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First Block I Manned Mission

1 September 1966

SYSTEMS ENGINEERING, APOLLO



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First Block I Manned Mission

1 September 1966



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ABSTRACT

PRESENTS THE CAPABILITIES OF THE APOLLO BLOCK I SPACECRAFT AS APPLIED TO THE FIRST MANNED EARTH ORBITAL DEVELOPMENT MISSION CONTAINS FUNCTIONAL AND PARAMETRIC DATA OF SIGNIFICANCE FOR MISSION PLANNING, ORGANIZED BY MISSION PHASES FROM LIFT-OFF THROUGH POST-LANDING OPERATIONS INCLUDING SOME SPECIFIC CONTINGENCY CONSIDERATIONS

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FOREWORD

The Mission Modular Data Book (First Block I Manned Mission) was prepared by the Spacecraft Requirements Group in accordance with SMU No 2, Minutes of Meeting To Define Revised NAA Support to NASA Mission Planning Effort, dated April 5, 1966

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1 0 INTRODUCTION

1 1 SCOPE OF THE MMDB

The Block I Mission Modular Data Book (MMDB) presents the spacecraft performance characteristics, capabilities and limitations, operational constraints, and subsystem and crew operations related to designated events. This information is applicable to earth orbital manned missions at altitudes less than 450 nautical miles. Switch settings, detailed crew tasks, and other data which are documented in the Apollo Operations Handbook (AOH) are not included in the MMDB but are referenced where applicable.

The modular data consist of a common (power) level and associated building blocks (BB) and MMDB sections which will present the spacecraft and crew information necessary.

- 1 To permit NASA to design trajectories and plan missions that are within the capabilities of the combined crew/spacecraft
- 2 To provide NASA with the flexibility necessary to perform real-time mission planning and mission redesign functions

1 2 BUILDING BLOCKS

Building blocks are self-contained packages of information for each function and/or spacecraft event. In general, the types of data presented consist of subsystem and crew operations, subsystem limits and resultant operational constraints, sequence of events, consumables, etc. Much of the data is presented in parametric form as functions of such parameters as spacecraft weight, time, maneuvering rate, deadband width, and mode of operation. A building block includes only those functions which must occur to perform the designated event.

Reference is made to separate sections on consumables (Sections 3 0 and 5 0) to avoid redundant presentation of consumable data in the event-oriented building blocks.

1 3 SUMMARY DATA

The MMDB summary chart, Figure 1-1, organizes the most significant data found in the normal operation building blocks into a form designed to aid the mission planner. The void areas mean that no significant



information fell easily under the particular heading The Average Watts column, in conjunction with the Duration column, indicates only the power requirement for that block The power curves in Section 3 0 must be used for determination of combined block power levels

1 4 MISSION SYNTHESIS LOGIC

In order for the data contained in this document to be meaningful and useful, it is important to review and understand various points of related information, including the following

- 1 Key aspects of MMDB development
- 2 Approach to construction of individual blocks
- 3 Approach to construction of the overall MMDB
- 4 Application of building block data to mission planning—both preflight and real-time

The purpose of the following paragraphs, therefore, is to discuss these four subjects in sufficient depth to assure that the user will appreciate the advantages and limitations of the MMDB as a mission planning tool The ultimate goal is to satisfy the intent of item 4 However, item 4 cannot be fully understood without reference to items 1 through 3 and for this reason the four subjects are discussed in parallel

1 4 1 Classification of Mission/Spacecraft Variables

Because of the magnitude and complexity of the data provided, it is important to present various classifications which will assist in understanding the scope and limitations of the data The original building block concept was reflected in the May 16 issue of the Block I Manned MMDB (report MMDB 12-1), which provided 35 blocks The revised list (report MMDB 12-2, 1 July 1966) contained 19 blocks, and the third and final list contains 25 Although the number of blocks has varied, the scope of data has for the most part remained constant except for the addition of contingency data The major differences have resulted from combinations of smaller blocks into larger blocks with subsections or alternate modes and from allocations of block data into separate subsections of the overall MMDB However, if the current list of blocks (see Paragraph 6 0) is examined, it will be noted that there are categorizations which can be derived to assist the mission planner as shown in Figure 1-2 These categorizations are of much greater significance to the planner than the mere quantity or sequential listing of blocks



A normal mission can be constructed with the 20 blocks indicated in Table 1-1 or with a minimum of the seven category A blocks. The category A blocks are mission events, phases, or operations which must be performed. Each block represents a single time-fixed event with respect to the launch site or the impact area and provides the mission planner with little or no planning flexibility. Except for performance-related dispersions or envelopes, these blocks represent a fixed element of mission planning. The category B blocks are all routine operations which, except for post-insertion checks, are repeated at fixed time intervals during the orbital phase. Although any of these functions may be shifted in time to accommodate a critical event in category C, it is important to note that these block functions must be accomplished at relatively fixed intervals and therefore leave the mission planner with little planning flexibility. The maximum mission planning flexibility is clearly associated with only the seven blocks in category C. These mission events may be dispersed over 14 days in orbit in almost any pattern or frequency and with a minimum of constraints. Because they are not mandatory events, they may be programmed to accomplish the maximum number of test objectives.

Although mission planning is basically limited to the seven category C blocks, it must be understood that these seven blocks are not uniform in scope. For example, BB-12 (SPS ΔV) is a higher-order block in that its timeline, duty cycles, and electrical power and consumables data include several lower-order blocks, or portions of blocks, in both category B and C. These include the following:

- BB-7 IMU Alignment
- BB-9 Drifting Flight
- BB-14 Subsystem Status Checks
- BB-15 Subsystem Maintenance
- BB-16 AGC Update

The above five blocks must not be "added to" the SPS ΔV block, but they may be performed or required at other times independently of a ΔV . Actually, many of the category B blocks are built-in to the category A and C blocks. These and other problems associated with normal mission synthesis using the blocks will be discussed later in this section.

There are five blocks dealing with possible contingencies, each represents an independent situation. Aborted or alternate missions will probably include normal mission blocks in categories A, B, C, and D, as well as the contingency block.



Category D blocks provide basic capability data associated with the guidance and control (G&C) and are not associated with any one mission event, phase, or operation. They are really subsystem data blocks, because they have no finite operational timeline, duty cycle, power requirement, etc.

1 4 2 Construction of Blocks and Supporting MMDB Sections

Although there are currently 25 building blocks defined in Paragraph 6 0, this number is not a true representation of the scope of block data. Blocks 8, 9, 10, 11, 12, 13, 14, 15, 16, and 25 are listed as ten types of block data, but each of these is actually a multiple block consisting of a subset of working blocks. The real number of working blocks associated with these ten types is 26. A working building block is a unique collection of operational and performance data associated with a mission related operation. BB-15, subsystem maintenance, for example, has three working blocks of data, each of which provides the following information:

Basic block data

- 1 An operational timeline segment (block duration)
- 2 Electrical power
- 3 Propellant consumption

Supporting block data

- 1 Ground rules and assumptions
- 2 Mission functional flows
- 3 Attitude maneuvers
- 4 Duty cycles
- 5 Parametric performance data

In constructing the operational timeline segment and electrical power and propellant consumption for each block, the five items of supporting data are taken into account. In many cases, the basic data are only representative of the blocks because the assumptions regarding the supporting data



Table 1-1 Block Categorization By Mission Synthesis Logic

NORMAL MISSION			
Category A	Category B	Category C	Category D
Mandatory Mission Operations	Mandatory Routine Operations, Orbital Phase	Programmable Mission Operations, Orbital Phase	Functional Capability
Ascent Phase BB-1 Ascent BB-2 Let Jettison Orbital Phase BB-6 CSM/S-IVB Separation Entry Phase BB-24 Pre-deorbit BB-25 SPS Deorbit and Entry Descent and Recovery Phase BB-35 Parachute Descent/Impact BB-37 Post-landing	BB-5 Post-Insertion BB-10 Crew Maintenance BB-14 Subsystem Status Checks BB-15 Subsystem Maintenance	BB-7 IMU Alignment BB-8 Navigation Sightings BB-9 Drifting Flight BB-12 SPS ΔV BB-16 AGC Update BB-17 Experiments BB-18 Cabin Depressurization	BB-11 Attitude Control BB-13 RCS Translation
CONTINGENCIES			
Ascent Phase	Orbital Phase	Entry Phase	
BB-42 LES Aborts BB-44 Launch Aborts - SPS	BB-41 Radiator Loss BB-45 Water Boiler Failure	BB-26 RCS Deorbit and Entry	



are subject to change For example, in BB-12 (SPS ΔV) the following basic data are provided

Nominal duration	84 minutes
Nominal electrical power	122 watts ac, 668 watts dc
Nominal RCS propellant consumption	33 pounds
Nominal SPS propellant consumption	function of burn time

These data are based on minimal crew activity and minimal spacecraft maneuvering and assume optimum ground tracking for AGC updating and data handling, optimum thermal control with no spacecraft constraints, and optimum availability of lighting and star background for the IMU alignment For a burn with known trajectory conditions and planned test objectives, each of the above assumptions in supporting data may be changed Each block and associated blocks should be carefully reviewed before the information is applied Considerable data associated with a block event are also found in other sections of the MMDB

1 4 3 The Common Level Concept and Drifting Flight

Because of the continuous demands for, and the criticality of, electrical power, a common level has been established as described in Section 3.0 This power level and the associated equipment are a constant common requirement for all blocks throughout the mission The common level, however, is a reference level only and is less than a minimum level for safe extended flight Thus, in each block, with respect to power, only that quantity above the common level is shown (Δ power) The common level concept, however, does not apply to block duration or propellant consumption

Drifting flight (BB-9) applies the common level to a minimum (AM-1) and nominal level (AM-2) of coasting mission operations A comparison of these three power levels is as follows

Common level	591 8, 591 4 watts ac and dc (total power)
AM-1 powered down	37 4, 90 5 watts ac and dc (Δ power)
AM-2 powered up	231 4, 181 7 watts ac and dc (Δ power)



Drifting flight includes the scheduling of the following subordinate blocks (category B normal mission)

BB-10	Crew Maintenance
BB-14	Subsystem Status checks
BB-15	Subsystem Maintenance

All other blocks in category C normal mission require higher expenditure rates of power and propellant than BB-9. Drifting flight, however, may occur for any period of time either during another block or apart from it. Because of this, in developing a mission, care must be exercised in applying the data covering the category B blocks. A fuel cell purge in one instance may normally occur during drifting flight as a separate block and in another instance may occur during an experiment.

Electrical power usage may be determined simply when building blocks have been laid end-to-end on the common level in the synthesis of a mission phase. When two blocks are "stacked" on the common level simultaneously, however, electrical power cannot be calculated directly by simply adding the power quantities associated with each block to the common power level. Such stacking of blocks may result in unrealistically high levels because of the introduction of identical components in each of the blocks. Therefore, if more than one block is placed on the common level, the contents of the block may be used as a source of raw data, but the power quantities above the common level should not be taken at face value.

1 4 4 Techniques in Mission Synthesis

The following paragraphs discuss in greater detail the relationship of building blocks and supporting data to mission planning and also provide recommended techniques for use of the data, reflecting its merits and limitations.

A complete mission plan may be evaluated in terms of various component parts in order to illustrate building block interfaces. These parts include

- 1 A trajectory time history (position, velocity, range, etc)
- 2 An attitude history (θ , ϕ , etc)



- 3 An operational timeline (events and duration)
- 4 A budget of expendables
 - a Cryogenics (power)
 - b Service module RCS or command module RCS propellants (during entry)
 - c SPS propellant
 - d Net water

These mission/MMDB interfaces are schematically portrayed in Figure 1-2. The adjoining comments are of considerable importance, especially when various blocks are combined in time and tradeoffs are required between averaging consumable usage over a time period or performing continuous profile analysis over the same period. Particular care must be exercised in the integration of data from Building Blocks 9, 10, 14, and 15.

For orbital phase planning (category C blocks), it is recommended that several steps be accomplished beforehand to obtain an estimate of the degree of mission planning flexibility available:

- 1 Sum all consumables associated with category A blocks and subtract the result from the available capacities. These expendables impose a fixed mission limitation regardless of mission duration.
- 2 Estimate the planned mission duration and compute the expendables associated with the category B blocks. These expendables impose a relative limitation as a function of mission time. Subtract the remainder from the result following step 1. The new remaining quantities are available for category C block operations.
- 3 Establish the total number of burns (excluding deorbit) and again deduct the expendables from the remainder as in steps 1 and 2.
- 4 Establish priorities for the remaining category C blocks and trade off their demands on the remaining consumables.
- 5 Once a reasonable consumable balance is established the normal detailed mission analysis can be continued.



NO	TITLE	DURATION HR MN SC	DUTY STA	AVG WATTS		CONSUMABLES LBS	OPERATIONAL CONSIDERATIONS	RECOMMENDED COMMUNICATIONS	MISSION PLANNING FACTORS			NO
				AC	DC				SCHEDULING	TRAJECTORY AND ATTITUDES	SUBSYSTEMS AND CREW	
1	ASCENT	00 10 07	123	339	2236		SPS STANDBY FOR SUBORBIT ABORT 25 FF MAX WIND VELOC AT LAUNCH FOR LOW ALT ABORT WATER IMPACT	TRKG-T/M-VOIC-UPDATA S-BD(B-1) UNTIL EOI + 90 SEC		CREW HEADS DOWN AT EOI	ALL CREWMEN SUITED IN PGA (UNPR) MAX LOAD ON CREW = 4G	1
2	LET JETTISON	00 00 03							WHEN Q=1 PSF (APPROX S4B IGNITION + 20 SEC)	LAUNCH VEHICLE INERTIAL ATT HOLD REQ		2
5	POST INSERTION	00 08 20	1234	335	993			VOICE-TELEM-TRACKING	STARTS AT S4B ENGINE SHUTDOWN	S4B PERFORMS PROGRAMMED PITCH TO LOCAL HORIZONTAL 1 MINUTE AFTER LOI		5
6	CSM/S-1VB SEPARATION	00 05 19	1234	167	217	SM RCS 30	MSFN INHIBIT S4B VENTING DURING SEPARATION AND SLA PHOTOGRAPHY	TELEMETRY-VOICE-UPDATA	S4B BATTERY LIFE - APPROX 6.5 HRS SUNLIGHT FOR SLA PHOTOGRAPHY	S4B - 1 DEG DEADBAND ATTITUDE HOLD CSM - 5 DEG DB UNTIL 10 FPS SEP VELOC	ALL CREWMEN SUITED IN PGA (UNPR)	6
7	IMU ALIGNMENT	S4B/CSM 00 15 00 CSM 00 42 28	1 34 1 34	21 129	506 567	SM RCS 9		MSFN VERIFY OPTICAL SHAFT AND TRUNION ANGLES GENERATED	15-40 MIN BEFORE DV MVR OR NAV SIGHTING	3-AXIS ATT HOLD - 5 DEG DEADBAND - OPTICS-POINTED ABOVE LOCAL HORIZON FINE AL AND CKS IN DELTA V ATTITUDE	15 MIN PSA WARM-UP PRIOR TO FINE AL	7
8	NAVIGATION SIGHTINGS EARTH LANDMARK S4B/CSM CSM CELESTIAL (L LMK/STAR)	23-33 MN APPX 29M	1 4 1 4	159 152	337 145	SM RCS 6 6	MAX 45 DEG SLANT ANGLE VIEW ADEQUATE SOLAR INCID ON LMK S4B MAINTAIN REQ CSM ATT	TELEMETRY-VOICE	AFTER ALL DELTA V EXCEPT DEORBIT IF TIME AND OPPORTUNITY PERMIT	Y-Z AXIS HOLD +X 0 TO -20 (FWD AND DOWN) NOTE-IF LMKs ARE SELECTED NEAR ORBITAL PLANE (10-20NM) A SMALL ROLL MVR WILL SHIFT THE SCT BLINDZONE 3 AXIS ATT HOLD - 0.5 DEG DEADBAND SDA POINTED AT L LMK		8
9	DRIFTING FLIGHT AM-1 POWERED DOWN AM-2 POWERED UP	24 00 00	1234				MONITOR RADIATOR INLET/OUTLET TEMP HEATSHIELD TEMP RCS PROP TEMP	T/M FOR CREW/SUBSYS MONITORING TRKG FOR STATE VECTOR DETERM VOICE ONCE/REV FOR CREW REFOR UPDATA FOR PERIODIC AGC UPDATE		3-AXIS DRIFT BIAS AS REQ FOR THERMAL CONTROL		9
10	CREW MAINTENANCE MEAL PREPARATION HOT 00 44 30 WARM 00 40 30 COLD 00 35 30 SNACK 00 28 30 PERSONAL HYGIENE BODY CLEANSING MICTURATION DEFECATION 5-6 MN 10-23 MN		4 4			INTAKE/DAY FOOD 4.5 WATER 18			MEALS EVERY 4-8.5 HRS/PER CREWMAN TWICE DAILY PER CREWMAN 4-6 PER DAY PER CREWMAN ONCE PER DAY PER CREWMAN		HELMET PRECLUDES EATING/DRINKING HOT WATER FOR ONLY 2 MEALS SIMULTAN	10
11	ATTITUDE CONTROL BAR-B-0 MODE WOBBLE MODE 3 AXIS CONTROL MODE AM-1 G+N 3 AX MVR (5 D/S) 3 AX HOLD (50 DB) AM-2 SCS AM-3 MANUAL DIRECT ROTATION MIN ATT IMPULSE						USES SCS CONTROL MODE CONTROL SYS OFF AFTER INITIATN USES G+N OF SCS CONTROL SYS SCS SYSTEM BMAG-AGCU-LOOP FOR BACKUP HIGH ENER DMFG (AFTER SPS BURN) TO 50 DB REQ APPX 10 MIN 2- 65 D/S MVR RATES - ALL AXES 1-1.5 D/S/S MAX ANGULAR ACCEL MAX DEADBAND HOLD +/- 4.2 TO 5 MIN DEADBAND HOLD +/- 2 TO 5 DEADBAND LIMIT CYCLE 2 DEG/SC EMERGENCY AND BACKUP FUNCTION			2 AXIS HOLD (+/- 5 DEG) -1 AXIS FREE DRIFT X AXIS SPIN STABILIZED WITHIN 29 DEG CONE (DECAY RATE UNDETERMINED) PREPROGRAMMED MVRs AT 0.5 DEG/SEC ANGULAR ACCEL 1-1.5 DEG/SEC/SEC ATT DEADBANDS MIN 5 DEG (NAV SIGHT) MAX 5 DEG (NORMAL) (0.02 DEG/SEC LIMIT CYCLE) AGCU-BMAG-LOOP DRIFT RATE - 9 DEG/HR EACH AXIS COUCH 1 SEAT BACK TO DOCKING POSITION FOR EXTERNAL REFERENCE MANEUVER ATT REF IS NOT ACCURATE OVER 20 D/S 1-1.5 D/S/S MAX ANG ACCEL LIMIT MVR RATE - HUMAN ENDURANCE AVAIL ONLY IN SCS AND G+N CONT MODES MIN RATE APPX 0.1 D/S ANY AXIS		11

