zero. The sync code verification output provides a pulse to both CPs after a valid 13-bit sync code has been detected.

As shown in the functional block diagram in Figure 3.6.1-1, the FSK subcarrier signal is first applied to an input amplifier stage. The amplifier drives 3 bandpass filters, one tuned to the logic zero subcarrier tone, a second tuned to the logic one subcarrier tone, and the third tuned to the 1400 Hz noise reference. The output of each filter is rectified through a precision half-wave rectifier that gives both a negative and positive output. The positive output associated with the "1" filter is summed with the negative output associated with the "0" filter in a conventional amplifier summing stage. From here, the output of the amplifier is fed to a low pass filter that drives a hard limiter which converts the positive and negative voltages into TTL levels. The resulting limiter output is sampled and temporarily held in a flip-flop before being clocked out to the real-time processor by the bit synchronizer.

The negative outputs of both the "1" and "0" filter/rectifiers are sent to the FSK demodulator squelch circuit along with the output of the noise filter. The squelch is a comparison circuit that compares the energy in the noise filter bandwidth to the total energy in the two tone filter bandwidths in order to determine whether a subcarrier is present or not. The noise filter is an active two-pole filter with a center frequency of 1400 Hz. Since the noise input to the tone filters is a function of the input signal strength to the transponder, the output of the noise filter is used as the reference to determine if a signal is present or not. This mechanization is called a variable threshold squelch. The output of the noise filter is sent to rectifier and integrator circuits before being compared with the integrated output of the tone filters. The comparator circuit provides an enable signal to the bit synchronizer when a signal is present and inhibits the bit synchronizer when there is no subcarrier input. The status of the squelch state is provided in telemetry by CDMD1S for CP1, and CDMD2S for CP2 (A logic "1" indicates the demod is unsquelched, and a logic "0" indicates that the demod is squelched). The performance of the squelch circuit is a function of uplink received signal strength. For an input level of -110 dBm or greater, the PSK demodulator will remain "unsquelched" indefinitely in the absence of a subcarrier. However, for lower signal strengths the PSK demodulator will "squelch" when the subcarrier is removed (i.e., the uplink command is completed) as a function of signal level. The characteristic of the squelch circuit is given in Figure 3.6.2.1.1-1.

The clock that is used to output the data from the PSK demodulator is generated by the bit synchronizer. The bit synchronizer receives a 1024 Hz square wave from the output control logic and divides it to a 4-bit per second variable phase clock. The phase of the clock is set during the acquisition time. At the beginning of a command sequence, a preamble of 48 bits of alternating logic ones and zeros must be transmitted. After squelch is released, the first zero-to-one data transition from the hard limiter resets the bit synchronizer to a phase which will cause the data flip-flop to be clocked at the optimum sample time. The phase of the clock is automatically adjusted in either direction to an accuracy of one-sixteenth of a bit time as required by the incoming data. After initial resetting of the bit synchronizer, the positions of the transitions in incoming data with respect to the phase of the clock are constantly monitored. As long as the transitions fall within a given time "window", the timing will remain unchanged. If a data transition occurs before or after the window, the clock phase will be shifted by one-sixteenth of a bit time in the appropriate direction to maintain optimum bit timing. This process will continue for the duration of a command sequence.

3.6.2.1.2 Real Time Processor. The PSK demodulator transmits RZ data, a 4 Hz clock and the sync code verification pulse to the Real Time Processor (RTP). These signals are received by the RTPs of both CPs, but only the CP that detects the appropriate address bits processes the data from the active PSK demodulator.

Before the RTP will begin processing the incoming uplink command, (either a real time command or a command intended to be stored for later execution) the sync code verification pulse must be received from an active PSK demodulator. After the sync code verification pulse is detected, the incoming command is simultaneously loaded into a shift register, fed to the address check logic and fed to the polynominal code check logic. From the uplink command format given in Figure 3.6.1-1, it can be observed that bits 13, 14 and 15 contain the spacecraft and CP address information. The RTP performs two address checks on these three bits. If the first address check detects an error, the input control logic is reset until the next sync code verification pulse is received. At this check, there is no telemetry indication that the command was not accepted. The second address check is performed when the last bit (i.e., bit 47) of the command is loaded into the shift register. At this time, the polynomial code check is also completed. Once the shift register is loaded, the polynomial code check and two address check states are examined. If no errors are found, and the command is to be routed to a COM, a processing pulse is sent to the output control logic. If the command is to be routed for storage, the command is routed directly to the SCL. If either the polynomial code or second address check is false, a reject bit (logic "1") is sent to telemetry (i.e., CREJXS, where X = 1 for CP1 and X = 2 for CP2). The reject bit does not prevent the processing of subsequent commands, and it can be reset by the CP CONFIGURE quantitative command (CPCQ1 for CP1, or CPCQ2 for CP2). When all checks are satisfactory, a counter in the telemetry logic is incremented by one and the current count is provided as telemetry output CCBDXC, where X was defined previously.

The timing in the CP is designed to accommodate real time and stored command executions nearly simultaneously. The main clock generates 8 Hz (i.e., 62.5 msec half period) time slots that are assigned alternately to real time and stored command processing. Bit 16 in the uplink command format is used to determine whether the output is to go to the output control logic or stored command logic. If the data are transferred to the output control logic section, the RTP adds a "redundant code check" bit to the outgoing word to indicate whether the information is valid or invalid, i.e., to indicate that the data bits have not picked up an error in transmission. The output control logic responds at the proper time to the processing pulse from the RTP by sending back to the RTP a high speed output clock pulse (generated in the output control logic for the purpose of transferring in data) to start the output process at the start of the next real-time time slot.

3.6.2.1.3 Stored Command Logic. The Stored Command Logic (SCL) consists of the command memory, memory control logic and configuration control logic. The SCL provides the capability for spacecraft control when real-time commands through the RF uplink are not available. Any command that can be executed from the ground in real-time can be stored in the command memory and executed under control of the SCL. All stored command mnemonics carry, as a sixth alphanumeric, the letter "A" for CP1, or the letter "B" for CP2. Sequences of commands with predetermined time delays can be executed by programming the command memory with both command data and time delay information.

The command memory is a 3072 bit shift register organized as 128 words (each word a command or a time delay) of 24 bits each (i.e., bits 17 through 40 of the uplink command format). Bit 16 of the uplink command format is used to select the command memory and bit 17 specifies whether a command or time delay (CSTQ1 for CP1; CSTQ2 for CP2 for a time delay command) is being transmitted to the command memory. The time code contained in the time delay word is 23 bit longs and is decremented at an 8 Hz rate (i.e., in 125 millisecond increments) until zero is reached, at which time the next 24 bits are read from the memory. Each time delay word can be coded to provide time delays from 125 milliseconds to 291 hours with a resolution of 125 milliseconds. Time delay words can be programmed consecutively in memory. Since the alternating real-time and stored command processing slots are 62.5 milliseconds in length, the maximum rate at which words (commands or time delays) can be executed from the command memory is one per 125 milliseconds.

The SCL provides several other functions in addition to the execution of stored commands and time delays. These are load, verification and command memory operational functions. Section 3.6.3.2 describes the operation of the SCL and the SCL state diagram.

The SCL in each CP is designed so that a failure of one SCL will not interfere with the operation of the other SCL. An SCL OFF discrete command (MEM1Ø for SCL 1 and MEM2Ø for SCL 2) is provided to turn off the SCL in case of a failure of the configuration control logic.

3.6.2.1.4 Output Control Logic. The Output Control Logic receives inputs from the real-time processor and SCL. To start the output process, the SCL or real-time processor transmits an enable flag to the output control logic to indicate that it desires to be serviced. At the beginning of the proper time slot (i.e., real-time for the real-time processor or stored for SCL), a signal is sent from the input select logic in the output control to the output shift register of the real-time processor or SCL. The Output Shift Register (OSR) in the output control logic sends a clock to the real-time processor or SCL to allow the information to be loaded in the output shift register. The output control logic generates the real-time and stored command processing time slots for the CP.

When the COM address portion of the word is loaded into the OSR, it is sent to the output decoder to determine which COM is to receive the information. Once the COM is selected, a 2 millisecond introduction pulse is sent to the COM. During the introduction, the input word is loaded into the OSR. The check bit at the end of the input word is then sampled to determine if the command data bits are valid. If the check bit is false, the output process is terminated.

The control bit contained in the uplink format that specifies whether the command is discrete or quantitative is then interrogated. When this is complete, the logic is set within the OSR to shift out reformatted data to the Manchester encoder. These data then go to the output decoder stage where it is routed to the selected COM output buffer.

3.6.2.1.5 Receiver Reverse Logic. The Receiver Reverse Logic (RRL) is used to automatically switch the antenna connections to the spacecraft receivers and select the omni antenna nominally every 36.4 hours ±14 sec. This is necessary to maintain control of the spacecraft in the case of a receiver failure when communication to the spacecraft is through an antenna connected to the failed receiver. The status of the time code stored in the RRL timer is given in 9.1 hour (±4 sec.) increments by two bits, bits 6 and 7, of CP status word 1, which is telemetry output RREVXC, where X was previously defined.

The RRL accepts an internal 4 Hz clock and counts 2^{19} periods (i.e., 36.4 hours) before executing the receiver reverse functions. The timer is reset when power is applied to the CP and whenever a valid command is received by either CP. Under normal conditions, there is no way to defeat the operation of the timer. When the timer runs out, two pulses will always be generated, one to select the omni and one to reverse the position of the RF switch that controls the antenna connections to the receivers.

The pulse generating circuits are activated by a transition on the timer output or from the CP CONFIGURE quantitative command used to control the RRL. When a normal or reverse pulse is received from the configuration control as a result of the quantitative command, the selected state is set and a normal or reverse pulse is generated. In this case no select omni pulse is generated. When the timer goes to zero, a select omni pulse is generated; and, if the RRL is in the normal state, a reverse pulse is generated and the RRL enters the reverse state, and vice versa. The state of the RRL is provided to telemetry as bilevel signal CREVXS, where X was defined earlier.

3.6.2.1.6 Telemetry Logic. The telemetry logic provides the CP status and command memory data to the Data Input Modules (DIMs) for insertion in the telemetry data stream. The status consists of four serial digital data words shifted out on four different lines in response to DIM read envelopes and a clock and two bilevel telemetry outputs. The serial digital data words are updated continuously until they are read into the DIMs. The contents of the command memory can be verified by one of these serial digital data outputs by using the command memory readout format and placing the SCL in the read state (refer to Section 3.6.3.2). Table 3.6.2.1.6-1 shows the word formats for the four serial digital words. See Appendix A for further details.

3.6.2.1.7 Power Supply. The power supply for the CP is a non-commandable supply. The functions performed by the power supply are generation of secondary voltages for the CP and COMs, current limiting, undervoltage and overvoltage detection and shutdown, power strobing and cyclic power control for overcurrent conditions. The undervoltage and overvoltage set points are beyond the UV/OL limits for the main bus lines; the latter will trip before the former will.

When an overcurrent condition (i.e., current > 660 milliamperes ±20%) is detected, the cyclic power control circuit turns the power supply off within approximately 1.5 seconds. The power supply remains off for approximately 60 seconds and then it is turned back on. If the overcurrent conditions remain, the power supply is again turned off in approximately 1.5 seconds. This cyclic action remains as long as the fault remains; once the fault is cleared the power supply remains on.

3.6.2.1.8 Internal Command Response. The CP receives both quantitative and discrete commands from the COMS to control the configuration and operation of the unit. The following sections describe the internal response of the CP to the different commands received.

3.6.2.1.8.1 CP CONFIGURE Quantitative Command (CPC01 for CP1; CPC02 for CP2). The 16-bit quantitative command (i.e., bits 25 through 40 of the uplink command format) used to configure the CP is shifted into a register in the configuration control logic in the SCL. Bits 33 through 40 of the quantitative command word are decoded and processed by the configuration control logic; the other 8 bits are not used. The verification pulse at the end of the quantitative command is used to initiate this processing. Two of the bits (bits 39 and 40) are used to select the CP. It is desirable to code bits 39 and 40 so as to select "either" command processor (code 11). By selecting the "either" code it will not be necessary to match the CP select code (code 01 for CP1 and code 10 for CP2) in bits 39 and 40 to the CP selected by bit 15. If the CP is not selected (code 00), no further processing is done. However, if the CP is selected, the other bits are decoded and used to control their specified functions.

Two bits of the quantitative command (bits 33 and 34) are decoded to provide a pulse to clear the command counter and reject status flip-flop in the telemetry logic (i.e., code 11) or, to control the receiver reverse functions in the receiver reverse logic. Either the normal omni antenna/receiver configuration (code 01) or the reverse omni antenna/receiver configuration (code 10) can be selected. When a normal or reverse pulse is received from the configuration control logic, the receiver reverse logic will generate a normal or reverse command, depending upon which is commanded. These commands are routed to switch drivers in the communications subsystem to select the desired omni antenna/receiver configuration.

The other four bits of the quantitative command (bits 35 through 38) are decoded by the configuration control logic to produce SCL control commands. Three of these commands (SCL CLEAR/ON (STORCMD = CLER1 or CLER2), INDEX (STORCMD = INDX1 or INDX2) and SCL OFF (STORCMD = OFF1 or OFF2)) are generated by the configuration control logic. The other commands are used to configure the SCL to various operation states (see Figure 3.6.3.2-1, SCL State Diagram). These commands are only partially processed by the configuration control logic. Signals are sent from the configuration control logic to the SCL control logic where processing of the SCL state command is completed.

As shown in the SCL State Diagram, state changes in the SCL are not only dependent on incoming commands, but are also affected by the present SCL state and other signals such as the separation switch and the 4096 second clock. Allowable state changes are stored in a Read Only Memory (ROM) in the SCL control logic. Each ROM location contains four bits representing an SCL state. The ROM address is determined by the command from the configuration control logic, the present SCL state, and other control signals.

The state can only change at the beginning of an SCL time slot. After the time slot ends the new state is selected by reading the content of the ROM at the specified address. This may or may not be the state specified in the command, depending on the allowable state changes in SCL operation.

The SCL CLEAR/ON, INDEX, and SCL OFF commands are decoded by the configuration control logic and processed during the verification pulse time of the quantitative command. The CLEAR/ON command sets a latch which controls the SCL power and triggers the initial condition circuit. These circuits are also in the configuration control logic. The CLEAR/ON command turns on power to the SCL and clears the memory. If power is already on, the memory is just cleared. The OFF command resets the latch which controls the SCL power and thus turns off the SCL power. The INDEX command is routed to the memory control logic and advances the memory until the first memory slot is at the shift register output.

3.6.2.1.8.2 SCL OFF Discrete Command. The SCL OFF command (i.e., BEM17) is a discrete command provided as a backup to the SCL OFF command provided in the quantitative command for configuring the SCL. This command is routed through an input buffer in the configuration control logic to the latch which controls the SCL power. This command will reset the latch and thus command SCL power OFF.

3.6.2.2 Command Output Module. The Command Output Module (COM) provides a standardized command interface to all subsystem and scientific instrument users. There are six (6) COMs on the Bus spacecraft and a seventh on the Large Probe. Power, grounding and control signals are provided to each COM from both CPs. Each COM distributes four (4) quantitative commands and 64 discrete commands to spacecraft users. Each quantitative command consists of a clock, envelope and data line. A backup discrete command input is provided to each COM to command it off in the event that a failure occurs that causes the power to remain on after the completion of processing a command; the unit is normally power strobed through the control input.

The COM has only two operating modes: standby and processing. The power dissipated by the COM is 1.6 milliwatts (maximum) during standby and 1.1 watts (maximum) during processing of a command. A true off state without power consumption does not exist in the COM. In addition, there is 1.6 milliwatts during standby and 1.0 watts during processing that is dissipated within the CP due to the inefficiency of the power supply. The COM OFF command is implemented to insure that an internal logic failure would not maintain a continuous 2.1 watt (maximum) load on the battery. The addition of this command permits the COM to be returned to the standby mode. In the event the COM has to be commanded off, that OFF command is sent through a different COM. (A COM that is hung up in the "ON" state may process commands normally, depending on the nature of the failure, but will be an undesirable steady state load. Certain failures could preclude the further use of the COM). There is no direct telemetry indication that a COM has failed in the processing mode. This type of failure can be investigated by sending a few operationally safe commands to the suspect COM and monitoring the associated telemetry for the expected responses. A failure to respond to all the commands sent is a positive indication that at least a segment of the COM is no longer usable.

The input control word to the COM consists of an introduction, data and a turn-off sequence. The introduction consists of a logic "1" level for approximately two milliseconds. This permits the power strobe circuit to turn power on for initial conditions to be established and for the oscillator to reach steady state. After the introduction ends, the data input begins and is sent to the manchester decoder. The output of the manchester decoder is shifted into a shift register in NRZ form.

The control logic then determines from the control bits in the shift register whether the command is discrete or quantitative. If the command is discrete, the output line address is decoded and the output is transmitted when the hyperpulse is received. For a quantitative command, the sixteen data bits are transferred to the correct quantitative command output. The control logic generates the envelope and clock signals from the manchester decoder and gates them to the output. The COM shuts down after the last bit of the quantitative command or removal of hyperpulse for a discrete command. During processing, checks are made in the control logic and manchester decoder circuits. If a data transition does not occur at the proper time, the parity check fails, or the hyperpulse arrives early, the output will be inhibited.

At the end of a quantitative command, a verification pulse is sent as part of the output. This pulse indicates that the correct quantitative command length was transmitted from the COM to the user. For a quantitative command, if the length of the command is different than 16 bits, the incorrect number of bits will be sent to the user without the verification pulse.

3.6.2.2.1 Internal Command Response. Each COM receives one discrete command, called the COM OFF command, via a different COM, to turn the COM off in case it does not reset from the process command mode (i.e., continuously ON state). The command is given by COMXØ for the Bus spacecraft, where X = 1, 3 and 5, and LCM1Ø for the Large Probe. When X = 1, the command turns off COMs 1 and 2, when X = 3, the command turn off COMs 3 and 4, and when X = 5, the command turns off COMs 5 and 6.

The COM OFF command is routed to an input buffer configured to operate in the memory mode. In normal operation, the input signal from the CP will turn unit power ON and latch the input buffer ON. At the completion of command processing the latch is turned off by a signal from the control logic. The COM OFF command is provided as a backup to turn the latch (and thus power) off in case of a failure in the control logic.

3.6.2.3 Pyrotechnic Control Unit. The Pyrotechnic Control Unit (PCU) is used to provide firing pulses for spacecraft pyrotechnic devices. The PCU receives a standard 35 ±4 millisecond pulse from the COMs and current amplifies the pulse to a minimum of five amperes into a 1 ±5% ohm load. The output current pulse is of the same duration as the input pulse. The Bus spacecraft contains two identical PCUs.

Each PCU consists of two fully redundant halves. In each half there are three squib drivers each with three outputs. A squib driver is activated by first sending an arm command and then following it with a fire command. One arm circuit enables one squib driver and a second arm circuit enables the remaining two squib drivers. Each PCU contains an automatic disarm which disarms the PCU 18.5 ±4.5 seconds after it is armed. An arm delay circuit is also included that delays the arming of the PCU for 4 ±2 seconds after receipt of the arm command. These timing relationships are shown in Figure 3.6.2.3-1.

The fully redundant structure of the PCU enables two independent signals to fire one redundant squib. A single command from a COM is cross-strapped to a squib driver in each half to fire both halves of redundant squibs simultaneously. The firing simultaneity for this configuration is less than 250 microseconds.

3.6.2.3.1 Internal Command Response. The PCU receives three different types of discrete commands, i.e., ARM, FIRE and DISARM. The internal response to these commands is described in the following sections.

3.6.2.3.1.1 PCU ARM Discrete Command. The PCU ARM (i.e., ORD11 or ORDA1; ORD13 or ORDA3; ORD21 or ORDB1; ORD22 or ORDB2) command is used to provide power to the squib drivers so that a subsequent FIRE command will fire the associated squibs. From the receipt of the ARM command, a timer in the PCU delays arming of the squib drivers by 4.0 ±2.0 seconds and disarms the drivers after 18.5 ±4.5 seconds. The FIRE command must be received between these events if the squibs are to be fired. (100% assurance of FIRING is obtained if the FIRE command is received between 6 and 14 seconds after the ARM command is received). The ARM command is routed to both redundant sections of the PCU.

The ARM command is amplified to the level required in the PCU by a discrete input buffer. The output of this buffer will set a switch which supplies 28 volts to the associated arm/disarm switch and resets the switch which supplies 28 volts to the other arm/disarm switch. The output of the discrete buffer also starts the timer in the PCU. After a delay of nominally 4.0 seconds a signal from the timer will activate (arm) the selected arm/disarm switch which will apply battery voltage to the associated squib drivers. After a total delay of nominally 18.5 seconds a signal from the timer will disarm the arm/disarm switch and thus remove battery voltage from the squib drivers.

The two PCU arm commands are interlocked. If one "arm" circuit is energized (i.e., relay closed), sending a command to the second "arm" relay will arm it, but will "disarm" the other arm/disarm relay. In other words, both "arm" relays cannot be closed at the same time (Reference: 1.5.18).

3.6.2.3.1.2 PCU FIRE Discrete Commands. The PCU FIRE (i.e., ORD12 or ORDA2; ORD14 or ORDA4; ORD15 or ORD16; ORD23 or ORDB3; ORD24 or ORDB4) command is routed to the squib drivers through an input buffer. Power will only be supplied to the input buffer and squib driver when the associated arm/disarm switch is armed. The squib driver amplifies the squib fire command and is capable of supplying current to fire three squibs. If the command is to fire redundant squibs, it is connected to two input buffers by wiring external to the PCU.

3.6.2.3.1.3 PCU DISARM Discrete Command. The PCU DISARM (i.e., ORD1Ø or ORDAØ) for PCU 1; ORD2Ø or ORDBØ for PCU 2) command is provided as a backup for the DISARM command generated by the 18.5 second timer in the PCU. This command is routed through an input buffer to the arm/disarm switches. If the timer fails to disarm the arm/disarm switch, this command will disarm the switch and thus remove battery voltage from the squib drivers. The DISARM command is routed to both redundant sections of the PCU. The DISARM command cannot truncate the 18.5 second timer count (i.e., disarm prior to completion of the nominal 18.5 second delay) when the timer is functioning properly.

3.6.3 Operational Description. The following sections describe the operational usage of the command subsystem, including real-time command, stored command and pyrotechnic device operations.

3.6.3.1 Real-Time Command Operations. All real-time command operations with the spacecraft are through the RF uplink. A PCM/FSK/PM uplink carrier is transmitted to the spacecraft receivers. The spacecraft contains two transponders; each contains a frequency addressable receiver. The receivers demodulate the uplink carrier and provide an PCM/FSK subcarrier signal to the FSK demodulator in the CP. Each receiver is connected to one FSK demodulator without any cross-strapping. The output of each FSK demodulator is cross-strapped to the central command processing circuitry in each CP. Consequently, either CP can be used to process real-time commands.

Commands are sent to the spacecraft at 4 bps using the 48 bit command format given in Figure 3.6.1-1. Prior to sending the 48 bit command word, a 48 bit preamble must be sent to synchronize the FSK demodulator with the incoming command. The preamble should be an alternating pattern of logic "1" and logic "0" tones in either order, i.e., 1010 . . . or 0101 . . . The logic "1" tone is 250 Hz and the logic "0" tone is 100 Hz. After the initial preamble is sent to the spacecraft, the FSK demodulator will remain synchronized if the tone frequency is changed a minimum of once in every 48 bit times.

Therefore, if 48 bits of logic "1" tones are sent followed by 48 bits of logic "0" tones, and this pattern is repeated continuously, the command word may be sent without preceding it with the preamble. However, when a command is transmitted it is necessary that the first bit of the command be started within 1/16 of a bit time of the idle bit transition time or the FSK demodulator will go out of synchronization. Therefore, the FSK demodulator will remain locked-up for 48 bit times without a transition in the tone frequencies, and once lock is lost the preamble must be sent prior to transmitting another command word.

The 48 bit command format consists of a 13 bit fixed sync pattern, 28 bits of address information and command data and seven bits of coding for the polynomial code check performed by the CP. The 13 bit sync pattern is given in Figure 3.6.1-1. The seven polynomial code bits are generated from the 28 data bits and are a function of the contents of these bits. The ARC command software automatically creates this seven bit code and attaches it to the end of the command word. The CP decodes these seven bits and uses this information to determine if an error in transmission has occurred in the 28 data bits received by the CP. This procedure detects random errors of any of the following types: single bit, double bit, odd number of bits, all bursts of length seven bits or less, 98.4% of bursts of length eight bits and 99.2% of longer than bursts of length eight bit random errors. If an error is detected by the CP, a command reject flag is set in CP telemetry output CREJXS, where X equals 1 for CP 1 and X equals 2 for CP 2.

The spacecraft and CP address information is contained in bits 13, 14 and 15 of the command format. To select the Multiprobe spacecraft, a "00" code must be placed in bit locations 13 and 14. The selection of the CP used to process the uplink command word is accomplished by bit 15. A "0" in this bit position selects CP 1 and a "1" selects CP 2. In the shelf layout given in

Figure 3.6.1-2, CP 1 is the bottom unit. As a further reminder, the PSK demodulator in either CP is connected to a transponder that is frequency-selected, whereas the remainder of each CP is selected by bit 15 of the command word.

Bit 16 is used to specify whether the command word is to be executed in real-time or stored in the command memory to be executed at a later time. If this bit is a logic "1", the command will be executed immediately and if it is a logic "0", the following 24 bits will be stored in the command memory. Before sending a command to the memory, the SCL must be commanded to state 14 (Loading) or the command will be ignored.

For real-time commands, bit 17 can be either a logic "1" or a logic "0" (i.e., "don't care") because this bit is used to specify whether the following data bits contain a time delay or command information in the stored command format. If commands are sent to the SCL and a logic "0" is selected, the data will be processed as a time delay, but if a logic "1" is selected, the data will be taken as coding for a command. If time delay information is entered into the command word, the following 23 bits (i.e., bits 18 through 40) are used for coding the time delay. The 23 bit code for the time delay is the binary representation for the desired time in increments of 125 milliseconds plus a bias of 125 milliseconds. Therefore, binary 0 is equal to 125 milliseconds, binary 1 equals 250 milliseconds, etcetera. The binary number is loaded LSB first, so that bit 18 in the command format is the LSB and bit 40 is the MSB. The telemetry verification of the memory contents (i.e., CMEMX) will be read out LSB first for the time delays as loaded.

The required time delay between two events can be calculated by using the following general equation:

$$T = 8t - n$$

where:

t = desired time delay between events in seconds

$n = n_2 - n_1$

n_1 = memory location (slot number) of the command entry from which time delay begins

n_2 = memory location (slot number) of the command entry being timed.

Example 1

Command ABC in slot 5.
Command XYZ in slot 7.
Desire 10 seconds delay between commands:

$$\begin{aligned} T &= 8t - n \\ &= (8 \times 10) - (7-5) \\ &= (80) - (2) \\ T &= 78 \end{aligned}$$

$$78_{10} = 1001110_2$$

Therefore the 23 bits of command data in the command word are

```
    01110010000000000000000
    ↑                     ↑
bit 18                 bit 40
```

When bits 18 to 40 are used for stored command information (bit 17 = "1") in the stored command format, these bits are structured to provide two types of commands - discrete and quantitative. Bit 22 is used to select either a discrete command (i.e., logic "0") or a quantitative command (i.e., logic "1"). For discrete commands, bits 18 through 21 select the COM to which the command is to be routed and bits 35 through 40 designate the COM output allocated to the user connected to the COM. These two sets of codes are conventional binary representations for the decimal number placed on these locations; i.e., COM 0 to COM 7 is specified as 0000 to 0111 and COM outputs 0 to 63 are coded as 000000 to 111111. COM 0 is a fictitious unit for sending an all zeroes test command to the spacecraft. COM 7 is located only on the Large Probe spacecraft, but for the Multiprobe spacecraft (as well as the Orbiter spacecraft), it is used for sending an all ones test command. Output 63 to COM 7 is not assigned to any user on the Multiprobe spacecraft. Bits 23 to 34 are all zeroes for discrete commands.

When a quantitative command is desired, bits 18 to 21 also select the COM, but bits 23 and 24 are coded to specify the COM quantitative command output, i.e., COM output 0 equals 00 and COM output 3 equals 11. Sixteen bits are allocated to code the quantitative data in the command. These data bits are in locations 25 through 40. The allocation of these bits in the quantitative commands to each of the spacecraft subsystem users is specified in PC-455 (Reference: Paragraph 1.5.1).

The time to process a command in the CP from the time it enters the PSK demodulator to the time it is sent to a COM is a minimum of -3.5 milliseconds and a maximum of +137 milliseconds. The actual time is random (uniform distribution).

3.6.3.2 Stored Command Operations. The use of the stored command capability on the spacecraft begins with the loading of the command memory through the use of real-time commands via the RF link. The command word format required to place commands (i.e., discrete or quantitative) and time delays in the memory was discussed in the previous section.

The operational use of the command memory is centered around the state diagram for the SCL. The SCL consists of the configuration control logic which processes command inputs to the SCL, the control logic and the command memory. Figure

3.6.3.2-1 presents the complete SCL state diagram. In order to describe the use of stored commands on the spacecraft, a detailed explanation of the SCL is presented in the following sections.

3.6.3.2.1 Initial Application of Bus Power and SCL ON/OFF Control. When the essential bus is connected to the CP for the first time, the SCL is initialized to be in the OFF state. To turn the SCL ON, the CP CONFIGURE quantitative command must be sent to the spacecraft. The coding for the CP CONFIGURE quantitative command is given in PC-455 (Reference: Paragraph 1.5.1). Subsequent ON/OFF control of the SCL is by the quantitative command since the CP cannot be commanded off. A backup discrete command, SCL OFF, is also available in case there is an SCL failure which prevents the SCL from being commanded off by the quantitative command. However, in the case of an overcurrent condition that causes the cyclic fuse to turn off the CP, the SCL will be turned off and remain off after the fault is cleared and the CP power supply operation resumes. For this case, the SCL will have to be commanded back on if SCL operations are required. The ON/OFF status of the CP and the SCL are provided in telemetry outputs CPWRXS and CSCLXS, respectively, where X equals 1 or 2 for CP1 or CP2, respectively.

3.6.3.2.2 Preparation for SCL Operations. The format for the uplink command word for loading commands and time delays into the memory is given in Figure 3.6.3-1 and was discussed in Section 3.6.3.1. The steps that need to be taken to prepare, load and verify the memory contents before executing the sequence are given as follows.

3.6.3.2.2.1 Turning On the SCL. To begin with, the SCL must be commanded on with the CP CONFIGURE quantitative command using one of the two CLEAR/ON command codes in the quantitative command structure as defined in PC-455, Reference: Paragraph 1.5.1. When this command is executed by the CP, the SCL is initialized to be in the Standby State (SCL state 15), all memory slots read zero, and the memory address pointer will initialize at address 0. The SCL ON/OFF status, state, and memory address are provided to telemetry as CSCLXS, CLOGXS and CMEMXC, respectively, where X equals 1 or 2 for SCL 1 or SCL 2, respectively. The structure of the serial digital telemetry outputs associated with the SCL are given in PC-454, Reference: Paragraph 1.5.2, and in Figure 3.6.1-1. Prior to turning on the SCL, CSCLXS should be "0", CLOGXS should be "1111", CMEMXC should be "1111111" and CMEMX should be "11111111". The telemetry output after commanding on the SCL should be "1" for CSCLXS, "1111" for CLOGXS, "0000000" for CMEMXC and "00000000" for CMEMX. CMEMX is the command memory readout telemetry channel.

3.6.3.2.2.2 Loading. Prior to sending commands to the memory, the SCL must be transferred to the Loading State (SCL state 14). This is accomplished by sending the LOAD command code (0100) in the quantitative command. Telemetry verification of CLOGXS should be "1110". Each SCL can be loaded only from its associated Command Processor (i.e., there is no cross-strapping between SCLs and CPs regarding loading of SCLs).

When loading the command memory, the address pointer, CMEMXC, will display the next memory location to be loaded. When the memory is full, the address pointer will recycle to address 0, and any additional inputs will be written over existing commands in the memory.

After loading the desired command sequence in the memory, the STANDBY command must be sent to take the SCL out of the Loading State; no other command will transfer the SCL out of the Loading State. The SCL does not automatically transfer to the Standby state when the memory is completely loaded.

3.6.3.2.2.3 Verification. The contents of the command memory can be verified prior to executing the loaded sequence by commanding the SCL into the Read State (SCL state 10). In this state CLOGXS is "1010". The Telemetry Processor (TP) must be then commanded into the Command Memory Readout format for the telemetry system to sample the contents of the memory. The commands to the spacecraft have to be sent in this order so as to prevent sampling the memory on the first sample in less than an eight bit byte. The TP and CP are unsynchronized so that the Read state could be started in the middle of a DIH read envelope and could cause all subsequent eight bit bytes to be skewed off by the number of bits contained in the first sampling of the memory.

In order to read the full contents of the command memory, the INDEX command should be sent to the SCL to place the address pointer at address zero. The INDEX command has the dominant purpose of setting the memory address pointer to zero. If the address pointer is not reset to zero, the telemetry output will begin at the address present when the first telemetry sample is taken and terminate when the address pointer is at zero. If the memory is sampled and not in the Read State, the telemetry output will be all zeroes if the SCL is on. At the completion of reading out the command memory into telemetry, the SCL automatically transfers back to the Standby state. When reading the memory, the memory address pointer, CSMIC, indicates the next memory location to be sampled. If the TP is commanded out of the Command Memory Readout format prior to the completion of the memory readout, the SCL should be set back to address 0 by sending the INDEX command.

The Command Memory Readout format is designed to read out memory entries from SCL 1 and memory entries from SCL 2 in each minor frame. A telemetry word is eight bits long so it takes three telemetry words to read out one memory entry into the minor frame format. The minor frame format is divided in half with words 9 through 35 devoted to SCL 1 and words 37 through 63 dedicated to SCL 2. Therefore, verification of the memory contents is accomplished by making a bit by bit comparison of the 24 bit words sent to the SCL with the 8 bit telemetry word received in the Command Memory Readout format.

3.6.3.2.2.4 Correcting the Contents of the Memory. If the wrong sequence is loaded or a new sequence is to be inserted into the memory, the CLEAR command can be sent to the CP to load zeroes in all the memory locations. This function can only be accomplished from the Standby state. Alternatively, the SCL can be commanded off from any state, and then commanded on with the CLEAR/ON command to load zeroes into the memory slots.

A single entry in the command memory can be corrected or changed, if necessary. This can be accomplished by first advancing the memory to the address location where the new entry is needed. To do this, the SCL must be commanded into the Standby state (SCL State 15) and then the ADVANCE and STANDBY commands must be sent in pairs to advance the address pointer by one step. The ADVANCE command will move the counter, but the STANDBY command is also needed to complete the sequence. When the SCL is advanced to the location desired, the SCL must be commanded to the Loading state (SCL state 14) and the new entry to be transmitted can then be entered into the memory by the uplink command format.

This process can be very time consuming if a correction or change has to be made more than halfway into the sequence because it takes more time to make a single correction than it does to reload the whole sequence again. Even for a short sequence, it is less time consuming to reload the whole sequence up to the place where the new entry has to be made, than to send twice the number of commands to advance the SCL to the required location. However, for the case of a marginal RF link, it is probably more efficient to make single or multiple corrections in this manner than to risk additional errors in the retransmission of the sequence.

3.6.3.2.2.5 Loading Multiple Sequences. A number of short command sequences can be loaded at the same time and executed individually by using the ADVANCE command. For example, if the second sequence is needed to be performed first, the

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ADVANCE command could be used to set the memory address pointer at the address location of the first command word in this sequence. The ADVANCE command must be followed by the STANDBY command to move the pointer one address location. Again, this capability only exists from the Standby state. In addition, if the second sequence has been completed and the first sequence needs to be performed next, the Index command can be sent to place the address pointer at the address location of the first command word of the first sequence.

3.6.3.2.3 Starting the SCL. The SCL can be started in three different ways; namely, by a real-time command, from the 4096 second clock generated in the TP or by the closure of the spacecraft separation switches. The 4096 second clock gives an accurate reference point for delaying the start of a command sequence, and the separation switch input is used for spacecraft separation to start a special command sequence to spin-up the spacecraft. The following sections describe the different ways the SCL can be started.

3.6.3.2.3.1 Immediate Start. To start the SCL in real-time, the IMMEDIATE START command must be sent to the CP. The command memory will begin operating within 400 milliseconds after the uplink command is received by the CP; real-time command processing slots occur every 125 milliseconds. The actual delay time depends on the type of command, the CP in use, and the SCL in use, as seen in Table 3.6.3.2.3-1. After the SCL is started it immediately transfers from the Standby State to the Run State (SCL state 12) and determines whether the entry is a command or a time delay. If the entry is a command, the SCL will transfer into the Process Command state (SCL state 8); if the entry is a time delay, the SCL goes into the Load Timer state (SCL state 13), and extracts that entry in the sequence out of the memory. The memory address pointer, CHEMXC, will then indicate the next location in memory. The two SCLs cannot be started simultaneously with real-time commands. Since it takes 12 seconds to transmit a command to the spacecraft, the closest the two SCLs can be started together is 12 seconds. However, if the first entry in one command sequence is used to command the start of the other SCL, both SCLs can be started within 250 milliseconds by sending one real-time command.

TABLE 3.6.3.2.3-1

TIME DELAY RANGE FOR COMMAND MEMORY OPERATION, FOLLOWING RECEIPT OF UPLINK COMMAND BY CP

	TIME DELAY (milliseconds)	
TYPE OF COMMAND:	CP1 to SCL1 (or CP2 to SCL2)	CP1 to SCL2 (or CP2 to SCL1)
Discrete	187 to 327	129 to 394
Quantitative	188 to 388	130 to 395

3.6.3.2.3.2 Timed Start. To start the command memory from the 4096 second clock, the TIMED START command must be sent to the CP. The 4096 second clock is a continuous square wave clock that is generated from the 2048 second bit of the spacecraft time code in each TP. The output of each TP is cross-strapped to both CPs as shown in Figure 3.6.1-1. Consequently, both SCLs can be started nearly simultaneously by this method. Since the two CPs operate asynchronously, the start of the two SCLs could be different by a maximum of 125 milliseconds. When the TIMED START command is received by the SCL, it transitions from Standby to the Timed Start 0 state (SCL state 1). The telemetry indication for this state for CLOGIS is "0001". If the 4096 second clock is a logic "0" when this state is entered, the SCL will remain in this state until the clock changes to logic "1" (i.e., from 0 to 2048 seconds in SCL state 1). When the 4096 second clock switches to logic

"1", the SCL transfers to the Timed Start 1 state (SCL state 5), and remains there for 2048 seconds until the clock again switches to logic "0". CLOGXS is "0101" in the Timed Start 1 state. If the 4096 second clock is a logic "1" when the TIMED START command is sent, it will transition immediately from SCL state 1 to SCL state 5, and remain there until the 4096 second clock switches to logic "0" (i.e., duration from 0 to 2048 seconds). The 4096 second clock is a square wave so that there is ample time to receive a telemetry status on the logic state of the clock (i.e., the second MSB of DCLOK2). The SCL transfers immediately into the Run state when the clock switches from logic "1" to logic "0", and the memory begins to process the loaded sequence.

The first command in the sequence will be executed within 129 to 254 milliseconds (for a discrete command) or 130 to 255 milliseconds (for a quantitative command) of the 4096 second clock transition because the CP can only process stored commands every 125 milliseconds. This is one of three error sources in starting the SCL.

The second error source is due to the way the clock is generated in the TP. The TP outputs the 4096 second clock transitions synchronously with the word rate clock. Therefore, the accuracy of this output is a function of operating bit rate at the time of the occurrence of the clock transition and the bit rates used prior to selecting the bit rate used during the transition. The previous bit rates affect the accuracy because some bit rates have word and minor frame periods that are not integer submultiples of 4096 seconds. Table 3.6.3.2.3-2 presents the results of an analysis of the maximum inaccuracy of the 4096 second clock due to the TP. The vertical scale in the matrix is self-explanatory, but the horizontal scale requires some discussion. This scale shows the highest bit rate that the TP was commanded to operate at, from the time it was first turned on, until the time it was commanded to the bit rate at which the 4096 clock transition took place. This does not mean that all bit rates had to be used up to and including the highest bit rate selected, but that at least the highest bit rate was selected at some time prior to going into the bit rate at the transition. This scale starts at 16 bps, because the TP is initialized to start operating at this rate.

A subtlety in these results is that the length of time in the highest bit rate has an effect on the accuracy. If the length of time is just right the error will be zero, but if the length of time is some special value the maximum error given in the table will result. This is best illustrated by an example. Take, for instance, the case where the highest bit rate selected is 341 1/3 bps and the bit rate at the transition is 8 bps. In the matrix, the maximum error is given as 500 milliseconds. One way to arrive at this maximum error (and there are a number of combinations) is to command on the TP and have it operate at 16 bps for 135 minor frames which is 4064 seconds into the first full 4096 second time period because the TP is initialized to start the first 4096 clock period 256 seconds after turn on. Then command on 341 1/3 bps for 21 minor frames, which is an additional 31.5 seconds. This now gives a total time period of 4095.5 seconds. If the TP is now transferred to 8 bps, the 4096 second clock will transition to logic "0" at 4096.5, for an error of 0.5 seconds. The reason for this is the word period at 8 bps is 1 second and the transition must wait until the end of the telemetry word to occur. If the starting bit rate of 16 bps was maintained for 134 minor frames instead of 135 (i.e., 4032 seconds into the period) and the 341 1/3 bps was used for a 42 minor frames rather than 21 (i.e., an additional 63 seconds into the period), the error would be zero after the 8 bps bit rate was commanded into operation. This is because only one second remained in the clock period which is coincident with the word period at 8 bps. Therefore, it is obvious that the error in starting the command memory is highly dependent on the bit rates and time periods over which they are used. Consequently, this effect must be accounted for in programming the start of the memory. In addition, an IMMEDIATE START command can be sent to the SCL when it is either in the Timed Start 0 or Timed Start 1 states to override the use of the 4096 second clock.

The third error source in starting a command sequence or executing a defined function is due to the stability of the oscillator in the CP. If time delays are used in the command sequence, either as the first entry in the sequence or interspersed throughout the sequence, the variation in the oscillator frequency will effect the programmed delays. This will cause the execution of the final event to be in error. The longer the accumulated time delay, the larger will be the uncertainty. The oscillator stability is 50 ppm worst case.

Additional discussion and examples are contained in Reference 1.5.3.

3.6.3.2.3.3 Separation Switch Start. To start the SCL from the closure of the spacecraft separation switch, the ARM SEPARATION SWITCH command, which is part of the CP CONFIGURE quantitative command, must be sent to the CP. This command must also be sent to the redundant CP to arm the redundant separation switch that, upon closure, activates the sequence loaded in the redundant CP command memory. The purpose of this command is to prevent an inadvertent closure or premature closure of the separation switch from starting the SCL and causing the spacecraft spin-up sequence to begin. The ARM SEPARATION SWITCH command transfers the SCL into Separation State 0 (SCL state 0). The telemetry status of CLOGXS for this state is "0000". If the separation switch is closed (i.e., SSEPXS equal to logic "1") prior to sending this command, the SCL will remain in state 0 and never start the spin-up sequence. Referring to Figure 3.6.1-1, it can be seen that each separation switch is connected to only one CP. Therefore, the premature closure of only one switch prior to the arm command will not prevent the spin-up sequence from occurring because the normal closure of the other switch will initiate a similar sequence loaded in the other SCL memory. In addition, Separation State 0 can be overridden by an IMMEDIATE START command which transfers the SCL to the Run State (SCL state 12). If the separation switch is open prior to sending the ARM command the SCL transfers immediately from Separation State 0 to Separation State 1 state (SCL state 4). The telemetry status as given by CLOGXS for this state is "0100". The SCL remains in this state until separation switch closure, at which time the SCL jumps to the Run State and executes the spin-up sequence. Closing of the separation switch causes a latch in the SCL to be set which prevents switch bounce from affecting the operation of this function. If needed, the Separation State 1 state can be overridden by the IMMEDIATE START command.

3.6.3.2.4 Stopping the SCL. After the SCL transfers to the Run State, it extracts a command memory word from the memory and begins the processing cycle. If the command memory word is a command (either discrete or quantitative), the SCL transitions to the Process Command State (SCL state 8), and remains there, instead of returning to the Run State, as long as the following command memory entries are commands. The telemetry status will remain constant at "1000" for CLOGXS for all the time that contiguous commands are processed out of the memory. To stop the SCL from this state, the STOP command must be sent to the CP. When this command is received by the SCL, a transfer will be made to the STOP 1 state (SCL state ?), and the SCL will remain in this state until another command is received. The SCL will complete processing of the current command before it switches over to STOP 1. An IMMEDIATE START command, an ADVANCE command or a STANDBY command followed by a RUN command is needed to get out of the STOP 1 state and continue processing. In this state they are effectively the same command. The ADVANCE command causes the SCL processing route to go through the Run State while the IMMEDIATE START command terminates directly in the Process Command or Load Timer status. The sampling of the telemetry system is not fast enough to distinguish the different paths; the whole process takes place in 125 milliseconds including the execution of the command if the next entry is a command. In summary, if either command is sent, the SCL will end up in the Process Command State if the next entry in memory is a command and in the Load Timer State (SCL state 13) if the next entry is a time delay.

When the SCL is in the Load Timer state, independent of how it got there (i.e., from states 2, 8 or 12), the SCL can again be stopped by sending the STOP command. From this state, the SCL will go to the Stop 2 state (SCL state 3) and will give a telemetry readout on CLOGXS of "0011". In the process of counting down a time delay (T = "1" in Figure 3.6.3.2-1 when the time delay command has been executed, and the time count has not yet decremented to zero), the SCL goes to and remains in the SUB 1 state (SCL state 9) until the time count is decremented to zero (i.e., T becomes "0"). If the time delay has not been completely counted down when a STOP command is issued, the SCL will go to the Stop 2 state and hold the last time count in the Subtract 1 counter (T remains "1"). The time countdown can be resumed by sending the IMMEDIATE START command and the SCL will return to the Sub 1 state. However, if the remaining time count must be skipped, the ADVANCE command will extract the next entry out of the memory by transferring the SCL to the Run State. If, by chance, the STOP command arrives just after the countdown of the time delay has been completed, the SCL will advance to the Stop 1 state. Telemetry status will be recognizable in the Stop 1, Stop 2, Process Command (for many contiguous commands) and Sub 1 (for long time delays) states, but will not be observable for the Run or Load Timer states because the SCL transfers through these states rapidly. sampling of the status of these states will occur on a very infrequent basis. Likewise for very short time delays or alternating commands and time delays in the memory, the Process Command and Sub 1 states will not be observed on a regular basis.

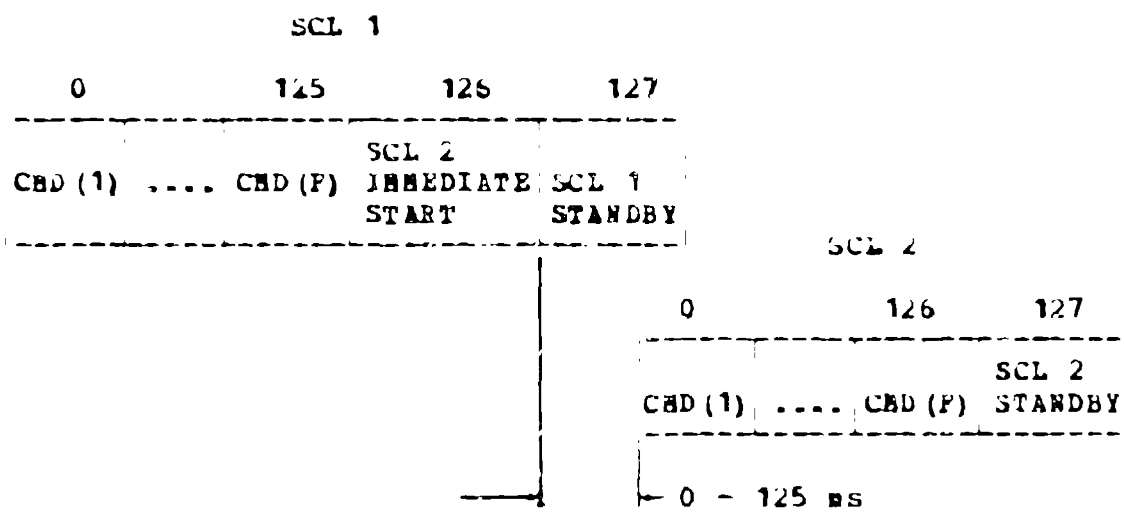
3.6.3.2.5 Considerations for Designing Command Sequences. The method for loading command words into the memory through the use of real-time commands has been discussed in a previous section. However, there are certain facts that should be considered prior to designing a sequence to be placed in the memory. The first fact is that the SCL will continue to process entries from the memory until commanded to stop. The SCL will cycle through all 128 memory slots and then repeat these entries over and over until terminated by a STANDBY, STOP or OFF command. However, if for example, only the first 20 slots are used in the memory for a particular command sequence, the SCL will process these 20 entries and then step through each of the remaining 108 slots in 125 millisecond steps (assuming each of these slots contains all zeroes). The SCL will repeat this process continuously, unless the 20th entry is one of three stop-type commands mentioned above. An extension of this is when multiple command sequences are loaded into the memory at one time. If each sequence is not terminated by a STANDBY or STOP command, all the sequences will be executed in series and continuously repeated.

A second consideration is that the SCLs in both CPs can be operated simultaneously, as with the spacecraft spin-up operation, but that the commands in each sequence must not address the same COS at the same time i.e., within the same 62.5 msec. period. If a control word is received at a COS from both CPs, the command will not get processed through the COS. The two CPs operate asynchronously; each oscillator in each CP is independent with a 50 ppm stability requirement. As a result, command words occupying the same slot in memory could be executed at the same time, or many seconds apart with a sequence containing many commands and long time delays. This fact must be accounted for in designing parallel sequences.

Another consideration is that both SCLs cannot start precisely at the same time because the stored command processing time slots are not synchronized between the CPs. Therefore, the

SCLs could start as much as 125 milliseconds apart with nominal clock frequencies in each CP.

Another use of the SCLs is for series operation to effectively increase the command memory to 256 locations. This can be accomplished by designing the sequence in one command memory to transfer to the other command memory. An example of this operation is given as follows:



This example shows how the two SCLs are used together to execute one 256 command sequence once without repeating it automatically. It is assumed that both SCLs were commanded on through real-time commanding prior to starting the sequence in SCL 1. For SCL 1, memory slots 0 through 125 are used for the first part of the desired sequence, but the last two slots must be reserved to transfer over to SCL 2 and terminate SCL 1. In slot 126, the SCL 2 IMMEDIATE START command is inserted to start SCL 2. Following this command, the SCL 1 STANDBY command is inserted in slot 127 to place SCL 1 in standby and prevent it from repeating its sequence. SCL 2 will start between 0 and 125 milliseconds after the SCL 2 IMMEDIATE START command is executed because of the asynchronous operation of the two CPs. Therefore, the first command word in memory

2 should be a 125 millisecond time delay or a command that is not routed to the same COM through which the SCL 1 STANDBY command is processed. Interference between the SCL 1 STANDBY command and the first command in memory 2 will cause neither command to be executed and result in the SCL 1 sequence being repeated simultaneously with the SCL 2 sequence. The final command in the SCL 2 sequence must be the SCL 2 STANDBY command to prevent repeating the sequence in SCL 2.

If there is no intention to repeat the 256 word sequence, the STANDBY commands should be replaced with OFF commands to conserve power. Should it be desired to repeat the sequence continuously, slot 126 in SCL 2 must contain the START command for SCL 1. There are a number of variations to this procedure, but basically this is the method that must be used to operate both SCLs in series.

3.6.3.2.6 SCL Operating Constraints. The configuration control logic in the CP can receive both real-time commands and stored commands to control the SCL operation. However, there must be a minimum of 125 milliseconds between all commands received by the SCL. If a stored command sequence is being processed, a real-time command should not be sent to the SCL within 125 milliseconds of the time the SCL is outputting a command to itself. Since the real-time command and stored command processing time slots are 62.5 milliseconds apart, it is possible for the SCL to receive two commands as close together as 62.5 milliseconds.

Similarly, if both SCLs are processing commands, one SCL should not send a command to the other SCL within 62.5 milliseconds of the time the other SCL is sending a command to itself or receiving a real-time command.

3.6.3.3 Pyrotechnic Device Operations. The operational aspects related to pyrotechnic devices on the Multiprobe spacecraft involve firing the Large and Small Probe In-Flight Disconnects (IFDs), separation of the Large and Small Probes, and deployment of scientific instrument devices, such as the BNMS Breakout Hat and BNMS Cal Gas. The following two sections describe these operations.

3.6.3.3.1 Separation of IPDs. The IPDs on the Large and Small Probes are separated prior to the release of the probes from the Bus spacecraft. To separate the Large Probe IPD, the ARM LARGE PROBE IPD AND BNMS B/O HAT command (ORD13 or ORDA3) must first be sent to PCU 1. Contiguous to this arm command, the FIRE LARGE PROBE IPD command (ORD14 or ORDA4) must be sent if real time commands are used.

The IPD for each of the Small Probes are separated in a similar way, except that all three IPDs are separated simultaneously. To arm the PCU for this event, the ARM SMALL PROBE IPD AND BNMS CAL GAS PYRO command (ORD22 and ORDB2) must be sent to PCU 2. Following this command the FIRE SMALL PROBE IPD command (ORD23 or ORDB3) must be sent contiguously to separate the IPDs. Again, this is necessary if real time commands are used for this operation.

The probe shelf temperature sensors monitored on the Bus spacecraft will go to full scale when the IPDs separate. These outputs are routed via the IPDs for telemetry in the Bus data handling subsystem.

Examples of the use of the above commands during the mission are shown in Sections 4.2.2 and 4.2.3.

3.6.3.3.2 Large and Small Probes Separation. The Large Probe is separated from the Bus spacecraft by an arm and fire command sent directly to PCU 1. If the commands are to be sent in real-time, they must be contiguous. The arm command is ARM LARGE PROBE SEPARATION (ORD11 or ORDA1) and the fire command is LARGE PROBE SEPARATION (ORD12 or ORDA2). When separation has occurred, telemetry output SLRELS will go to logic "0".

The separation of the Small Probes is described in Section 3.6.3.5.

3.6.3.3.3 Scientific Instrument Devices. The BNMS is the only scientific instrument that contains pyrotechnic devices on the Bus spacecraft. The BNMS has squibs to deploy the Breakoff Hat and to open the Cal Gas container.

There is one arm and two fire commands needed to deploy the Breakoff Hat. The arm command is ARM LARGE PROBE IPD AND BNMS B/O HAT (ORD13 or ORDA3) and the two fire commands are FIRE BNMS B/O HAT PRIMARY (ORD15) and FIRE BNMS B/O HAT SECONDARY (ORD16). Each fire command activates two squibs. If the arm and fire commands are sent in real-time, the arm command must be sent prior to each one of the fire commands to activate all four squibs.

The Cal Gas container is broken by one pair of arm and fire commands. For this event, the arm command is ARM SMALL PROBE IPD and BNMS CAL GAS PYRO (ORD22 or ORDB2) and the fire command is FIRE BNMS CAL GAS PYRO (ORD24 or ORDB4). Again, these commands must be contiguous if they are transmitted in real time.

3.6.3.4 Receiver Reverse Operations. The receiver reverse capability in the command subsystem is designed to prevent loss of uplink control of the spacecraft for more than 36 ±4 hours. The CP sends out two discrete commands automatically every 36 ±4 hours when no valid uplink commands are received in that time period. One command is used to select the forward omni and the other is sent to change the receiver/antenna RF switch to the normal or reverse position. When the switch is in the normal position, the reverse pulse is sent out, and vice versa. For redundancy, each CP performs the same function.

When power is initially applied to both CPs the receiver reverse counter in each CP is reset to zero and each begins counting. If a valid command is received by either CP, the counters in both CPs are reset to zero through the cross-strapping between CPs. Under nominal conditions, there is no way to defeat the operation of this function once prime power is applied to the CPs.

The application of power may cause the two CPs to initialize in different logic states, i.e., one CP may be in the normal state ready to send out the reverse pulse and the other in the reverse state ready to output the normal pulse. In order to place the CPs in the same state, both CP configure commands, CPCQ1 and CPCQ2, must be sent in the Receiver Normal mode, or both commands must be sent in the Receiver Reverse mode. If this condition is not corrected, the two outputs from the CPs will negate each other and the receiver switch will not change position. The logic state of CP1 and CP2 are given in telemetry as CREV1S and CREV2S, respectively, where logic "1" is normal and logic "0" is reverse.

To insure that the receiver reverse logic in both CPs are in the same state, the CP quantitative command must be sent to each CP. Bits 33 and 34 of the quantitative commands must be set to "01" to obtain the normal state and "10" to get the reverse state. If the "Either CP" address for Bits 39 and 40 (i.e., "11") is not used, then those two bits must be carefully selected to address the CP to which the command is to be sent, i.e., "01" for CP 1 and "10" for CP 2. Even though there is only a single quantitative command to each CP from a different COM, there is a possibility that the receiver reverse function can be defeated through selection of the wrong address bits in the quantitative command sent to a CP. If the wrong CP address is sent, the normal and reverse outputs will be inhibited, but the omni select output will always occur at receiver reverse timeout. The two flip-flops that control the power strobe to the output buffer and the gating of the output pulse are placed in opposite logic states. Consequently, the output pulse will be gated to an "off" output buffer and will be inhibited from going to the "on" output buffer. This occurs basically because one flip-flop is connected to a decoder that senses the address bits and the other is connected to a decoder that does not. The status of the normal/reverse logic is only sensed on one flip-flop so that it is impossible to determine from telemetry if the wrong address bits were sent.

It takes a combination of three human errors and hardware failures for this problem to have a catastrophic effect on the mission. The combination is: (1) a receiver failure to necessitate the use of the receiver reverse capability, (2) a CP failure (or a human error that causes the CP to be addressed incorrectly), and (3) a human error that causes the remaining operational CP (or second operational CP) to be addressed incorrectly. If there is uncertainty as to whether the CPs are correctly configured prior to entering a long period without command transmissions, the correct quantitative commands could be retransmitted to the spacecraft. This is done by sending both CP configure commands, CPCQ1 and CPCQ2, in the Receiver Normal mode, or sending both commands in the Receiver Reverse mode.

To preclude the occurrence of this problem, it is best to always code bits 39 and 40 as "11". This code selects either CP, and bit 15 of the uplink command should be used only to select the desired CP.

Furthermore, if the CP should experience an overcurrent condition that causes the power supply to be turned off by the cyclic fuse, and if the fault was later removed and power re-applied, the receiver reverse counter will be reset to zero and the logic will initialize in some random state. This means the two CPs may not be synchronized and, consequently, the CP CONFIGURE quantitative command should be sent to each CP so that the two CPs will output the same commands simultaneously.

3.6.3.5 Small Probes Release Operations. The three Small Probes on the Multiprobe spacecraft are released simultaneously with a single FIRE command to the PCU that is routed through the Attitude Data Processor (ADP). As shown in Figure 3.6.1-1, the CDU outputs a discrete command to an ADP and the ADP in turn transfers the command to the PCU.

There are four discrete commands involved in this operation; two that go to ADP 1 and two that are sent to ADP 2. The purpose of all these commands is to provide redundant inputs to each ADP from redundant CDUs without cross-strapping in the spacecraft harness.

Prior to releasing the Small Probes, the ARM SMALL PROBE SEPARATION command (ORD21 and ORDB1) must be sent to PCU 2. The Small Probes will be released by real-time commands so that the ADP 1 SMALL PROBE RELEASE command (REL11 or RELA1) or the ADP 2 SMALL PROBE RELEASE command (REL21 or RELB1) must follow contiguously the ARM command. Only one ADP is powered on during the Small Probe release operation, so the appropriate command must be sent.

The ADP that receives the RELEASE command delays the issuance of the command to PCU 2 until the occurrence of the next Roll Index Pulse (RIP). The delay through the ADP is a function of the time of arrival of the command and the spin rate of the spacecraft. The nominal spin rate planned for Small Probe release is 48.5 rpm so that the worst case delay is on the order of 1.2 seconds. The PCU timing diagram presented in Section 3.6.2.3 shows that the PCU will automatically disarm 18.5 ±4.5 seconds after receipt of the ARM command. Under worst case conditions, this permits a delay of two seconds through the ADP. The two second worst delay results from the time difference between the time it takes to receive a real-time command (i.e., 12 seconds) and the minimum time to disarm (i.e., 14 seconds). The minimum spin rate is expected to be 40 rpm which results in a delay of 1.5 seconds in the ADP or a margin of 0.5 seconds. Consequently, the ARM and RELEASE commands must be contiguous to release the probes. When the ADP issues the command to PCU 2 synchronously with the RIP, a telemetry status flag is set in bit position 5 (i.e., APRELS) of ADP Status Word 5.

The command from the ADP is cross-strapped in the harness to the A and B sides of PCU 2 and fires six (6) squibs simultaneously; the primary three

(3) and the redundant three (3). This mechanization prevents non-simultaneous release of the three Small Probes. When the probes are released from the attachment ring, a status flag for each Small Probe is sent to telemetry indicating release. The telemetry outputs for Small Probes 1, 2, and 3 are S1RELS, S2RELS and S3RELS, respectively.

An example of the use of the above commands is given in Section 4.2.3.

3.6.3.6 Coast Timer Loading Operations. The coast timer on each of the Large and Small Probes is used to start the Entry Sequence Programmer (ESP), which in turn issues time dependent commands during the descent phase of the probe's mission. The time delay is loaded into the coast timer by the COAST TIMER SET quantitative command to the Command/Data Unit (CDU) on each probe. On the Large Probe, the primary command (LCTQ1) is processed by the Large Probe COM (i.e., COM 7 on COM channel 7Q1) and the redundant command (LCTQA) is processed by a COM (i.e., COM 1 on COM channel 1Q3) on the Bus spacecraft. For the case of the Small Probes, both the primary (SCTQ1, SCTQ2, and SCTQ3 for COM assignments (1Q0, 3Q0, and 5Q0 respectively) and redundant (SCTQA, SCTQB, SCTQC for COM assignments -- 2Q0, 4Q0, and 6Q0 respectively) commands are received through the In-Flight Disconnect (IFD) from COMs on the Bus spacecraft.

The coast timer has the capability to process a 24.27 day time delay (i.e., 2^{16} x 32 seconds) with a resolution of 32 seconds. The time delay consists of 16 bits of data placed into the quantitative command format LSB first. To compute the binary number needed for the command, the following formula should be used:

$$N = \frac{\Delta To - 63}{32} \quad \text{where } \Delta To \text{ is in seconds}$$

Exampl Suppose a coast duration of 22 days, 1 hour, 32 minutes and 5 seconds is desired.

$\Delta To = 1,906,325_{10}$ seconds

$N = 59,570.687_{10}$ seconds

Since N is not an integer and since the coast timer can only be programmed with integers, we select the programming number N to be $59,570_{10}$ and account for the .687 seconds by issuing a start timer command .687 seconds later than required. (We assumed in this example that the 32 second divisor is exact, i.e., the time base is perfect). The 16 bit coast magnitude command number is simply the binary equivalent of $59,570_{10}$.

	LSB															MSB
N =	0	1	0	0	1	1	0	1	0	0	0	1	0	1	1	1

i.e.,

$59570_{10} = 2^1+2^4+2^5+2^7+2^{11}+2^{13}+2^{14}+2^{15}$

After the coast time is loaded in a probe, the countdown is started by the START COAST TIMER command unique to the probe. This command (LCTA9 or LCT19) is processed by the Large Probe COM (i.e., COM 7) and a Bus COM (i.e., COM 5) for the Large Probe respectively; and two COMs on the Bus spacecraft for each Small Probe (SCT19 or SCTA9; SCT29 or SCTB9; SCT39 or SCTC9 for SP1, 2, and 3 respectively). Prior to sending the START COAST TIMER command, the time code stored in the coast timer can be verified by Bus telemetry. The telemetry output is LSB first as loaded and consists of two eight bit words read out into channel CXTIMC, where X equals L, 1, 2, 3 for the Large and three Small Probes, respectively. The two eight bit words must be ordered by the ground software into the 8 MSB and 8 LSB bits to reconstruct the original 16 bit time code. The coast timer outputs one 8 bit word with each sampling by telemetry and does not account for the ordering of the words except when the START TIMER COMMAND is received. When the START command is received, the coast timer reorders the time code so that the correct 16 bit code will be processed.

Before the START is sent, the full 16 bit time code can be verified. However, once the coast timer has started counting, the time code can no longer be verified. The coast timer is under the control of its own 0.5 Hz clock and ignores the read clock from telemetry once it has started running. Therefore, the telemetry output will be the LSB of the shift register holding the count, and so the telemetry will show all ones or all zeros. The shift register performs an end around shift every two seconds, so it is possible for the LSB to change from a one to a zero, or vice versa, in the middle of a telemetry sample. In this case, the eight bit telemetry word will consist of groups of ones and zeros. While the coast timer is running, a random readout into telemetry of these types of words indicates that it is most likely performing properly, but does not show conclusively that a failure has not occurred.

The coast timer can be stopped by sending a new quantitative command containing a new time code or just some random time code. There is no other way to stop it once the START command has been executed. After receipt of the quantitative command, the coast timer will remain stopped until the next START command. The data contained in the quantitative command will be loaded into the coast timer as a new time delay.

Examples of the use of the above commands during the mission are shown in Sections 4.2.2 and 4.2.3.

3.6.4 Command Response. Table 3.6.4-1 presents the command responses for the command subsystem. The table lists every command that directly affects the subsystem and the telemetry indication that verifies the proper execution of the command. The mnemonics for each of the command and telemetry parameters are also included.

TABLE 3.6.2.1.6-1

COMMAND PROCESSOR TELEMETRY OUTPUTS

Telemetry Word	Format	Active State: Logic 1 Inactive State: Logic 0	Mnemonic (See Note 1)
Word 1	Bit 0 → Bit 3 (MSB) (LSB)	SCL State Status; see SCL State diagram, Figure 3.6.3.2-1.	CLOGXS
	Bit 4	SCL ON/OFF Status.	CSCLXS
	Bit 5	Demodulator Status that indicates squelch state.	CDMDXS
	Bit 6 → Bit 7 (MSB) (LSB)	These two bits are the MSB bits of the receiver reverse timer, and produce four time combination: 27.3 Hrs., 18.2 Hrs., 9.1 Hrs., and 0 Hrs.	RREVXC
Word 2	Bit 0	Reject flag indication that real time processor has detected an error in a RT command.	CREJXS
	Bit 1 → Bit 7 (MSB) (LSB)	7-Bit count indicating number of verified real time commands processed.	CCMDXC
Word 3	Bit 0	Separation switch status.	SSEPXS
	Bit 1 → Bit 7 (MSB) (LSB)	SCL address pointer indicating present location in SCL memory.	CMEMXC
Word 4	Bit 0 → Bit 7 (MSB) (LSB)	Represents 8 bits of 24-bit SCL command word stored in memory. During SCL memory dump, 3 telemetry words are needed to completely read the 24-bit SCL command word.	CMEMX

NOTE 1: X = 1 for CP 1.
X = 2 for CP 2.

TABLE 3.6.3.2.3-2

ACCURACY OF 4096 SECOND CLOCK

HIGHEST BIT RATE SELECTED SINCE TP TURNON

OPERATING BIT RATE AT 4096 SECOND TRANSITION	16	64	128	$170\frac{2}{3}$	256	$341\frac{1}{3}$	512	$682\frac{2}{3}$	1024	2048
8	0	0	0	0	0	500	500	750	750	750
16	0	0	0	0	0	0	0	250	250	250
64		0	0	0	0	0	0	0	0	0
128			0	0	0	0	0	0	0	0
$170\frac{2}{3}$				$31\frac{1}{4}$	$32\frac{1}{4}$	$31\frac{1}{4}$	$31\frac{1}{4}$	$31\frac{1}{4}$	$31\frac{1}{4}$	$31\frac{1}{4}$
256					0	0	0	0	0	0
$341\frac{1}{3}$						$15\frac{5}{8}$	$15\frac{5}{8}$	$15\frac{5}{8}$	$15\frac{5}{8}$	$15\frac{5}{8}$
512							0	0	0	0
$682\frac{2}{3}$								$7\frac{13}{16}$	$7\frac{13}{16}$	$7\frac{13}{16}$
1024									0	0
2048										0

CONTENT OF EACH CELL IS THE MAXIMUM ERROR IN MILLISECONDS BETWEEN THE DESIRED START TIME AND THE OCCURRENCE BY THE CP OF THE 4096 SECOND CLOCK TRANSITION.

TABLE 3.6.4-1

COMMAND RESPONSES FOR COMMAND SUBSYSTEM

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	Title	Response	Mnemonic	Indication and/or Remarks
The sixth alphanumeric is "A" for CP1, or "B" for CP2.	Stored Command	The SCL of the appropriate CP, if it is in the LOAD state, will accept the stored command, and its address pointer will advance by one count for each stored command.	CLOG1S CLOG2S	SCL State: State 14 (Load)
			CMEM1C CMEM2C	Command Memory Address Pointer: Command Memory address will advance one count for each memory load command.
CMTQ1 for CP1; or CMTQ2 for CP2.	Stored time delay command.	No apparent difference from response to any stored command (above).		• Same as for any stored command, above. • Memory verification will indicate if correct time delay was loaded.
CP Configure SCL Command) (CPCQ1 or CPCQ2) STORCMD = XXXXX.	SCL Standby (0001) (STORCMD = STDBY)	If SCL is ON and in any state except 10, SCL will go to State 15.	CLOG1S CLOG2S	SCL State: State 15.
	SCL Immediate Start (0010)	If SCL is ON and in States 0, 1, 4, 5 or 15, SCL will go to State 12 for 62.5 ms and then switch among States 8, 9, 12 and 13 depending on the stored command being processed. If SCL is ON and in State 2 and the next memory entry is a command (MSB=1), SCL will go to State 8 and continue processing. If SCL is ON and in State 2 and the next memory entry is a delay (MSB=0), SCL will go to State 13 and continue processing. If SCL is ON and in State 3, SCL will go to State 9 and continue processing the delay stored in the time delay counter.	CLOG1S CLOG2S	SCL State: States 8, 9, 12 and 13, depending on stored command being processed and TM sampling of state.
			CMEM1C	Command Memory Address Pointer: Command Memory address will be advancing as commands and time delays are being processed.
				Other TM: Other subsystems will be commanded by the stored commands.

TABLE 3.6.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	Title	Response	Mnemonic	Indication and/or Remarks
CPConfigure (SCL Command) (Continued) (CPCQ1 or CPCQ2) STORCMD = XXXXX.	SCL Timed Start (0011) (STORCMD = TIMED)	If SCL is ON and in any state except 6, 10, 11 or 14, SCL will go to State [illegible] If and when the 4096 clock [illegible], SCL will go to State [illegible] When the 4096 clock (i.e., the second MSB of DCLOK2) goes from one to zero, SCL will go from State 5 to State 12 for 62.5 ms then switch among States 3, 9, 12 and 13, depending on the stored commands being processed.	CLOG1S CLOG2S	SCL State: State 1 until the 4096 clock (i.e., the second MSB of DCLOK2) goes to one and then the SCL goes to 5. If clock is already one, the transition from State 1 to 5 will occur at once. When clock [illegible]es from one to zero, switching between States [illegible], [illegible], 12 and 13 will occur, depending on stored commands being processed and TM sampling of state.
			CMEM1C CMEM2C	Command Memory Address Pointer: When 4096 clock goes from one to zero, command memory address will start advancing as commands and time delays are being processed.
				Other TM: Other subsystems will be commanded by the stored commands.
	SCL Load (0100) (STORCMD = LOAD)	If SCL is ON and in State 15, SCL will go to State 14. SCL must be in State 14 to load the memory by sending memory load commands.	CLOG1S CLOG2S	SCL State: State 14.
			CMEM1C CMEM2C	Command Memory Address Pointer: Command memory address will advance one count for each memory load command.
	SCL Advance (0101) (STORCMD = ADVAN)	If SCL is ON and in State 15, SCL will go to State 11. The memory [illegible] shifted 24 bits which results in a one-word advance in memory. SCL will then go to State 6 and remain there until a standby command is received.	CLOG1S CLOG2S	SCL State: State 6 (Advance complete). State 11 will probably not be observed by TM.
			CMEM1C CMEM2C	Command Memory Address Point: Advances count by one for each issuance of advance/standby command pair.

TABLE 3.6.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	**Title**	**Response**	**Mnemonic**	**Indication and/or Remarks**
CP Configure (SCL Command) (Cont'd) (CPCQ1 or CPCQ2) STORCMD = XXXXX.	SCL Advance (0101) (STORCMD=ADVAN) (Cont'd)	If SCL is ON and in State 2 or 3, the SCL then goes to State 12 for 62.5 ms, and switches among States 8, 9, 12 and 13, depending on the stored commands being processed.	CLOG1S CLOG2S	SCL State: States 8, 9, 12 and 13 depending on stored commands being processed and TM sampling of state.
			CMEM1C CMEM2C	Command Memory Address Pointer: Command memory address will be advancing as commands and time delays are being processed.
				Other TM: Other subsystems will be commanded by the stored commands.
	SCL Stop (0110) (STORCMD = STOP)	If SCL is ON and in State 8, SCL will go to State 2. If SCL is ON and in State 13 or 9, and the time delay counter is zero, SCL will go to State 2. If SCL is ON and in State 13 or 9 and the time delay counter is not zero, SCL will go to State 3. The counter will stop counting and retain the count that existed when the STOP command was received.	CLOG1S CLOG2S	SCL State: State 2 or 3, depending on conditions listed under command response.
	SCL Arm Separation Switch (0111) (STORCMD=ARMSP)	If SCL is ON and in State 15, and separation switch is closed, SCL will go to State 0 and remain indefinitely until commanded out of that state. If SCL is ON and in State 15, and separation switch is open, SCL will go to State 0 and then immediately to State 4. When the separation switch is closed, SCL will go from (Continued)	CLOG1S CLOG2S	SCL State: State 0, if the separation switch is closed (i.e., SSEPXS = 1). State 4 if the separation switch is open (i.e., SSEPXS = 0).

TABLE 3.6.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	Title	Response	Mnemonic	Indication and/or Remarks
CP Configur (SCI Command)(Cont'd) (CPCQ1 or CPCQ2) STORCMD = XXXXX.	SCI Arm Separation Switch (C111) (STORCMD=ARMSP) (Continued)	State 4 to State 12 and start processing stored commands as described under SCL Immediate Start Command. (Closing of the separation switch sets a latch in SCL which can only be reset by removing essential bus voltage from the unit which is not possible by command).		
	SCI Clear/ON (1000 or 1001) (STORCMD = CLER1 or CLER2).	If SCL is OFF, SCL power will be turned ON with SCI in State 15. Command memory will be cleared and the command memory address pointer will be zero. If SCL is ON and in State 15, command memory will be cleared and the command memory address pointer will be zero.	CLOG1S CLOG2S	SCI State: State 15.
			CSCL1S CSCL2S	SCL State: ON (Logic 1)
			CMEM1C CMEM2C	Command Memory Address Pointer: Zero.
			CMEM1 CMEM2	Command Memory Readout: Entire memory reads zero.
			PBUSLI	Spacecraft Loads Current: An increase of about 72 milliamperes (1 LSB) when SCL is turned ON.
			PLIMTI	Bus Voltage Limiter Current: Decreases as much as PBUSLI has increased, if sufficient surplus solar panel current is present.