PC REP VALUES ARE DELTA ATTS TO THE COMMON LEVEL
PRIOR TO SM SEPARATION AND TOTAL WATTS THEREAFTER

Figure 1-1 MMDB Summary Chart (Sheet 1 of 3)



NO	TITLE	DURATION HR MN SC	DUTY STA	AVG WATTS		CONSUMABLES LBS	OPERATIONAL CONSIDERATIONS	RECOMMENDED COMMUNICATIONS	MISSION PLANNING FACTORS			NO
				AC	DC				SCHEDULING	TRAJECTORY AND ATTITUDES	SUBSYSTEMS AND CREW	
16	AGC UPDATE MSFN/UPDATA LINK MDE MSFN/VOICE MODE	00 04 15 00 08 15	34 34	46 0	262 261		ONLY STATE VECTOR UP-DATE REQ AFTER DEORBIT BURN BACK-UP TO UPDATA LINK MODE	TELEMETRY-VOICE-UPDATA VOICE	30-90 MIN PRIOR TO SPS BURN EVERY 3-5 REVS BETWEEN DEORBIT BURN AND ENTRY INSUFFICIENT TIME FOLLOWING SPS DEORBIT	PRIOR TRACKING REQ BY 3 OR MORE STATIONS FOR ORBITAL PARAMETERS DETERMINATION	UPDATING MUST AWAIT COMPLETION OF AN- OTHER PROGRAM IN PROGRESS	16
17	EXPERIMENTS M-1A CARDV RFLX COND M-3A INFLIGHT EXER M-4A INFLT PHONOCARD M-5A BIO-ASSY BDY FL M-9A HUM OTOLTH FUNC S-5A SYN TERR PHOTOG S-6A SYN WTHR PHOTOG T-3 INFLT NEPHELOMTR MED DATA ACQ SY	00 06 50 00 12 55 00 32 20 SET UP 00 06 05 TEST 00 12 05 STOW 00 06 45 00 36 32 00 06 00 00 06 00 00 04 30 00 06 07	2 4 1234 1 34 4 1234 1234 4 1234	0 0 0 0 0 0 0 0 0 0 0 0	0 0 20 0 41 0 0 0 0		SUBJ - COMMANDER AND NAVIGATOR SUBJ - 2 CREWMEN	TAPE RECORDER TAPE RECORDER	1 5 HR PRIOR TO ENTRY (DONNING 4 5 - 7 MIN) 3/DAY/CREWMAN 1/DAY/CREWMAN (APPROX SAME TIME EACH DAY) 0900-1500 LOCAL TIME 0900-1500 LOCAL TIME EVERY 4 HRS UNTIL INSTRUMT PWR SUP EXHAUSTED			17
18	CABIN PRESSURIZATION DEPRESSURIZATION REPRESSURIZATION (CAB PR REG ONLY) (CPR+EMERG INFLOW)	00 25 00 01 14 24 00 52 18	1 34	0	95	OXY 1 44 OXY 9 53		VOICE				18
24	PRE-DEORBIT	APPX 12H		35	65	SM RCS 1	COOL DOWN CABIN TO 70F FOR ENT HEAT CM RCS ENGINES TO 91F CONTROLLED FREE DRIFT COLD SOAK		START CABIN CHILL DOWN 8-12 HRS BEFORE ENTRY	3 AXIS MVR AT 0 2 DEG/SEC		24
25	SPS DEORBIT AND ENTRY AM-1 G+N PART A PART B AM-2 SCS PART A PART B	NOMINAL 00 18 00	123			SPS APX1150 CM RCS NOMINAL 44 WORST 76 (CAP 112)		TELEM-TRACKING-VOICE-UPDATA		5 MN REQ FROM BURN TO SEP SEP ATT = +X FWD/UP 60 DEG TO VEL VECTOR 5 MN REQ FROM SEP TO 400K FOR 3200 FT SM CLEARANCE AT 400K FOR NON-COLLISION PROPAB 9999 (2 5 MN ABS MIN FOR ENTRY READINESS) CM ATT HOLD DURING SEP + 5 SEC ENTRY RANGE = 900-3500 NM(400K TO DR CH) MAX ACCEL L F =10G ALL MVRs MANUAL R=17 F=5 Y=5 DEG/SEC	CM RCS INJECTOR VALV 55F PRIOR TO SEP	25
26	RCS DEORBIT AND ENTRY PART A PART B		123	169 591	716 862	SM RCS 256 1		TELEM-TRACKING-VOICE-UPDATA	EJECTION CAPABILITY ONCE/ORBIT DESIRED	RETRO MUST OCCUR AT APOGEE +/- 20 DEG FULL NEG LIFT TO 0 2-1 5 G THEN FULL POS LIFT TO AFEX JET(3500 NM MAX RANGE) CONSTANT LOC VERT ATT DURING EJECT THRST ROLL AT 50 DEG/SEC FOR SPIN STAB WITH ONE QUAD OUT	ALL CREWMEN SUITED IN PGA (UNPR) 500 SEC MAX FIRING TIME	26
35	PARACHUTE DSCNT IMPACT	00 07 45	123	493	869	RCS DUMP NOM 182		VOICE			DESC RATE 2 MAINS-34FFS 3 MAINS-27FFS DURING PARA DESC +X UP 15 DEG OFF L VERT	35
37	POST LANDING OPRATIONS	48 00 00		0	69		ACTIVATE BEACON LIGHT IF LAND- ING NEAR SUNSET	VOICE BEACON XNTR			SC MAINTAINED IN UPRIGHT POSITION	37

Figure 1-1 MMDB Summary Chart (Sheet 3 of 3)



THE DATA IN EACH BLOCK, IN RELATED BLOCKS, AND IN SECTIONS 1 0, 2 0, 3 0, 4 0, 5 0 AND 7 0 MUST BE CAREFULLY STUDIED BEFORE ANY NUMBERS ARE APPLIED IN ANALYSIS. SHORT CUTS OR GROSS SIMPLIFICATIONS WILL RESULT IN SIGNIFICANT ERRORS.

THE USAGE OF EXPENDABLES MUST ALSO BE CONTINUALLY COMPARED TO AVAILABLE CAPACITIES AND FUTURE DEMANDS IN ORDER TO DEVELOP FEASIBLE BUDGETS.

WHEN TWO BLOCKS ARE STACKED ON THE COMMON LEVEL SIMULTANEOUSLY, ELECTRICAL POWER CAN NOT BE CALCULATED DIRECTLY BY SIMPLY ADDING TO THE COMMON POWER LEVEL THE POWER QUANTITIES ASSOCIATED WITH EACH OF THE TWO BLOCKS.

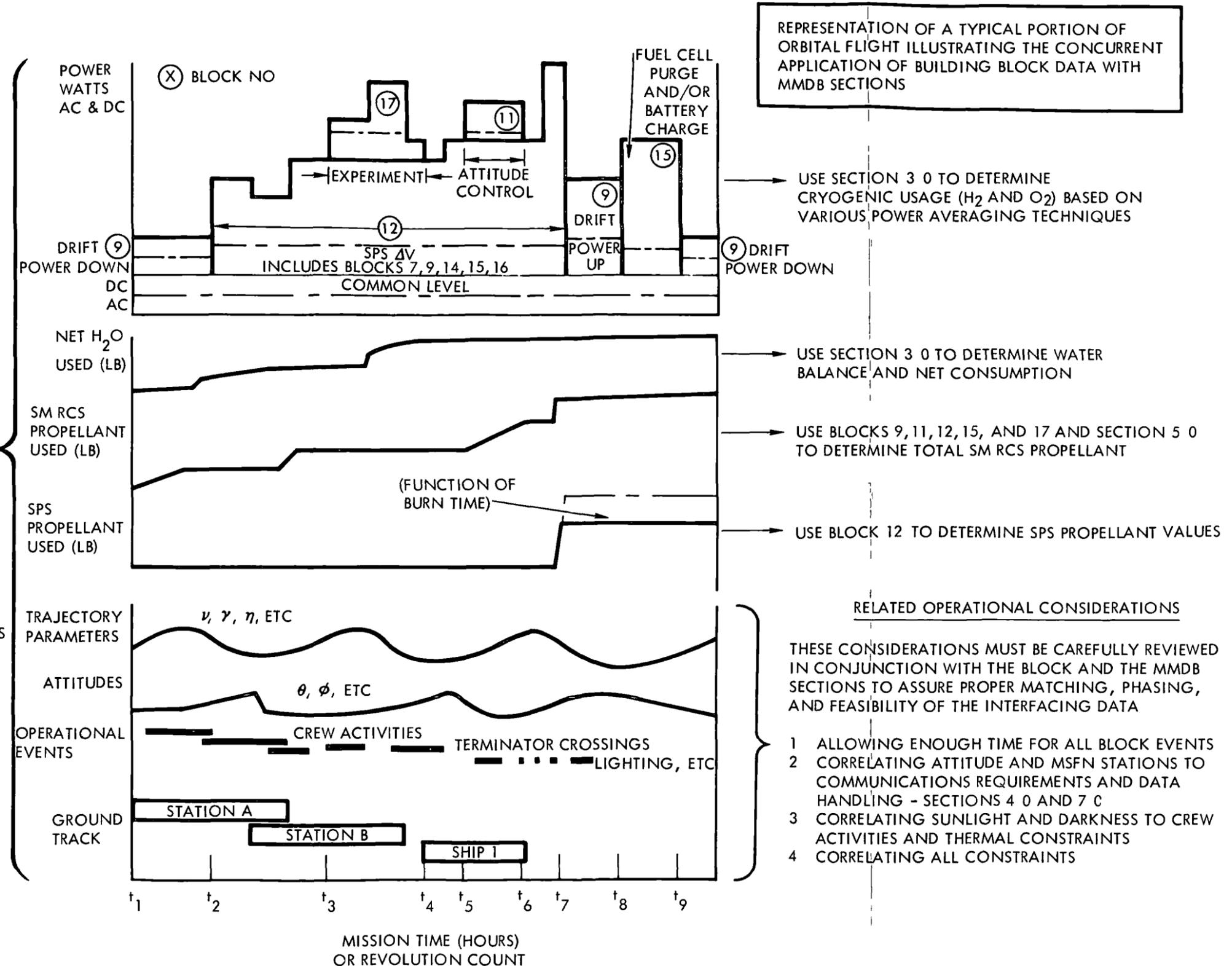


Figure 1-2 MMDB Application to Mission Synthesis



2 0 SPACECRAFT CONSTRAINTS

2 1 INTRODUCTION

Constraints on the spacecraft attitude are required to prevent excessive exposure of certain surface features to solar heating, earth albedo, or cold space. Four constraints have been identified:

- 1 Environmental control subsystem (ECS) radiator inlet temperature
- 2 Service module reaction control subsystem (RCS) propellant temperature and propellant valve temperature
- 3 Heat shield temperature
- 4 Service propulsion subsystem (SPS) propellant feedline temperature

The first three constraints are discussed in this section only, and the fourth is discussed in this section and in BB-15.

Constraints inherent in the AOH procedures are not included in the MMDB nor are operational constraints, although certain acknowledged performance limitations are discussed in the appropriate blocks.

Table 2-1 summarizes the constraints, and Figures 2-1 through 2-2 present parametric data related to these constraints.

2 2 CONSTRAINTS

2 2 1 ECS Radiator Inlet Temperature

The ECS radiator inlet temperature should be maintained at 75 F or warmer to ensure against freezing the radiator. On the other hand, excessive water boiling will result if radiators are directly exposed to the rays of the sun for prolonged periods. Orientations exposing the radiator surface normals to solar incidence angles less than 45 degrees should not be maintained; on the average, for longer than 20 minutes per orbit, nor should spacecraft attitude be constrained inertially or held fixed relative to the earth without roll for a period longer than one orbit if the solar incidence to the radiator is within 45 degrees of the radiator normal. Under no conditions should spacecraft attitude be constrained in an inertial or earth relative orientation without roll for longer than 3 hours.



The ECS radiator inlet and outlet temperatures may be monitored by the crew, but only the inlet temperature is telemetered to the Manned Space Flight Network (MSFN) for monitoring

Recent computer runs and radiator tests have shown that radiator inlet temperatures as low as 70 F are permissible providing the following conditions are met

- 1 Average or random orientation
- 2 Roll rate ≥ 2 rph
- 3 Current level ≥ 50 amperes (Command module power ≥ 800 watts)
- 4 Astronauts monitor outlet circuit temperature of each radiator
Orientation or command module electrical load is changed to prevent either radiator outlet temperature from dropping below 30 F
- 5 Radiator inlet temperatures are monitored to avoid dropping below the 70 F limit

Extreme radiator sooting can be detected by rapid depletion of the water supply and high radiator outlet temperature. If the radiator outlet temperature averages above 53 F as a result of extreme sooting, high electrical loads, or poor radiator orientation, it is expected that the water tanks will be depleting at a rate incompatible with a maximum duration mission (Paragraph 3 8). If severe sooting should occur, the command module electrical load should be decreased in order to reduce the radiator outlet temperature and stop excessive water boiling. It is expected that an average electrical load of 50 amperes (800 watts in command module) or less will be required to complete a 14-day mission when radiators are sooted so that the radiator surface solar absorptivity is degraded to 0.5

Observance of ECS radiator constraints will also ensure a satisfactory environment for electrical power subsystem (EPS) radiator operation

2 2 2 Service Module RCS Temperatures

The service module RCS engines are qualified to work within the range of 35 to 175 F— the propellant valve temperature limits. A red warning light in the cabin will indicate when temperatures exceed this range. Temperatures above 175 F are not expected, except possibly temporarily during boost. Heaters that cycle automatically are provided on each quad to maintain temperatures above the lower limit.



Table 2-1 Summary of Thermal Attitude Constraints

System	Condition to be Avoided	Reason	Action Required
Environmental control radiators	Inlet temperature < 75 F Radiator normal < 45 degrees from sun for prolonged periods	Avoid radiator freezing Excess water consumption (boiling)	Monitor radiator inlet temperature (crew and/or MSFN) 1 Avoid drifting attitudes with radiator normal < 45 degrees from sun (average) for > 20 minutes 2 Do not attitude-hold (inertial or local) for > one orbit if radiator normal is < 45 degrees from sun 3 Avoid attitude holds, inertial or local, > 3 hours duration
Service module RCS	Propellant temperature < 40 F at tank-engine interface Propellant valve temperature < 35 F or > 175 F	Engine not qualified for propellant temperatures below 40 F Valves not qualified outside specified limits	Avoid shielding any quad from sun and avoid pointing toward deep space for < 10 hours, or fire critical RCS quad at least every 10 hours Monitor warning light system and adjust spacecraft attitude if necessary
Heat shield	Ablator temperature < -150 F	Ablator cracking	Maintain an awareness of extended worst-case cooling attitudes (see response curve, Figure 2-1)



Table 2-1 Summary of Thermal Attitude Constraints (Cont)

System	Condition to be Avoided	Reason	Action Required
Heat shield (Cont)	Ablator temperature >+200 F	Ablator outgassing and reduced strength	<p>Avoid temperatures >200 F for >2 hours, i.e., avoid prolonged worst-case attitude (see response curve, Figure 2-2)</p> <p>Adequate thermocouple instrumentation is not provided to assure detection of limiting temperatures under worst-case conditions</p>
SPS	Propellant temperature <40F at feedline-engine interface	Engine not qualified for propellant temperatures below 40 F	<p>Monitor feedline temperatures, turn on heaters at 50 F</p> <p>Solar-soak engine briefly if heater capacity is inadequate</p> <p>Avoid prolonged worst-case engine cooling attitude (-X axis away from sun)</p>



Nevertheless, it is possible for the 40 F lower temperature limit of the propellant to be violated at the RCS tank outlet if one quad is continuously pointed away from the sun for longer than 10 hours. Therefore, attitude should be monitored during extended periods between firings to assure that safe temperatures are maintained.