TABLE 3.6.4-1. (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	**Title**	**Response**	**Mnemonic**	**Indication and/or Remarks**
CP Configure (SCL Command)(Cont'd) (CPCQ1 or CPCQ2) STORCMD = XXXXX.	SCL Index (1010 or 1011) (STORCMD = INDX1 or INDX2)	If SCL is ON and in states 15 or 10, command memory will be end around shifted until the first stored word occupies address 0. SCL will go to State 15.	CLOG1S CLOG2S	SCL State: State 15.
			CMEM1C CMEM2C	Command Memory Address Pointer: Zero.
	SCL Read (1100 or 1101) (STORCMD = READ1 or READ2)	If SCL is ON and in state 15, SCL will go to State 10. SCL must be in State 10 for memory verification. SCL will go from State 10 to State 15 when the address pointer goes to zero during memory verification or by an index command.	CLOG1S CLOG2S	SCL State: State 10.
			CMEM1C CMEM2C	Command Memory Address Pointer: Command memory address will be advancing during memory verification.
	SCL OFF (1110 or 1111) (STORCMD = OFF1 or OFF2)	SCL Power will be turned OFF.	PBUSLI	Spacecraft Loads Current: A decrease of about 72 milliamperes (1 LSB) when SCL is turned OFF.
			PLIMTI	Bus Voltage Limiter Current: Increases as much as PBUSLI has decreased, if sufficient surplus solar panel current is present.
			CSCL1S CSCL2S	SCL Status: OFF (Logic 0)
			CLOG1S CLOG2S	SCL Status: All Logic 1 Bits.

TABLE 3.6.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	**Title**	**Response**	**Mnemonic**	**Indication and/or Remarks**
CP Configure (Receiver and Telemetry Commands) (CPCQ1 or CPCQ2) RCV = XXXX	Receiver Normal (RCV = NORML)	The Receiver Normal command will set the Command Processor Receiver Reverse State to NORMAL and generate an envelope to select the normal omni antenna/receiver configuration.	CREV1S CREV2S	CP Receiver Reserve State: Normal (Logic 1).
			RRCVRS	RF Switch Position: Receiver 1 to forward antenna and Receiver 2 to aft antenna (Logic 1).
	Receiver Reverse (RCV = RVRSE)	The Receiver Reverse command will set the Command Processor Receiver Reverse State to REVERSE and generate an envelope to select the reverse omni antenna/receiver configuration.	CREV1S CREV2S	CP Receiver Reverse State: Reverse (Logic 0).
			RRCVRS	RF Switch Position: Receiver 2 to forward antenna and Receiver 1 to aft antenna (Logic 0).
	Clear Command Counter and Reject Flag (RCV = CLEAR)	The command counter and reject flag in the CP will be set to zero.	CREJ1S CREJ2S	Command Reject: Zero.
			CCMD1C CCMD2C	Command Counter: Zero.
CP Configure (CP Select) (CPCQ1 or CPCQ2) CMDPROC-SEL = XXXX	Command Processor Select (CMDPROCSEL = None/No. 1/No. 2/ Either 0/1/2/3).	Sets up logic to configure receiver reverse for normal or reverse outputs.	N/A	No telemetry verification.

TABLE 3.6.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	**Title**	**Response**	**Mnemonic**	**Indication and/or Remarks**
COM1Ø COM3Ø COM5Ø	COM 1 & 2 OFF COM 3 & 4 OFF COM 5 & 6 OFF	For some failure modes in the COM which leave the COM powered ON, the COM can still be used by sending a COM OFF command after each command using that COM. In normal operation, the COM is automatically turned OFF at completion of command processing.	N/A	If a COM fails to respond to a command, send a COM OFF command and try to send the command again. If the COM responds to the command, the COM can still be used by sending a COM OFF command after each command using the COM.
MEM1Ø	SCL 1 OFF	Discrete command which will turn SCL 1 Power OFF.	CSCL1S	SCL 1 Status: Zero.
			PBUSLI	Spacecraft Loads Current: A decrease of about 72 milliamperes (1 LSB) when SCL is turned OFF.
			PLIMTI	Bus Voltage Limiter Current: Increases as much as PBUSLI has decreased, if sufficient surplus solar panel current is present.
MEM2Ø	SCL 2 OFF	Discrete command which will turn SCL 2 Power OFF.	CSCL2S	SCL Status: Zero.
			PBUSLI	Spacecraft Loads Current: A decrease of about 72 milliamperes (1 LSB) when SCL is turned OFF.
			PLIMTI	Bus Voltage Limiter Current: Increases as much as PBUSLI has decreased, if sufficient surplus solar panel current is present.
ORD11 ORDA1	Arm Large Probe Separation	Provide power to the squib drivers for Large Probe Separation starting 4.0 seconds after the command and ending 16.5 seconds after the command.	N/A	Verified if associated fire command is accepted. There is no telemetry indication of PCU arm/disarm functions.

TABLE 3.6.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	Title	Response	Mnemonic	Indication and/or Remarks
ORD12 ORDA2	Large Probe Separation	If associated squib drivers are armed, this command fires Large Probe Separation squibs.	SLRELS	Large Probe Stowed/Released Status: Released (Logic 1).
			N/A	Bus spacecraft attitude and spin rate disturbances.
ORD13 ORDA3	Arm Large Probe IFD and BNMS B/O Hat	Provide power to the squib drivers for Large Probe IFD and BNMS B/O Hat, starting nominally 4.0 seconds and ending 18.5 seconds after the command.	N/A	Verified if associated fire command is accepted. There is no telemetry indication of PCU arm/disarm functions.
ORD14 ORDA4	Fire Large Probe IFD	If associated squib drivers are armed, this command fires Large Probe IFD squibs.	N/A	All telemetry channels routed to Bus DIMs via IFD go to full scale.
ORD15	Fire BNMS B/O Hat Primary	If associated squib driver is armed, this command fires BNMS B/O Hat Primary squib.	N/A	Indirectly verified by proper instrument operation.
ORD16	Fire BNMS B/O Hat Secondary	If associated squib driver is armed, this command fires BNMS B/O Hat Secondary squib.	N/A	Indirectly verified by proper instrument operation.
ORD1Ø ORDAØ	Disarm PCU 1	For some failure modes in which the timer in the PCU fails to disarm the squib drivers, this command will disarm them if sent after 18.5 seconds from arming.	N/A	There is no telemetry indication of PCU arm/disarm functions.

TABLE 3.6.4-1 (Continued)

COMMAND			TELEMETRY VERIFICATION	
Mnemonic	**Title**	**Response**	**Mnemonic**	**Indication and/or Remarks**
ORD21 ORDBA	Arm Small Probe Separation	Provides power to the squib drivers for Small Probe Separation, starting 4.0 seconds after the command, ending 18.5 seconds after the command. The associated fire commands are issued by the attitude control subsystem.	N/A	Verified if associated fire command is accepted. There is no telemetry indication of PCU arm/disarm functions.
ORD22 ORDB2	Arm Small Probe IFD and BNMS Cal Gas Pyro.	Provides power to the squib drivers for Small Probe IFD and BNMS Cal Gas Pyro starting 4.0 seconds after the command and ending 18.5 seconds after the command.	N/A	Verified if associated fire command is accepted. There is no telemetry indication of PCU arm/disarm functions.
ORD23 ORDB3	Fire Small Probe IFD	If associated squib drivers are armed, fire Small Probe IFD squibs.	N/A	Verified if all Small Probe temperatures, bilevel and timer verification telemetry go to full scale.
ORD24 ORDB4	Fire BNMS Cal Gas Pyro	If associated squib drivers are armed, fire BNMS Cal Gas Pyro squibs.	N/A	Indirectly verified by proper instrument operation.
ORD2Ø ORDBØ	Disarm PCU 2	For some failure modes in which the timer in the PCU fails to disarm the squib drivers, this command will disarm them if sent after 18.5 seconds from arming.	N/A	There is no telemetry indication of PCU arm/disarm functions.

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****                                ****
****     This Figure is a Foldout.  ****
****                                ****
****          See APPENDIX C        ****
****                                ****
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Figure 3.6.1-1

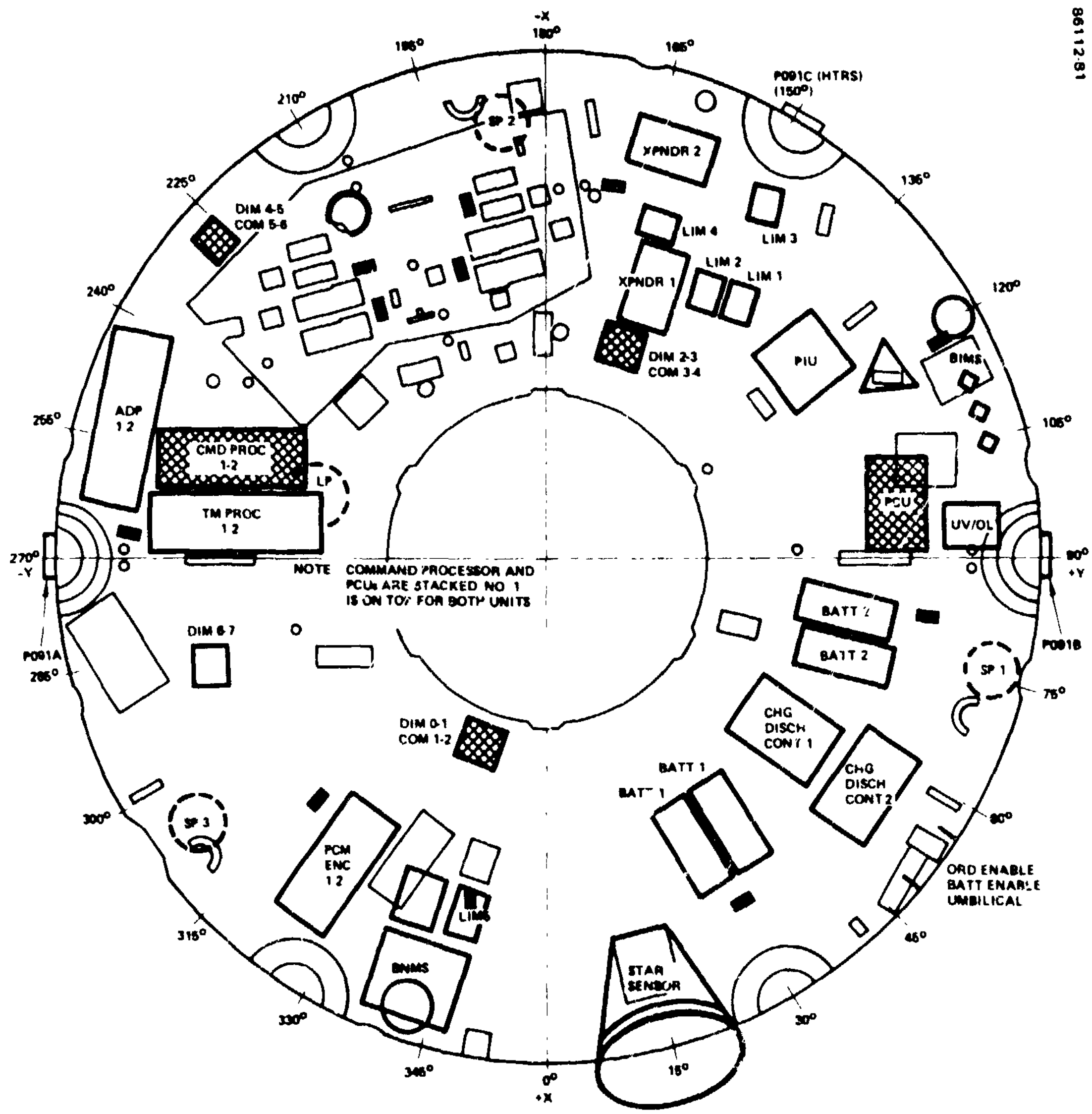

FIGURE 3.6.1-2 SHELF LAYOUT OF COMMAND SUBSYSTEM

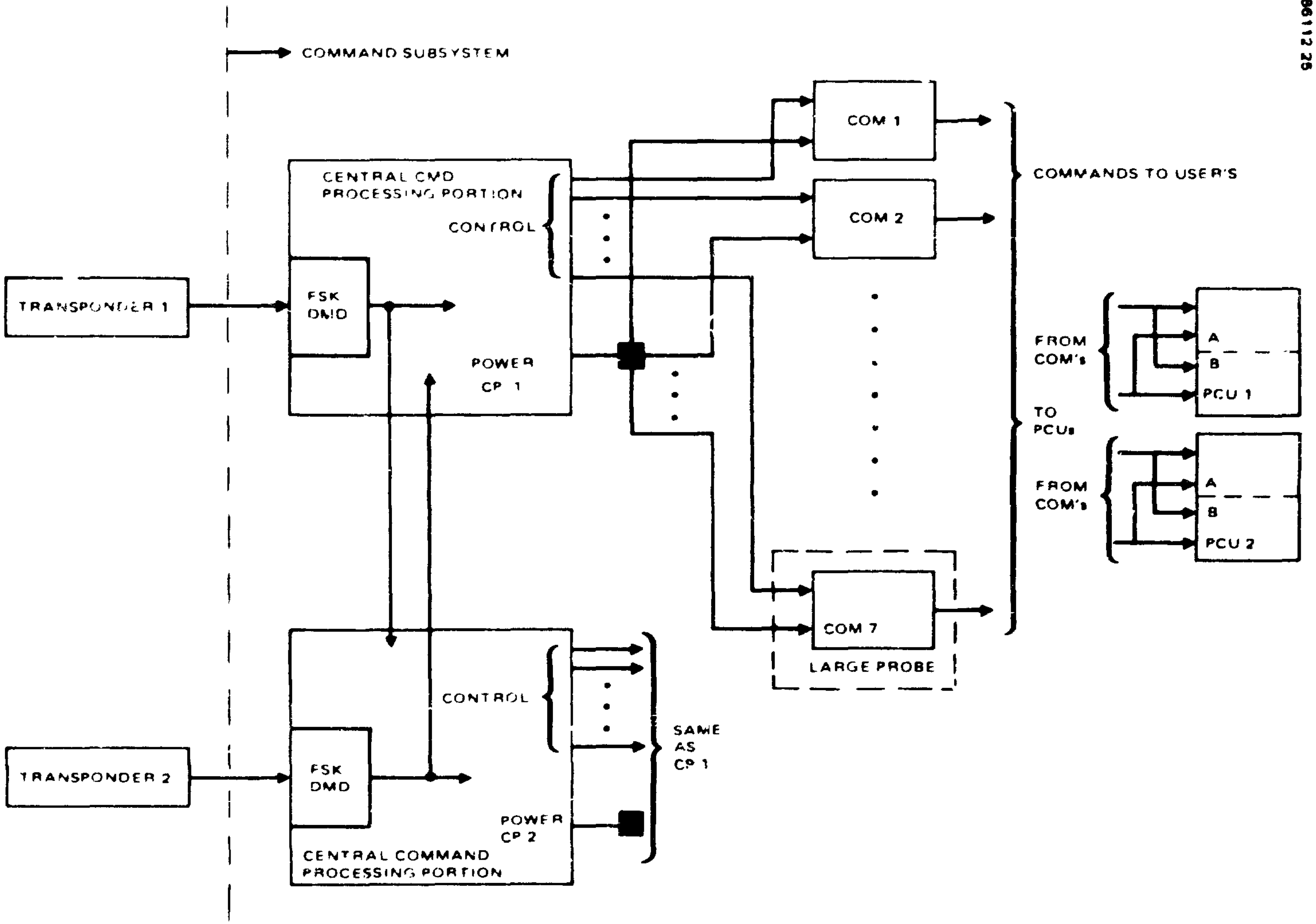

FIGURE 3 6 1 3 MULTIPROBE COMMAND SUBSYSTEM REDUNDANCY BLOCK DIAGRAM

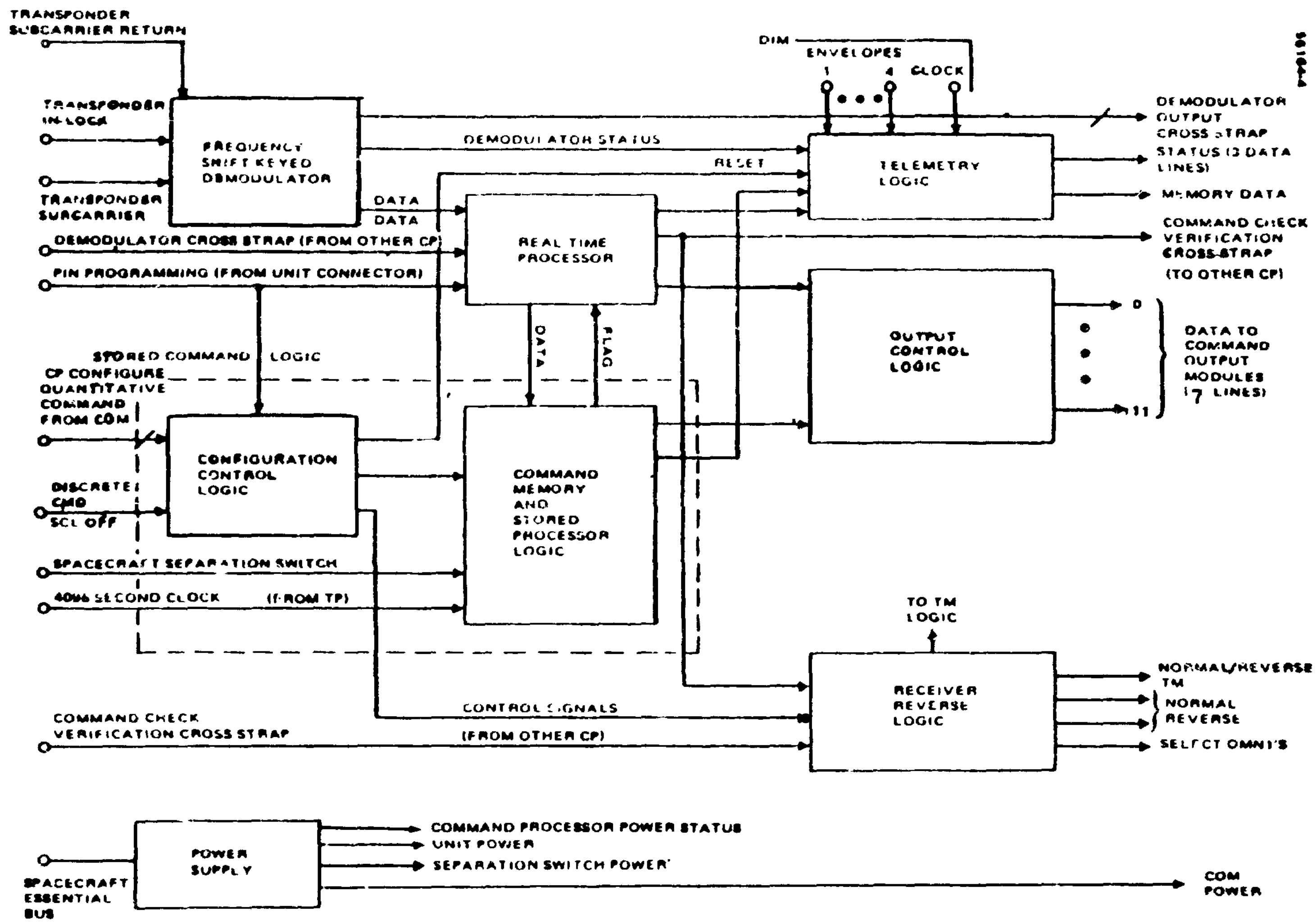

Figure 3.6.2.1-1. Functional Block Diagram of Single Command Processor

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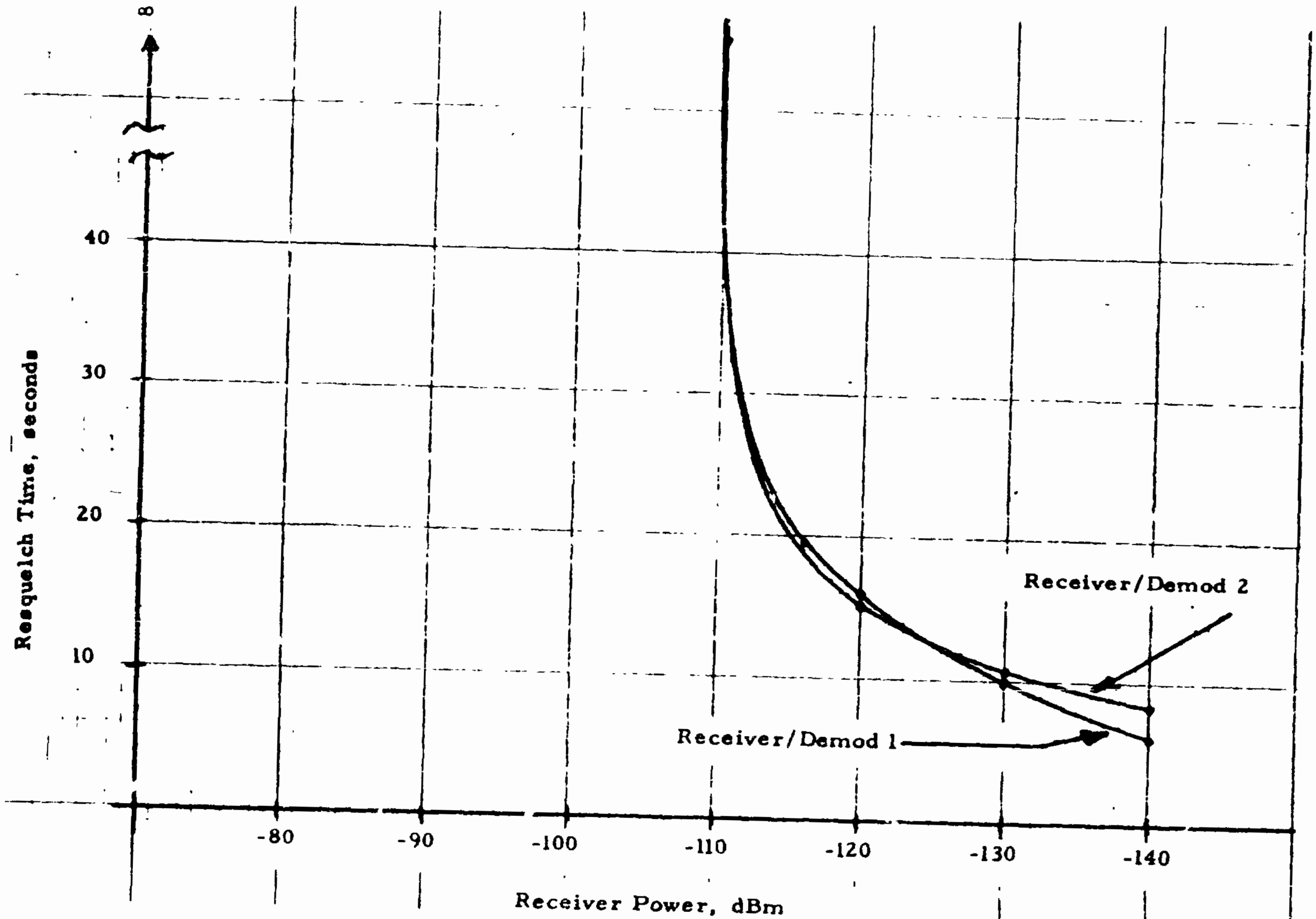


Figure 3.6.2.1.1-1. Resquelch Time Versus Receiver Input Power (Worst Case)

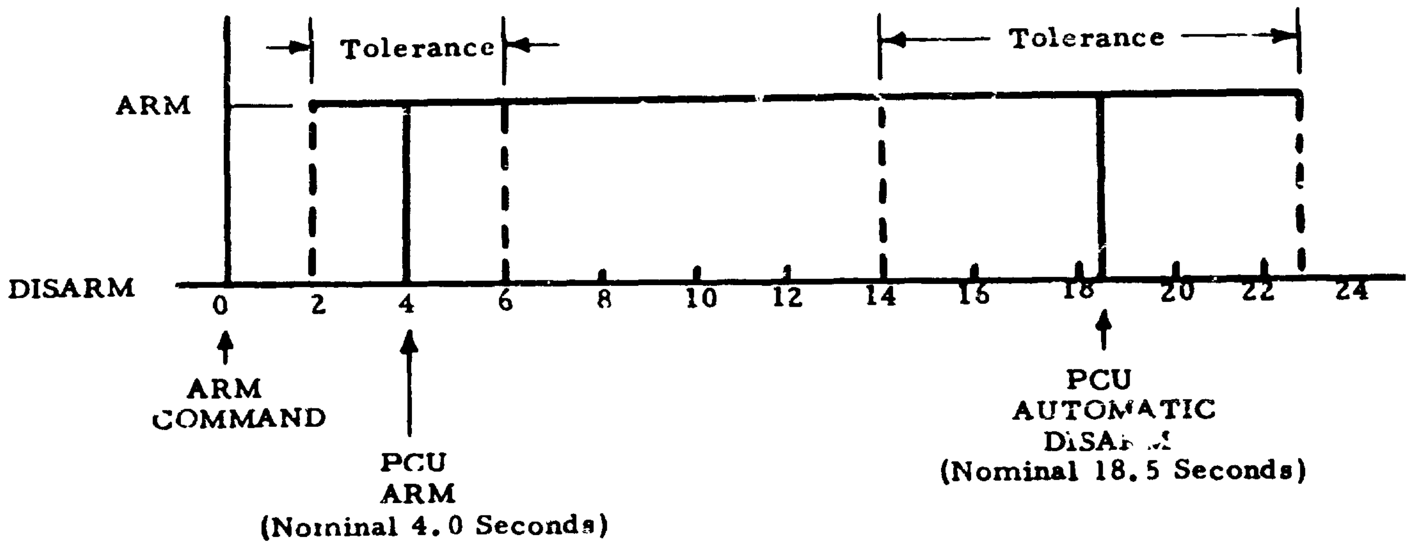
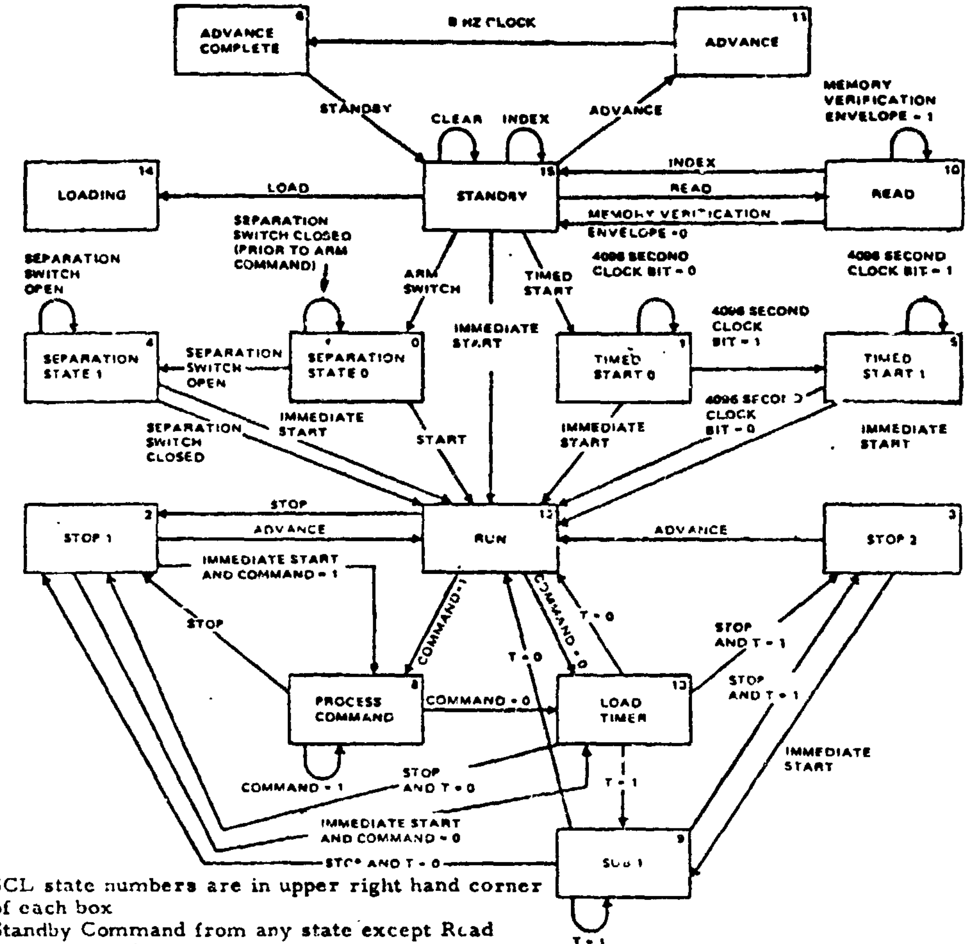


Figure 3.6.2.3-1. PCU Timing Relationships

Revision



• SCL state numbers are in upper right hand corner of each box
• Standby Command from any state except Read goes to standby
• Timed start command from any state except 6, 10, 11 and 14 goes to state 1
• T=1 when a time delay command has been executed, and the time delay has not yet decremented to zero
• T=0 when the time delay has decremented to zero
• COMMAND=0 for a time delay entry
• COMMAND=1 for a command entry.

Figure 3.6.3.2-1. SCL State Diagram

3.7 COMMUNICATIONS SUBSYSTEM

3.7.1 Subsystem Description. The Bus communication subsystem generates an S-band downlink signal, phase modulates it with the PSK modulated telemetry subcarrier from the telemetry processor, and transmits it, with nominally either 10 or 20 watts of RF power fed into one of several antennas. The subsystem also receives and demodulates the uplink phase modulated S-band signal and provides the PSK tones to the command processor. Hemispherical transmit and receive coverage is provided for the S-band signals by the multiple antennas shown in Figure 3.7.1-1. The forward omni covers approximately zero to 95° from the +Z axis, and 95° to 180° is covered by the aft omni. The medium gain horn covers approximately 150° to 180° from the +Z axis. Selection of the desired antenna and transmitter/receiver combination is accomplished by means of the RF switches, as shown in the functional block diagram of Figure 3.7.1-2 and the appropriate "ON/OFF" command of the power amplifiers and transponder exciters. Transponder 1 receiver or transponder 2 receiver selection is done by tuning the uplink frequency to the desired receiver's unique operating frequency (2111.266204 MHz and 2110.584105 MHz, respectively) since both receivers are always on. The "in-lock" status signal from each receiver is sent to the command processor to guard against the noise output of the unused receiver from being processed by the command processor. The transmitter consists of four 10-watt solid-state power amplifiers which can be operated one at a time or in pairs. When operated in pairs, their outputs are summed by a 3 dB hybrid to provide the 20 watt S-band RF capability. Each of the four power amplifiers is driven by a dedicated solid-state driver amplifier that receives its dc power from the power amplifier power converter that it is driving. All four driver amplifiers are driven simultaneously by means of the four-way power divider (6 dB hybrid, whose input is selected by the SPDT switch (S-switch) to be either one of the transponder exciters). A simultaneous transmit and receive capability through either of the two omni antennas is provided by the two diplexers. (The medium gain horn is usable for spacecraft transmission only.)

The communication subsystem units are arranged on the spinning equipment shelf as shown in Figure 3.7.1-3. Placement of the units is intended to minimize coax line length and RF insertion loss. The power amplifiers, due to their high internal heat dissipation, have been located over the shelf thermal louvers.

A detailed Logic Flow diagram for the subsystem is shown in Figure 3.7.1-4 (Appendix C). It identifies all command inputs to their terminal points, and all telemetry outputs from their generic sources.

3.7.2 Units Descriptions

3.7.2.1 Transponder. The transponder consists of a receiver section and an exciter section. A functional block diagram of the transponder is shown in Figure 3.7.2.1-1. The frequency plan shown in the block diagram is given in terms of the S-band downlink frequency, nominally 2294 MHz, as indicated by 240 F_1. The frequency indicated by F_2 is the second IF frequency and is nominally 12.25 MHz.

3.7.2.1.1 Transponder Receiver. The transponder receiver, hereafter referred to as the receiver, is an S-band phase lock receiver that demodulates the uplink command tones from the carrier and provides a frequency source for the exciter that is phase coherent with the uplink carrier. The uplink RF is routed first to the RF converter module. This module limits the receiver predetection bandwidth to 60 MHz by means of the preselector filter.

After conversion to the first IF frequency of $13F_1$, the signal is routed to the first IF amplifier where it is amplified and converted to the second IF frequency of F_2. The second IF amplifier further amplifies the signal, performs narrow-band filtering and provides a hard limited output and a linear output to the phase detector assembly.

The detector demodulates the linear input to provide a coherent AGC and the in-lock signals. The hard limited input is demodulated to provide the error signals for the phase lock loop and the command subcarrier. The phase lock error signal is conditioned by the second order loop filter in the VCO module. The output of the loop filter controls the VCO phase and frequency and is also telemetered as the static phase error (SPE). The VCO output frequency is multiplied and translated (via a fixed oscillator at $2F_1$) in the local oscillator assembly to provide the mixer frequencies of $26F_1$ to the RF converter, and $(13F_1) - F_1$ to the first IF amplifier modules. It also provides the reference frequency ($2F_1$) to the detector module for the coherent phase detection process.

Power for the receiver modules is provided by a power converter that converts the nominal 28 volt input voltage (essential bus) to +9V (receiver), +9V (relay voltage for exciter control functions) and -6V (receiver). Overcurrent protection for the receiver is provided by a current limiter set at 200 ±30 ma. Receiver fusing is included externally in the spacecraft harness (3/8 amp fuse). The receiver cannot be commanded OFF, and is ON whenever dc is applied to the dc input. Since both receivers are connected to the spacecraft essential bus, they are always ON and receiver addressing is via appropriate uplink frequency selection. The important operational characteristics of the receiver are as follows:

• Noise Figure	7.4 dB
• Carrier Threshold (at receiver input terminal)	-153 dBm
• Threshold Loop Noise Bandwidth ($2B_{LO}$)	18 Hz
• Tracking Capability	±200 kHz at 55 Hz/sec at -140 dBm input level
• AGC Range	100 dB minimum
• Command Capability	None
• Command Threshold (Calculated, for BER = 3.5 x 10^{-4})	-118.6 dBm/m² (worst case flux density) (-136.61 dBm at the receive antenna output port).

Best Lock Frequency Stability (Also See Figure 3.7.2.1-2):

Condition	Transponder No. 2 (SN 5)	Transponder No. 1 (SN 6)
-40°F to +126°F	22.0 kHz	15.4 kHz
+32°F to +90°F	6.5 kHz	4.1 kHz
at +31°F for 10 hours	3.8 kHz	2.3 kHz

Telemetry Information (More details are found in Appendix A):

- Automatic Gain Control (AGC)
- Static Phase Error (SPE)
- In-lock Status
- VCO Temperature

3.7.2.1.2 Transponder Exciter. The exciter provides an S-band signal that is phase modulated by the telemetry subcarrier. The frequency source for the exciter is either the receiver VCO output, or the redundant transponder VCO, or an auxiliary oscillator in the exciter. The frequency source is selected according to the logic shown in Table 3.7.2-1. The auxiliary oscillator is ON whenever the exciter is ON, regardless of whether the receiver is locked to the uplink frequency or not. The inhibit coherent mode command causes the exciter to use the auxiliary oscillator frequency source when the receiver is locked and the transfer to VCO command (test only, shorted out by flight test access connector) causes the exciter to use the unlocked VCO as the frequency source. Selection of the frequency source is done by a solid-state switch, with both sources always present at the input to the switch.

A 30 F_1 signal, generated in the X11/X15 multiplier, is applied to the phase modulator where it is phase modulated by the telemetry subcarrier. The telemetry subcarrier from the telemetry processor is regenerated in the exciter in order to control the amplitude of the modulating signal that is applied to the phase modulator. This makes the modulation index stability independent of the interface between the telemetry processor and the communication subsystem, thus resulting in a stable modulation index. The commandable selection of modulation index is accomplished by attenuating the regenerated subcarrier with a variable voltage divider. The X8 multiplier/S-band power amplifier generates the 240 F_1 output, amplifies it and keeps the output level constant by means of an automatic leveling loop.

A dc to dc power converter provides +11, +9 and -6 Vdc for the exciter modules. Overcurrent protection for the exciter is provided by a current limiter set for 360 ±50 ma. Exciter fusing is included externally in the spacecraft harness (3/4 amp fuse). The exciter is commanded ON/OFF by the command that turns the power converter ON/OFF. The ON/OFF command is such that only one exciter can be on at a time, but both can be off simultaneously.

The important operational characteristics of the exciter are as follows (further details of commands and telemetry are in Section 3.7.4 and Appendix A, respectively):

- Bus Modulation Index — Commandable to 1.18 radians or 0.65 radians (67.6° or 37.2° respectively)
- Probes Modulation Index — Commandable to 1.17 radians or 1.025 radians (67° or 57.3° respectively).
- Auxiliary Oscillator Frequency Stability vs Temperature:

Temperature (°F)	Frequency (MHz) Transponder 2 (SN 5)	Transponder 1 (SN 6)
-4°	2292.019800	2292.762000
+14°	2292.030120	2292.771840
+32°	2292.0[illegible]000	2292.777240
+41°	2292.037680	2292.778680
+50°	2292.038400	2292.779280
+61°	2292.038280	2292.777160
+68°	2292.037800	2292.778680
+77°	2292.037080	2292.777720
+90°	2292.035640	2292.776280
+125°	2292.034680	2292.773640

- Command Capability (Refer to Section 3.7.4) for details)
  - Exciter 1 ON, 2 OFF
  - Exciter 2 ON, 1 OFF
  - Exciters 1 and 2 OFF
  - Bus High Mod Index
  - Bus Low Mod Index
  - Probes High Mod Index
  - Probes Low Mod Index
  - Inhibit Coherent Mode
  - Restore Coherent Mode
  - Transfer to VCO ON (test only)
  - Transfer to VCO OFF (test only)
- Telemetry Information (Refer to Appendix A for details)
  - Auxiliary Oscillator Temperature
  - Exciter ON/OFF Status
  - Inhibit/Restore Coherent Mode Status
  - Transfer to VCO ON/OFF Status

3.7.2.2 Driver Amplifier. The driver amplifier consists of three transistor stages that amplify the +14 dBm input from the exciter to approximately +34 dBm. The first stage operates as Class B and the second and third stages operate as Class C. The dc power for the driver amplifier is supplied by the power amplifier dc regulator. There are no fuses or current limiting in the driver amplifier. There are no commands or telemetry for the driver amplifier. The driver amplifiers are turned ON/OFF whenever the power amplifiers ar turned ON/OFF respectively.

3.7.2.3 Power Amplifier. The power amplifier amplifies the S-band output signal from the driver amplifier and provides a minimum of 9.5 watts output. This is accomplished by two high power, MSC3005, transistors in parallel. The RF input power is split into two paths by the same type of 3 dB hybrid that combines the output from the two MSC3005s, as shown by the block diagram in Figure 3.7.2.3-1. The two transistors are protected by the output isolator, so that it is possible to operate the amplifier into an open circuit or short circuit (due to spacecraft failure), although operationally this should always be avoided due to the additional stress encountered.

DC power for the two RF transistors is provided by a temperature compensated series regulator. Temperature compensation is necessary to limit the current consumption to the specified 1.2 amperes at the ambient and lower temperatures where the transistors put out more RF power but draw more current. This regulator also supplies the dc power to the driver amplifier. The control circuits for the amplifier are in the dc section or "dc frame". On/Off control is accomplished by means of a latching circuit that latches the regulator on with the "ON" pulse command and turns it off with the "OFF" pulse command or if the bus voltage drops to a level of approximately seven volts. There is also current limiting, which is set at two amperes, and if the fault is such so as to cause more current to be drawn, the regulated voltage will decrease ("fold back") in order to maintain the two amperes current limit. Furthermore, for a severe fault, the regulated voltage can fall below the seven volts threshold and the regulator will unlatch, that is turn off. The amplifier can be turned on again by the "ON" command but, if the fault still exists, it will only shut off again.

The power amplifier is fused internally with two (2) four ampere fuses and a 0.2 ohm resistor is in series externally in the harness with one fuse so that one fuse will always blow first.

- Power Amplifier Operational Characteristics

Output Power	9.5 watts minimum
Current Consumption	1.2 amperes (0.4 amperes additional for driver amplifier)
Current Limit	2 amperes
Minimum Bus Voltage to Remain "Latched" On	7 volts
Telemetry Information	Power Output Amplifier Temperature (Refer to Appendix A for details)

3.7.2.4 Hybrids, Diplexer, Isolator. Two types of hybrids are used in the Bus Communication Subsystem. The 6 dB hybrid is used to split the output power of the exciter four ways to drive the four driver amplifiers. The 3 dB hybrid is used as a power summer to combine the output of two power amplifiers. Both hybrids are passive devices and have no command or telemetry capability.

Diplexer. The diplexer permits simultaneous transmission and reception through the same antenna. The diplexer utilizes two coaxial (TEM) mode filters connected as shown in the schematic in Figures 3.7.2.4-1A and 3.7.2.4-1B; operation is explained by the block diagram in the same figures. Energy from the transmitter is prevented from entering the receiver by the bandpass filter at the receiver port that is tuned to the receive center frequency. This filter has high attenuation at the transmit frequency and low attenuation at the receive frequency. Transmitter energy due to spurs that might fall into the receive band is attenuated by the band reject filter that is tuned to the receive frequency also. This filter has high attenuation at the receive frequency at the transmitter input port but looks like an open circuit at the antenna port at the receive frequency.

The response of the SW 5 diplexer, for a combination of each of the ports, is shown in Figure 3.7.2.4-2. Since the diplexer is a passive device, it has neither a command nor a telemetry capability.

Isolator. The isolator is a three-port ferrite circulator with a matched termination on the third port. The termination is capable of dissipating 12 watts. The signal is passed in the forward direction with very low insertion loss (less than 0.3 dB) and with very high insertion loss (greater than 25 dB) in the reverse direction. It is used between the driver amplifier and the power amplifier. The power amplifier is protected by its own bult-in isolator (same basic design, but 40 watt termination).

3.7.2.5 Switches and Switch Driver. Two types of RF latching relay switches are used in the Bus Communications Subsystem, an S switch and a C switch. The S switch is a SPDT switch and the C switch is a cross-over switch in which two inputs are alternated between two outputs, as shown in Figure 3.7.2.5-1.

Two coils are used on each switch, one for each position, thus requiring two circuits to provide the switching current pulses. In the absence of switching pulses, the switches remain in the state corresponding to the last pulse. A minimum specified pulse voltage of 24 volts is required to cause switching.

Switch Driver. The switch driver consists of seven identical modules packaged in a single unit. Each module is basically two command pulse amplifiers which increase any one of the input command signals to the voltage and current levels required to operate the RF switch. The standard 35 msec, 9 to 17 Vdc command pulse at any input, controls a transistor switch that applies the unregulated Bus (essential bus) to the designated RF switch coil; pulsing a "2" command input provides a pulse to the "2" side of the RF switch, and a pulse at a "1" input provides a pulse to the "1" side of the switch. A bilevel telemetry output is provided to indicate commanded switch status. A "0" indicates that the last executed signal was position "1" or "normal" and a "1" indicates that the last executed signal was position "2" or "reverse".

When power is first applied, or removed and reapplied, the telemetry comes up in the "0" state, regardless of the actual switch position. The switch drivers are connected to the spacecraft essential bus.

3.7.2.6 Antennas. The Bus utilizes a forward omni and an aft omni antenna to obtain 4π steradian antenna coverage for command reception (each is connected to its own command receiver at the s e time), and telemetry transmission (only one omni time is usable with a transmitter in a normal operating mode). Additionally, the medium gain horn provides (transmission only) directional coverage centered on the spacecraft minus Z axis. A brief description and a performance summary for these antennas is given below:

3.7.2.6.1 Antenna Description

Medium Gain Horn Antenna Description. The medium gain horn antenna is a simple conical configuration. The horn is mounted on the aft end of the Bus to provide communication coverage (transmit only) for elevation angles from 150 to 180° referenced to the plus Z axis. Right hand circular polarization is provided. The horn is a thin aluminum shell 0.030 inch thick with a 4-

bolt hole base flange, two adjustable tuning screws (also aluminum) and a TNC connector.

Forward Omni Antenna Description. The forward omni antenna is a two-arm log conical spiral. Identical units are mounted on top of masts located on the forward side of both the Multiprobe Bus and Orbiter spacecrafts to provide RF communication coverage over angles from 0° to approximately 95° from the plus Z axis.

The antenna consists of an epoxy glass conical shell on which two copper conductors are deposited. The radiating elements are fed at the top of the cone by a microstrip balun which is supported in a fiberglass tube. A coax to microstrip transition is located at the base of the antenna. This design radiates a right-hand circularly polarized axial mode pattern.

Aft Omni Antenna Description. The aft omni antenna is a common turnstile element above a conical ground plane. Identical units are mounted on top of masts located on the aft end of both the Multiprobe Bus and Orbiter spacecrafts to provide RF communication coverage over angles from 95° to 180° from the plus Z-axis.

The turnstile element is used to produce circular polarization and typically produces a relatively narrow 3 dB beamwidth (70°) pattern. The conical ground plane is incorporated to broaden the beamwidth and generate the nearly hemispherical gain coverage.

The antenna is all aluminum welded construction except forn a small teflon dielectric bead in the input connector.

3.7.2.6.2 Antenna Patterns

Omni Antennas. A plot of the minimum EIRP (Effective Isotropic Radiated Power) for the forward and aft omni antennas, is given in Figure 3.7.2.6-1. The difference between this plot and actual antenna gain is that the transmitter power and circuit loss to each antenna has been included; however, the shape of the curves is identical to the actual antenna gain. Such a presentation has been judged to be more useful due to the desirability of indicating the spherical antenna coverage of the spacecraft on one set of coordinate axes and since each antenna has different feed circuit loss. It is important to note that Figure 3.7.2.6-1 includes the minimum gain of the antennas at each elevation angle as a function of azimuth. That is, the plots are obtained by making an antenna measurement while holding elevation angle constant and varying the azimuth angle. The azimuth angle, for which the gain is minimum, is then used to derive Figure 3.7.2.6-1. The variation between minimum and maximum gain is indicated by the conic plots, or gain versus azimuth angle, given a constant elevation angle (θ), as shown in Figure 3.7.2.6-2A for the Forward Omni, and Figure 3.7.2.6-2B for the Aft Omni.

The minimum receive gain for the omni antennas is shown in terms of flux density in Figure 3.7.2.6-3. The command link threshold, is based on the specified -102.3 dbm per square meter maximum uplink power density, and a bit error rate (BER) of 3.5×10^{-6}. This BER has been shown to provide the specified probability of false command execution and missed command, and corresponds to a signal to noise ratio of 17.2 dB at the transponder output.

Medium Gain Horn. A summary of the medium gain horn performance is given in Table 3.7.2-2. A diagram of the Horn antenna pattern coordinates, with definition of θ and ϕ, is shown in Figure 3.7.2.6-4. The azimuth (ϕ = 0°) and elevation (ϕ = 90°) patterns for the Horn flight unit for f=2295 MHz are shown in Figures 3.7.2.6-5 and 3.7.2.6-6, respectively. Conic pattern cuts at θ = 5°, 20°, and 30° are shown in Figure 3.7.2.6-7.

3.7.2.7 Engineering Instrumentation - (See Appendix A)

3.7.3 Operations Description

3.7.3.1 Normal Operating Modes

3.7.3.1.1 Transmission Modes. The Bus communication subsystem has a number of operating modes which are defined according to the transmitter configuration, the antenna used, and the receiver used. The two basic transmitter modes are high power and low power, but since there are redundant power amplifiers, there are several combinations of amplifiers available for each mode. Furthermore, there are two basic routes that the RF power can take, either to (the horn or fwd omni) or to the aft omni. Table 3.7.3-1 lists the modes which result from these various combinations. The switch positions, and associated commands and telemetry plus the power amplifier commands and telemetry for the twelve transmitter modes, are given in Table 3.7.3-1. Eighteen spacecraft RF transmission modes result from the 12 transmitter modes being used in conjunction with the three spacecraft antenna, as given in Table 3.7.3-2 (only odd number transmitter modes are used with the horn or forward omni antennas and even number transmitter modes are used with the aft omni). Another eighteen spacecraft transmission modes (total of 36) exist as a result of using transponder number two exciter (number one exciter is used for the first 18 modes). Switch positions, commands, and associated telemetry for the thirty-six spacecraft transmission modes are given in Table 3.7.3-2. The telemetry indications given in Tables 3.7.3-1 and 3.7.3-2 provide a convenient means for identifying the spacecraft transmission modes. The spacecraft EIRP for the first 18 modes (identical for second 18) is given in Table 3.7.3-2.

The communication subsystem has the capability of being commanded to either a Bus high modulation index (1.18 radians) (MIH11 or MIHA1) or a Bus low modulation index (0.65 radians) (MIL11 or MILA1) for bus telemetry subcarrier modulation of the downlink carrier. In general, for Bus subcarrier only operation (All Probes subcarriers OFF) the Bus high modulation index is utilized for the Bus higher data rates, and the Bus low modulation index is used for the Bus low data rates. When the Bus data stream is operated concurrently with any probe data stream (dual subcarrier mode) however, use of Bus low mode index is recommended, regardless of choice of Bus data rate.

Analogously, the capability of being commanded to either a probes high modulation index (1.17 radians) (MIH21 or MIHB1) or a probes low modulation index (1.025 radians) (MIL21 or MIL81) exists for probes telemetry subcarrier modulation of the downlink carrier. In general, for Probe subcarrier only operation (Bus subcarrier OFF), the probes high modulation index is utilized for the higher data rate from the probe, and the probes low modulation index is used for the lower data rate from the probe. When any probe data stream is operated concurrently with the Bus data stream (dual subcarrier mode), use of the probe low mod index is recommended for most phases of the mission, regardless of choice of the probe data rate.

When either the probes high or probes low modulation index is commanded, the Bus modulation index is automatically switched to low. Bus high modulation index could be reinstated, if desired, following a Probes Mod Index command, by commanding Bus High Modulation Index Select, although such a configuration is generally not as efficient (Higher Bit Error Rate) as using Bus Low Modulation Index in the presence of a probe subcarrier.

The Probes modulation index selection is applied within the communications subsystem to whichever probe subcarrier it receives, i.e., whichever probe is powered ON. Whenever any probe is turned ON, the associated subcarrier is turned ON automatically. The Large Probe subcarrier can be commanded OFF via the Bus uplink while Large Probe power remains ON, but the same is not true for any Small Probe (a Small Probe subcarrier can be commanded OFF while it's power remains ON only via it's entry sequence programmer capability). The Large Probe subcarrier can be commanded ON again via the Bus uplink by sending a data rate selective command (LBR13 for 256 bps select, or LBR14 for 128 bps select), or sending the (Large) Probe Checkout Power ON command again (PCO19 or PCOA9).

Attempting to transmit two probes subcarriers simultaneously will result in garbled data, as each Small Probe subcarrier is at the same frequency (≈4KHz), and the Large Probe subcarrier is close enough in frequency (≈9KHz) to cause garbled data when generated simultaneously with any one Small Probe subcarrier.

Further details regarding Probes' communications operation is contained in Sections 3.7.4, 5.1 and 5.2.

Downlink S-band carrier only operation is possible by commanding the BUS subcarrier OFF via the Telemetry Processor Control command (TPCQ1 for TP1; TPCQA for TP2), concurrent with all probes being powered OFF.

Telemetry will indicate a non-zero RF output power for a power amplifier only when an exciter is turned ON to provide RF input to that amplifier. (Reference: Paragraph 1.5.18).

Telemetry data rates vs. time in the nominal mission for Bus only transmission are shown in Figures 3.7.3-1 and 3.7.3-2. These were extracted from Reference: Paragraph 1.5.31.

Telemetry data rates vs. time in the nominal mission for Bus/Large Probe, and Bus/Small Probes combinations (all via the Bus downlink carrier) are shown in Tables 3.7.3-3 and 3.7.3-4.

3.7.3.1.2 Reception Modes. Since the two transponder receivers are always powered "ON", their use for reception of the uplink signal is controlled by selecting the uplink frequency to correspond to the nominal rest frequency of the desired transponder (transponder 1:2111.266204 MHz and transponder 2:2110.584105 MHz). It is also necessary to take into consideration which antenna is connected to the desired receiver and the communication angle as determined by the spacecraft attitude. In general, whenever the bus is oriented perpendicular to the ecliptic plane either the Aft Omni or the Fwd Omni will be selected for both transmission and reception. The aft omni antenna is always connected to one receiver and the fwd omni antenna is always connected to the alternate receiver, as shown in Table 3.7.3-5, but the choice between forward omni and aft omni for reception is dependent on communication angle (as dictated by spacecraft orientation) and the desired transmission mode, as given in Table 3.7.3-2.

The receiver reverse command eliminates the possibility of losing reception capability due to several possible spacecraft failures. These possible failures are receiver failure, and other failures which cause uplink communications to be lost. In the event of one of these failures occurring, the on-board command processor automatically issues a receiver reverse command after a period of 36 hours has occurred without processing any spacecraft command. The command is sent to coax switch 1SW022 and causes the forward omni feed line to be connected to the downlink signal path. At the same time, the antenna input connections to both transponder receivers are reversed by actuation of coax switch 1SW019.

When the receiver reverse command is executed by the spacecraft, the uplink frequency must be shifted to that of the transponder which will be connected to the forward omni. Also, the downlink will be connected automatically to the forward omni, and the new downlink frequency will become 240/221 times the new uplink frequency after onboard phase-lock is established.

The receiver reverse command may also be actuated by ground command, as discussed in Section 3.6.

However, when actuated by ground command, only switch 1SW019 is actuated.

3.7.3.1.3 Exciter and Coherent Mode Usage. Either Exciter 1 or Exciter 2 can be used with either receiver. Automatic cross strapping of the coherent frequency source from the receiver that is in lock is provided, as described in 3.7.2.1.2. Thus, although Exciter 2 (also Receiver 2) is designated as the primary exciter, Exciter 1 can be used as well. However, after some in-flight operational history of the spacecraft has been accumulated, one of the exciters may appear more desirable from the standpoint of frequency stability of the auxiliary oscillator when in the non-coherent mode.

Coherent Mode Versus Non-Coherent Mode. The normal operation of the spacecraft will be with simultaneous uplink and downlink, thus providing for coherent operation of the communication links. As long as the last coherent mode command executed by the spacecraft was "Restore Coherent Mode" (COH19 or COHA9), then selection of the auxiliary oscillator automatically occurs with the absence of an uplink, and the coherent mode is automatically selected when uplink lock reoccurs. The "Inhibit Coherent Mode" command (COH1Ø or COHAØ) prevents this automatic transference in either direction, and causes the auxiliary oscillator to be the frequency source whether or not an uplink is present.

3.7.3.1.4 Communication Subsystem Initialization. Upon application of DC power to the communication subsystem, the units will be in the following states:

Unit	"Initial DC Power ON" State:	Comments
Transponder Receiver	N/A	Receiver is on the S/C essential bus and is therefore always ON.
Exciter	ON/OFF TM - "OFF"	
	Transfer to VCO TM - "OFF"	Test only - Wired out for flight.
	Inhibit/Restore Coherent - Mode TM - "Restore"	
	Probes Mod Index (No TM) - High	
	Bus Mod Index (No TM) - High	
Power Amp	ON/OFF TM - "OFF"	
Driver Amp	Same as Power Amplifier	
RF Coax Sw.	N/A	Magnetic latching; will be in state of last command that was sent.
Switch Driver	N/A	Each Switch Driver is on the essential bus and is therefore always ON. However: • For initial S/C power up, the switch driver ILM will initialize regardless of switch position in the logic "0" state (= position 1).

Unit	"Initial DC Power ON" State:	Comments
Switch Driver (Continued)		• The switches must be commanded to their desired position in order to force the status bits to indicate actual switch position. • The fact that a switch command changed the appropriate status bit to indicate the switch has moved to the proper position does not guarantee that the switch actually moved. It only indicates that the desired command pulse was generated.

3.7.3.2 Use of Redundancy. The Bus Communication Subsystem contains four (4) power amplifiers which offer a redundancy of high and low power modes, as discussed in 3.7.3.1. Two transponders offer uplink reception redundancy, as discussed in 3.7.3.1, also. The Aft Omni offers redundancy for the Medium Gain Horn for earth look angles 150° to 180° w.r.t. the spacecraft +Z axis. However, this redundancy is at the expense of degraded link performance, i.e., a lower data rate.

3.7.3.3 Non-Standard Modes. The non-standard modes for the Bus Communication Subsystem are as follows:

(a) Only 1 power amplifier "ON" that is connected to the 3 dB hybrid (power summer): It is possible to configure 3SW019 or 3SW022 so that either amplifier 1, 2, 3 or 4 only is "ON" and connected to the input of the 3 dB hybrid. This will result in a power output from the hybrid of approximately

5 watts, with 5 watts being dissipated in the integral hybrid load. In this mode, the hybrid mounting surface temperature will reach the acceptance test level of 136°F, but thermal analysis indicates that the internal temperature may reach 165°F. Although the hybrid will probably survive, this mode is not recommended as a normal operating mode.

(b) Simultaneous transmission through a (horn or fwd omni) antenna and the aft omni antenna: The communication subsystem may be configured so that the downlink telemetry signal is transmitted by (either the horn or fwd omni) antenna and the aft omni. There is no readily apparent advantage to this mode and it may create an erratic and poorly shaped radiation pattern due to the interferometric effect of two nearby antennas radiating the same signal. Furthermore, this non-standard mode necessitates the use of non-standard mode 1 discussed above, since, by design, one antenna would be fed by a power amplifier (1 or 2) that bypasses the 3 dB hybrid, and the other antenna would be fed by a power amplifier (3 or 4) via the 3 dB hybrid.

3.7.3.4 Operational Restrictions. The following restrictions apply to the operation of the Bus Communication Subsystem:

(a) Do not switch "Hot", i.e., do not change the position of an RF switch while an RF transmitter signal is passing through it, except in an emergency situation (Reference: Paragraph 1.5.21). The power amplifiers should always be commanded "OFF" before actuating the RF switches that feed RF into them, or pass RF from them. This is to protect both the switches and the power amplifiers. Inadvertent failure to observe this restriction is not likely to damage these units, but repeated violations may eventually inflict damage.

The following sequence of operations should be carried out if switching of RF switches is to be performed:

(1) Turn off units which provide input RF power to the switch (if such units are commandable).

(2) Turn off units which obtain RF power from the switch (if such units are commandable).

(3) Initiate switch command.

(4) Turn on units turned off in (2).

(5) Turn on units turned off in (1).

(6) Verify switch is in proper configuration by telemetry and/or spectrum analysis.

In an emergency situation, where an RF link may be lost unless switching is quickly performed, hot switching is allowed. Steps (3) and (6) should then be executed in that order.

(b) Never operate a power amplifier into an open circuit. This restriction applies to amplifiers 3 or 4. Caution must be used to ensure that switch 3SW022 is configured so that the 3 dB hybrid is connected to whichever amplifier is turned "ON" or about to be commanded "ON". Refer to Table 3.7.3-1 for the correct switch position and command.

(c) The spacecraft Aft omni should not be used at launch, as the geometrical interference from the attached Centaur is significant.

(d) The 3 dB hybrid is used as a power summer to combine the output of two power amplifiers. Should only one of the two power amplifiers, that supply an input signal to the hybrid, be "ON", half of the signal power will be dissipated in the integral hybrid load and the other half, approximately five watts, will be output signal from the hybrid. Operation of the hybrid in this manner will cause the hybrid to be hotter than normal. Although the temperature will be within the hybrid design limitations, this mode is not recommended for normal operation.

(e) The best lock frequency of the P-V receivers will "push" if the acquisition sweep rate is low. That is, the spacecraft receiver VCO will move away from the uplink signal. Motorola has stated the maximum rate the VCO will "push" is 5.9 Hz/sec and have recommended that acquisition sweep rates be greater than 10 Hz/sec.

During the weak signal compatibility testing at CTA-21, an acquisition sweep rate of 10 Hz/sec caused no pushing while a 5 Hz/sec rate definitely did. It is recommended a minimum acquisition rate of 15 Hz/sec be used to provide a healthy margin of safety.

3.7.4 Communications Subsystem Command Response. Table 3.7.4-1 presents the command responses for the Communications Subsystem. The table lists every command that directly affects the subsystem, and the telemetry indication that verifies the proper execution of the command. The mnemonics for the command and telemetry parameters are also included.

When a unit is in the unpowered OFF state, all telemetry from that unit will be reading zero (uncalibrated), except temperature telemetry which is powered by DIMs.

TABLE 3.7.2-1

TRANSPONDER EXCITER FREQUENCY SOURCE SELECTION LOGIC

Telemetered Command Status		Telemetered In Lock Status		Selected Frequency Source for Downlink Only
Inhibit Coherent Mode (RCOHXS)*3	Transfer to* VCO (RVCOXS)*3	Own Receiver In Lock (RLOKXS)*3	Redundant Receiver In Lock (RLOKYS)*4	
0	0	No	No	Auxiliary Oscillator *2
0	0	No	Yes	Redundant Receiver VCO
0	0	Yes	Either Yes or No	Own Receiver VCO
0	1	No	No	Own Receiver VCO
0	1	No	Yes	Redundant Receiver VCO
0	1	Yes	Either Yes or No	Own Receiver VCO
1	Either 0 or 1	Either Yes or No	Either Yes or No	Auxiliary Oscillator *2

*Test Only. This command is disabled (set to a permanent "0" state) by ground connection made by test access flight plug.

*2 Auxiliary oscillator is always the one on in the exciter of interest, since only one exciter can be commanded on at a time.

*3 X = 1 or 2.

*4 Y = Designation for Redundant Receiver, (i.e., when X = 1, then Y = 2; and when X = 2, then Y = 1).

TABLE 3.7.2-2

MEDIUM GAIN HORN PERFORMANCE SUMMARY

Measurement Angle From Electrical Boresight Axis*	$\pm 5^{o}$	$\pm 20^{o}$	$\pm 30^{o}$
Gain in dBi (At f = 2295 MHz)	13.8	10.3	6.3

*NOTE: Electrical Boresight axis is mounted, within a maximum misalignment tolerance, to be coincident with the cruise mode S/C minus Z axis.

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TABLE 3.7.3-1. BUS S-BAND TRANSMITTER MODES

Mode No.	Power Mode	Antenna Used	Power Amp(s) Used	Power Amp Commands	Switch Positions: 3SW019 Position	Switch Positions: 3SW022 Position	Switch Positions: 2SW019 Position	Switch Commands: 3SW019	Switch Commands: 3SW022	Switch Commands: 2SW019	Telemetry Indications: Power Amp: Power Out.	Telemetry Indications: Power Amp: Temp	Telemetry Indications: Switch Drivers (Bit State): 3SW019 RAMP1S	Telemetry Indications: Switch Drivers (Bit State): 3SW022 RAMP8S	Telemetry Indications: Switch Drivers (Bit State): 2SW019 RANT1S
1 ①	Low Pwr 1	Horn or Fwd Omni Antenna	#1 ON, Rest OFF	AMP19/AMPA9 AMP3Ø/AMPCØ	2	NA	2	AMP11/ AMPA1	NA	ANT11/ ANTA1	RAMP1W	RAMP1T	1	NA	1 ①
2	Low Pwr 1	Aft Omni	#1 ON, Rest OFF	AMP19/AMPA9 AMP3Ø/AMPCØ	2	NA		AMP11/ AMPA1	NA	ANT12/ ANTA2	RAMP1W	RAMP1T	1	NA	0
3	Low Pwr 2	Horn or Fwd Omni Antenna	#2 ON, Rest OFF	AMP29/AMPB9 AMP3Ø/AMPCØ	1	NA	2	AMP12/ AMPA2	NA	ANT11/ ANTA1	RAMP2W	RAMP2T	0	NA	1
4	Low Pwr 2	Aft Omni	#2 ON, Rest OFF	AMP29/AMPB9 AMP3Ø/AMPCØ	1	NA	1	AMP12/ AMPA2	NA	ANT12/ ANTA2	RAMP2W	RAMP2T	0	NA	0
5	High Pwr 2&4	Horn or Fwd Omni Antenna	2 & 4 ON, Rest OFF	AMP29/AMPB9 AMP49/AMPD9	2	1	1	AMP11/ AMPA1	AMP41/ AMPD1	ANT12/ ANTA2	RAMP2W RAMP4W	RAMP2T RAMP4T	1	0	0
6	High Pwr 2&4	Aft Omni	2 & 4 ON, Rest OFF	AMP29/AMPB9 AMP49/AMPD9	2	1	2	AMP11/ AMPA1	AMP41/ AMPD1	ANT11/ ANTA1	RAMP2W RAMP4W	RAMP2T RAMP4T	1	0	1
7	High Pwr 1&3	Horn or Fwd Omni Antenna	1 & 3 ON, Rest OFF	AMP19/AMPA9 AMP39/AMPC9	1	2	1	AMP12/ AMPA2	AMP31/ AMPC1	ANT12/ ANTA2	RAMP1W RAMP3W	RAMP1T RAMP3T	0	1	0
8	High Pwr 1&3	Aft Omni	1&3 ON, Rest OFF	AMP19/AMPA9 AMP39/AMPC9	1	2	2	AMP12 AMPA2	AMP31/ AMPC1	ANT11/ ANTA1	RAMP1W RAMP3W	RAMP1T RAMP3T	0	1	1
9	High Pwr 1&4	Horn or Fwd Omni Antenna	1&4 ON, Rest OFF	AMP19/AMPA9 AMP49/AMPD9	1	1	1	AMP12/ AMPA2	AMP41/ AMPD1	ANT12/ ANTA2	RAMP1W RAMP4W	RAMP1T RAMP4T	0	0	0
10	High Pwr 1&4	Aft Omni	1&4 ON, Rest OFF	AMP19/AMPA9 AMP49/AMPD9	1	1	2	AMP12/ AMPA2	AMP41/ AMPD1	ANT11/ ANTA1	RAMP1W RAMP4W	RAMP1T RAMP4T	0	0	1
11	High Pwr 2&3	Horn or Fwd Omni Antenna	2&3 ON, Rest OFF	AMP29/AMPB9 AMP39/AMPC9	2	2	1	AMP11/ AMPA1	AMP31 AMPC1	ANT12/ ANTA2	RAMP2W RAMP3W	RAMP2T RAMP3T	1	1	0
12	High Pwr 2&3	Aft Omni	2&3 ON, Rest OFF	AMP29/AMPB9 AMP39/AMPC9	2	2	2	AMP11/ AMPA1	AMP31/ AMPC1	ANT11/ ANTA2	RAMP2W RAMP3W	RAMP2T RAMP3T	1	1	1

NOTES: ① Launch Mode: Forward Omni is in use.

TABLE 3.7.3-2

BUS SPACECRAFT RF TRANSMISSION MODES

Transmission Mode No.	Antenna Used:	Transmitter Mode:	Exciter Used:	Switch Positions: 1SW022	Switch Positions: 2SW022	Switch Commands: 1SW022	Switch Commands: 2SW022	Sw. Drivers Telemetry (Bit State) 1SW022 RANT2S	Sw. Drivers Telemetry (Bit State) 2SW022 RXCTRS	EIRP: (dBm/SR.)	Comments
1	Medium Gain Horn	1	1	2	2	ANT21/ ANTB1	EXC11/ EXCA1	1	1	41.5	Peak of Beam, @180° Elevation angle from +Z Axis.
2		3								41.7	
3		5								44.3	
4		7								44.3	
5		9								44.4	
6		11								44.3	
7	Fwd Omni	1		1		ANT22/ ANTB2		0		29.1	@ 0° from +Z Axis.
8		3								29.1	
9		5								31.7	
10		[illegible]								31.6	
11		9								31.7	
12		11								31.6	
13	Aft Omni	2		NA		NA		NA		32.6	@180° from +Z Axis.
14		4								32.8	
15		6								35.4	
16		8								35.3	
17		10								35.5	
18		12								35.2	
19 Thru 36	Same combinations as above.	Same combinations as above.	2	Same Combinations as above.	1	Same combinations as above.	EXC21/ EXCB1	Same combinations as above.	0	Same combinations as above.	

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TABLE 3.7.3-3

LARGE PROBE CHECKOUT (DUAL SUBCARRIER) DATA RATE CAPABILITY

A. L + 60 Days

Output Power = 20 Watts

Ground Antenna = 64 Meter

Bus Antenna = Forward Omni

Launch Date	Maximum Data Rate		Modulation Index	
	Large Probe	Bus	Large Probe	Bus
Before August 16	256	32	67.0^{o}	37.2^{o}
After August 16	256	64	67.0^{o}	37.2^{o}

B. E - 27 Days

Output Power = 20 Watts

Ground Antenna = 64 Meter

Bus Antenna = Medium Gain Horn

Communications Angle (Angle from -Z Axis)	Maximum Data Rate		Modulation Index	
	Large Probe	Bus	Large Probe	Bus
0^{o} - 22^{o}	256	256	67.0^{o}	37.2^{o}
22^{o} - 30^{o}	256	128	67.0^{o}	37.2^{o}
30^{o} - 36^{o}	256	64	67.0^{o}	37.2^{o}
36^{o} - 38^{o}	128	64	67.0^{o}	67.6^{o}

TABLE 3.7.3-4

SMALL PROBE CHECKOUT (DUAL SUBCARRIER) DATA RATE CAPABILITY

A. L + 60 Days

Output Power = 20 Watts

Ground Antenna = 64 Meter

Bus Antenna = Forward Omni

Maximum Data Rate		Modulation Index	
Small Probe	Bus	Small Probe	Bus
64	128	58.4°	37.2°

B. E - 27 Days

Output Power = 20 Watts

Ground Antenna = 64 Meter

Bus Antenna = Medium Gain Horn

Communications Angle (Angle from -Z Axis)	Maximum Data Rate		Modulation Index	
	Small Probe	Bus	Small Probe	Bus
0° - 2°	64	1024	58.4°	37.2°
2° - 16°	64	512	58.4°	37.2°
16° - 25°	64	256	58.4°	37.2°
25° - 32°	64	128	58.4°	37.2°
32° - 37°	64	64	58.4°	37.2°
37° - 42°	64	32	58.4°	37.2°
42° - 44°	16	32	58.4°	67.6°

TABLE 3.7.3-5

RECEIVER/ANTENNA COMBINATIONS

Receiver Mode	Switch Position for 1SW019:	Telemetry Indicator (RRCVRS Bit State)	Antenna Used By Receiver 1 / S/C Xmission Mode (From Table 3.7.3-2)	Antenna Used By Receiver 2 / S/C Xmission Mode (From Table 3.7.3-2)
Normal	Position 1 (Switch "Normal" State)	0	Fwd Omni/Any	Aft Omni/Any
Reverse	Position 2 (Switch "Reverse" State)	1	Aft Omni/Any	Fwd Omni/Any

NOTE: See Table 3.6.4-1, Section 3.6 for explanation of "CP Configure" command that is used to change the receiver modes.

TABLE 3.7.4-1

BUS COMMUNICATIONS SUBSYSTEM COMMAND RESPONSE

COMMAND	COMMAND TITLE	COMMAND DESCRIPTION AND SUBSYSTEM INTERNAL RESPONSE	TM MNEMONIC	TM TITLE AND/OR REMARKS
POWER AMPLIFIERS				Assumes PA2 was previously ON:
AMP19 AMPA9	Power Amplifier 1 ON/2 OFF.	Actuates solid state switches within PA1 and PA2 so that PA2 is turned OFF and PA1 is turned ON.	RAMP1W	RF Power Output 1 - 7 to 10 Watts (@ S/C Ambient)
			RAMP2W	RF Power Output 2 - <1 Watt (@ S/C Ambient)
			RAMP1T	PA1 Temperature rises and settles at (86° to 104°F)(@ S/C Ambient)
			RAMP2T	PA2 Temperature Decreases & settles at the range of 77° to 95°F.
			PBUSLI	S/C Loads current increases by approximately 1.5 Amp.
AMP29 AMPB9	Power Amplifier 2 ON/1 OFF.	Actuates solid state switches within PA1 and PA2 so that PA2 is turned ON and PA1 is turned OFF.		Assumes PA1 was previously ON:
			RAMP1W	RF Power Output 1 - <1 Watt (@ S/C Ambient)
			RAMP2W	RF Power Output 2 - 13 to 16 Watts (@ S/C Ambient)
			RAMP1T	PA1 Temperature Descreases and settles at the range of 86° to 104°F.
			RAMP2T	PA2 Temperature Rises and Settles at the range of (82° to 106°F).
			PBUSLI	S/C Loads current increases by approximately 1.5 Amps.
AMP1Ø AMPAØ	Power Amplifiers 1 and 2 OFF.	Actuates solid state switches within PA1 and PA2 so that PA1 and PA2 are turned OFF.		See Note #1:
			RAMP1W	RF Power Output 1 - <1 Watt (At S/C Ambient).
			RAMP2W	RF Power Output 2 - <1 Watt (@ S/C Ambient).
			RAMP1T/ RAMP2T	According to which of the PA1 or PA2 was previously ON, PA1 temperature or PA2 temperature decreases and settles at range of (86° to 104°F).
			PBUSLI	S/C loads current decreases by approximately 1.5 amps.
			PLIMTI	Bus voltage limiter current likely increases by the same amount as PBUSLI had decreased.
AMP39 AMPC9	Power Amplifier 3 ON/ 4 OFF	Actuates solid state switches within PA3 and PA4 so that PA4 is turned OFF and PA3 is turned ON.		Assumes PA3 and PA4 were previously OFF:
			RAMP3W	RF Power Output 3 - 11 to 13 Watts (@S/C Ambient).
			RAMP4W	RF Power Output 4 - <1 Watt.
			RAMP3T	PA3 Temperature rises and settles at 75° to 88°F.
			PBUSLI	S/C Loads current increases by approximately 1.5 amps.
			PLIMTI	Bus voltage limiter current likely decreases by same amount as PBUSLI has increased.
AMP49 AMPD9	Power Amplifier 4 ON/ 3 OFF.	Actuates solid state switches within PA3 and PA4 so that PA4 is turned ON and PA3 is turned OFF.		Assume s PA3 and PA4 were previously OFF:
			RAMP3W	RF Power output 3 - <1 Watt.
			RAMP4W	RF Power output 4 - <11 to 13 Watts. (@ S/C Ambient)
			RAMP4T	PA4 Temperature rises & settles at -78° to 94°F.
			PBUSLI	S/C Loads current increases by approximately 1.5 Amps.
			PLIMTI	Bus voltage limiter current likely decreases by the same amount as PBUSLI had increased.

NOTE #1. The following telemetry will not be monitorable when the command is executed unless PA3 OR PA4 is in use for the downlink (this would result in non-standard mode #1 as described in Section 3.7.3.3).

TABLE 3.7.4-1 (Continued)

COMMAND	COMMAND TITLE	COMMAND DESCRIPTION AND SUBSYSTEM INTERNAL RESPONSE	TM MNEMONIC	TM TITLE AND/OR REMARKS
POWER AMPLIFIERS (Cont'd)				
AMP3Ø AMPCØ	Power Amplifiers 3 & 4 OFF.	Actuates solid state switches within PA3 and PA4 so that PA3 and PA4 are turned OFF.	RAMP3W	RF Power Output 3 - <1 Watt @ S/C Ambient.
			RAMP4W	RF Power Output 4 - <1 Watt @ S/C Ambient.
			RAMP3T/ RAMP4T	According to which of PA3 or PA4 was previously ON, PA3 temperature or PA4 temperature decreases & settles at the range of 60° - 85°F.
			PBUSLI	S/C loads current decreases by approximately 1.5 amps.
			PLDATI	Bus voltage limiter current likely increases by the same amount as PBUSLI had decreased
SWITCH DRIVERS				See Note #2.
ANT11 ANTA1	Low Power to Fwd Omni or Horn Antenna/High Power to Aft Omni Select.	Actuates coax switch 2SW019 so that output of the 3 dB hybrid is connected to the aft omni antenna and the output of either PA1 or PA2 is connected to the input of coax switch 1SW022.	RANT1S	Aft Omni/Forward or Horn Antenna to HI/LO Power State bilevel logic "1" (= Aft to HI).
				See Note #2.
ANT12 ANTA2	High Power to Fwd Omni or Horn Antenna/Low Power to Aft Omni Select.	Actuates coax switch 2SW019 so that the output of the 3 dB hybrid is connected to the input of coax switch 1SW022 and the output of either PA1 or PA2 is connected to the aft omni antenna.	RANT1S	Aft Omni/Fwd Omni or Horn Antenna to HI/LO Power States = Bilevel Logic "0" (= Aft to LO).
				See Note #3.
ANT21 ANTB1	Medium Gain Horn Antenna Select.	Actuates mast mounted coax switch 1SW022 so that the medium gain horn antenna is connected to one output of coax switch 2SW019. The forward omni is not usable.	RANT2S	Fwd Omni/Horn Switch Position = Bilevel Logic "0" (= Horn).
				See Note #3.
ANT22 ANTB2	Forward Omni Antenna Select.	Actuates mast mounted coax switch 1SW022 so that the Fwd Omni Antenna is connected to one output of coax switch 2SW019. The Horn Antenna is not usable.	RANT2S	Converse of above, i.e., Logic "1" (= Fwd Omni).
AMP31 AMPC1	Amplifier 3 Select.	Actuates coax switch 3SW022 so that Amplifier 3 is connected to one of the inputs of the 3 dB hybrid.	RAMP3S	Amplifier 3/4 switch position = Bilevel logic "1"(=Amp 3) Switch 3SW022 must be in this position before sending command AMP3Ø/AMPCØ (turns PA3 "ON").
AMP41 AMPD1	Amplifier 4 Select.	Actuates coax switch 3SW022 so that Amplifier 4 is connected to one of the inputs of the 3 dB hybrid.	RAMP3S	Amplifier 3/4 Switch Position = Bilevel logic "0"(=Amp 4) Switch 3SW022 must be in this position before sending command AMP4Ø/AMPDØ (turns PA4 "ON").

Note #2. If the constraint of never switching "HOT" (Refer to Section 3.7.3.4) is honored, the following TM will not be monitorable when the command is executed (No downlink present).

Note #3. If the constraint of never switching "HOT" (Refer to Section 3.7.3.4) is honored, the following TM will be monitorable when the command is executed only if the downlink is via the Aft Omni.

TABLE 3.7.4-1 (Continued)

COMMAND	COMMAND TITLE	COMMAND DESCRIPTION AND SUBSYSTEM INTERNAL RESPONSE	TM MNEMONIC	TM TITLE AND/OR REMARKS
SWITCH DRIVERS (Continued)				See Note #4.
AMP11 AMPA1	Amplifier 1 to Low Power/ Amplifier 2 to High Power Select.	Actuates coax switch 2SW019 so that PA2 is connected to one of the inputs of the 3 dB hybrid and PA1 is connected to Switch 2SW019.	RAMP13	Amplifier 2/1 to HI/LO Power Status. Bilevel logic "0" (= PA1 to HI).
AMP12 AMPA2	Amplifier 1 to High Power/ Amplifier 2 to Low Power Select.	Actuates coax switch 2SW019 so that the PA1 is connected to one of the inputs of the 3 dB hybrid and PA2 is connected to switch 2SW019.		See Note #4.
			RAMP18	Amplifier 2/1 to HI/LO Power Status. Bilevel Logic "1" (= PA2 to HI).
EXC11 EXCA1	Exciter 1 Select.	Actuates coax switch 2SW022 so that the exciter output from transponder number 1 is connected to the 6 dB power divider that drives the amplifiers.		See Note #5.
			RXCTRS	Exciter 1/2 Switch Position = Bilevel logic "1" (Exc. 1) Command should be accompanied by command EXC19/EXCA9 that turns on Exciter 1 and turns off Exciter 2 normal operation.
EXC21 EXCB1	Exciter 2 Select.	Actuates coax switch 2SW022 so that the exciter output from transponder number 2 is connected to the 6 dB power divider that drives the amplifiers.		See Note #5.
			RXCTRS	Exciter 1/2 switch position = Bilevel logic "0" (= Exc 2) Command should be accompanied by command EXC29/EXCB9 that turns on Exciter 2 and turns off Exciter 1 for normal operation.
TRANSPONDERS 1 & 2				See Note #5.
EXC19 EXCA9	Exciter 1 ON/2 OFF.	Actuates magnetic latching relay switches inside transponders so that Exciter 1 turns ON and Exciter 2 turns OFF.	RXCT1S	Exciter 1 ON/OFF = Bilevel logic "1" (Exc.1 ON).
			RXCT2S	Exciter 2 ON/OFF = Bilevel logic "0" (=Exc.2 OFF). If transponder 1 is in auxiliary oscillator mode, downlink frequency will shift if Exciter 2 was previously ON.
EXC29 EXCB9	Exciter 2 ON/1 OFF.	Converse of above.		See Note #5.
			RXCT1S RXCT2S	Converse of above. (Interchange "1" and "2" in comment).
EXC10 EXCA0	Exciters 1/2 OFF.	Actuates magnetic latching relay switches inside transponders so that both exciters are turned OFF.		See Note #5.
			RXCT1S	Exciter 1 ON/OFF = Bilevel logic "0" (= EXC 1 OFF).
			RXCT2S	Exciter 2 ON/OFF = Bilevel logic "0" (= EXC 2 OFF). Downlink will cease when this command is received.

Note #4. If the constraint of never switching "HOT" (refer to Section 3.7.3.4) is honored, the following TM will be monitorable when the command is executed only if non-standard Mode #1 (PA3 or PA4 is ON - described in Section 3.7.3.3) is in use.

Note #5. The following TM will not be monitorable when the command is executed, as the downlink has to be re-established.

TABLE 3.7.4-1 (Continued)

COMMAND	COMMAND TITLE	COMMAND DESCRIPTION AND SUBSYSTEM INTERNAL RESPONSE	TM MNEMONIC	TM TITLE AND/OR REMARKS
TRANSPONDERS 1 & 2 (Cont'd)				
COH1Ø COHAØ	Inhibit Coherent Mode	Actuates logic inside transponder that is ON that prevents solid state switch from selecting the VCO as the exciter frequency source when the receiver is locked to uplink signal. Auxiliary oscillator is frequency source.		For whichever exciter is ON, the corresponding following telemetry indicates bilevel logic 1 (= inhibit); the other parameter indicates bilevel logic 0 (unpowered).
			RCOH1S	Exciter 1 Inhibit/Restore coherent mode.
			RCOH2S	Exciter 2 Inhibit/Restore coherent mode.
				The downlink frequency will correspond to auxiliary oscillator frequency of the exciter that is ON. Commands may still be received & processed.
COH19 COHA9	Restore Coherent Mode	Allows solid state switch inside transponder that is ON to select VCO as exciters' frequency source, when the receiver is locked to an uplink signal. Downlink frequency will be 240/221 times uplink frequency.	RCOH1S	Exciter 1 Inhibit/Restore coherent mode = 0 (= Restore)
			RCOH2S	Exciter 2 Inhibit/Restore coherent mode = 0 (= Restore)
				Downlink frequency will be 240/221 times the uplink frequency when phase locked.
MIH11 MIHA1	Bus High Mode Index Select	Actuates solid state switch inside transponder that is ON to cause 1.18 radians mod index to be selected for exciters for spacecraft TM subcarrier.	NONE	No TLM. Downlink carrier suppression will increase by approximately 6.4 dB over low mod index only operation.
MIL11 MILA1	Bus Low Mod Index Select.	Actuates solid state switch inside transponder that is ON to cause 0.65 radians mod index to be selected for exciters for spacecraft TM subcarrier.	NONE	No TLM. Downlink carrier suppression will decrease by approximately 6.4 dB relative to Hi Mod Index only operation or decrease by approximately 2.0 dB over carrier only operation.
VCO19 VCOA9	Exciter Transfer to VCO ON (Test only-wired out).	Actuates solid state switch inside transponder that is ON that causes exciter frequency source to be VCO, when the receiver is not locked to uplink signal.		For whichever exciter is ON, the corresponding following telemetry indicates bilevel logic 1 (= ON); the other parameter indicates logic 0 (= Unpowered).
			RVCO1S	Exciter 1 Transfer to VCO ON/OFF
			RVCO2S	Exciter 2 Transfer to VCO ON/OFF
				Downlink frequency will shift from auxiliary oscillator frequency to 240/221 times the receiver best lock frequency.
VCO1Ø VCOAØ	Exciter Transfer to VCO OFF (Test only-wired out).	Actuates solid state switch inside transponder that is ON that causes exciter frequency source to revert to auxiliary oscillator whether receiver is or is not locked to uplink signal.	RVCO1S	Exciter 1 Transfer to VCO ON/OFF = 0 (= OFF).
			RVCO2S	Exciter 2 Transfer to VCO ON/OFF = 0 (= OFF).
				Downlink frequency will shift back to auxiliary oscillator frequency of the exciter that is ON.
MIH21 MIHB1	Probes High Mod Index Select	Actuates solid state switch inside transponder that is ON to cause: (a) 1.17 radians mod index to be selected for Probes' TM subcarrier. (b) 0.65 radians mod index to be selected for Bus TM subcarrier.	NONE	No TLM. Downlink carrier suppression will increase by 8.2 dB over Bus Subcarrier (Low Mod Index) only operation.
MIL21 MILB1	Probes Low Mod Index Select	Actuates solid state switch inside transponder that is ON to cause: (a) 1.025 Radians mod index to be selected for Probes' TM subcarrier. (b) 0.65 Radians mod index to be selected for Bus TM subcarrier.	NONE	No TLM. Downlink carrier suppression will increase by 5.7 dB over Bus subcarrier (Low Mod Index) only operation.

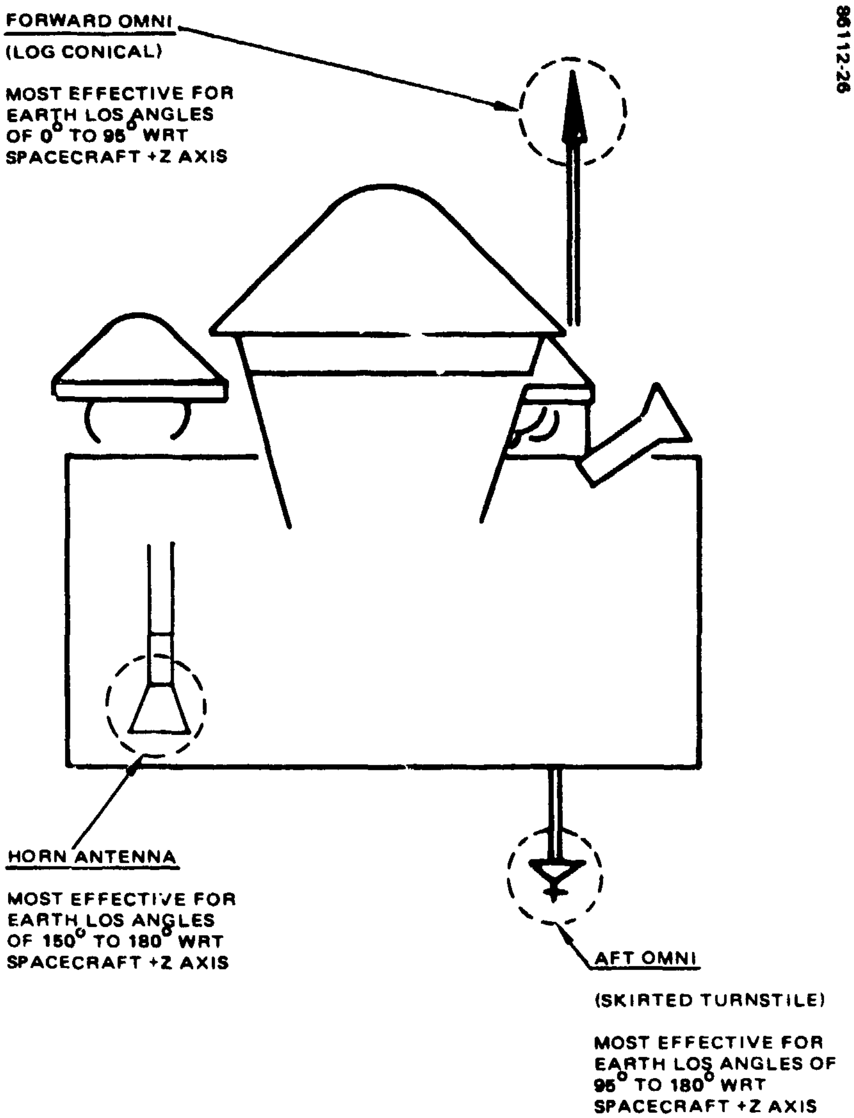

FIGURE 3 7.1-1. BUS COMMUNICATION SUBSYSTEM ANTENNA CONFIGURATION

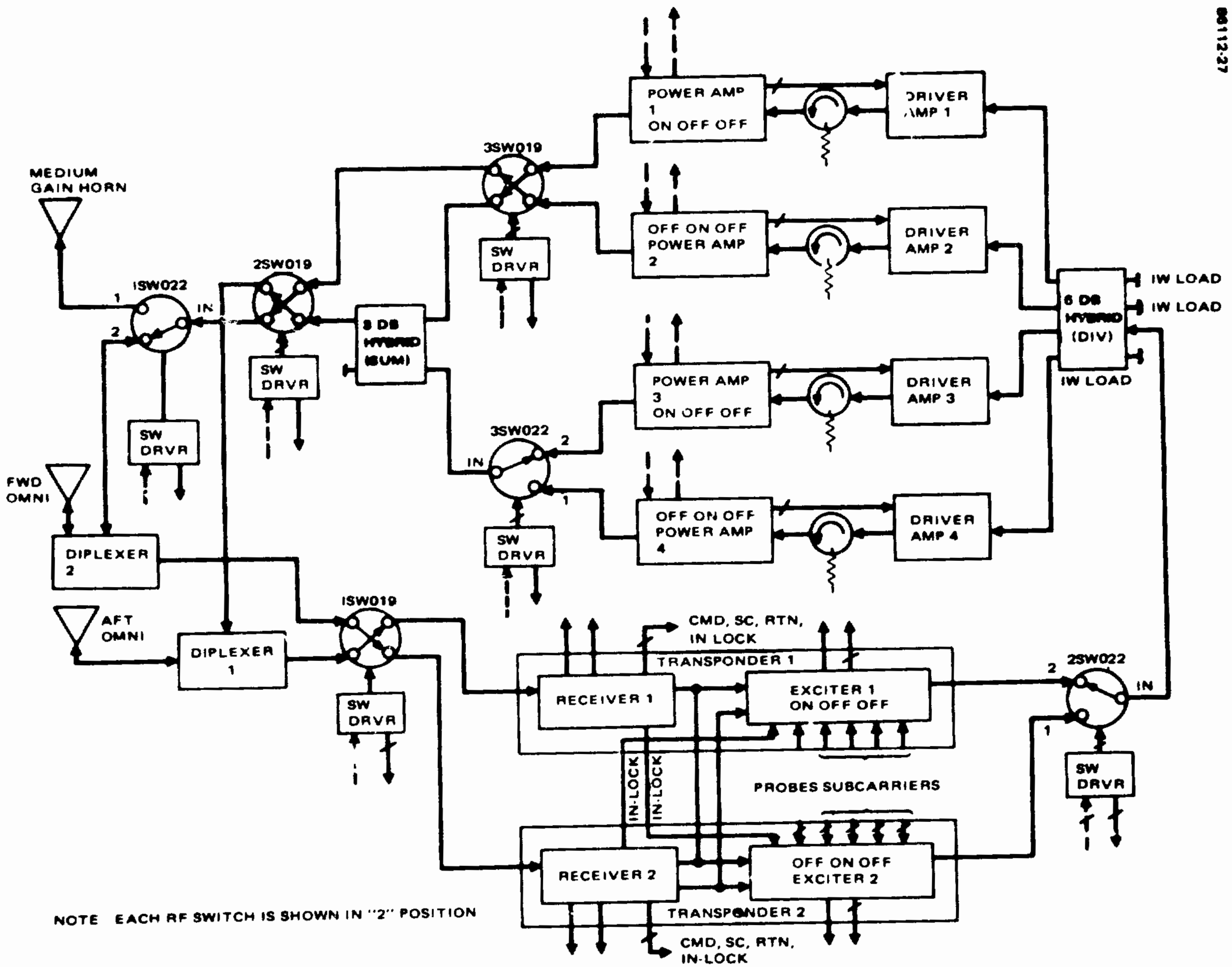

FIGURE 3.7.1-2. BUS COMMUNICATION SUBSYSTEM FUNCTIONAL BLOCK DIAGRAM

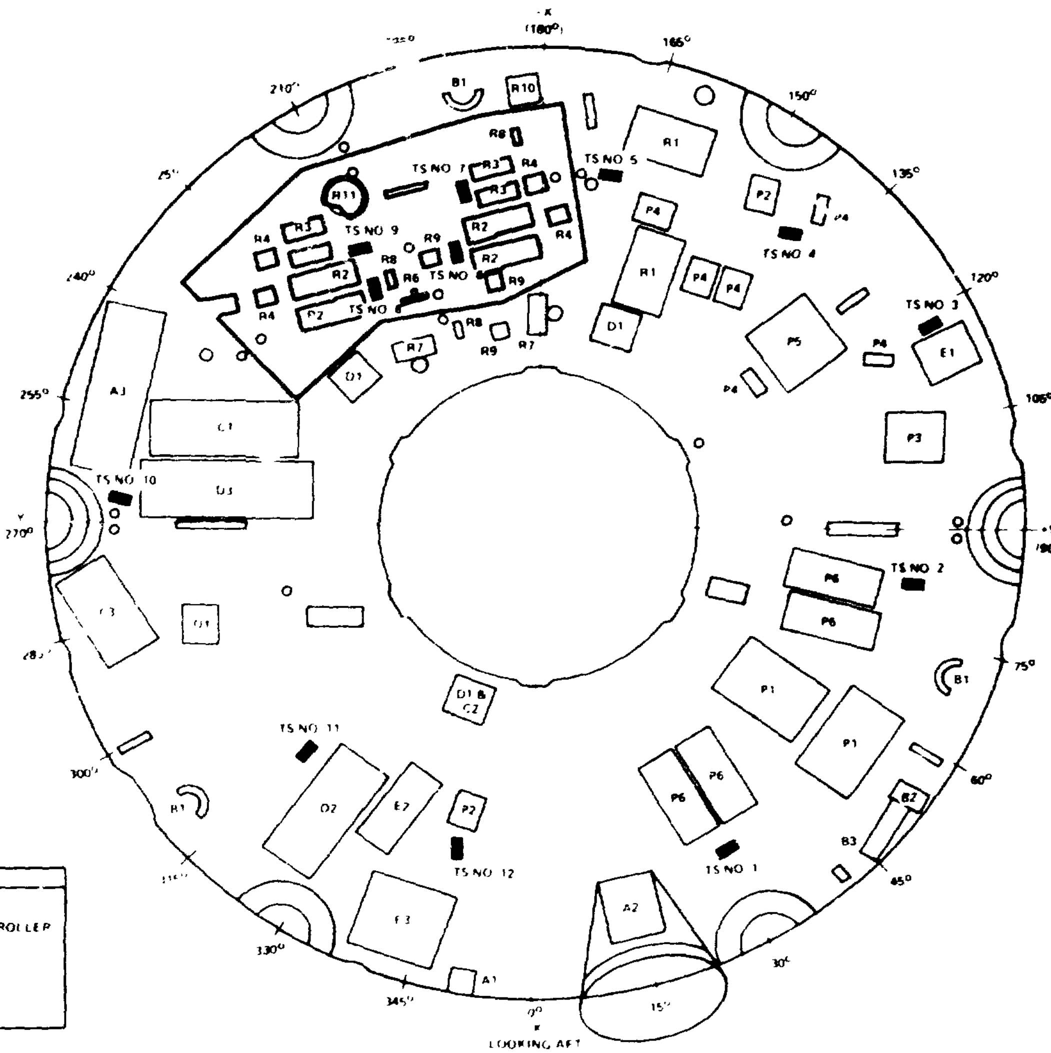

FIGURE 3.7.1-3. BUS COMMUNICATIONS SUBSYSTEM SHELF LAYOUT

NO	MNEMONIC
TS1	SHLØ1T
2	SHLØ2T
3	SHLØ3T
4	SHLØ4T
5	SHLØ5T
6	SHLØ6T
7	SHLØ7T
8	SHLØ8T
9	SHLØ9T
10	SHL1ØT
11	SHL11T
12	SHL12T

CODE	NOMENCLATURE
E1	BIMS SENSOR
E2	BNMS ELECTRONICS
E3	BUMS SENSOR
R1	TRANSPONDER
R2	POWER AMP
R3	DRIVER AMP
R4	ISOLATOR
R5	6 DB HYBRID
R6	3 DB HYBRID
R7	DIPLEXER
R8	S SWITCH
R9	C SWITCH
R10	SWITCH DRIVER
R11	FWD OMNI MAST
D1	DUAL DATA INPUT MODULE
D2	PCM ENCODER
D3	TM PROCESSOR
C1	COMMAND PROCESSOR
C2	COMMAND OUTPUT MODULE
C3	PYRO CONTROL UNIT
A1	SUN SENSOR ASSEMBLY
A2	STAR SENSOR
A3	ATTITUDE DATA PROCESSOR

CODE	NOMENCLATURE
P1	CHARGE DISCHARGE CONTROLLER
P2	BUS VOLTAGE LIMITER
P3	UNDER VOLTAGE OVER VOLTAGE CONTROLLER
P4	CURRENT SENSOR
P5	POWER INTERFACE
P6	BATTERY PACK (2 PER BATTERY)
B1	IFO BRACKET
B2	UMBILICAL BRACKET
B3	OEP BSP BRACKET

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****                                 ****
****   This Figure is a Foldout.     ****
****                                 ****
****        See APPENDIX C           ****
****                                 ****
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Figure 3.7.1-4

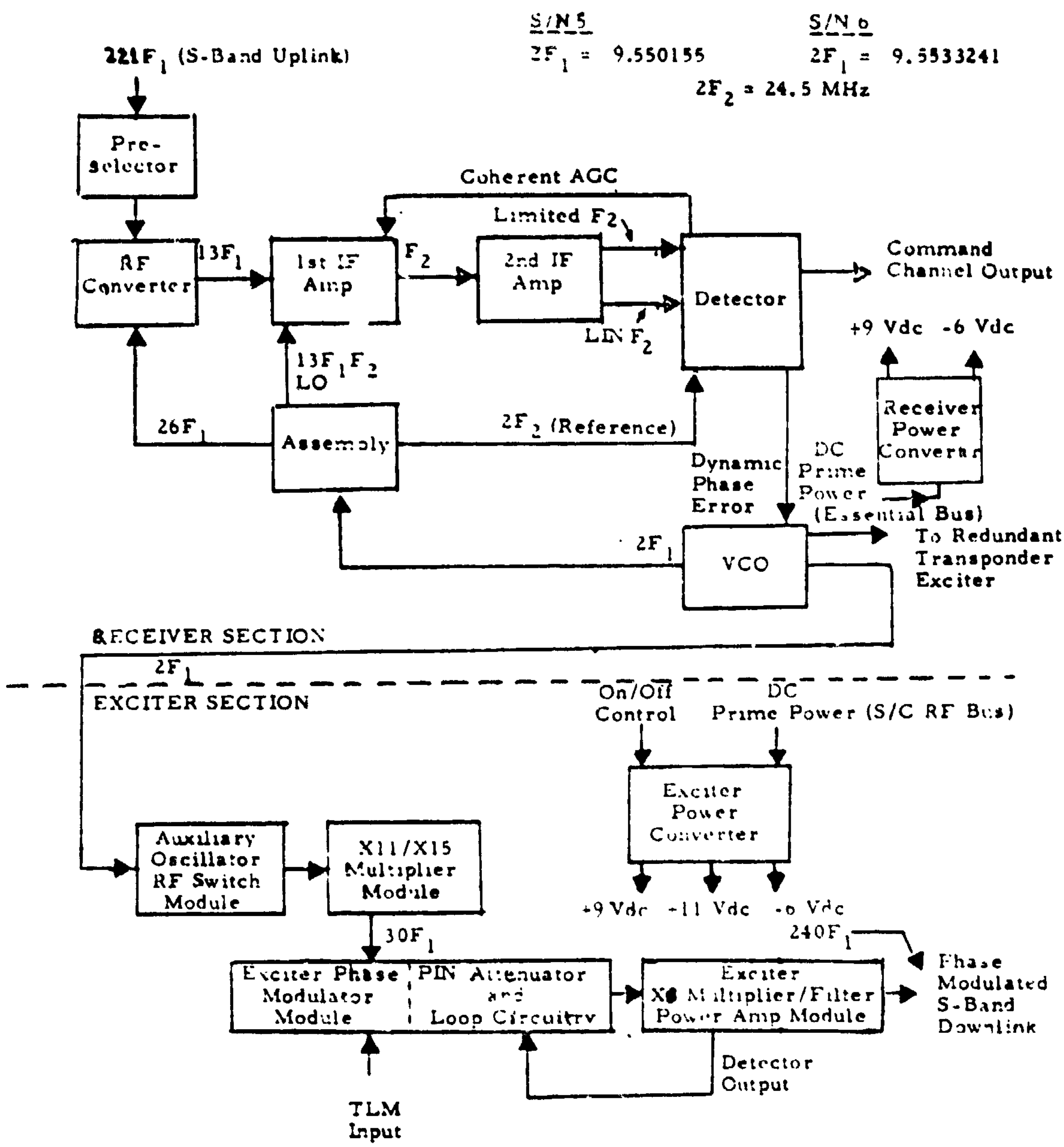

Figure 3.7.2.1-1. Transponder Functional Block Diagram

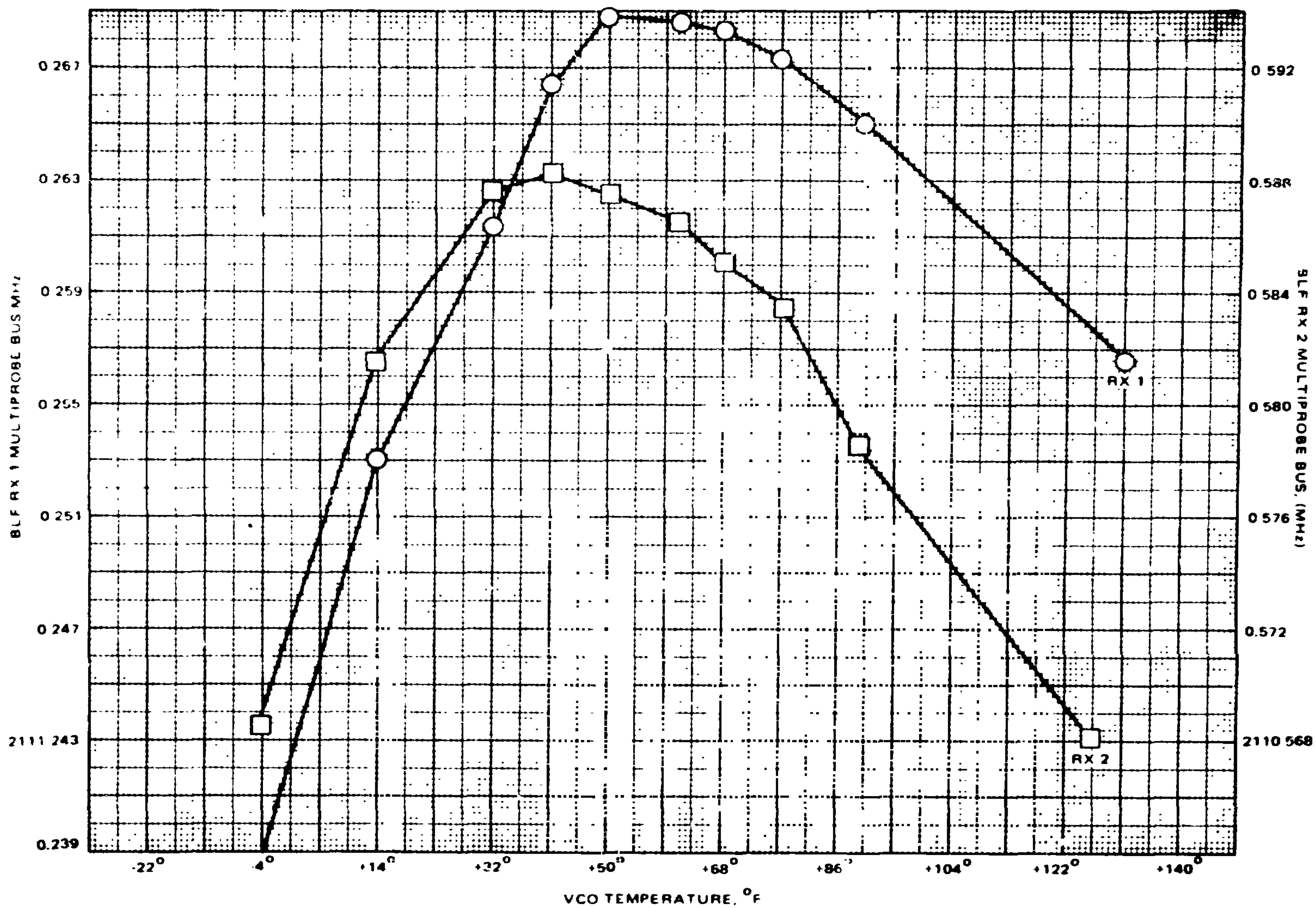

FIGURE 3.7.2.1-2. MULTIPROBE BUS BEST LOCK FREQUENCY VERSUS VCO TEMPERATURE (UNIT TRANSPONDER CURVES)

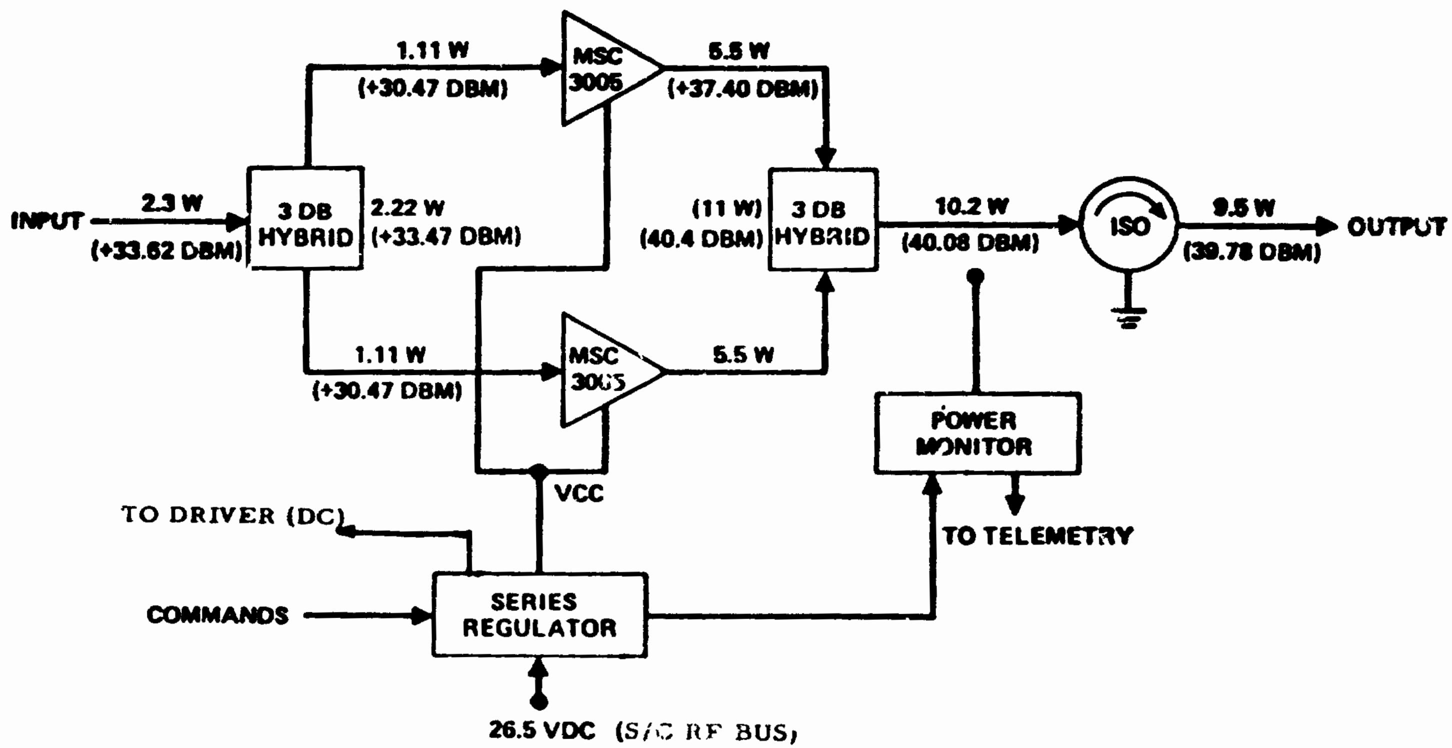

Figure 3.7.2.3-1. Power Amplifier Block Diagram, With Nominal Signal Levels Shown

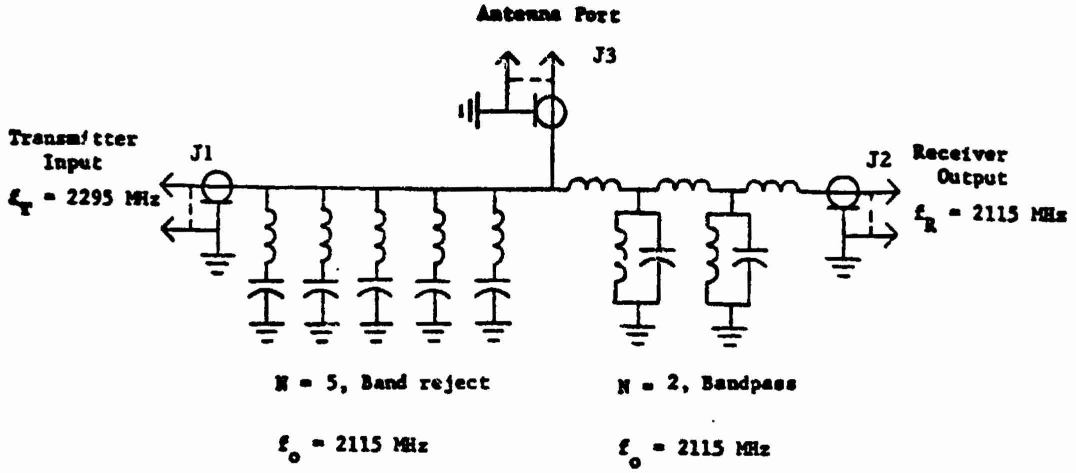

Figure 3.7.2.4-1A. Diplexer Schematic Diagram.

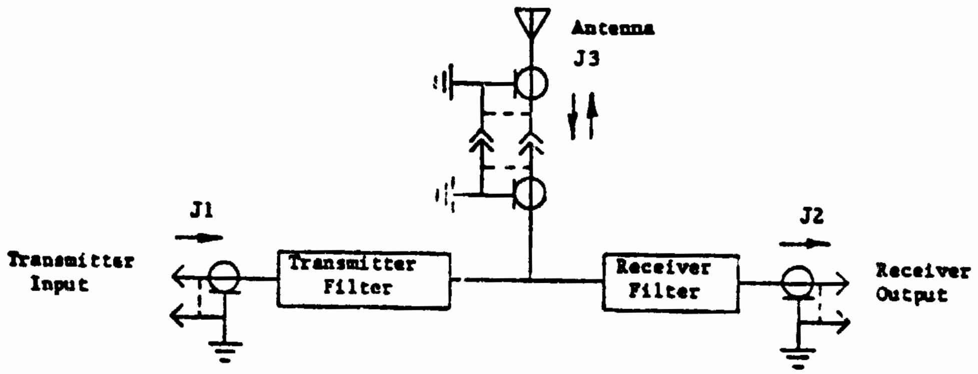

Figure 3.7.2.4-1B. Diplexer Block Diagram.

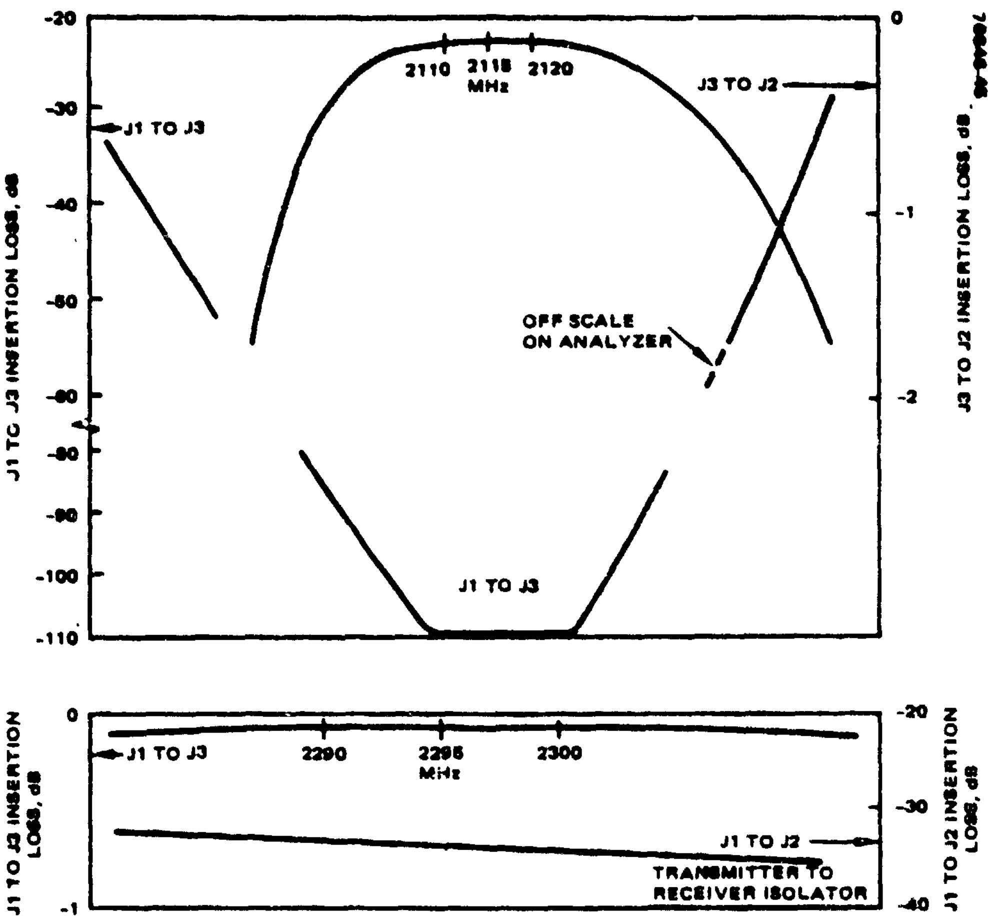

FIGURE 3.7.2.4-2. DIPLEXER MEASURED RESPONSE (AT UNIT LEVEL)

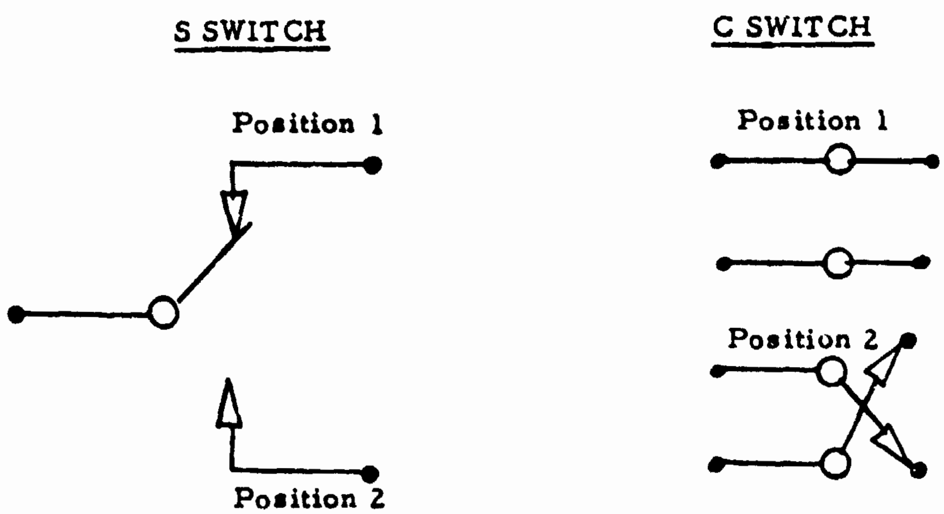

Figure 3.7.2.5-1. RF Switch Schematics

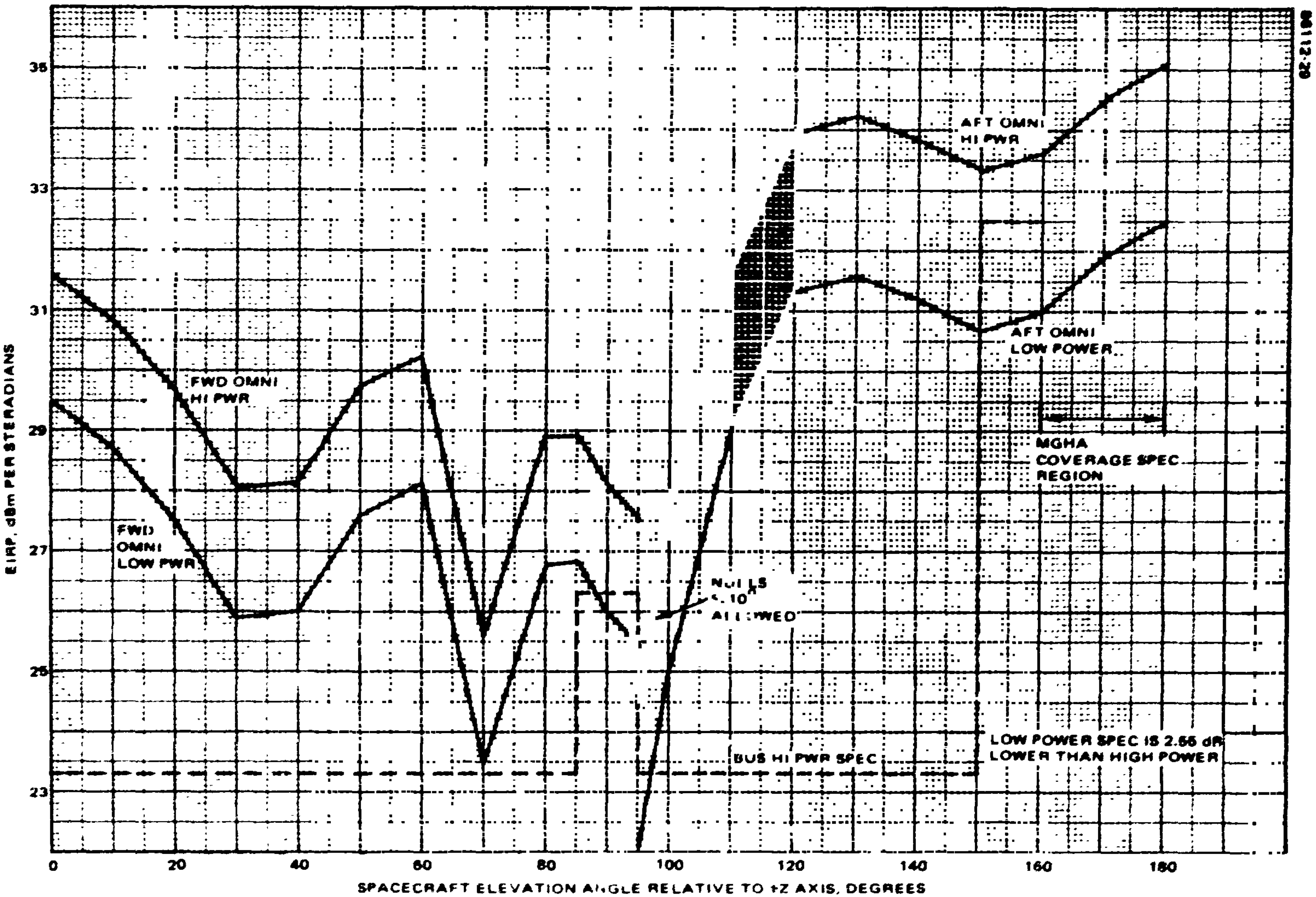

FIGURE 3.7.2.6-1. BUS OMNI ANTENNAS' TRANSMIT PERFORMANCE IN TERMS OF RADIATED POWER DENSITY

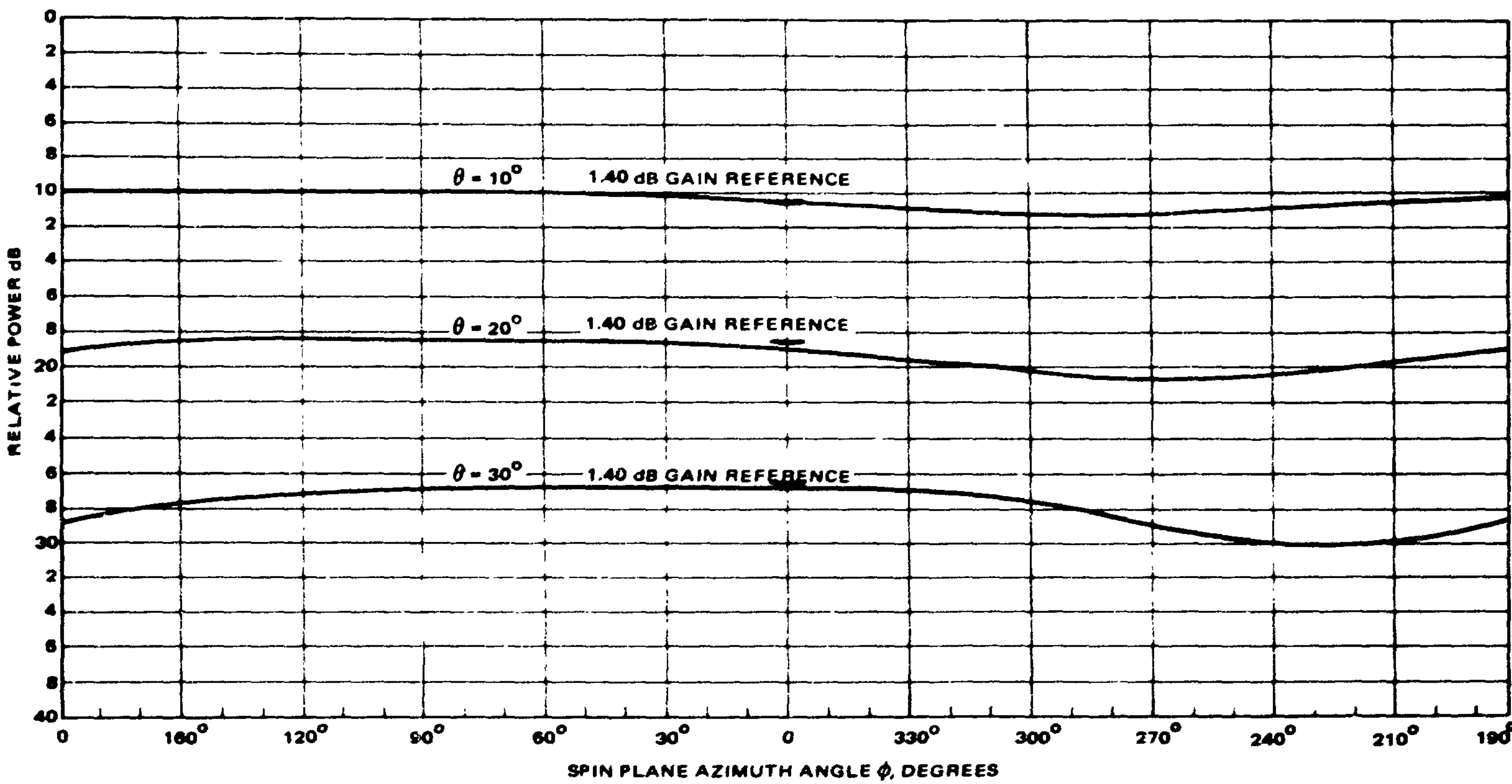

FIGURE 3.7.2.6-2A. FORWARD OMNI RHCP GAIN VERSUS AZIMUTH ANGLE (ϕ) AS A FUNCTION OF ELEVATION ANGLE θ

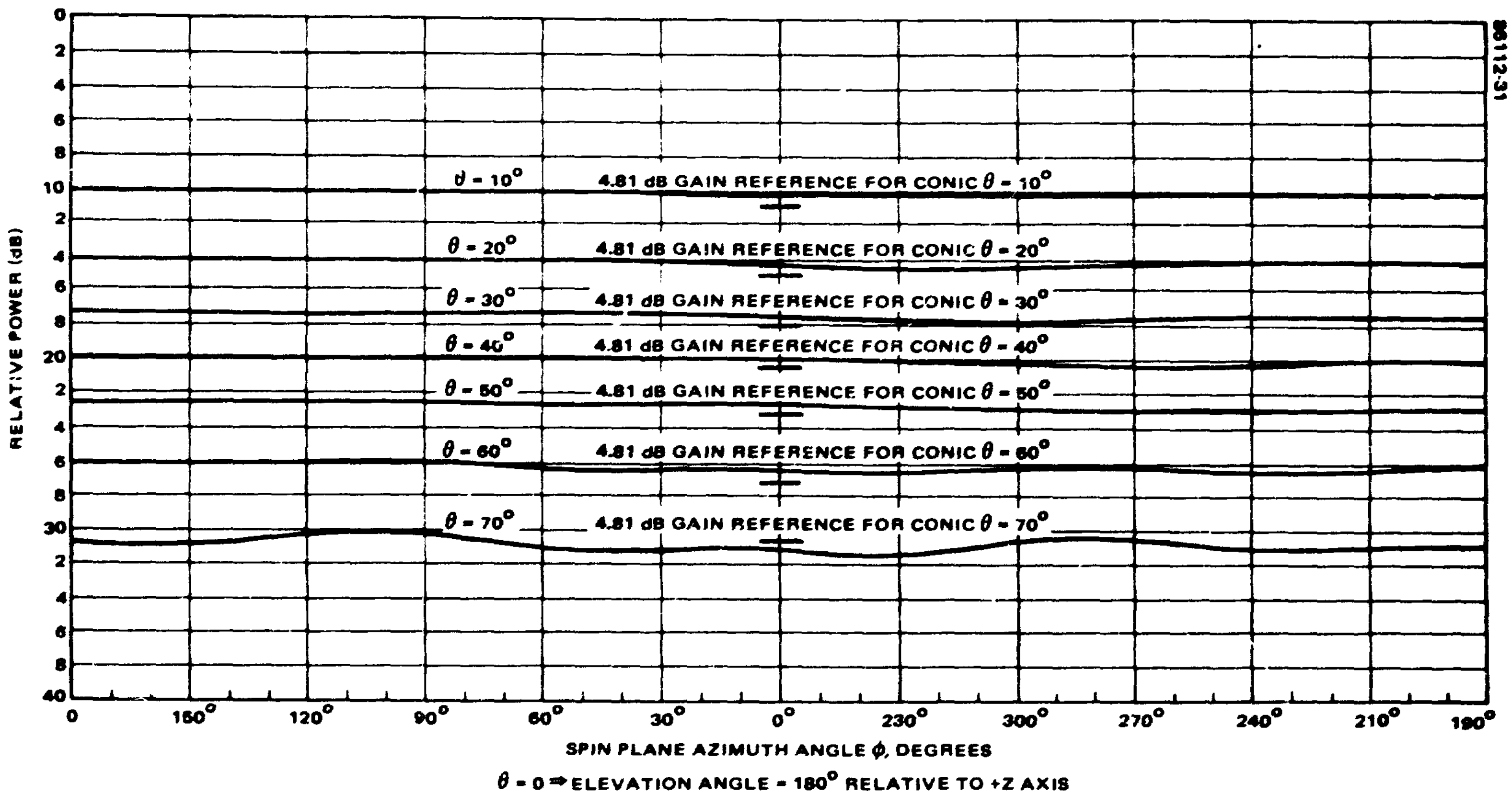

FIGURE 3.7.2.6-2B. AFT OMNI RHCP GAIN VERSUS AZIMUTH ANGLE (ϕ) AS A FUNCTION OF ELEVATION ANGLE θ

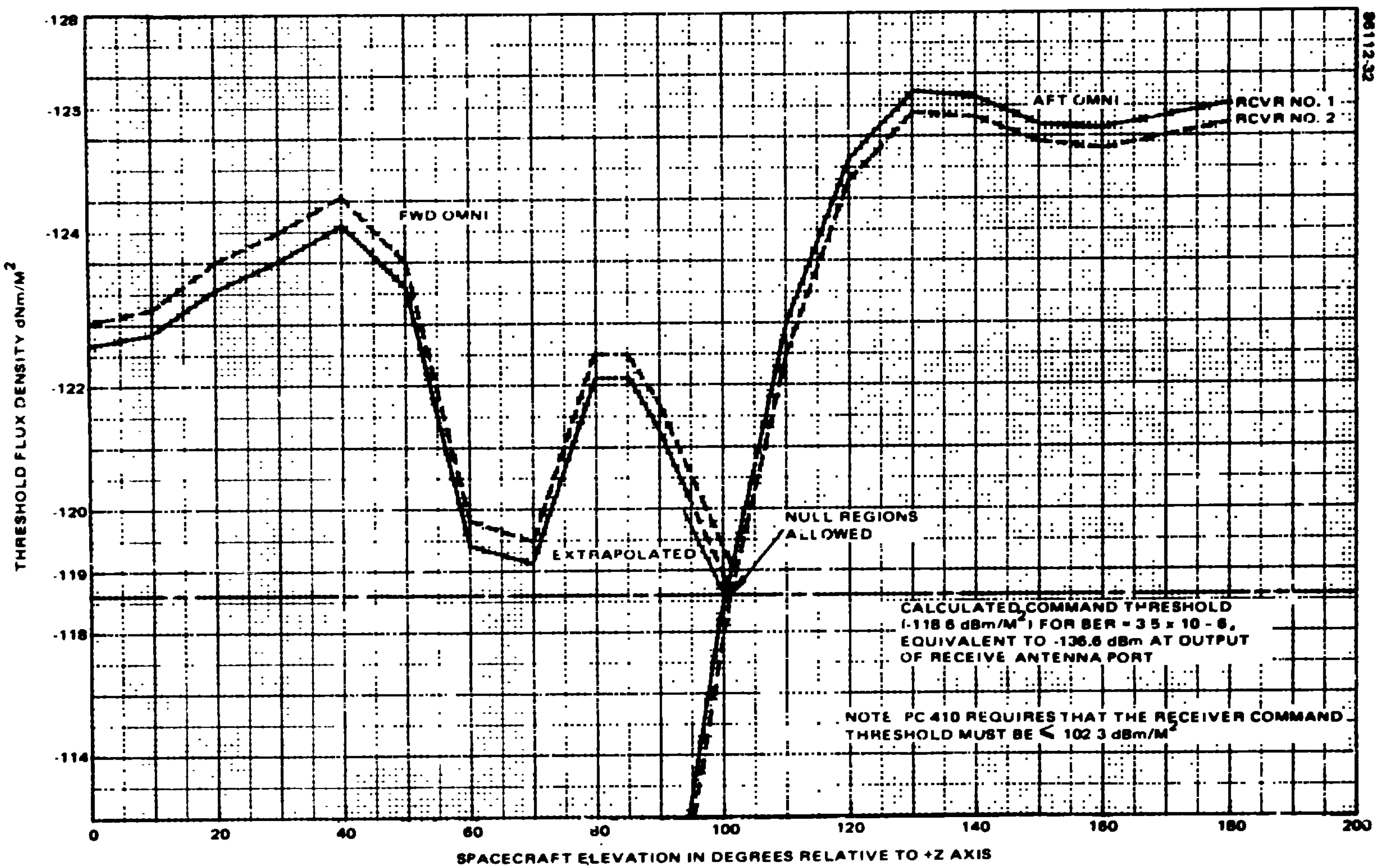

FIGURE 3.7.2.6-3 BUS OMNI ANTENNAS' RECEIVE PERFORMANCE

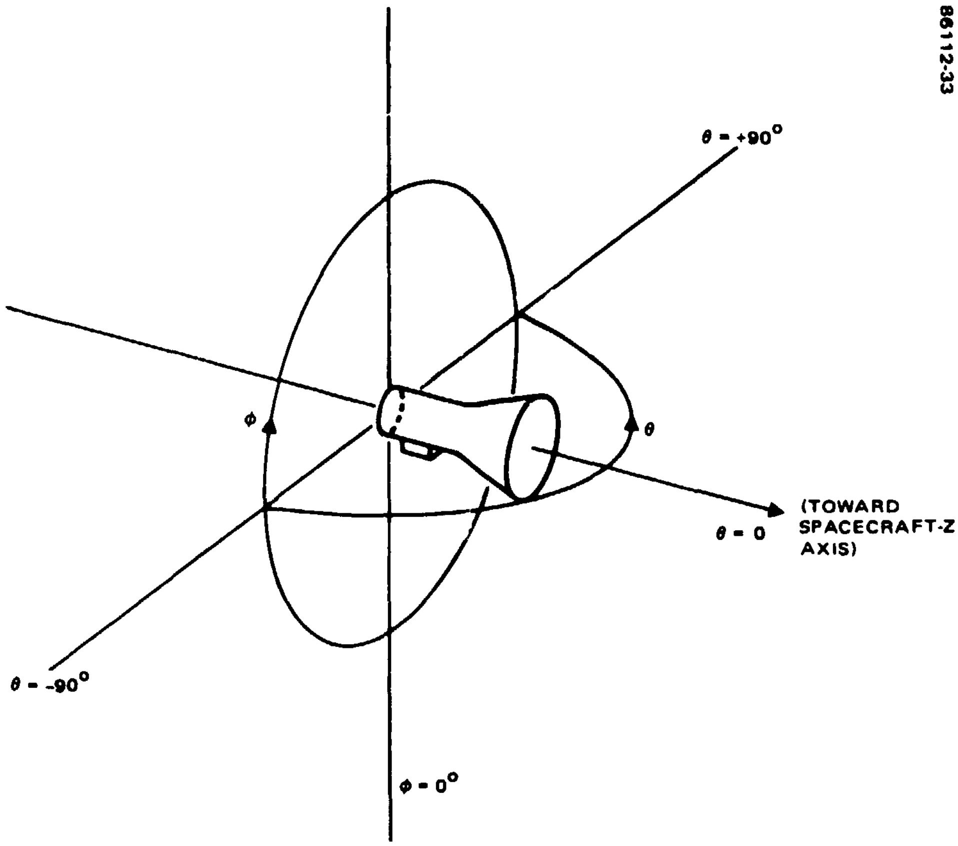

FIGURE 3.7.2.6-4 MEDIUM GAIN HORN ANTENNA PATTERN COORDINATES' DIAGRAM

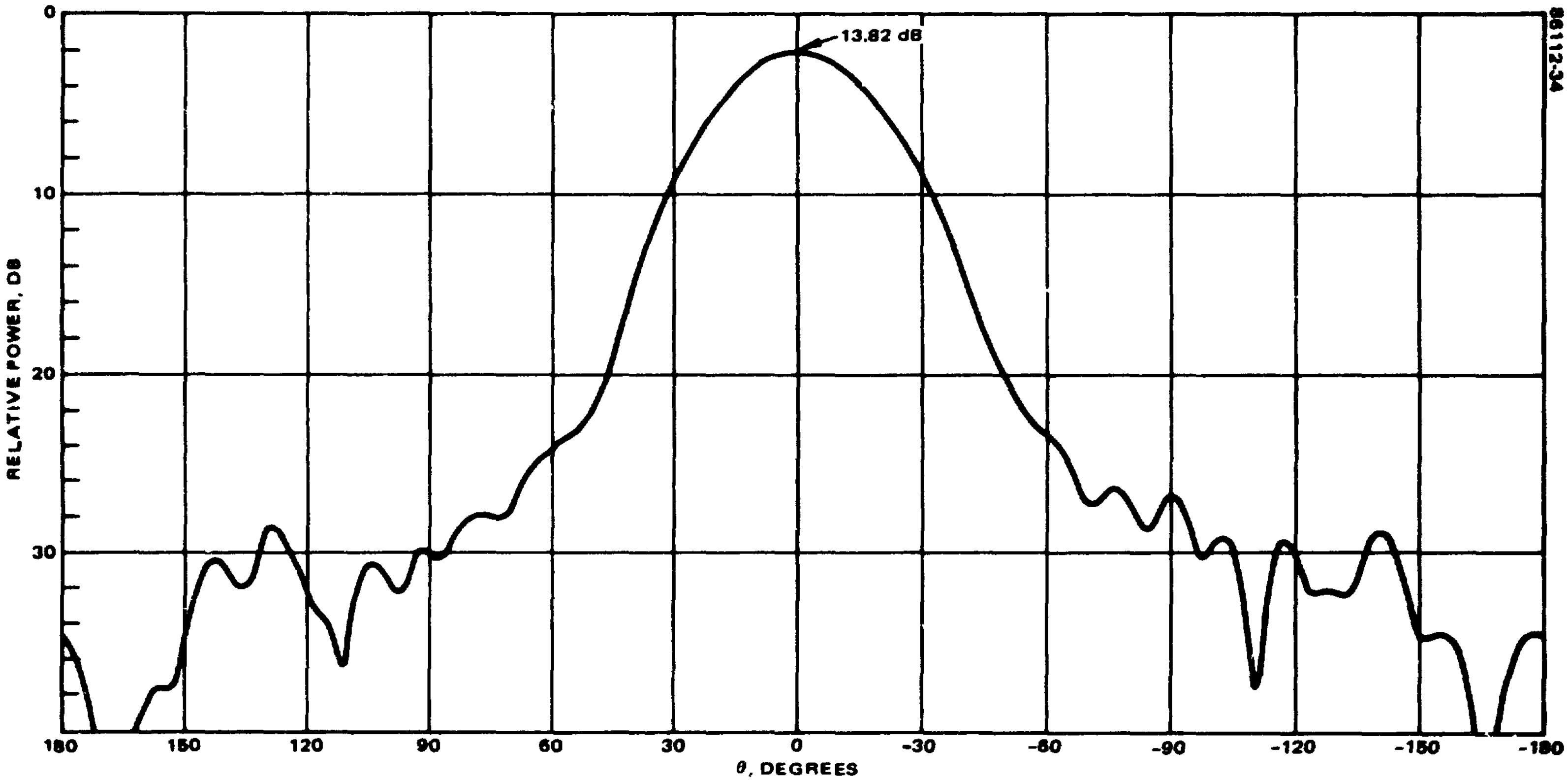

FIGURE 3.7.2.6-5 MEDIUM GAIN HORN (FLIGHT UNIT) AZIMUTH PATTERN, 2295 MHz

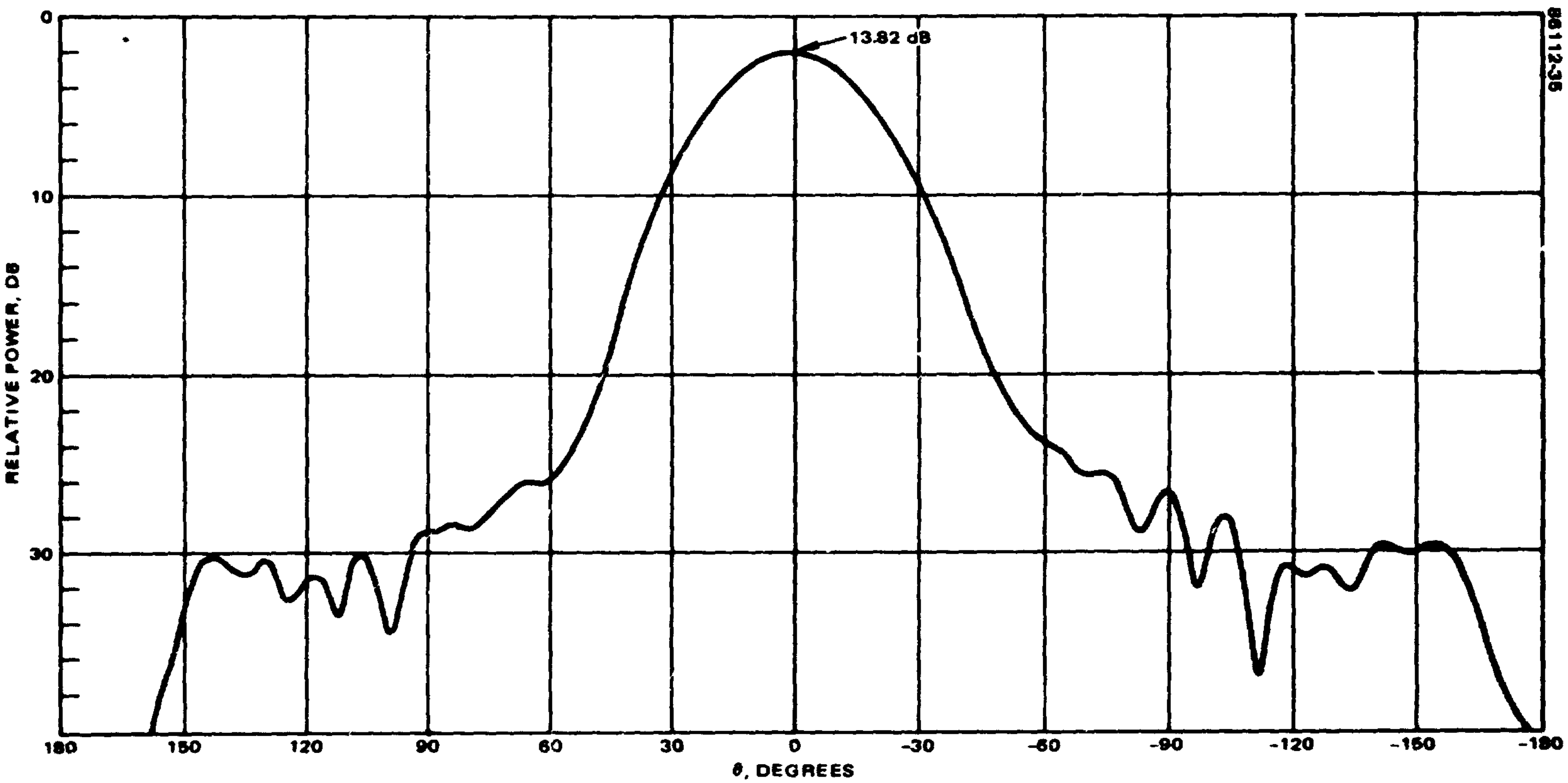

FIGURE 3.7.2.6-6 MEDIUM GAIN HORN (FLIGHT UNIT) ELEVATION PATTERN, 2295 MHz

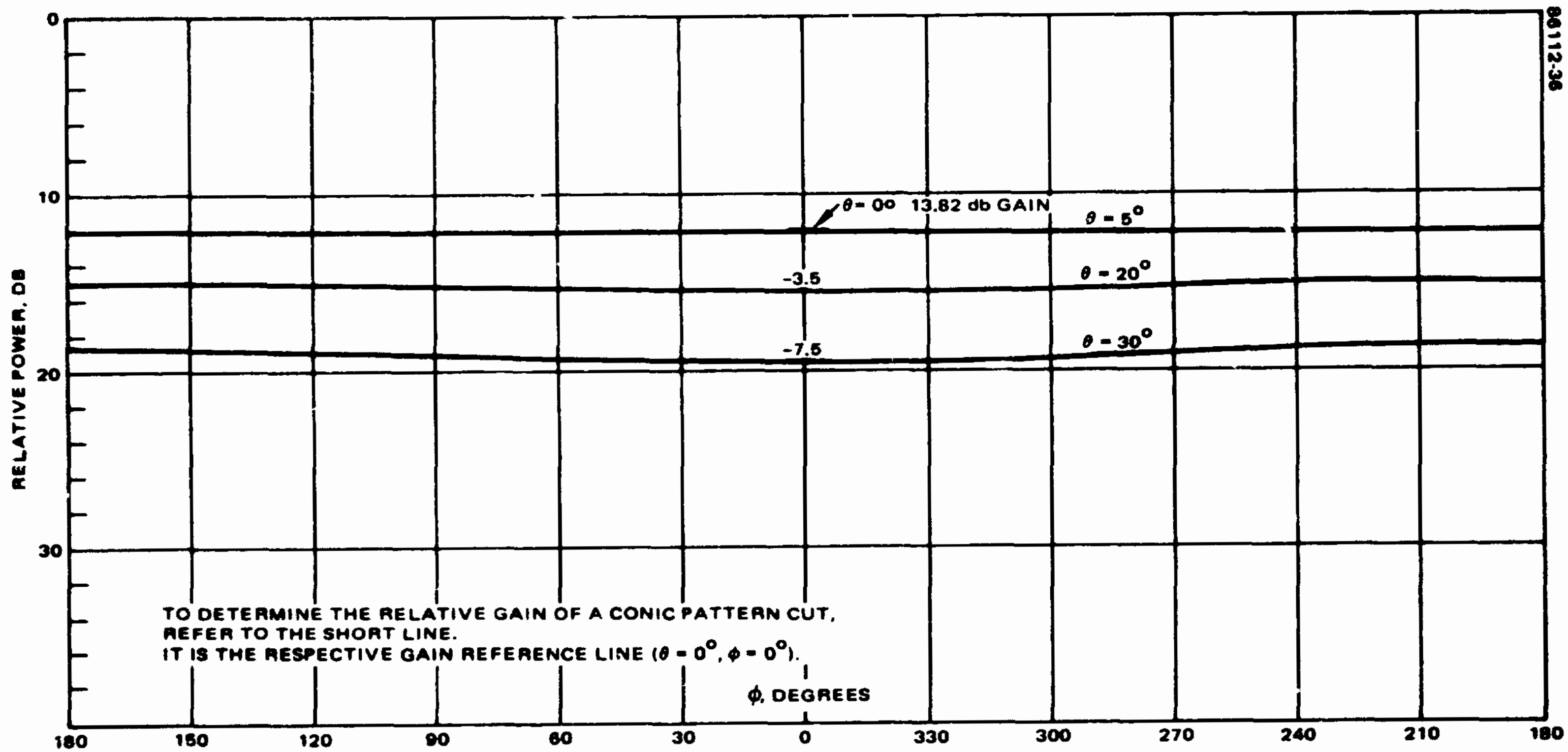

FIGURE 3.7.2.6-7 MEDIUM GAIN HORN (FLIGHT UNIT) CONIC PATTERN CUTS, 2295 MHz

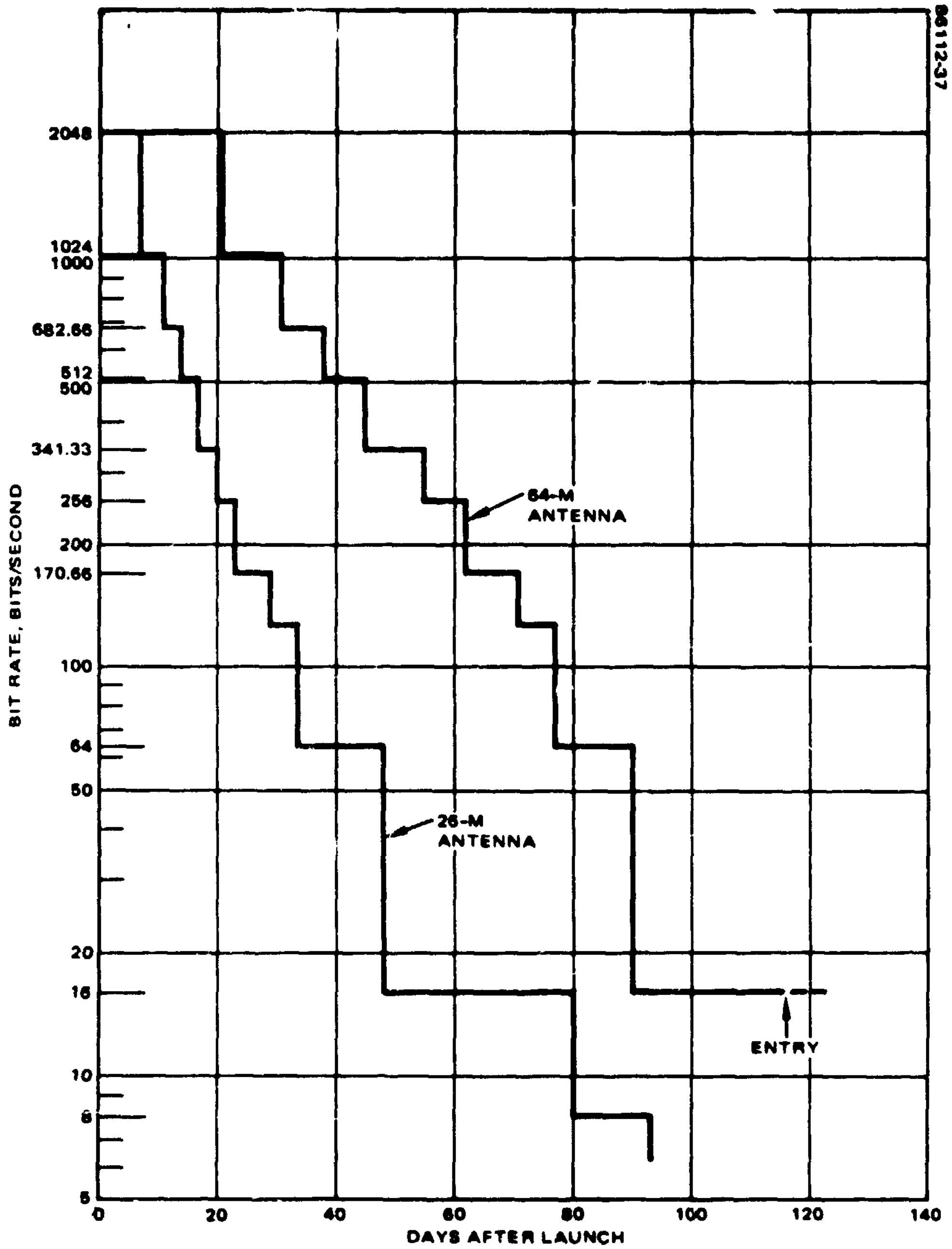

FIGURE 3.7.3-1 MULTIPROBE BUS ONLY DATA RATE CAPABILITY — OMNI ANTENNA

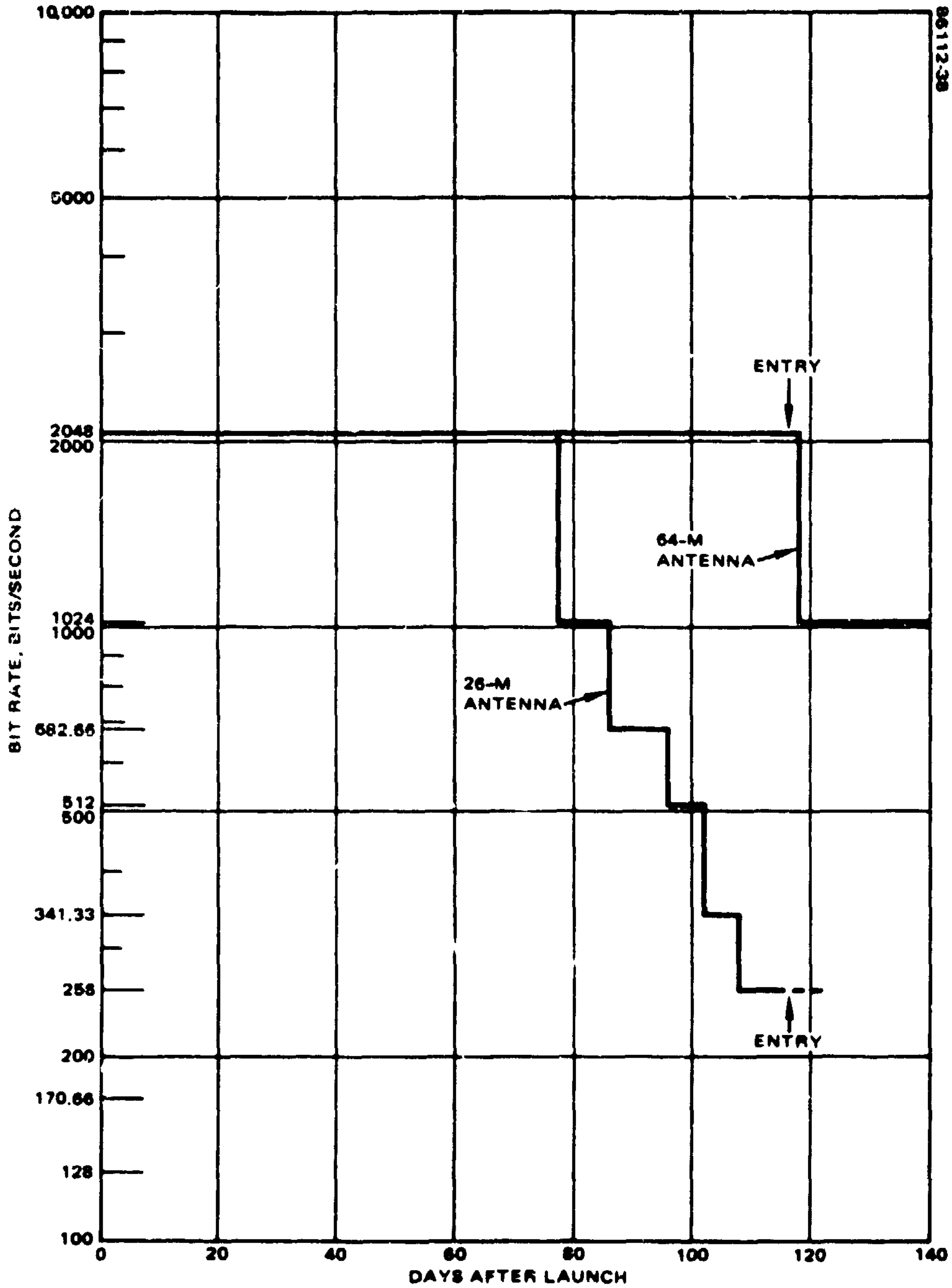

FIGURE 3.7.3-2. MULTIPROBE BUS ONLY DATA RATE CAPABILITY – HORN ANTENNA

3.8 POWER SUBSYSTEM

3.8.1 Power Subsystem Description. The Bus power subsystem provides semi-regulated power at 28 volts ±10% to all Bus loads, probe heaters and probe checkout buses. Prior to each probe's release, power is transferred from the probe checkout bus to the probe internal battery. The probe batteries provide power to their respective loads at 28 volts ±10% during atmosphere entry and descent, although at probe release, with a relatively high battery temperature and minimum electrical loads, the Larg Probe bus voltage can be as high as 32.0 volts and the Small Probe buses can be as high as 33.7 volts. The individual users condition this power, where necessary, by additional regulation, power switching, and dc/dc converters that deve' p the specific voltages required by that user.