2 2 3 Heat Shield Temperature

The heat shield ablator lower temperature limit of -150 F may be exceeded if the thin (-Z) portion of the ablator is continuously pointed away from the sun for longer than three hours, and surface cracking could result. Figure 2-1 shows ablator response time for maximum cooling attitudes. The envelope of attitudes which allows a sufficiently cold environment for the thinnest portion of the ablator to cool below -150 F is extremely small. Because of the moderate response time, it is unlikely that a critically cold condition will be approached during the mission.

If the heat shield ablator temperature is allowed to rise above 200 F, outgassing will result and cause a corresponding degradation to the stress margin.

No portion of the ablator should be allowed to remain above 200 F for any aggregate period longer than 2 hours. Figure 2-2 shows response times for 0.5-inch and 1.0-inch ablator thicknesses in a maximum heating condition.

2 2 4 SPS Propellant Feedline Temperature

The SPS feedlines (both Aerojet and NAA) must be maintained above 40 F.

Electrical heaters and insulation are provided on the Aerojet lines and heaters are provided on the NAA lines to maintain safe temperatures. The external line temperatures are telemetered to the MSFN and should be monitored. The MSFN should instruct the crew to turn the heaters on when temperatures drop below 50 F. If spacecraft attitude is maintained such that the SPS (-X axis) is pointed away from the sun for an extended duration and heater capacity is insufficient to maintain line temperatures above 40 F, then the spacecraft should be maneuvered or allowed to drift from this worst-case orientation, until acceptable line temperatures are reached.

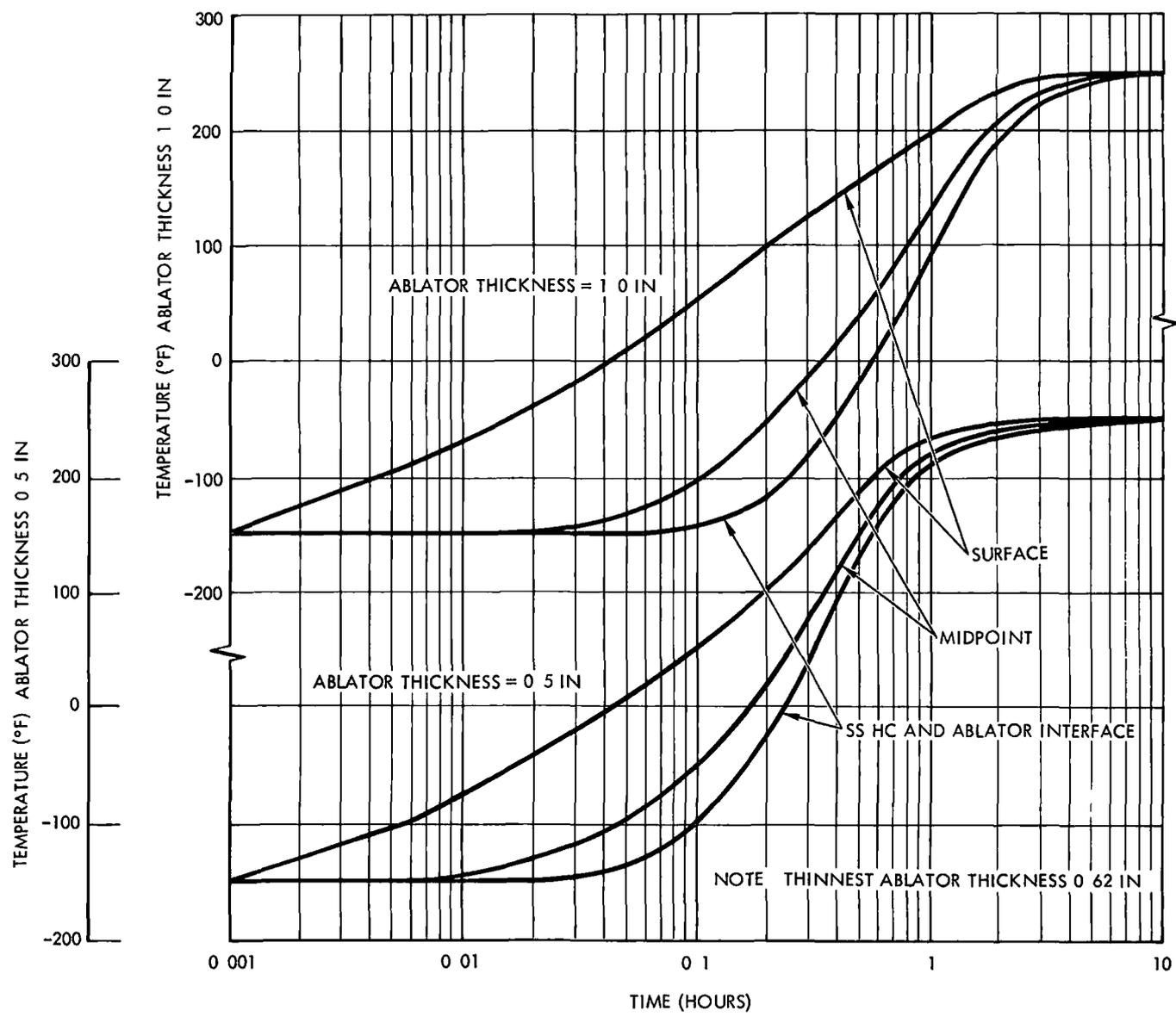


Figure 2-2 Transient Temperature Distribution of Command Module Forward Heat Shield, Maximum Solar Heat Input

2-7

SID 66-1177



3 0 ELECTRICAL POWER

3 1 INTRODUCTION

In the development of this section, attention was given to the effects of power plant regulation, inverter efficiency, and distribution losses within the parametric curves to facilitate rapid and easy use of the building block data. In using the building block data, it should be noted that the block loads, which are depicted at nominal voltages, will change significantly for deviations from nominal bus voltages. In addition, the effects of bus voltage on inverter efficiency have been included in the a-c portions of the curves in this section and not in the a-c load of the individual building blocks. Accordingly, the electrical power data within the individual building blocks must be treated as parametric data and used only for entering the curves in this section.

Table 3-1 lists common level components to avoid unnecessary repetition of loads data in the blocks. In general, the common level components should be added to those components in the building block (keeping the ac and the dc separate) to obtain the total nominal component load. For example, the component nominal a-c watts for the common level will be added to the nominal a-c watts for each of the blocks under consideration. Time-weighted averaging should be used when adding blocks of unequal durations. Averaging is not necessary if point estimates are desired. The total nominal d-c power is obtained in a similar manner. Losses must be treated separately at the component level (i.e., ac and dc cannot be added because inverter characteristics do not affect dc loads).

When changing power levels, the permissible rate for powering up or powering down the spacecraft is primarily a function of the fuel cell stack steady-state temperature and the rate at which the stack changes its temperature. Powering up or down therefore is more dependent upon the longer term electrical power averages and EPS radiator orientations than the precise power and orientation conditions from which the power change starts. Voltage regulation of the command module main d-c bus is a primary concern during the power change operations, and the d-c bus voltage reading should be used to determine the permissible step in power. During power down, the bus voltage should not be allowed to rise above 30 volts and not below 26.5 volts when powering up. For example when powering down, equipment may be turned off until the bus voltage reads 30 volts. This operating configuration should be maintained until such time as the voltage drops off to approximately 29.5 volts. Additional equipment may then be turned off until



Table 3-1 System/Component Power Level and Common Level Duty Cycle

STABILIZATION AND CONTROL						
Mode Code						
1 Monitor		4 SCS ΔV				
2 SCS attitude control (hold)		5 G&N ΔV				
3 SCS attitude control (maneuver)		6 G&N attitude control				
		7 G&N entry				
COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	COMMAND MODULE EQUIPMENT
RGP		All modes	17 3		0	X
BMAG		1, 2, 3 6	7 4	25 0	0	X
		5, 7, 4	7 9	30 0	0	
FDAI		All modes	5 0	0 5	0	X
AS/GPI		1, 2 3 6 7	0 6		0	X
		4, 5	1 8		0	
Delta V display		4, 5	6 6		0	X
Rotation controller		All modes	3 8		0	X
SCS control panel		6, 7	0 6	2 3	0	X
		2, 3 4 5	0 6	1 2	0	
			0 6		0	
ECA Pitch		1	11 8	0 6	0	X
		2, 3 6	11 8	1 9	0	
		4 5	20 9	7 5	0	
		7	11 8	6 7	0	
ECA roll		1	18 0	0 9	0	X
		2, 3, 4 5 6	18 0	3 1	0	
		7	18 0	9 7	0	
ECA yaw		1	11 8	0 6	0	X
		2, 3 6	11 8	1 9	0	
		4, 5	20 9	7 5	0	
		7	11 8	6 7	0	
ECA auxiliary		All modes	21 2	1 9	0	X
ECA display		1 6	7 4	32 5	0	X
		4, 5	11 6	31 6	0	
		7	11 6	40 9	0	
		2, 3	7 4	24 4	0	
Electronics display		1	11 5	17 4	0	X
		6	11 5	16 8	0	
		5	12 1	18 9	0	
		7	1 3	18 4	0	
		2 3	12 3	5 8	0	
TVC	2	Operate	20 0	30 0	0	X
		Standby	20 0		0	



Table 3-1 System/Component Power Level and Common Level Duty Cycle (Cont)

GUIDANCE AND NAVIGATION						
Mode Code						
A Major maneuvers AGC IMU OPERATE		D Inactivity and monitor AGC OPERATE IMU STANDBY				
B IMU alignments sextant sightings AGC IMU OPTICS D&C OPERATE		E Sextant sightings AGC OPTICS D&C OPERATE IMU STANDBY				
C Landmark tracking (low-orbit tracking) Same as B		F Inactivity AGC IMU STANDBY				
COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	COMMAND MODULE EQUIPMENT
AGC OPERATE		A B, C, D, E		115 0	0	
STANDBY		F		15 0	100	X
IMU OPERATE		A B C		325 0	0	
STANDBY		D, E F		61 7	100	X
Optics		B C E	14 4	124 4	0	X
Displays and controls		B, C, E	7 0	18 7	0	
		A		10 7	0	X
		D		10 0	0	
Crew systems						
Personal communications				1 6	100	X
Biomedical instrumentation				2 0	100	X
Crew optical alignment sight				8 4	0	X
Impact and flotation Pumps	2			560 0	0	X
Vent valves (solenoid valves)	3	5 to 10 minutes steady state		30 0	0	X
Solenoid lockout release	4	Pulse transient		60 0	0	X



Table 3-1 System/Component Power Level and Common Level Duty Cycle (Cont)

COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	COMMAND MODULE EQUIPMENT
Communications						
VHF/FM transmitter			46 0	1 5	0	X
VHF/AM equipment		Transmit		61 5	0	
		Standby		14 0	0	X
		Receive		1 5	100	
HF/SSB-AM transceiver		Transmit		40 0	0	
		Beacon		29 0	0	X
		Receive		0 6	0	
S-Band transponder			13 5		0	X
S-Band power amplifier	2	High	72 0		0	X
		Low	26 0		0	
C-Band transponder		Interrogate	75 0	3 0	0	
		Noninterrogate	52 0	3 0	0	X
Audio center		High		12 8	0	
		Low		4 3	100	X
		Standby		1 5	0	
Signal conditioner			42 0		100	X
PCM telemetry		Hi/low	10 5		100	X
Data storage		Operate	32 5	0 5	0	X
		Standby	14 0		0	
Television			5 0		0	X
Premodulation processor			4 0	2 6	100	X
Central timing				21 0	100	X
UHF Updata link				9 6	100	X
Flight qualification recorder			15 0	34 0	0	X
2-KMC switch				15 0	100	X
VHF recovery beacon				8 0	0	X
Audio center diode switch				1 1	30	X
Voice recorders	2		2 5		0	X
Electric power						
Fuel cells						
H ₂ pump H ₂ O separator	3	High (pre-launch)	115 0		0	
glycol pump		Low	105 0		100	



Table 3-1 System/Component Power Level and Common Level Duty Cycle (Cont)

COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	COMMAND MODULE EQUIPMENT
pH meters	3		2 0		100	X
Pressure transducers	9			2 0	100	
H ₂ flow meters	3			1 0	100	X
O ₂ flow meters	3			1 0	100	X
H ₂ purge solenoids	3			17 5	0	
In-line heaters	3			160 0	0	
O ₂ purge solenoids				17 5	0	
Cryogenic gas storage						
H ₂ tank heaters	4		0 0	10 0	13 7	
O ₂ tank heaters	4		0 0	77 5	14 6	
H ₂ tank fans	4		5 0		13 7	
O ₂ tank fans	4		14 0		14 6	
Pressure transducers and temperature sensors	4			1 5	100	X
Signal conditioners	4		4 0		100	
DC-DC converter				3 0	100	
Power distribution						
Battery charger		At nominal output current	41	36 0	0	X
Sensors over/undervolt	4			0 75	100	X
Power factor correction unit			7 5		100	X
Inverter 1				△	100	X
Inverter 2		Idling at no load		112 0	0	
Battery A					0	
Battery B					0	X
Battery C					0	
Instrumentation CM				101 5	100	X
SM				91 5	100	

△ Operating inverter load is handled as a loss and is automatically accounted for in the parametric curves



Table 3-1 System/Component Power Level and Common Level Duty Cycle (Cont)

COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	COMMAND MODULE EQUIPMENT
Gas chromatograph			8 0		100	X
Data storage electrical assembly	2	One powered	2 4		0	X
Displays and controls						
Digital event timer	2	Operate Standby		2 0 1 0	0 100	X
CW detection unit				7 5	100	X
CW matrix indicator				3 6	100	X
CW lamp test	2			74 0	0	X
Floodlights						
LEB Secondary	2	Fixed		7 0	0	X
LEB Primary	2	Variable		7 0	0	X
SES Secondary	3	Fixed		7 0	0	X
SES Primary	3	Variable		7 0	100	X
CS Secondary	3	Fixed		7 0	0	X
CS Primary	3	Variable		7 0	0	X
Reaction control						
Service module RCS						
Engine heaters	4			36 0	62 5	
RCS engine coils	16	Automatic Direct		118 0 34 0	0 0	
He isolation valves	8			54 0	0	
Propellant isolation valves	8			49 0	0	
Command module RCS						
Isolation valves	4			49 0	0	X
RCS engine coils	12	Automatic Direct		105 0 52 5	0 0	X
Service propulsion						
Propellant utilization valve					0	
Propellant utilization gauging system			62 6	16 8	0	
Injector pre valves	2			42 0	0	
He solenoid valves	2			56 0	0	
Feedline heaters	26	(All on)		33 0	0	



Table 3-1 System/Component Power Level and Common Level Duty Cycle (Cont)

COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	COMMAND MODULE EQUIPMENT
Pilot valves (SCS)	4			42 0	0	
Gimbal actuator motors		Idle		1570 0	0	
		Boost		1692 0	0	
		Delta V		2220 0	0	
Environmental control						
PLV fan		High		15 0	0	X
		Low		6 5	0	
PLV gate valves	2			50 4	0	X
PLV attitude sensor switch relay				3 7	0	X
Suit compressor	2	High	232 0		0	X
		Low	85 0		100	
Glycol pump	2	1 operates	36 0		100	X
Cabin fans	2	1 operates	19 0		100	X
Glycol temperature control			2 5		100	X
Glycol temperature control valve			7 2		10	X
Cabin temperature control			2 5		100	X
Cabin temperature control valve			7 2		20	X
Backpressure control			2 5		100	X
Backpressure control valve			7 2		90	X
Wetness control			5 0		100	X
Power supply				10 5	100	X
O ₂ flow transducer				2 4	100	X
Pressure transducer	3			0 8	100	X
Backpressure sensor				1 28	100	X
Glycol transducers	2			1 28	100	X
Glycol evaporation control valve				3 0	50	X
Steam duct heater (2)				3 0	100	X
Potable H ₂ O tank potentiometer				1 28	100	X
SM water shutoff valve				160 0	0	
Glycol shutoff valve (powered by GSE prelaunch only)				160 0	0	



Table 3-1 System/Component Power Level and Common Level Duty Cycle (Cont)

COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	COMMAND MODULE EQUIPMENT
Cycle accumulation valve				3 0	1 6	X
Potable H ₂ O supply assembly main heater				35 0	20 0	X
Sustaining heater				10 0	80 0	X
Urine line heater				5 7	100	X
Suit sensors				1 002		
Cyclic accumulation control				3 5	1 6	X
Miscellaneous ECS transducers and sensors (8)				2 0	100	X
Suit circuit						
Backpressure control			2 5		100	X
Glycol valve			2 5		100	X
Wetness control			5 0		100	X
Glycol diverter valve			7 2		1	X
Water control valve			7 2		5	X
Backpressure valve			7 2		5	X
Radiator control valves (used during boost only)	2		14 4		0	X
Sequential events control						
Master events sequence controller					0	X
Earth landing sequence controller					0	
CM RCS controller					0	
SM jettison controller					0	
<p>COMMON LEVEL TOTAL</p> <p>P_{AC} (nominal) = 591 8 watts</p> <p>P_{DC} (nominal) = 591 4 watts</p>						



the bus again reaches the 30-volt limit. The procedure can be repeated until the desired power level is achieved. Powering up should be done in a similar manner. Because of the expected bus voltages under normal three-fuel-cell operation, it is anticipated that fewer power steps will be required during power ups than during power downs.

A building block or combination of blocks may be compared with the system performance limits after determining the various electrical power and power-related parameters.

For operational limitations and restrictions refer to Paragraphs 2 6 3 1 and 2 6 4 1 of the Apollo Operations Handbook (AOH).

3 2 SYSTEM/COMPONENT POWER LEVELS

Table 3-1 identifies spacecraft equipment (grouped by subsystem) which has been tracked for electrical power purposes. Power levels at nominal voltages (28 volts dc and 115 volts ac) are shown by component/mode.

3 3 COMMON LEVEL

Equipment operation common to all blocks up to command module-service module separation has been specified and totaled separately in Table 3-1. The common level duty cycles form the base from which all block duty cycles and power parameters are defined. All blocks up to command module-service module separation may be added to the common level. The common level alone does not define a flight condition. The common level totals are:

$$P_{AC} \text{ (nominal)} = 591.8 \text{ watts} \quad P_{DC} \text{ (nominal)} = 591.4 \text{ watts}$$

Equipment which is physically located in the command module and whose heat dissipation must be rejected by the ECS is identified in Table 3-1.

3 4 COMMAND MODULE BUS VOLTAGE VERSUS NOMINAL LOADS

Parametric data necessary to determine command module bus voltage as a function of P_{AC} (nominal) and P_{DC} (nominal) for various EPS configurations are provided in Figures 3-1 through 3-4.

These figures include fuel cell regulation, inverter efficiency, power distribution system line losses up to the bus, off nominal load voltage effect, and an assumed power factor of 0.9. The bus voltage derived from the curve is the actual bus voltage expected to be read from the command module.



instrumentation under the assumed loading conditions. Line or distribution losses between the command module bus and the d-c component loads and between the inverter and the a-c component loads are neglected. These losses (about 1 percent of the component loads) were considered insignificant or within the tolerance of the component loads.

3 5 COMMAND MODULE BUS CURRENT VERSUS NOMINAL LOADS

Figure 3-5 provides parametric data necessary to determine command module bus current as a function of nominal loads based on the command module bus voltage determined in the previous section. Figure 3-5 presents two curves I_{DC}^* versus P_{AC} (nominal) and I_{DC} versus P_{DC} (nominal), both direct current as a function of bus voltage. I_{DC}^* represents that component of command module d-c bus current required to satisfy the a-c load requirements and inverter loss demands. I_{DC} represents that component of command module d-c bus current required to satisfy the d-c load requirements. The sum of I_{DC}^* and I_{DC} represents the total command module bus current.

In those EPS configurations which have only fuel cells in service, $I_{DC}^* + I_{DC}$ represents total fuel cell current (I_{FC}). In those EPS configurations which have only batteries in service, $I_{DC}^* + I_{DC}$ represents total battery current (I_{BATT}).

3 6 FUEL CELL CURRENT DETERMINATION FOR FUEL CELL PLUS BATTERY EPS CONFIGURATIONS

For those EPS configurations which include both the fuel cells and the batteries

$$I_{DC}^* + I_{DC} = I_{FC} + I_{BATT}$$

Figure 3-6 provides the parametric data necessary to determine I_{FC} as a function of command module bus voltage as determined in Paragraph 3 4. Figure 3-6 also shows total fuel cell current versus command module bus voltage for one, two, and three fuel cells.

Having determined I_{DC}^* and I_{DC} from Paragraph 3 5, I_{BATT} can be determined by

$$I_{BATT} = I_{DC}^* + I_{DC} - I_{FC}$$



3 7 HYDROGEN AND OXYGEN USAGE

Descriptions of the hydrogen and oxygen cryogenic storage systems are given in the AOH, Paragraphs 2 6 2 1, pages 2-168 to 2-173. The total usable hydrogen is 56 pounds. The total usable oxygen is 640 pounds.

3 7 1 Fuel Cell Cryogenic Consumption

In general, instantaneous demands on the fuel cells are of little concern. Instead, the average condition over a significant period (a building block duration) will provide adequate information for estimating reactants consumed. Average total component loads over the building block duration are provided and should be used. Again, time-weighted averaging should be used when considering multiple blocks of unequal durations.

Figure 3-7 provides the parametric data necessary to determine cryogenic consumption (H_2 and O_2) for a one, two, or three-fuel cell EPS configuration. Only the H_2 curve is given. The O_2 consumption rate is eight times the H_2 rate. The water generation rate of the fuel cells may be calculated by multiplying the consumption rate of the H_2 by nine.

Fuel cell purging, metabolic, and cabin leak requirements are not included. See BB-15 (Subsystem Maintenance) for purging requirements.

3 7 2 Cabin Leakage and Metabolic Oxygen Requirements

Cabin leakage occurs at a rate of 0.2 pounds per hour at a nominal cabin pressurization of 5 psi. At pressure other than 5 psi

$$\text{Leakage (lb/hr)} = \frac{0.2 \times \text{actual pressure (psi)}}{5 \text{ psi}}$$

Metabolic oxygen is consumed at an average rate of 0.23 pounds per hour for three astronauts. At emergency levels (high activity), consumption increases to 0.26 pounds per hour.

For oxygen requirements during depressurizations/repressurizations, see BB-18 (Cabin Depressurization).



3 8 WATER

For a description of the water supply subsystem, see the AOH, Paragraph 2 7 2 5, pages 2-244 to 2-226. The storage capacity of the water supply system is as follows

Potable water = 36 pounds

Waste water = 56 pounds

Service module waste water = 112 pounds

3 8 1 Water Balance

The following equation gives the change in available water

$$\begin{aligned} \Delta H_2O &= H_2O \text{ produced by fuel cells} \\ &+ LiOH, CO_2 \text{ reaction by-product} \\ &- \text{Urine dump} \\ &- \text{Supplemental ECS water requirements} \end{aligned}$$

Figures 3-8 through 3-10 depict ΔH_2O as a function of I_{FC} for six possible combinations of environmental loads and radiator orientations

3 8 2 Water Production by Fuel Cells

H_2O production in pounds per hour can be determined by multiplying the H_2 consumption rate of Figure 3-7 by nine

3 8 3 Lithium Hydroxide Reaction

The water reaction by-product created by the chemical union of $LiOH$ with CO_2 is produced at the rate of 0.11 pounds per hour

3 8 4 Urine Dump

Urine dump will discharge water at the average rate of 0.33 pounds per hour for three astronauts



3 8 5 Supplemental ECS Water Requirements

Supplemental water requirements (boil-off) alone may be computed by solving the water balance equation for supplemental water using Figures 3-8, 3-9 or 3-10 and Paragraphs 3 8 2, 3 8 3, and 3 8 4. These data are based on the following assumptions:

Radiator characteristics Area = 60 sq ft

$$\epsilon = 0.92$$

$$\alpha = 0.2$$

100 nautical-miles earth orbit

3 8 5 1 Radiator Heat Load

The average radiator heat load (Q_{load}) is affected by crew metabolic loads (Q_{met}), heat of reaction of the CO_2 canisters (Q_{CO_2}), command module electrical heat loads (Q_{cm}), and energy radiated by the command module to the external environment (Q_{env}) in the following manner:

$$Q_{load} = Q_{met} + Q_{CO_2} + Q_{cm} - Q_{env} \text{ (Btu/hr)}$$

For the purpose of this presentation the following approximations are assumed:

$$Q_{met} = 1390 \text{ Btu/hr} \quad Q_{CO_2} = 325 \text{ Btu/hr}$$

3 8 5 2 Command Module Electrical Heat Load

Electrical components dissipating the heat within the command module are identified in Table 3-1. In addition to those components, all inverter losses are dissipated within the command module. A small amount of distribution losses (I^2R) are also dissipated within the command module.

Consideration of the response time of the radiator system to specific electrical load changes (heat dissipation changes) and the constant nature of the non-command module loads make it possible to relate Q_{CM} and, consequently, Q_{load} , water boiloff requirements, and water balance to fuel cell current as shown in Figures 3-8 through 3-10.



3 8 5 3 Radiator Orientation

Since the ability of the radiators to dissipate heat depends upon the total thermal flux incident upon them, water boiloff becomes a function primarily of radiator orientation with respect to the sun

The following radiator orientations are considered

<u>Worst Case</u>	A spacecraft attitude which continuously exposes a radiator to the sun
<u>Moderate Case</u>	A spacecraft attitude such that the radiators are exposed to an average heat flux similar to random drift
<u>Best Case</u>	A spacecraft attitude which continuously exposes both radiators to deep space (i.e., the radiator normals are perpendicular to the vehicle sun line and also normal to the orbit plane such that the earth's albedo effect is minimized)

3 8 5 4 Environmental Loads

The amount of heat energy radiated by the command module to the external environment (Q_{env}) is a function of command module orientation with respect to the sun

The following environmental loads and their associated spacecraft attitudes are considered

- 1 Maximum Q_{env} (1590 Btu/Hour) This environmental load is associated with a spacecraft attitude which maintains the command module pointing away from the sun
- 2 Nominal Q_{env} (630 Btu/Hour) This load is associated with a spacecraft attitude which subjects the command module to some environment associated with the average of solar pointing and deep space (random drift)
- 3 Minimum Q_{env} (260 Btu/Hour) This load is associated with a spacecraft attitude which maintains the command module pointing towards the sun



3 8 5 5 Possible Spacecraft Attitude

All combinations of Q_{env} (maximum, nominal, minimum) with radiator orientations (worst, moderate, best) are not possible because of conflicting spacecraft attitudes. For example, a spacecraft attitude which exposes both a radiator to the sun (worst case of radiator orientation) and the command module to the sun (minimum Q_{env}) is impossible.

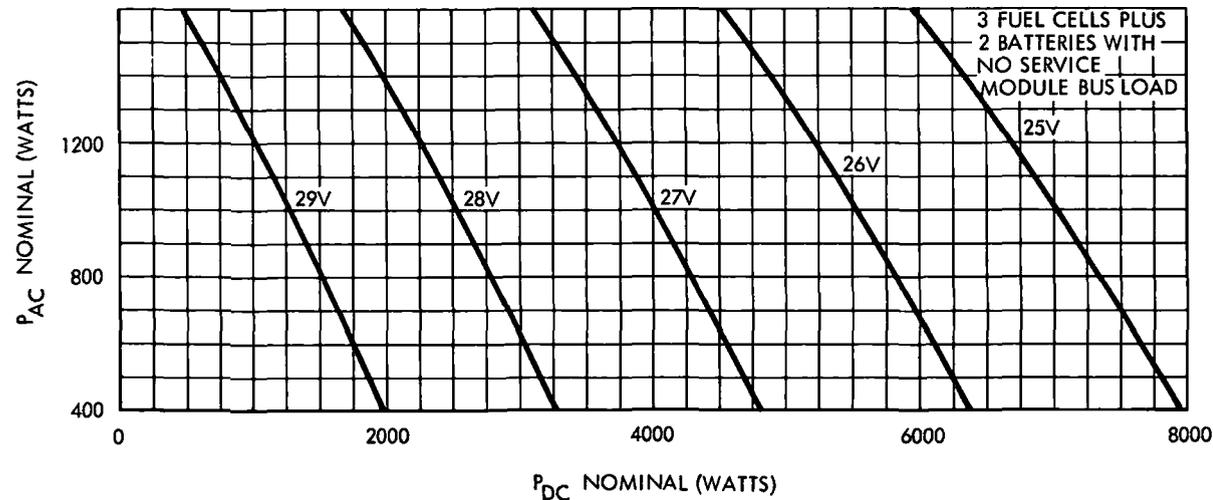
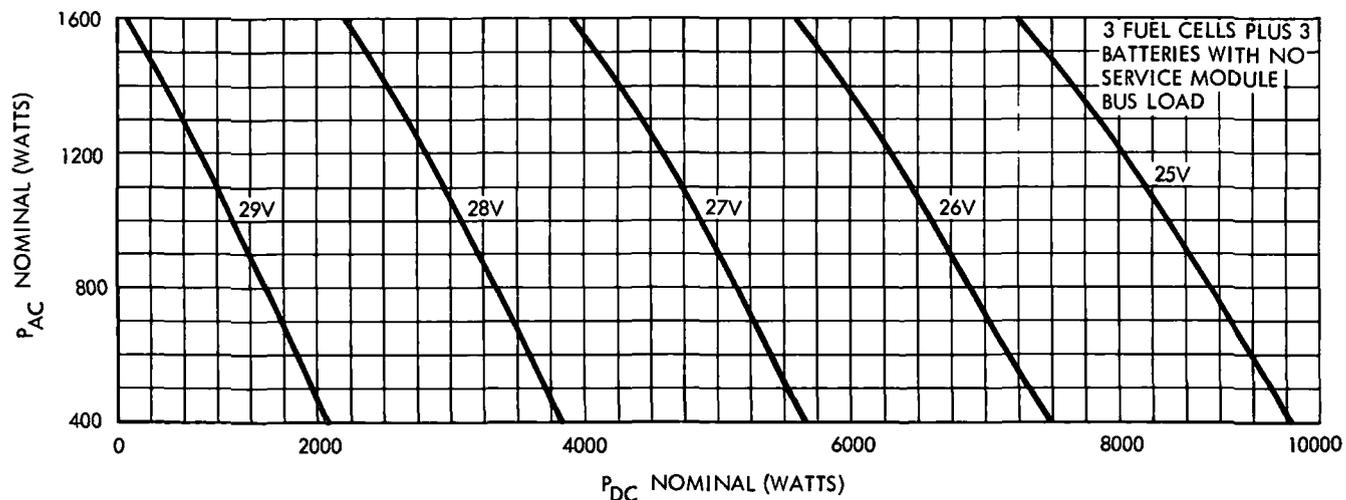
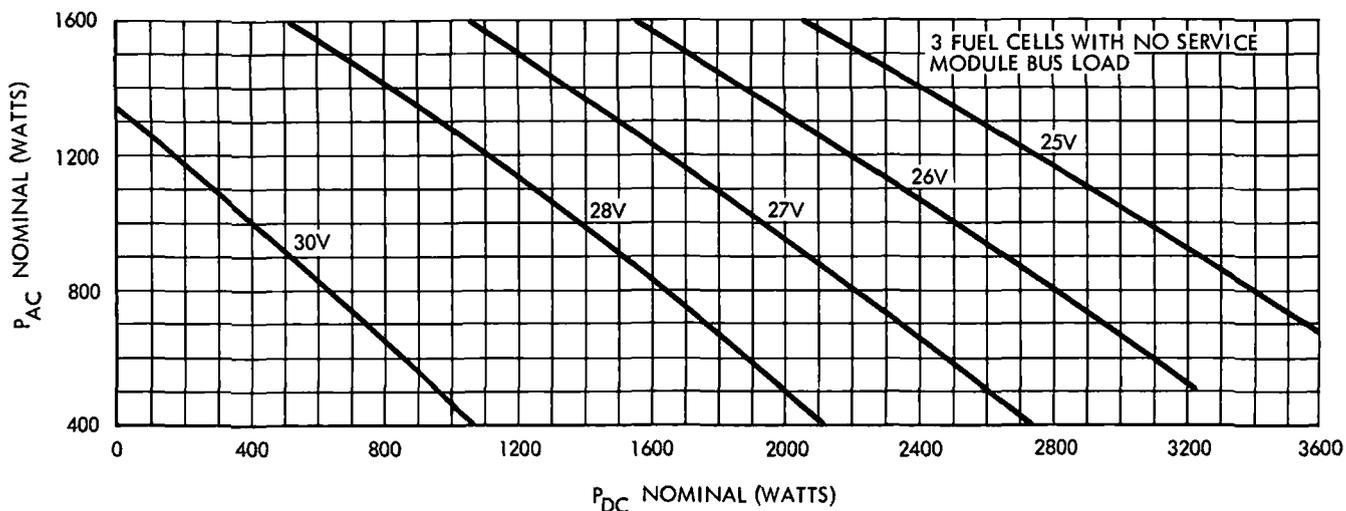


Figure 3-1 Command Module Bus Voltage Versus Nominal Load, Three Fuel Cell Operation