3.8.1.1 Functional Description. Figure 3.8.1.1-1 (Appendix C) shows a functional block diagram of the power subsystem. Power is provided to all loads on 4 different power buses:

(a) The essential bus - which cannot be commanded OFF,
(b) The science bus - for Bus science and probes checkout.
(c) The switched loads bus, and
(d) The RF transmitter bus.

The primary power source is the solar panel. The Bus panel has a total of 13,060 solar cells connected in a series parallel arrangement that optimizes power output and minimizes stray magnetic fields, ripple, and shadowing effects of the thrusters and star sensor sun shield.

During most mission phases there will be a surplus of solar panel power available to meet the load requirements. A power surplus always forces the solar panel voltage upward above the nominal 28 volt value. To prevent excessive power bus voltages, the voltage limiters sense the bus voltage and shunt off surplus solar panel power to load resistors mounted on the rear sections of the solar array substrate and the equipment shelves. The bus limiters maintain the bus voltages below 30.0 volts at all times.

When the solar panel cannot provide adequate power for all spacecraft loads at low sun angles and during launch, the two nickel cadmium batteries come on line automatically through the discharge regulators. The regulators normally maintain the bus voltage above 27.5 volts at all times. Battery energy is subsequently replenished through small charge arrays that boost the main array voltage to a voltage level that results in recharging of the batteries.

If a spacecraft overcurrent or undervoltage on either battery occurs, loads are removed by the undervoltage/overload (UV/OL) switch to protect the spacecraft from potential catastrophic failure. Those loads, however, that are deemed vital to the spacecraft survival are hardwired to the essential bus and cannot be switched off. These include all command subsystem units, propulsion heaters, and r.f. subsystem switch drivers.

If a fault occurs that raises the total spacecraft load current above 16.5 ±0.75 amperes, the other 3 power buses (science, switched load, RF transmitter buses) will sequentially trip off. If the spacecraft loads decrease below 16.25 amperes, the tripping sequence is terminated. If a fault occurs that lowers the battery voltage to 27.55 ±0.15 volts, all three buses will be switched off. When the battery voltage recovers to 28.3 volts, a UV/OL reset relay command can be sent to power up all three non-essential buses again.

The UV/OL switch has an override mode that inhibits load removal. This feature can be used if the trip circuitry fails or if it becomes necessary to operate selected spacecraft loads even under fault conditions.

Excitation for the pyro bus is derived from a battery tap located 16 cells (of a total of 24) from the ground reference level. This tap is also used to provide large fault clearing currents to the power bus in the event of a heavy fault current that saturates the discharge controllers.

A total of eight current sensors are used to monitor power subsystem performance. Each sensor consists of a 50 millivolt resistive shunt and a hybrid differential amplifier with a gain of 102.4 that develops a 5.12 volt output signal at full scale. Four of these sensors are integrated into the charge/discharge controllers - they measure battery charge and discharge currents. The spacecraft loads current sensor is integrated into the UV/OL switch because it not only provides a telemetry signal but also an overcurrent trip signal to the UV/OL turnoff sequence generator. The other 3 current sensors shown in Figure 3.8.1.1-1 are packaged as individual units.

The charge controller provides a high rate charge by connecting the boost charge string directly to its associated battery and a low-rate charge by inserting a 47 ohm resistor between the charge string and the battery. Each battery pack has a thermal switch that closes at 95 ±5°F and automatically turns off battery charging. After the battery temperature drops and the thermal switch opens again, battery charging is resumed automatically.

Near Earth low solar heat input conditions or a UV/OL trip can reduce the equipment shelf temperature to dangerously low levels. For this reason two of the five bus limiters are connected to heater resistors mounted on the back side of the equipment shelves. To guarantee that the first 130 watts of excess solar panel power is shunted into these shelves the operating set voltage of each of these two limiters (#2 and #5) is lowered by closure of thermal switches when the shelf temperature drops to 35 ±5°F or the RF shelf drops to 60 ±5°F.

The power interface unit (PIU) provides power switching for the probe checkout buses, probe and propulsion heaters, and excitation of probe internal/external power switching relays. Fuses for the heaters and science instruments are also located in the PIU.

3.8.1.2 Equipment Summary and Locations. The complete Multiprobe power subsystem consists of the following units:

- Solar panel (with six 26.0 ohm load resistor circuits bonded to rear of substrate)
- Four 12-cell battery packs (2 per battery)
- Two charge/discharge controllers
- Three 29.5 volt (-1) bus limiters
- Two 30.0 volt (-2) bus limiters
- One undervoltage/overload switch
- One power interface unit
- Three current sensors, three types: 0-1.5, 0-12, 0-18 amperes (Five additional current sensors are integrated into the charge/discharge controllers and the UV/OL switch).
- Four shelf thermal switches
- Four 26.0 ohm equipment shelf load resistor circuits.

The locations of the shelf mounted units are shown in Figure 3.8.1.2-1.

3.8.2 Units Descriptions. Described below are the individual power subsystem units.

3.8.2.1 Solar Panel. The Bus solar panel is designed to supply the power requirements of the loads under varying conditions of solar intensity, temperature and sun angle. A total of 13,060 two x two cm solar cells are used on the Multiprobe panel. A thin 8 mil, 20 ohm-cm lightweight cell was selected to minimize panel weight. Each cell has a 6 mil microsheet coverglass to minimize radiation degradation.

The Basic layout of the Bus solar panel uses a total of sixty 3 x 70 cell groups interconnected, three cells in a parallel set, 70 such sets in series. The cell groups are positioned at the bottom of the substrate to minimize shadowing at low sun angles by the radial thrusters and the star sensor sun shield.

The Bus has ten individual "1 x 23" battery charge strings for each battery (boost charge array). They are all connected in parallel and spaced approximately 36 degrees apart on the cylindrical substrate. This small number of solar cells (230 per battery) easily provides the required charge current.

The Bus panel is designed to survive a massive solar flare. Solar panel degradation computations have been made assuming that this flare can occur at any time. At any point in the mission the equivalent fluence of this solar proton event is scaled according to the inverse of the square of the distance from the sun. If this solar flare occurs when the Bus is near Venus, a permanent loss of approximately 13% will result. (See Figure 3.8.3.3-1).

The two Bus science instruments require that all exposed solar cell terminals and wiring be covered with a non-conductive material to minimize plasma charging of the spacecraft structure. To meet this requirement, the void area between and surrounding each solar cell is filled with RTV 566 adhesive. This encapsulation or grouting process results in a small loss in solar panel power due to blockage of light to the solar cell active area and is acc   dated in the solar panel performance predictio.

Panel temperature is telemetered by PPAN2T (Solar Panel Temperature 2) located at θ=259°, approximately 25 inches from the top of the panel; and PPAN1T (Solar Panel Temperature 1) located at θ=259°, approximately 9 inches from the bottom of the panel.

3.8.2.2 <u>Nickel Cadmium Batteries</u>. Each battery consists of two 12-cell packs. A pack assembly sketch, which illustrates the method of construction, is shown in Figure 3.8.2.2-1. Each pack contains 12 individually insulated 7.5 AH nickel cadmium cells, 11 extruded thermal shunts and two end plates, all held together by two tension bars torqued to compressively load the cells.

The batteries will be fully charged prior to launch at a C/10 (0.75 ampere) rate through the umbilical connector from the blockhouse. The batteries can be charged independently with the battery enable plugs removed and the spacecraft completely powered down. Charging can also continue through the umbilical after the plugs are installed, if desired, until liftoff.

The batteries are charged during the mission with a small boost charge solar array. In order to fully charge the batteries, their voltage must be raised above the nominal 28 volt bus voltage. At a C/10 (0.75 amperes) rate each cell voltage must rise to approximately 1.45 volts/cell or 24 x 1.45 = 34.8 volts for the complete battery. At C/50 (0.150 amperes) each cell voltage must rise to approximately 1.413 volts/cell or 24 x 1.416 = 33.9 volts for the complete battery. This voltage boost is obtained by means of a small array that boosts up the main array voltage to the desired value.

Each of the four packs has a temperature sensor located near the middle of the pack. Each pack also has a thermal switch that turns off battery charging if its temperature reaches 95 ±5°F.

Maximum battery depth of discharge (DOD) will occur during Small Probe release when the sun angle is relatively low (17 to 26 degrees, depending on launch and probe entry dates).

Figure 3.8.2.2-2 describes battery performance as a function of energy (A-H) removed at 75°F; 4.5 AH represents a DOD of 60% of rated capacity. For a battery load of C/2 or 3.75 amperes, the battery voltage stays above 29.5 volts or 1.23 volts per cell at the 60% DOD level. At this relatively high battery voltage the discharge controllers will stay in regulation at output voltages exceeding 27.4 volts. This data indicates that with a relatively high discharge rate the batteries will provide sufficient voltage to maintain the regulator output above 27.4 volts, even at 80% DOD.

The data shown in Figure 3.8.2.2-2 is for a new battery. Mission simulation data indicates that there will be a small amount of voltage fade due to time aging. However, the maximum battery current during Small Probe release will not exceed C/5 or 1.5 amperes. Therefore, the discharge characteristics shown in Figure 3.8.2.2-2 are very close to those that will be obtained during Small Probe release.

The nickel cadmium batteries must provide high peak currents (up to 30 amperes) for 35 milliseconds to actuate pyrotechnic devices. The BNMS pyrotechnics will be actuated when the batteries are fully charged. The Large and Small Probes' pyrotechnic devices will be actuated with the battery DOD between 0 and 50%, depending primarily on the sun angle at the probe release attitude.

3.8.2.3 Bus Voltage Limiter Electronics. Voltage limiters are used to dissipate excess panel capacity in load resistors in order to maintain the bus voltage below 30.0 volts. The limiters are divided into two groups with different set points to prevent simultaneous operation of all limiters at their maximum internal power levels. The low set point limiters (-1) begin to conduct after the bus reaches 29.5 volts and achieve full conduction or saturation before the bus voltage becomes 29.6 volts. When the bus reaches 30.0 volts the upper set point limiters (-2) start to operate in a similar manner. When the bus voltage reaches 30.1 volts all of the bus limiters are in full conduction.

A simplified block diagram of a bus limiter is shown in Figure 3.8.1.1-1. Each of the five bus limiters can be enabled or disabled by command. Each limiter has controlling circuitry that senses the bus voltage and applies drive current to two power transistors which shunt current through load resistors to ground. The two power transistors turn on sequentially, as the bus voltage rises, in order to minimize the maximum thermal dissipation in each limiter. The offset diode forces Q2 (and the B shelf heaters) to go into full conduction before Q1 (and the A shelf heaters) starts to conduct. The dissipation in each power transistor is very low after saturation is reached because the saturation voltage drop is less than 0.15 volts.

The upper set point limiters have two additional terminals. Their nominal 30.0 volt set points can be lowered to either 28.5 (limiter 5) or 29.0 (limiter 2) volts by the closing of shelf thermostatic switches.

Three limiters (1, 3, 4) start to conduct at 29.5 volts and dissipate surplus panel capacity in the solar panel substrate. Two voltage limiters (2, 5) start to conduct when the bus voltage reaches 30.0 volts and dissipate surplus panel capacity in shelf heaters. When the shelf is warm, limiters 2 and 5 are inactive and all surplus solar panel power is dissipated in the solar panel substrate load resistors.

Limiter 5 is connected to thermostatic switches located near $\theta = 350°$. Transistor Q2 is connected to battery shelf heaters and transistor Q1 is connected to RF shelf heaters. As explained above, Q2 goes into full conduction before Q1 starts to conduct. The thermostatic switches will come on when their temperature reaches 35 ±5°F and lower the voltage limiter set point to 28.5 volts. This is lower than all the other limiters and forces the first excess 33 watts of solar panel power to be dissipated in the battery shelf heaters. The next 33 watts will be dissipated in the RF shelf heaters. The switches open when the shelf temperature reaches 55 ±5°F.

Limiter 2 is connected to thermostatic switches located near power amplifiers 3 and 4 at $\theta = 210°$. These switches come on when their temperature drops to 60 ±5°F and lower the set point of limiter 2 to 29.0 volts. If the battery shelf thermostatic switches are not closed, 66 watts of excess panel capacity will now be dissipated by limiter 2 and its associated load heaters. Once again, the first 33 watts is dissipated in the battery shelf. This guarantees adequate heat for the batteries even if bus limiter 5 fails. The thermostatic switches are set to operate at a relatively high temperature of 60 ±5°F in order that they track the battery shelf temperature in case limiter 5 fails. The BF shelf thermostatic switches open when the shelf temperature reaches 70 ±5°F. If both sets of thermostatic switches are closed simultaneously, the first 66 watts of excess solar panel capacity is dissipated by limiter 5.

3.8.2.4 Bus Limiter Load Resistors. The five bus limiters each require 26 ohm load resistors for a total of 10 load circuits. Six of these are bonded to the rear of the solar array substrate and the other four are bonded to the bottom of the equipment shelves.

Each solar array circuit consists of five parallel 130 ohm sections and each 130 ohm section, in turn, consists of two 65 ohm resistors in series. Each of these ten 65 ohm sections are approximately 1.80 inches high and 26.5 inches wide and cover a complete 1.8 inch band around the entire inside perimeter of the substrate. The wire is non-magnetic and twisted to provide magnetic field cancellation.

Each shelf load circuit consists of four 6.5 ohm sections connected in series. Each load resistor section is 8.8 x 2.3 inches in size.

3.8.2.5 Charge/Discharge Controllers. Figure 3.8.1.1-1 shows a block diagram of the charge/discharge controller associated with each battery. The charge controller section connects a boost charge array in series with the battery through switching relays K1 and K2. High charge rate is selected by commanding both relays to their upper positions (BAT19 or BATA9; and BAT13 or BATA3 for battery 1. For battery 2: BAT29 or BATB9; and

BAT23 or BATB3), which results in a direct connection between the charge array and the battery. Low charge rate is selected by commanding both relays to their lower positions (BAT1Ø or BATAØ; and BAT14 or BATA4 for battery 1. For battery 2: BAT2Ø or BATBØ; and BAT24 or BATB4). This places a 47 ohm resistor between the battery and charge array and forces the operating point of the latter below the knee (constant voltage portion) of its voltage-current characteristics. Battery charging is turned off whenever the two relays are in opposite positions.

The charge rate of one battery is selectable by ground command independent of the charge rate selected for the other battery. An overtemperature trip circuit is included to turn off battery charging if the temperature of either of its associated battery packs reaches 95 ±5°F. The battery thermal switches are connected in parallel and closure of either switch results in a trip command pulse to the K1 relay driver. If relay K2 is in the high charge rate or upper position, relay K1 will be transferred to the lower position. If relay K2 is in the low-charge rate or lower position, an overtemperature trip signal will drive relay K1 into the upper position. In both cases charging will turn off. When the battery pack temperature decreases by approximately 10°F, the thermostatic switches will open again, an onboard automatic reset command pulse will return relay K1 to its previous position, and charging will be resumed. Charging can also be restored after a trip by ground command to relay K1.

When the essential bus voltage is maintained above 28 volts, the discharge controllers are in a stand-by mode. When the solar panel cannot provide sufficient current to power the spacecraft loads by itself, the bus voltage will decrease. Either the primary or redundant discharge controller (whichever had been selected by ground command) comes on line automatically at 27.80 ±0.065 volts. The 0.1 ohm resistors in series with each regulator force load current sharing between the two batteries. These resistors cause the bus voltage to decrease as a function of load current although the regulator output voltage is maintained at 27.80 ±0.065 volts by the regulator feedback loop.

The maximum load will be 3 amperes per regulator during launch, resulting in an output voltage downstream of the 0.1 ohm resistor of 27.80 - 0.30 = 27.50 volts. At this load current, the minimum required drop across the regulator is approximately 0.6 volts. The output voltage will continue to be regulated as long as the battery voltage remains above 27.50 + 0.6 = 28.1 volts or 1.171 volts per cell. If the batteries discharge beyond this point the regulator will saturate and the output voltage will decrease in accordance with the decrease in battery voltage. When the battery voltage reaches the UV/OL trip point of 27.55 volts or 1.148 volts/cell the regulator output voltage will drop to 27.55 - 0.60 = 26.95 volts.

If the primary discharge regulator of either controller fails, the redundant regulator associated with that controller can be switched in to replace it. Should a battery fail completely, the remaining battery and its controller can support the entire load requirement within the ampere-hour energy limitations of the one remaining battery. Each discharge regulator is capable of providing a maximum of 11 amperes continuously. In the example cited above, a single regulator would regulate at 27.80 - 0.6 = 27.2 volts at 6 amperes until the battery reached 27.2 plus 1.2 volts regulator drop for a total of 28.4 volts (1.183 volts/cell).

Two current sensors are incorporated into each controller to measure battery charge and discharge current (PCHG1I and PDIS1I respectively for battery 1; PCHG2I and PDIS2I respectively for battery 2).

3.8.2.6 Power Interface Unit. The Power Interface Unit (PIU) provides centralized switching and fuse protection for the propulsion heaters, probes heaters, and science instruments. It also turns on and off a common probe checkout Bus and provides relay drive power to probe relays to transfer to internal power prior to probe release.

Magnetic latching relays are used where load switching is required. Each latching relay is driven by its own hybrid relay driver circuit. In those cases where flight critical functions are controlled, redundant relays are connected together to ensure reliable switching. The status of all relays is monitored with bilevel telemetry signals.

All fuses are connected in a parallel redundant configuration. The series resistor in the redundant leg is sized large enough to force approximately 90% of the current through the primary fuse, yet small enough to ensure a minimum bus voltage of 25.2 volts to the loads, if the primary fuse fails.

All bus and Probe heaters are on the essential bus and are fused in the PIU. The four small radial jet and tank heaters are on continuously; they cannot be commanded OFF. The tank heaters are redundant. A latching relay selects either the primary or secondary tank heater group by ground command (HTT19 or HTTA9; HTT29 or HTTB9). No single point failure will prevent one of the two heater groups from being turned ON.

The probe checkout relay applies Bus checkout power to all four probes simultaneously. However, only one probe should be turned on at any one time, since the modulation scheme for each probe's telemetry bit stream has been designed for only one-probe-at-a-time operation. Probe checkout power is connected to the science bus output of the UV/OL and a short circuit in a probe during checkout will trip the science bus only. Although probe checkout is obtained from the science bus, the science current sensor (PSCICI) reads only bus instrument current.

3.8.2.7 Undervoltage/Overload Switch. The Undervoltage/Overload switch unit (UV/OL) provides power to the four spacecraft load buses. A 0-18 ampere, 50 mv resistive shunt is externally mounted on the UV/OL unit. It measures the load current (PBUS11 - Spacecraft Loads Current) provided to all four power buses. Three of these buses pass through magnetic latching relay contacts which are tripped open if the spacecraft load current is excessively high or if either battery terminal is too low.

The essential bus loads cannot be switched off because they are vital to the survival of the spacecraft. The other loads can be tripped off if either battery terminal voltage drops to 27.55 ±0.15 volts or the spacecraft load current exceeds 16.5 ±0.75 amperes.

A trip signal is generated to turn off science loads 75 milliseconds after a fault condition occurs (refer to Table 3.8.2.7-1). If removal of the science loads reduces spacecraft loads to a value less than 16.5 amperes within 50 milliseconds, the tripping sequence is inhibited. If spacecraft loads are still above 16.5 amperes, another trip signal is generated 125 milliseconds after the fault occurs. This will trip off the switched loads bus also. If the current still does not recover after trip of the switched loads bus, the RF transmitter bus is also tripped off by a signal generated 175 milliseconds after the fault occurs.

The same trip signals described above are also generated when the voltage of either battery decreases to 27.55 ±0.15 volts. When the battery voltage rises above 28.3 volts after a undervoltage trip, as a result of a transition from battery discharge status to battery charge status, the tripping sequence is inhibited. However, it normally requires several seconds to recover to this voltage. Since the three trip signals are generated within 100 milliseconds of each other, a battery undervoltage trip will always switch off all three non-essential power buses. After the battery voltage rises to 28.3

volts, a "UV/OL relay reset" ground command (PSP11 or PSPA1) will reset all three buses.

The three relays, K1, K2 and K3 which provide the bus protection described above, are all reset by the "UV/OL relay reset" command. Relay K4 provides an override capability that can be utilized, at the discretion of ground control, to bypass the trip function and remove the protection feature (PSP1Ø or PSPAØ).

Once the "UV/OL relay reset" command is sent, only the science bus can be powered down again by ground command (INS1Ø or INSAØ) unless an overcurrent or undervoltage condition occurs.

It is possible to power up temporarily after a trip, in order to make a quick spacecraft telemetry assessment, and then power down again in the following manner. First, the override (not protected) feature via relay K4 must be enabled (PSP1Ø or PSPAØ). Then spacecraft loads are turned on, a few major frames of TM data are recorded, and then K4 is disabled again (PSP19 or PSPA9). The override feature is also used if a failure occurs in the trip circuitry (trips when it should not), or if any one of the two batteries fails.

A capacitor precharge circuit is incorporated into the UV/OL switch. The purpose of this circuit is to limit the magnitude of current inrush to the input capacitors of all the loads on the large probe checkout and switched loads buses through two ohm series resistors. This prevents large switching voltage transients when these buses are connected to the essential bus through relays K1 and K2.

A relatively large 390-ohm resistor is in series with the switched loads bus to limit inrush current to less than 0.1 ampere when this bus is powered up. However, a small 3-ohm resistor is used in the science precharge bus. The reason for such a small value is due to nature of the probe power loads. Figure 3.8.2.7-1 shows how the Bus power is applied to the large probe for checkout.

In order to precharge the probe science instrument input filters, it is necessary to first turn on the CDU and a number of other small loads (approximately 300 milliamperes are required) through the precharge switch, isolation diode, and 3-ohm isolation resistor. In order to insure a minimum voltage of 25.2 volts in the probes at all times, the isolation resistance must be kept low. After the CDU is turned on, the probe science relays are commanded on; this applies bus voltage to the input power terminals of all of the probe instruments and precharges their respective input capacitors. The science bus is then turned on with a UV/OL relays reset command, the precharge circuit is turned off, and probe checkout is initiated.

Two reverse connected diodes are wired across each of the three switchable buses. They prevent potentially dangerous negative bus voltages which could be generated by turning off loads with large inductive elements in their input filters.

3.8.2.8 Engineering Instrumentation. The power subsystem telemetry signals are explained in detail in Appendix A.

The temperature sensors on the solar panel are precision wide range platinum resistors. Thermistors are used on the battery packs.

The current sensor uses a dual 50 mv current shunt and a hybrid differential amplifier with a gain of 102.4 to develop a full scale telemetry signal of 5.12 volts (0.05 x 102.4 = 5.12). The current sensor is connected in series with the positive buses. It is powered directly from the bus where the measurement is made.

Four of the current sensors are built into the charge/discharge controllers. One of the current sensors is an integral part of the UV/OL unit. The other three sensors are packaged as individual units. Further details about these telemetry signals are located in Appendix A.

3.8.3 Operations Description. This section describes how to power manage the Multiprobe spacecraft. It explains how to configure the power subsystem properly by ground command and how to assess its performance from the available telemetry signals.

3.8.3.1 Power Bus Voltage Operating Ranges. Figure 3.8.3.1-1 describes the power bus operating voltage ranges during various mission operating modes. The nominal power bus voltage is 28.0 volts. During those operational phases when the solar panel is fully illuminated, the actual bus voltage will be higher than this value. During launch and possibly during Large and Small Probe release, when the discharge controllers are active, the bus voltage will be under 28.0 volts.

The solar panel is sized to provide power somewhat in excess of that which is required by the loads and the bus voltage is driven upward until clamped by the bus limiters. Bus limiters 1, 3, and 4 have set points at 29.5 volts and bus limiters 2 and 5 have set points at 30.0 volts. During most mission phases there is a surplus of solar panel power. Bus limiters 1, 3, and 4 together are capable of absorbing over 7 amperes of excess panel capacity. The other two limiters will not become active unless a large number of spacecraft loads are turned off or the shelves are cold.

Voltage limiters 2 and 5 are connected to load heater resistors bonded to the rear of the equipment shelves. The thermostatic switch associated with voltage limiter 5 will be activated near Earth and its set point will be lowered to 28.5 volts. The first excess 33 watts of panel capacity will be forced into the battery shelf heaters and next 33 watts will be dissipated in the rf shelf heaters. If the thermostatic switches associated with voltage limiter 2 are activated due to a cold rf shelf, its set point will be lowered to 29.0 volts and the first incremental excess of 33 watts of panel capacity will once again be forced into the battery shelf heaters and the next 33 watts will be dissipated in rf shelf heaters. Even if one of the above two limiters fail, the first 33 watts always goes into the battery shelves.

When the solar panel output slowly decreases (during probe pre-release maneuvers, for instance), the current provided by the solar panel slowly decreases and the power bus voltage also decreases. When the bus voltage drops to 27.80 ±0.065 volts, the discharge controller comes on automatically to help share the load. The discharge controller output is regulated very close to 27.80 volts even at high loads. There are 0.1 ohm resistors connected between each regulator output and the power bus to force accurate load share between the two regulators. Since the highest battery load will be approximately 3 amperes per battery (during launch), the lowest bus voltage during eclipse will be 27.80 -(0.1) (0.3)=27.50 volts.

The Multiprobe battery loads are relatively low and the voltage bus limiters 2 and 5 will probably never come on at their higher set points. This tends to restrict the power bus voltage range to 27.5 -29.6 volts. Harness drops will reduce this voltage somewhat but the lowest voltage at any load will not be lower than 27.3 volts.

3.8.3.2 Energy Balance Maintenance. The spacecraft must be powered managed to stay in a suitable energy balance situation at all times. During most of the mission, the spacecraft will be in full illumination and the sun line will be near 90 degrees with respect to the spin axis. During this time, the spacecraft loads must not exceed the solar panel capability for any appreciable period of time. The batteries can supplement the solar panel during short transition periods, but a continuous negative energy situation cannot be tolerated.

The spacecraft energy balance condition is best assessed with the current sensors. A simplified diagram of the power sources, loads and current sensor measurements is shown in Figure 3.8.3.2-1. All power sources are shown on the left and all power loads are on the right.

The current provided by the main array for spacecraft load use is measured by the solar panel current sensor. Battery charge current is provided by the main array, plus the boost charge arrays, and is measured by the two battery charge current sensors. If battery charging is turned off or reduced by switching from high rate to low rate, the solar panel current sensor telemetry signal will increase by the same amount as the decrease in charge current. The solar panel current that is utilized by the loads, plus the current supplied by the batteries when they ar in a discharge state, is measured by the spacecraft load current sensor. The excess current that is not needed is shunted off by the limiters and is measured in the limiter current sensor.

Total Main Array current is the sum of $I_{SP} + I_{CH1} + I_{CH2}$ (refer to Figure 3.8.3.2-1) Solar Panel Current (I_{SP}) measures solar panel current supplied to the spacecraft loads. It measures total main array current only if battery charging is commanded off.

Full illumination conditions can be defined by a current equation that shows the power sources on the left and the loads on the right: $I_{SP} + I_{CH1} + I_{CH2} = I_{SCL} + I_{BL}$ (Batteries charging)

where

I_{SP} = solar panel current

I_{SCL} = spacecraft loads current

I_{BL} = bus limiter current

I_{CH1} and I_{CH2} = telemetered battery 1 and battery 2 charge currents

During launch, all spacecraft loads are supported by the batteries through the discharge controllers. The battery currents are measured by the two battery discharge current sensors. The spacecraft load current is again measured by the spacecraft load current sensor. However, the small shunt current loss in each discharge controller is not measured directly. Figure 3.8.3.2-2 describes this shunt current loss as a function of load current. The bus limiters, of course, are not active during eclipse. Each bus limiter draws only 5 milliamperes of standby current. Since the bus limiter current sensor full scale range is 0 to 12 amperes, or 47 milliamperes per telemetry bit, the telemetry signal will be very small. The eclipse situation can be summarized by the current equation:

$$I_{BD1} + I_{BD2} = I_{SCL} + I_{BL} + I_{SH1} + I_{SH2}$$

where

I_{BD1} and I_{BD2} = telemetered battery 1 and battery 2 discharge currents

I_{SCL} = spacecraft load current

I_{BL} = bus limiter current (approximately 25 ma)

I_{SH1} and I_{SH2} = discharge controller shunt currents as determined from Figure 3.8.3.2-2

There will be short time periods when the solar panel and batteries must share the load. This includes launch, Small Probe release, and possibly Large Probe release. When the spacecraft spin axis moves away from being normal to the sun line-of-sight, the available solar panel current decreases and the bus limiter current also decreases by a corresponding amount and then becomes 5 milliamperes/limiter standby current. After the bus voltage drops to 27.80 volts, the discharge controllers become active. The charge current will then by-pass the batteries and flow directly into the discharge controllers through the battery discharge current sensors. As the solar panel current continues to decrease, the batteries will then start to discharge. The current equation for this situation is somewhat more complex than the two preceding conditions. Once again, all power sources are on the left and the loads are on the right:

$$I_{SP} + I_{TBD1} + I_{TBD2} = I_{SCL} + I_{BL} + I_{SH1} + I_{SH2}$$

where

I_{SP} = solar panel current

I_{TBD1} = True battery 1 discharge current = $I_{BD1} - I_{CH1}$

I_{TBD2} = True battery 2 discharge current = $I_{BD2} - I_{CH2}$

I_{SCL} = spacecraft load current

I_{BL} = bus limiter current (approximately 25 ma)

I_{SH1} and I_{SH2} = discharge controller shunt current as determined from Figure 3.8.3.2-2

It should be noted that when loads are being shared by the solar panel and batteries, the <u>true</u> battery discharge currents are $I_{BD1} - I_{CH1}$ and $I_{BD2} - I_{CH2}$: During launch, of course, the charge current sensors read zero and I_{BD1} and I_{BD2} indicate the true battery discharge current directly.

The discharge controller shunt loss, shown in Figure 3.8.3.2-2 represents the shunt current required when the battery voltage is high enough to maintain the regulator in an active regulator mode. When the battery voltage drops to a voltage level where the series pass regulator transistor drop gets too low, the latter goes into a saturated non-regulating mode and the output voltage starts to decrease. In the saturated mode, the drive circuitry is attempting to maintain regulation by delivering its maximum drive current capability to the series pass transistor. This value is approximately 230 milliamperes. Therefore, the shunt loss of the regulator will sharply increase from the small values shown in Figure 3.8.3.2-2 to approximately 230 milliamperes when the controllers go out of regulation. Under normal operating conditions, it is not anticipated that the battery voltage levels will drop down to levels that result in saturated mode operation. This would occur only under failure mode conditions.

3.8.3.3 Solar Panel Performance as Function of Solar Constant. In order to plan power operations, it is very useful to know what the available current will be at the nominal 28.0 volt bus voltage for all solar constants that will be encountered during the Multiprobe mission. Figure 3.8.3.3-1 shows plots of solar panel current at 28 volts as a function of solar constant. The lower curve is a worst case predict that assumes a massive solar flare will occur. The upper curve is a maximum predict that assumes that no radiation damage occurs and that the solar cells will perform at their maximum potential.

3.8.3.4 Battery Usage and Charging. During most of the mission, the batteries will be on trickle charge. High rate charging will be needed only before and after probe release sequences.

Section 3.8.2.5 describes how the battery charger operates. The charge current available during the various mission times is a function of a number of factors. This can be most easily explained by the use of battery boost charge array voltage/current curves and load lines for various critical mission times (Figure 3.8.3.4-1).

During high rate charge the load line operating region is always above the knee or on the constant current portion of the curve. Therefore, the charge rate is a direct function of the solar constant. It will vary from 0.17

amperes (during Small Probe separation) to 0.7 amperes near Venus.

During low rate charging the load lines intersect the curves beyond the knee of the curve. The charge rate will vary between 110 and 170 ma when the bus voltage is at 29.5 volts and from 80 to 140 ma at a bus voltage of 28.0 volts.

The trickle or low charge rates quoted above assume that the battery is fully charged or near full charge and has a terminal voltage of approximately 34 volts (1.416 volts/cell). When a partially discharged battery is initially placed on charge, its voltage will be somewhat lower by approximately 2 or 3 volts. This moves the abscissa intercept of the load lines to the left and increases the initial charge current to a value that is 40 to 60 ma higher. The trickle charge rate will then slowly decrease as the battery reaches full charge. Charge current increases by approximately 20 ma for each 1 volt reduction in battery terminal voltage or 1 volt increase in power bus voltage.

Battery charging will be commanded to low rate charge at launch and remain in this configuration approximately 95 days. Approximately 1 day before the battery is needed for Large or Small Probe release, high rate charging should be commanded on for approximately 4 hours. This will maximize the capacity and battery voltage for the probe release sequences. Recharge of the batteries after probe release sequences should also be performed at high rate.

The maximum battery DOD will occur during Small Probe release. Battery discharge current at this time is a function of sun angle and the spacecraft S-band transmitter load configuration. A high sun angle (near 26°) and low power (10 watts) S-band transmitter output results in a relatively low battery discharge current (or possibly zero discharge current) whereas a low sun angle and high power (20 watts) S-band transmitter output results in a much larger discharge current. High power S-band operation must be time limited to prevent battery DOD in excess of 60 percent.

Battery charging will normally never be turned off. As explained in Section 3.8.2.5 battery charging is turned off when relays K1 and K2 are in opposite positions. If it is necessary to turn off battery charging for some reason, the preferred relay states for charging turnoff are relay K1 high and K2 low. The reason is as follows: If, instead, relay K2 was left in the high state, and relay K1 was left in the low state, a battery overtemperature condition followed by a battery cool down would generate a reset signal to relay K1 which would transfer the latter to a high position and high rate charging would start automatically. If, on the other hand, charging is turned off in the preferred manner, a battery overtemperature condition followed by a cool down would result in a reset signal to K1 which would transfer the latter to a low position and low rate charging would start automatically. Although, it is extremely unlikely that turning off battery charging would be followed by actuation of the overtemperature switch, it is preferable in this case that low rate rather than high rate charging be turned on. In any case, if charging comes on automatically as a result of a reset signal, the overtemperature circuit will turn charging off again if the batteries get too hot. The overtemperature switch and its associated circuit would continue to automatically turn battery charging on and off and, thus, protect the batteries from excessive temperatures.

The solar panel charge strings are spaced approximately 36 degrees apart on the cylindrical substrate, as explained in Section 3.8.2.1. This results in approximately a 6 percent ripple of the current over the constant current portion of the V/I curve. At high charge rates this ripple current will be seen on the charge current telemetry signals. Low charge rate operation is performed below the knee of the V/I curve. Since the open circuit voltage of a solar cell is relatively insensitive to solar illumination levels, there will be a much lower charge current ripple during low rate charge.

To get an accurate measurement of charge current, approximately 10 measurements should be averaged.

3.8.3.5 Use of Precharge Circuit. As explained in 3.8.2.7, a precharge circuit is incorporated into the Bus undervoltage/ overload unit to slowly precharge large capacitors on the Large Probe checkout and switched load buses in order to minimize inrush currents and prevent switching transient disturbances to the other spacecraft loads.

The precharge circuit should be used during Large Probe checkouts to precharge the input filter capacitors of some of the Large Probe instruments. Precharging of Bus and Small Probe instruments is not necessary. The command sequence to accomplish Large Probe power turn-on, with initial precharge, is as follows:

- UV/OL relays reset
- Power system protection ON
- All science OFF
- Probe checkout power ON
- Precharge ON
- LP Command/data unit ON
- Science power primary relay ON
- UV/OL relays reset
- Precharge OFF

The precharge circuit should be used as a first step in powering up the switched loads bus again after an undervoltage or overcurrent fault has resulted in a trip of this bus. All of the loads on the switched loads bus (with one exception) are turned on and off by electronic latch circuits. Only the star sensor is turned on and off with a mechanical latching relay. Therefore, if a UV/OL trip occurs, the star sensor load will still be on the bus after it is reactivated. When the precharge circuit is turned on, the star sensor will draw a continuous current of approximately 25 milliamperes through the 390 ohm isolation resistor. This results in a switched loads bus voltage of only 16 to 18 volts. Fortunately at this low voltage, star sensor OFF command circuitry still functions. After sending a "Precharge ON" command, both the star sensor channels must be commanded off to allow the switched loads bus to be precharged to approximately 28 volts before the "UV/OL relay reset" or "Power system protection OFF" command is sent.

The precharge circuit can also be used to verify that there are no short circuit faults on the probe checkout buses before the probe checkouts are performed. The probe checkout bus goes to all four probes through IPD's, a large number of connectors, and long harness runs. These buses are not protected by fuses. It is possible that launch vibrations can induce a short circuit in one of the probe checkout buses. Therefore, prior to initiation of probe checkouts, it would be prudent to use the precharge circuit to verify that there are no short circuits on any of the four probe checkout buses. This can be accomplished in the following manner: Verify that UV/OL Protection is ON (PSPROS is in 1 state) and Science Bus Reset Relay (PSCBUS) is in 0 state (i.e., all science OFF). Send command to precharge circuit to turn it on (PCG19 or PCGA9) and verify that PRCHGS goes to 1 state. Then send command probe checkout power ON (PCO19 or PCOA9), verify that precharge circuit stays on, and that there is no increase in the spacecraft loads current (PBUSLI). A short circuit on any of the four probe checkout buses would turn the precharge circuit off. A partial fault condition would result in an increase in the reading of the spacecraft loads current. The fault current would be limited to 1 ampere by the precharge current limited switch. If a fault condition of this type is detected, the precharge circuit should be turned off immediately.

The precharge circuit can service only one probe at a time (Reference: Paragraph 1.5.18).

3.8.3.6 Power Bus Fault Protection and UV/OL Trip Recovery. The spacecraft has a number of features that protect it from power bus faults. Potential fault conditions are overvoltage, undervoltage and overcurrent.

The Bus voltage limiters provide overvoltage protection by absorbing excess solar capability and restricting transient overshoot voltages to values less than 31 volts.

Each spacecraft load has protective fuses and most spacecraft units also have electronic current limiting to protect against overcurrent conditions. It is almost impossible to protect against harness shorts, but internal unit short circuits will be effectively isolated by the fuses and current limit circuits.

It is possible for the spacecraft to go out of energy balance if the spacecraft spin axis drifts off the sun line normal, if excessive loads are commanded on inadvertently by equipment faults or mission operations errors, or a spacecraft unit develops a fault current that is of insufficient magnitude to open a fuse. The net result would be that batteries would start to discharge at a time when they normally should be on charge. These operating conditions could deplete the battery and threaten the spacecraft with marginally low voltage conditions. To remedy these battery undervoltage and/or overcurrent conditions, the UV/OL switch will trip off science, switched load, and HP transmitter bus loads as explained in Section 3.8.2.7.

In most instances, an analysis of the telemetry data, prior to a UV/OL trip, will reveal the nature of the difficulty and thereby suggest corrective action. However, if a trip results in sudden loss of the downlink carrier and/or digital telemetry signals with no clues to the nature of the problem, it will be necessary to make an assessment of the spacecraft operating conditions to formulate corrective action. In this case, it would be prudent to power up the switched loads and HP transmitter buses temporarily to get a few major frames of data and then power down again to the minimum essential bus loads while the data is being evaluated.

When it is desired to power up the buses temporarily after a trip, it should be accomplished by commanding to an override or "power system protecti[illegible] off" mode. Execution of the "UV/OL relay re[illegible] command is undesirable in this case, since the switched load and RF transmitter reset relays, K2 and K3, can subsequently be powered down only by another undervoltage or overcurrent trip signal.

The command sequence to temporarily power up the spacecraft after a UV/OL trip is as follows:

- Precharge on (wait one second)
- PSI* off and PSI2* off (star sensor off commands)
- Power system protection off (override on)
- Precharge off
- Commands to restore RF downlink and telemetry
- Power system protection on (override off) to power down again.

After corrective action has been implemented to remove the fault, the power buses should be commanded back into the "protected" mode with relay K4 off and K1, K2 and K3 reset relay enabled by the "UV/OL relay reset" command.

Almost all non-essential spacecra[illegible] science loads are turned on with electron[illegible]ch circuits. Removal of bus power t[illegible]se [illegible]ds also turns off these latches. Aft[illegible] restored to their respective buses, i[illegible] necessary to send pulse turn-on comm[illegible] turn them on again. There are only two no[illegible]ential power bus units that do not have elect[illegible]nic latch circuits. As explained above, one of them is the star sensor. The other is the transponder exciter. They are both turned on by mechanical latching relays. When power is restored to their respective power buses after a trip, they will turn on again. The star sensor can be turned off through the precharge circuit as explained above. The transponder exciter can be turned off (if it is necessary to do so) only after RF transmitter bus power is restored. However, it does not interfere with the normal operation of the precharge circuits on the science and switched load buses.

A battery undervoltage trip will remove <u>all 3</u> non-essential power buses even if the battery starts to charge after the Science and/or Switched Loads buses are tripped off. Battery voltage does not rise fast enough to interrupt the trip sequence. An overcurrent condition that does not reduce battery voltage below 27.55 volts will be interrupted when load removal drops total spacecraft loads current under 16.25 amperes; this could result in removal of 1, 2 or 3 non-essential power buses (Reference: Paragraph 1.5.18).

The all science OFF command will be ineffective whenever the spacecraft is operating with the power system protection OFF. Thus, in this configuration, instruments must be turned OFF by utilizing individual OFF commands (Reference: Paragraph 1.5.18).

3.8.3.7 <u>Use of Bus Voltage Limiters</u>. The five voltage limiters will be enabled prior to launch and they should stay enabled throughout the mission. A voltage limiter should be disabled only if it is defective. Each bus limiter is capable of absorbing 2.35 amperes or 11.75 amperes total for the five limiters. They will easily absorb all excess solar panel capacity at any time in the mission, even if a UV/OL trip occurs.

3.8.3.8 <u>Propulsion Heater Performance Evaluation</u>. The Multiprobe has the following complement of jet thrusters: four radial, one aft axial and one forward axial. All of the radial line heaters and the four radial jet thruster heaters are on continuously. The axial jet thruster heaters and associated line heaters can be commanded on and off.

All six jet thrusters have temperature sensors; the axial lines also have temperature sensors. However, the long radial lines do not have temperature sensors. Radial line 1&2 heater status (VJ12HS) is monitored by a small series 12-ohm resistor with a scale factor of 83.3 ma/volt. At 28 volts, this heater requires 51.6 ma and results in a telemetry signal of 0.62 volts (31 data units). Radial line 3&4 heater status (VJ34HS) is also monitored by a small 12-ohm resistor with a scale factor of 83.3 ma per volt that also requires 51.6 ma at 28 volts. Improper operation of the radial line heaters will be denoted by a sharp change in the TM signal.

The propulsion tank heater switch in the PIU controls operation of not only the tank heaters themselves but also a large number of associated heaters for propellant, fill and drain, and gas lines; fill and drain valves; latch valves; and a pressure transducer. The propulsion tank heaters and their associated heaters are all upstream of the latch valves. All of these heaters are redundant. The PIU switch selects either the primary or secondary group of heaters (HTT19 or HTTA9; HTT29 or HTTB9). No single point failure will prevent one of the two heaters from being commanded on. Either the primary or secondary group is on continuously.

The two tanks and their propellant lines, have temperature sensors to monitor the operation of their heaters. At launch, the primary heaters will be commanded on. If any of the tank or propellant line temperature sensors indicates heater failure, the secondary group of heaters should be switched on and the primary group should be switched off.

There is not a sufficient number of temperature sensors to monitor all of the other small heaters in parallel with the tank and propellant line heaters. The resolution of the 0 to 18 ampere spacecraft loads current sensor is inadequate to verify their proper operation. Therefore, two additional current sensor measurements, with good low current resolution, were added to monitor two primary tank heater subgroups. The following group of heaters and their nominal current at 28 volts is monitored by a 16.5 ohm current sensor (VLVPHS - Latch Valve Primary Heater Status):

Latch valve 1A	10.46 ma
Latch valve 2A	10.46 ma
Pressure transducer	10.46 ma
Fill and drain line 1	8.20 ma
Fill and drain line 2	8.20 ma
	47.78 ma

This TM channel will read 0.788 volts at 28 volts. The scale factor is 60.61 ma/volt or 1.21 ma per data unit. Failure of any one of the above heaters will result in a minimum change of 6 or 7 data units.

The second group of primary heaters and their nominal current at 28 volts is (VFDVHS - Fill and Drain Valve Primary Heater Status):

Fill and drain valve 1	18.42 ma
Fill and drain valve 2	18.42 ma
Fill and drain valve 3	18.42 ma
Fill and drain 3 gas line	19.36 ma
	74.62 ma

This TM channel has an 8 ohm current sensor that develops a 0.597 volt signal when the voltage is 28 volts. The scale factor is 125.1 ma/volt or 2.50 ma per data unit. Failure of one of the above heaters will result in a minimum change of 7 or 8 data units.

The telemetry values of these 4 propulsion heaters will fluctuate slightly as the bus voltage fluctuates. Also the propulsion heaters and the small current sensors each have a 5% tolerance. In addition, heater resistance increases by approximately 10% when the propulsion heater temperatures are near their maximum levels. Therefore, the actual measured data deviates slightly from the above nominal values. Shown below are actual measured values at a bus voltage of 29.5 volts at approximately +68°F:

Latch valve heater group	48.9 ma
Fill and drain valve heater group	75.0 ma
R1/R2 line heaters	51.6 ma
R3/R4 line heaters	53.3 ma

3.8.3.9 Bus/Probe IPD Power Interfaces. Each probe has two relays to transfer from checkout power to internal battery power prior to probe separation. Each relay has a dedicated relay driver circuit in the bus PIU. Actuation of either one or both relays will accomplish the desired transfer to internal power. The status of these eight relays is continuously monitored by Bus telemetry through the IPDs.

The Large Probe has two shelf heaters that are turned on and off by relays located in the Bus PIU. Each Small Probe also has a shelf heater that is controlled by relays in the Bus PIU.

The temperature sensors for each probe battery are also hardwired to Bus telemetry for continuous monitoring during cruise.

Each probe battery has a heater that is actuated by a relay. This relay should be off during cruise - it will be actuated by the probe pre-timeout signal approximately 3 hours before Venus atmosphere entry. The 4 battery relay on/off signals are provided across the 4 IPDs for continuous monitoring during cruise. It is a monitoring function only - there is no means of actuating the battery relays from the Bus.

3.8.3.10 Failure Modes, Redundancy and Corrective Action. The power subsystem has redundant voltage limiters, discharge regulators, and battery cells which allow normal or near normal spacecraft operation to continue in case of failure. The UV/OL protective circuits have an override mode that allows by-passing of the reset relays. The propulsion tank heater circuits are redundant and their operation cannot be compromised by any single point failure. A summary of potential failure modes and corrective action is shown in Table 3.8.3.10-1.

3.8.4 Power Subsystem Command Response. Table 3.8.4-1 explains the function of each power subsystem command and how the associated telemetry signals measure the response to these commands.

During all mission phases (with the exception of Small Probe Release), there will be excess solar panel capacity, that forces current through the voltage limiter load resistors. Whenever this is the case, an increase in solar panel current results in an increase of bus limiter current by the same amount. Also, when a load is turned off, as reflected in a decrease in the spacecraft load current, the bus limiter current must increase by this same amount.

TABLE 3.8.2.7-1

RECOGNITION OF UV/OL TRIP

Time of Occurrence After Fault Appears	Subsystem Response	Ground Recognition	
		TM Mnemonic	TM & Response
75 Msec.	Science Bus Relay to OFF; Power to science loads is cutoff, science loads reset to OFF.	PSCBUS	Science Bus Relay Status = 0 (OFF)
		PSCICI	Science Current decreases to zero.
		PBUSLI	S/C Loads Current decreases by same amount as PSCICI.
		PLIMTI	Bus Voltage Limiter current likely increases by same as PSCICI decreased.
125 Msec.	Switched Loads Bus relay to OFF; all switched loads reset to OFF, except the star sensor.		Loss of downlink telemetry data.
175 Msec.	Xmtr Bus Relay to OFF; all RF Xmtr Bus loads reset to OFF, except Xponder-exciter.		Loss of downlink carrier.

TABLE 3.8.3.10-1

FAILURE MODES AND CORRECTIVE ACTIONS

Failure Mode	Corrective Action/Comments
Bus Voltage Limiter fails	Send disabled command to remove from power bus; 1 limiter is redundant.
Discharge Controller fails	Each battery has redundant discharge regulator - select redundant unit by command.
Current sensor fails	Current sensor elements consist of 2 parallel power resistors (shunts) to prevent open in power bus - if sensor electronics fails, unknown current can be derived from other current sensor measurements with aid of equations in Section 3.8.3.2.
Charge Controller Relay K1 fails in high state	By means of relay K2 can command to high charge and off only - if battery gets too hot in high charge state, must periodically command on and off by ground or memory command.
Charge Controller Relay K1 fails in low state	By means of relay K2 can command to low charge or off only.
Charge Controller Relay K2 fails in high state	By means of relay K1 can command to high charge and off only - if battery gets too hot in high charge state, must periodically command on and off by ground or memory command.
Charge controller Relay K2 fails in low state	By means of relay K1 can command to low charge or off only.
Overtemperature Circuit inadvertently turns off Relay K1	Relay K1 can be commanded back to previous position by ground command.
UV/OL trips off inadvertently	Bypass UV/OL reset relays by turning on relay K4 with "Power Subsystem Protection Off" command.
Precharge Circuit fails	If UV/OL trip occurs and loads unlatch after "UV/OL relays reset" command, send pulse commands to turn them on again.
Radial Jet Heater 1, 2, 3, or 4 fails.	Redundant radial jets available if defective heater results in excessively cold jet.

TABLE 3.8.3.10-1 (Continued)

Failure Mode	Corrective Action/Comments
Cannot turn on or turn off axial jet heater	Use redundant axial jet with suitable temperature as verified by temperature sensor.
Cannot turn forward axial jet heater on or off	If forward axial jet temperature not suitable, use redundant aft axial jet.
Open cell in a battery pack (very low probability event)	Loss of complete battery - turn off charge to failed battery.
Shorted cell in a battery pack	Battery will continue to operate with one or two shorted cells with reduced capacity.
One or more heaters of primary tank group fails	Transfer to secondary tank heater group.
Cannot turn on large or small probe heater	Probe temperature near Earth may fall below minimum non-operating specification levels.
Cannot turn off large or small probe heater	Minimize operation time during probe checkout. Heaters will turn off after IFD separation.
Probe internal power transfer relay 1 or relay 2 fails	Relays and drive circuits redundant. Actuation of either relay will isolate checkout bus and transfer to internal battery.
Cannot turn on probe checkout bus	Brief probe checkouts and commands to timers must be performed on internal battery power.
Cannot turn off probe checkout bus	All four probe timer circuits will have power applied continuously resulting in small continuous parasitic load.
R1 and R2 Line Heater Status TM Value not nominal	Radial 1 and Radial 2 Line Heaters defective; use Radial 3 and Radial 4 jets instead.
R3 and R4 Line Heater Status TM Value not nominal	Radial 3 and Radial 4 line heaters defective; use Radial 1 and Radial 2 jets instead.

TABLE 3.8.4-1

POWER SUBSYSTEM COMMAND RESPONSE

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
BAT10 BATA0	Battery 1 - Relay 1 Low Rate Charge	Commands battery 1 to lo charge rate if K2 in lo state; turns battery 1 charge off if K2 in hi state.	PB1R1S	Battery 1, Relay 1 Status goes to low state (="0")
			PCHG1I	Battery 1 Charge Current changes value to low charge rate level or to zero.
			PPAN1I	Solar Panel Current changes by same quantity as battery charge current but change is in opposite direction.
BAT19 BATA9	Battery 1 - Relay 1 Hi Rate Charge	Commands battery 1 to hi charge rate if K2 in hi state; turns battery 1 charge off if K2 in low state.	PB1R1S	Battery 1, Relay 1 Status goes to hi state (="1")
			PCHG1I	Battery 1 Charge Current changes value to high charge rate level or to zero.
			PPAN1I	Solar Panel Current changes by same quantity as battery charge current but change is in opposite direction.
BAT11 BATA1	Battery 1 Primary Discharge Regulator Select	Input of primary discharge regulator connected to Battery 1 and output to essential bus.	PREG1S	Primary/Redundant Discharge Regulator 1 Status goes to primary state (="1")
BAT12 BATA2	Battery 1 redundant Discharge Regulator Select	Input of redundant discharge regulator connected to Battery 1 and output to essential bus.	PREG1S	Primary/Redundant Discharge Regulator 1 Status goes to redundant state (="0").

TABLE 3.8.4-1 (Continued)

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
BAT13 BATA3	Battery 1 - Relay 2 Hi Rate Charge	Commands Battery 1 to hi Charge Rate if K1 in hi State; Turns Battery 1 charge off if K1 in lo state.	PB1R2S	Battery 1, Relay 2 Status goes to hi state (=1)
			PCHG1I	Battery 1 Charge Current changes value to hi charge rate Level or to zero.
			PPANLI	Solar Panel Current changes by same quantity as battery charge current, but change is in opposite direction.
BAT14 BATA4	Battery 1 - Relay 2 Low Rate Charge	Commands Battery 1 to lo charge rate if K1 in lo State; turns Battery 1 charge off if K1 in hi state.	PB1R2S	Battery 1, Relay 2 Status goes to lo state (=0)
			PCHG1I	Battery 1 Charge Current changes value to low charge rate level or to zero.
			PPANLI	Solar Panel Current changes by same quantity as battery charge current, but change is in opposite direction.
BAT2Ø BATBØ	Battery 2 - Relay 1 Low Rate Charge	Commands Battery 2 to low charge rate if K2 in low state; turns Battery 2 charge off if K2 in hi state.	PB2R1S	Battery 2, Relay 1 Status goes to lo State (=0)
			PCHG2I	Battery 2 Charge Current changes value to low charge rate level or to zero.
			PPANLI	Solar Panel Current changes by same quantity as battery charge current, but change is in opposite direction.
BAT29 BATB9	Battery 2 - Relay 1 Hi Rate Charge	Command Battery 2 to hi charge if K2 in hi state; turns Battery 2 charge off if K2 in low state.	PB2R1S	Battery 2, Relay 1 Status goes to hi state (=1)
			PCHG2I	Battery 2 Charge Current changes value to high charge rate level or to zero.
			PPANLI	Solar Panel Current changes by same quantity as battery charge current, but change is in opposite direction.

TABLE 3.8.4-1 (Continued)

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
BAT21 BATB1	Battery 2 Primary Discharge Regulator Select	Input of primary discharge regulator connected to Battery 2 and output to essential bus.	PREG2S	Primary/Redundant Discharge Regulator 2 Status goes to primary state (="1").
BAT22 BATB2	Battery 2 Redundnat Discharge Regulator Select	Input of redundant discharge regulator connected to Battery 2 and output to essential bus.	PREG2S	Primary/Redundant Discharge Regulator 2 Status goes to redundant state (="0")
BAT23 BATB3	Battery 2 - Relay 2 High Rate Charge	Command Battery 2 to hi charge if K1 in hi state, turns battery 2 charge off if K1 in lo state.	PB2R2S	Battery 2, Relay 2 Status goes to hi state (="1")
			PCHG2I	Battery 2 Charge Current changes value to high charge rate level or to zero.
			PPANLI	Solar Panel Current changes by same quantity as battery charge current, but change is in opposite direction.
BAT 24 BATB4	Battery 2, Relay 2 Lo Rate Charge	Commend Battery 2 to lo charge if K1 in lo state; turns battery 2 charge off if K1 in hi state	PB2RS	Battery 2, Relay 2 Status goes to lo state (="0")
			PCHG2I	Battery 2 charge current changes value to lo charge rate level or to zero
			PPANLI	Solar Panel Current changes by same quantity as battery charge current but change is in opposite direction.
PSP19 PSPA9	Power System Protection ON.	Commands relay K4 of UV/OL into OFF position.	PSPROS	Power System Protection ON/OFF goes to ON state (UV/OL Protection active) (="1").
PSP1Ø PSPAØ	Power System Protection OFF.	Commands relay K4 of UV/OL into ON position.	PSPROS	Power System Protection ON/OFF goes to OFF state ("0"); applies power to science, switched load and r.f. transmitter buses (UV/OL Protection overridden).
INS1Ø INSAØ	All Science OFF	Commands relay K1 of UV/OL into OFF position.	PSCBUS	Science Bus Reset Relay Status goes to OFF state (="0");power to science bus removed.
			PBUSLI	Spacecraft Loads Current will decrease.
			PSCICI	Science Current will decrease to zero.

TABLE 3.8.4-1 (Continued)

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
HTJ1Ø HTJAØ	Forward Axial Jet Heaters OFF.	Turns OFF Forward Axial Jet Heaters.	PHTFJS	Forward Axial Jet Heaters ON/OFF goes to OFF state (="0")
			VJET5T	Forward Axial Jet Temperature decreases.
HTJ29 HTJB9	Aft Axial Jet and Line Heaters ON	Turns ON Aft Axial Jet 6 Heaters and Lines	PHTAJS	Aft Axial Jet Heaters ON/OFF goes to OFF state (="1")
			VJET6T	Aft Axial Jet Temperature rises.
			PBUSI1	Spacecraft Loads Current sensor resolution inadequate to measure 42 ma current change.
HTJ2Ø HTJBØ	Aft Axial Jet and Line Heaters OFF	Turns OFF Aft Axial Jet 6 Heaters and Lines.	PHTAJS	Aft Axial Jet Heaters ON/OFF goes to OFF state (="0")
			VJET6T	Aft Axial Jet Temperature Decreases.
LIM19 LIMA9	Bus Limiters 1 and 2 Enable.	Latching relay connects bus limiters 1 and 2 to essential bus.	PLIM1S	Bus Limiter 1 Enable/Disable goes to enabled state (="1")
			PLIM2S	Bus Limiter 2 Enable/Disable goes to enabled (="1")
LIM1Ø LIMAØ	Bus Limiter 1 Disable.	Latching relay disconnects bus limiter 1 from essential bus	PLIM1S	Bus Limiter 1 Enable/Disable goes to disabled state (+"0")
LIM2Ø LIMBØ	Bus Limiter 2 Disable.	Latching relay disconnects bus limiter 2 from essential bus.	PLIM2S	Bus Limiter 2 Enable/Disable goes to disabled state (="0")

TABLE 3.8.4-1 (Continued)

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
HTL1Ø HTLAØ	Large Probe and Small Probe 1 Heaters OFF.	Removes power from Large Probe and Small Probe 1 heaters.	PLHTRS	Large Probe Heater ON/OFF goes to OFF state (="0")
			P1HTRS	Small Probe 1 Heater ON/OFF goes to OFF state (="0")
			PBUSLI	Spacecraft loads current decreases.
HTS19 HTSA9	Small Probe 1 Heater ON	Applies power to Small Probe 1 heater	P1HTRS	Small Probe 1 Heater ON/OFF goes to ON state (="1")
			PBUSLI	Spacecraft loads current increases by 0.09 amps.
HTS29 HTSB9	Small Probe 2 Heater ON	Applies power to Small Probe 2 heater	P2HTRS	Small Probe 2 Heater ON/OFF goes to ON state (="1")
			PBUSLI	Spacecraft loads current increases by 0.09 amps.
HTS39 HTSC9	Small Probe 3 Heater ON.	Applies power to Small Probe 3 heater	P3HTRS	Small Probe 3 Heater ON/OFF goes to ON state (="1")
			PBUSLI	Spacecraft loads current increases by 0.09 amps.
HTS2Ø HTSBØ	Small Probes 2 and 3 Heaters OFF	Removes power from Small Probes 2 and 3 heater	P2HTRS	Small Probe 2 Heater ON/OFF goes to OFF state (="0")
			P3HTRS	Small Probe 3 Heater ON/OFF goes to OFF state (="0")
			PBUSLI	Spacecraft Loads Current decreases.

TABLE 3.8.4-1 (Continued)

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
LIM39 LIMC9	Bus Limiter 3 and 4 Enable.	Latching relay connects bus limiters 3 and 4 to essential bus	PLIM3S	Bus Limiter 3 Enable/Disable goes to enabled state (="1")
			PLIM4S	Bus Limiter 4 Enable/Disable goes to enabled state (="1")
LIM3Ø LIMCØ	Bus Limiter 3 Disable.	Latching relay disconnects bus limiter 3 from essential bus.	PLIM3S	Bus Limiter 3 Enable/Disable goes to disabled state (="0")
LIM4Ø LIMDØ	Bus Limiter 4 Disable.	Latching relay disconnects bus limiter 4 from essential bus	PLIM4S	Bus Limiter 4 Enable/Disable goes to disabled state (="0")
LIM59 LIME9	Bus Limiter 5 Enable.	Latching relay connects bus limiter 5 to essential bus	PLIM5S	Bus Limiter 5 Enable/Disable goes to enabled state (="1")
LIM5Ø LIMEØ	Bus Limiter 5 Disable.	Latching relay disconnects bus limiter 5 from essential bus	PLIM5S	Bus Limiter 5 Enable/Disable goes to disabled state (="0")
PCO19 PCOA9	Probe Checkout Power ON	Applies bus checkout power to all 4 probes	PCHEKS	Probe Checkout Power ON/OFF goes to ON state (="1")
PCO1Ø PCOAØ	Probe Checkout Power OFF	Removes bus checkout power from all 4 probes	PCHEKS	Probe Checkout Power ON/OFF goes to OFF state (="0")
HTL19 HTLA9	Large Probe Heater ON.	Applies power to large probe heater.	PLHTRS	Large Probe Heaters ON/OFF goes to ON state (="1")
			PBUSLI	Spacecraft Loads Current increases by approximately 0.75 amperes.

TABLE 3.8.4-1 (Continued)

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
LPP19 LPPA9	Large Probe Internal Power ON	Applies 35 ms pulses to ON coils of Large Probe internal power relays 1 and 2.	PLPR1S	Large Probe Internal Power Relay 1 ON/OFF goes to ON state (="1")
			PLPR2S	Large Probe Internal Power Relay 2 ON/OFF goes to ON state (="1")
LPP1Ø LPPAØ	Large Probe Internal Power OFF	Applies 35 ms pulses to OFF coils of Large Probe internal power relays 1 and 2.	PLPR1S	Large Probe Internal Power Relay 1 ON/OFF goes to OFF state (="0")
			PLPR2S	Large Probe Internal Power Relay 2 ON/OFF goes to OFF state (="0")
SPP19 SPPA9	Small Probe 1 Internal Power ON	Applies 35 ms pulses to OFF coils of Small Probe 1 internal power relays 1 and 2.	P1PR1S	Small Probe Internal Power Relay 1 ON/OFF goes to ON state (="1")
			P1PR2S	Small Probe Internal Power Relay 2 ON/OFF goes to ON state (="1")
SPP1Ø SPPAØ	Small Probe 1 Internal Power OFF	Applies 35 ms pulses to OFF coils of Small Probe 1 internal power relays 1 and 2.	P1PR1S	Small Probe 1 Internal Power Relay 1 ON/OFF goes to OFF state (="0")
			P1PR2S	Small Probe Internal Power Relay 2 ON/OFF goes to OFF state (="0")
SPP29 SPPB9	Small Probe 2 Internal Power ON	Applies 35 ms pulses to ON coils of Small Probe 2 internal power relays 1 and 2.	P2PR1S	Small Probe 2 Internal Power Relay 1 ON/OFF goes to ON state (="1")
			P2PR2S	Small Probe 2 Internal Power Relay 2 ON/OFF goes to ON state (="1")
SPP2Ø SPPBØ	Small Probe 2 Internal Power OFF	Applies 3 ms pulses to OFF coils of Small Probe 2 internal power relays 1 and 2.	P2PR1S	Small Probe 2 Internal Power Relay 1 ON/OFF goes to OFF state (="0")
			P2PR2S	Small Probe 2 Internal Power Relay 2 ON/OFF goes to OFF state (="0")

TABLE 3.8.4-1 (Continued)

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
PSP11 PSPA1	UV/OL Relays Reset.	Commands Relays K1, K2 and K3 into ON position.	PSCBUS PLDBUS PRFBUS	Science Bus Reset Relay Status, Switched Loads Reset Relay Status, and Xmtr Bus Reset Relay Status signals all go to hi state (="1")
			PBUSLI	Spacecraft Loads Current will increase from last observed value if science bus & switched loads bus had tripped OFF.
PCG19 PCGA9	Precharge ON	Commands precharge switch ON.	PRCHGS	Precharge ON/OFF status goes to ON state (="1")
PCG1Ø PCGAØ	Precharge OFF	Commands Precharge switch OFF.	PRCHGS	Precharge ON/OFF Status goes to OFF state (="0")
HT119 HTTA9	Primary Propellant Tank Heaters Select	Switches essential bus power from secondary to primary tank heaters.	PHTTKS	Primary/Secondary Propulsion Tank Heater status goes to Primary state (="1")
			VLVPHS VFDVHS	L/V Primary Heater Status is nominal 48 ma; F&D Valve Primary Heater Status is nominal 75 ma.
HTT29 HTTB9	Secondary Propellant Tank Heaters Select	Switches essential bus power from primary to secondary tank heaters	PHTTKS	Primary/Secondary Propulsion Tank Heater Status goes to secondary state (="0")
			VLVPHS VFDVHS	L/V Primary Heater Status and F&D Valve Primary Heater Status both go to zero ma.
HTJ19 HTJA9	Forward Axial Jet Heaters ON	Turns ON forward axial jet heaters.	PHTFJS	Forward Axial Jet Heaters ON/OFF goes to ON state (="1"). Spacecraft load current sensor resolution inadequate to measure 15 ma current change.
			VJET5T	Forward Axial Jet Temperature rises.

TABLE 3.8.4-1 (Continued)

Command Mnemonic	Command Title	Command Response	Telemetry Mnemonic	Telemetry Title/Comments
SPP39 SPPC9	Small Probe 3 Internal Power ON	Applies 35 ms pulses to ON coils of Small Probe 3 internal power relays 1 and 2.	P3PR1S	Small Probe 3 Internal Power Relay 1 ON/OFF goes to ON state (="1")
			P3PR2S	Small Probe 3 Internal Power Relay 2 ON/OFF goes to ON state (= 1")
SPP30 SPPC0	Small Probe 3 Internal Power OFF	Applies 35 ms pulses to OFF coils of Small Probe 3 internal power relays 1 and 2.	P3PR1S	Small Probe 3 Internal Power Relay 1 ON/OFF goes to OFF state (="0")
			P3PR2S	Small Probe 3 Internal Power Relay 2 ON/OFF goes to OFF state (="0")

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****                                ****
****   This Figure is a Foldout.    ****
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Figure 3.8.1.1-1

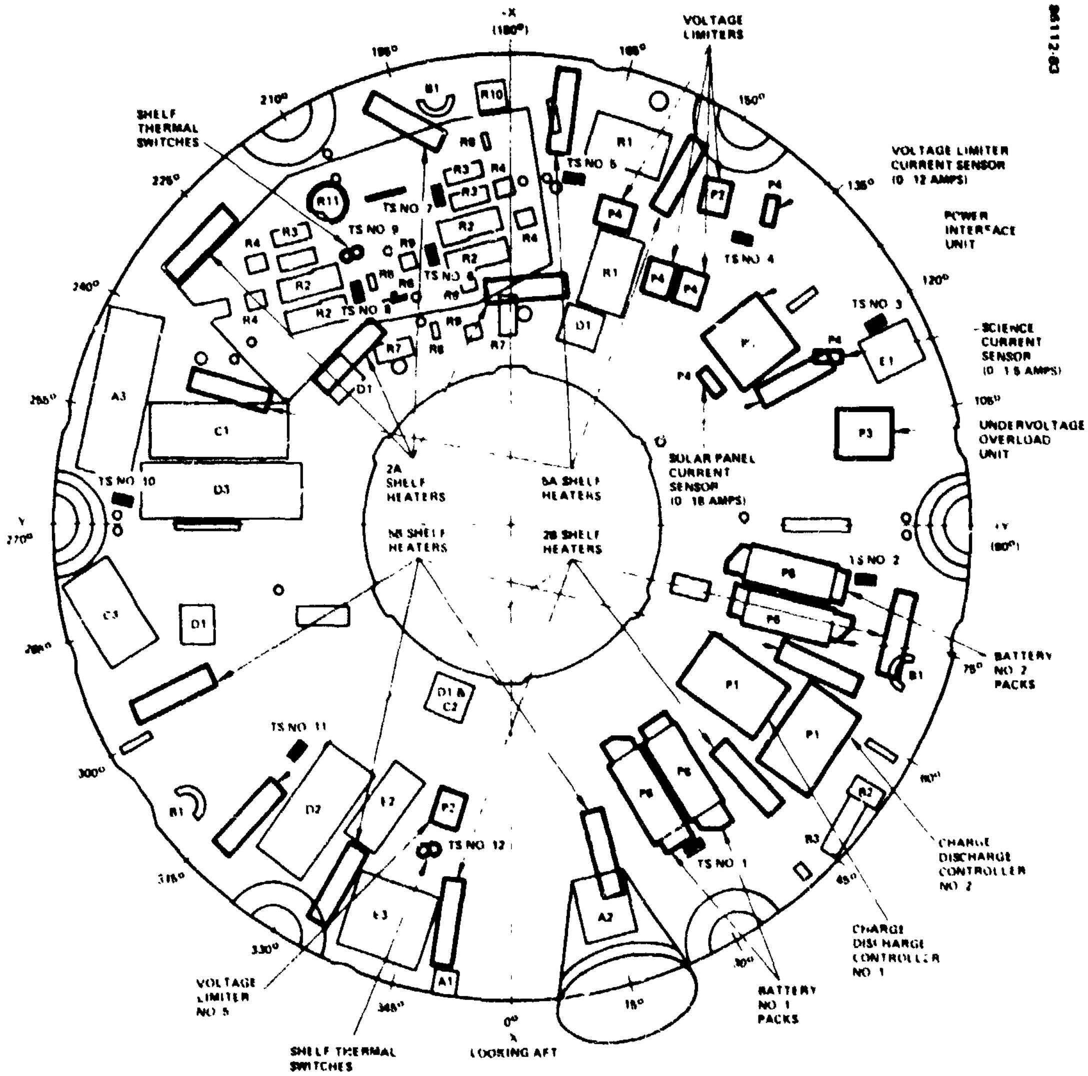

FIGURE 3.8.1.2 1 BUS SHELF POWER SUBSYSTEM UNIT LOCATIONS

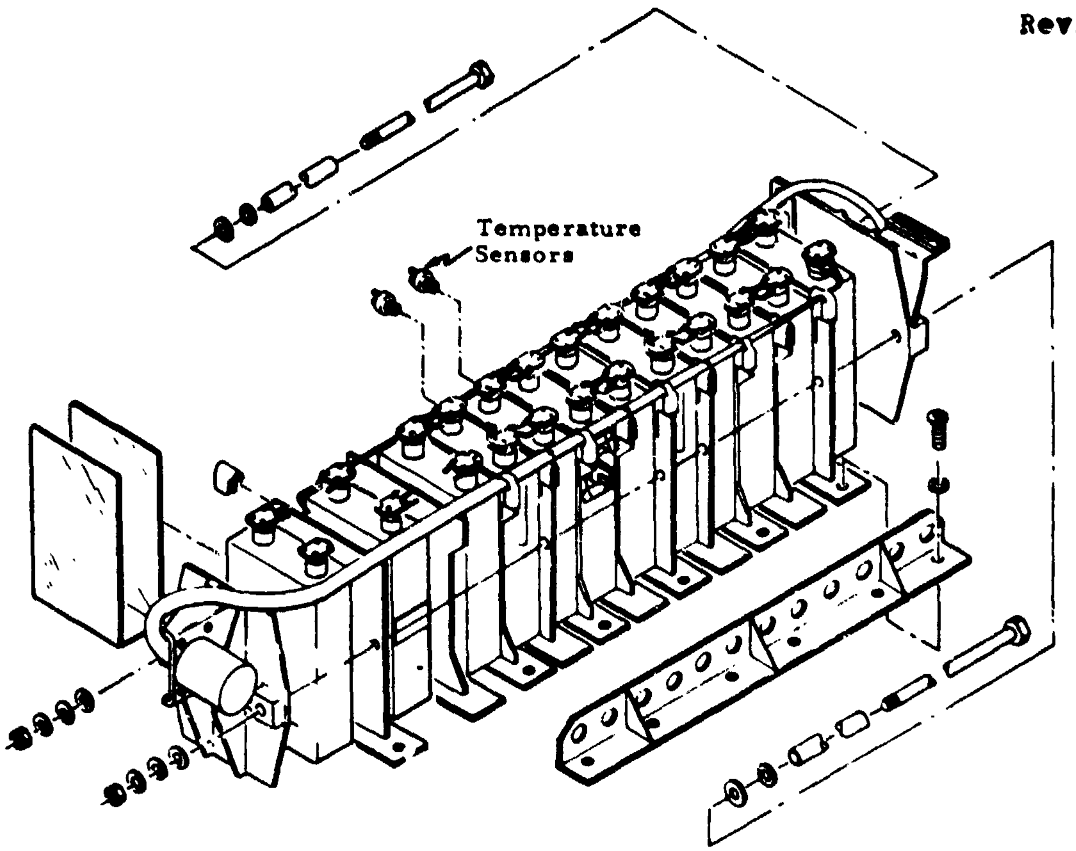

Figure 3.8.2.2-1. Twelve-Cell Battery Pack.

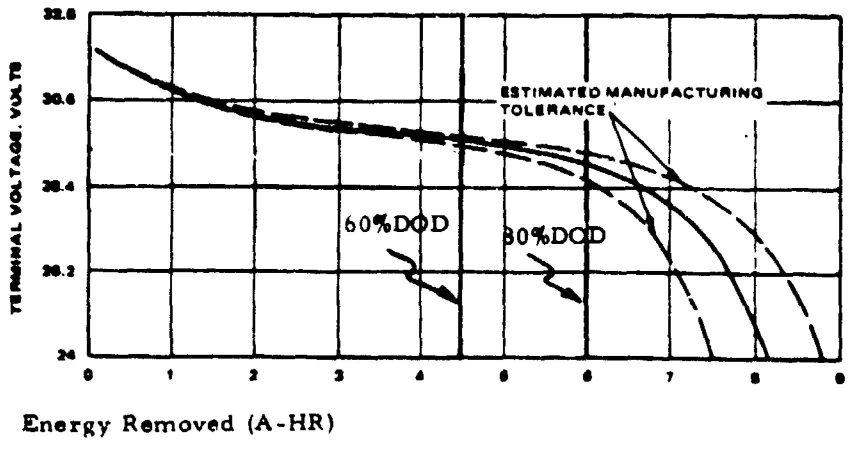

Figure 3.8.2.2-2. First Cycle Performance (75°F and 3.75A Discharge Rate).

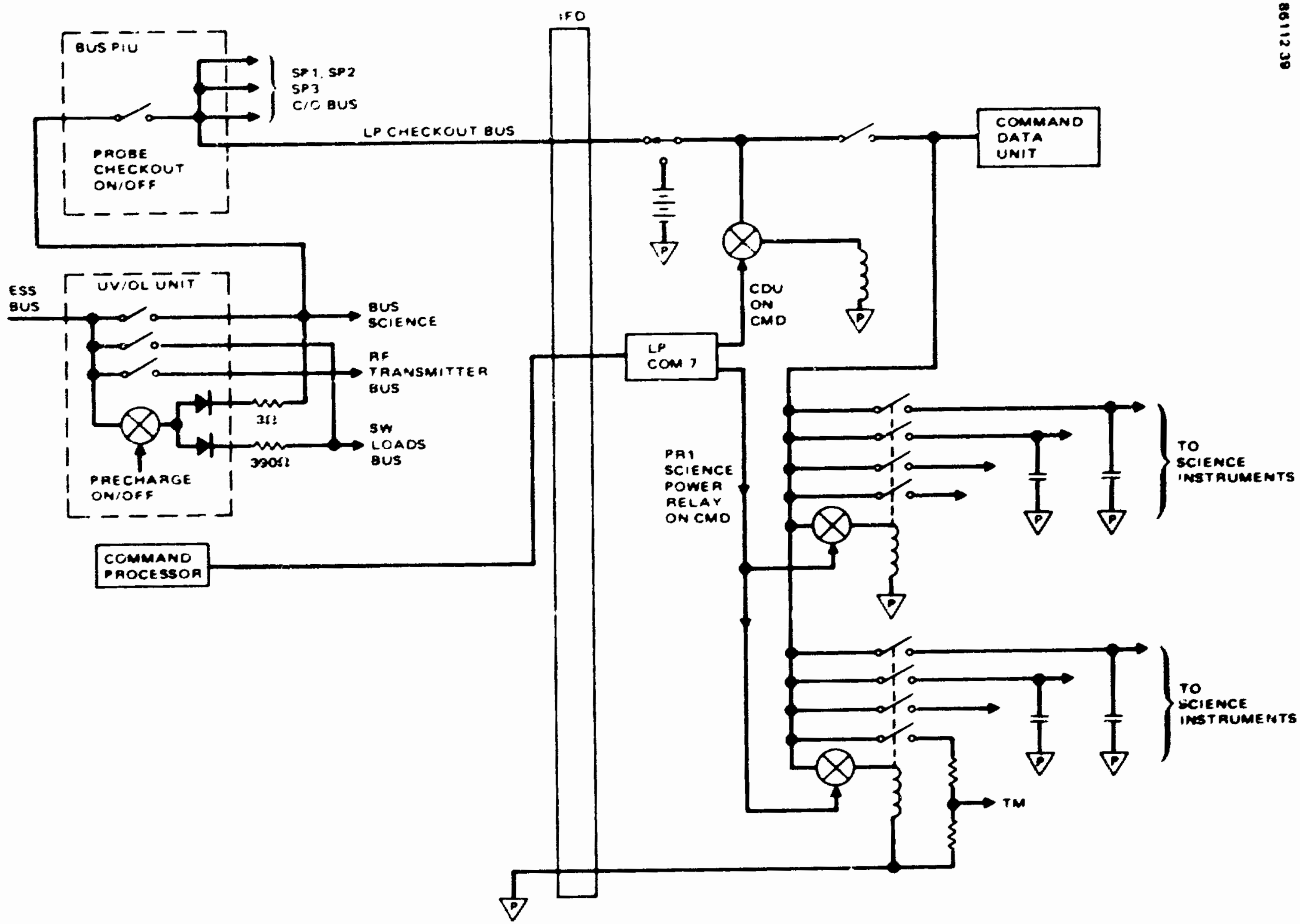

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FIGURE 3 8 2 7-1 BUS/LARGE PROBE POWER INTERFACES

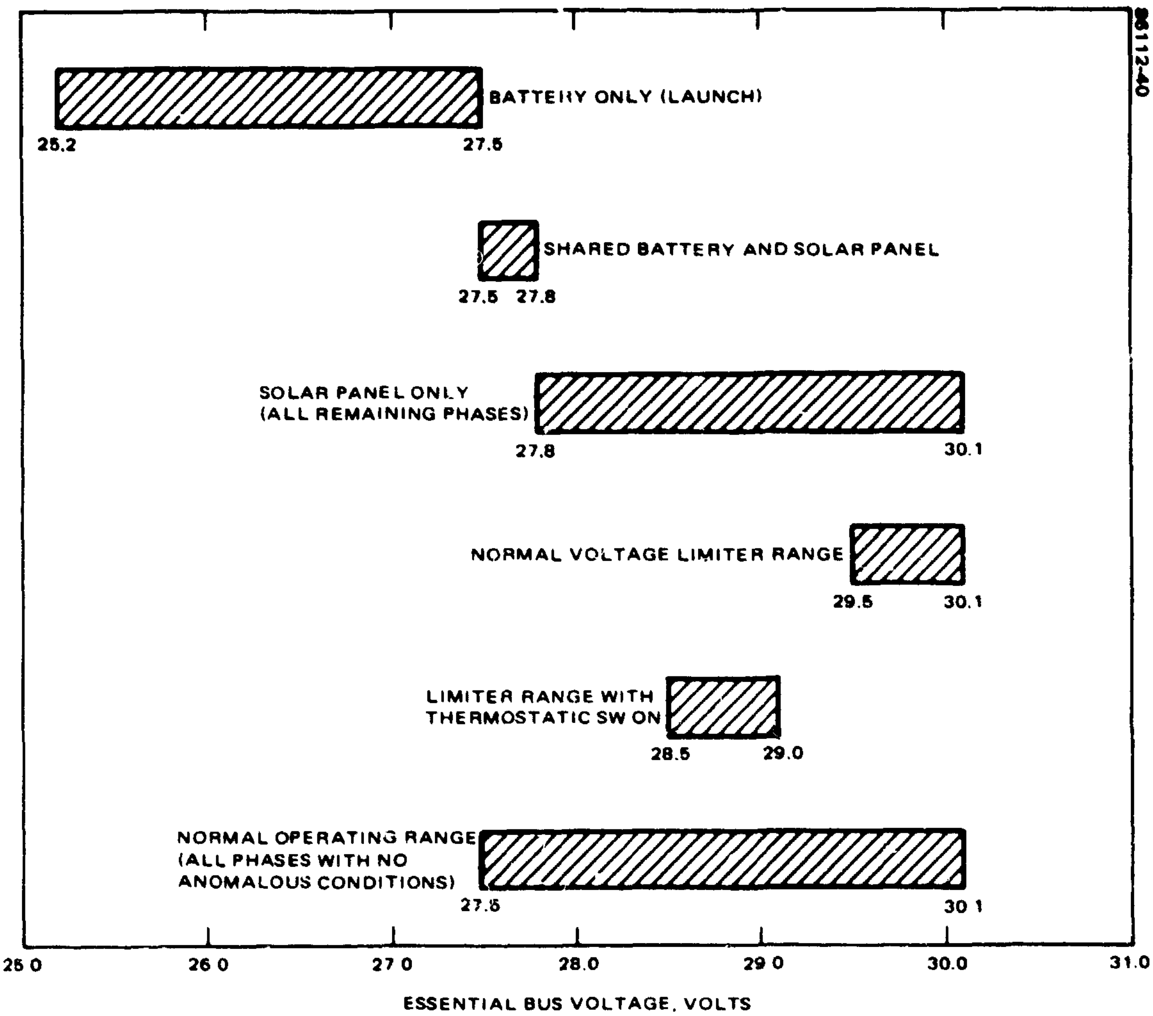
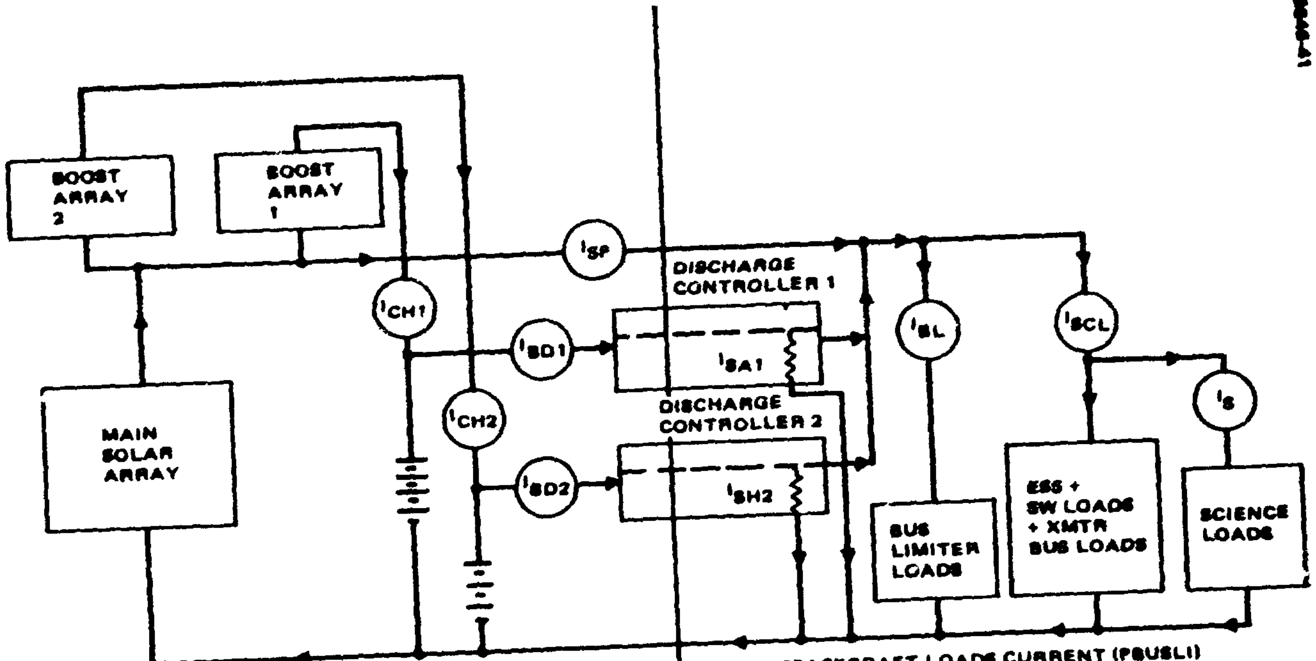


FIGURE 3.8.3.1-1 MULTIPROBE BUS VOLTAGE RANGES



I_{CH1} – BATTERY 1 CHARGE CURRENT (PCHG1I)
I_{CH2} – BATTERY 2 CHARGE CURRENT (PCHG2I)
I_{SP} – SOLAR PANEL CURRENT (PPANLI)
I_{BD1} – BATTERY 1 DISCHARGE CURRENT (PDIS1I)
I_{BD2} – BATTERY 2 DISCHARGE CURRENT (PDIS2I)
I_{SCL} – SPACECRAFT LOADS CURRENT (PBUSLI)
I_{BL} – BUS LIMITER CURRENT (PLIMTI)
I_S – SCIENCE CURRENT (PSCICI)
I_{SH1} – DISCHARGE CONTROLLER 1 SHUNT LOSS
I_{SH2} – DISCHARGE CONTROLLER 2 SHUNT LOSS

FIGURE 3.8.3.2-1. POWER SUBSYSTEM CURRENT MEASUREMENTS

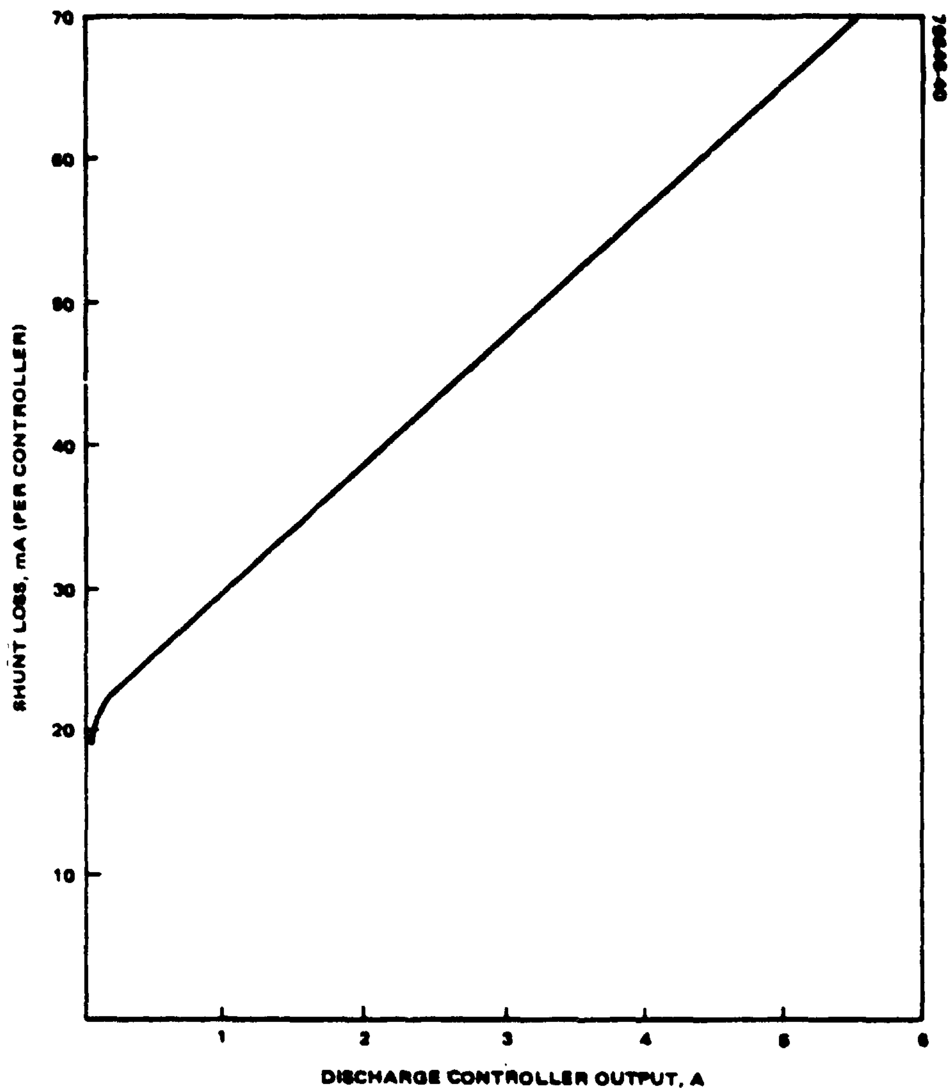


FIGURE 3.8.3.2-2. DISCHARGE CONTROLLER SHUNT CURRENT LOSS AS FUNCTION OF OUTPUT CURRENT

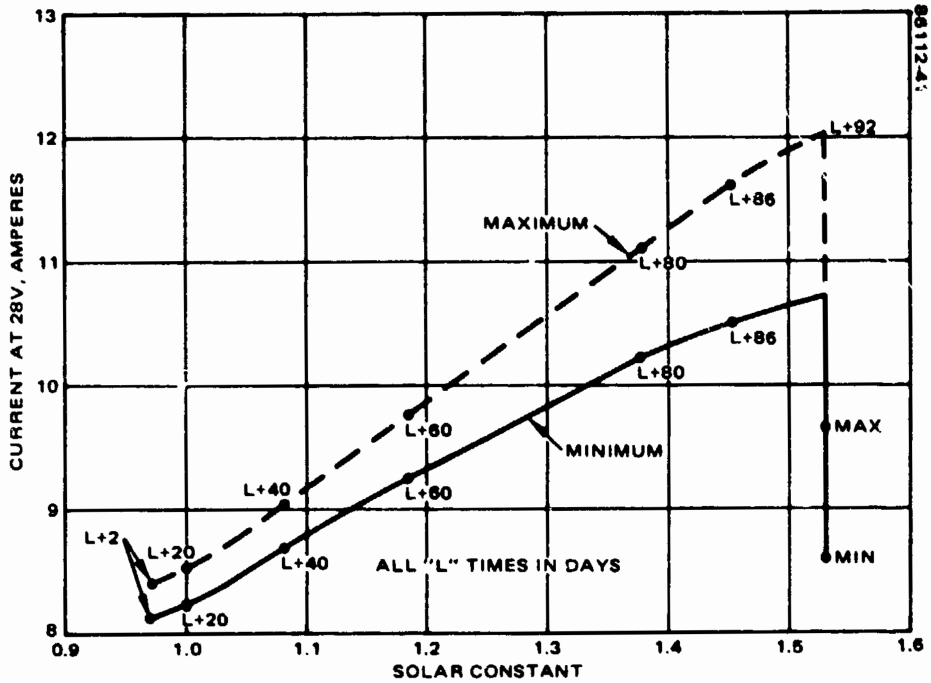


FIGURE 3.8.3.3-1. SOLAR PANEL CURRENT AS FUNCTION OF SOLAR CONSTANT BEFORE REORIENTATION

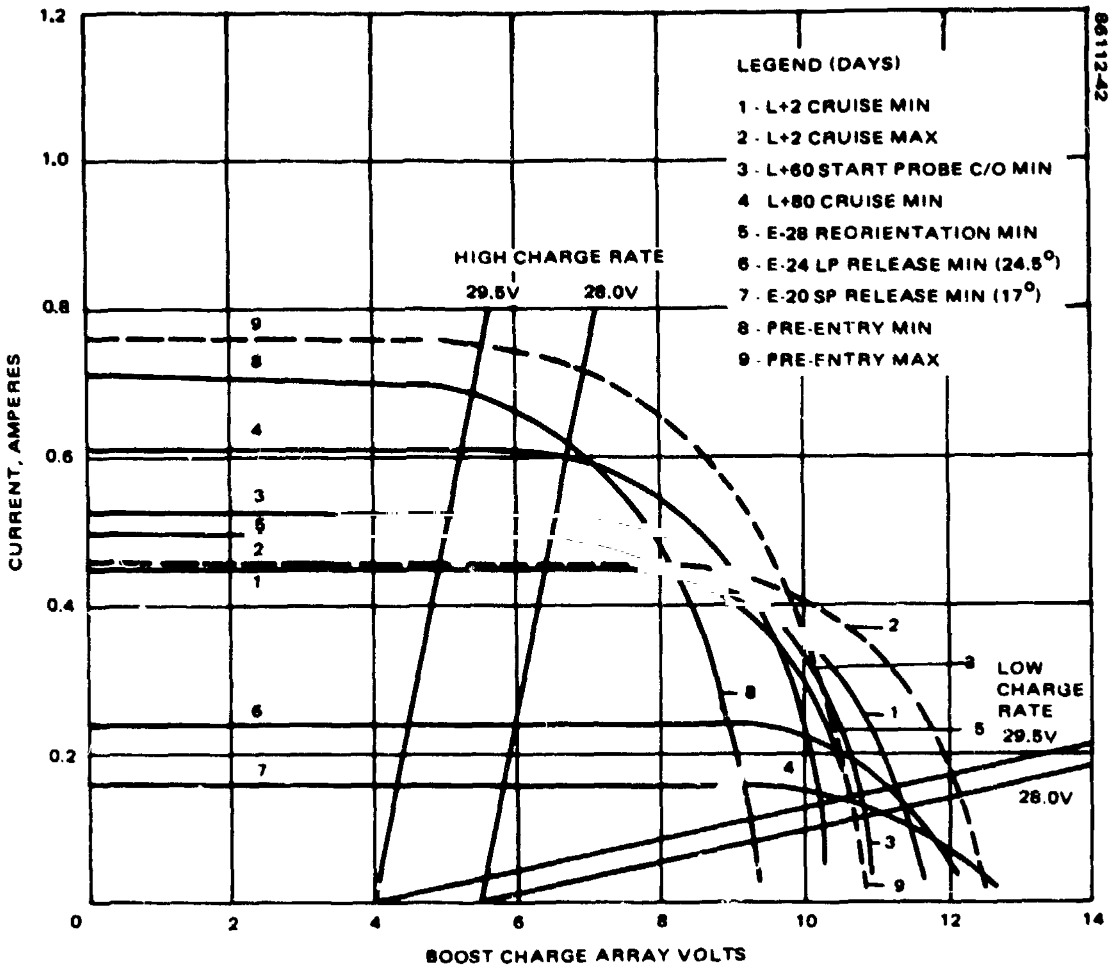


FIGURE 3.8.3.4-1. BOOST CHARGE ARRAY VOLTAGE/CURRENT CURVES

4.0 SPACECRAFT MISSION OPERATIONS

Detailed performance of the Multiprobe system in normal operating modes and backup modes is presented ahead.

4.1 MISSION MECHANICS

The mechanics of the Multiprobe mission are delineated by descriptions of (i) the nominal mission profile (4.1.1), (ii) disturbances to nominal spacecraft configurations (4.1.2), and (iii) changes in spacecraft configurations (4.1.3).

4.1.1 Nominal Mission Profile. The nominal mission profile is introduced by a comprehensive mission description from lift-off to end of life (4.1.1.1). A detailed attitude profile (and options) follows (4.1.1.2), with illustrations of spin axis attitude, sun angle and communication angle when appropriate. The spin rate profile (and options) are presented in 4.1.1.3. The maneuver profile propellant budget, maneuver charactersitics and constraints are discussed in 4.1.1.4.

4.1.1.1 Mission Description.

(a) Launch Phase (Lift-Off to Spacecraft Separation). The Multiprobe will be launched with an Atlas Centaur launch vehicle from Cape Canaveral. Launch will take place during a one hour window on one of ten successive days in the period from 11 August through 23 August 1978. The launch vehicle will place the Multiprobe on the desired interplanetary trajectrory after a 16 to 21-minute coast period in a 90 nmi earth parking orbit.

After Centaur second burn (MECO 2) and prior to spacecraft separation, the Centaur will reorient the spacecraft +Z axis to an approximately normal to the ecliptic attitude in the direction of the south ecliptic pole. The south ecliptic polar direction has been selected for the Multiprobe spin axis cruise attitude because of the greater number of visible stars in the southern ecliptic hemisphere. The spacecraft +Z axis is initially tilted ≈12 degrees away from the south ecliptic toward the local sunline in order to compensate for a deterministic attitude displacement during spinup.

(b) Near Earth Phase (Separation to 36 Hours After Lift-Off). Spacecraft separation switches initiate redundant command sequences, each sequence being stored in one of of the two spacecraft command processors prior to launch. Two spinup thrusters are fired to impart a 15 ±0.5 rpm spin rate and the spacecraft is then configured for initial ground station acquisition (Section 4.2.1). It is expected that ground station acquisition at Honeysuckle will occur within the first hour after launch. Cebreros, DSS-62, provides nominal coverage during the first 6 to 16 hours while Goldstone, DSS-12, should acquire ≈14 hours after lift-off.

The spacecraft is designed so that the nominal spin (+Z) axis will be the axis of maximum moment of inertia. Centaur reorientation nominally tilts the +Z axis approximately 12 degrees from the south ecliptic pole toward the sunline in order to compensate for a 12 degree deterministic attitude displacement during spinup. However, Centaur, separation and spinup errors contribute to a 10-degree uncertainty in the average attitude so that the average sun angle at acquisition is 90 ±10 degrees. In the absence of nutation, the +Z axis would be aligned to the angular momentum vector. Since nutation induced by spinup is small, i.e., less than 2 degrees, any residual nutation should be damped out by the nutation damper prior to acquisition.

The spacecraft is initially below the ecliptic after centaur injection. However, it rapidly rises above the ecliptic, so that several hours after separation, the initial earth look angle would be 75 to 90 degrees w.r.t. the +Z axis, if the +Z axis were oriented toward the south ecliptic pole. Because the average attitude after spinup has a potential 10-degree error, the average earth look angle at acquisition lies between 65 and 100 degrees.

Spacecraft engineering telemetry will nominally be transmitted via the spacecraft aft omni antenna during the initial acquisition period and via th forward omni during the later acquisition period. The sun sensor is used to initially assess spin speed, sun angle and residual nutation. In the presence of nutation, the average value of [illegible] time intervals represents the spin period (nominally 15 ±0.5 rpm) while the average value of [illegible]$_2$ time intervals divided by spin period is a measure of sun look angle (nominally 90 ±10 degree). Nutation generates a quasi-sinusoidal variation in [illegible]$_2$ about the average value at body nutation frequency (inertial nutation frequency minus spin frequency), i.e., ≈28% of spin frequency. The amplitude of the variation in [illegible]$_2$ time intervals is a measure of residual nutation (nominally <2 degree).

The attitude will be nominally reoriented to within 2 degrees of the south ecliptic pole in preparation for the cruise phase. Prior to this reor (< 10 degrees), star sensor measurements are obtained to define attitude as well as maneuver parameters. The maneuver to the south ecliptic pole will nominally be based on attitude information so that when attitude measurements are obtained after the maneuver, an initial calibration of axial jet(s) pulsed performance can be made.

The spacecraft trajectory carries it above the ecliptic plane so that the earth's elevation with respect to the spacecraft spin plane will be positive, i.e., toward the spacecraft +Z axis. The earth's elevation starts at +10 to ±18 degrees and decreases slowly through the cruise phase. The forward omni provides the best earth look angle for telemetry and command throughout the cruise phase with the spin axis oriented along the south ecliptic pole.

(c) Interplanetary Cruise Phase (36 Hours After Liftoff to Venus Encounter. For a Type I Earth-to-Venus trajectory, the angle between the sun-Earth line at launch and the sun-venus line at arrival (heliocentric transfer angle) is less than 180 degrees. As shown in Figure 4.1.1.1-1, this trajectroy will always remain inside of the Earth's orbit, pass between the Earth and sun (inferior conjunction) at about 75 days and proceed to intercept Venus at 0.72 AU from the sun at about 116 days after launch.

Trajectory correction maneuvers (TCM) will be needed to compensate for launch vehicle injection errors and maneuver execution errors. The corrections are expected to total not more than 12.8 m/s (3σ) in spacecraft velocity change (ΔV). Three trajectory correction maneuvers are planned, for approximately five and twenty days after launch, and twenty-eight days before Venus encounter. The first maneuver is the largest, requiring a (99.5% probability of not exceeding) ΔV of 12 m/sec to correct launch vehicle injection errors. This maneuver can be performed in the south ecliptic polar attitude using successive firings of axial and radial jets. Since either radial jet pair generates thrust normal to the spin axis and the aft and forward axial jets generate thrust parallel to the spin axis, the required ΔV can be delivered in any direction by a vector combination of individual axial and radial jet impulses.

However, the weight penalty associated with use of the vector mode for the first midcourse can be significant, so that use of the axial mode (precession + continuous axial thrust) or radial mode (precession + pulsed radial thrust) for this maneuver could save as much as 9 lbs. of propellant. The magnitude of the multiprobe first midcourse and the large cant angles of the multiprobe radial jets necessitate the trade. At the time of the first midcourse, spacecraft sun angle is constrained to be greater than 65 degrees and less than 120 degrees if a specific attitude is to be maintained for at least 4 hours. This constraint always permits use of the radial mode when the ΔV direction is within 62 degrees of the sunline and use of the axial mode when the ΔV direction is within 90 ±25 degrees of the sunline.

The second and third TCM's expected to require not more than a ΔV of 0.7 m/s and 0.1 m/sec, respectively, are executed with the vector mode; these maneuvers correct execution errors resulting from the previous maneuver and modelling errors compared with the actual solar pressure encountered in the mission. The vector mode has been nominally selected for these TCM's because it does not appreciably change the steady state cruise configuration while incurring a small propellant penalty for the worst case ΔV direction.

Command and control of the Multiprobe will normally be exercised utilizing the DSN 26-meter net except that when maneuvers are being performed, the 64-meter stations will be used. Prior to the start of the first two TCM's, the earth look angle is 72 to 80 degrees; prior to the third TCM, the look angle is 76 to 84 degrees. The combination of forward and aft omni's will ensure command function in the event of an anomalous attitude change. Prior to and following any axial or radial jet firing, attitude, spin rate and nutation will be determined from sun and star sensor data. Earth look angle during TCM's in the cruise attitude cause 20 to 30% of the ΔV imparted by axial jets to be reflected in range rate change and thus doppler frequency shift. The large cant angles of both radial jet pairs can cause as much as 30 to 45% of any ΔV imparted to be reflected in range rate change and thus doppler frequency shift. Thus, near-real-time measurement of performance during the TCMs is available via doppler shift.

The order of axial and radial jet firing can be significant. For radial jet pair pulsed maneuvers of five meters/sec, the accumulated precession and spin speed change is on the order of 3.9 degrees and 1.4 rpm, respectively; the residual nutation is negligible. For a single axial jet continuous maneuver of the same magnitude, precession is 0.5 degree, spin speed change is ≈0.6 rpm, and nutation is 2 degrees. In order to minimize the effect of coupling errors due to the first part of the vector maneuver on the performance of the second part, the following sequence is recommended: radial jet pair pulsed maneuvers have first priority when the ΔV correction is small such as the second and third corrections; axial jet maneuvers have first priority when the radial ΔV is more than several m/sec, but at least a half-hour should be allocated between parts of nutation damping. An attitude touchup and spin speed trim will be executed if required after the maneuver is complete and nutation is damped.

The initial reorientation to the south ecliptic pole affords an opportunity to calibrate the axial jet(s) in the pulsed mode. A radial jet pair in the pulsed mode has potentially strong spin and precession coupling during a velocity maneuver. A calibration maneuver (perhaps a day earlier than the first TCM) on the cruise radial jet pair is recommended to anticipate and plan for any large coupling errors that might be experienced during the first TCM.

Star and sun sensors will be used to provide attitude data for maneuvers as well as steady state operations. The star sensor with its redundant silicon detectors is expected to be responsive to 25 stars. The star sensor field of view is the sector between 46 and 70 degrees from the spacecraft spin axis. This field sweeps out a 24-degree wide band of the sky as the spacecraft spins. The stars which fall in the sensor field of view depend on the spacecraft attitude. For the nominal cruise attitude (south ecliptic polar), five stars are potentially visible: Sirius, Rigel Kentaurus, Rigel, Beta Grus, and Fomalhaut. Sometime during the interplanetary cruise, the relative celestial longitude of each one of these stars with respect to the sun will cause sun interference. However, at least three of the five stars ar useful attitude references at all times. Sun angle measurements are available for sun look angles greater than 15 degrees and less than 165 degrees, when the appropriate mid-range or extended range sensor is selected.

Attitude determination in its simplest form requires a sun measurement and a star measurement. Multiple stars permit estimation of sensor biases, and therefore improve attitude accuracy and evaluation of solar disturbance torques. Star sensor data on the available star set will be obtained periodically throughout cruise to improve attitude estimation. Assessment of attitude changes in association with TCM's or attitude touchups employs the minimum data set with updated sensor biases. Spin period determination is routinely made by averaging sun sensor $\psi\psi$ time intervals. Nutation transients and decay can be observed in the quasi sinusoidal variation in $\psi\psi_2$ time intervals at 25 to 50% of spin frequency, depending on the Multiprobe configuration. Telemetry will be transmitted primarily via the forward omni during the first ≈ 89 days.

(d) <u>Multiprobe Encounter (28 Days Entry to Bus Entry)</u>. The encounter phase of the mission starts, for targeting purposes, at 28 days before entry into the Venus atmosphere with a third midcourse correction, which will provide additional precision for targeting of the Large Probe. Following this maneuver, the spacecraft spin axis will be precessed to an attitude in the ecliptic plane so that the medium gain horn can be used for communications. This reorientation is executed with both axial jets to minimize any velocity perturbation. The communications angle is ≈150 degrees w.r.t. the spacecraft +Z axis, consistent with use of the horn. The sun angle is approximately 54 degrees in the new attitude. The planet Jupiter and the stars Al Suhail and Procyon are also available for attitude determination. Four days of tracking follow to permit precise determination of the trajectory before release of the Large Probe.

At 24 days before entry the multiprobe will be oriented (with the axial jet couple) so that the Large Probe will enter the atmosphere at zero degree angle of attack. The release attitude, which requires a 44 degree precession, has a communications angle outside the useful range of the medium gain horn, so that the aft omni is primary. The sun angle can vary between 24 to 37 degrees depending on launch date. The planet Saturn and the stars Arcturus and Al Suhail are available for attitude determination. Data collection begins immediately after the reorientation; confirmation of attitude and any required touchup nominally takes place within the next several hours so that the release sequence can begin.

Immediately after Large Probe release, the spin axis orientation will be precessed to the Small Probe targeting attitude to once again allow use of the medium gain horn. The communications

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Revision

angle changes to about 163 degrees while the sun angle increases to about 48 degrees. The planet Jupiter and star Al Suhail are again visible. At E-23 days, the Multiprobe will be spun up to 48.5 rpm and a pulsed radial jet ΔV maneuver will be performed to effect a ΔV of 5 m/sec to achieve the desired Small Probe targeting. Three days of tracking follow to permit precise determination of the trajectory before release of the Small Probes.

At 20 days before entry the multiprobe will be oriented (wit' the axial jet couple) so that the proper separation of the probes on the surface of the planet will be provided by the spin-induced centrifugal force acting perpendicular to the spacecraft spin axis. The release attitude, which requires a 50 degree precession, has a communications angle less than 150 degrees, so that the aft omni is primary rather than the medium gain horn. The sun angle can vary between 16 to 25 degrees depending on launch date. Power limitations at such low sun angles limit the dwell time at the release attitude to 4 hours. Consequently, the precession to the release attitude is done in two parts: An initial precession to a holding attitude with a 28 degree sun angle; and a second precession to the required attitude. This strategy increases the overall dwell time to 10 hours. Several other benefits also result: The star sensor cooldown period is longer, upgrading performance at the release attitude; the stars Al Suhail, Arcturus, and Saturn are visible at the holding attitude, insuring a precise attitude determination; and the first part of the maneuver provides updated jet calibration data to use for the second part, a small precession of about 10 degrees. After reorientation to the release attitude, the star Al Suhail is available and Arcturus may be available for attitude determination. Data collection begins immediately after reorientation. Confirmation of attitude and possibly an attitude touchup take place within the next two hours. The release sequence begins when the attitude and spin rate are judged satisfactory.

Immediately after release, the spin axis will be precessed to an attitude which allows use of the medium gain horn and provides a sun angle of 40 degrees. The stars Al Suhail, Acrux One and Regulus are available for attitude determination.

At E-18 days, the bus will be oriented so that a ΔV maneuver of 19 m/sec with the forward axial jet will move the trajectory aim point to that desired for bus entry and slow the arrival by 90 minutes so that the bus will arrive after impact of all probes on Venus. The required ΔV attitude, which requires a 34 degree precession, also has a communications angle less than 30 degrees, so that the aft omni is primary. The sun angle is about 28 degrees. The star Al Suhail is available for attitude determination. After the continuous forward axial jet burn, the bus is precessed back to the E-20 transit attitude. The forward axial jet is employed for all precessions associated with this maneuver in order to take advantage of its retarding velocity increment.

At E-8 days, the bus will be oriented to the final entry attitude so that angle of attack will be near zero at atmospheric entry. The entry attitude, which requires an 18 degree precession, has a communications angle near 180 degrees so as to take advantage of the medium gain horn. The sun angle is about 50 degrees. The planet Saturn is available for attitude determination.

At E-2 days, the bus will be despun to 9.45 rpm in preparation for entry. This maneuver is delayed to this time in the mission in order to limit the propagation time of the accelerating velocity increment due to the canted spinup jets. A final trajectory trim maneuver may be done, if required, at one day before entry to reduce the uncertainty in entry flight path angle. The bus nominally arrives at Venus on December 9, 1978 and provides the desired scientific sampling before its destruction during atmospheric entry.

4.1.1.2 Attitude Profile. The spacecraft spin axis is the axis of maximum moment of inertia about which the spacecraft is spun for attitude stabilization. The positive spin axis is nominally coincident with the spacecraft +Z axis. In the absence of nutation, the positive spin axis is also coincident with the spacecraft angular momentum and angular velocity vectors. Spacecraft attitude is the direction of the spacecraft angular momentum vector. In the absence of nutation, spacecraft attitude is identical with spin axis attitude. With nutation present, spacecraft attitude represents the average direction of the positive spin axis. Attitude will be defined by the celestial latitude and longitude of the "average" direction of the positive spin axis, as shown in Figure 4.1.1.2-1. A detailed attitude profile expressed in these coordinates is discussed below.

(a) Launch and Near Earth Phase. Prior to spacecraft separation, the Centaur will orient the spacecraft +Z and +X axes such that, after separation and spinup, spacecraft attitude will nominally be parallel to the south ecliptic pole and the average sun look angle will be ≈90 degrees. Figure 4.1.1.2-2 shows that the Centaur orients the +Z axis to -78.2 degrees latitude, θ_S degrees longitude, and the +X axis to +11.6 degrees latitude and θ_S -10.6 degrees longitude. θ_S is the celestial longitude of the sunline prior to separation; it varies from 134 to 150 degrees over the launch opportunity. Separation and spinup nominally establish spacecraft attitude (angular momentum vector) at the south ecliptic pole. The cone of possible attitudes indicated in the figure reflects a possible attitude error of 10 degrees due to Centaur control, separation and spinup errors. Therefore, the average sun look angle can range between 80 and 100 degrees. The earthline is also delineated in the figure with latitude δ_E and longitude θ_E. Both angles vary rapidly during the first two hours following injection. The latitude, δ_E, then settles to -10 to -15 degrees depending on launch date. The longitude, θ_E, becomes quasi steady at 40 to 50 degrees as a function of launch date. The resulting average earth look angle lies between 65 and 90 degrees.

The spinup process generates ≈2 degrees of residual nutation and causes a ±2 degree variation in sun and earth look angles as the positive spin axis cones around the spacecraft attitude at inertial nutation frequency (approximatley 25 percent greater than spin frequency). Figure 4.1.1.2-3 illustrates the motions of the +Z axis and positive spin axis, and how the look angle to an inertial target will vary in the presence of nutation and spin axis tilt from the +Z axis. The nutation damper will damp out the ±2 degree variation in look angles (<30 minutes time constant at 15 rpm spin rate).

The sun sensor transfer function and field of view are illustrated in Figure 4.1.1.2-4. The mid-range sun sensor is nominally selected after spinup for initial observation at acquisition. The stars Rigel Kentaurus, Rigel, Beta Grus, Fomalhaut and Hadar are available for attitude determination after acquisition. The touchup reor to the south ecliptic pole will nominally be based on sun and star information. An initial calibration of axial jet(s) pulsed performance can then be made after attitude measurements at the cruise attitude are obtained.

(b) Interplanetary Cruise Phase. During the interplanetary cruise portion of the multiprobe mission, the spacecraft positive spin axis (+Z axis) will be maintained within 2 degrees of the south ecliptic pole (except as needed for trajectory correction maneuvers). Therefore, the celestial latitude of the positive spin axis is -88 to -90 degrees. The celestial longitude would be arbitrary (0 to 360 degrees) if the attitude were not biased to take advantage of the entire attitude deadband and minimize the frequency of attitude touchups required to compensate for solar torque precession. Attitude biasing implies that the difference in celestial longitudes of the sunline and spin axis is ±90 degrees, so that as solar torque precesses the spin axis around the sunline, the entire attitude deadband is utilized.

The Multiprobe sun look angle history for the cruise phase is shown in Figure 4.1.1.2-5. The +Z axis is assumed oriented to the south ecliptic pole. The Multiprobe earth look angle history for the cruise phase is shown in Figure 4.1.1.2-6. Part of the attitude variation due to solar torque would be reflected in earth look angle through most of the cruise since the earth and sun lines of sight are near coincidence for short periods of time only. This is illustrated in Figure 4.1.1.2-7 by the sun-spacecraft-earth angle during cruise.

Five stars are available for attitude determination and roll reference during cruise when the spin axis is oriented near the south ecliptic pole. At least three stars are useful at any time. Rigel, Beta Grus, and Fomalhaut do not suffer any sun inteference throughout cruise. Sirius has interference during the initial 20 days after launch, while Rigel Kantaurus has interference during the last 30 days of cruise.

Trajectory correction maneuvers are nominally executed in the south ecliptic polar attitude by a vector combination of individual axial and radial jet impulses. Forward and aft omnis are available for command function in the event of an anomalous attitude change. Two optional TCM methods exist which might avoid any propellant penalty associated with the vector mode, particularly during a large first TCM. The axial jet mode requires precession of the spin axis to the desired ΔV direction, continuous aft or forward axial jet thrust, and reorientation of the spin axis back to the south ecliptic pole. Power and thermal considertions require sun look angles between 65 and 120 degrees for 4 hour dwell at any potential maneuver attitude. With the earthline about 90 degrees from the sunline at first TCM, the earth look angle could range between 0 and 180 degrees. The available stars or planets are dependent upon the specific attitude required. The radial jet mode requires precession of the spin axis until the desired ΔV direction lies in the radial jets thrust plane (i.e., the plane that contains radial jets thrust vectors), pulsed radial jet pair thrust, and reorientation of the spin axis back to the south ecliptic pole. The sun look angle range is 65 to 120 degrees while the earth look angle range is between 0 and 180 degrees. The available stars again are dependent upon the specific attitude required. Both of these methods require precession at the cost of ≈1 lb/69 degrees. The maximum weight saving associated with these methods for the worst case first TCM ΔV magnitude and direction is ≈9 pounds. The use of either method will depend on a trade-off of actual weight saving against operational complexity and star availability at the maneuver attitude.

(c) Encounter Phase. Figure 4.1.1.2-8 summarizes the Multiprobe spin axis attitude history during the encounter phase. At E-28 days, the spacecraft spin axis is reoriented into the ecliptic plane to initiate use of the medium gain horn. The communications and sun angles w.r.t. the spacecraft +Z axis are 151 and 54 degrees, respectively. The planet Jupiter and the stars Al Suhail and Procyon are nominally visible in this attitude.

At 24 days before entry, the Multiprobe is reoriented prior to Large Probe release so that its spin axis is co-linear with the Large Probe velocity vector at atmospheric entry. The loci of required Multiprobe attitudes associated with Large Probe entry points on the boundaries of the regions of acceptable target points are shown in Figure 4.1.1.2-9 for three launch dates and arrival on December 9, 1978. In the figure, the boundaries on Multiprobe attitude for viewing stars and planets are also shown with the shaded side of the boundary indicating the star or planet is either not in the field of view or subject to sun interference. The figure indicates that four stars -- Arcturus, Al Suhail, Canopus and Regulus -- may be in the star sensor field of view; the planet Saturn will always be visible. The use of Arcturus as a reliable reference is somewhat questionable because it is subject to sun interference over part of the attitude region of interest. The sun angle at release can vary between 24 and 37 degrees and tends to decrease as the launch date is delayed. The communications angle at release can vary between 140 and 154 degrees, and also tends to increase as the launch date is delayed.

After Large Probe release, the spin axis is reoriented to the Small Probe targeting attitude as illustrated in Figure 4.1.1.2-8. The communications and sun angles are 163 and 47 degrees, respectively. The planet Jupiter and star Al Suhail are nominally visible in this attitude.

At 20 days before entry, the Multiprobe is reoriented so that proper separation of the Small Probes on the surface of the planet will be provided by the spin induced centrifugal force acting perpendicular to the spacecraft spin axis. The range of required Multiprobe attitudes as a function of launch date and time of release are shown in Figure 4.1.1.2-10 for arrival on 9 December 1978. In the figure, the boundaries on

Multiprobe attitude for viewing stars and planets are also shown. The figure indicates that the planet Saturn and star Arcuturus may be visible; the star Al Suhail will always be visible. Arcturus may be too close to the region of sun interference to provide a reliable reference. The planet Saturn, while not in the field of view at most Small Probe release attitudes, does provide a very reliable reference for the small probe holding attitude discussed in 4.1.1.1 and defined in Figure 4.1.1.2-10. Arcturus is also a reliable reference at this attitude. The sun angle at release can vary between 16 and 29 degrees and tends to increase as either launch date or release time is delayed. The communications angle at release can vary between 146 and 152 degrees and tends to increase as the release time is delayed.

After release of the Small Probes, the spin axis is reoriented back toward the ecliptic as shown in Figure 4.1.1.2-8. The communications and sun angles are 166 and 40 degrees, respectively. The stars Al Suhail, Acrux One and Regulus are nominally visible in this attitude.

At 18 days before entry, the Multiprobe is reoriented for bus targeting as shown in Figure 4.1.1.2-8. The communications and sun angles are 143 and 28 degrees, respectively. Only the star Al Suhail is nominally visible in the bus targeting attitude. The Multiprobe is reoriented to the E-20 transit attitude after the maneuver is completed.

At 8 days before entry, the Multiprobe is reoriented to the final entry attitude with angle of attack near zero. This attitude has a communications angle near 180 degrees to take full advantage of the medium gain horn at entry. The sun angle is 40 degrees immediately after the maneuver, and 52 degrees just prior to entry. Only the planet Saturn is nominally visible in the bus entry attitude.

4.1.1.3 Spin Rate Profile. Immediately following separation from the Centaur, the Multiprobe is spun up to the nominal cruise spin speed range of 15±.5 rpm by a prestored command sequence. The cruise spin rate has been selected on the basis of several trade-offs. The cruise spin rate provides sufficient spin "stiffness" to limit attitude errors and residual nutation resulting from subsequent midcourse maneuvers. Thrust pointing error and nutation induced by a continuous axial jet ΔV maneuver (both inversely proportional to spin speed squared) are bounded at 0.6 and 2 degrees, respectively. Attitude change induced by a pulsed radial jet pair ΔV maneuver (inversely proportional to spin speed) is bounded at 9.3 degrees. The same gyroscopic stiffness limits cruise attitude precession due to solar torque (inversely proportional to spin speed) to ≈0.1 degree/day. The spin rate is limited to 15 rpm during cruise to minimize propellant required for precession maneuvers (proportional to spin speed) while being consistent with minimum gyroscopic stiffness requirements.

Following release of the Large Probe at the 15 rpm spin rate, the Multiprobe is spun up to about 48.5 rpm. This is the nominal rate corresponding to Small Probe release at E-20 days. The spin rates required for release at times other than E-20 days vary between 40 and 60 rpm. The increase in spin rate contributes a total of approximately 2.2 meters/second useful ΔV (approximately 0.066 meters/second/rpm) for Small Probe targeting because of the significant cant of the spinup thrusters.

After Small Probe release, the bus spin rate is left at the high 48.5 rpm rate until two days prior to entry, when the bus is despun to 9.45 rpm, the desired entry spin rate. Earlier despin would contribute an axial ΔV which would accelerate the time of bus arrival. Mission requirements dictate a retardation of bus velocity to effect a 90-minute delay in entry time with respect to Large Probe entry.

Figure 4.1. .3-1 illustrates the nominal Multiprobe spin rate history. The phase lock loop (PLL) spin ranges and spin rate detector limits are also shown in the figure. Since the acceptable spin rates for Large Probe entry, Small Probes deployment, and bus entry are well defined, the only spin rate option is during cruise. A spin rate higher than 15 rpm incurs additional weight penalty while a lower spin rate suffers large attitude perturbations.

Spin speed can vary as a result of cross-coupling during thrusting maneuvers and external disturbance torques generated during separation events. Spin change accruing from the first TCM is expected to be less than 4 rpm; the spin change resulting from any targeting maneuver should be less than 1.5 rpm. Spin trims during cruise or encounter should be consistent with the nominal profile or an available option. Variation in the spin rate of the Multiprobe as a result of either Large Probe or Small Probes separation is expected to be less than 0.25 rpm.

4.1.1.4 <u>Maneuver Mission Profile</u>. Table 4.1.1.4-1 delineates the chronological sequence of nominal spin speed, attitude and velocity maneuvers during the Multiprobe mission. Each maneuver has an associated row of tabulated values defining maneuver magnitude, required propellant, maneuver mission time, nominal thruster(s) employed, pulse width selected, number of pulses and execution time. Spin speed maneuvers are nominally executed by continuously firing a pair of radial jet spinup or despin thrusters. Attitude maneuvers are nominally executed by pulsing the axial jet couple at spin frequency. Attitude maneuvers associated with bus targeting are executed with the forward axial jet to take advantage of the associated velocity increment. The midcourse velocity maneuvers are assumed to be executed in the vector mode, and the magnitudes of both axial and radial ΔV corrections are assumed maximum and equal, corresponding to the worst case required ΔV magnitude and direction. The maximum available pulse width has been selected for the first radial ΔV midcourse corrections to limit execution time; this results in negligible change in overall impulse efficiency.

The Multiprobe is initially loaded with 60 lbs of propellent. Figure 4.1.1.4-1 illustrates remaining propellant versus mission time. Note that the first midcourse consumes the most propellant. This maneuver is discussed further in Section 4.3.1. About 37 lbs of propellant are nominally required for all maneuvers so that approximately 23 lbs of propellant are available for calibration maneuvers and contingency planning.

All maneuvers should be executed within a sun look aspect angle range of 65 to 120 degrees in order to avoid any limitation in attitude dwell time due to thermal and power considerations. If, in addition, the sun aspect angle is maintained greater than 55 degrees, the mid-range sun sensor is always visible and no sensor switching is required. Maneuvers are nominally executed in sunlight so that the sun can always be employed as the spin reference pulse for the PLL and spin rate detector. This is particularly important during long continuous axial jet burns, since a single bit error in the jet select magnitude command or a logic failure could cause one of the spin thrusters to inadvertently fire. Earth look angle is unlimited when both forward and aft omnis are in receive mode. However, the forward omni should be in transmit mode for look angles less than 95 degrees while the aft omni should be in transmit mode for look angles greater than 65 degrees. If an attitude maneuver requires crossing either barrier, provision should be made to switch the appropriate omni to the transmit mode in order to avoid loss of telemetry. Long, continuous burns are executed with both omnis in receive mode and with the omni having the best earth look angle in transmit mode; this practice would insure telemetry coverage of any anomalous behavior and provide command capability for any immediate actions that might be required.

During any maneuver, spin period and sun angle should be the selected attitude measurement words. After the initial spin-up maneuver at separation, the spin rate detector should also be enabled for the remainder of the mission. For continuous axial jet burns, the sun gate and PLL loss of lock are enabled so that the maneuver will terminate automatically when the time count reaches zero, the JCE output is switched off, the PLL loses lock or the spin rate range is exceeded. One of the last two conditions will quickly terminate the maneuver in the event a spin thruster is inadvertently fired. For continuous radial jet burns (spin maneuvers), the PLL loss of lock and sun gate are disabled to permit the maneuver to continue as the PLL loses lock and to always provide a spin reference pulse to the spin rate detector, respectively. Therefore, this type of maneuver will terminate when the time count reaches zero, the JCE output is switched off or the spin rate range is exceeded. For pulsed maneuvers (precession, velocity or spin), the PLL loss of lock and sun gate are enabled and the same shutdown conditions as those for the continuous axial burns apply. These conditions insure accurate thrust direction and no erroneous spin thruster firing. However, a duty cycle detector enabled only in pulse mode can also terminate the maneuver. If the duty cycle exceeds limits dependent on spin speed and thruster pulse width selection, automatic shutdown occurs. This feature basically limits any anomalous pulse widths to less than 60 degrees of the spin cycle and therefore limits the error in the direction of applied jet impulse. The duty cycle detector, which cannot be disabled by ground command, precludes the use of the 512 ms pulse width above 20 rpm.

4.1.2 Disturbances. External forces will perturb spacecraft attitude during the mission. Attitude drift due to solar pressure is discussed in Section 4.1.2.1. Attitude perturbations due to aerodynamic forces arising during bus entry is presented in Section 4.1.2.2. Nutation can be induced by external forces (e.g., jet maneuvers); nutation is discussed in Section 4.1.2.3. Wobble refers to the tilt of the +Z axis relative to the axis of maximum moment of inertia; the sources and effects of wobble are summarized in Section 4.1.2.4.

4.1.2.1 Solar Disturbance Torque. An external torque due to solar pressure arises when the spacecraft center of pressure (c.p.) and center of mass (c.m.) are not coincident. The magnitude of the torque and therefore the attitude drift rate are proportional to the solar pressure flux and the c.p./c.m. offset. Since solar pressure is inversely proportional to the square of the distance from the sun, the precession rate of the Multiprobe at Venus (0.7 Au) would be about twice that at earth (1 Au) for a given c.p./c.m. offset. During cruise, the center of pressure lies about 20 inches below the spacecraft center of mass. Figure 4.1.2.1-1 illustrates a timeline of the Multiprobe solar precession rate during cruise. Positive precession rate indicates that the c.p. is aft of the c.m. and that the direction of precession is given by the right-hand rule with the right thumb pointing from the sun to the spacecraft.

The cumulative solar torque precession for the Multiprobe during cruise in the ecliptic normal attitude is about 9 degrees. Appropriate biasing of the attitude relative to the sunline to take advantages of the entire attitude deadband would limit the number of attitude touchups to three.

4.1.2.2 Aerodynamic Disturbances. An external (drag) torque arises during bus entry when the spacecraft aerodynamic center of pressure and center of mass are not coincident. The approximate altitude at which earth communications can be expected to be lost is of interest.

Because the bus is spinning, the surface configuration presented to the oncoming gas flow is symmetrical about the spin axis. Therefore, the net force vector applied to the vehicle will always lie in a plane containing the velocity vector ($\bar{V}$) and the spin axis ($\bar{\omega}$). The instantaneous torque vector and, hence the instantaneous momentum change vector, are normal to the plane containing $\bar{V}$ and $\bar{\omega}$. As the spin axis precesses in a direction normal to the instantaneous $\bar{V}$-$\bar{\omega}$ plane, the force components rotate in such a way that they stay in that plane. The resulting motion of the spin axis will describe a cone about the velocity vector. If the torque components that tend to drive $\bar{\omega}$ away from $\bar{V}$ are larger than those that tend to drive them together, the flight mode is unstable and $\bar{\omega}$ will cone about $\bar{V}$ in an ever increasing spiral. If the mode is stable, $\bar{\omega}$ will spiral inward, toward $\bar{V}$. The mode is unstable for the Probe Bus. Since the earth-vector is approximately 14° from the spin axis at encounter and since the gain margin of the earth communications antenna becomes negative at a cone angle of 30°, the earth communications will be lost when the spin axis spirals out to a point that is about 16° from the velocity vector.

The nominal angle of attack is zero, which, if precisely true, would yield no initial disturbance torque and no spiral. In actuality, the angle of attack will not be exactly zero and the spiraling motion will occur. The exact choice for an initial angle of attack has little effect on the outcome. The rate of change of atmospheric density with altitude is such that from 250 km to about 120 km the spiraling motion will add only about 1 degree to the angle of attack no matter what the initial angle is over a 10-degree range. Then, when the spiral does begin to increase, it diverges so rapidly that communications would be lost at about the same altitude for any initial angle of attack.

4.1.2.3 Nutation. A spinning body will always tend towards a spin about its axis of maximum moment of inertia, because this is the lowest rotational energy state. A "pure spin" equilbrium is characterized by coincidence of the body spin (maximum inertia) axis, angular velocity vector and angular momentum vector. External moments such as those arising during jet maneuvers will usually perturb the "pure spin" state by accumulating angular velocity and angular momentum orthogonal to the body spin axis. Nutation refers to the angular motion of the spinning body under such a perturbation. The resulting nutational motion for a body whose spin axis is an axis of symmetry (i.e., moments of inertia about all axes perpendicular to the spin axis are equal) is illustrated in Figure 4.1.2.3-1. In inertial space, the body spin axis is observed to cone counterclockwise around the angular momentum vector at the inertial nutation rate, ω_n. The latter frequency is the product of the spin-to-transverse moment of inertia ratio, σ (greater than one), and the spin speed, ω_z. Two important observations can be made from study of the figure. The first is that with respect to a body-fixed observer, the angular momentum vector appears to cone counterclockwise around the body spin axis at inertial nutation frequency minus spin speed (i.e., body nutation frequency, $\Omega = (\sigma-1)\ \omega_z$). This is the frequency at which any dampers on the spinning body are excited. The second observation is that any sensor (e.g., sun sensor) which samples the angle between the spin axis and an inertial target direction once a spin period, will detect an amplitude modulation on the measured angle at the difference (body nutation) frequency. Thus, for example, nutation would generate a sinusoidal variation about the average value of the $\psi\psi_2$ date type at 20% of spin frequency, if σ were 1.2. An attitude sensor/spin rate detector such as the sun sensor is, therefore, a useful nutation/mass properties sensor on a spinning body.

The Pioneer Venus Multiprobe is a slightly asymmetrical body, i.e., moments of inertia about axes perpendicular to the spin axis are unequal. The resulting nutational motion for such a body is somewhat more complicated than the symmetrical case, as illustrated in Figure 4.1.2.3-2. The body spin axis is observed to precess counterclockwise around the angular momentum vector at a nutation angle, θ, which varies between θ_{min} and θ_{max}. The precession rate can still be identified as the inertial nutation rate, ω_n, where the latter frequency is the product of the effective spin-to-transverse moment of inertia σ_e (greater than one) and the spin speed ω_z. σ_e is defined by:

$$\sigma_e = 1 + \sqrt{(\sigma_1 - 1)\ (\sigma_2 - 1)}$$

Where σ_1 is the ratio of the spin to maximum transverse moment of inertia (Iz/Ix), and σ_2 is the ratio of the spin to minimum transverse moment of inertia (Iz/Iy). The nutation angle varies because of the tendency for the nutation angle to increase when the angular momentum vector approaches the plane defined by the axes of spin and maximum transverse moments of inertia. Since the angular momentum vector appears (to a body-fixed observer) to cone about the body spin axis at body nutation frequency ($\Omega_e = (\sigma_e - 1)\ \omega_z$), it will approach the plane of interest at twice this frequency. In inertial space, then, the spin axis spirals from θ_{min} to θ_{max} and back to θ_{min} at twice body nutation frequency, while precessing about the angular momentum vector at inertial nutation frequency. The ratio of the maximum to minimum nutation angles is defined by:

$$\frac{\theta_{max}}{\theta_{min}} = \sqrt{\frac{\sigma_2 - 1}{\sigma_1 - 1}}$$

This ratio is approximately 1.03 for the Pioneer Venus Multiprobe, so that any distortion in the amplitude of the sinusoidal variation in sun angle at body nutation frequency is negligible.

Nutation will be induced by any thrusting maneuver which generates a torque about the spacecraft center of mass that is orthogonal to the spin axis for a noninteger number of body nutation periods. After spinup, the continuous firing of a single axial jet is the major source of nutation. A thruster firing for an integer plus a half nutation period will develop a peak average nutation proportional to the transverse torque and inversely proportional to the spin rotational energy ($1/2\ I_z\omega_z^2$) and (σ_e-1). Maximum nutation perturbation during cruise at 15 rpm is 2 degrees. A small nutation (<0.25 degree) will also be induced by continuous firings of radial thrusters during spin trim maneuvers.

Axial and radial thrusters will always be pulsed for a small fraction of the body nutation period. As a result, each pulse will induce a change in the nutation angle equivalent to the precession (angular movement of the angular momentum vector) per pulse. However, since the pulsing frequencies (spin speed and twice spin speed) are asynchronous with body nutation frequency, Ω_e, nutation will alternately increase and decrease. The maximum nutation, θ_p, resulting from a pulsing maneuver at frequency W_p which generates a precession per pulse, α_p, is given by:

$$\theta_p = \frac{\alpha_p}{\sin\left[\pi\left(\frac{\Omega_p}{\bar{w}_p}\right)\right]}$$

Precession maneuvers which pulse axial jets at spin frequency will generate the maximum nutation disturbance associated with pulse maneuvers. θ_p

is approximately 30% greater than the precession per pulse.

Nutation is damped by employing onboard movable devices that dissipate energy associated with the transverse angular rates so that the principal axis of maximum moment of inertia can become coincident with the angular momentum (constant in the absence of external torque). The spin speed will always increase slightly during the passive damping process, consistent with both conservation of angular momentum and the lowest possible energy state for "pure spin". The analytical method, corroborated by many in-orbit observations, for describing the converging character of the nutation angle is the time constant approximation. The basic assumption is that the rate of nutation angle change is proportional to nutation angle; the resulting exponential decay of nutation angle is described via the time constant (the reciprocal of the proportionality constant). Nutation dampers will generate different rates of decay over different regions of nutation angle; time constants, therefore, are identified with specific ranges of nutation.

The method for onboard nutation damping is provided by the freon tube damper described in 3.3.2.6. The damping performance of this device is a function of spin speed, mass properties, temperature, and nutation angle level. Figure 3.3.2.6-1 illustrates its performance over spin speed and temperature for small nutation angles(<1°). Table 3.3.2.6-1 defines damper performance for key mission events and their associated spin speed and nutation levels.

4.1.2.4 <u>Wobble</u>. The spacecraft Z axis is nominally aligned along the axis of maximum moment of inertia. In the absence of nutation, then, every point on the Multiprobe rotates about the Z axis. Uncertainties in the spacecraft alignment and balancing processes cause the true spin axis (axis of maximum moment of inertia) to be tilted with respect to the spacecraft Z axis. Consequently, every point on the multiprobe rotates about the tilted spin axis. This implies that the Z axis cones about the true spin axis at the tilt angle. This motion is referred to as wobble in deference to the behavior of the despun HGA beam on the orbiter; the motion is more properly labeled spin axis tilt on the Multiprobe.

The wobble or spin axis tilt angle is proportional to the spacecraft residual dynamic imbalance and inversely proportional to the difference between the spin and transverse moments of inertia. Since the Pioneer Venus Multiprobe is a slightly asymmetrical body, the wobble angle would be largest if the dynamic imbalance were located in the plane defined by the spin and maximum transverse moments of inertia. The dynamic imbalance component due to each error source has been assumed to lie in the worst plane in order to conservatively bound the total wobble angle error. The Multiprobe is a variable composite of the bus and probes. Three distinct configurations can be identified for wobble angle summaries; namely, the bus only, the bus + 3 Small Probes, and the bus + 3 Small Probes + Large Probes. Therefore, any dynamic imbalance of the parts (bus or probes) and installation tolerances in their assembly will, in general, generate different wobble angles for each configuration.

Table 4.1.2.4-1 lists the various uncertainty errors and their contributions to the wobble angle of the bus only (all probes separated). Residuals associated with any contributor are small so that the total wobble angle uncertainty is less than 0.014 degree. There are systematic error sources that are also listed in this table. The bus will be nominally balanced for the cruise configuration. Since the cap on the neutral mass spectrometer is nominally ejected prior to entry, a systematic 0.1 degree tilt of the true spin axis from the +Z axis (toward $\theta \approx 160°$) will be present during entry. Retraction of the Large Probe IFD connector will cause a small additional tilt ($\approx 0.003°$) the total rigid body wobble of the bus only configuration is 0.1 $\pm$0.014 degree.

Table 4.1.2.4-2 lists the various uncertainty errors and their contribution to the wobble angle of the Bus and 3 Small Probes (Large Probe separated). The residual imbalance of the bus (described above) contributes a wobble angle of 0.005 degree in this configuration. An uncertainty of 0.005 inch in the lateral location of the bus center of mass is the main integration error, causing an additional wobble of 0.003 degree. Uncertainty in the dynamic imbalance of each Small Probe is small, with a wobble contribution of only 0.001 degree. An uncertainty of 0.035 inch in the station of any Small Probe center of mass is the main integration error, causing a wobble of 0.027 degree per probe. There is a systematic error source that is also listed in this table. A measurable dynamic imbalance has been allocated to each Small Probe to accommodate potential difficulty in balancing the probes (balance weight/plane limitations). Recent preliminary balance of two Small Probes indicates that the allocated wobble contribution due to this source is conservative. The total rigid body wobble of the probe bus + 3 Small Probes configuration is ±0.007 ±0.046 degree.

Table 4.1.2.4-3 lists the various uncertainty errors and their contribution to the wobble angle of the probe bus + Large Probe + 3 Small Probes (cruise configuration). Wobble contributions due to residual bus imbalance, Small Probe imbalance and their integration into the Multiprobe have been appropriately scaled to this configuration. The residual imbalance of the Large Probe contributes a wobble angle of 0.006 degree in this configuration. An uncertainty of 0.032 inch in the lateral location of the Large Probe center of mass is the main integration error, causing a wobble of 0.047 degree. The Large Probe is assumed to be nominally balanced; any difficulty in realizing this state can be overcome by laterally positioning the Large Probe on the Multiprobe such that the measurable center of mass offset counterbalances any measurable product of inertia. The total rigid body wobble of the probe bus + Large Probe + 3 Small Probes configuration is ±0.011 ±0.087 degree.

There are two non-rigid parts of the spacecraft: namely, hydrazine propellant and nutation damper fluid, that can increase the wobble. Any spin axis tilt toward one hydrazine tank would cause fluid to migrate to the other tank in order to keep the free surface in each tank equidistant from the spin axis. The result of this migration is to amplify the wobble component in the plane containing the tanks and the Z axis. The magnitude of the amplification is dependent on the propellant fill fraction, difference in station between the system center of mass and propellant tanks, and the difference between the spin and transverse moments of inertia. Studies indicate that the worst case amplification of 1.85 occurs in the cruise configuration at a propellant fill fraction of 33%. The substantial difference (≈30 inches) between stations of the system center of mass and propellant tanks is the main contributor to the large amplification. Worst case amplification factors of 1.08 and 1.18 apply to the bus only and bus +3 Small Probe configurations, respectively.

Similarly, any spin axis tilt toward the nutation damper would cause damper fluid to move such that the free surface is always parallel to the spin axis. The readjustment of damper fluid amplifies the wobble component in the plane containing the damper and the Z axis; the worst case amplification is 1.03. When both hydrazine and damper fluid are present on-board, the displacement of one fluid is coupled to the displacement of the other. Studies indicate that the worst case resultant amplification factors due to both fluids are 1.9, 1.22 and 1.12 for the bus + all probes, bus + Small Probes and bus only configurations. Table 4.1.2.4-1 indicates that the maximum expected wobble angle for the bus prior to entry is 0.128 degree. Table 4.1.2.4-2 indicates that the maximum expected wobble angle for the bus + 3 Small Probes is 0.067 degree. In order to assess the total wobble angle for the bus + all probes, it is necessary to note that any Large Probe center of mass offset toward propellant tanks to compensate for its measurable dynamic imbalance will cause propellant redistribution between tanks. Table 4.1.2.4-3 indicates that an intentional offset of the Large Probe center of mass by 0.05 inch causes a wobble angle of 0.03 degree. After amplification, the maximum expected wobble angle for the bus + all probes is 0.196 degree.

Multiprobe wobble causes a small reduction in the received signal strength from the medium gain horn and a negligible change in the omni patterns. Wobble will also affect sun and star sensor alignment parameters; calibration of biases in these parameters due to spin axis tilt will be necessary in order to accurately define attitude. Wobble will also affect axial jet alignment, causing equal and identical spin biases on the two axial jets.

There are several times in the mission where wobble has a transitory nature. ΔV maneuvers may temporarily draw propellant asymmetrically from one tank causing momentary wobble changes of at most 0.5 degree; after redistribution of propellant (less than 1 hour), only the fuel amplification effect discussed above will be present. It is expected that wobble will also change whenever any of the probes are released.

4.1.3 <u>Mission Dynamics</u>

4.1.3.1 <u>Launch Vehicle Separation Spacecraft Spinup Dynamics</u>. Spacecraft separation occurs when the Centaur sequencer fires the two explosive bolts releasing the V-band clamp which holds the spacecraft to the attach fitting. When the attach fitting and spacecraft physically separate, two redundant separation switches are activated, each independently initiating one of the two command memories that contains the spin-up sequence of commands. The spacecraft clears the attach fitting 2.12 seconds after separation (Ts+2.12 seconds), spinup jet firing follows at Ts+3.5 seconds, and spinup to 15 rpm is completed at Ts+122 seconds.

With all probes attached, the center of mass (c.m.) of the Multiprobe spacecraft is located along the Z-axis. As a consequence, the lateral force of each of the four separation springs (arising from the axial compression) can be selectively aligned to hold the deterministic portion of the spacecraft tip-off rate to 0.03 degree/second. The tip-off rate indicated in Table 4.1.3.1-1 is inclusive of the Centaur rate prior to separation, estimated at 0.7 degree/second (RSS for pitch and yaw).

With the Multiprobe separated, the initial spinup maneuver begins at Ts+3.5 seconds. During spinup, the spacecraft momentum vector will be under the influence of deterministic torques perpendicular to the nominal spin direction. These deterministic transverse torques result from the independent canting of the two pairs of radial jets to fire through system c.m. locations at different times in the mission. As shown in Figure 3.4.1-3, jets R3 and R4 are aimed at the spacecraft c.m. location prior to Large Probe release to minimize precession during the nominal ΔV maneuvers. The other pair of jets (R1 and R2) is aimed at the center of mass with only the three Small Probes attached to minimize precession during ΔV maneuvers in that phase of the mission.

The radial jet pair which is not aimed at the current c.m. location could be used for precision attitude control, or as a backup attitude precession mode.

The transverse torque causes a deterministic attitude displacement of the spacecraft momentum vector toward the initial direction of the total torque, as shown in Figure 4.1.3.1-1. This dynamic phenomena can be understood by noting that for a body whose ratio of roll inertia to pitch inertia is near one (1), the principal axis tends to cone about the instantaneous angular momentum vector in inertial space at nearly the same rate at which the body spins about its principal axis. Therefore, the total torque exerted on such a body tends to be fixed in inertial space and momentum tends to accumulate along the initial direction of the total torque.

The results of this analysis are seen to yield a momentum vector tilt of 11.8 degrees as shown in the review of spinup performance given in Table 4.1.3.1-2. A priori knowledge of the magnitude and direction of this motion enables the Centaur vehicle to be used to bias the spacecraft attitude prior to separation so that the deterministic effects experienced during separation and initial spinup will position the average attitude vector to a desired attitude. In this way, with deterministic errors combined with Centaur reorientation, the final attitude uncertainty of 10.2 degrees is seen to result purely from random sources.

Since the desired average attitude vector pointing for the Multiprobe spacecraft following spinup is in the general direction of the south ecliptic pole, it is, therefore, necessary only to position the attitude of the Centaur along a cone about the south pole pointing direction whose half-angle is 11.8 degrees, as is shown in a simplified view (Figure 4.1.3.1-2), looking at the spacecraft average attitude vector from the south ecliptic pole. With the desired roll orientation of the spacecraft X-axis determined from other requirements, the roll position of the Centaur (in effect, the location of the Centaur attitude vector along the edge of the cone) can be prescribed so that the momentum tilt occurring during the subsequent spinup maneuver will return the spacecraft to a south pole pointing direction. For the situation pictured in Figure 4.1.3.1-2, with the requirement that the tilt be performed in the spacecraft Z-geometric axis/sunline plane, the Centaur must place the spacecraft coordinates as shown in Figure 4.1.3.1-1.

4.1.3.2 Large Probe Separation From Probe Bus. The release of the Large Probe is scheduled to occur 24 days prior to Venus entry with the vehicle at a sun angle of ≈30° and spinning at 15 rpm.

The release subsystem consists of three matched springs located at a 22.5 inch radius around the base of the Large Probe. The spring characteristics are listed in Table 4.1.3.2-1. The springs are actuated by an explosive nut with redundant pressure cartridge, with a 3/8" bolt which is held captive after ejection.

The only conceivable clearance problem existing during separation concerns potential recontact of the lower lip of the aeroshell of the Large Probe with the forward omni-antenna. This antenna lies radially outboard at a distance of 38.5" from the bus centerline and extends axially to a point some 54" from the separation plane. The first bending natural frequency of the antenna is above 30 cps, and with the vehicle spinning at 15 rpm, flexibility effects were not considered important in the separation analysis.

Worst case studies of off-nominal conditions such as c.g. offset, probe dynamic imbalance and offset, misalignment impulse and initial bus nutation show positive clearance when initial nutation is less than 4 degrees. (The nominal clearance is 10.3 inches). A summary of Large Probe separation system performance is shown in Table 4.1.3.2-2.

4.1.3.3 Small Probe Separation From Probe Bus/Small Probe Despin. The three Small Probes carried by the Multiprobe are scheduled to be released 20 days prior to Venus entry, with the spacecraft at a sun angle of ≈20° and with a 48.5 rpm spin rate.

In the stowed position, the Small Probes are carried equidistant around the edge of the bus, with their centers nominally located at a radius of 39 inches from the geometric Z-axis of the bus. As shown in Figure 4.1.3.3-1, each probe is supported by a bus mounted ring, and is held to the vehicle with a pre-loaded semicircular clamp of radius 15 inches which cups the edge of the probe. At one end, the clamp interfaces with the bus mounted ring with an open hinged tang, while the explosive nut/bolt release assembly is located at the other end.

The explosive nut/bolt interface also houses a spring which provides energy to accelerate the clamp away from the probe during separation. The open hinge at the other end is machined so that the clamp will separate from the bus after it has rotated sufficiently (approximately 90°) to clear the emerging probe.

The release spring has been chosen to impart a relative velocity of 540°/sec to the clamp at relaxation to provide sufficient radial clearance between the probe and clamp, and the clamp is preloaded to 1200 lbs. to withstand centrifugal forces acting on the probe in the spin environment. Other release system characteristics are outlined in Table 4.1.3.3-1.

At the separation event, the probe is under the influence of the centrifugal forces and also an impulsive type force due to the release of energy stored in pre-loading the clamp. As the probe moves from the bus, it follows a trajectory closely approximating an involute, as shown in Figure 4.1.3.3-2.

Potential recontact of two structures which protrude downward from the Small Probe, the SNFR/SAS housing, and the omni-antenna radome, are of primary concern. The nominal clearance values for these structures, and the clearance geometry for both the radial and axial planes is shown in Figure 4.1.3.3-2. To provide for additional clearance the upper surface of the bus structure has been cut out, as shown in these figures.

The maximum radial and axial clearance losses recorded in analytical studies of the separation are given in Table 4.1.3.3-2 which indicates that there will be no clearance problem. The performance of the separation subsystem as pertaining to ΔV targeting biases and post separation attitudes is given in Table 4.1.3.3-3.