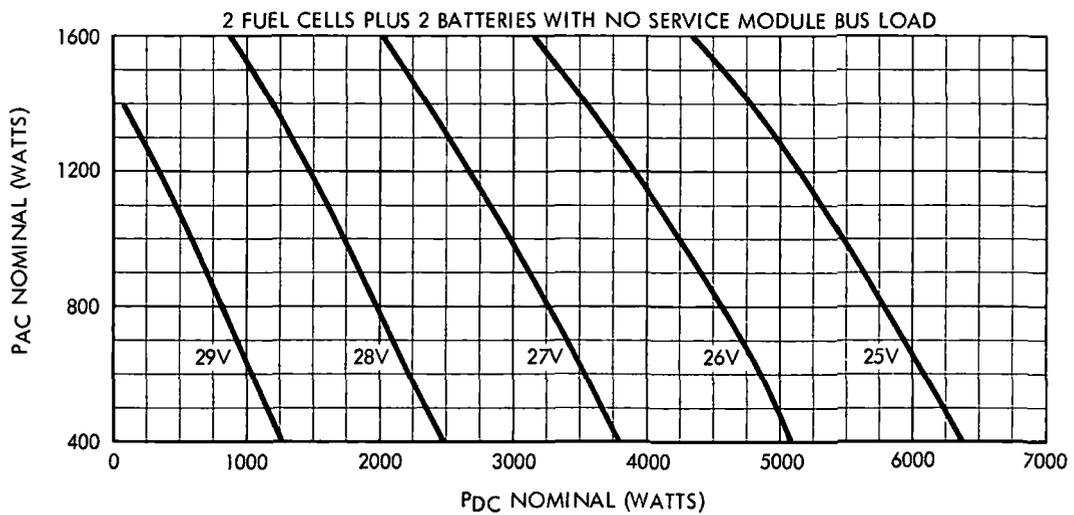
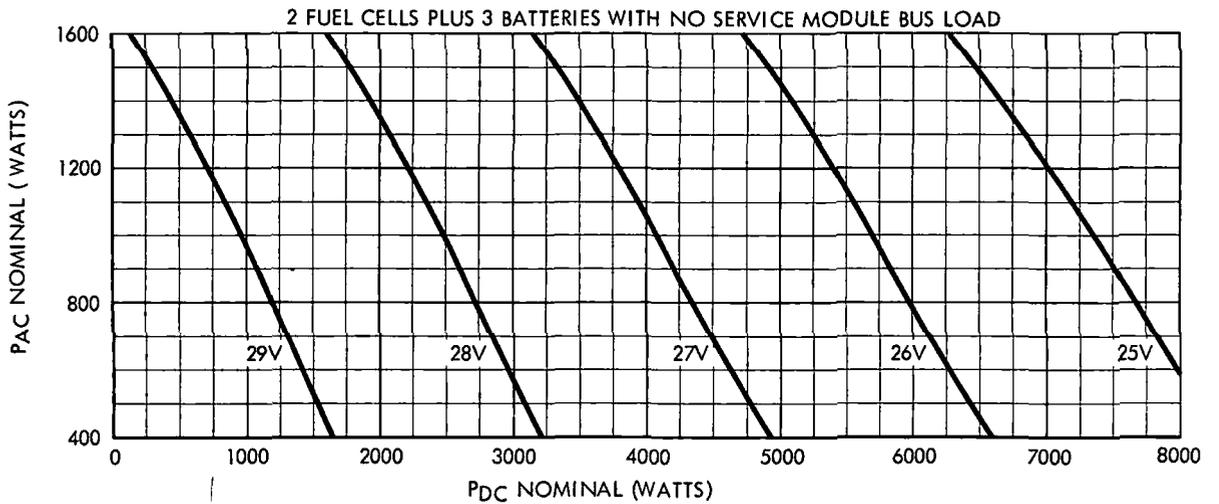
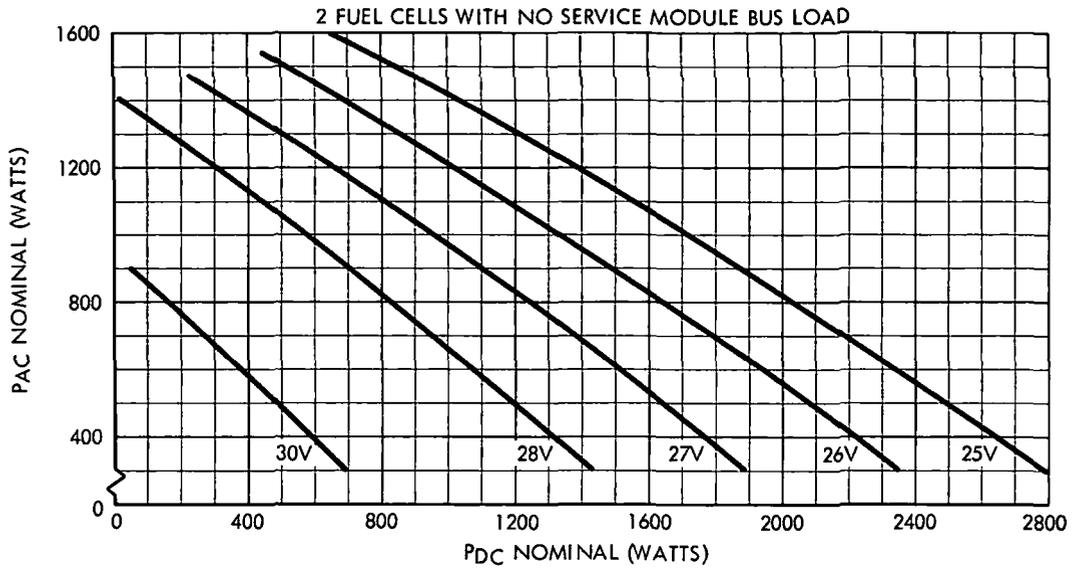


Figure 3-2 Command Module Bus Voltage Versus Nominal Load, Two Fuel Cell Operation

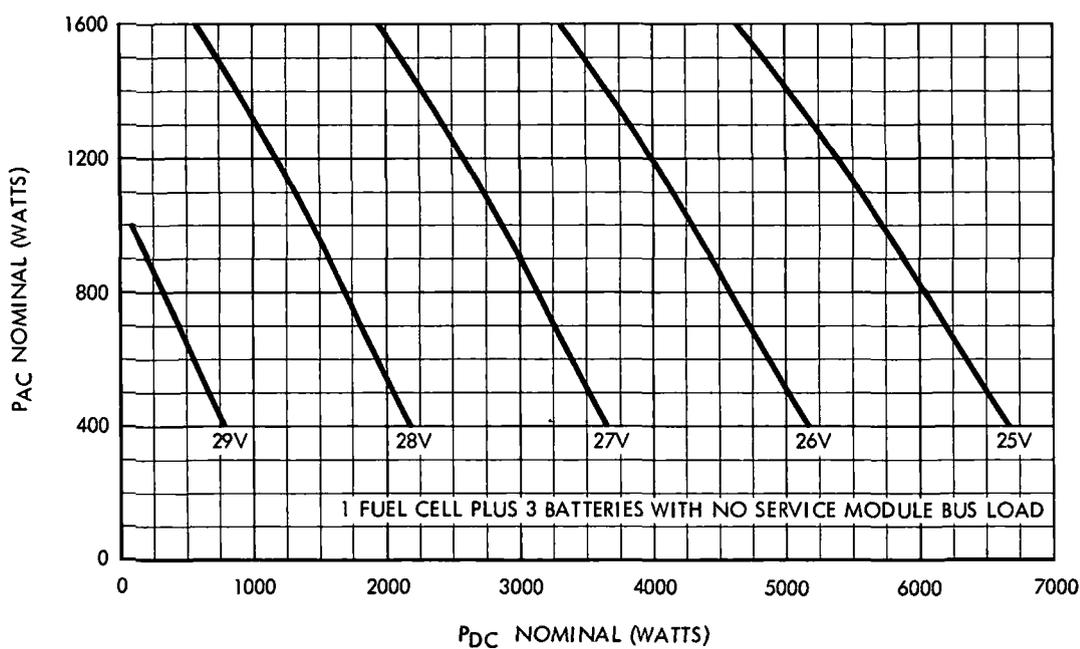
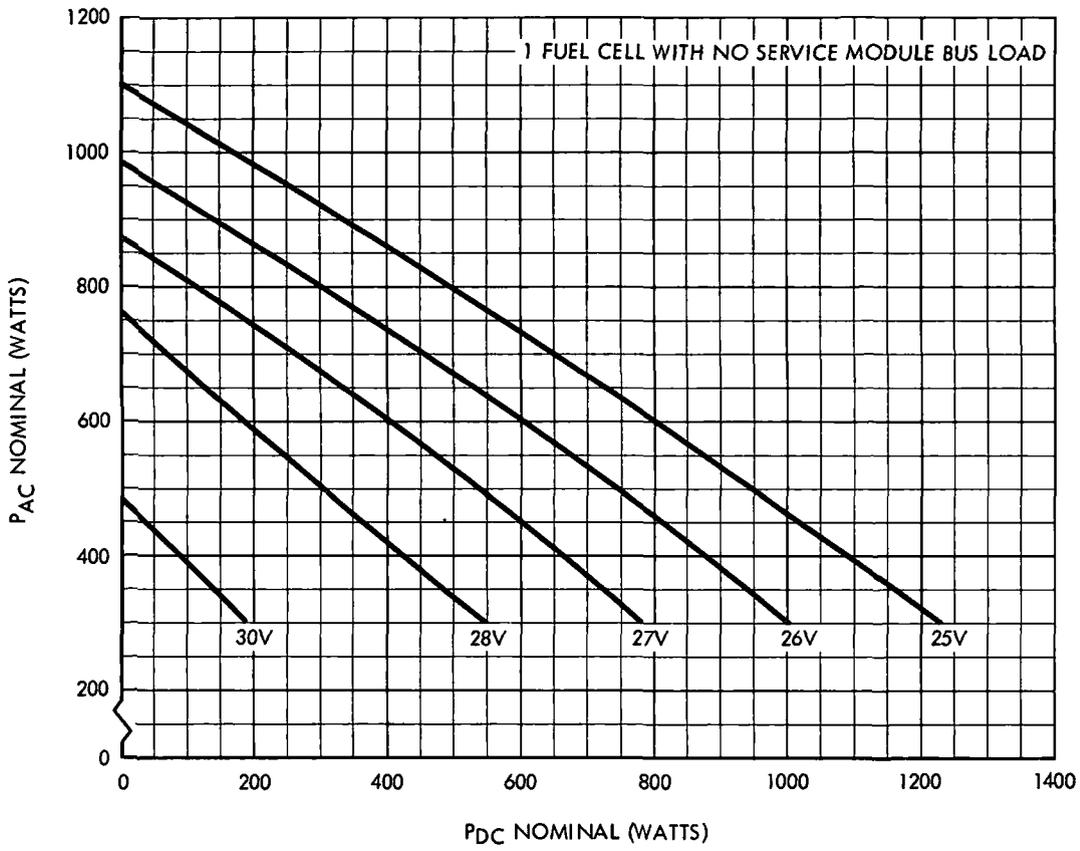


Figure 3-3 Command Module Bus Voltage Versus Nominal Load, One Fuel Cell Operation

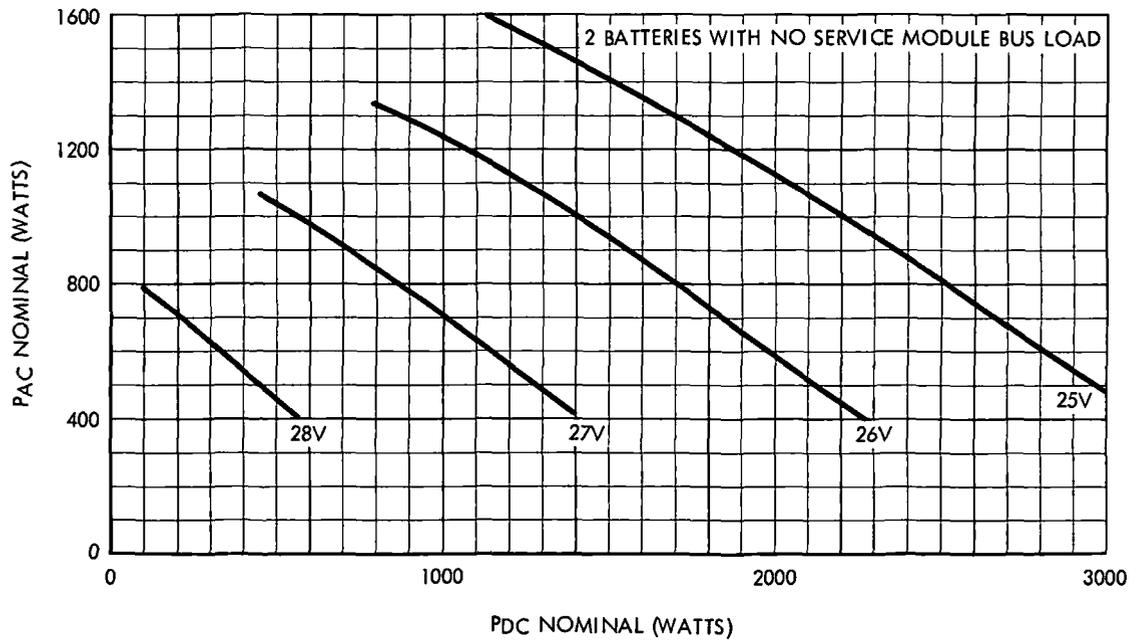
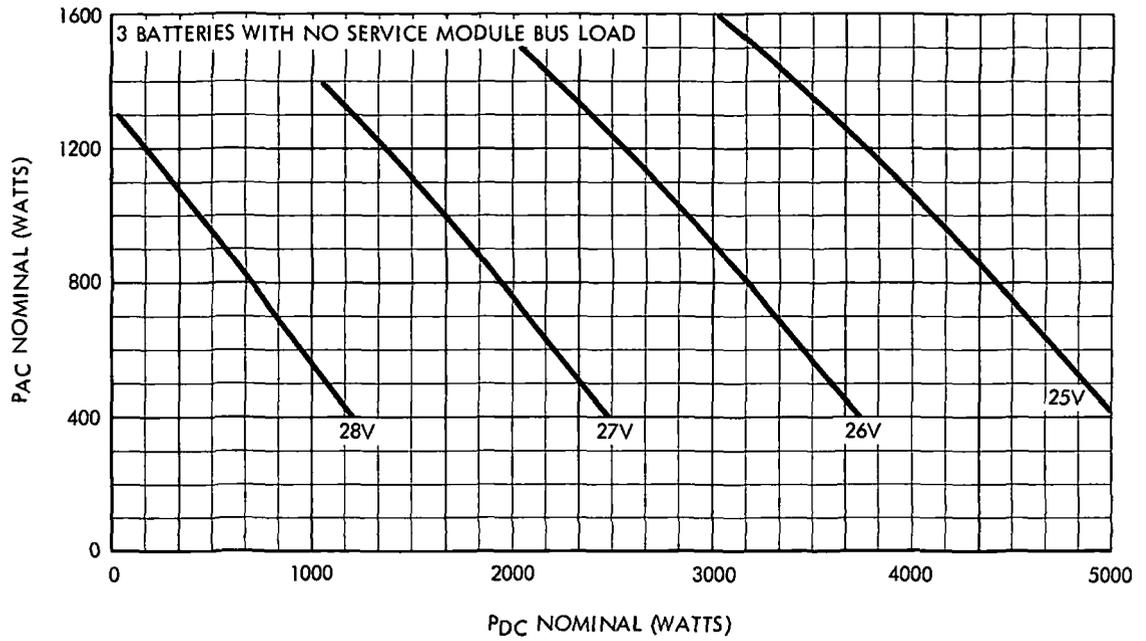