TABLE 4.1.1.4-1

MULTIPROBE MANEUVER PROFILE

NOTES:
S = Time of Separation
L = Time of Launch
E = Time of Encounter
* = Two Part Maneuver

A = Axial Jet
R = Radial Jet
+ = Spin-Up

Maneuver Description	Mission Phase (Cross-Coupling Errors Treated In 4.3.1) Nominal Maneuver: ΔV M/Sec	ΔP Deg.	Δ RPM	Prop. Req. Lbs.	Mission Time (Days)	Thruster	Pulse Width (Msec)	No. of Pulses	Execution Time (Δ Hours)
Initial Spin-up	0.69	11.6	+15.0	1.64	S	R1 · R3	-	-	0.032
First Midcourse Rad ΔV	12	-	-	11.27	L+5	R3 · R4	512	1813	2.01
First Midcourse Ax. ΔV	12	-	-	9.93	L+5	A5 + A6	-	-	0.547
Second Midcourse Rad ΔV	0.7	-	-	0.63	L+20	R3 · R4	128	444	0.493
Second Midcourse Ax. ΔV	0.7	-	-	0.57	L+20	A5 + A6	-	-	0.032
Third TCM Radial ΔV	0.1	-	-	0.09	E-28	R3 · R4	128	63	0.070
Third TCM Axial ΔV	0.1	-	-	0.08	E-28	A5 + A6	-	-	0.005
End Fire Reorientation	-	90	-	1.3	E-28	A5 · A6	128	935	1.039
Large Probe Reorient.	-	44	-	0.64	E-24	A5 · A6	128	457	0.508
End Fire Reorientation	-	48	-	0.64	E-24	A5 · A6	128	462	0.513
Small Probe Spin-Up	2.24	-	+33.5	2.93	E-23	R1 · R3	-	-	0.087
Small Probe Target (Rad.)	4.0	-	-	2.34	E-23	R1 · R2	128	1779	0.611
Small Probe Sep. Reor.*	-	49.7	-	2.17	E-20	A5 · A6	128	1724	0.592
End Fire Reorientation	-	31.5	-	0.61	E-20	A5 · A6	128	488	0.168
Bus Target. Reor.	2.15	33.8	-	0.63	E-18	A5	128	1003	0.345
Bus Target. (Axial)	15.0	-	-	3.9	E-18	A5	-	-	0.257
End Fire Reorientation	2.17	33.8	-	0.63	E-18	A5	128	1078	0.370
Reor for Bus Entry	1.27	18	-	0.37	E-8	A5	128	629	0.216
Bus Spin-Down	[illegible]2	-	-38.5	1.66	E-8	R2 · R4	-	-	0.051

TABLE 4.1.2.4-1

MULTIPROBE WOBBLE ANGLE SUMMARY I

(BUS ONLY)

Contributor	Wobble Angle (Deg)
UNCERTAINTY ERRORS	
1. Alignment to Spin Balance Machine	±0.006
2. Spin Balance Machine Residual	±0.001
3. Propellant Tank/Lines Residuals	±0.003
4. Battery Pack Changeouts	±0.008
5. Thermal Distortion	±0.01
RSS Uncertainty	±0.014
MEASURABLE ERRORS	
1. Large Probe IFD Connector (Retracted at Separation)	0.003
2. BNMS Cap (Ejected Prior to Bus Entry)	0.104
Total Rigid Body Wobble	0.1 ±0.014
Worst Case Amplification Factor	1.12
Maximum Expected Wobble Angle	0.128

TABLE 4.1.2.4-2

MULTIPROBE WOBBLE ANGLE SUMMARY II

(BUS + 3 SMALL PROBES)

Contributor		Wobble Angle (Deg)
UNCERTAINTY ERRORS		
A. Bus		
• Residual Bus Imbalance		±0.005
• Integration of Bus in Multiprobe		±0.003
B. Small Probe		
• Residual Small Probe Imbalance	Per Small Probe	±0.001
• Integration of Small Probe in Multiprobe	Per Small Probe	±0.027
RSS Uncertainty		±0.048
MEASURABLE ERRORS		
Allowable Small Probe Dynamic Imbalance	Per Small Probe	±0.004
Total Rigid Body Wobble		0.007 ±0.048
Worst Case Amplification Factor		1.22
Maximum Expected Wobble Angle		0.067

TABLE 4.1.2.4-3

MULTIPROBE WOBBLE ANGLE SUMMARY III

(BUS + LARGE PROBE + 3 SMALL PROBES)

Contributor	Wobble Angle (Deg)
UNCERTAINTY ERRORS	
A. Bus	
• Residual Bus Imbalance	±0.008
• Integration of Bus in Multiprobe	±0.009
B. Large Probe	
• Residual Large Probe Imbalance	±0.006
• Integration of Large Probe in Multiprobe	±0.047
C. Small Probe	
• Residual Small Probe Imbalance	Per Small Probe ±0.001
• Integration of Small Probe in Multiprobe	Per Small Probe ±0.041
RSS Uncertainty	±0.087
MEASURABLE ERRORS	
Allowable Small Probe Dynamic Imbalance	Per Small Probe ±0.006
Total Rigid Body Wobble	0.011 ±0.087
Propellant Redistribution Due to Large Probe Center of Mass Offset of 0.05 Inch	±0.03
Worst Case Amplification Factor	1.9
Maximum Expected Wobble Angle	0.196

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TABLE 4.1.3.1-1

CENTAUR REORIENTATION REQUIREMENT FOR MULTIPROBE

	CELESTIAL LATTITUDE (DEGREES)	CELESTIAL LONGITUDE (DEGREES)
Spacecraft Z-Axis Direction	-78.2°	θ_S
Spacecraft X-Axis Direction	+11.6°	θ_S -10.6°

θ_S - Desired celestial longitude for spacecraft X-axis

TABLE 4.1.3.1-2

MULTIPROBE SPIN-UP PERFORMANCE SUMMARY

ERROR SOURCE	ATTITUDE ERROR (DEG)	RESIDUAL NUTATION AT END OF MANEUVER (DEG)
1. TRANSVERSE TORQUE (DETERMINISTIC, 19% OF SPIN TORQUE)	11.8	1.9
2. TIP-OFF RATE (RANDOM, 0.72°/SEC)	8.9	0.4
RESULTANT*	8.9	2.0
3. ATTITUDE UNCERTAINITY OF CENTAUR	5.0	---
TOTAL	10.2	2.0

* DETERMINISTIC ATTITUDE ERROR CANCELLED BY CENTAUR REORIENTATION AND ROLL CONTROL.

TABLE 4.1.3.2-1

ARATION SPRING CHARACTERISTICS

FREE HEIGHT	5.2 INCH
COMPRESSED HEIGHT	3.2 INCH
SPRING RATE	125 LB./IN.
COMPRESSED SPRING FORCE	250 ±3 LB.
STROKE	1.1 ±.03 IN.
NUMBER OF SPRINGS	3

TABLE 4.1.3.2-2

LARGE PROBE SEPARATION SYSTEM PERFORMANCE

- SEPARATION VELOCITY ~2.5 FT/SEC (SPIN RATE 15 RPM)
- TIME TO CLEAR OMNI ~1.8 SEC (MAX NUTATION PRIOR TO SEPARATION < 4 DEGREE)
- MAX ANGLE OF ATTACK ERROR ~4.8 DEGREE

ANGLE OF ATTACK ERROR SOURCE	DEGREES		
	ATTITUDE ERROR (ANGULAR MOMENTUM)	NUTATION (PRINCIPAL AXIS)	WOBBLE (GEOMETRICAL AXIS)
BUS ATTITUDE UNCERTAINTY	2.00	0.10	.17
LARGE PROBE DYNAMIC IMBALANCE (1.25°) (1.25°)	0.30	0.95	1.25
SEPARATION TIPOFF (2°/SEC)	0.93	0.93	0.00
RSS	2.23	1.33	1.26

TABLE 4.1.3.3-1

SMALL PROBE SEPARATION SUBSYSTEM CHARACTERISTICS

SPINNING RATE	100 $\pm$5 lb/in
COMPRESSED SPRING FORCE	86 lb.
STROKE	0.66 in.

NOMINAL SPIN RATE	(RPM)	48.5
NOMINAL PROBE VELOCITY	(METERS/SEC)	5.0
SPRING RELEASE TIME	(MILLISECONDS)	6.0
ROTATIONAL VELOCITY OF CLAMP AT END OF SPRING STROKE	(DEG/SEC)	538.3
CLAMP RELEASE TIME	(MILLISECONDS)	141.0
CLAMP ROTATIONAL RATE AT TIME OF RELEASE	(DEG/SEC)	1073.1

TABLE 4.1.3.3-2

SMALL PROBE CLEARANCE

	Point No. (See Fig. 4.1.3.3-2)	Nominal Clearance	Worst Loss of Clearance
		(In.)	(In.)
Radial Points	1	0.38	0.06
	2	0.99	0.33
	3	0.00	*
	4	0.00	*
	5	0.00	*
Axial Points	101	0.96	0.48
	102	1.60	0.80
	103	5.00	1.47

*Grows Monotonically during release.

TABLE 4.1.3.3-3

SMALL PROBE SEPARATION AND DESPIN SUBSYSTEM PERFORMANCE

Description		Degrees				(M/Sec)		Degrees
	Spin Speed (RPM)	Attitude Error	Nutation	Wobble	Max. Angle of Attack Error	Out-of-Plane ΔV	In-Plane ΔV	In-Plane ΔV Direction
After Separation/Before Despin	48.5	3.8	2.2	1.25	7.25	0.18	0.1	1.1
After Despin	12.1	4.8	7.4	1.25	13.5			

NOTE:
- Error Sources include Probe location, Mass, Dynamic Balance, Release Time, Tip-off, Bus Attitude and Targeting Uncertainty.
- Maximum Allowance Entry Angle of Attack.

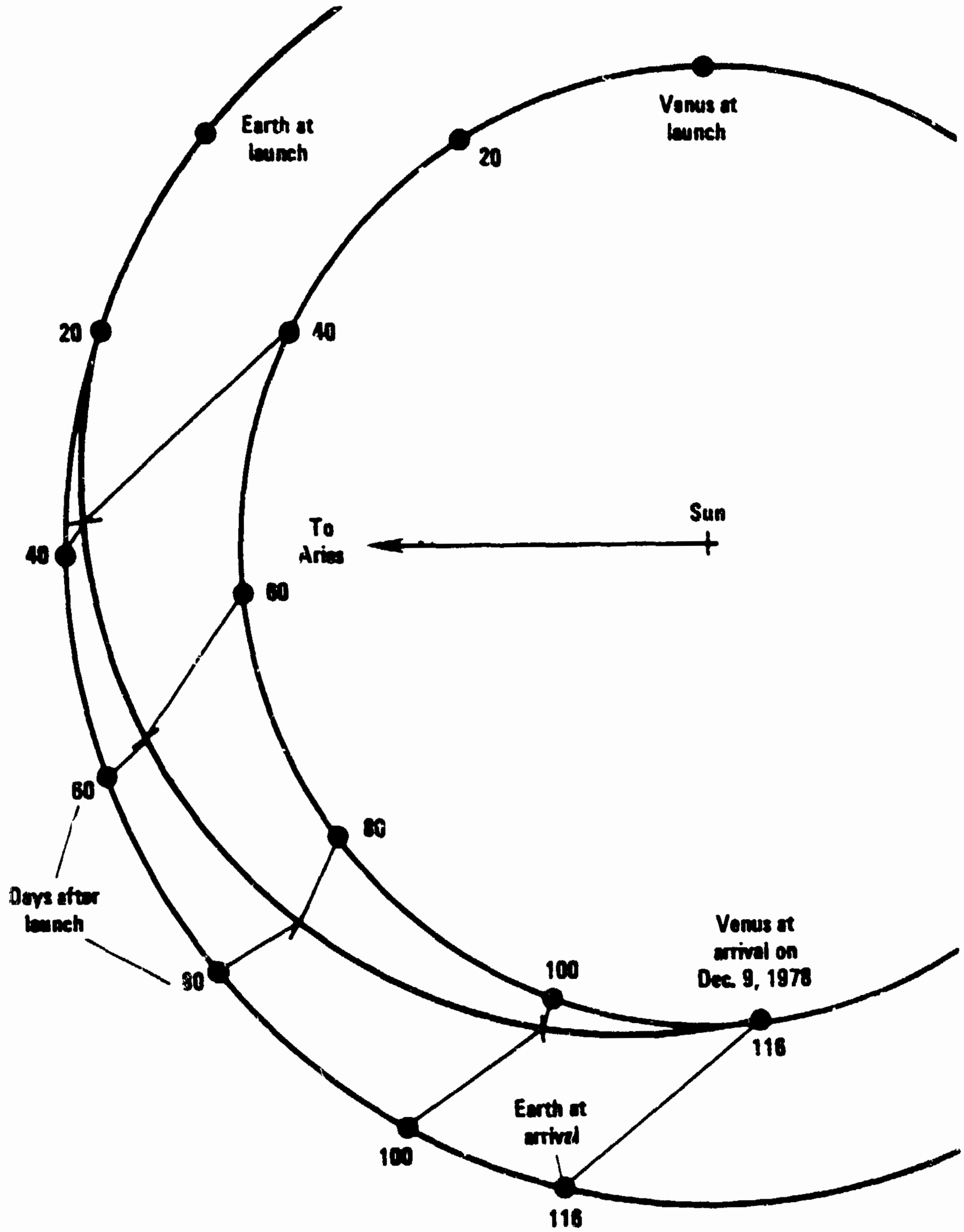

Figure 4.1.1.1-1. Multiprobe Trajectory Trace In Ecliptic Plane

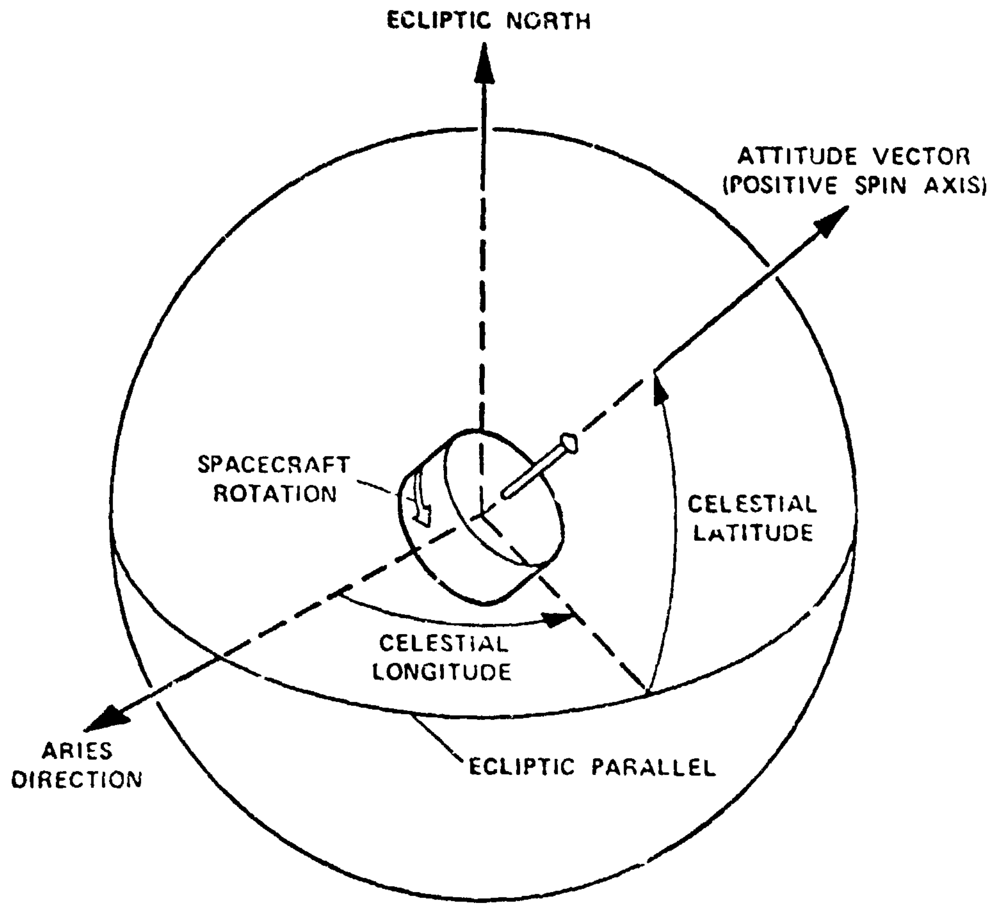

Figure 4.1.1.2-1. Representation Of Multiprobe Attitude

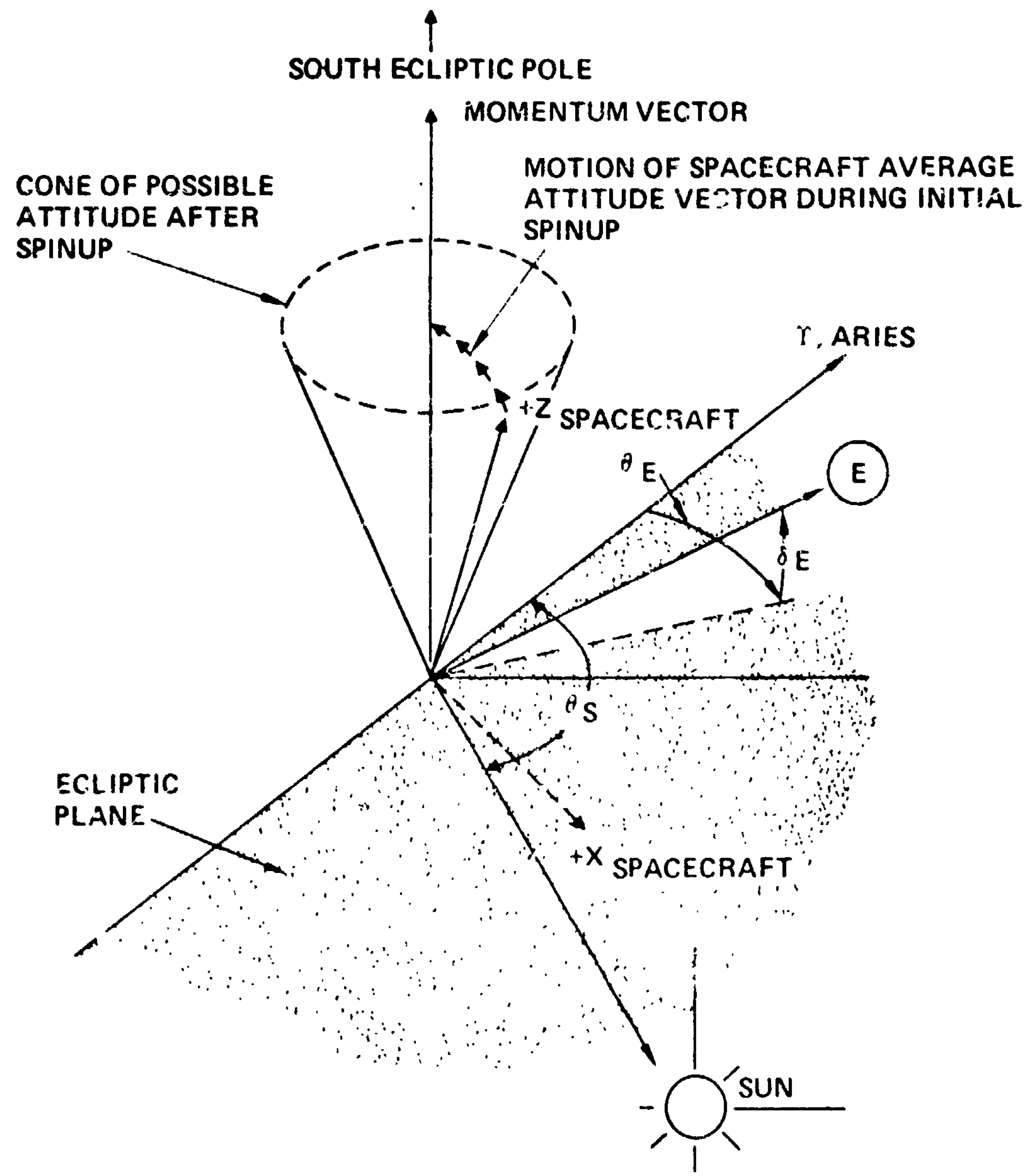

FIGURE 4.1.1.2-2 SEPARATION, SPINUP, AND INITIAL ACQUISITION GEOMETRY

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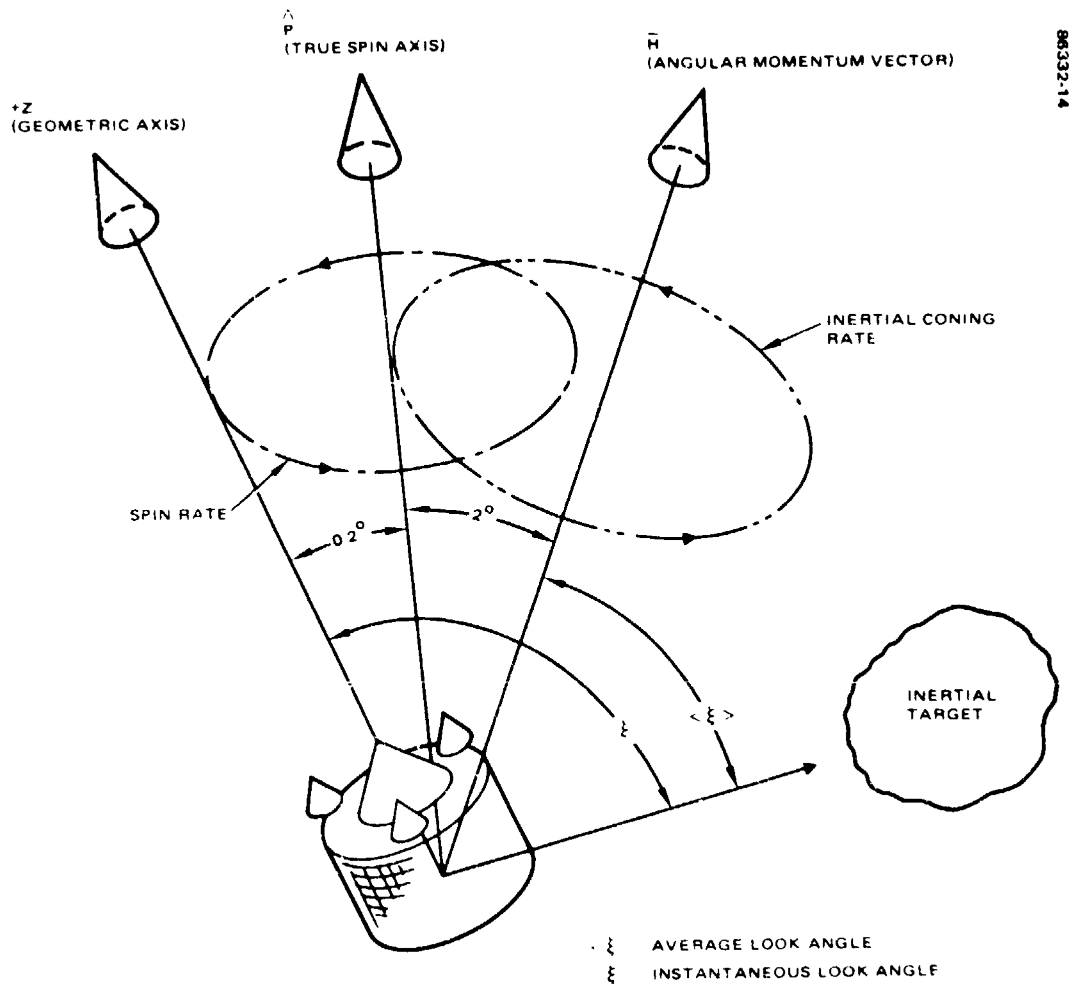

FIGURE 4.1.1.2.3 MOTION OF S/C +Z AXIS AND SPIN AXIS IN THE PRESENCE OF NUTATION, INCLUDING EFFECT OF SPIN AXIS TILT FROM THE S/C +Z AXIS

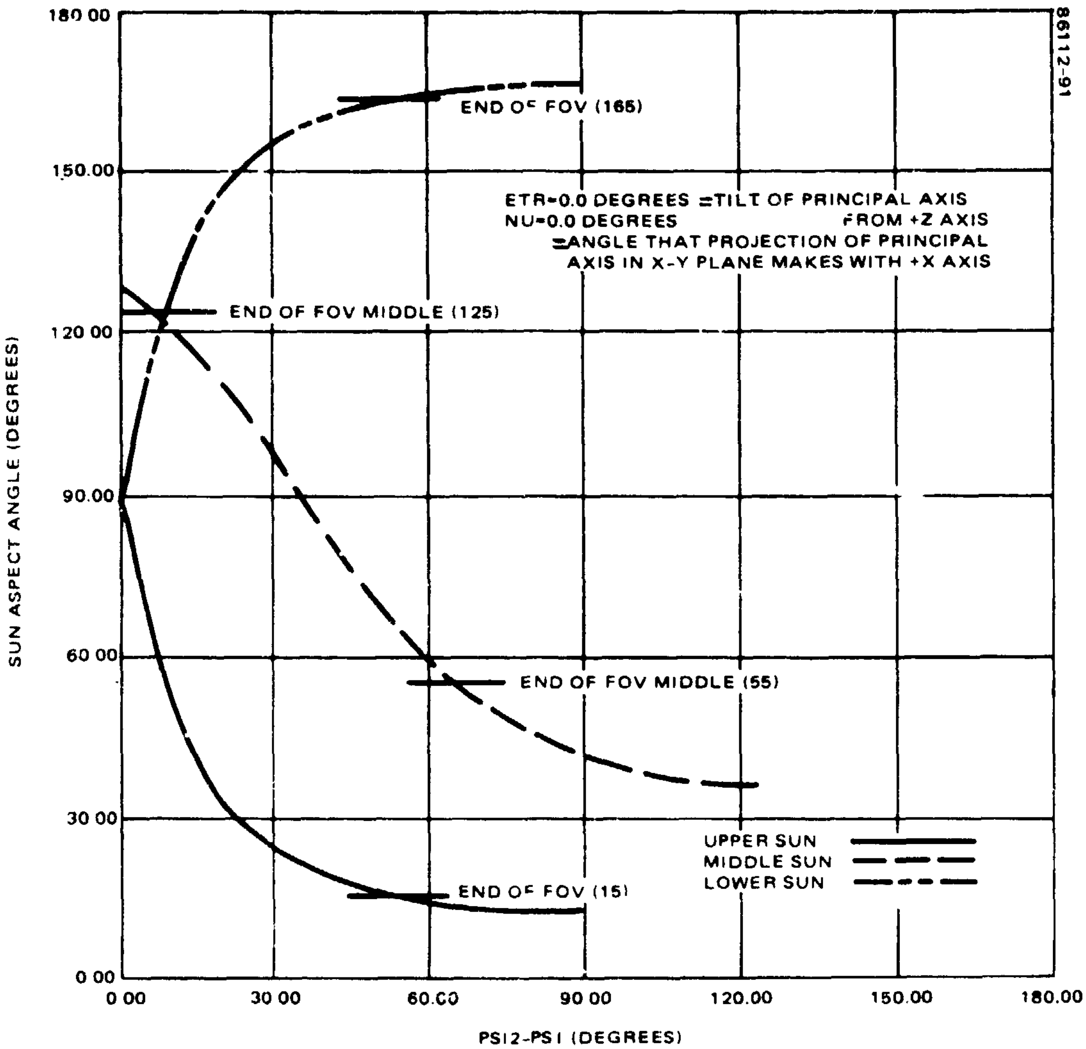

FIGURE 4.1.1.2-4 SUN SENSOR TRANSFER FUNCTION

NOTE· +Z AXIS ORIENTED TO SOUTH ECLIPTIC POLE DURING CRUISE

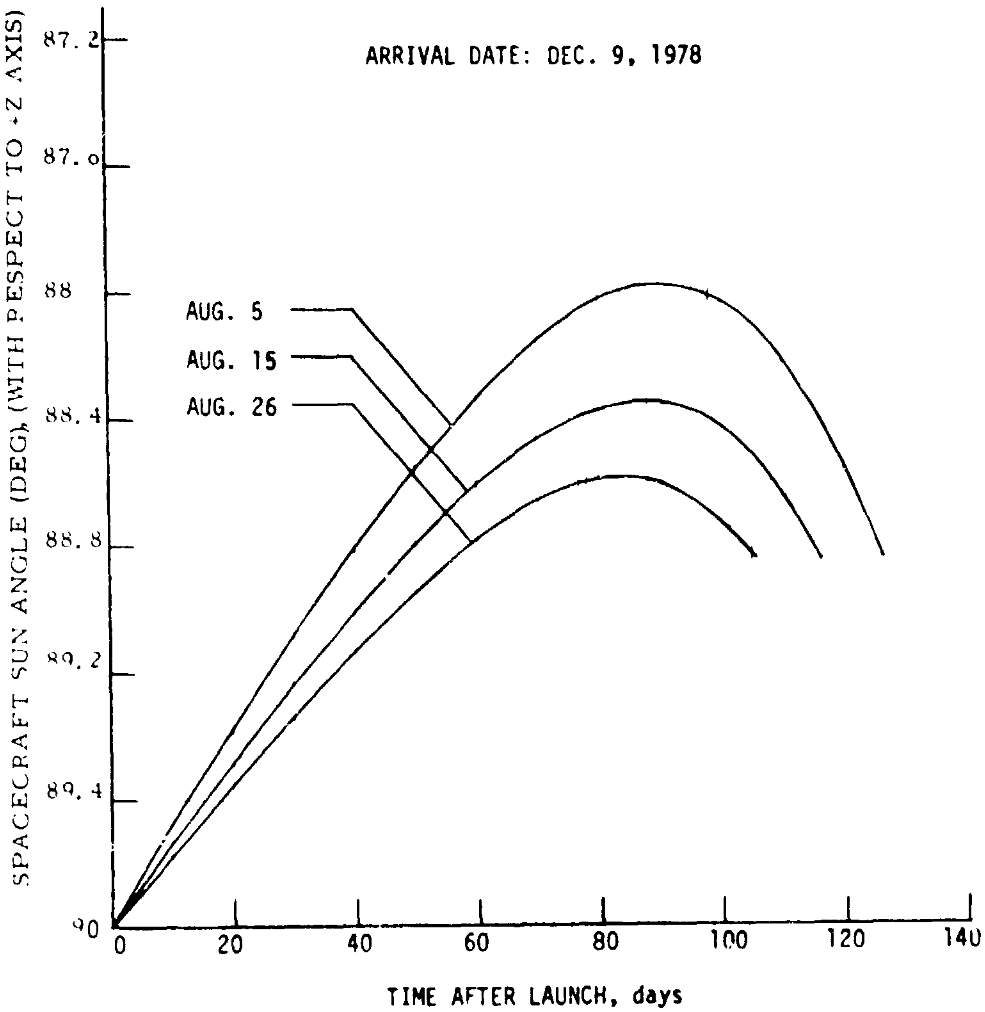

Figure 4.1.1.2-5. Multiprobe Cruise Sun Angle History

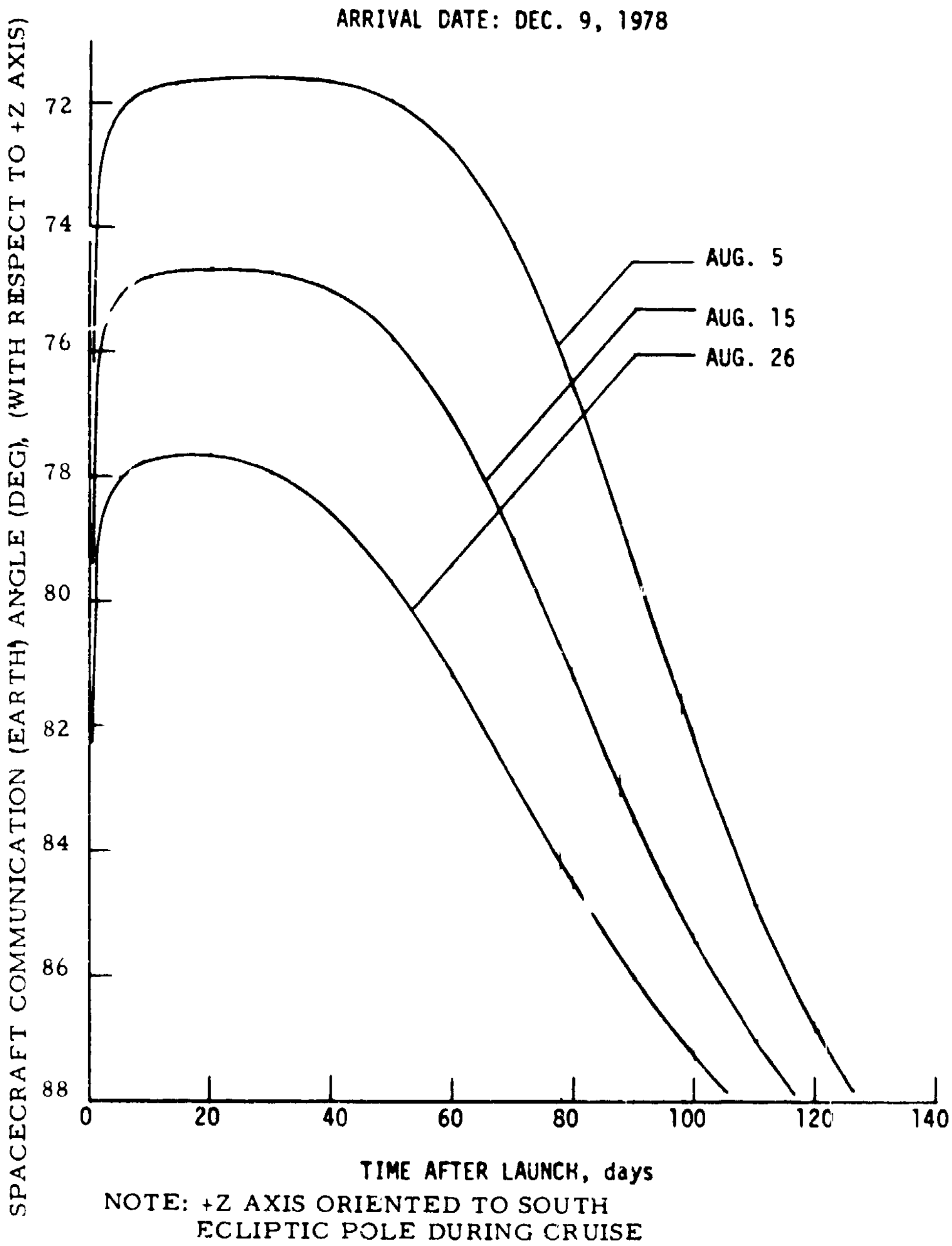

Figure 4.1.1.2-6. Multiprobe Cruise Communication Angle History

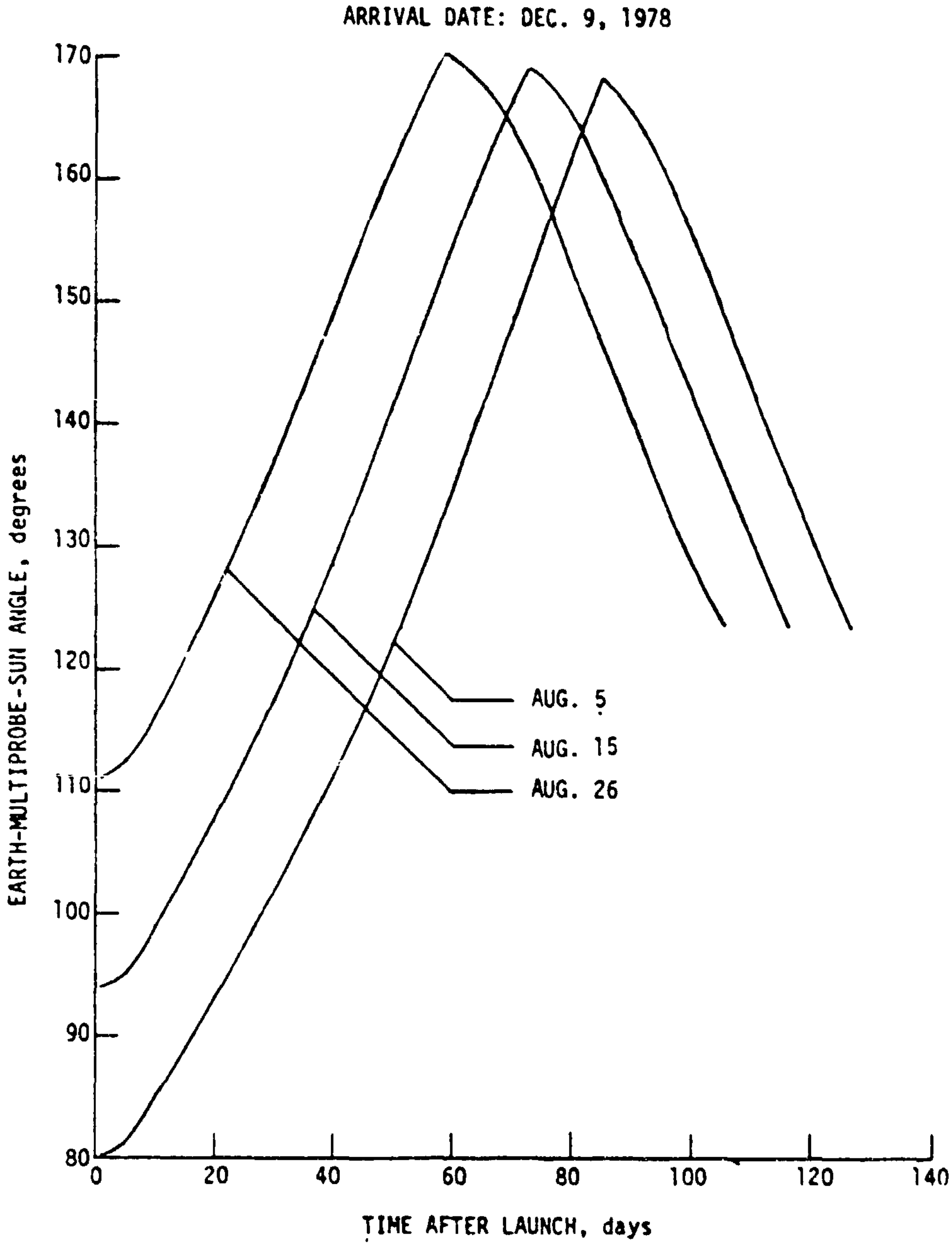

Figure 4.1.1.2-7. Earth-Multiprobe-Sun Angle During Interplanetary Cruise

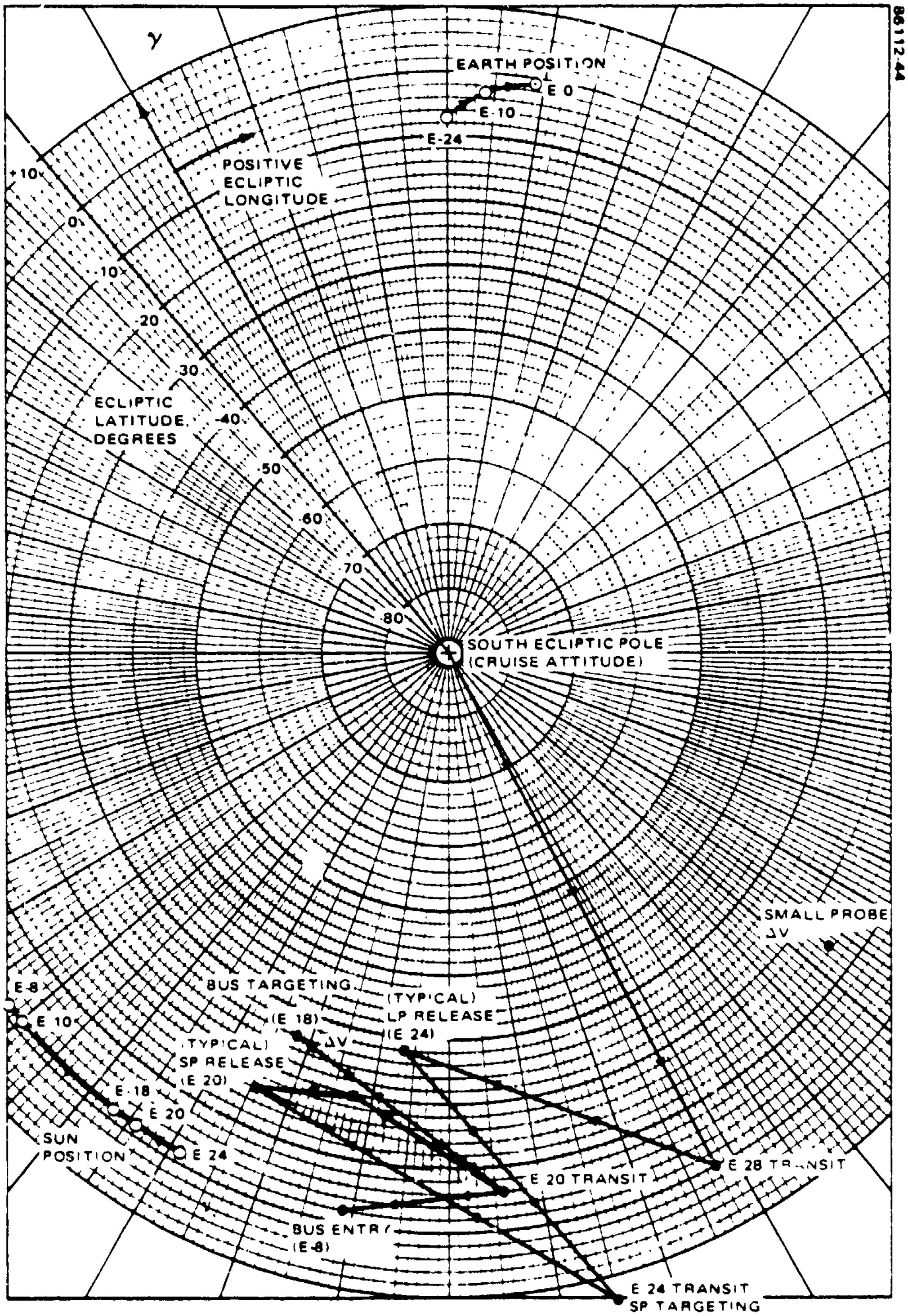

FIGURE 4 1 1 2-8 MULTIPROBE SPIN AXIS ATTITUDE HISTORY DURING ENCOUNTER

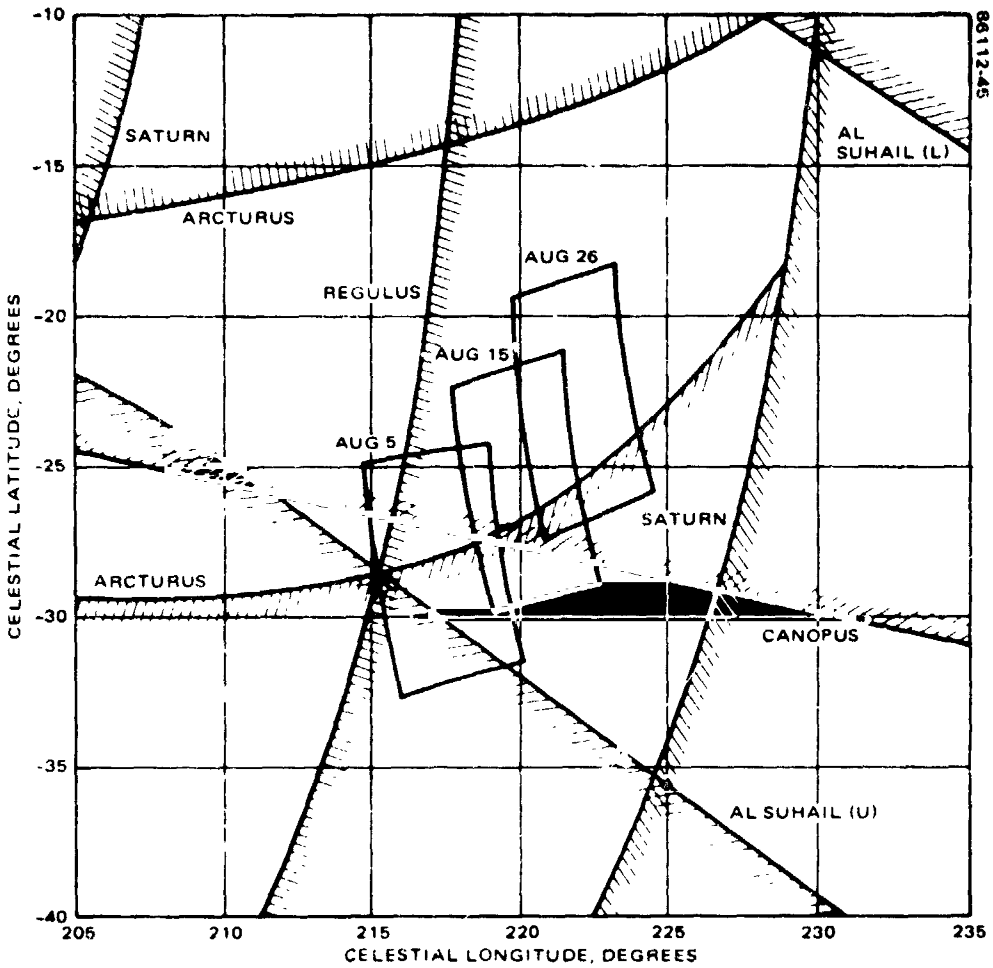

FIGURE 4.1.1.2-9 BUS ATTITUDE AT LARGE PROBE RELEASE – ARRIVE 9 DECEMBER 1978

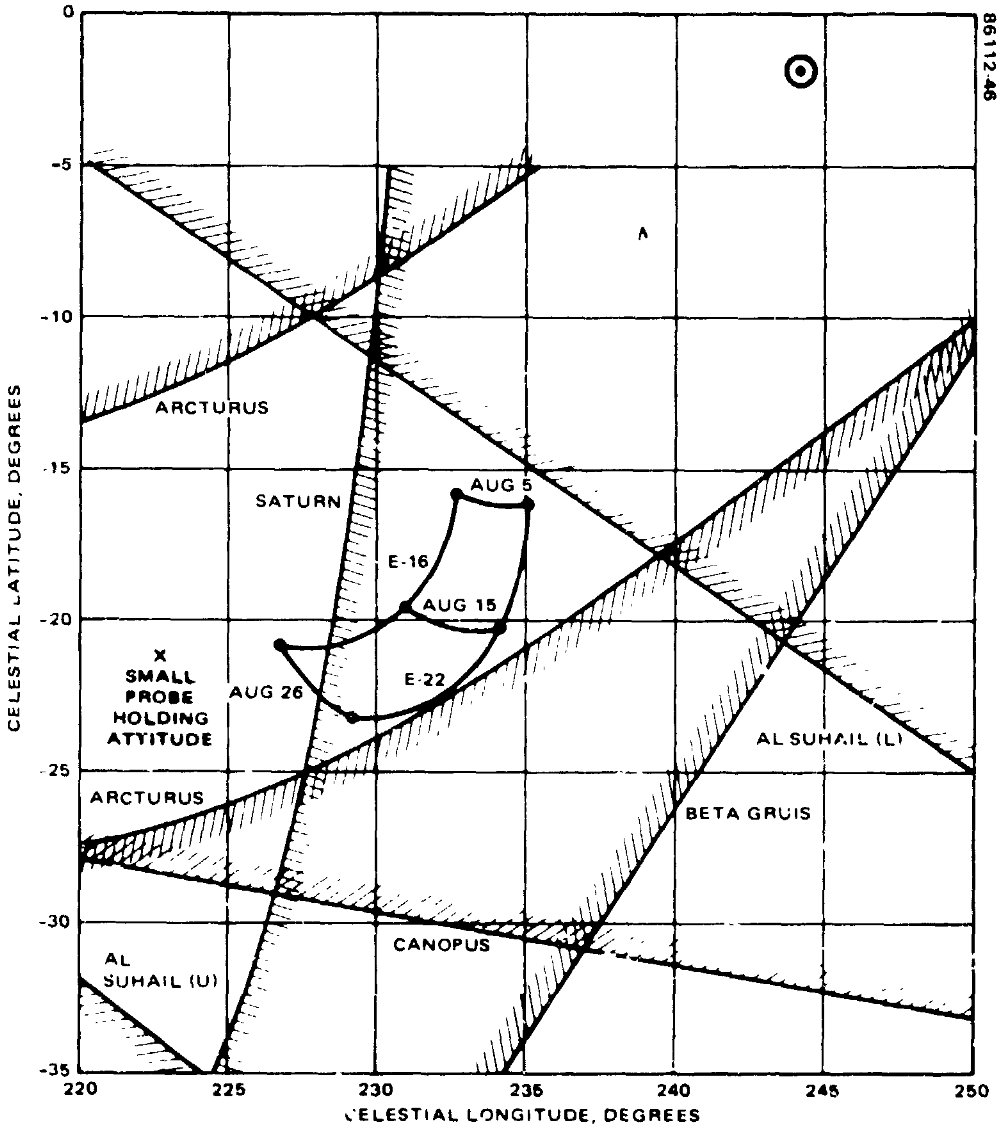

FIGURE 4.1.1.2-10. BUS ATTITUDE AT SMALL PROBE RELEASE – ARRIVE
9 DECEMBER 1978

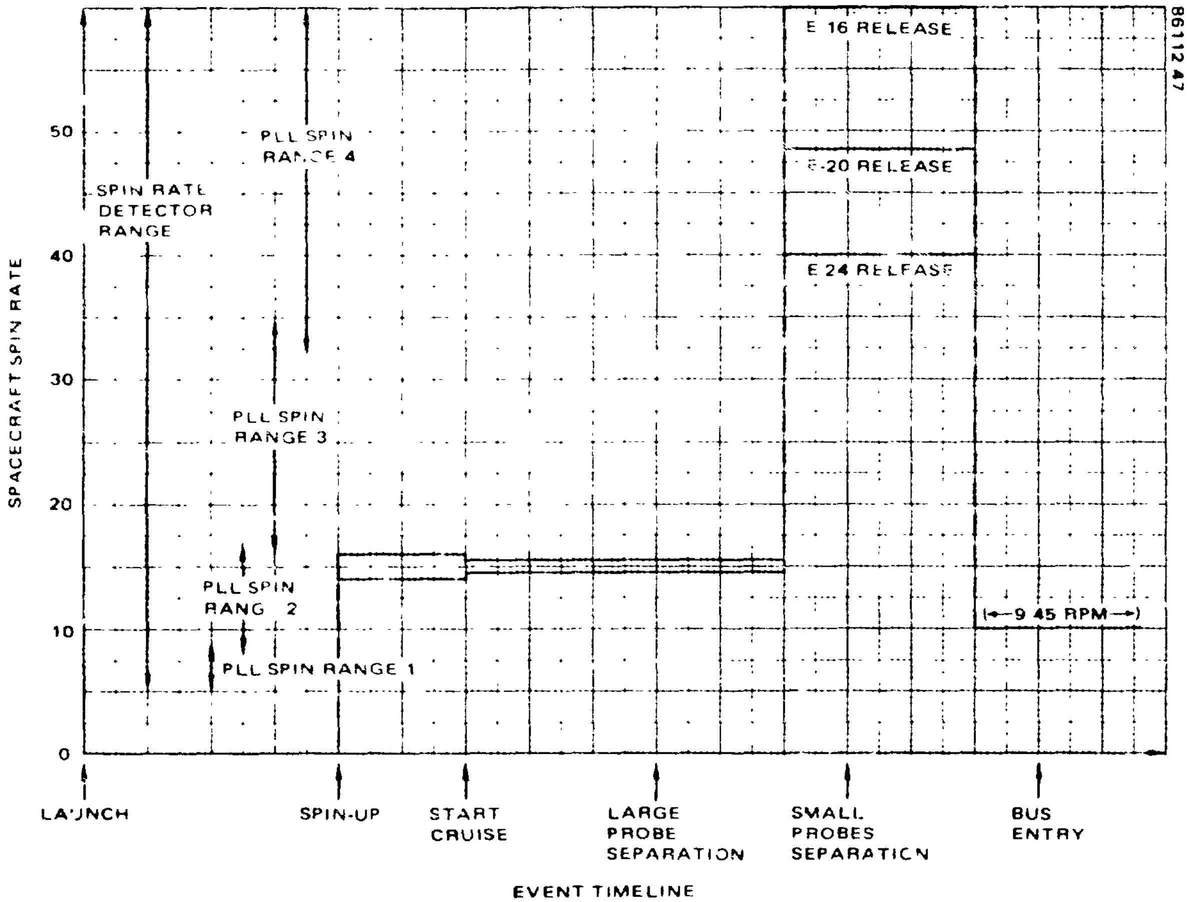

FIGURE 4.1.1.3 1 MULTIPROBE SPIN RATE HISTORY

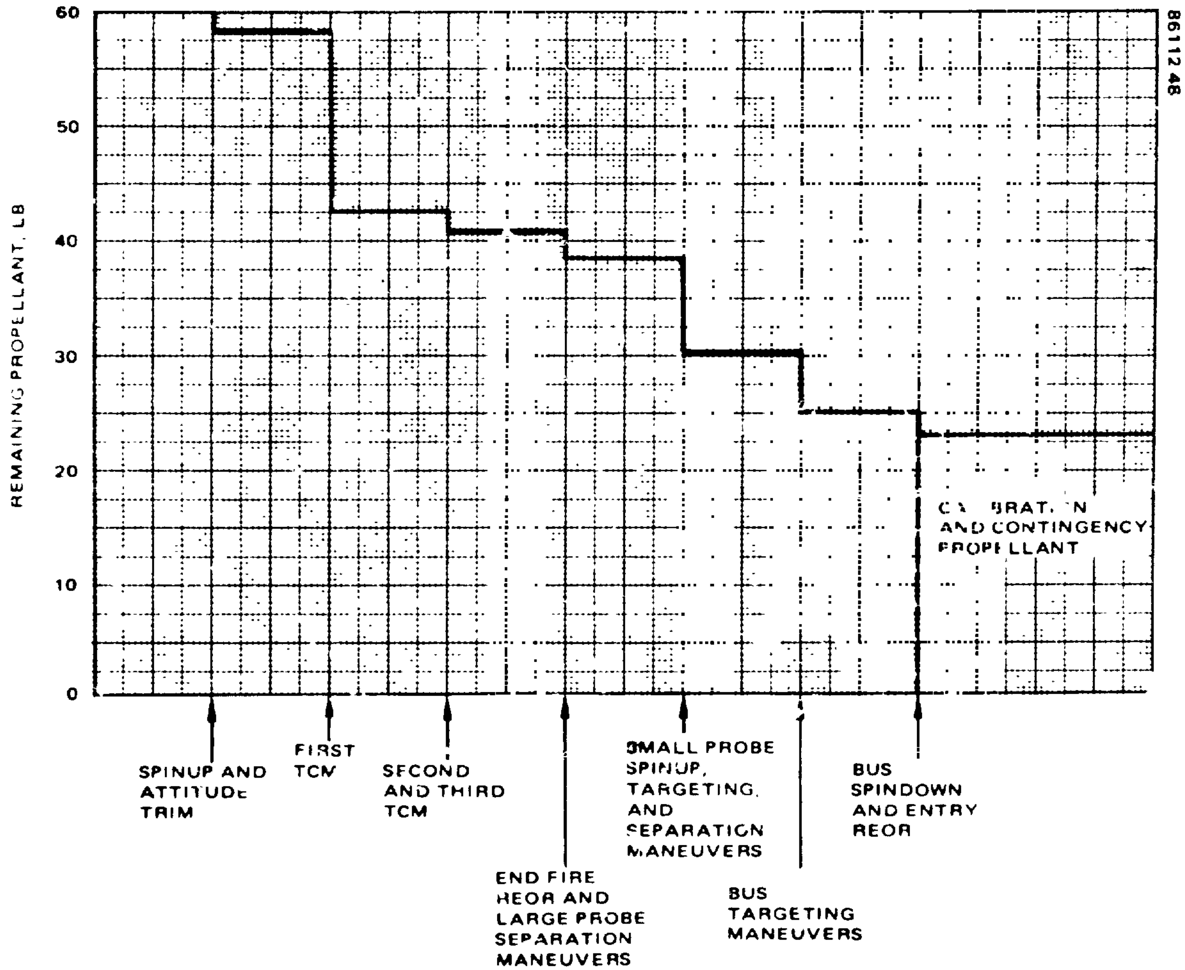

FIGURE 4.1.1.4-1. MULTIPROBE PROPELLANT UTILIZATION PROFILE

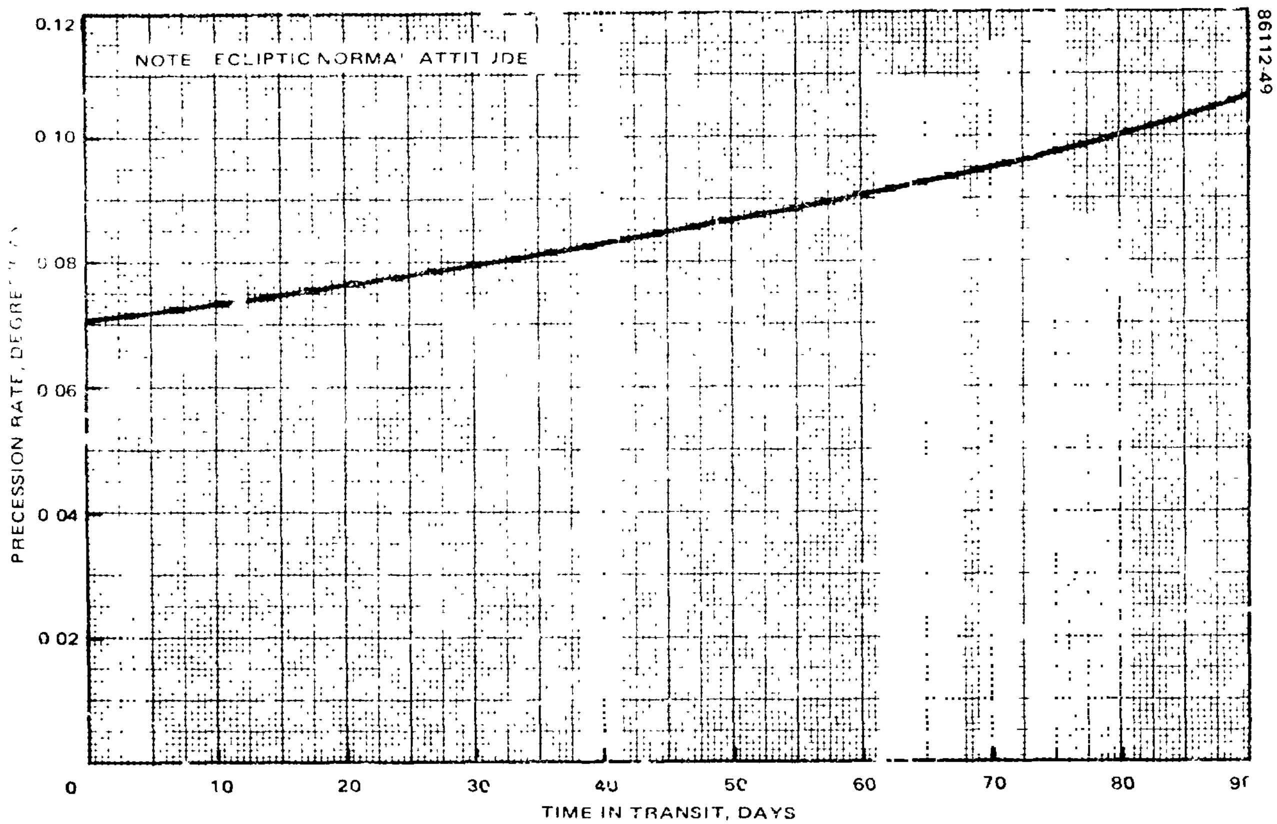

FIGURE 4.1.2.1.1. MULTIPROBE SOLAR TORQUE PRECESSION RATE DURING CRUISE

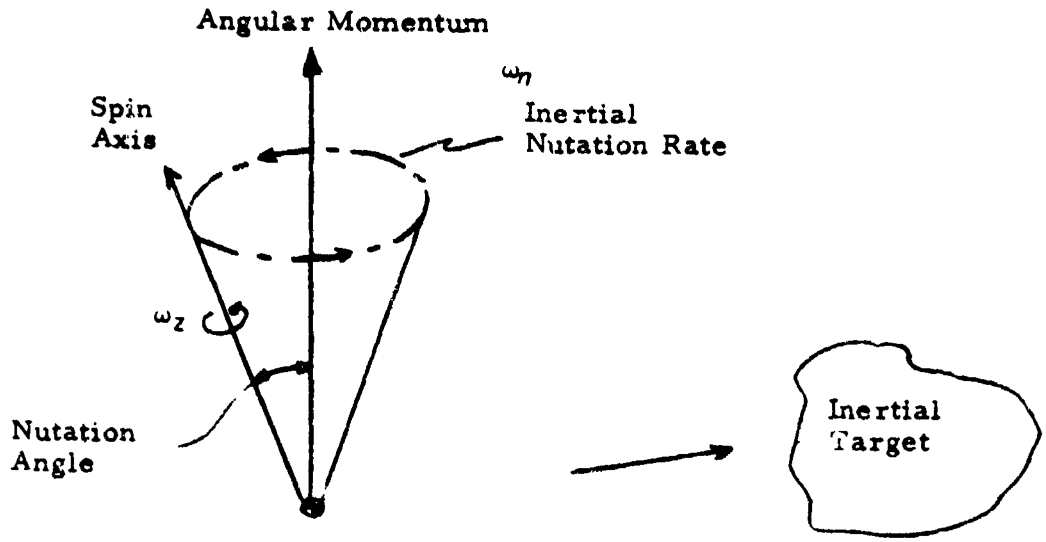

Figure 4.1.2.3-1. Nutation for Symmetric Body

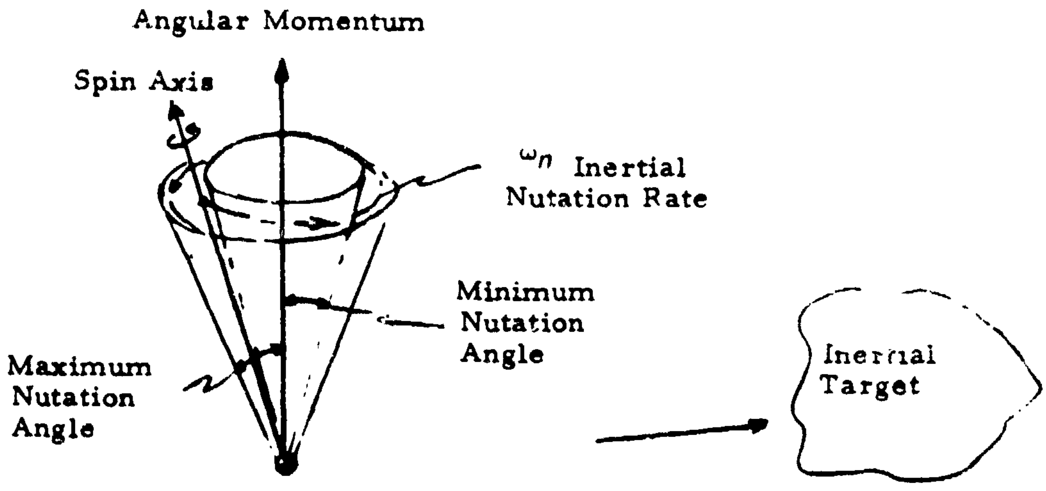

Figure 4.1.2.3-2. Nutation for Asymmetric Body

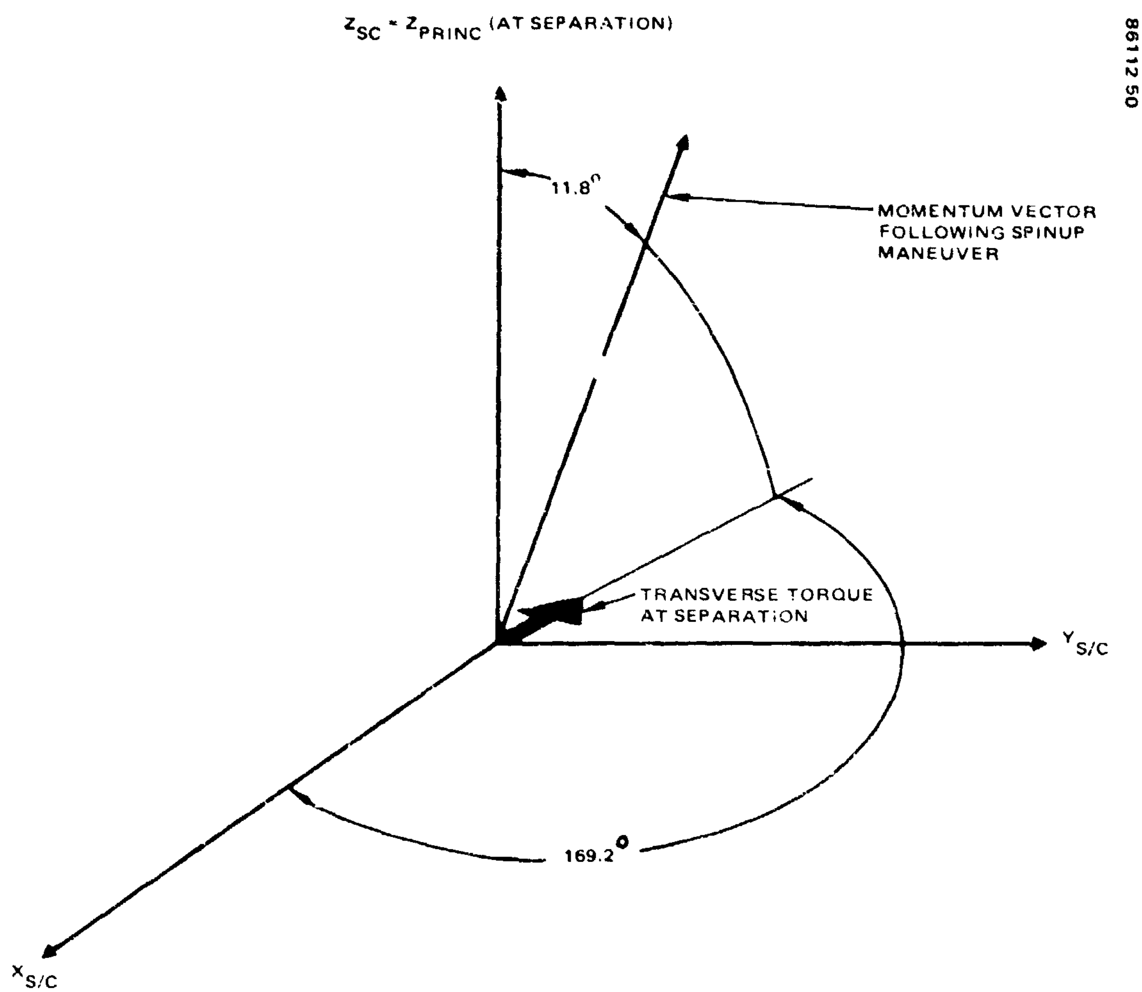

FIGURE 4.1.3.1-1. MULTIPROBE ATTITUDE

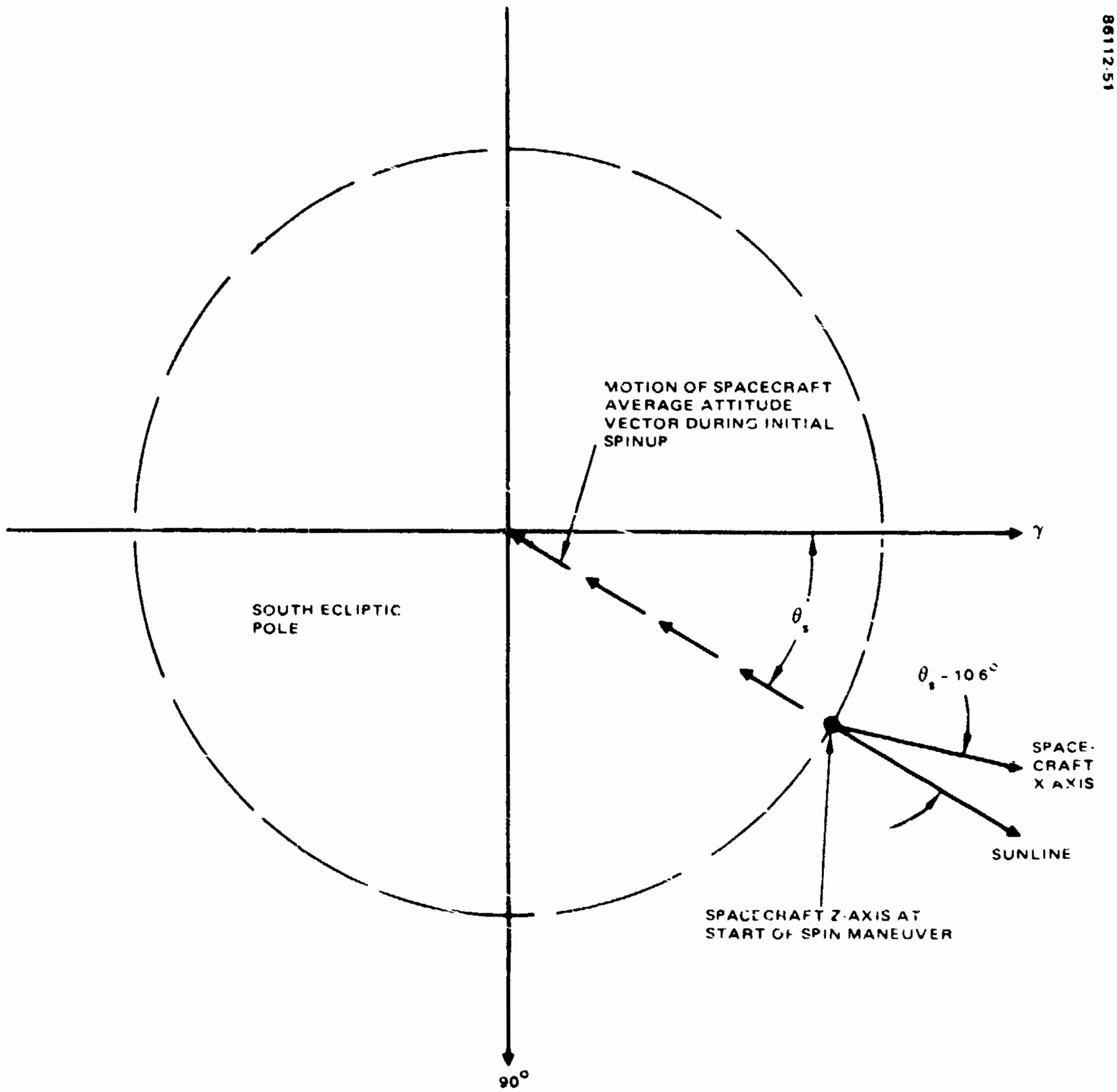

FIGURE 4.1.3.1.2 SIMPLIFIED VIEW OF MULTIPROBE REORIENTATION MANEUVER

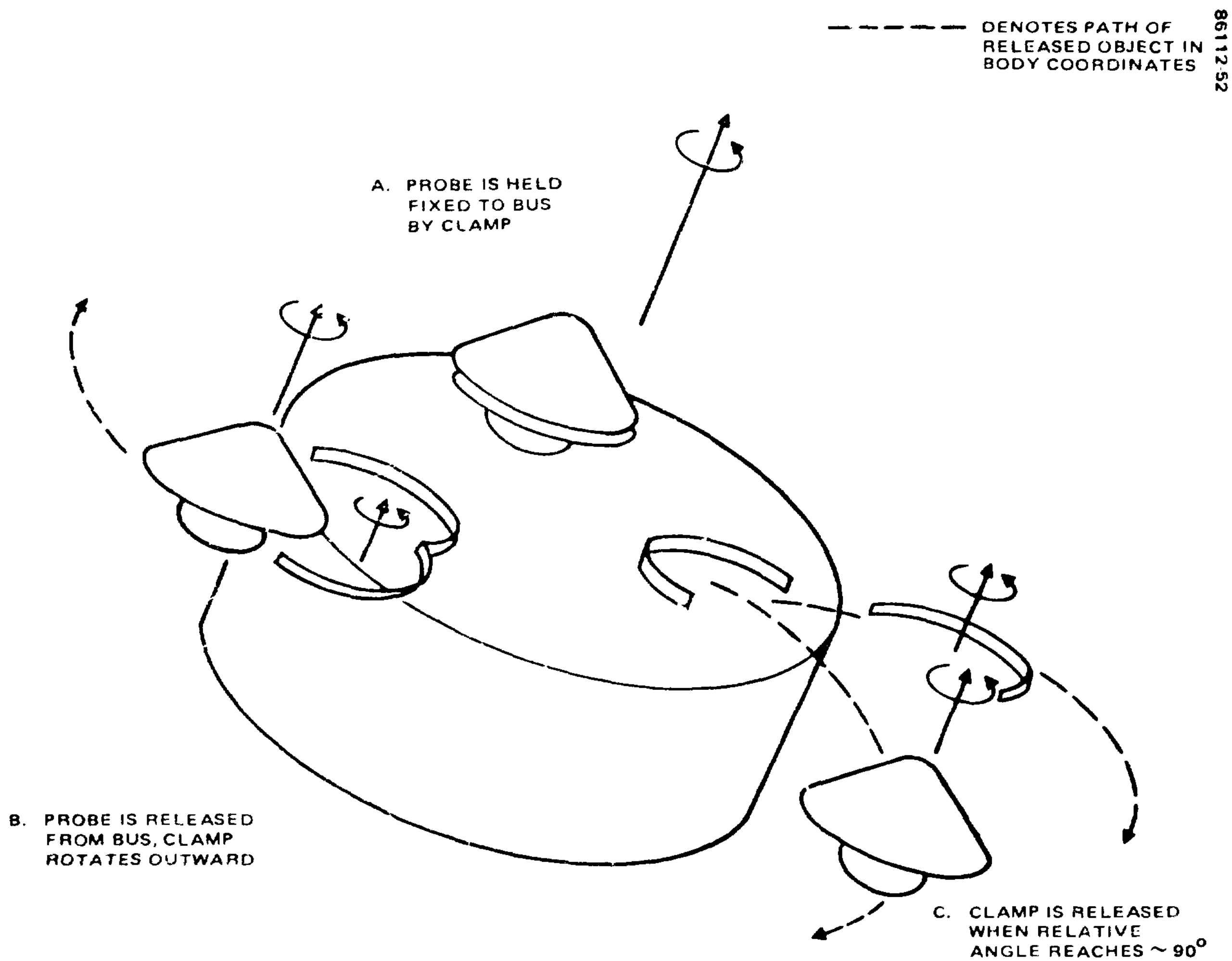

FIGURE 4.1.3 3-1. SMALL PROBE SEPARATION

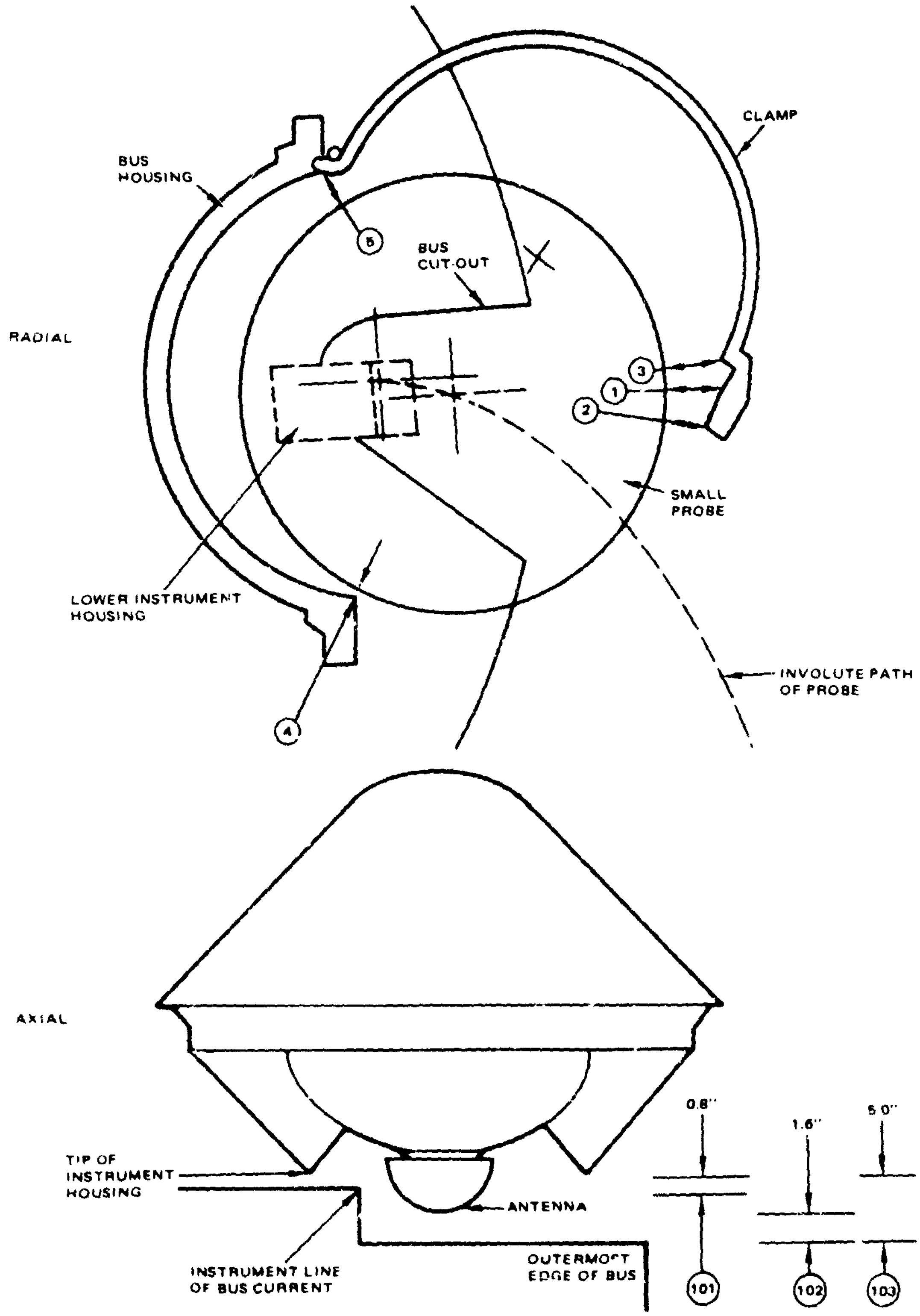

FIGURE 4.1.3.3 2. SMALL PROBE CLEARANCE GEOMETRY

4.2 KEY MISSION EVENTS

The step-by-step sequence of actions for each of several key mission events is described below.