Figure 3-4 Command Module Bus Voltage Versus Nominal Load, Battery Operation

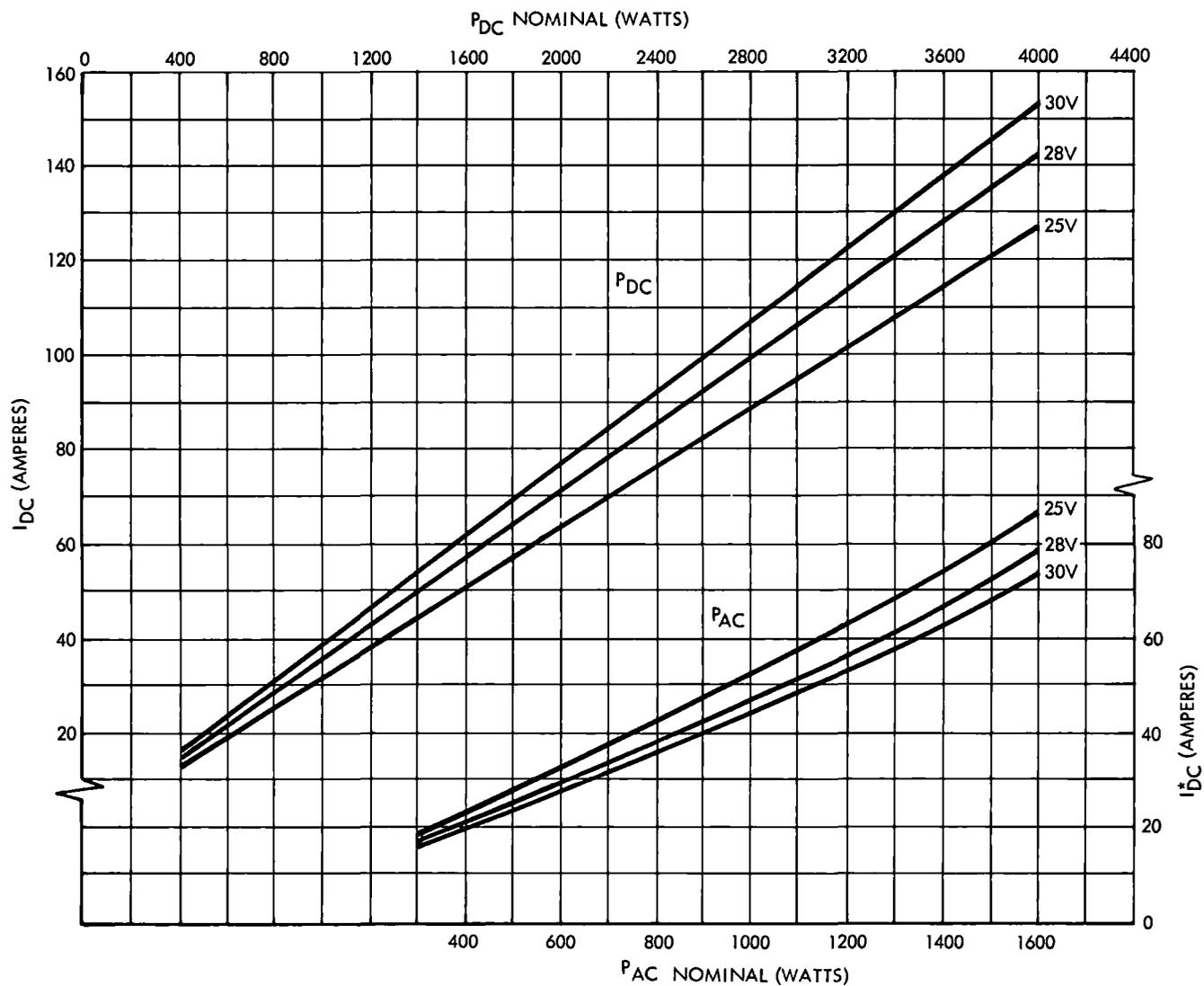


Figure 3-5 Fuel Cell Current Versus Nominal P_{AC} and P_{DC}

3-20

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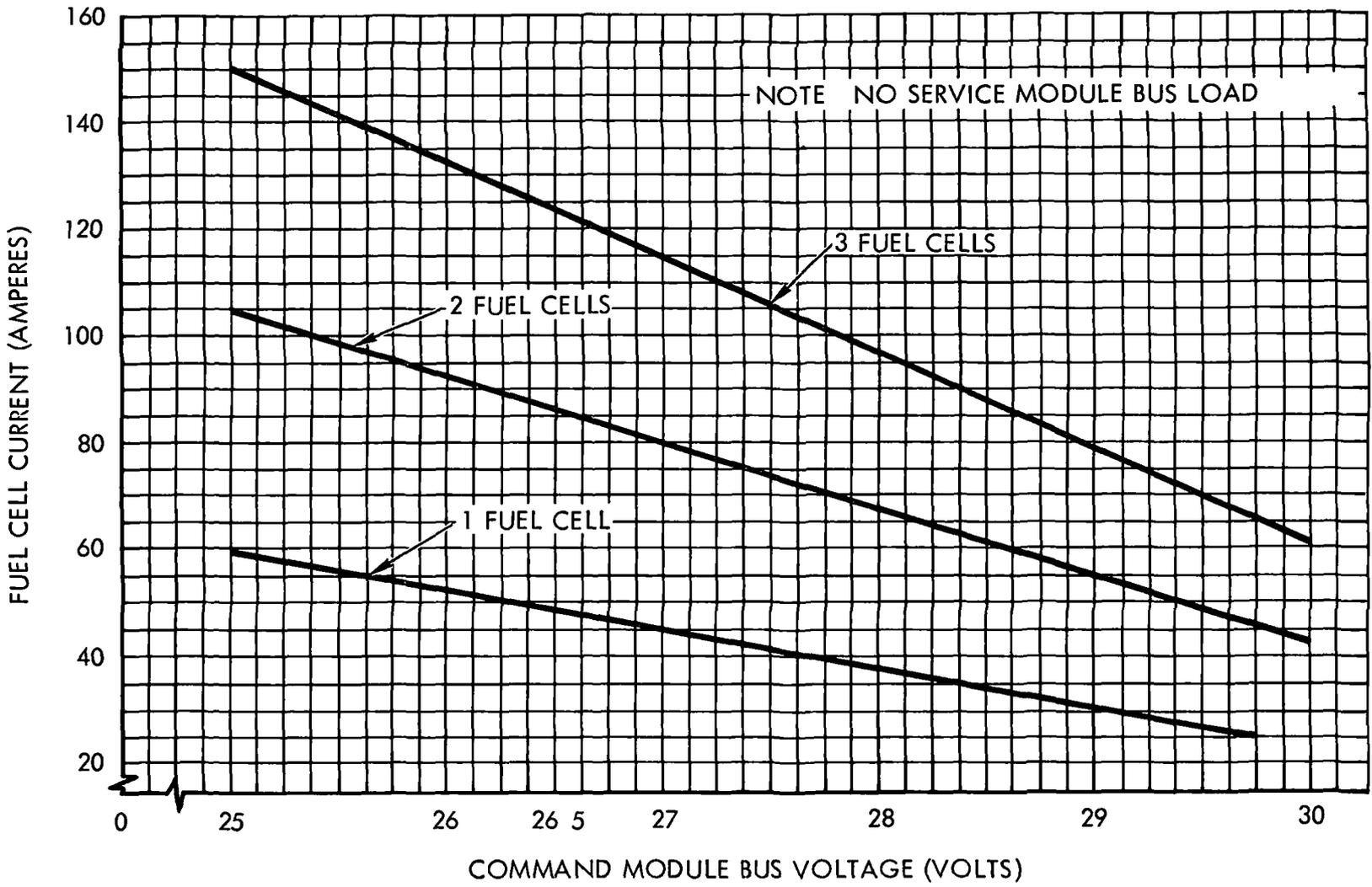


Figure 3-6 Total Fuel Cell Current Versus Command Module Bus Voltage

3-21

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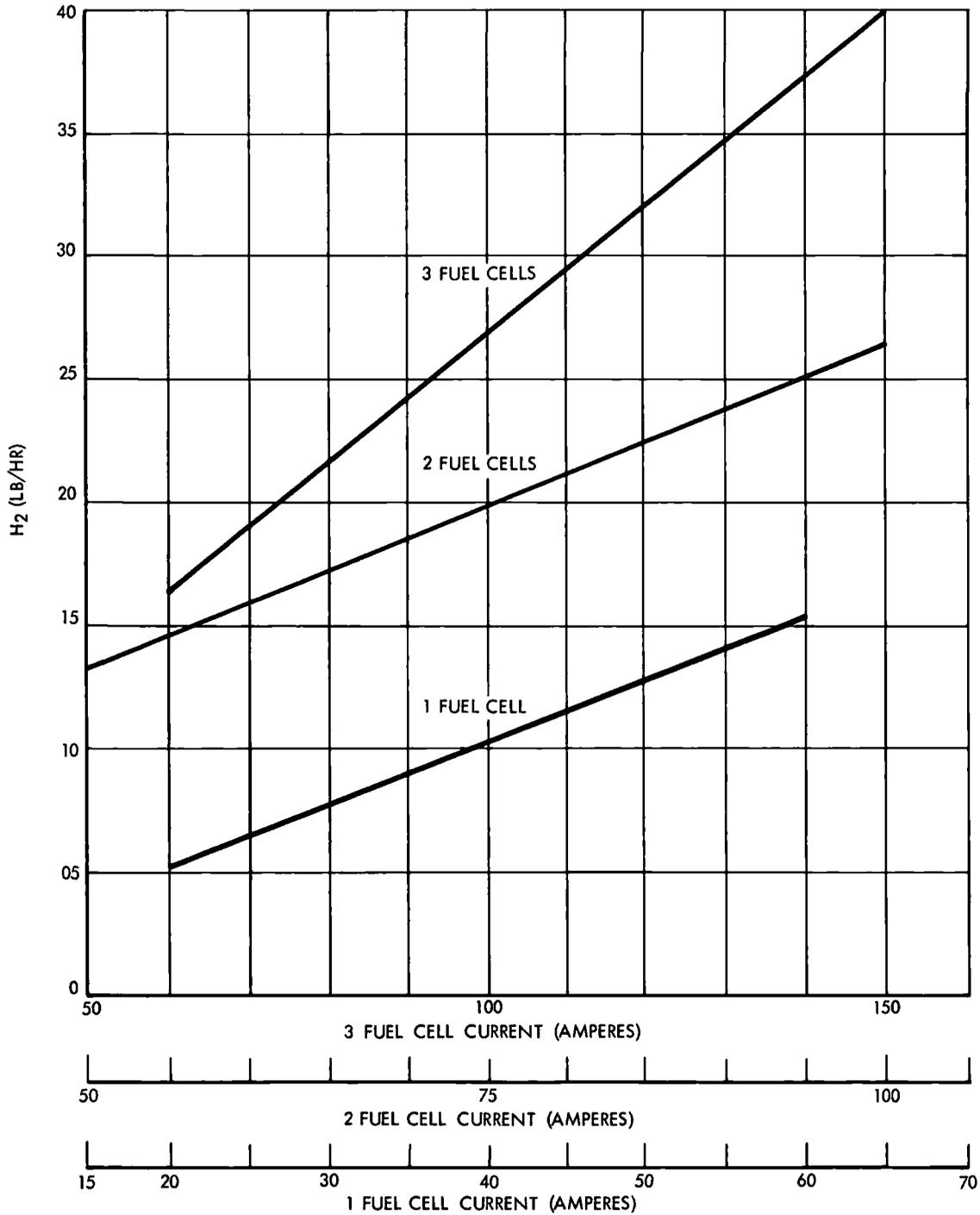


Figure 3-7 Cryogenic Consumption Versus Fuel Cell Current—
One, Two, and Three Fuel Cell Operation

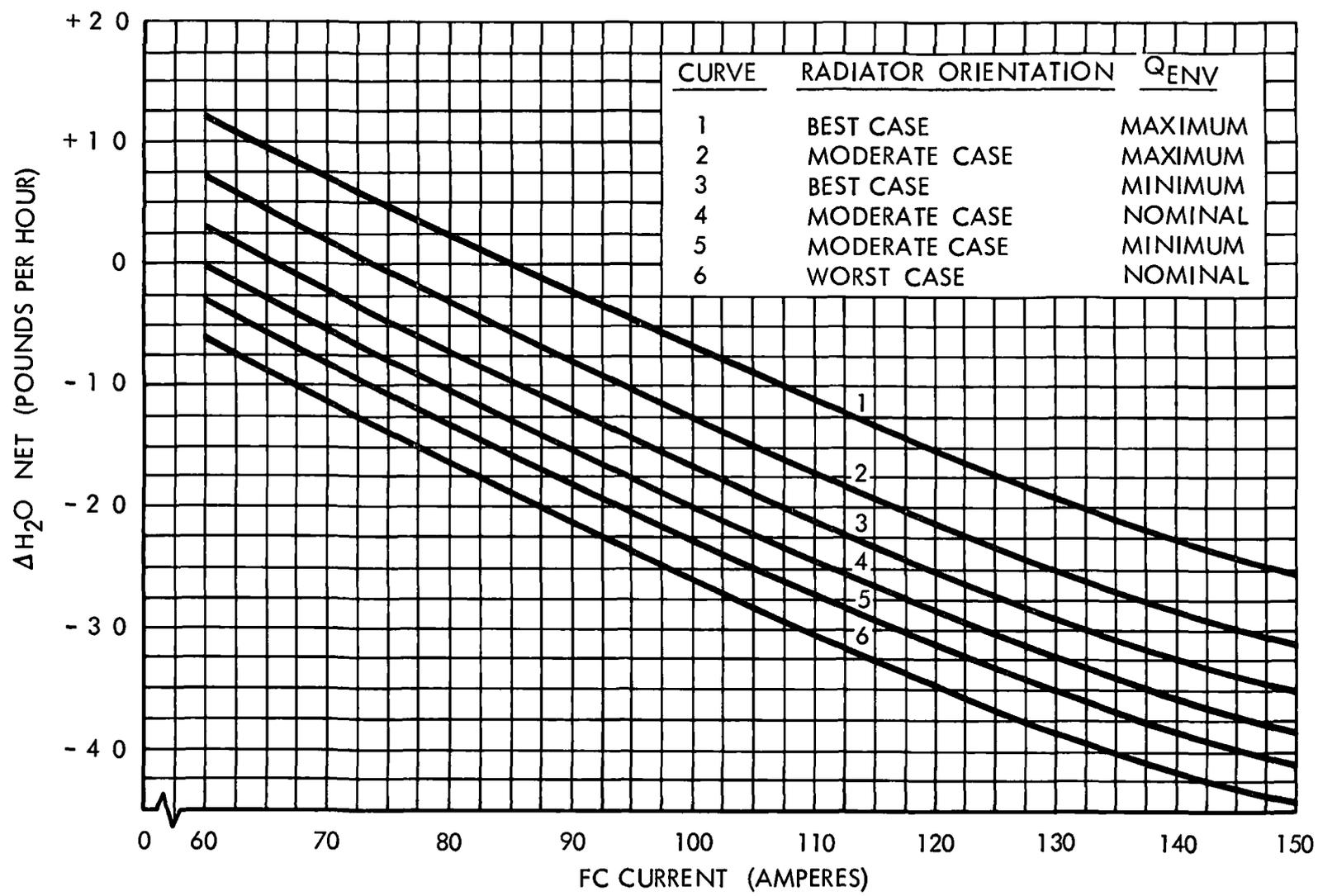


Figure 3-8 Net Δ Water Production Versus Output for Three Fuel Cells

3-23

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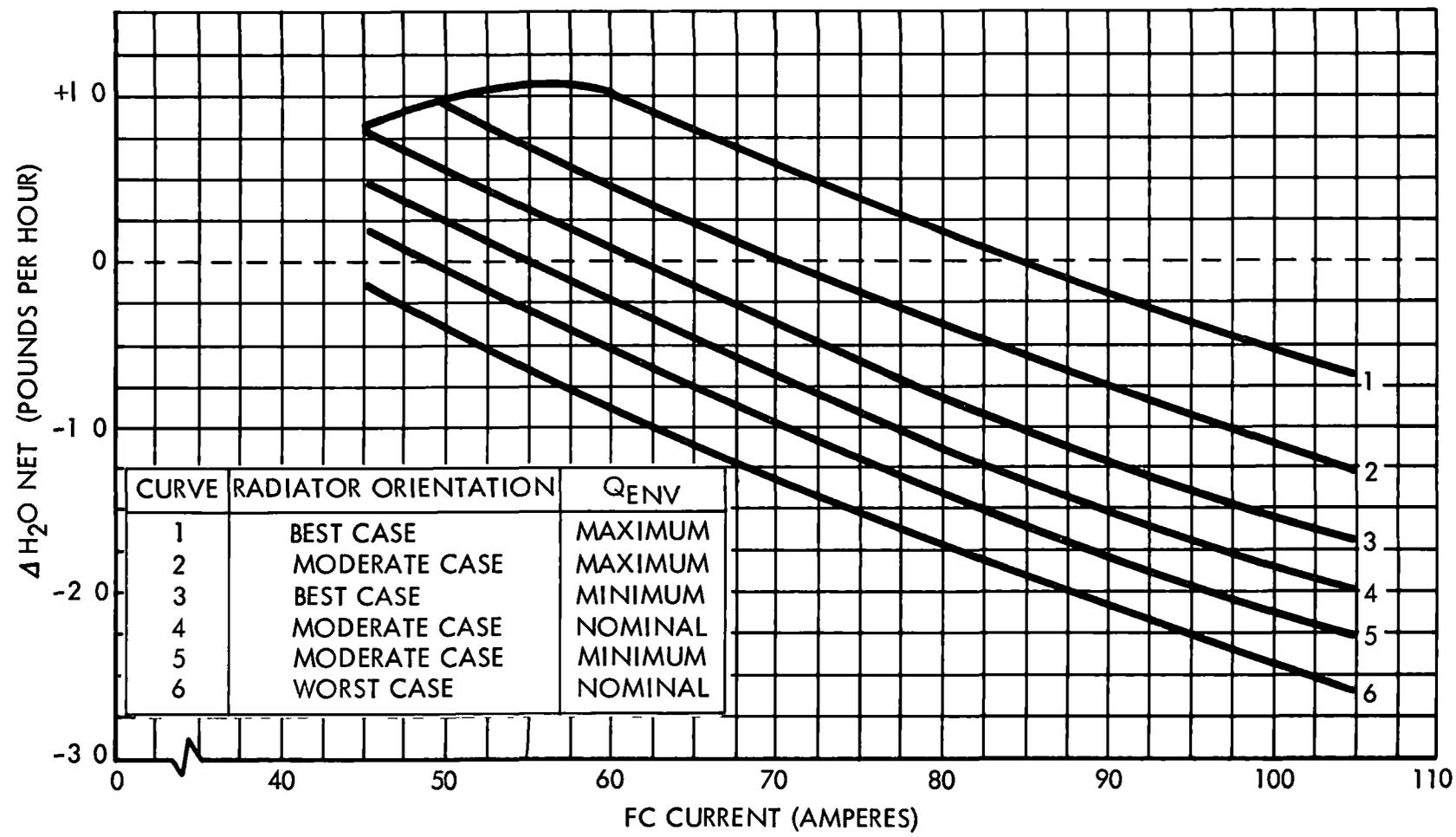


Figure 3-9 Net Δ Water Production Versus Output for Two Fuel Cells

3-24

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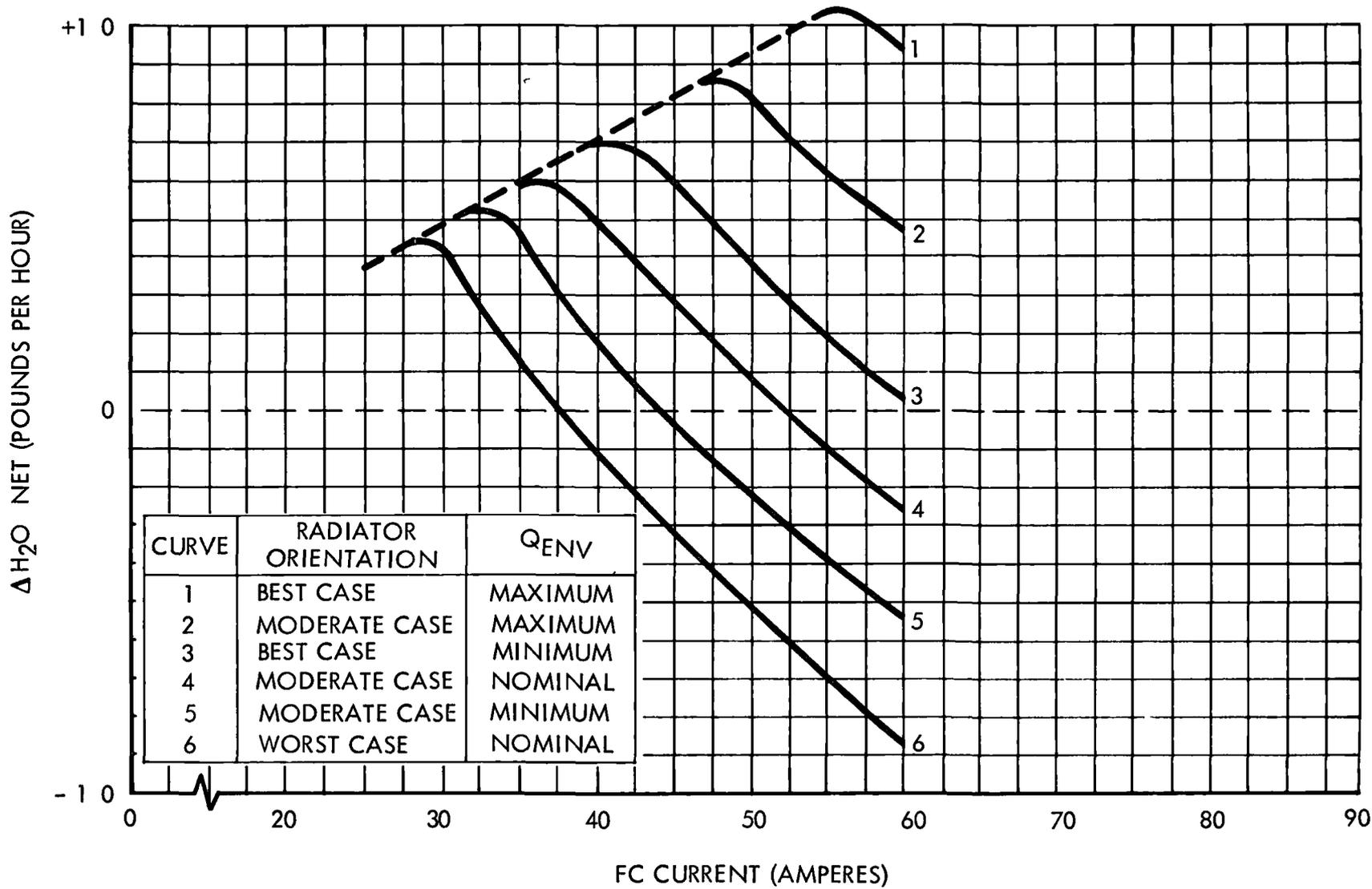


Figure 3-10 Net Δ Water Production Versus Output for One Fuel Cell

3-25

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4 0 COMMUNICATIONS

4 1 INTRODUCTION

The following modes of communication are employed on Block I manned missions

Mode	Frequency (mc)
VHF/AM voice	296 8
HF (recovery) voice	10 006
UHF update link	450 0
VHF PCM/FM telemetry	237 8
C-band tracking	5690, 5765
Tracking (unified S-band)	2106 4, 2287 5
Telemetry (unified S-band)	2287 5
Voice (unified S-band)	2106 4, 2287 5

In addition to a brief discussion of the unified S-band subsystem check-out, this section contains information necessary for evaluating communications compatibility between the spacecraft and the Manned Space Flight Network (MSFN). The evaluating procedure is described in Figure 4-1. Spacecraft to MSFN communication requirements are not defined in this section but are defined either in the individual blocks, specified by the NASA, or established by MSFN or crew selection in real time.

4 2 UNIFIED S-BAND CHECKOUT

An anticipated test is the checkout of the unified S-band communications subsystem. The specific modes to be checked out are to be determined by the NASA. It is expected that Modes A, B1, B2, C, D, and E are to be checked out with various uplink combinations of ranging, voice, and update.

The following general procedures will apply for an S-band mode check-out overpass. Approximately two minutes before each pass over a properly equipped MSFN station, the appropriate communication equipment must be activated as requested during a previous MSFN/SC contact, and the



appropriate antenna must be selected. The minus Z (surviving) antenna is used when the spacecraft to the MSFN line of sight (LOS) is in the hemisphere that is symmetrical about the minus Z axis, while the plus Z antenna is used when the LOS is in the plus Z hemisphere.

During the station pass, a member of the crew must be available for special operations such as dumping telemetry, transmitting emergency key, operating the television equipment, accepting and verifying updata, changing modes of operation, switching antennas, and accepting mode-selection data for future station passes. Operations will continue until the LOS at which time all equipment may be deactivated.

4 3 VHF, UHF, C-BAND PRIMARY COMMUNICATIONS

All block I antennas are fixed to the spacecraft structure. As a result, to point a more favorable region of antenna coverage (increased gain) toward a MSFN station, the orientation (attitude) of the spacecraft must be taken into consideration. Very high frequency (VHF) and ultra high frequency (UHF) communications utilize either the Z nonsurviving scimitar antenna (SCIN) or the -Z surviving SCIN antenna. The gain characteristics for each of these antennas have been combined into one operational antenna and are presented in Figures 4-2 and 4-3 for VHF PCM/FM telemetry and VHF AM voice, respectively. The operational antenna patterns combine the individual antenna-gain characteristics within the antenna-switching regions defined in Figure 4-4. As a result, Figures 4-2 and 4-3 represent a composite pattern and are applicable only if the proper antenna is used as shown in Figure 4-4.

4 4 MISSION CHARACTERISTICS

A particular mode of communication is sensitive basically to two mission parameters: vehicle-to-MSFN slant range and antenna gain in the direction of the vehicle-to-MSFN LOS.

The characteristics of each of the modes of communication are summarized in Table 4-1. The nominal circuit margin in Column 3 is referenced to a vehicle-to-MSFN slant range defined in Column 4. In all cases the circuit margin is referenced to a spacecraft antenna gain of three decibels below isotropic. Column 2 defines the maximum vehicle-to-MSFN slant range for which attitude considerations are not required. That is, the lowest operational antenna gain (Figures 4-2 and 4-3) will support the mode of communications to the slant range indicated in Column 2. Since the maximum slant range for a Block I manned earth orbital mission is approximately 1000 nautical miles (NM), both UHF updata link and C-band tracking are assured during spacecraft to MSFN line-of-sight periods regardless of spacecraft attitude.



Table 4-1 Communication Mode Performance Data

Mode	Slant Range (nm) Not Attitude Sensitive	Nominal (db) Circuit Margin	Reference Range (nm)
VHF PCM/FM telemetry	280	-5 13	2000
VHF AM voice	750	+3 58	2000
UHF updata link	3200	+16 24	2000
C-band tracking up (FPQ-6, TPQ-18) down	4800 2800	+16 64 +11 91	4000 4000
Unified S-band PM			
Tracking	8000	+11 61	15,000
Telemetry	700	-10 03	15,000
Voice	1250	-4 61	15,000
Unified S-band FM			
TV voice Telemetry	300	-17 24	15,000



During a MSFN station overpass, the change in spacecraft-to-MSFN slant range causes the communication-mode circuit margin to vary. This relationship is presented in Figure 4-5. The chart is divided at zero decibels circuit margin into satisfactory and unsatisfactory performance. In terms of the VHF PCM/FM telemetry mode, unsatisfactory performance results in an increase in the bit error rate (BER). Unsatisfactory performance in the voice mode causes the quality of voice to degrade and may cause periods of word unintelligibility.

4.5 COMMUNICATIONS COMPATIBILITY

To ensure spacecraft-to-MSFN communications compatibility for a station overpass, a procedure is presented in Figure 4-1. During much of the free drifting flight it is desirable from a crew standpoint to use only one antenna, thus avoiding the switching functions. However, it is estimated that about 50 percent of the telemetry communications will be degraded or lost by not having the proper antenna switched on. As a result, the ground MSFN should advise the astronauts as to which antenna to use when it is essential that communications be received. To aid in the proper antenna selection, the MSFN should monitor inertial measurement unit (IMU) gimbals angles (when operating) and maintain a record of spacecraft position, optical measurements and/or crewman's optical alignment sight (COAS) measurements. The MSFN should have the capability to combine these data with those of crew visual observations and perform the necessary transformations to compute spacecraft attitude. A record of spacecraft attitude would also be required for post-flight evaluation of both the primary communications subsystem and the backup system (unified S-band).