4.2.1 Separation and Initial Spinup

4.2.1.1 Introduction. Multiprobe spacecraft separation from the Centaur launch vehicle occurs at a zero spin rate and out of view of ground stations with command capability. Depending on launch date and time, ground station(s) become visible anywhere between 20 minutes and 4 hours after launch. To achieve attitude stability and prevent tumbling, spacecraft spinup must be accomplished as soon as possible after separation; much before initial ground station acquisition.

Multiprobe spacecraft spinup is effected with simultaneous use of the spacecraft stored command processors. The spinup sequence of commands is loaded into the command memories prior to launch, and initiated upon spacecraft/Centaur separation. The two spinup thrusters are fired to effect a 15.0 rpm spin rate and the spacecraft is then configured for initial ground station acquisition, all via stored command. Centaur reorientation requirements and Centaur/Multiprobe separation dynamics are presented in Section 4.1 of this document.

4.2.1.2 Command Memory Loading and Verification. The two Multiprobe command memories will be loaded with their respective spinup command sequences about three hours prior to liftoff. This corresponds to the beginning of the standard 60-minute built-in hold in the countdown. Both memories will have their contents verified after loading. A final verification will be made approximately 15 minutes before liftoff, after the spacecraft has been switched to internal power. (Switching from external power to internal power does not affect the contents of either command memory). Detailed procedures for loading and verifying the command memories are delineated in Section 3.6.3.2 of this document.

4.2.1.3 Spacecraft Subsystem Launch Configuration. At liftoff, the Multiprobe subsystems will be configured in the following operational status modes as listed in Table 4.2.1.3-1.

4.2.1.4 Command Memory Initialization. At liftoff the Stored Command Logic (SCL) 1 and 2 are in the "Arm Separation Switch" state. Upon closure of the spacecraft/attach fitting separation switches at separation, the SCL states switch to "immediate start" (initiation of the stored command sequences). Figure 4.2.1.4-1 depicts the functional spinup sequence implementation. One contact of each separation switch shorts its respective ADP "ON" command to ground while the switch is in the launch configuration. Each switch prohibits its respective command processor from executing the spinup sequence prior to separation, and circumvents a mission catastrophic failure due to a possible single point failure in the SCL. This failure causes a change of state in the SCL; e.g., "arm" to "run". (See Section 3.6.3.2 for further delineation of this failure mode). Separation Switches 1 and 2 inhibit ADP 1 ON and ADP 2 ON (ADP19 via COM assignment 5D28 and ADPB9 via COM assignment 6D31), respectively. ADPs 1 and 2 may still be commanded ON prior to launch via commands ADPA9 and ADP29 (via COM assignments 6D28 and 5D31), respectively. The stored sequences will only send ADP 1 commands via COM 5, and ADP 2 commands via COM 6.

4.2.1.5 Stored Command Sequence. Table 4.2.1.5-1 presents the detailed sequence of commands stored in each SCP along with time of execution relative to separation. Reasons for time delays, etc., are given in the "comments" column of the Table.

4.2.1.6 Spacecraft Subsystem Acquisition Configuration. The spacecraft configuration at initial ground station acquisition is shown in Table 4.2.1.6-1.

4.2.2 Large Probe Separation

4.2.2.1 General. This phase of the mission encompasses all of the events from reconfiguring the S/C for the Small Probes' stable oscillators "bakeout" period (nominally at E-45 days) through release of the Large Probe (nominally at E-24 days).

The overall timeline of time-tagged events is shown in Table 4.2.2-1, the detailed flight sequence of commands and verifying telemetry are shown in Table 4.2.2-2, and the references are listed in Table 4.2.2-3.

The starting and interim configurations, including earth l.o.s. and sun l.o.s., are shown in Table 2.3.1-1.

Much of the information is based also on References: Paragraphs 1.5.6 and 1.5.34.

4.2.3 Small Probe Targeting and Separation

4.2.3.1 General. This phase of the mission encompasses all of the events occurring immediately after Large Probe Separation (nominally at E-24 days) through release of the Small Probes (nominally at E-20 days).

The overall timeline of time-tagged events is shown in Table 4.2.3-1, the detailed flight sequence of commands and verifying telemetry are shown in Table 4.2.3-2, and the references are listed in Table 4.2.2-3.

The starting and interim configurations, including earth l.o.s. and sun l.o.s. are shown in Table 2.3.1-1.

Much of the information is based also on Reference 1.5.6.

4.2.4 Bus Targeting

4.2.4.1 Introduction. The Bus targeting maneuver is required to move the trajectory aim point and to delay the time of Bus entry until after all probes have impacted the surface to provide a radio signal reference for analysis of probe trajectories within the atmosphere. The Bus targeting segment of the Multiprobe mission consists of three separate maneuvers. At E-18 days, a ΔV maneuver totaling 19.2 m/sec maximum, will be performed to move the trajectory aim point to that desired for Bus entry and retard Bus arrival.

At E-8 days a Bus targeting touchup will be performed (if necessary) and the Bus will be oriented to the final entry attitude. At E-2 days a despin from 48.5 rpm to 9.45 rpm, the entry spin rate, and a final attitude touchup will be performed. This section describes the entire Bus targeting sequence of events from post Small Probe release at E-20 days until final despin at E-2 days as chronologically listed in Table 4.2.4-1. The history of Bus attitude during this mission segment is shown in the polar hemispherical plot presented in Section 4.1.1.2. The Bus entry mission segment, from E-2 days until entry, is presented in Section 4.2.5 of this document.

4.2.4.2 Cruise Attitude From Small Probes Release. Immediately after Small Probe release at E-20 days the spacecraft transmitter will be returned to low power mode, and the spacecraft spin axis will be precessed to an attitude which permits use of the medium gain horn antenna and provides a minimum spacecraft sun angle of 40°. The Bus cruise attitude after Small Probe release is selected to satisfy communications and thermal constraints. For cruise or "non-critical" mission periods, only the DSN 26 meter network is available for spacecraft coverage. To effect a 26-meter net downlink for the communications distances encountered in this latter phase of the Multiprobe mission, the medium gain horn antenna must be employed. Since its effective beamwidth is a half-cone angle of 30° aligned with the spacecraft negative Z-axis, an earth communications angle of at least 150° measured w.r.t. the spacecraft +Z axis must be maintained. At the same time, spacecraft sun aspect angle must be maintained greater than 40°. This is to preclude Bus thermal problems (see section 3.2.3) as well as provide adequate solar panel power margin (see section 3.8.3.9). The celestial attitude for the bus positive z-axis which satisfies both of these constraints while at the same time minimizing hydrazine propellant consumption is a celestial latitude of -6.0° and celestial longitude of 204.0°.

During this cruise phase, the Bus subsystems will be configured in the operational status modes as listed in Table 4.2.4-2.

4.2.4.3 Targeting Requirements. The Bus is to be targeted to a point within the region of entry locations as shown in Figure 4.2.4.3-1 for entry flight path angles (FPA) of -7°, -8° or -9°. Scientific preferences are to guarantee descent to a specified minimum altitude (125 km) while minimizing the rate of descent to this altitude. To satisfy both of these preferences the targeting of the Bus would be chosen so as to have the entry FPA as close to the skipout boundary as would be permitted by navigational uncertainties. The vicinity of the skipout boundary for a typical trajectory is between FPAs -7° and -8°. In addition, Bus entry is to be retarded to occur at least 60 minutes after entry of the last probe vehicle. These two requirements are met by effecting a Bus ΔV targeting maneuver with direction and magnitude as shown in Figures 4.2.4.3-2 and 4.2.4.3-3, respectively. Note the dependence on launch and arrival dates for the ΔV magnitude and direction.

4.2.4.4 Precession/Targeting Maneuver. It is desirable to perform the Bus targeting maneuver as soon as possible after Small Probe release in order to conserve propellant. The closer to Venus, the more propellant required to effect the same targeting/retardation. A nominal 48-hour period is allocated after Small Probe release to allow for tracking data assimilation and recharging of the Bus batteries. Hence, the selection of E-18 days for the nominal execution of the Bus targeting maneuver.

Since the required ΔV maneuver is one to effect retardation of the Bus approaching Venus, the nominal method of delivery will be t precess the

Bus spin axis to the required attitude and deliver the ΔV magnitude with a continuous burn of the forward axial thruster. Also, the forward axial thruster will be used alone in the pulsed mode in precessing to the targeting attitude and returning to the same cruise attitude after delivering the continuous ΔV burn. The two precessions ([illegible]t 18 minutes each) are each approximately 30° to 35° in magnitude (depending on launch and arrival dates). By executing the precessions with the forward axial thruster alone as opposed to using the dual axial thruster mode (optional mode), a utilizable ΔV component of about 2 m/sec (each precession) can be realized. The ΔV components produced by the precessions will slightly change the attitude from Figure 4.2.4.3-2 at which the Bus must deliver the continuous-burn ΔV. Similarly, the magnitude of the continuous-burn ΔV will be reduced significantly (approximately 4 m/sec) from that shown in Figure 4.2.4.3-3.

Prior to precessing to the Bus targeting attitude, an attitude determination will be performed. The details of this operation are presented in Section 4.3.2 ("Attitude Determination") of this document. Once the cruise attitude and spin rate have been determined, the precise precession maneuver parameters required such as ACS angle delay, pulse width, and number of pulses can be determined. The Bus targeti[illegible] ttitude that is anticipated will preclude u[illegible] the medium gain horn antenna. As such, the [illegible]mni antenna and the high RF power mode will [illegible] ele[illegible]d by the commands listed in Table 4.[illegible]-1, [illegible]h will be transmitted just prior to the pre[illegible]on. Once uplink and downlink have been e[illegible]shed on the 64-meter DSN station the prece[illegible]aneuver will commence according to the seque[illegible] of Table 4.2.4-1.

Once at this nominal Bus targeting attitude, spacecraft sun aspect angle and earth (communication) lock angle will be in the ranges of 24° to 35° and 138° to 148°, respectively. The spread in ranges is due to the variations in launch and arrival dates as well as Bus entry location parameters. Either one or both of the stars Al Suhail and Arcturus are within the star sensor FOV for the entire range of Bus targeting attitudes. This will provide adequate attitude measurements for an attitude determination operation as presented in Section 4.3.2 of this document.

For approximately four hours at the Bus targeting attitude, the Bus subsytems will be configured in the operational modes and configurations as listed in Table 4.2.4-2. The continuous forward axial ΔV maneuver is performed according to the detailed sequence presented in Section 4.3 1.2. Following the continuous ΔV maneuver the Bus will be reoriented back to the post-Small Probe release attitude presented in Section 4.2.4.2. DSN station coverage will return to the 26-meter network after the Bus downlink is switched to the medium gain horn antenna according to Table 4.2.4-1.

Battery discharge current must be monitored during the entire bus targeting maneuver detailed above to limit excessive levels of battery DOD. Depending on the sun angle at the targeting attitude and accumulated solar panel degradation up to this portion of the mission, battery discharge current may vary anywhere between zero and 1.7 amps.

The above outlined nominal precession/targeting maneuver is predicated upon the exclusive use of the forward axial thruster. In the event the forward axial thruster cannot be used, one of two optional modes of performing the precession and ΔV maneuvers may be used. These optional modes are:

(a) Precess the spacecraft +Z axis (with the aft axial thruster in the pulsed mode) to an attitude 180° opposite the nominal Bus targeting attitude given above, and deliver the required ΔV with a continuous burn of the aft axial thruster. Reorient the spacecraft back to the cruise attitude.

(b) Precess the spacecraft to an attitude with the "post-small-probe-release" radial thruster pairs' (R1 and R2) line of thrust parallel to the direction of the required ΔV. Deliver the ΔV magnitude required by using R1 and R2 in the pulse pair mode. Reorient the spacecraft back to the cruise attitude. Use of the radial pair R3 and R4 for this optional maneuver would result in a significant unwanted attitude precession since R3 and R4 are aligned through the spacecraft cruise center of gravity.

Either of the two optional modes listed above require about 5.5 to 6.0 pounds more propellant to execute than the nominal forward axial mode previously presented. In addition, the maneuvers detailed in alternate modes 1 and 2 required about 2 and 2.5 hours longer to execute than the nominal forward axial mode.

4.2.4.5 Cruise to E-8 Days. The cruise attitude (celestial latitude -6.0° and celestial longitude 204.0°) is again chosen for the same reasons as delineated in Section 4.2.4.2. The Bus subsystems will be configured in the operational status modes as listed in Table 4.2.4-2. This cruise attitude is maintained until E-8 days for two reasons; 1) this duration allows for ten days of undisturbed tracking data assimilation, and 2) beginning after E-8 days the Bus may be reoriented to the Bus entry attitude without violating the minimum 40° sun angle steady-state thermal requirement.

4.2.4.6 Targeting Touchup/Reor to Entry Attitude. At E-8 days a targeting touchup will be performed, if necessary, based on the previous ten days of undisturbed tracking in the prevailing cruise attitude. A precession to the Bus entry attitude will be performed with trims and touchups (if necessary) in the sequence detailed in Table 4.2.4-1. Spacecraft attitudes for Bus entry spacecraft for the full range of launch dates, arrival dates, and entry flight path angles are depicted in Figures 4.2.4.6-1 and 4.2.4.6-2. Subsystem operating modes and configurations are listed in Table 4.2.4-2.

4.2.4.7 Despin (E-2 Days). At E-2 days the Bus will be despun from 48.5 rpm, the nominal Small Probe release spin rate, to 9.45 ±0.1 rpm, the desired Bus entry spin rate. Despin will be effected in the sequence detailed in Section 4.3.1.3. Final despin is delayed until this point because the radial despin jet thrusters are significantly canted towards aft and cause a +Z axis ΔV component which is opposite in direction than the desired retarding ΔV maneuver performed for Bus targeting. Delaying final despin beyond E-2 days will interfere with preparations for the Bus entry phase as delineated in Section 4.2.5. Despin at E-18 days would require approximately an additional 3 m/sec forward axial continuous burn; or roughly a 1.0 pound propellant penalty. Subsystem operating modes and configurations are as listed in Table 4.2.4-2.

4.2.5 Bus Entry. The purpose of this section is to describe the Bus spacecraft mission operating sequence from two days before entry (just after final spacecraft despin to 9.45 rpm) to final burnup in the Venusian atmosphere. This entire command/event sequence is delineated in Table 4.2.5-1.

Following final spacecraft despin to 9.45 ±0.1 rpm at E-48 hours as described in Section 4.2.4.7, final attitude and spin rate trim maneuvers will be planned and performed. Attitude and spin rate determinations are performed as shown in Table 4.2.5-1. The appropriate trim maneuvers, if required, are then calculated and executed. These will be the final maneuvers of the Bus mission. Two hours after the final maneuver, the BNMS scientific instrument calibration gas pyro and the breakoff hat (cover) pyro will be fired. The two-hour time period is to allow for all final outgassing to occur which might contaminate the experiment.

During the two-hours "wait" period described above, the spacecraft command processor command memories are loaded with the backup spacecraft configuration command sequence (timed to execute at E-4 hours) and the final entry command sequence (timed to execute near E=0). The Bus entry stored command sequence portion will be a series of scientific instrument commands for the two Bus instruments, BNMS and BIMS, and will be specified by NASA/ARC. Spacecraft subsystem configuration will not nominally be changed from that presented in Table 4.2.5-2. One at a time, the two command processor units' stored command logic subunits (SCLs) are loaded, verified, and finally started as detailed in Table 4.2.5-1 and Figure 4.2.5-1. The entry sequence is started at this early time (E-44 hours) to preclude the possibility of the SCLs not being able to be loaded because of a spacecraft receiver failure. At the Bus entry attitude, a command uplink can only be maintained with the aft omni antenna. The forward omni antenna is not visible from earth at this attitude, and the medium gain horn antennas has a transmit only capability. If the receiver switched to the aft omni should fail, a 36.4 hour time period will elapse before the receiver revese function switches the remaining receiver to the aft omni. Planning to load the SCL nominally at E-44 hours allows a margin of about seven hours prior to entry (worst case) in which the SCL may be loaded.

After starting the SCL sequences the BNMS calibration gas pyro and breakoff cover will be fired via the commands listed in Table 4.2.5-1. Final scientific instrument commands (set up for entry) will be transmitted, if required, and the spacecraft will be configured as shown in Table 4.2.5-1 to alternately assimilate attitude and engineering data for the remaining until entry. Trajectory data will be gathered on the ground in support of the radio science experiment.

Revision

About ten hours prior to entry the Bus downlink will begin to continuously monitored for reference against the Large and Small Probe downlink frequencies throughout their respective entries into the atmosphere. During this period, as many as two uplinks (Bus and Large Probe) and five downlinks (Bus and all four probes) must be simultaneously maintained by the DSN. Bus and probe relative entry and descent times are to be specified by NASA/ARC. Final Bus configuration commands are sent; high RF power, Bus entry format, and 1024 bits per second in preparation for Bus entry one hour after the last probe vehicle has entered the Venusian atmosphere.

TABLE 4.2.1.3-1

MULTIPROBE SUBSYSTEM LAUNCH CONFIGURATION

SUBSYSTEM/UNIT	OPERATIONAL CONFIGURATION
COMMUNICATIONS	
Transponders	• Exciter 1 ON/2 OFF • Restore Coherent Mode (ON) • Bus Hi Mod Index Select • Probes Mod Index Select (don't care)
Power Amplifiers	• Power Amp 1 ON • Power Amps 2, 3, 4 OFF
Switch Drivers	• Exciter 1 Select • Power Amp 3 Select • Forward Omni Antenna Select* • Amp 1 Low Power/Amp 2 High Power Select • High Power to Aft Omni/Low Power to Fwd Omni or Horn Select • Receivers Normal Select (via Command Processor Configure Command)
COMMAND	
Command Processors	• Command Processors 1 and 2 ON (both memories in "Arm Separation Switch" State)
COMs	• All Seven (7) COMs ON
PCUs	• PCU 1 Disarmed • PCU 2 Disarmed
CONTROLS	
Attitude Data Processors	• ADP 1 OFF • ADP 2 OFF • JCE Buffers Output Disabled
Star Sensor	• All Star Sensor Channels OFF
POWER	
Bus Limiters	• All Five (5) Bus Limiters Enabled
Charge/Discharge Controller	• Low Rate Charge Select (both relays - both batteries) • Primary Discharge Reg Select (both batteries)
UV/OL Control	• UV/OL Power System Protection OFF • Pre-Charge OFF

*Centaur/Launch Vehicle Constraint - Prohibits RF radiation into Centaur (i.e., do not use Aft Omni during Launch phase).

TABLE 4.2.1.3-1 (Continued)

SUBSYSTEM/UNIT	OPERATIONAL CONFIGURATION
PROBES	• All Heaters OFF • All Subsystems OFF • All Science OFF
SCIENTIFIC INSTRUMENTS	• All Science OFF
DATA HANDLING	
Telemetry Processor	• Telemetry Processor 1 ON/2 OFF • Bus Engineering Format • 256 Bits/Sec • Data ON • Convolutional Encoding OFF
PCM Encoder	• PCM Encoder 1 ON/2 OFF
DIM	• All Eight (8) DIMs ON
PROPULSION/THERMAL	
Latch Valves and Heaters	• All Jet Heaters ON • Primary Tank/Line Heaters Select • Latch Valves 1 and 2 Closed

TABLE 4.2.1.5-1

MULTIPROBE FLIGHT SEPARATION/SPINUP SEQUENCE

STEP NO.	RELATIVE EXECUTION TIME H·M·S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
	0·00·00	<u>Separation</u> (All times below are referenced to this event)			<u>Separation</u> (All times below are referenced to this event)			<u>Separation</u> Separation switch signals initiate SCL command sequences and enable ADP ON commands.		Telemetry verification channels are listed below in the event that a downlink data stream is received.
1	0·00·00.125	Time delay = 0.375 sec	CMTQ1	20 00 00	Time Delay = 0.375 sec	CMTQ2	20 00 00	• This time delay plus others listed in several steps ahead are for the purpose of circumventing a SCP failure mode in which time delay codes in one SCL are ignored and the commands stored in that SCL are executed at 1/8 second intervals. The alternate SCL will then reconfigure the S/C (after it's own correctly processed time delays) to execute a nominal spinup sequence. • These initial time delays also allow for clearance (and an expected tip off) from the Centaur before the S/C jets are fired.		
2	0·00·00.500	ADP 1 ON	ADP19	A8 00 1C	ADP 2 ON	ADPB9	B0 00 1F		AADP1S AADP2S	(ADP 1 ON/OFF = ON (1) (ADP 2 ON/OFF = ON (1)
3	0·00·00.625	Time Delay = 0.125 sec (TD Code = 0.0 sec.)	CMTQ1	00 00 00	Time Delay = 0.12. sec (TD Code = 0.0 sec.)	CMTQ2	00 00 00			

TABLE 4.2.1.5-1. (Continued)

STEP NO.	RELATIVE EXECUTION TIME H:M:S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
4	0:00:00.750	ADP1 Mode Select • PLL Spin Range: 32-70.8 rpm • PLL Loss of Lock Inhibited • Star Gate A: Channel 1 • Star Gate B: Channel 1 • Sim PSI Input • Sun Select • Sim SRR Select • Star Normal • Disable Sun Gate • SRR Normal	ATQ03	AE 4D F0	ADP 2 Mode Select • PLL Spin Range: 32-70.8 rpm • PLL Loss of Lock Inhibited • Star Gate A: Channel 1 • Star Gate B: Channel 1 • Sim PSI Input • Sun Select • Sim SRR Select • Star Normal • Disable Sun Gate • SRR Normal	ATQ0C	B6 4D F0	• The PLL loss of lock circuit is inhibited, as the PLL cannot track large spin rate changes. • The largest available spin rate range is selected to aid the PLL to settle faster, prior to jets firing.		Cannot verify ADP status-TM is meaningless with both ADPs ON.
5	0:00:00.875	ADP 1 PLL Spin Period Magnitude - LSBs • PLL Spin Period Mag; LSBs for 60 rpm	ATQ08	AE E0 50	ADP 2 PLL Spin Period Magnitude - LSBs • PLL Spin Period Mag; LSBs for 60 rpm	ATQ0H	B6 E0 50	• Inserting a simulated spin rate (60 rpm) that is the largest available integer multiple of the post-spin-up spin rate aids the PLL to lock onto the real SRR that will be selected after spinup to 15 rpm.		"
6	0:00:01.000	ADP 1 Mode Select	ATQ03	AE 4D F0	ADP 2 Mode Select	ATQ0C	B6 4D F0	• Repeat of step 4 was for ease of verification in pre-launch ground test. This identical sequence for Flight serves the purpose of back-up commanding.		"
7	0:00:01.125	ADP 1 PLL Spin Period Magnitude - MSBs • PLL Spin Period Magnitude; MSBs for 60 rpm	ATQ07	AE 6F 00	ADP 2 PLL Spin Period Magnitude - MSBs • PLL Spin Period Magnitude; MSBs for 60 rpm	ATQ0G	B6 6F 00	• Same comment as for step 5.		"

TABLE 4.2.1.5-1. (Continued)

STEP NO.	RELATIVE EXECUTION TIME H:M:S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
8	0:00:01.250	ADP 1 Mode Select	ATQØ3	AE 4D FO	ADP 2 Mode Select	ATQØC	B6 4D FO	• Second repeat of step 4; see comment in step 6.		Cannot verify ADP status-TM is meaningless with both ADPs ON.
9	0:00:01.375	ADP 1 Jet Control • Enable Jet 1 • Enable Jet 3 • Normal Fire Mode • Wide Pulse (512 m sec) • Time Count • Continuous Fire • Inhibit Spin Rate Detector	ATQØ2	[illegible] 8A 1A	Latch Valve 2 Open	VALB9	90 00 1D	For ATQØ2(&ATQØB ahead): • Select R1, R3 (spinup jets) • Select time count • Select Cont. Mode • Spin rate detector inhibit (spinup begins below 3.7 rpm)	VALV2S	Latch Valve 2 open/closed = open (1) Cannot verify ADP status TM is meaningless with ADPs ON.
10	0:00:01.500	ADP 1 Jet Countdown • Jet Countdown Magnitude = 225 Counts = 115.200 sec	ATQØ4	AE C8 70	ADP 2 Jet Control • Enable Jet 1 • Enable Jet 3 • Normal Fire Mode • Wide Pulse (512 m sec) • Time Count • Continuous Fire • Inhibit Spin Rate Detector	ATQØB	B6 8A 1A	• Input time code equivalent to 117 sec. jet firing duration to bring S/C from 0 to 15 rpm.		"
11	0:00:01.625	Latch Valve 1 Open	VAL19	88 00 1B	ADP 2 Jet Countdown • Jet Countdown Magnitude = 225 counts = 115.200 sec	ATQØD	B6 C8 70	"	VALV1S	Latch Valve 1 open/closed = open (1)
12	0:00:01.750	Time Delay = 1.125 sec (TD Code = 1.000 sec)	CMTQ1	08 00 00	Time Delay = 0.625 sec (TD Code = 0.500 sec.)	CMTQ2	10 00 00	• Time delay is split into two successive blocks in order to stagger events for unambiguous verification during pre-launch ground tests.		

TABLE 4.2.1.5-1. (Continued)

STEP NO.	RELATIVE EXECUTION TIME H:M:S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
13	0:00:02.875	Latch Valve 2 Open	VAL29	88 00 1D	Time Delay = 0.750 sec (TD Code = 0.625 sec)	CMTQ2	50 00 00		VALV2S	Latch Valve 2 Open/ Closed = open (1)
14	0:00:03.000	Time Delay = 0.250 sec (TD Code = 0.125 sec)	CMTQ2	40 00 00	Latch Valve 1 Open	VALA9	90 00 1B		VALV1S	Latch Valve 1 open/ closed = open (1)
15	0:00:03.375	ADP 1 JCE Buffer Enable	ATQ09	AE 10 00	ADP 2 JCE Buffer Enable	ATQ0I	B6 10 00			Cannot verify ADP status-TM is meaningless with both ADPs ON.
16	0:00:03.375	ADP 1 Jet Fire Interlock	ATQ11	AE 50 00	ADP 2 Jet Fire Interlock	ATQ0K	B6 50 00			"
17	0:00:03.500	ADP 1 Jet Fire	ATQ12	AE D0 00	ADP 2 Jet Fire	ATQ0L	B6 D0 00	• Spin-up nominally begins.	VJET1T VJET2T	Radial jet 1 temperature increases. Radial jet 2 temperature increases.
18	0:00:03.625	Time Delay = 1 min 56.375 sec. (TD Code = 1 min. 56.250 sec.)	CMTQ1	22 E0 00	Time Delay = 1 min 56.375 sec. (TD Code = 1 min. 56.250 sec.)	CMTQ2	22 E0 00			Cannot verify ADP status-TM is meaningless with both ADPs ON.
19	0:02:00.000	ADP 1 JCE Buffer Disable	ATQ10	AE 90 00	ADP 2 JCE Buffer Disable	ATQ0J	B6 90 00	• To backup nominal JCE countdown register timeout for thruster shutdown.		"
20	0:02:00.125	ADP 1 Jet Countdown • JCE Countdown Magni- Magnitude = 0 counts = 0 sec	ATQ04	AE C0 00	Latch Valve 2 Close	VALB6	90 00 1E	• Further backup of ADP 1 countdown.	VALV2S	Latch Valve 2 open/ closed = Closed (0)

TABLE 4.2.1.5-1. (Continued)

STEP NO.	RELATIVE EXECUTION TIME H:M:S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
21	0:02:00.250	ADP 1 Jet Control • Disable All Jets • Normal Fire Mode • Narrow Pulse (128 m sec) • Time Count • Pulse Fire • Enable Spin Rate Detector	ATQØ2	AE 80 11	ADP 2 OFF	ADPBØ	B0 00 20	• ADP 2 turnoff permits valid attitude measurement & ADP status TM. • Further backup of Jets shutoff	AADP2S AJNACC AJET1S thru AJET4S AJETMS APULLS AMACCS AJETMS ASDETS AJCE1S AJCE2S AJCEFS	ADP2 ON/OFF = OFF (0) JCE Countdown = All zeros. Jet Select Bits = All zeros. Normal/Alternate Fire Mode = Normal (1). Pulse Width Select - 128 m sec (0). Pulse/Time Count Select = Time (0). Cont/Pulse Fire Select = Pulse (1). Spin Rate Detector = Enabled (1) JCE 1 Buffer Output State = OFF (=0). JCE 2 Buffer Output State = OFF (=0). Jet Fire Enable Status = Disabled (=0).
22	0:02:00.375	Latch Valve 1 Close	VAL1Ø	88 00 1C	Command Processor 2 Configure: • SCL 2 Standby	CPCQ2	B5 00 07	• SCL 2 is set to Standby to insure no repeat of spinup sequence. • SCL 2 is not yet turned OFF in order to retain memory contents in the event the spinup did not occur, and it is elected to repeat execution of the SCL 2 contents. If the Standby command is effective, the subsequent commands in this column will not get executed, only a real-time command will change the SCL 2 state.	CLOG2S VALV1S	SCL 2 State Status = Standby (=1111). Latch Valve 1 Open/Closed = Closed (0).

TABLE 4.2.1.5-1. (Continued)

STEP NO.	RELATIVE EXECUTION TIME H:M:S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
23	0:02:00.500	ADP 1 Mode Select • PLL Spin Range: 8 - 17.7 rpm • PLL Loss of Lock Inhibited • Star Gate A Channel 1 • Star Gate B Channel 1 • Mid Range Sun Sensor • Sun Select • SRR Select • Star Normal • Disable Sun Gate • SRR Advance	ATQ#1	AE 49 99	Command Processor 2 Configure (Note 1) • SCL 2 STOP	CPCQ2	B5 00 1B	• SCL 2 STOP is backup to the previous command. • PLL spin range selected to encompass nominal post-spinup spin rate of 15 rpm. • SRR & SRR Advance Selected for lock onto sun as SRR.	CLOG2S	SCL 2 State Status = STOP 1 (=0010), only if standby command is ineffective. Otherwise, STOP command has no effect in Standby State.
									ASPINS	PLL spin range select = 10 (8 - 18 rpm).
									ALOLES	PLL Loss of Lock = 0 (Inhibited).
									A*GASS	Star Gate A Select = 1 (PSI*).
									A*GBSS	Star Gate B Select = 1 (PSI*)
									ASUNSS	Sun Sensor Select = 00 (Mid)
									ASRRMS	Roll Reference Select = 11 (sun).
									A*ACQS	Star Acq./Normal = 0 (normal)
									ASUNGS	Sun Gate = 0 (Disabled)
									ADVANS	SRR Advance Status = 1 (Advance)
24	0:02:00.625	ADP 1 Measurement Select • SRR - SRR • SRR - PSI 2	ATQ#1	AE 00 05	Command Processor 2 Configure (Note 1) • SCL 2 OFF	CPCQ2	B5 00 3F	• SCL 2 OFF is backup to previous command	AM1ADS	Measurement A Address = SRR to SRR
									AM2ADS	Measurement B Address = SRR to PSI 2
									ATTM	Attitude Measurement Data is plausible.
									CSCL2S	SCL 2 Status = OFF (0).

NOTE 1: These commands will not be executed and are included in the SCL as backups.

TABLE 4.2.1.5-1 (Continued)

STEP NO.	RELATIVE EXECUTION TIME H:M:S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
25	0:02:00.750	Power Amplifiers 1 and 2 OFF	AMP1Ø	98 00 18	SCL 2 OFF (Note1)	MEM2Ø	90 00 2B	• SCL 2 OFF discrete command is backup to the previous OFF command. • Power Amps OFF is first command to communications subsystem to switch downlink to AFT omni. (Aft omni is favorable for initial ground station acquisition at Honeysuckle circa Launch plus 1 hour.)		Loss of downlink - No TM available.
26	0:02:00.875	Low Power to Aft Omni Select	ANT12	A8 00 01						No TM available.
27	0:02:01.00	<u>Command Processor 1 Configure</u> • RCVRS Normal	CPCQ1	AD 00 43				• Command places the prime receiver on the omni that is favorable for initial ground station acquisition & sets CP 1 receiver logic to "normal" state.		No TM available.
28	0:02:01.125	<u>Command Processor 2 Configure</u> • RCVRS Normal	CPCQ2	B5 00 43				• Command is backup to above and also is required to set CP 2 receiver logic to "normal" state.		"

TABLE 4.2.1.5-1. (Continued)

STEP NO.	RELATIVE EXECUTION TIME H:M:S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
29	0:02:01.250	Power Amplifier 1 ON/ 2 OFF	AMP19	98 00 19				• Applies low transmission power to above selected aft omni.		Recovery of downlink carrier and TM
									RANT1S	AFT/(Fwd or Horn) to Hi/Lo pwr = 0 (Aft to Low)
									RAMP1W	RF power output = approximately same level (7 to 10 watts for ambient S/C) as before step 25.
									CREV1S	CP 1 Receiver reverse state = Normal (=1).
									CREV2S	CP 2 Receiver reverse state = Normal (=1).
									RRCVRS	RF switch position = 0 (Normal:RCV 2 to aft omni)
30	0:02:01.375	Restore Coherent Mode	CON19	98 00 07				• Inserted here to insure that coherent mode is enabled for initial acquisition. (S/C may be launched with coherent mode inh[illegible] ed to avoid RFI [illegible] oblem launch).	RCON2S	Exciter 2 Inhibit/Restore coherent mode = 0 (= Restore)
31	0:02:01.500	Command Processor 1 Configure • SCL 1 Standby	CPCQ1	AD 00 07				• SCL 1 is set to standby to insure no repeat of the spinup. • SCL 1 is not yet turned OFF in order to retain memory contents in the event the spinup does not occur, and it is elected to repeat execution of the SCL 1 contents. If the Standby command is effective, the subsequent commands will not get executed; only a real-time command will change the SCL 1 state.	CLOG1S	SCL 1 State status = Standby (= 1111)

TABLE 4.2.1.5-1. (Continued)

STEP NO.	RELATIVE EXECUTION TIME H:M:S	COMMAND MEMORY 1			COMMAND MEMORY 2			COMMENTS	TELEMETRY VERIFICATION	
		COMMAND	COMMAND MNEMONIC	HEX	COMMAND	COMMAND MNEMONIC	HEX		MNEMONIC	TITLE & STATUS
32	0:02:01.625	Command Processor 1 Configure • SCL 1 STOP	CPCQ1	AD 00 1B				• SCL 1 Stop is backup to previous commands.	CLOG1S	SCL1 State Status = STOP 1 (= 0010) only if standby command is ineffective. Otherwise, STOP command has no effect in STANDBY State.
33	0:02:01.750	Command Processor 1 Configure • SCL 1 OFF	CPCQ1	AD 00 3F				• SCL 1 OFF is backup to previous command.	CSCL1S	SCL 1 Status = OFF (0).
34	0:02:01.875	SCL 1 OFF	MEM10	88 00 2B				• SCL 1 OFF discrete command is backup to the previous OFF command.	CSCL1S	SCL 1 Status = OFF (0).

TABLE 4.2.1.6-1

MULTIPROBE SUBSYSTEM ACQUISITION CONFIGURATION

SUBSYSTEM/UNIT	OPERATIONAL CONFIGURATION
COMMUNICATIONS	• Same as Launch (See Table 4.2.1.3-1).
CONTROLS	• Same as Launch except ADP 1 ON.
COMMAND	• Same as Launch except SCL 1 and SCL 2 are "OFF."
DATA HANDLING	• Same as Launch (See Table 4.2.1.3-1).
POWER	• Same as Launch (See Table 4.2.1.3-1).
PROPULSION/THERMAL	• Same as Launch (See Table 4.2.1.3-1).
SCIENTIFIC INSTRUMENTS	• All OFF.

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TABLE 4.2.2-1

START OF SMALL PROBES BAKEOUT PERIOD
THROUGH LARGE PROBE SEPARATION TIMELINE OF EVENTS

START TIME	MULTIPROBE MISSION PHASE & MISSION EVENT	REMARKS
	START OF SMALL PROBES' BAKEOUT PERIOD THROUGH HORN ATTITUDE OPERATIONS	
E-45 Days	Reconfigure S/C for Small Probes' stable oscillator "bakeout" period	Ref: Par. 1.5.34.
E-40 Days	Large Probe Heater Turn OFF	Ref. M14
E-30 Days	TCM #3	• Interplanetary target accuracy to be accomplished in three TCMs maximum (Ref: M2).
E-30 Days	Attitude and Orbit Determination.	
E-28D03H	Forward Axial Jet Heater OFF; Precess to Horn Attitude.	• Heater is turned OFF immediately prior to precession to attitude that exposes jet to more solar intensity (Ref: M7 & M13). • Precession done to use Horn and 26 M. DSN. Station for transmission, as omnis are usable only via 64 M. DSN Station after L+93 Days (Ref. Para. 1.5.19 and M4). • Precession is done in two steps, separated by switching S/C transmitter to the aft omni (Refer to Section 3.7 for antennas gain patterns). • Nominal $\Delta 90^{\circ}$ precession total. • Also, Ref. M8.
E-27D23H 30M	Switch to Horn for Transmission.	• Ref: M4, M7 and M8.
E-27D23H 15M	Attitude Determination.	
E-27D22H	Return to Single Transmitter.	

TABLE 4.2.2-1 (Continued)

START TIME	MULTIPROBE [MISSION PHASE] & MISSION EVENT	REMARKS
	PRECESS TO RELEASE ATTITUDE THROUGH LARGE PROBE SEPARATION	
E-24D12H (=LPR-12H, where LPR = Large Probe Release Time)		
LPR-11H 30M	Load Command Memory for last Large Probe checkout; Last Large Probe Checkout.	
LPR-9H	Return to Single Transmitter.	
LPR-6H 55M	Batteries to HI Charge Rate.	• To replenish worst case discharge due to probes checkout (Ref: M4). • Ref: M7.
LPR-6H	Batteries to Trickle Charge Rate.	Ref: M7.
LPR-5H 40M	Add Second Transmitter; Switch to ACS Format.	Ref: M4, M5, M7 and PIA #M-9.
LPR-5H 30M	Prepare Large Probe; Transfer to Probe Battery and Load Coast Timer, then return to Bus Engineering Format.	• LP/Bus Bit rates are 256/8, respectively. • Ref: PIA #M-10.
LPR-4H 30M	Large Probe Coast Timer initiation.	
LPR-4H 10M	Reduce bit rate; switch to Aft Omni.	• In preparation for precession to LP Release Attitude. • Use Horn for earth l. o. s. ≤30° w. r. t. S/C -Z axis (Ref: J. Salvatore of HAC). • LP Release attitude produces earth l. o. s. ≈36° w. r. t. S/C -Z axis.

TABLE 4.2.2-1 (Continued)

START TIME	MULTIPROBE MISSION PHASE & MISSION EVENT	REMARKS
LPR-4H	Precess to Large Probe Release Attitude.	• To produce 0° angle of attack. • Nominal $\Delta 44^{\circ}$ precession - Ref: M5. • Ref: M1 and M8.
LPR-3H	Attitude Determination and Attitude Trim (if required).	• To attain attitude within $\pm 2.5^{\circ}$ of desired attitude (Ref: M1).
LPR-2H 15M	Spin Rate Trim (if required).	• To attain spin rate of 15 $\pm$0.15 rpm (Ref: M1).
LPR-30M	Prepare LP for Release.	
LPR-15M	Separate IFDs.	
LPR ≡0 (=E-24 D)	Release Large Probe.	

TABLE 4.2.2-2
START OF SMALL PROBES' BAKEOUT PERIOD
THROUGH LARGE PROBE SEPARATION DETAILED FLIGHT SEQUENCE

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
		• Initial conditions are as shown in the appropriate columns of Table 2.3.1-1 (Multiprobe nominal equipment configurations during the mission). Essentially, it consists of: 64 M. DSN in use (for imminent TCM #3), Fwd omni in use for downlink, transmitter Hi power, S/C in cruise attitude, and spin rate at 15 rpm.		
1 (E-45D)		Reconfigure S/C for Small Probes' Stable Oscillators "bakeout" period.		• Stable oscillator in each Small Probe is turned ON and left ON continuously for ≈25 days in order to stabilize the frequency during its use just prior to S.P. entry through S.P. Impact. • It is very important that the bakeout be continuous, i.e., the cumulative OFF time of the stable oscillators during bakeout should be kept to an absolute minimum (<2 HRS between first turn ON and last pre-release turn-OFF).
1A		• Verify that the Science Reset Relay is closed ("ON").	PSCBUS	Science Bus Reset Relay Status = 1 (ON).
1B		• Turn ON Probe Checkout Power:		
1B1	PCO19 OR PCOA9	Probe Checkout Power ON.	PCHEKS	Probe Checkout Pwr ON/OFF = 1 (ON)
				• For X = 1 and 2 and 3:
			PXPR1S	SP X Internal Pwr Relay 1 ON/OFF = 0 (OFF).
			PXPR2S	SP X Internal Pwr Relay 2 ON/OFF = 0 (OFF).

TABLE 4.2 2-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
1C		• Reduce Bus Bit Rate:		• For simultaneous transmission with impending Small Probe subcarrier data.
1C1	TPCQ1: Bit Rate = 8	Telemetry Processor 1 Control (Select 8 bps)		Momentary loss of bit sync, then:
			Word 3	Bit Rate Selection = 8 bps
1D		• Select Probes' Lo Mod Index (and Bus Lo Mod Index):		• Recommended choices of Mod. Indices for simultaneous Probe/Bus Operation (Refer to Para. 3.7.3.1.1). • Sending either Probes' Mod Index select command also automatically selects the Bus Lo Mod Index.
1D1	MIL21 OR MILB1	• Probes' Lo Mod Index Select.		• No TLM available for verification. • Since only the Bus Subcarrier is ON at this time, the downlink carrier suppression will decrease by approximately 6.4 dB relative to Hi Mod Index only operation.
1E		Turn ON SPX CDU and then SPX Stable Oscillator:		• X = 1 or 2 or 3
1E1	SCDX9	SPX C/DU and RF Power Relay ON.		• Probe X subcarrier appears - Downlink carrier suppression will increase by 5.7 dB over Bus Subcarrier (Lo Mod Index) only operation.
				• SPX Telemetry appears at 64 bps rate and in the Upper Descent format (initial conditions

TABLE 4.2.2-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
1E1 (Cont'd)			PBUSLI	S/C Loads current increases a nominal 436 ma (@ 29 Vdc).
			PLIMTI	Bus voltage limiter current likely decreases by the same amount as PBUSLI had increased - if there is sufficient excess solar panel current.
				• After lockup to the SP telemetry stream occurs, verify as follows:
			PXCD1S	SPX C/DU and RF Power Relay 1 ON/OFF = 1 (ON).
			PXCD2S	SPX C/DU and RF Power Relay 2 ON/OFF = 1 (ON).
			PXBUSV	SPX Bus Voltage: Should read same value as PEBUSV (Essential Bus Voltage)
			PXOSCS	SPX Stable Oscillator ON/OFF = 0 (OFF).
			PXBUSI	SPX Bus Current should read ≈same value as the Δ increase in PBUSLI.
			RXHTOI	SPX Stable Oscillator Heater Current should read zero amps.
1E2	SOSX9	SPX Stable Oscillator ON.	PBUSLI	S/C Loads Current — Each increases about 200 ma (cold start) immediately, then each decreases with time (see Fig. 4.2.2-X) for a typical net increase of 30 ma.
			PXBUSI	SPX Bus Current

TABLE 4.2.2-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
1E2 (Cont'd)			RXHTOI	SPX Stable Oscillator Heater Current ≈0.2 Volts (TM) initially, then rises as seen in Figure 4.2.2-X.
			PXOSCS	SPX Stable Oscillator ON/OFF = 1 (ON).
1E3		• Monitor telemetry listed in previous step for about 20 minutes to verify proper stable oscillator current consumption.		• Refer to Figures 4.2.2-X, 4.2.2-5, and 4.2.2-6.
1F		• Turn OFF SPX CDU and turn ON SPY Stable Oscillator. (X = 1 or 2 or 3, Y = 1 or 2 or 3 and also Y ≠ X)		Bus Communications Subsystem is designed to accommodate only one Probe subcarrier ON at a time without garbling telemetry.
1F1	SCDX#	SPX C/DU and RF Power Relay OFF.		• Probe X subcarrier disappears - Downlink carrier suppression will decrease by 5.7 dB over Bus subcarrier (Lo Mod Index) only operation
			PBUSLI	S/C Loads current decreases a nominal 436 ma. @ 29 Vdc.
			PLIMTI	Bus Voltage limiter current likely increases by the same amount as PBUSLI had decreased - if there is sufficient excess Solar Panel Current.
1F2		• Turn ON SPY CDU and then its Stable, Oscillator.		Y is a different SP than the previous SP.
1F2.1		• Repeat Steps 1E1 through 1E3 for SPY.		
1G		• Turn OFF SPY CDU and turn ON remaining third SP:		

TABLE 4.2.2-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION		
			TELEMETRY MNEMONIC	REMARKS & TM DATA	
1G1		• Repeat Step 1F1 for SPY, then Step 1E1 through 1E3 for the third SP			
1H		• Turn OFF third SP:			
1H1		• Repeat Step 1F1 for the third SP.			
1J		• As further assurance that the Stable Oscillators are ON, repeat turn ON Command for each SP Stable Oscillator:		• Execute for X = 1 and 2 and 3. • There is no Step 1I	
1J1	SOSX9	SPX Stable Oscillator ON.	PBUSLI	S/C Loads Current	• Current consumption of ≈30 ma for a stable oscillator that is powered ON is less than 1 count for each of these TM parameters - • A 200 ma transient occurs upon turn ON that lasts anywhere between a few seconds (even if the stable oscillator had been OFF for a matter of seconds) and a duration as seen in Fig. 4.2.2-X for a cold oscillator.
			PLIMTI	Bus Voltage Limiter Current	
1K		• Throughout the 25 days "bakeout" period, do as follows:			

TABLE 4.2.2-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
1K1		• Verify frequently the TM at the right.	PSCBUS	Science Bus Reset Relay Status = 1 (ON)
			PCHEKS	Probe Checkout Power ON/OFF = 1 (ON)
				• For X = 1 and 2 and 3:
			PXPR1S	SPX Internal Power Relay 1 ON/OFF = 0 (OFF).
			PXPR2S	SPX Internal Power Relay 2 ON/OFF = 0 (OFF).
1K2		• Verify that none of the following commands are executed. If any one is, then the affected Probe(s) Stable Oscillator should be turned ON immediately via the appropriate part or all of Steps 1A through 1H :		
		Command that will Turn OFF One or More SP Stable Oscillators:		AFFECTED SP:
	SAMX0	SPX Power Amplifier OFF/Stable Oscillator OFF		SPX, where X = 1 or 2 or 3.
	PCO10 OR PCOA0	Probe Checkout Power OFF.		All 3 S.P.
	INS10 OR INSA0	All Science OFF		All 3 S.P.
1K3		• It is suggested, as further insurance, that the following actions be done immediately following periods of S/C activity (e.g., Probes Checkout, TCM #3):		
1K3.1		• Verify Probe Checkout Power is ON.	PCHECKS	Probe Checkout Pwr ON/OFF = 1 (ON)
				For X = 1 and 2 and 3:
			PXPR1S	SPX Internal Pwr Relay 1 ON/OFF = 0 (OFF)

TABLE 4.2 2-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
1K3.1 (Cont'd)			PXPR2S	SPX Internal Power Relay 2 ON/OFF = 0 (OFF).
1K3.2		• Execute turn ON Command for each SP Stable Oscillator:		• Execute for X = 1 and 2 and 3.
1K3.2.1	SOSX9	SPX Stable Oscillator ON.	PBUSLI PLIMTI	S/C Loads Current Bus Voltage Limiter Current • No change indicates each Stable Oscillator is ON, or had been OFF for a short time, & the turn ON transient of 200 ma was too short in duration to be seen by the TM system (current consumption of ≈30 ma for a warm Stable Oscillator is less than 1 count for each of these TM parameters.) • Discernable change of 200 ma indicates the Oscillator had been OFF.
1K3 2.2		• If there had been a detectable change in the telemetry listed in the previous step that indicated one or more stable oscillators had been OFF, then the cause of that unwanted turn OFF must be avoided throughout the "bakeout" period.		

TABLE 4.2.2-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
2 (E-40D)	HTL1Ø OR HTLAØ	Large Probe and Small Probe 1 Heaters OFF.	PLHTRS	Large Probe Heater = 0 (OFF)
			PLBHRS	Large Probe Battery Heater Relay ON/OFF = 0 (OFF)
			PBUSLI	S/C Loads current decreases a nominal 768 ma., due to Large Probe shelf heater turnoff.
			PLBATT	Large Probe Battery Temperature Decreases and stabilizes.
3 (E-30D)		• Perform TCM #3 per the appropriate detailed sequences in Section 4.3.1 (Maneuvers). • Perform Attitude Determination per Section 4.3.2. • Perform a trajectory determination per the standard tracking procedure.		
4 (E-28D 3H)	HTJ1Ø OR HTJAØ	Forward Axial Jet Heaters OFF.	PBUSLI	S/C Loads current decreases a nominal 31 ma., due to heaters turnoff.
			VJET5T	Forward Axial Jet 5 Temperature decreases & stabilizes

TABLE 4.2.2-2. (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
5 (E-28D03H)		(Process to Horn Attitude)		Ref: M7
5A		• Perform the appropriate detailed precession sequence in Section 4.3.1 (Maneuvers), except load the number of pulses required for this precession magnitude, and the angle delay magnitude corresponding to that uniquely required for this precession. • (Partial precession - Do not close latching valves after this precession. Refer to remarks.)		• Precess approximately $\Delta 20^{\circ}$ to $\Delta 30^{\circ}$ (of a total required $\Delta 90^{\circ}$ nominal), or until ground received BER increases to TBD, or S/N ratio decreases to TBD dB. (Ref: M8, M9 and M11).
5B		• After the above partial precession is completed, switch S/C transmission to the aft omni:		• Ref: Par. 1.5.21.
5B1	AMP3Ø OR AMPCØ	Power Amplifiers 3 & 4 OFF.		• Likely loss of bit sync & telemetry. • Possible loss of carrier.
5B2	AMP1Ø OR AMPAØ	Power Amplifiers 1 & 2 OFF.		• Loss of downlink carrier.
5B3	ANT11 OR ANTA1	HI Power to aft omni select.		• No downlink - not verifiable in real time.
5B4	AMP19 OR AMPA9	Power Amplifier 1 ON/2 OFF.		• Possible recovery of downlink carrier (should be phase-locked to uplink).

TABLE 4.2.2-2. (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
5B6	AMP39 <u>OR</u> AMPC9	Power Amplifier 3 ON/4 OFF.		• Recovery of downlink carrier demod sync to subcarrier, & bit sync to telemetry. Frame sync will follow later because of low bit rate. • Ground received signal strength should be stronger than at the start of step 5B.
			RANT1S	Hi Pwr to Fwd or Horn/Lo Pwr to Aft Omni = (Hi Pwr to Aft Omni).
5C		• Precess the remaining segment of the total required precession (performed functionally the same as the last precession) - then <u>Close</u> latching valves.		
6 (E-27D 23: 30M)		<u>Switch to Horn for Transmission</u>		• Ref: Par. 1.5.21
6A	ANT21 <u>OR</u> ANTB1	Medium Gain Horn Select.		• No change in Ground Received signal.
			RANT2S	Horn/Fwd Omni = 1 (Horn)
6B	AMP3Ø <u>OR</u> ANTCØ	Power Amplifiers 3 & 4 OFF		• Likely loss of bit sync & telemetry. • Possible loss of carrier.

TABLE 4.2.2-2. (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
6C	AMP1Ø OR AMPAØ	Power Amplifiers 1 & 2 OFF		• Loss of downlink carrier.
6D	ANT12 OR ANTA2	Hi Power to Fwd/Horn Select.		• No downlink - not verifiable in real time.
6E	AMP19 OR AMPA9	Power Amplifier 1 ON/2 OFF.		• Possible recovery of downlink carrier (should be phase-locked to uplink).
6F	AMP39 OR AMPC9	Power Amplifier 3 ON/4 OFF.		• Recovery of downlink carrier, demod sync to subcarrier, & bit sync to telemetry. Frame sync will follow later because of low bit rate. • Ground received signal strength should be stronger than at the start of step 6.
			RANT1S	Hi Pwr to Fwd or Horn/Lo Power to Aft Omni = 1 (Hi Pwr to Horn).
7		<u>Increase Bit Rate</u>		• Assumes 256 bps is sustainable for Xmtr Hi Pwr, Horn, & remainder of link budget.
7A	TPCQ1; Bit Rate = 256	Telemetry Processor 1 Control (Select 256 bps)		Momentary loss of bit sync, then:
			WORD 3	Bit Rate Selection = 256 bps.

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TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
8 (E-27D 23H15M)		• Perform Attitude Determination per Section 4.3.2.		
9 (E-27D 22H)		Decrease Bit Rate and Retur to Single Transmitter:		
9A		Decrease Bit Rate:		• Assumes 128 bps is sustainable for Xmtr Lo Pwr, Horn & remainder of link budget.
9A1	TPCQ1; Bit Rate = 128 bps	Telemetry Processor 1 Control (Select 128 bps)		Momentary loss of bit sync, then:
			WORD 3	Bit Rate Selection = 128 bps.
9B		Return to Single Transmitter:		
9B1	AMP3Ø OR AMPCØ	Power Amplifiers 3 and 4 OFF.		• Likely loss of bit sync and telemetry. • Possible loss of carrier.
9B2	AMP1Ø OR AMPAØ	Power Amplifiers 1 and 2 OFF.		• Loss of downlink carrier.
9B3	ANT11 OR ANTA1	Low Power to Horn Select.		• No downlink - not verifiable in real time.
9B4	AMP11 OR AMPA1	Amplifier 1 to Low Power Select.		• No downlink - not verifiable in real time.

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
9B5	AMP19 OR AMPA9	Power Amplifier 1 ON/2 OFF.		• Recovery of downlink carrier, demod sync to subcarrier & bit sync to telemetry. Frame sync will follow later because of low bit rate. • Ground received signal strength should be weaker than at the start of Step 9B.
			RANT1S	High Power to Fwd or Horn/Low Power to Aft Omni = 0 (Low Power to Horn).
			RAMP3W	RF Power Output 3 = 0 Watts.
			RAMP3T	PA 3 Temperature - Decreases and stabilizes at 69°F to 88°F.
			RAMP1S	Amp 1/2 to Hi/Lo Power = 0 (Amp 1 to Low Power).
10 (E-24D12H ≡ LPR-12H where LPR ≡ LP Release Event)		<u>Add Second Transmitter and Increase Bit Rate:</u>		
10A		<u>Add Second Transmitter:</u>		
10A1	AMP1Ø OR AMPAØ	Power Amplifiers 1 and 2 OFF.		• Loss of downlink Carrier.

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TABLE 4.2.2-2. (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
10A2	ANT12 OR ANTA2	High Power to Fwd/Horn Select.		• No downlink - not verifiable in real time.
10A3	AMP12 OR AMPA2	Amplifier 1 to High Power Select.		
10A4	AMP19 OR AMPA9	Power Amplifier 1 ON/2 OFF.		• Possible recovery of downlink carrier (should be phase-locked to uplink).
10A5	AMP39 OR AMPC9	Power Amplifier 3 ON/4 OFF.		• Recovery of downlink carrier, demod sync to subcarrier, and bit sync to telemetry. Frame sync will follow later because of low bit rate. • Ground received signal strength should be stronger than at the start of Step 10A.
			RANT1S	High Power to Fwd or Horn/Low Power to Aft Omni = 1 (High Power to Horn).
			RAMP3W	RF Power Output 3 = 10 Watts.
			RAMP3T	PA 3 Temperature - Increases and stabilizes at 78°F to 88°F.
			RAMP1S	Amp 1/2 to High/Low Power = 1 (Amp 1 to High Power).
10B (≈ LPR - 11H50M)		Increase Bit Rate:		• Assume 256 bps is sustainable for Xmt High Power and remainder of link budget.

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
10B1	TPCQ1; (Bit Rate = 256 bps)	Telemetry Processor 1 Control (Select 256 bps).		Momentary loss of bit sync, then:
			WORD 3	Bit Rate Selection = 256 bps.
11 (LPR - 11H 30M)		<u>Load Command Memory for Last Large Probe Checkout.</u>		
11A	CPCQ1; Either CP (CP Select); No OP (RCVR); OFF (SCL)	Command Processor 1 Configure - (SCL OFF)		• To clear SCL memory contents with certainty.
			CSCL1S	SCL = 0 (OFF).
11B	CPCQ1; Either CP (CP Select); No OP (RCVR); Clear/ ON (SCL)	Command Processor 1 Configure (SCL Clear/ON)		• Turns SCL Power ON, sets SCL to Standby, and initializes memory address pointer (Ref: Section 3.6.3.2.2).
			CSCL1S	SCL = 1 (ON).
			CLOG1S	SCL Logic State = 15 (Standby)
			CMEM1C	Command Memory 1 Address Pointer = All Zeros - Points to first 24-bit word slot in memory.
11C	CPCQ1; Either CP (CP Select); No OP (RCVR); Load (SCL).	Command Processor 1 Configure (SCL Load)	CLOG1S	SCL Logic State = 14 (Load)

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
				Checkout power is already ON in order to support S.P. stable oscillators operations.
11C1	As Req'd.	First Command to be Stored	CMEM1C	"Command Memory 1 Address Pointer" has advanced by a count of 1 after issuance of this command; and will increase by a count of 1 for each subsequent issuance of a command.
11C2	As Req'd.	Second Command to be Stored		
⋮	⋮	⋮		
11CN		Nth Command to be Stored.		Checkout power must be left ON after L.P checkout in order to support S.P. stable oscillators operation.
11D		After last special command for this sequence has been stored, send:		
	CPCQ1; Either CP (CP Select); No OP (RCVR); STOP (SCL).	Command Processor 1 Configure - (SCL STOP) - (STORED COMMAND).		• To insure no automatic repeat of the stored command sequence once it has been initiated.
			CLOGIS	SCL Logic State = 14 (Still = Load State).
			CMEM1C	"Command Memory 1 Address Pointer" = Location of this last command stored in memory (record for later use).
11E	CPCQ1; [illegible]ther CP (CP [illegible]ect); No OP (RCVR); Standby (SCL).	Command Processor 1 Configure - (SCL STANDBY)		• To take SCL out of load state; no other command will accomplish this and keep memory contents intact (Ref: Section 3.6.3.2).
			CLOGIS	SCL Logic State = 15 (Standby).

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
11F	CPCQ1; Either CP (CP Select); No OP (RCVR); Index (SCL).	Command Processor 1 Configure (SCL INDEX).		• To move address pointer to first 24-bit word slot in memory.
			CLOG1S	SCL Logic State = 15 (Standby).
			CMEM1C	Command Memory 1 Address Pointer = All Zeros - Points to first 24-bit word slot in memory.
		• Command Memory is now indexed to first stored command, and ready to be verified or executed.		
12 (≈ LPR-11H15M)		<u>Verify Command Memory Contents Before Execution:</u>		
12A	CPCQ1; Either CP (CP Select); No OP (RCVR); Read (SCL).	Command Processor 1 Configure (SCL Read)		• Required logic state for memory readout.
			CLOG1S	SCL Logic State = 10 (Read)
			CMEM1C	Command Memory 1 Address = All Zeros - Required in order to read entire memory in one cycle (Ref: Section 3.6.3.2).
12B	TPCQ1; CMRO	Telemetry Processor 1 Control - (Select "Command Memory Readout" TM Format).	WORD 3	Telemetry format selection = 0101 (Command Memory 1 Readout).
			CMEM1	Command Memory 1 Readout - begins reading out memory contents. When the end of the memory is reached, & the SCL automatically transfers to the STANDBY state, this memory readout will persist as all zeros.

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
12B (Cont'd)			CMEM1C	Command Memory 1 Address Pointer - Increases by a count of 1 after each 24-bits is readout in CMEM1. Resets to all zeros when the end of the memory is reached, and stops increasing.
			CLOGIS	SCL Logic State = 10 (Read) Until end of memory is reached, then automatically transfers to 15 (STANDBY) and stays in that state.
12C	TPCQ1; ENGR.	Telemetry Processor 1 Control - (Select "Bus Engineering" TM Format)		• To evaluate bus prior to continuing to Large Probe checkout.
			WORD 3	Telemetry Format Selection = 0001 (Bus Engineering Format)
13 (≈ LPR - 11H)		<u>Last Large Probe Checkout</u>		
13A (LPR-3H 30M)		Reduce Bus Bit Rate:		• For simultaneous transmission with impending Large Probe subcarrier data.
13A1	TPCQ1; Bit Rate = 8	Telemetry Processor 1 Control (Select 8 bps)		Momentary loss of bit sync, then:
			WORD 3	Bit Rate Selection = 8 bps.
13B		• Initiate contents of Command Memory, and record all telemetry:		• Large Probe data rate of 256 bps, as required for some scientific instruments, is assumed to be selected via the Command Memory sequence.

TABLE 4.2.2-2. (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
13B1	CPCQ1; Either CP (CP Select); No OP (RCVR); Immediate Start (SCL).	Command Processor 1 Configure (SCL Immediate Start)	CLOG1S	SCL Logic State: Transfers first to "Run" state (=12). If a stored command is not a time delay, this will transfer to the "Process Command" state (=8); if a stored command is a time delay, this will transfer to the "Load Timer" state (=13). Last stored command is a "STOP" command, and this will become."STOP 1" (=3)
			CMEM1C	Command Memory 1 Address Pointer: Increase by count of 1 as each stored command is executed.
14 (LPR-9H)		Return to Single Transmitter		
		• Repeat Step 9, then return here.		
15 (LPR-8H 55M)		(Batteries to Hi Charge Rate)		
15A		For Battery 1 to Hi Charge Rate:		

TABLE 4.2.2-2. (Cont'd)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
15A1	BAT19 OR BATA9	Battery 1 - Relay 1 Hi Rate Charge	PB1R1S	Battery 1. Relay 1 Status = 1 (To Hi Charge Position)
			PCHG1I	Battery 1 Charge Current = 0 Amp
			PLIMTI	Bus Voltage Limiter Current - Increases
15A2	BAT13 OR BATA3	Battery 1 - Relay 2 Hi Rate Charge	PB1R2S	Battery 1, Relay 2 Status = 1 (To Hi Charge Position)
			PCHG1I	Battery 1 Charge Current = 0.750 Amps (C/10)
			PLIMTI	Bus Voltage Limiter Current Decreases
15B		• Battery 2 to Hi Charge Rate:		

TABLE 4.2.2-2. (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
15B1	BAT29 OR BATB9	Battery 2 - Relay 1 Hi Rate Charge.	PB2R1S	Battery 2, Relay 1 Status = 1 (To Hi Charge Position).
			PCHG2I	Battery 2 Charge Current = 0 Amp.
			PLIMTI	Bus Voltage Limiter Current Increases.
15B2	BAT23 OR BATB3	Battery 2 - Relay 2 Hi Rate Charge	PB2R2S	Battery 2 - Relay 2 Status = 1 (To Hi Charge Position)
			PCHG2I	Battery 2 Charge Current = 0.750 Amp (C/10).
			PLIMTI	Bus Voltage Limiter Current Decreases
15C		• Monitor TM at Right. • When conditions are met, return batteries to trickle charge rate via event ahead.	PB1P1T	Battery 1, Pack 1 Temperature.
			PB1P2T	Battery 1, Pack 2 Temperature
			PB2P1T	Battery 2, Pack 1 Temperature
			PB2P2T	Battery 2, Pack 2 Temperature
			PBAT1V	Battery 1 Terminal Voltage.
			PBAT2V	Battery 2 Terminal Voltage.

TABLE 4.2.2-2. (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
15C (Cont'd)				When the battery voltage rises during high rate charge & then "rolls-over" & decreases by 2 data units (≈0.3 V) from its peak value; and/or the battery temp. rate of rise suddenly becomes steep, transfer to Low (trickle) charge rate via the event ahead.
16 (≈LPR -6H)		(Batteries to Trickle Charge Rate)		
16A		• To Reduce Battery 1 Charge Rate:		
16A1	BAT1Ø OR BATAØ	Battery 1 - Relay 1 Lo Rate Charge.	PB1R1S	Battery 1, Relay 1 Status = 0 (To Lo Charge Position)
			PCHG1I	Battery 1 Charge Current = 0 Amp.
			PLIMTI	Bus Voltage Limiter Current - Increases.
16A2	BAT14 OR BATA4	Battery 1 - Relay 2 Lo Rate Charge.	PB1R2S	Battery 1, Relay 2 Status = 0 (To Lo Charge Position).
			PCHG1I	Battery 1 Charge Current = 150 ma (C/50) Average.
			PLIMTI	Bus Voltage Limiter Current - Decreases

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
16B		• To reduce Battery 2 Charge Rate:		
16B1	BAT2Ø OR BATBØ	Battery 2 - Relay 1 Low Rate Charge	PB2R1S	Battery 2, Relay 1 Status = 0 (To Low Charge Position).
			PCHG2I	Battery 2 Charge Current = 0 Amp.
			PLIMTI	Bus Voltage Limiter Current Increases.
16B2	BAT24 OR BATB4	Battery 2 - Relay 2 Low Rate Charge.	PB2R2S	Battery 2 - Relay 2 Status = 0 (To Low Charge Position).
			PCHG2I	Battery 2 Charge Current = 150 ma. (C/50) Average.
			PLIMTI	Bus Voltage Limiter Current Decreases
17 (≈ LPR - 5H40M)		Add Second Transmitter; Switch to ACS Format.		
17A		• Repeat Step 10, then return here.		
17B	TPCQ1; ACS Format Select	Telemetry Processor No. 1 Control - Select ACS Format.		When loading a probe coast timer, a Bus format that does not contain subcom C should be selected until the loading has been accomplished. This will prevent any interference between the Subcom C read envelope and the loading process which would result in a misloaded register.

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
18 (LPR-5H30M)		Prepare Large Probe for Release; Transfer to Large Probe Battery, Load and Initiate Coast Timer:		
18A	LPP19 OR LPPA9	Large Probe Internal Power ON.	PLBR1S	Large Probe Internal Power Relay 1 ON/OFF = 1 (ON).
			PLBR2S	Large Probe Internal Power Relay 2 ON/OFF = 1 (ON).
			PLBATT	Large Probe Battery Temperature rises and stabilizes as a result of battery being steadily discharged.
18B	LCTQ1 OR LCTQA	Coast Timer Set (Time Delay as Required).		
18C	TPCQ1	Telemetry Processor No. 1 Control - Bus Eng Format Select.		To verify a coast time that has been loaded into a coast timer, a Bus format that contains subcom C must be selected. Within subcom C, the LP coast timer value is located in words 5 & 6 and SP's 1, 2, & 3 are located in words 21 & 22, 37 & 38 and 53 & 54 respectively. In each case, the first word contains the eight least significant bits and the second word contains the eight most significant bits. If the change to select the format containing subcom C should happen to occur exactly between the two coast timer readout words, such as between words 5 & 6, the contents of those two words (Continued)

TABLE 4.-.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
18C (Cont'd)				will be interchanged, i.e., the first word will contain the eight most significant bits and the second word will contain the eight least significant bits. The contents of the remaining three coast timer readouts will be correct. To alleviate the situation, it will be necessary to command out of the format and reload the coast timer.
			CLTIMC	Large Probe Coast Time Verification - Telemetered as commanded.
18D	LCT19 OR LCTA9	Start Coast Timer.	CLTIMC	Large Probe Coast Time Verification - Indicates Countdown.
19		Switch to Aft Omni; Increase Bit Rate, if possible.		• Assumes 16 bps is sustainable via Aft Omni and impending Large Probe Release Attitude.
19A		Repeat Step 5B, then Return Here.		
19B	TPCQ1; Bit Rate = 16 bps	Telemetry Processor 1 Control (Select 16 bps)		Momentary loss of bit sync, then:
			WORD 3	Bit Rate Selection = 16 bps.
20		Precess to Large Probe Release Attitude		
		• Perform the appropriate detailed precession sequence in Section 4.3.1 (Maneuvers), except load the number of pulses required for this precession magnitude and the angle delay magnitude corresponding to that uniquely required for this precession.		• Δ 44° Nominal precession. Ref: M8, M9 and M11.

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
21 (LPR-3H)		Attitude Determination and Attitude Trim (If Required).		
21A		• Perform Attitude Determination per Section 4.3.2 for the stars visible at this point in mission.		• This is performed to insure Large Probe release attitude is sufficiently accurate. (Ref: M1 - Within $\pm 2.5^{\circ}$ of desired attitude).
21B		Attitude Trim (If Required) • If a refinement in attitude is required, perform the appropriate detailed precession sequence in Section 4.3.1 (Maneuvers).		
22 (LPR-2H15M)		Spin Rate Trim (If Required) • If ATTM telemetry indicates a need to trim the spin rate, perform the appropriate detailed spin maneuver sequence in Section 4.3.1 (Maneuvers).	ATTM1Z OR ATTM2Z	(SRR to SRR) should be a spin period corresponding to a spin rate of 15 $\pm$0.15 rpm (Ref: M1).
23 (LPR-30M)		Prepare Large Probe for Release; Separate IFD's, and Release Large Probe.		
23A LPR-15M, minimum 6S, & maximum 14 Sec between 1st Arm & Fire Commands	ORD13	Arm Large Probe IFD and BNMS B/O Hat		
	ORD14	Fire Large Probe IFD		
	ORDA4	Fire Large Probe IFD		
				IFD Separation is indicated by all Large Probe TM to the Bus changing suddenly to full-scale values.

TABLE 4.2.2-2 (Continued)

STEP # & START TIME	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
23A (Cont'd)			PLBATT	Large Probe Battery Temp. (All Change Suddenly to Full-Scale Values.)
			SLAF1T	Large Probe Aft Shelf Temp 1 (All Change Suddenly to Full-Scale Values.)
			SLFW1T	Large Probe Fwd Shelf Temp 1 (All Change Suddenly to Full-Scale Values.)
			CLTIMC	Large Probe Coast Time Verification
	ORD1Ø	Disarm PCU 1.		
	ORDAØ	Disarm PCU 1		
23B (LPR = 0) Minimum 6 Secs; Maximum 14 secs. between 1st Arm & Fire Commands	ORD11	Arm Large Probe Separation		
	ORD12	Large Probe Separation		• May cause detectable transient in Downlink Signature.
	ORDA2	Large Probe Separation		• May cause detectable transient in Downlink Signature.
			SLRELS	Large Probe Stowed/Released Status changes to Released (=0).

TABLE 4.2.2-3

REFERENCES FOR TIMELINE AND COMMAND SEQUENCES OF SECTIONS 4.2.2 AND 4.2.3.

REFERENCE IDENTIFIER	
M1	Paragraph 2.2.2 of Reference 1.5.20
M2	View Graph 1.4.16 of Reference 1.5.5
M3	View Graph 1.19.4-1 of Reference 1.5.5
M4	Multiprobe Mission Sequence - HAC Memo No.HS507/1679 - Hartenstein - Dated 4 November 1974.
M5	Paragraph 2.1 of Reference 1.5.3.
M6	Table 2.5.2-1 (Page 2-65) of Reference 1.5.3
M7	Page 2.49 and Table 2.4.1-1 of Reference 1.5.3
M8	Table 2.3.2-1 (Page 2-48) of Reference 1.5.3
M9	Figure 2.2.1-21 of Reference 1.5.3
M10	Page 4-9 of Reference 1.5.13
M11	Figures 2.2.1-23, 6.3.12-4, 6.3.12-5, 6.3.13-2 and 6.3.13-3 of Reference 1.5.3.
M12	Paragraph 2.2.1 of Reference 1.5.20.
M13	AVO from R. Fehr of HAC, dated 6/13/77.
M14	Multiprobe TTM Review, February 24, 1977, and Lee Hennis of HAC.

TABLE 4.2.3-1

POST-L.P. SEPARATION THROUGH S.P. SEPARATION TIMELINE OF EVENTS

START TIME	MULTIPROBE MISSION PHASE & MISSION EVENT	REMARKS
	POST-L.P. SEPARATION THROUGH S.P. SEPARATION	
LPR+15Min. (LPR ≡ Large Probe Release Event)	Reorient for Small Probes targeting; Switch to Horn.	• $\Delta 48.4^{o}$ Precession - Ref: M8.
LPR+35Min.	Return to Single Transmitter	• Ref: M7 • Earth l.o.s. $\approx 18^{o}$ w.r.t. S/C -Z axis permits increase in bit rate even at low S/C Xmtr power.
LPR+50Min.	Batteries to Hi Charge Rate	• Per R. Daniel of HAC circa 6/12/77
E-23D 2H30M	Spinup to 48.5 rpm (Nominal)	• To produce lateral ΔV of 5.08M/Sec for Small Probes at their release - Ref: M12.
E-23D 2H	Attitude Determination & Attitude Trim (If Required)	
E-23D 1H	Retarget for Small Probes	• Nominal ΔV of 5.1 M/Sec - Ref: M5 & M8. • Allows 3 days of tracking prior to Probes' release.
E-23D	Attitude and Orbit Determination	
E-20D 14H ≡ SPR-14H (where SPR ≡ SP Release Event)	ΔV Trim.	

TABLE 4.2.3-1. (Continued)

START TIME	MULTIPROBE MISSION PHASE & MISSION EVENT	REMARKS
SPR-13H	Load Command Memory for last S.P. Checkout; Last S.P. Checkout (Each Sequentially), & stable oscillators turn OFF.	• S.P./Bus bit rates are nominally 64/8 • This is the termination of the twenty-five days stable oscillators "bakeout" period.
SPR-9H 30M	Prepare Small Probes; transfer to Probes' batteries & load S.P. coast times.	
SPR-8H 30M	S.P. Coast Timers Initiation.	
SPR-7H	Precess to Intermediate Attitude.	• Allows star sensor to cool while the S/C batteries remain in a charging or zero discharging state. (Sun look angle is nominally 28°).
SPR-3H	Precess to S.P. Release Attitude	• Nominal Δ50° precession, including precess to Intermediate Attitude - Ref: M3, M5, M7 & M8.
SPR-2H 45M	Attitude Determination & Attitude Trim (If Required)	• To attain attitude within ±2.5° of desired attitude - Ref: M1.
SPR-2H	Spin Rate Trim (If Required)	• To attain spin rate of 48.5 ±0.4 rpm - Ref: M1 & M4.
SPR-30M	Prepare for S.P. Release	• Switch to S/C Xmtr Hi Pwr & 128 bps (nominal).
SPR-15M	Arm S.P. & Separate IFD's.	
SPR = 0 (E-20D)	Release Small Probes	

TABLE 4.2.3-2

POST-L.P. SEPARATION THROUGH S.P. SEPARATION DETAILED SEQUENCE

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
		• Initial conditions are as shown in the appropriate columns of Table 2.3.1-1 (Multiprobe Nominal Equipment Configurations During the Mission). Essentially, it consists of: 64M. DSN in use, Aft Omni in use for downlink, transmitter Hi Power, S/C in L.P. Release Attitude and Spin Rate at 15 rpm.		
1 (LPR-15M)		Reorient for Small Probes Targeting		
		• Perform the appropriate detailed precession sequence in Section 4.3.1 (Maneuvers), except load the number of pulses required for this precession magnitude and the angle delay magnitude corresponding to that uniquely required for this precession.		• ≈ Δ48° precession (Ref: M8.)
2 (LPR+35M)		Switch to Horn for Transmission		
		• Perform step 6 of Table 4.2.2-2, then return here.		
3 (LPR+60M)		Batteries to Hi Charge Rate		
		• Perform step 15 of Table 4.2.2-2, then return here.		

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TABLE 4.2.3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
4 (E-23D2H 30M)		Spinup to 46.5 RPM (Nominal)		
		• Perform the appropriate detailed spinup sequence in Section 4.3.1 (Maneuvers)		
5 (E-23D1H 30M)		Attitude Determination and Attitude Trim (If Required)		
5A		• Perform attitude determination per section 4.3.2 for the stars visible at this point in the mission.		
5B		• If a refinement in attitude is required, perform the appropriate detailed precession sequence in Section 4.3.1 (Maneuvers).		• Attitude required to be within $\pm 2.5^{\circ}$ of desired attitude. Ref: M1.
6 (E-23D1H)		Retarget for Small Probes		
		• Perform the appropriate detailed ΔV sequence in Section 4.3.1 (Maneuvers).		• Nominal ΔV of 5.1 M/sec. Ref: M5 and M8. • Allows three days of tracking prior to Probes' release.
7 (E-23D)		Attitude and Orbit Determination		
		• Perform attitude determination per Section 4.3.2. • Perform a trajectory determination per the Standard Tracking Procedure.		

TABLE 4.2.3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
8 E-20D 14H (≡SPR-14H where SPR ≡ Small Probes Release Event ≡ E-20D)		<u>ΔV Trim (If Required)</u>		
		• Repeat Step 6 for vernier correction, if Required.		
9 (SPR-13H)		<u>Load Command Memory For Last Small Probes' Checkout</u>		
		• Perform step 11 of Table 4.2.2-2, except: (1) Load commands unique to small probes checkout. (2) The capacity of one command memory may be insufficient. The second command memory may have to be linked to operate sequentially after the contents of the first command memory have been executed. Refer to section 3.6.3 for further information. (3) After loading the memories, return here		• Checkout power is already ON at start of checkout sequence, in order to support S. P. stable oscillators operation (stable oscillators should have been ON continuously since E-45 days for an intended 25-day "bake-out" period). • Stable oscillators & checkout power should be turned OFF at end of checkout sequence.

TABLE 4.2.3-2 (Continued)

STEP & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
10 (SPR-12H 15M)		Verify Command Memory (IES) Contents Before Execution:		
		• Perform Step 12 of Table 4.2.2-2, then return here.		
11 (SPR-12H)		Last Small Probes' Checkout		• Checkout the Small Probes sequentially.
11A		• Perform Step 13 of Table 4.2.2-2, then return here.		• Includes turn OFF of stable oscillators & checkout power at the end of the checkout sequence.
11B		After all Small Probes' subcarriers have been turned OFF, increase Bus Bit Rate to highest supportable level:		
11B1	TPCQ1 Bit Rate = 64	Telemetry Processor 1 Control (Select 64 bps).		• Assumes 64 bps is highest supportable via Horn, Low Transmitter Power, and remainder of link budget.
12 (SPR-9H 30M)		Prepare Small Probes for Release; Transfer to Small Probes Batteries, Load and Initiate Coast Timer:		
12A	TPCQ1	Telemetry Processor No. 1 Control - ACS Format Select.		When loading a probe coast timer, a Bus format that does not contain subcom C should be selected until the loading has been accomplished. This will prevent any interference between the subcom C read envelope and the loading process which would result in a misloaded register.

TABLE 4.2.3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
12B	SPP19 OR SPPA9	Small Probe 1 Internal Power ON.	P1PR1S	SP 1 Internal Power Relay 1 ON/OFF = 1 (ON).
			P1PR2S	SP 1 Internal Power Relay 2 ON/OF' = 1 (ON).
			P1BATT	Small Probe 1 Battery Temperature rises and stabilizes as a result of battery being discharged.
12C	SPP29 OR SPPB9	Small Probe 2 Internal Power ON.	P2PR1S	SP 2 Internal Power Relay 1 ON/OFF = 1 (ON).
			P2PR2S	SP 2 Internal Power Relay 2 ON/OFF = 1 (ON).
			P2BATT	SP 2 Battery Temperature rise and stabilizes as a result of battery being discharged.
12D	SPP39 OR SPPC9	Small Probe 3 Internal Power ON.	P3PR1S	SP 3 Internal Power Relay 1 ON/OFF = 1 (ON).
			P3PR2S	SP 3 Internal Power Relay 2 ON/OFF = 1 (ON).
			P3BATT	SP 3 Battery Temperature rises and stabilizes as a result of battery being discharged.
12E	SCTQ1 OR SCTQA	SP 1 Coast Timer Set (Time Delay as required).		

TABLE 4.2.3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
12F	SCTQ2 OR SCTQB	SP 2 Coast Timer Set (Time Delay as required)		
12G	SCTQ3 OR SCTQC	SP 3 Coast Timer Set (Time Delay as required)		
12H	TPCQ1	Telemetry Processor No. 1 Control - Bus Eng. Format Select.		To verify a coast time that has been loaded into a coast timer, a Bus format that contains subcom C must be selected. Within subcom C, the I P Coast Timer value is located in words 21 & 22, 37 & 38 and 53 & 54, respectively. In each case, the first word contains the eight least significant bits and the second word contains the eight most significant bits. If the change to select the format containing subcom C should happen to occur exactly between the two coast timer readout words, such as between words 5 & 6, the contents of those two words will be interchanged, i.e., the first word will contain the eight most significant bits and the second word will contain the eight least significant bits. The contents of the remaining three coast timer readouts will be correct to alleviate the situation it will be necessary to command out of the format and reload the coast timer.
			C1TIMC	SP 1 Coast Timer Verification - Telemetered as commanded.

TABLE 4 2 3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
12H (Cont d)			C2TIMC	SP 2 Coast Timer Verification - Telemetered as commanded
			C3TIMC (7SD10)	SP 3 Coast Timer Verification - Telemetered as commanded
12I (SPR-8H 30M)	SCT19 OR SCTA9	SP 1 Start Coast Timer	C1TIMC	• SP 1 Coast Timer Verification - indicates countdown.
12J	SCT29 OR SCTB9	SP 2 Start Coast Timer	C2TIMC	• SP 2 Coast Timer Verification - indicates countdown
12K	SCT39 OR SCTC9	SP 3 Start Coast Timer	C3TIMC (7SD10)	• SP 3 Coast Timer Verification - indicates countdown
13 SPR-7H		Precess to Small Probes Intermediate Attitude		
		• Perform the appropriate detailed precession sequence in Section 4 3 1 (Maneuvers)		• Nominal Δ 40 ° precession to a sun look angle of 28° and an earth look angle of 30°. • Allows star sensor to cool while the S/C batteries remain in a charging or zero discharging state
14 (SPR-3H		Precess to Small Probes Release Attitude		
		• Perform the appropriate detailed precession sequence in Section 4 3 1 (Maneuvers).		• Nominal Δ 18 ° precession to a sun look angle of 17° and an earth look angle of 31°. • Batteries are in a discharging state

TABLE 4.2 3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
15 SPR-2H 45M		Attitude Determination and Attitude Trim (If Required)		
15A		• Perform Attitude Determination per Section 4.3.2 for the Stars visible at this point in the mission		
15B		• If a refinement in attitude is required, perform the appropriate detailed precession sequence in Section 4.3.1 (Maneuvers).		• Attitude required to be within $\pm 2.5^{\circ}$ of desired attitude. Ref: M1.
16 (SPR-2H)		Spin Rate Trim (If Required)		• To attain spin rate of 48.5 $\pm$0.4 rpm - Ref: M1
		• If ATTM Telemetry indicates a need to trim the spin rate, perform the appropriate detailed spin maneuver sequence in Section 4.3.1 (Maneuvers)	ATTM1Z OR ATTM2Z	(SRR to SRR) should be a spin period corresponding to a spin rate of 48.5 $\pm$0.4 rpm. Ref: M1.
17 (SPR-30M)		Prepare for Small Probes Release:		
17A		Load the desired Small Probes' Roll Release Angle.		• Prelaunch tests have indicated that the conservative time delays between (application of electrical power to the Release Squibs) and (the instant that a Small Probe is no longer influenced by the rotational motion of the Bus) are: SP-1 (Dummy): 8.6 msec. SP-2 : 9.2 msec. SP-3 : 10.7 msec. **The actual release delay times may be as much as 3 milliseconds less.**

TABLE 4.2.3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
17A1	ATQ06 (for ADP 1 Only)	ADP Configure - Roll Index Delay Magnitude (Address No. 5) (Magnitude = As Required).	ARIPAD	Roll Index Delay Magnitude = Commanded Value.
			ATTM1Z OR ATTM2Z	(SRR to RIP): Step function change to commanded value (angle in degrees) divided by spin rate.
17B		• Switch to Spacecraft High Power via Horn per Step 10A of Table 4.2.2-2, then return here.		
17C		• Increase TM bit rate to highest available level (assumed to be 128 bps for nominal link budget)		
	TPCQ1, Bit Rate = 128 bps	Telemetry Processor 1 Control (Select 128 bps)		Momentary loss of bit sync, then:
			WORD 3	Bit Rate Selection = 128 bps.
18 (S^OR-15M)		Arm Small Probes, Separate IFD's and Release Small Probes:		

TABLE 4.2.3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
18A	ORD22	Arm Small Probe IFD & BNMS CAL Gas Pyro.		
Minimum 6 seconds & Maximum 14 seconds between 1st Arm & Fire Commands	ORD23	Fire Small Probe IFD		
	ORDB3	Fire Small Probe IFD		IFD Separation is indicated by all telemetry from a probe to the Bus changing suddenly to full-scale values
			P1BATT	Small Probe 1 Battery Temperature — Sudden change to full-scale values indicates SP1 IFD Separation.
			S1AF1T	Small Probe 1 Aft Shelf Temperature 1 — Sudden change to full-scale values indicates SP1 IFD Separation.
			S1FW1T	Small Probe 1 Fwd Shelf Temp 2 — Sudden change to full-scale values indicates SP1 IFD Separation.
			C1TIMC	Small Probe 1 Coast Timer Verification. — Sudden change to full-scale values indicates SP1 IFD Separation.

TABLE 4.2.3-2 (Continued)

STEP # (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION	
			TELEMETRY MNEMONIC	REMARKS & TM DATA
18A (Cont'd)			P2BATT	Small Probe 2 Battery Temperature — Sudden change to Full-scale values indicates SP2 IFD Separation.
			S2AF1T	Small Probe 2 Aft Shelf Temperature 1
			S2FW1T	Small Probe 2 Fwd Shelf Temperature 2
			C2TIMC	Small Probe 2 Coast Timer Verification.
			P3BATT	Small Probe 3 Battery Temperature — Sudden change to Full-scale values indicates SP3 IFD Separation.
			S3AF1T	Small Probe 3 Aft Shelf Temperature 1
			S3FW1T	Small Probe 3 Fwd Shelf Temperature 1
			C3TIMC	Small Probe 3 Coast Timer Verification.
	ORD2Ø	Disarm PCU 2.		
	ORDBØ	Disarm PCU 2.		
18B (SPR = 0) Min. 6 sec. & Max.14 sec. between 1st Arm & Fire Commands	ORD21	Arm Small Probe Separation.		
	REL11	ADP 1 Small Probe Release		• May cause detectable transient in Downlink Signature.

TABLE 4.2.3-2 (Continued)

STEP # & (START TIME)	COMMAND MNEMONIC	COMMAND OR ACTION	REMARKS & VERIFICATION: TELEMETRY MNEMONIC	REMARKS & VERIFICATION: REMARKS & TM DATA
18B (Cont'd)	RELA1	ADP 1 Small Probes Release		• May cause detectable transient in Downlink Signature.
			S1RELS	Small Probe 1 Stowed/Released Status. — All Changed to Released (= 0).
			S2RELS	Small Probe 2 Stowed/Released Status. — All Changed to Released (= 0).
			S3RELS	Small Probe 3 Stowed/Released Status. — All Changed to Released (= 0).

TABLE 4.2.4-1

BUS TARGETING SEQUENCE OF EVENTS

RELATIVE TIME	COMMAND MNEMONIC	COMMAND TITLE OR EVENT	TELEMETRY VERIFICATION	
			TLM MNEMONIC	TLM TITLE
E-20 Days		Small Probe Release (see Section 4.2.3)		
E-20 Days		Post SP Release Cruise (see Section 4.2.4.2)		
E-18 Days (T = 0)		Begin Bus Targeting Mission Segment:		
	AMP39 or AMPC9	Power Amplifier 3 ON/4 OFF	RAMP3W	(Radiating via Aft Omni) RF Power Output 3 = 10 Watts
			PBUSLI	S/C loads current increases a nominal 1.20 amps
			PLIMTI	Bus voltage limiter current decreases a nominal 1.20 amps
	AMP12 or AMPA2	Amplifier 2 Low Power/Amplifier 1 High Power Select	RAMP1S	Amp 1/2 to Hi/Lo Power Status = 1 (1 to Hi) (Hi Power radiating via aft omni).
	MIH11 or MIHA1	Bus High Mod Index Select		DSN Receive Parameter
		Lock-Up DSN 64-m Station		DSN Receive Parameter
		Perform Attitude Determination (see Section 4.3.2)		
		Determine Precession Parameters (see Section 4.2.4.4)		

TABLE 4.2.4-1 (Continued)

RELATIVE TIME	COMMAND MNEMONIC	COMMAND TITLE OR EVENT	TELEMETRY VERIFICATION	
			TLM MNEMONIC	TLM TITLE
T + 2 Hours		Execute Precession to Bus Targeting Attitude (see Section 4.3.1.1)		
		Perform Attitude Determination (see Section 4.3.2)		
T + 6 Hours		Attitude Trim Maneuver (Optional) (see Section 4.3.1.3)		
		Perform Continuous ΔV Targeting Maneuver (see Section 4.3.1.2)		
		Execute Precession to Horn Attitude (See Section 4.3.1.1)		
		Perform Attitude Determination (see Section 4.3.2)		
	ANT12 or ANTA2	Low Power to Aft Omni/High Power to Fwd Omni or Horn Select	RANT1S	Hi/Lo Power to Fwd or Horn/Aft Omni Status = 1 (Hi power to horn)
T + 8 Hours		Return to DSN 26-m Station		DSN Receive Parameters
E - 17 Days		Return Batteries to Low Charge Rate:		
	BAT1Ø or BATAØ	Battery 1 Relay 1 Low Rate Charge	PBAT1S	Battery 1 Relay 1 Status = 0 (low charge)
	BAT14 or BATA4	Battery 1 Relay 2 Low Rate Charge	PBCR1S PCHG1I	Battery 1 Relay 2 Status = 0. Battery 1 Charge Current is nominally 150 ma.
	BAT2Ø or BATBØ	Battery 2 Relay 1 Low Rate Charge	PBAT2S	Battery 2 Relay 1 Status = 0 (low charge)

TABLE 4.2.4-1 (Continued)

RELATIVE TIME	COMMAND MNEMONIC	COMMAND TITLE OR EVENT	TELEMETRY VERIFICATION	
			TLM MNEMONIC	TLM TITLE
E-17 Days (Continued)	BAT24 or BATB4	Battery 2 Relay 2 Low Rate Charge	PBCR2S PCHG2I	Battery 2 Relay 2 Status = 0. Battery 2 Charge Current is Nominally 150 ma.
			PLIMTI	Bus voltage limiter current increases
		Cruise to E-8 Days (See Section 4.2.4.5)		
E - 8 Days		Perform Attitude Determination (See Section 4.3.2)		
		Perform Targeting Touchup (Optional) (See Section 4.3.1.2)		
		Perform Precession to Bus Entry Attitude (See Section 4.3.1.1)		
		Perform Attitude Determination (See Section 4.3.2)		
		Perform Attitude Trim (Optional) (See Section 4.3.1.3)		
		Begin Cruise to E - 2 Days (See Section 4.2.4.6)		
E - 2 Days		Perform Despin to 9.45 $\pm$0.1 rpm (See Section 4.3.1.3)		
		Perform Attitude Determination (See Section 4.3.2)		

TABLE 4.2.4-1 (Continued)

RELATIVE TIME	COMMAND MNEMONIC	COMMAND TITLE OR EVENT	TELEMETRY VERIFICATION	
			TLM MNEMONIC	TLM TITLE
E - 2 Days (Continued)		Perform Attitude Trim (Optional) (See Section 4.3.1.3)		
		Begin Bus Entry Mission Segment (See Section 4.2.5)		

TABLE 4.2.4-2

BUS SUBSYSTEM OPERATIONAL CONFIGURATION

SUBSYSTEM/UNIT	MISSION PHASE				
	POST-SMALL PROBE RELEASE (Section 4.2.4.2)	CHANGES FROM POST-SMALL PROBE RELEASE CONFIGURATION			
		TARGETING ATTITUDE (Section 4.2.4.4)	CRUISE TO E-8 DAYS (Section 4.2.4.3)	E-8 DAYS TO E-2 DAYS (Section 4.2.4.6)	FINAL DESPIN E-2 DAYS (Section 4.2.4.7)
COMMUNICATIONS					
Transponders	● Exciter 1 ON/2 OFF	-	-	-	-
	● Restore Coherent Mode (ON)	-	-	-	-
	● Bus Low Mod Index Select	Hi Mod Index	Hi Mod Index	Hi Mod Index	Hi Mod Index
	● Probes Mod Index Select (don't care)	-	-	-	-
Power Amplifiers	● Power Amp 1 ON ● Power Amps 2, 3, 4 OFF	Amps 1 & 3 ON Amps 2 & 4 OFF	Amps 1 & 3 ON Amps 2 & 4 OFF	Amps 1 & 3 ON Amps 2 & 4 OFF	Amps 1 & 3 ON Amps 2 & 4 OFF
Switch Drivers	● Exciter 1 Select	-	-	-	-
	● Power Amp 3 Select	-	-	-	-
	● Medium Gain Horn Antenna Select	-	-	-	-
	● Amp 1 Low Power Select	Amp 2 Low Pwr Select	Amp 2 Low Pwr Select	Amp 2 Low Pwr Select	Amp 2 Low Pwr Select
	● High Power to Aft Omni/Low Power to Forward Omni or Horn Select	-	High Power to Horn	High Power to Horn	High Power to Horn
	● Receivers Normal Select (via command processor configure command)	-	-	-	-
COMMAND					
Command Processors	● Command Processors 1 & 2 ON (both memories in "OFF" state)	-	-	-	-
COMs	● All Six (6) COMs ON	-	-	-	-
PCU's	● PCU's Disarmed.	-	-	-	-
CONTROLS					
Star Sensor	● PSI* ON	-	-	-	-
	● PSI2* OFF	PSI2* ON	-	-	-
	● PSI* Sensor Gain & Bandwidth (As Required)	-	-	-	-
Attitude Data Processors	● ADP 1 ON	-	-	-	-
	● ADP 2 OFF	-	-	-	-
	● SRR to SRR	-	-	-	-
	● SRR to PSI2	-	-	-	-
	● All Jets Disabled	-	-	-	-
	● Spin Rate Detector Enabled	-	-	-	-
	● SRR Advance Disabled	-	-	-	-
	● Sun Gate Enabled	-	-	-	-
	● Star Acquisition to Normal	-	-	-	-
	● Selected SRR = Sun	-	-	-	-
	● Sun Sensor Select (extended Range-Upper)	-	-	-	-
	● PLL Loss of Lock Enable		-	-	-
	● PLL Spin Range Select 32 to 70.8 rpm.	-	-	-	8.0 to 17.7 rpm
	● PLL Spin Period Mag Equivalent to 48.5 rpm.	-	-	-	9.45 rpm
	● JCE Buffer Output Disabled	-	-	-	-
	● Other Parameters (don't care)				

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TABLE 4.2.4-2 (Continued)

SUBSYSTEM/UNIT	MISSION PHASE				
	POST-SMALL PROBE RELEASE (Section 4.2.4.2)	CHANGES FROM POST-SMALL PROBE RELEASE CONFIGURATION			
		TARGETING ATTITUDE (Section 4.2.4.4)	CRUISE TO E-8 DAYS (Section 4.2.4.5)	E-8 DAYS TO E-2 DAYS (Section 4.2.4.6)	FINAL DESPIN E-2 DAYS (Section 4.2.4.7)
PROPULSION/THERMAL					
Heaters	• All Jet Heaters ON, except Fwd Axial Jet Heater OFF	-	-	-	-
	• Primary Tank/Line Heaters Select	-	-	-	-
	• All Probe Heaters OFF	-	-	-	-
DATA HANDLING					
Telemetry Processor	• Telemetry Processor 1 ON/2 OFF	-	-	-	-
	• Bus Engineering Format	ACS Format	-	-	ACS Format
	• 128 Bits/Sec	64 to 256 Bps	128 Bps	256 Bps	256 Bps
	• Data ON	-	-	-	-
	• Convolution Encoding ON	-	-	-	-
PCM Encoder	• PCM Encoder 1 ON/2 OFF	-	-	-	-
DIM	• All Eight (8) DIMs ON	-	-	-	-
POWER					
Bus Limiters	• All Five (5) Bus Limiters Enabled	-	-	-	-
Charge/Discharge Controller	• High Rate Charge Select (both relays - both batteries)	-	Low Rate Chg. Select	Low Rate Chg. Select	Low Rate Chg. Select
	• Primary Discharge Reg. Select (Both Batteries)	-	-	-	-
UV/OL Control	• Power System Protection ON	-	-	-	-
SCIENTIFIC INSTRUMENTS	• All Science OFF	-	-	-	-
OTHER	• Probe Checkout Power OFF	-	-	-	-
	• Large Probe Internal Power OFF	-	-	-	-
	• Small Probe 1 Internal Power OFF	-	-	-	-
	• Small Probe 2 Internal Power OFF	-	-	-	-
	• Small Probe 3 Internal Power OFF	-	-	-	-

TABLE 4.2.5-1

BUS ENTRY SEQUENCE OF EVENTS

RELATIVE TIME	COMMAND MNEMONIC	COMMAND TITLE OR EVENT	TELEMETRY VERIFICATION	
			TLM MNEMONIC	TLM TITLE
E-48 Hours		Complete Final Despin Maneuver (See Section 4.2.4.7).		
		Transfer to DSN 64 Meter ground station (if not already transferred).		Lockup of uplink and downlink at 64-meter ground station.
		Perform Attitude and Spin Rate Determinations (See Section 4.3.2)		
E-47 Hours		Perform Attitude and Spin Rate Trim Maneuvers (if Necessary). (See Sections 4.3.1.1 and 4.3.1.3).		
E-46 Hours		Determine precise occurrence of next 4096 second clock transition after E-44 Hours. Resolve in Universal Time UT relative to time of Bus entry.	DCLOK1 DCLOK2 DCLOK3	Spacecraft clock (24 bits): Calculate nearest multiple of 4096 seconds. (MSB of DCLOK2 is 4096 second clock bit).
		Load and verify Bus Entry sequence as shown in Figure 4.2.5. (See Section 3.6.3.2).		
		START STORED BUS ENTRY SEQUENCE:		
$\approx$E-44 Hours $= t_o$	CPCQ1	Command Processor 1 Configure (Timed Start)	CMEM1C CLOG1S	Verified at next transition of 4096 second clock bit from "1" to "0." Command memory address pointers will increment one, and SCL state will change from "TIMED START 1" (= 0101) to "RUN" (= 1100).
t_o + 12 Seconds	CPCQA	Command Processor 2 Configure (Timed Start)	CMEM2C CLOG2S	

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TABLE 4.2.5-1 (Continued)

RELATIVE TIME	COMMAND MNEMONIC	COMMAND TITLE OR EVENT	TELEMETRY VERIFICATION	
			TLM MNEMONIC	TLM TITLE
≈E-42 Hours, to E-40 Hours.	. . .	Scientific Instrument Commands to configure BNMS for calibration gas sequence; TBD by NASA/ARC.		
t_1	ORD22 OR ORDB2	Arm SP IFD and BNMS Cal Gas Pyro.		No "arm" status telemetry exists.
t_1 + 12 Seconds	ORD24 OR ORDB4	Fire BNMS Cal Gas Pyro.		Verification from BNMS instrument telemetry.
t_1 + 24 Seconds	ORD13 OR ORDA3	Arm Large Probe IFD and BNMS B/O Hat.		No "arm" status telemetry exists.
t_1 + 36 Seconds	ORD15	Fire BNMS B/O Hat Primary		Verification from BNMS Instrument telemetry.
t_1 + 48 Seconds	ORD13 OR ORDA3	Arm Large Probe IFD and BNMS B/O Hat.		No "arm" status telemetry exists.
t_1 + 1 Minute	ORD16	Fire BNMS B/O Hat Secondary		Verification from BNMS instrument telemetry.
t_1 + 1 Minute 12 Seconds	ORD1Ø OR ORDAØ	Disarm PCU 1		No "arm" status telemetry exists.
E-40 Hours to E-10 Hours	. . .	Scientific Instrument Commands to configure BNMS and BIMS for entry; TBD by NASA/ARC.	. . .	Telemetry verification of "TBD" Commands.
E-40 Hours to E-10 Hours	TPCQ1	Telemetry Processor 1 Control (select 1024 bps and ACS or Bus engineering formats) (Alternate attitude & engrg. data as req'		Observed change in format status (word 3) of every minor frame.

TABLE 4.2.5-1 (Continued)

RELATIVE TIME	COMMAND MNEMONIC	COMMAND TITLE OR EVENT	TELEMETRY VERIFICATION: TLM MNEMONIC	TELEMETRY VERIFICATION: TLM TITLE
≈ E-10 Hours	TPCQ1	Telemetry Processor 1 Control (Select 1024 bps and Bus entry format).		Observed change in format status (word 3) of every minor frame.
		Begin continuous monitoring of Bus downlink until turnup after Bus entry (E = 0).		
E-4 Hours	STORED COMMANDS * = SCP1 ** = SCP2	BACKUP SPACECRAFT CONFIGURATION STORED COMMAND SEQUENCE (BEGINS AUTOMATICALLY):		
	TLM19* TLMA9**	Telemetry Processor 1 ON/2 OFF Telemetry Processor 1 ON/2 OFF	DTLM1S	TM Processor 1 ON/2 OFF
	TPCQ1* TPCQ1**	Telemetry Processor 1 Control (Select 1024 bps/Bus entry format)		Observed change in format status (word 3) of eve , minor frame.
	AMP19* AMPA9**	Power Amplifier 1 ON/2 OFF Power Amplifier 1 ON/2 OFF	RAMP1T RAMP1W	Power Amp 1 Temp (80°F to 104°F) RF Power Output 1 = 10 Watts
	AMP39* AMPC9**	Power Amplifier 3 ON/4 OFF Power Amplifier 3 ON/4 OFF	RAMP3T RAMP3W	Power Amp 3 Temp (78°F to 88°F) RF Power Output 3 = 10 Watts
	ANT21* ANTB1**	Medium Gain Horn Antenna Select Medium Gain Horn Antenna Select	RANT2S	Horn/Forward Omni Switch Position = 1 (Horn).
	ANT12* ANTA2**	Low Power to Aft Omni/High Power to Forward Omni or Horn Select Low Power to Aft Omni/High Power to Forward Omni or Horn Select	RAN[illegible]S	High/Low Power to Forward or Horn/Aft Omni Status = 1 (High Power to Horn).

TABLE 4.2.5-1 (Continued)

RELATIVE TIME	COMMAND MNEMONIC	COMMAND TITLE OR EVENT	TELEMETRY VERIFICATION	
			TLM MNEMONIC	TLM TITLE
E-4 Hours (Continued)	AMP31* AMPC1**	Amplifier 3 Select Amplifier 3 Select	RAMP3S	Amplifier 3/4 Switch Position = 1 (#3 Selected).
	AMP12* AMPA2**	Amplifier 2 Low Power/Amplifier 1 High Power Select Amplifier 2 Low Power/Amplifier 1 High Power Select	RAMP1S	Amplifier 1/2 o High/Low Power Status = 1 (#1 to High Power).
	EXC11* EXCA1**	Exciter 1 Select Exciter 1 Select	RXCTRS	Exciter 1/2 Switch Position = 1 (#1 Selected).
	EXC19* EXCA9**	Exciter 1 ON/2 OFF Exciter 1 ON/2 OFF	RXCT1S	Exciter 1 ON/OFF = 1 (#1 ON).
	COH19* COHA9**	Restore Coherent Mode Restore Coherent Mode	RCOH1S	Exciter 1 Inhibit/Restore Coherent Mode Status = 0 (Restore).
	MIH11* MIHA1**	Bus High Mod Index Select Bus High Mod Index Select		DSN Receive Parameters Indicate High Mod Index in use.
	PCM19* PCMA9**	PCM Encoder 1 ON/2 OFF PCM Encoder 1 ON/2 OFF	DPCM1S	PCM Encoder 1 ON/OFF = 1 (ON).
E - 4 Hours to Bus Entry (E = 0)	. . .	Scientific Instrument Commands TBD at times TBD by NASA/ARC. All commands sent in redundant pairs from SCP1 and SCP2.	. . .	Telemetry verification of "TBD" Commands.

TABLE 4.2.5-2

BUS SUBSYSTEM ENTRY CONFIGURATION

SUBSYSTEM/UNIT	OPERATIONAL CONFIGURATION
COMMUNICATIONS	
Transponders	• Exciter 1 ON/2 OFF • Restore Coherent Mode (ON) • Bus High Mod Index Select • Probes Mod Index (don't care)
Power Amplifiers	• Power Amps 1 and 3 ON • Power Amps 2 and 4 OFF
Switch Drivers	• Exciter 1 Select • Power Amp 3 Select • Medium Gain Horn Antenna Select • Low Power to Aft Omni/High Power to Forward Omni or Horn Select • Receivers Normal Select (via command processor configure command) • Amp 2 Low Power/Amp 1 High Power Select
COMMAND	
Command Processors	• Command Processors 1 and 2 ON (both memories in "RUN" state)
COMs	• All six (6) COMs ON
PCUs	• PCUs Disarmed
CONTROLS	
Star Sensor	• PSI* ON • PSI2* OFF • PSI* Sensor Gain and Bandwidth (As Req'd)
Attitude Data Processors	• ADP 1 ON • ADP 2 OFF • SRR to SRR • SRR to PSI2 • All Jets Disabled • Spin Rate Detector Enabled • SRR Advance Disabled • Sun Gate Enabled • Star Aoquisition to Normal • Selected SRR = Sun

TABLE 4.2.5-2 (Continued)

SUBSYSTEM/UNIT	OPERATIONAL CONFIGURATION
CONTROLS (Continued)	
Attitude Data Processors (Cont'd)	• Sun Sensor Select (extended range-upper) • PLL Loss of Lock Enable • PLL Spin Range Select 8.0 to 17.7 rpm • PLL Spin Period Mag Equivalent to 9.45 rpm • JCE Buffer Output Disabled • RIP Delay for BNMS Selected • Other Parameters (don't care)
DATA HANDLING	
Telemetry Processor	• Telemetry Processor 1 ON/2 OFF • Bus Entry Format • 1024 Bits/Sec • Data ON • Convolutional Encoding ON
PCM Encoder	• PCM Encoder 1 ON/2 OFF
DIM	• All Eight (8) DIMs ON
SCIENTIFIC INSTRUMENTS	• All Science ON (configuration modes as specified by NASA/ARC)
POWER	
Bus Limiters	• All Five (5) Bus Limiters Enabled
Charge/Discharge Controller	• Low Rate Charge Select (both relays - both batteries) • Primary Discharge Reg Select (both batteries)
UV/OL Control	• Power System Protection ON • Pre-Charge OFF
OTHER	• Probe Checkout Power OFF • Large Probe Internal Power OFF • Small Probe 1 Internal Power OFF • Small Probe 2 Internal Power OFF • Small Probe 3 Internal Power OFF
PROPULSION/THERMAL	
Heaters	• All Jet Heaters ON, except Forward Axial Jet Heater OFF • Primary Tank/Line Heaters Select • All Probe Heaters OFF

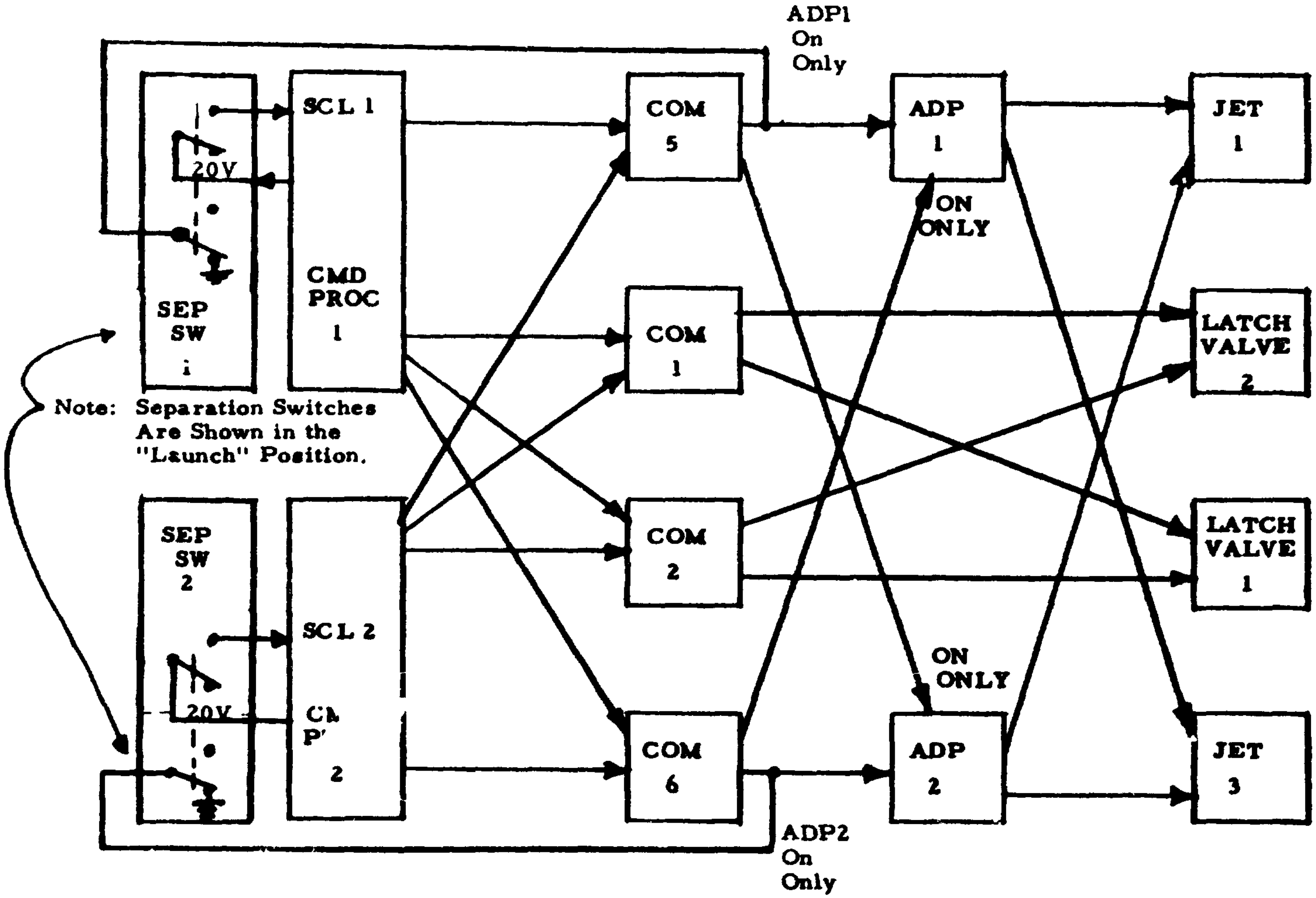

Figure 4.2.1.4-1. Spinup Sequence Functional Implementation

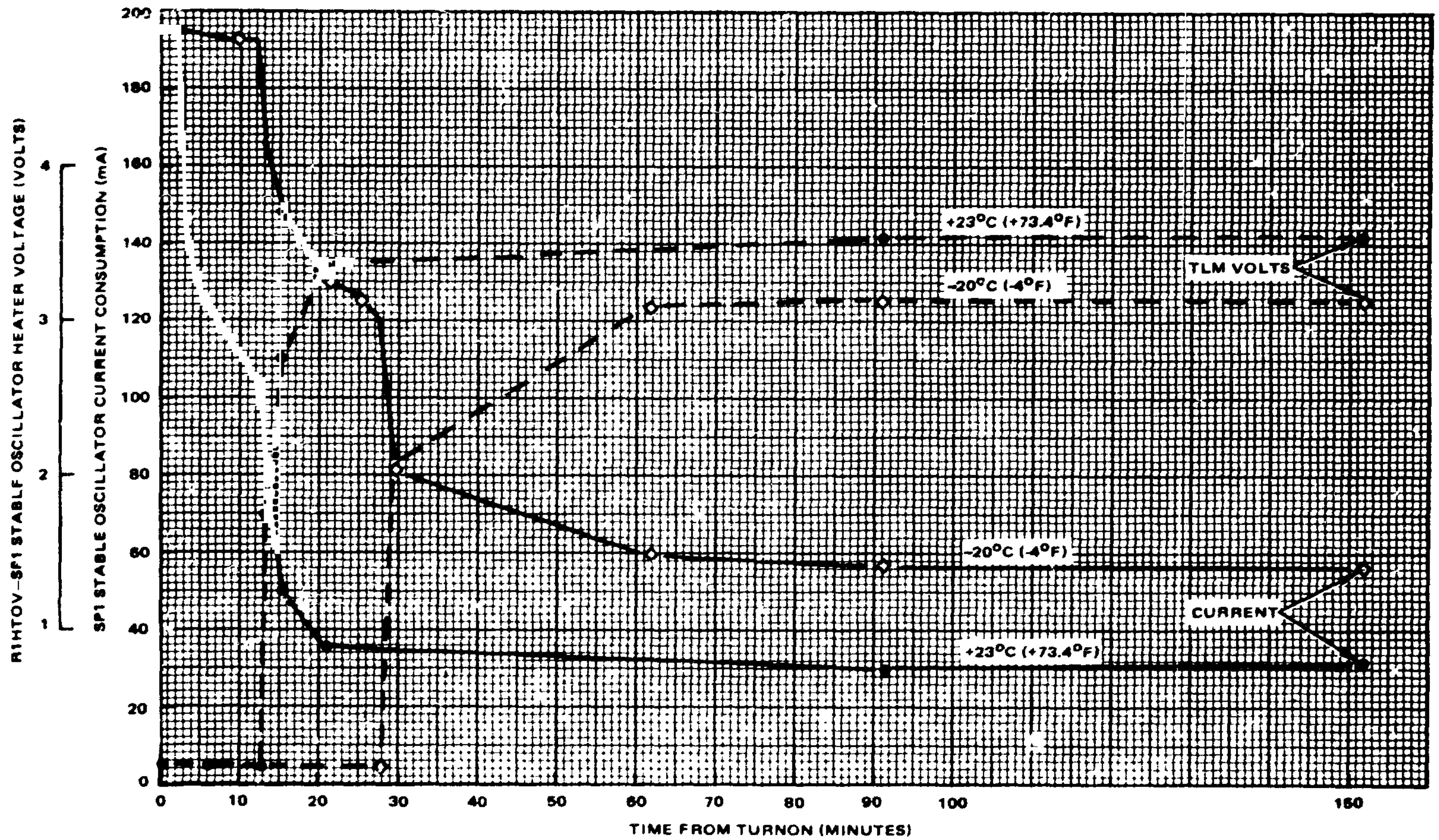

FIGURE 4.2.2-1. SMALL PROBE 1 (SN 003) STABLE OSCILLATOR TURNON CHARACTERISTIC ("COLD START")

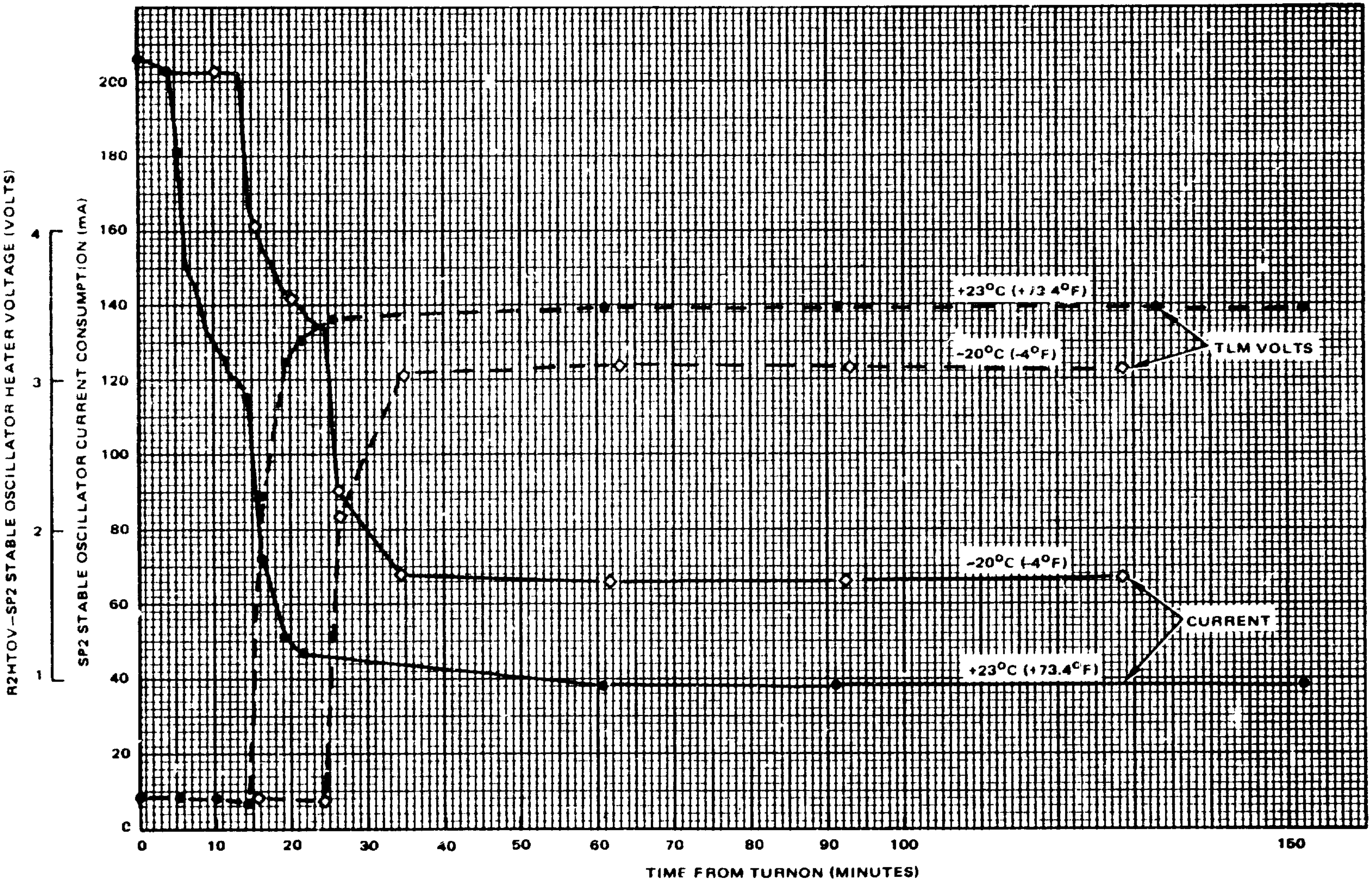

FIGURE 4.2.2-2. SMALL PROBE 2 (SN002) STABLE OSCILLATOR TURNON CHARACTERISTIC ("COLD START")

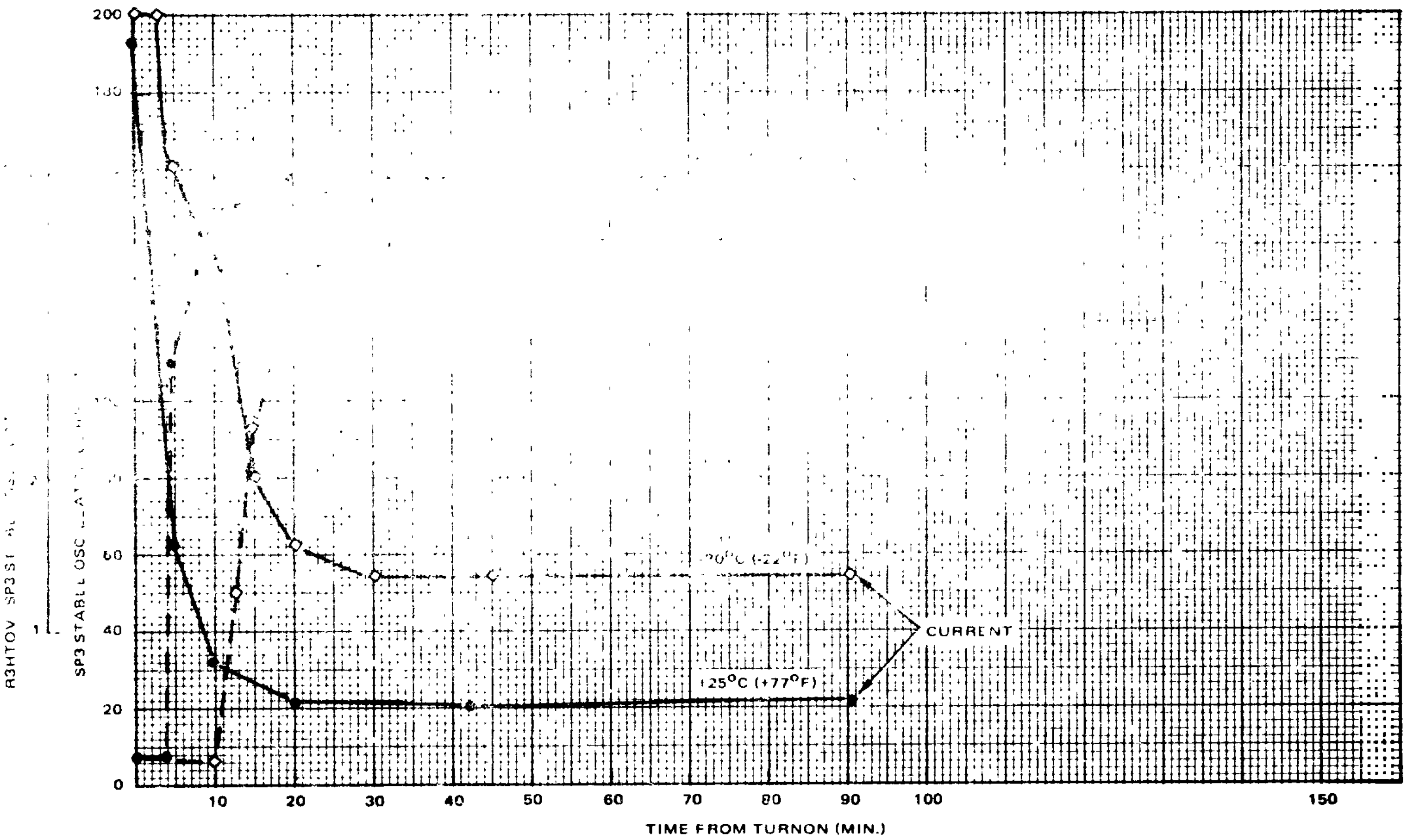

FIGURE 4.2.2-3. SMALL PROBE 3 (SN001) STABLE OSCILLATOR TURNON CHARACTERISTIC ("COLD START")

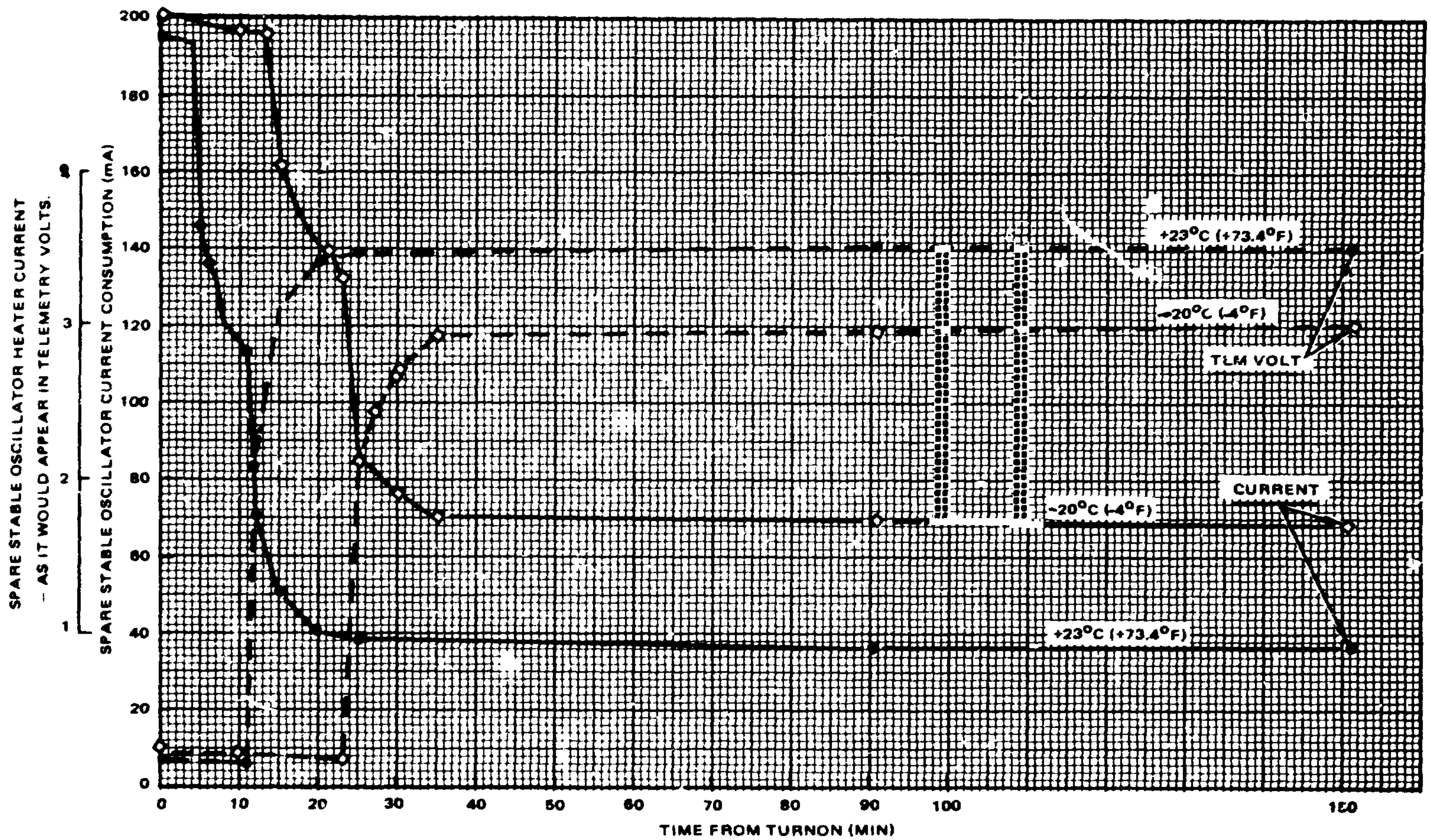

FIGURE 4.2.2-4. SPARE (SN004) STABLE OSCILLATOR TURNON CHARACTERISTIC ("COLD START")

Revision

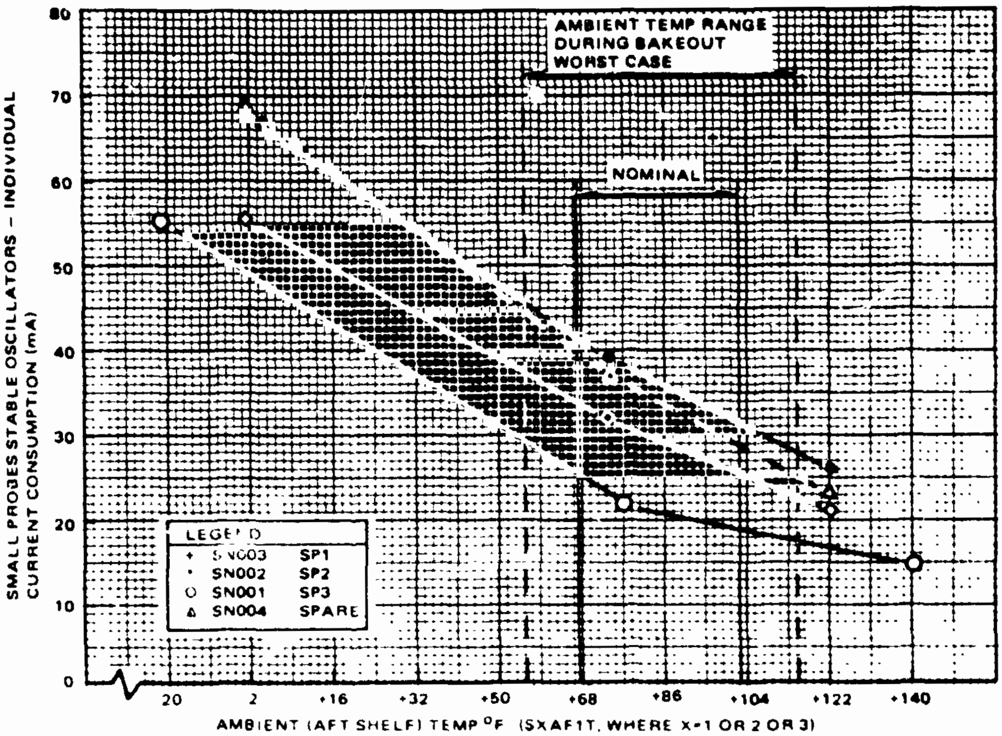

FIGURE 4 2 2 5 SMALL PROBES STABLE OSCILLATORS INDIVIDUAL STEADY STATE CURRENT CONSUMPTION VS TEMPERATURE

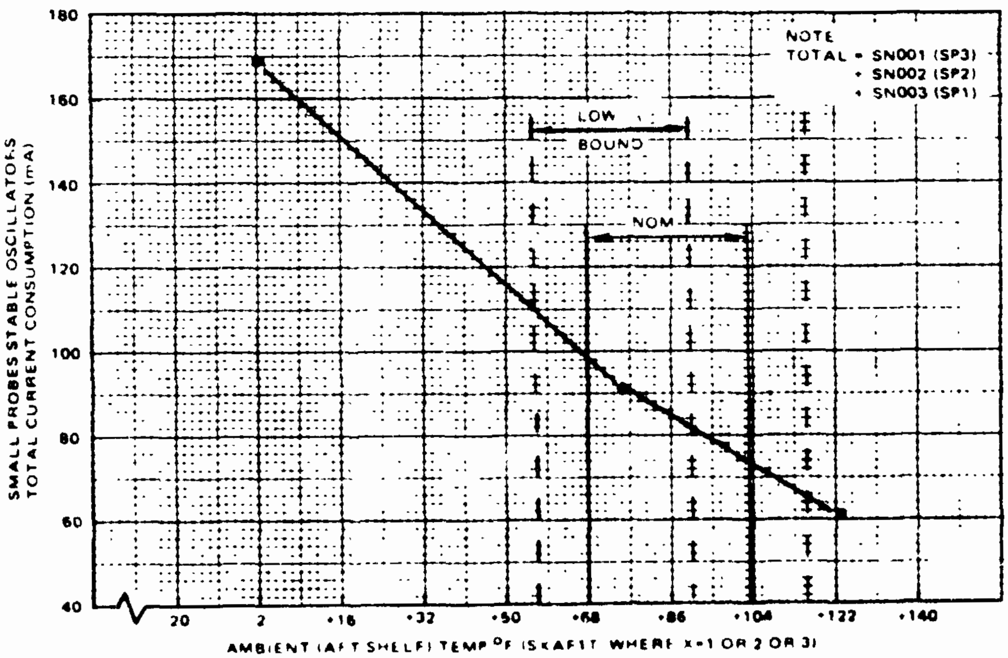

FIGURE 4 2 2 6 SMALL PROBES STABLE OSCILLATORS TOTAL STEADY STATE CURRENT CONSUMPTION VS TEMPERATURE

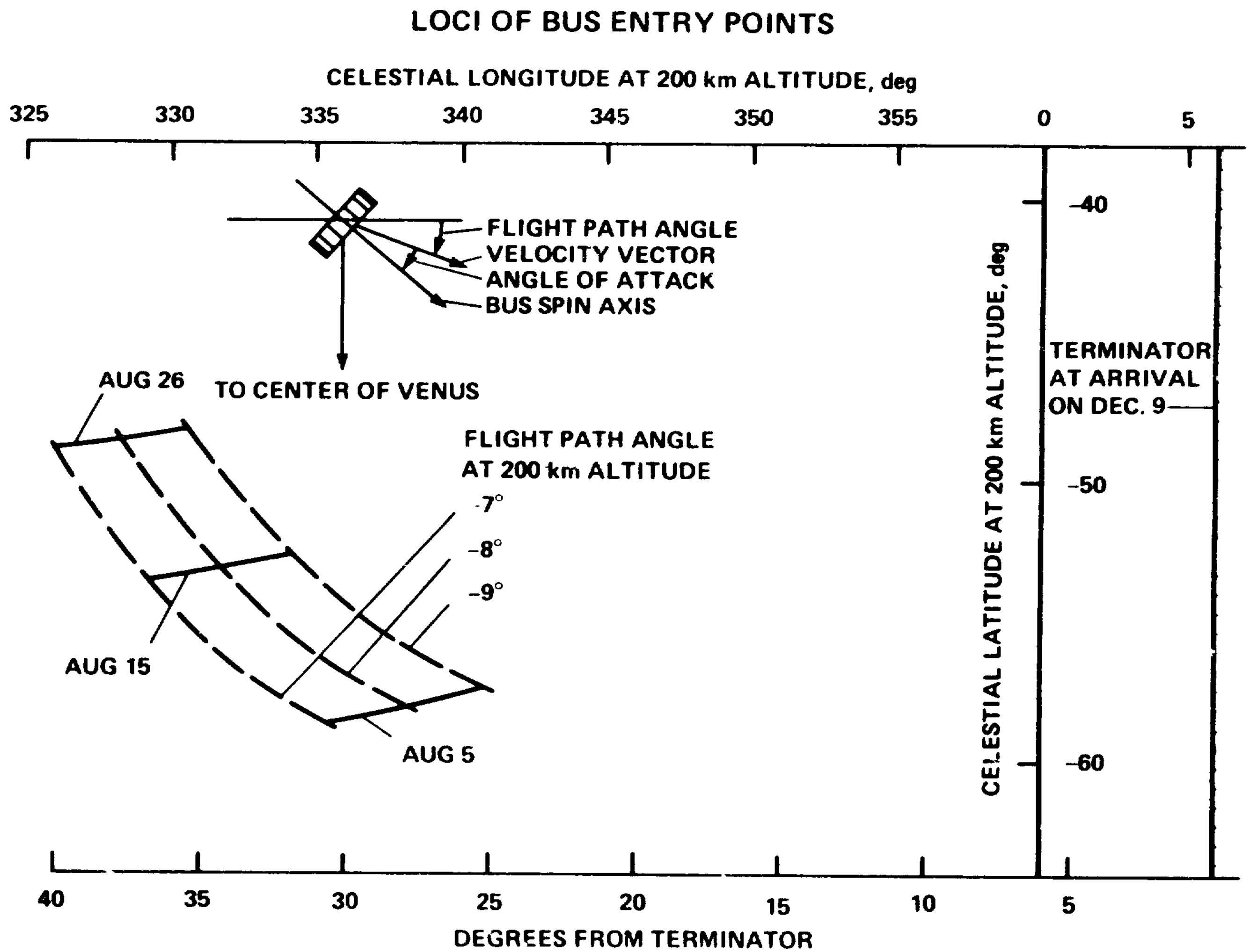

Figure 4.2.4.3-1. Bus Entry Locations

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Revision No.
Revision

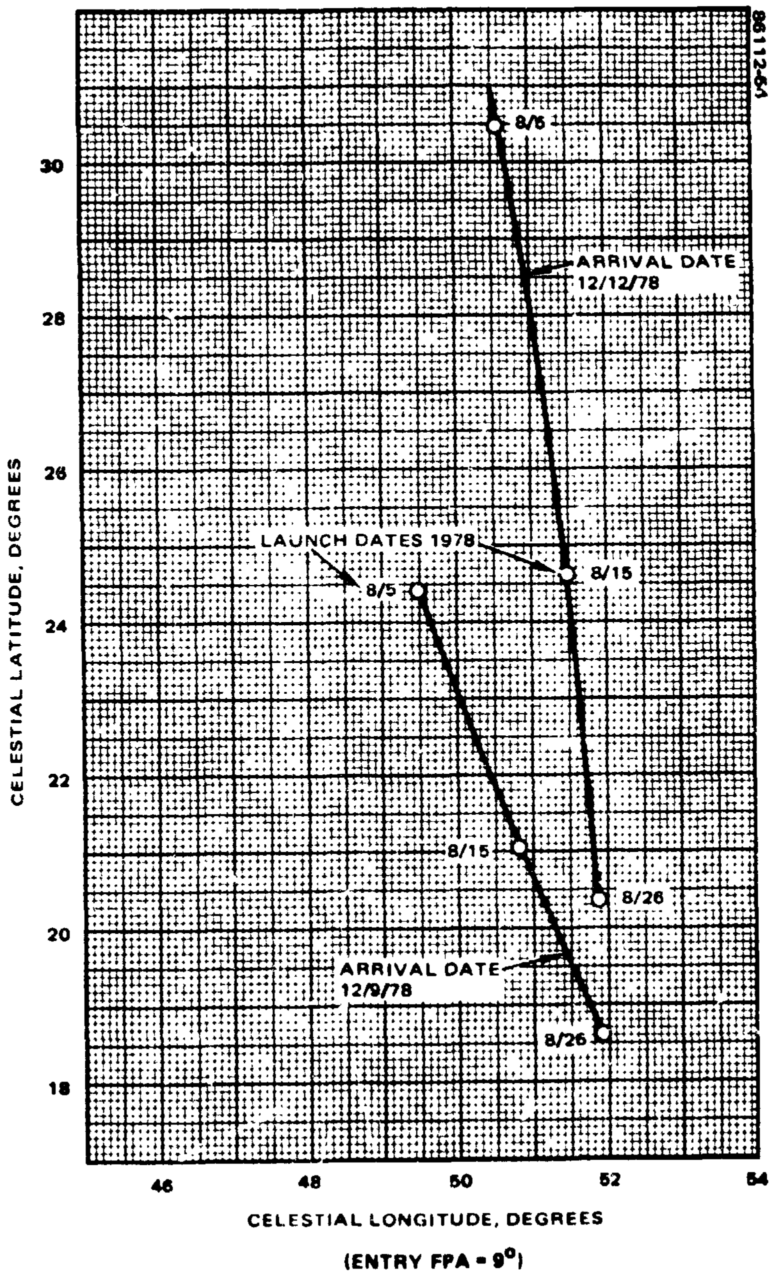
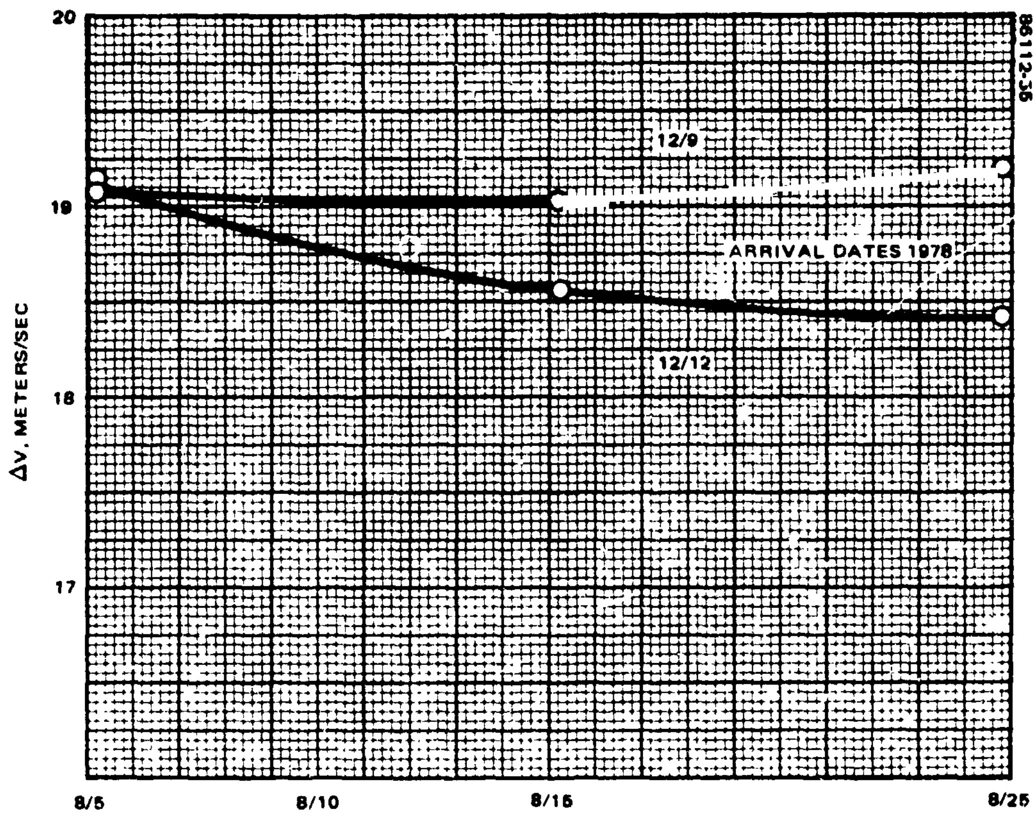


FIGURE 4.2.4.3-2. BUS TARGETING ΔV DIRECTION

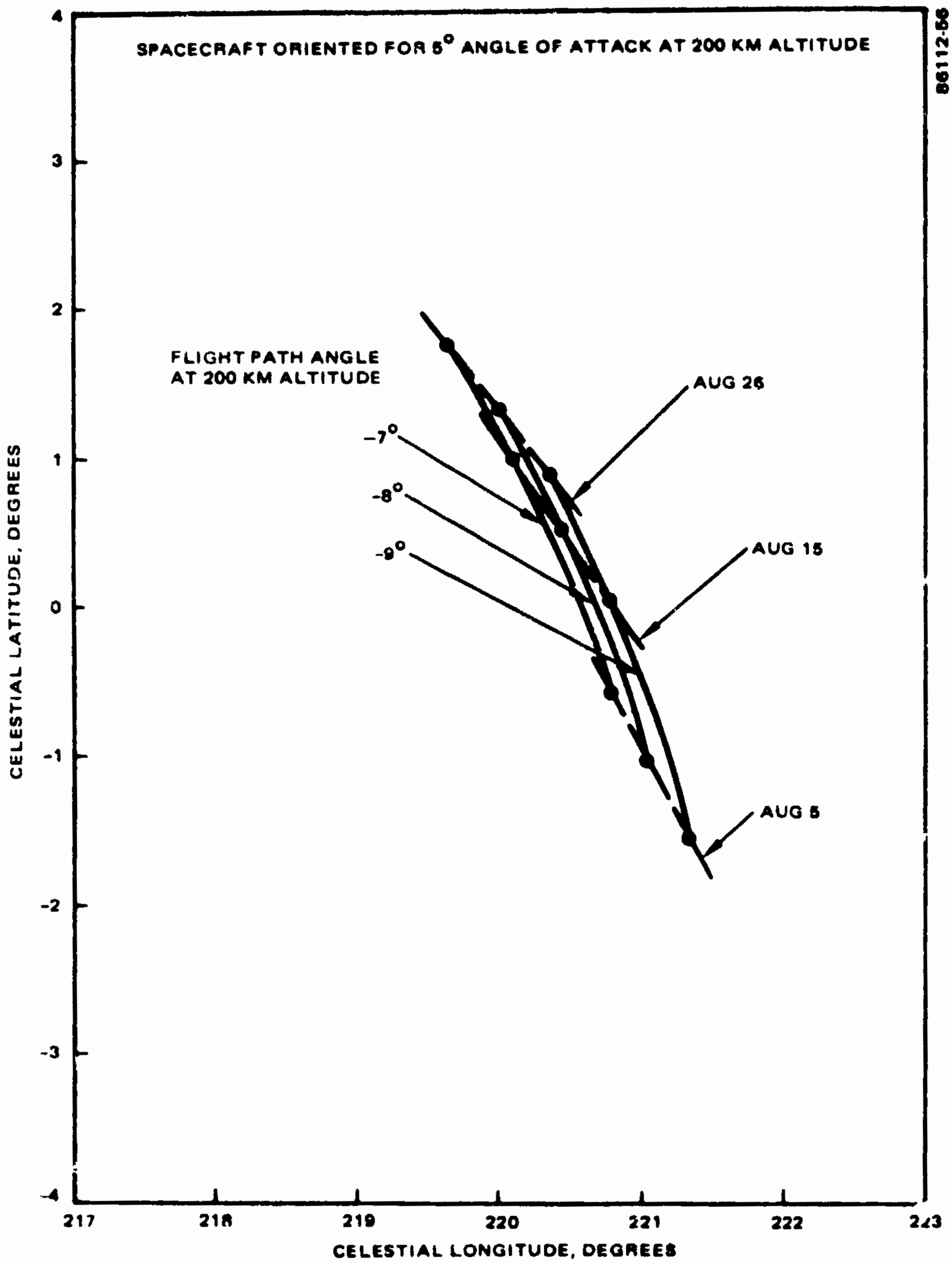


LAUNCH DATE, 1978

(ENTRY FPA = -9°)

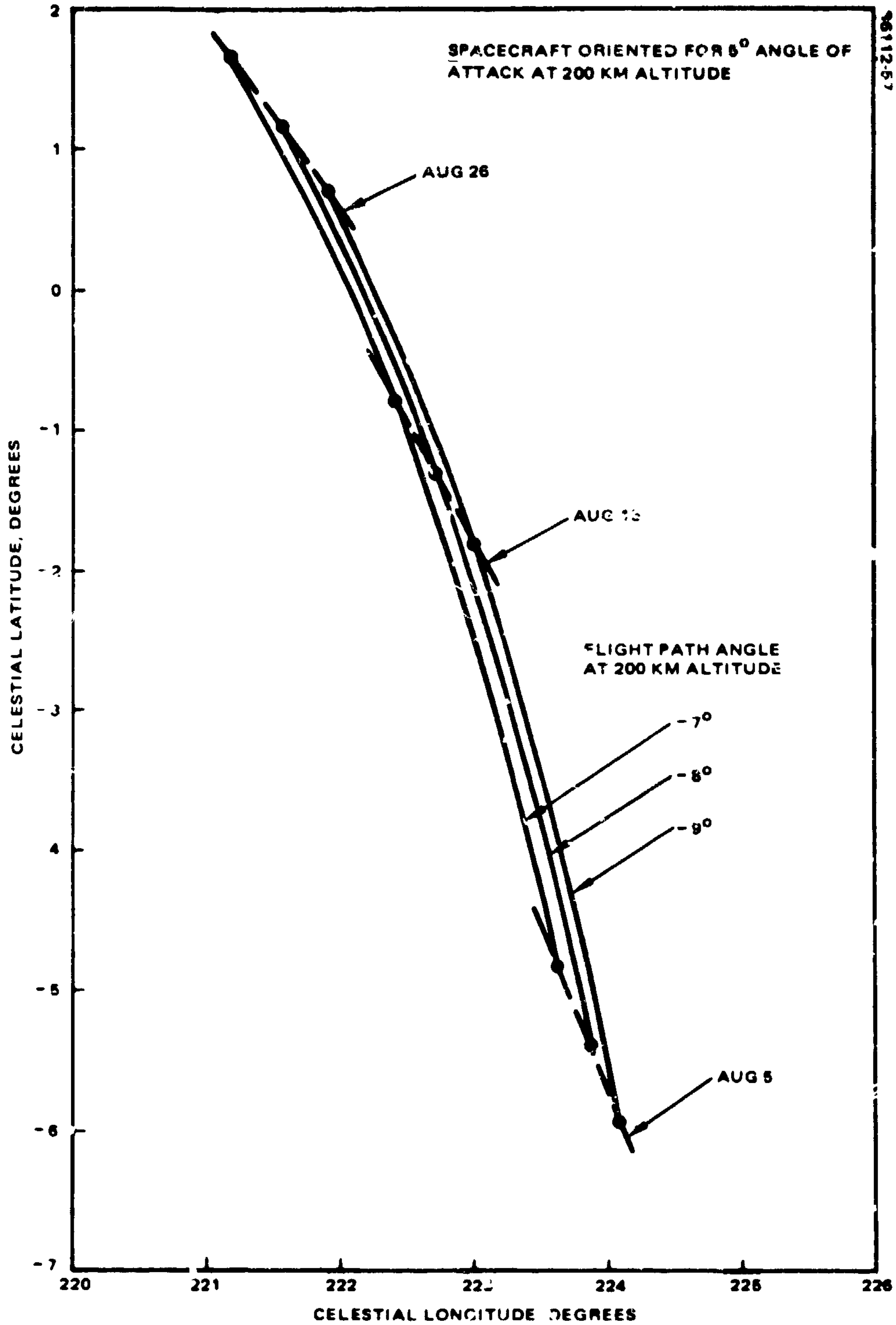
FIGURE 4.2.4.3-3. BUS TARGETING ΔV MAGNITUDE

Revision



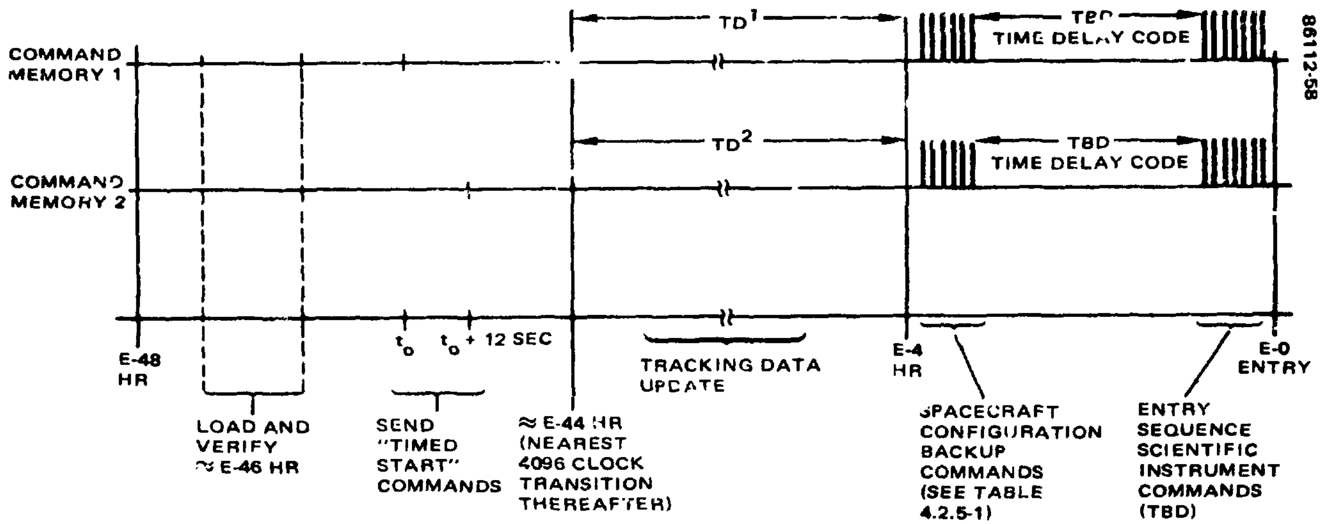
ARRIVE ON 9 DECEMBER 1978

FIGURE 4.2.4.6-1. SPACECRAFT ATTITUDE AT BUS ENTRY



ARRIVE ON 12 DECEMBER 1978

FIGURE 4.2.4.6-2. SPACECRAFT ATTITUDE AT BUS ENTRY



TD^1 = TIME DELAY EQUIVALENT TO TIME BETWEEN E-4 HOURS AND NEAREST 4096-SECOND CLOCK TRANSITION AFTER E-44 HOURS WITH COMMAND PROCESSOR 1 CLOCK STABILITY BIAS INCORPORATED.

TD^2 = SAME AS TD^1 EXCEPT WITH COMMAND PROCESSOR 2 CLOCK STABILITY BIAS INCORPORATED.

COMMAND PROCESSOR ACCURACY (STABILITY) DETERMINED FOR EACH COMMAND PROCESSOR DURING INTERPLANETARY CRUISE, PREFERABLY IN LAST 20 DAYS OF CRUISE. EACH COMMAND PROCESSOR'S CLOCK TIMING IS CALIBRATED AGAINST REAL TIME ON GROUND. CALIBRATION IS EFFECTED BY STORING AN EXACT 40.0 HOUR TIME DELAY CODE FOLLOWED IMMEDIATELY BY AN RF MODULATION INDEX CHANGE COMMAND, AND MEASURING THE TIME BETWEEN START OF THE MEMORY AND THE OBSERVED CHANGE IN DOWNLINK MODULATION INDEX.

FIGURE 4.2.5-1. BUS ENTRY COMMAND MEMORY UTILIZATION SEQUENCE