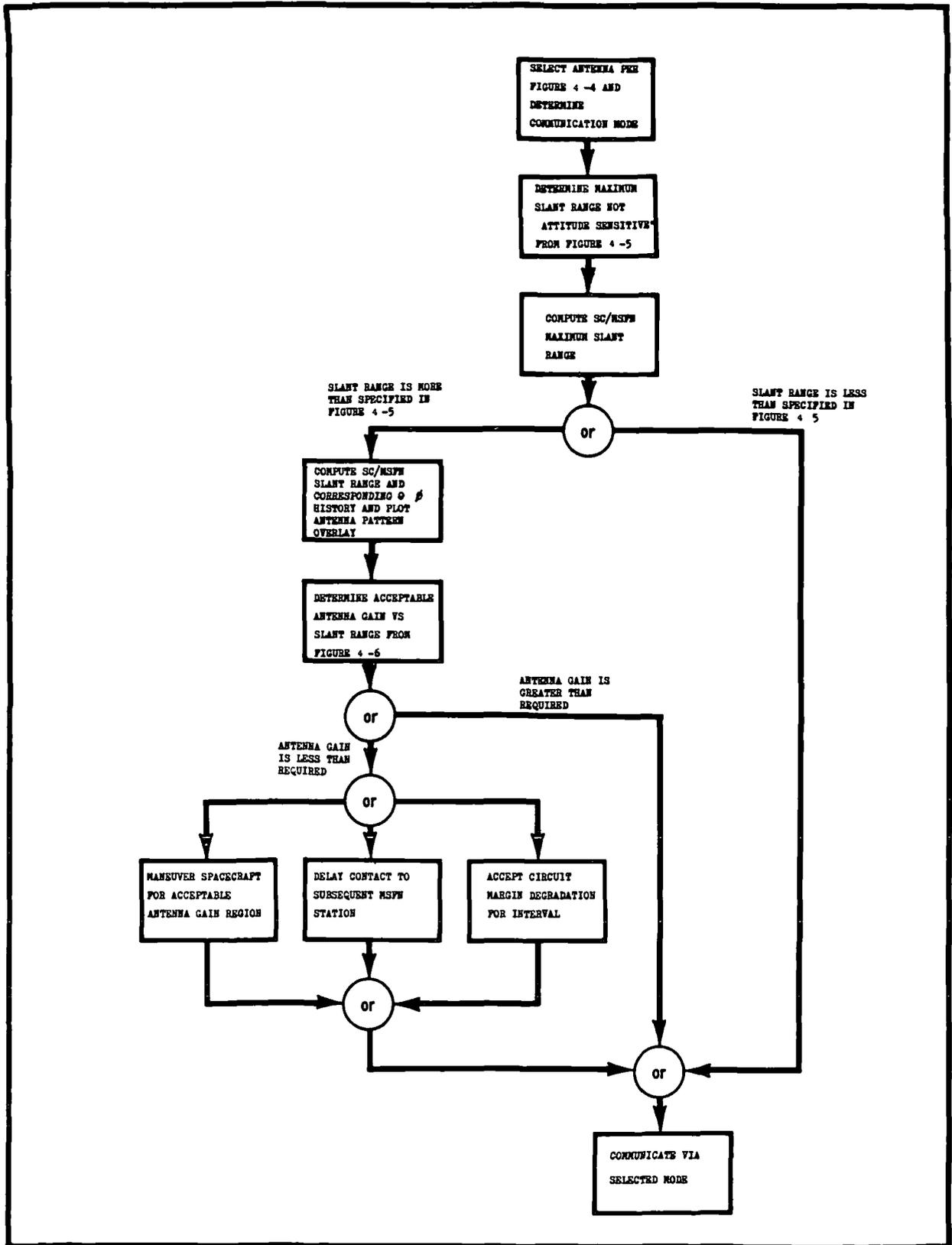


Figure 4-1 Communication Compatibility Procedure

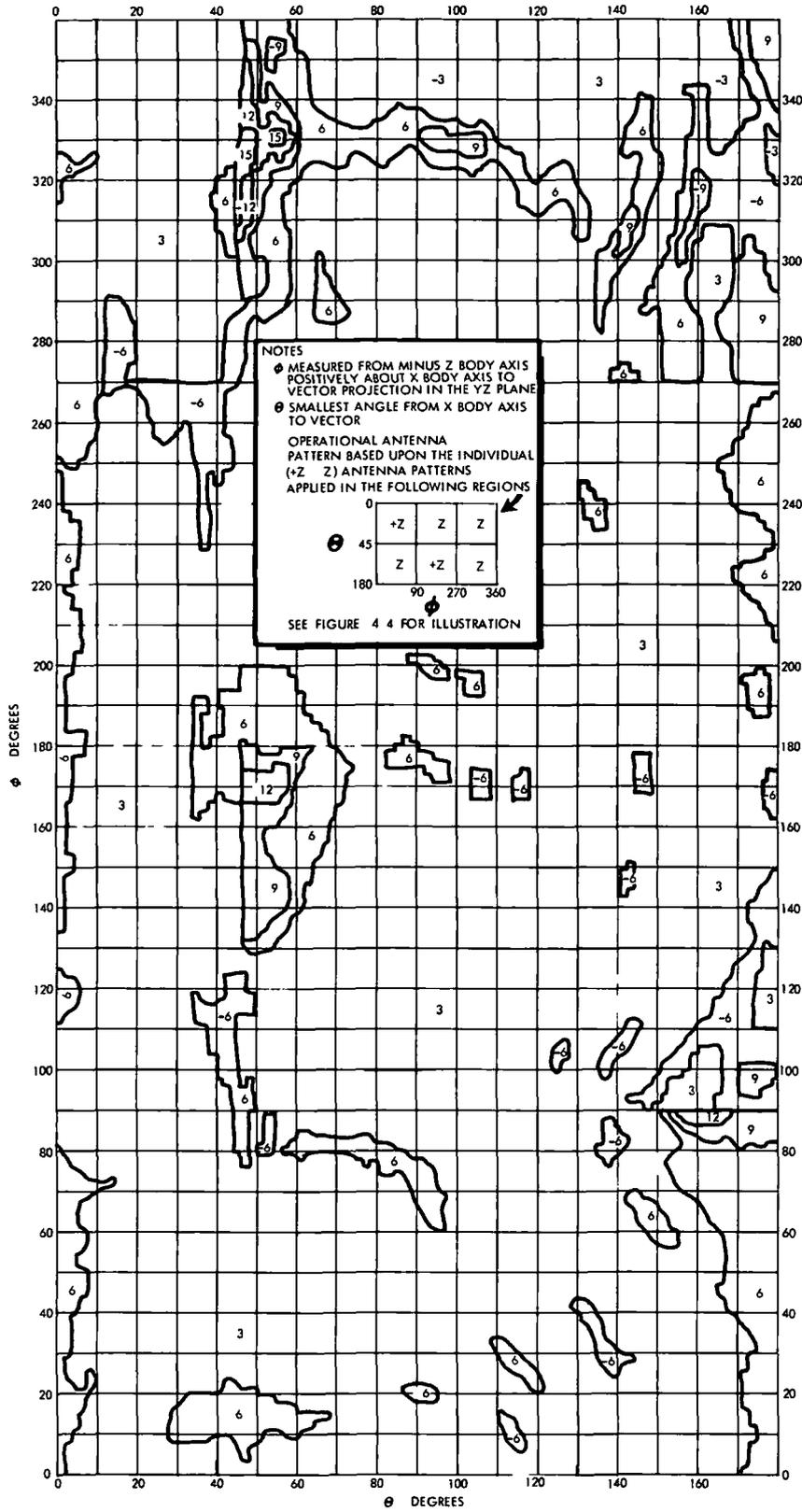


Figure 4-2 VHF PCM/FM Telemetry Operational Antenna Pattern

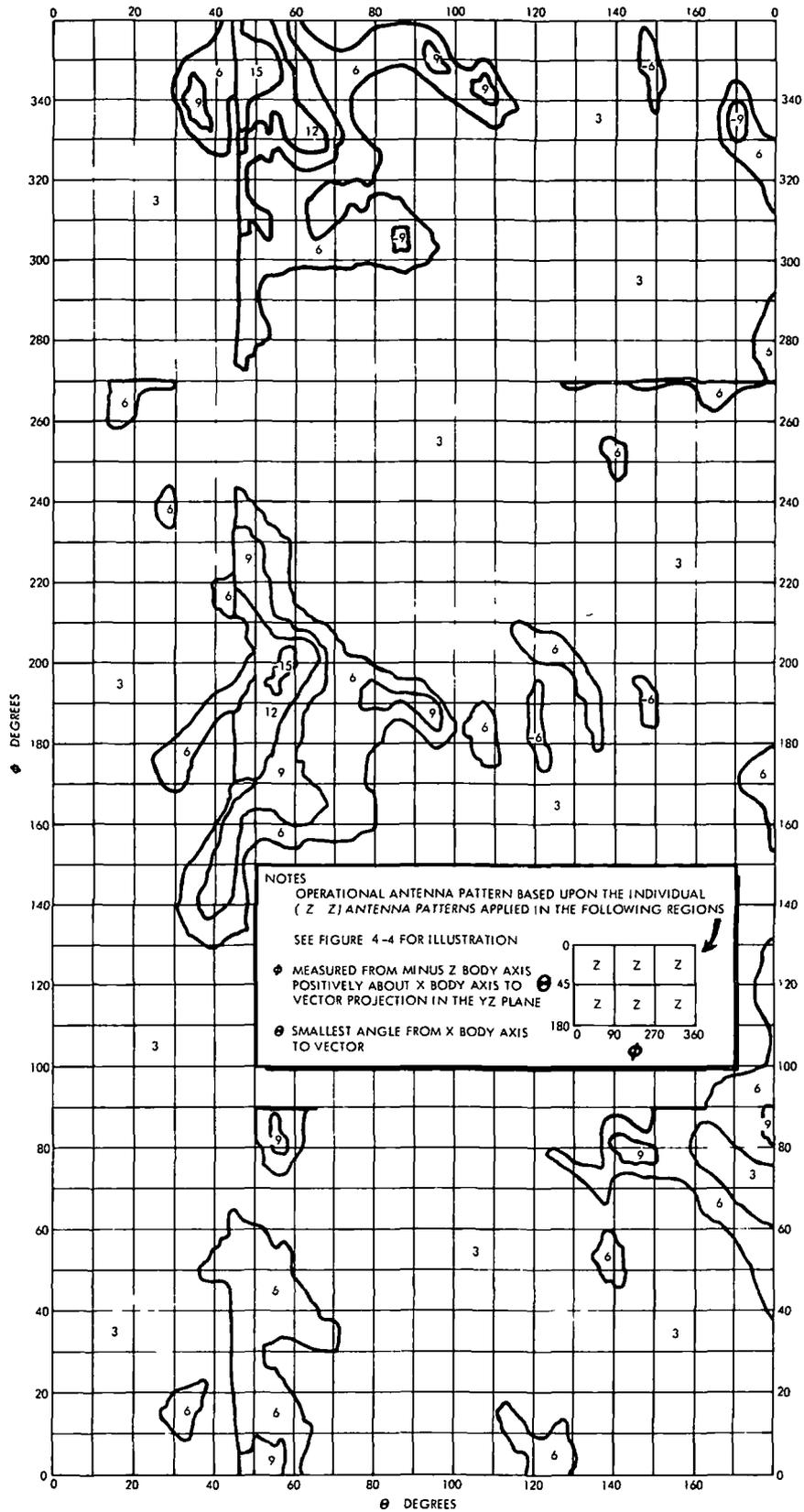
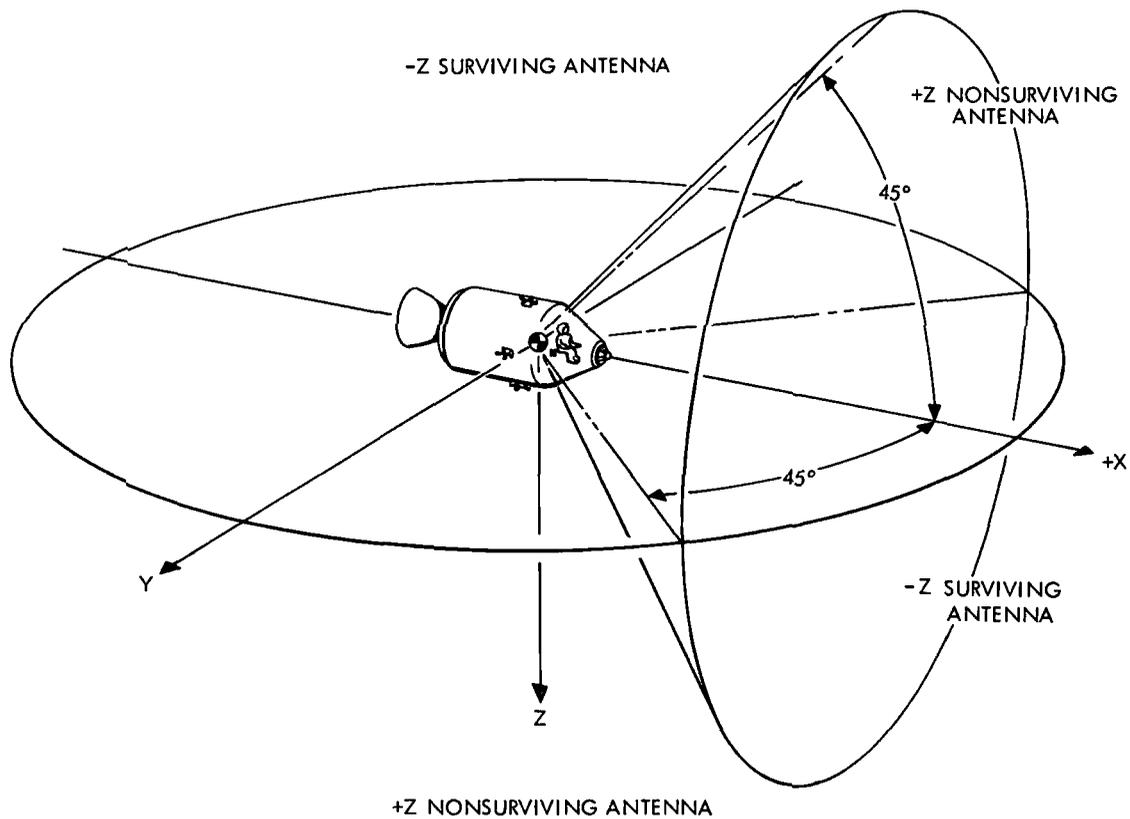


Figure 4-3 VHF AM Voice Operational Antenna Pattern



NOTE -Z ANTENNA USED WHEN VEHICLE/MSFN LINE-OF-SIGHT IS IN -Z HEMISPHERE, +Z ANTENNA USED WHEN VEHICLE/MSFN LINE-OF-SIGHT IS IN +Z HEMISPHERE EXCEPT WHEN LINE-OF-SIGHT IS WITHIN 45 DEGREES OF +X AXIS, THEN USE OPPOSITE ANTENNA

Figure 4-4 Antenna Switching Regions VHF/UHF

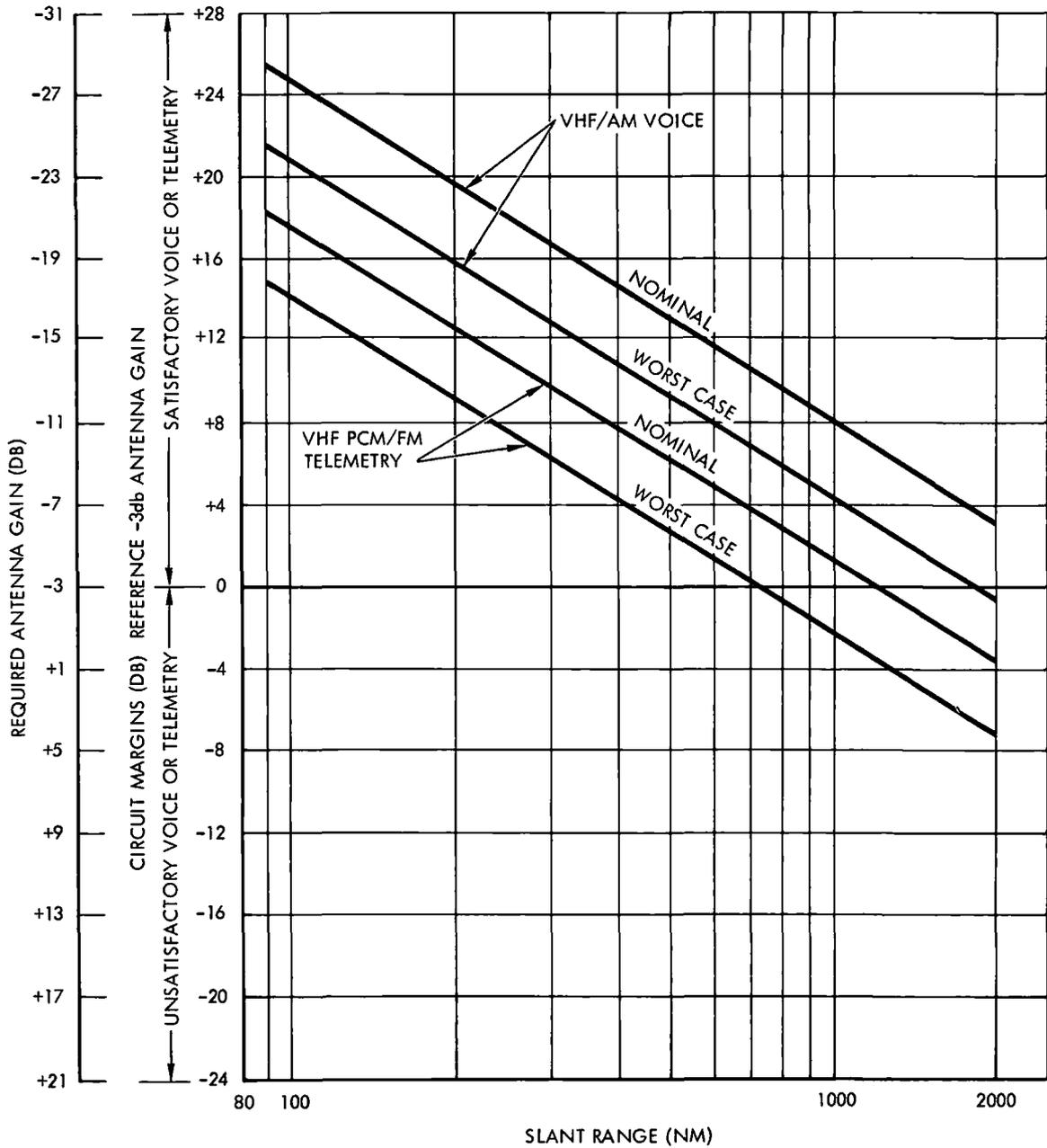


Figure 4-5 Telemetry and Voice Performance



5 0 PROPELLANT REQUIREMENTS

5 1 MANUAL ATTITUDE CONTROL MANEUVER REQUIREMENTS

The following assumptions are applicable

- 1 Because of the dynamic slosh model used, a nominal maneuver of 50 ± 0.5 degrees per axis was chosen
- 2 Dynamic disturbances accounted for are SPS propellant slosh, 130 nautical mile earth orbit aerodynamics and gravity gradient, ECS steam venting, and EPS and ECS rotating machinery
- 3 Curves A and B of Figure 5-1 are for the following weights and inertias

Curve	Weight lb	Inertia in Slug-Feet Squared		
		I_{xx}	I_{yy}	I_{zz}
A	29,500	15,800	53,500	54,000
B	22,300	12,600	40,000	38,700

- 4 The data may be ratioed to account for different maneuver angles. The propellant consumption would be decreased by 10 percent and increased by 20 percent if the maneuver angles were 30 degrees and 100 degrees respectively
- 5 Single axis maneuver propellant consumption is considered to be the same as the G&N single axis maneuver in Paragraph 5-2

Figure 5-1 presents two curves -- manual proportional rate control-three axis and manual direct control-three axis--versus maneuver rate

5 2 GUIDANCE AND NAVIGATION (G&N) ATTITUDE CONTROL MANEUVER REQUIREMENTS

The same assumptions as 1, 2, and 4 in Paragraph 5 1 apply, in addition to the following

- 1 Nonmaneuvered axes are held with a narrow deadband (± 0.2 degree) while the other axes are moved



- 2 Single jet reaction control subsystem (RCS) firing per axis
 $I_{sp} = 180$ seconds
- 3 G&N maneuver rate of 0.5 degrees per second

Figure 5-2 shows G&N attitude maneuver propellant requirements and G&N attitude hold propellant requirements versus spacecraft weight

Figure 5-3 (lower) present service module RCS propellant requirements for maintenance of the "barbecue" thermal control mode attitude versus spacecraft weight. The following additional assumptions apply

- 1 Attitude hold in pitch and yaw at ± 4.2 degrees deadband
- 2 Spin about roll axis at 0.5 degrees per second

Figure 5-4 presents service module RCS propellant requirements to damp free drift rates versus time in free drift

5.3 PLUS X TRANSLATION PROPELLANT SETTLING, RCS REQUIREMENTS

The following assumptions apply

- 1 RCS engine thrust equals 100 pounds
- 2 I_{sp} at attitude correction equals 185 seconds
- 3 I_{sp} at translation equals 278 seconds
- 4 Dynamic disturbances stated in Paragraph 5-1 are neglected
- 5 Roll control propellant requirements are neglected

Figure 5-3 (upper) shows service module RCS propellant requirements for settling service propulsion subsystem (SPS) propellants versus spacecraft weight, for three configurations of RCS engine utilization

Figure 5-5 (upper) shows the propellant required for service module RCS velocity maneuvers versus spacecraft weight for three configurations of RCS engine utilization

5.4 HIGH ENERGY SLOSH DAMPING REQUIREMENTS

The propellant requirements for attitude hold in three axes immediately following an SPS burn and extending over a 10-minute period after the SPS burn



are presented in Figure 5-6 (upper) This curve includes the total RCS requirement and should not be added to Figure 5-2 However, after the end of the 10-minute slosh damping period, the rates in Figure 5-2 (lower) should be used

For attitude holds delayed after the termination of SPS burn, Figure 5-6 (lower) may be used to adjust the propellant quantities shown in Figure 5-6 (upper)

5 5 USABLE PROPELLANT

The initial service module RCS propellant available (usable tank capacity) is 790 pounds Due to off-nominal mixture ratios at initiation of thrusting, and temperature variations, the actual propellant used is expected to exceed the nominal amounts shown in the curves

Figure 5-5 (lower) shows curves to allow estimation of usable tank capacity remaining, and propellant remaining, for nominal mission operations The abscissa is the propellant nominally consumed over an extended period of operations the cumulative usage as determined by the application of the preceding curves The "remaining tank capacity" is an estimate of the actual propellant in the tanks conceivably expendible for a single burn The "remaining for nominal Mission Operations" is the value that should be applied to the propellant usage curves when estimating the number of additional maneuvers of a diversified nature that can be made In the preparation of Figure 5-5, it was estimated that the effective use of one pound of propellant will result in a loss of 0.1 pounds Longer burns will be less The 1.1-to-1.0 ratio is an average for diversified firings, averaged over a typical long duration earth orbital mission

5 6 ENGINE PERFORMANCE CHARACTERISTICS

RCS engine specific impulse and mixture ratio characteristics, as a function of electrical pulse width, are presented in Figure 5-7 High and low values shall be used as 3 σ deviations

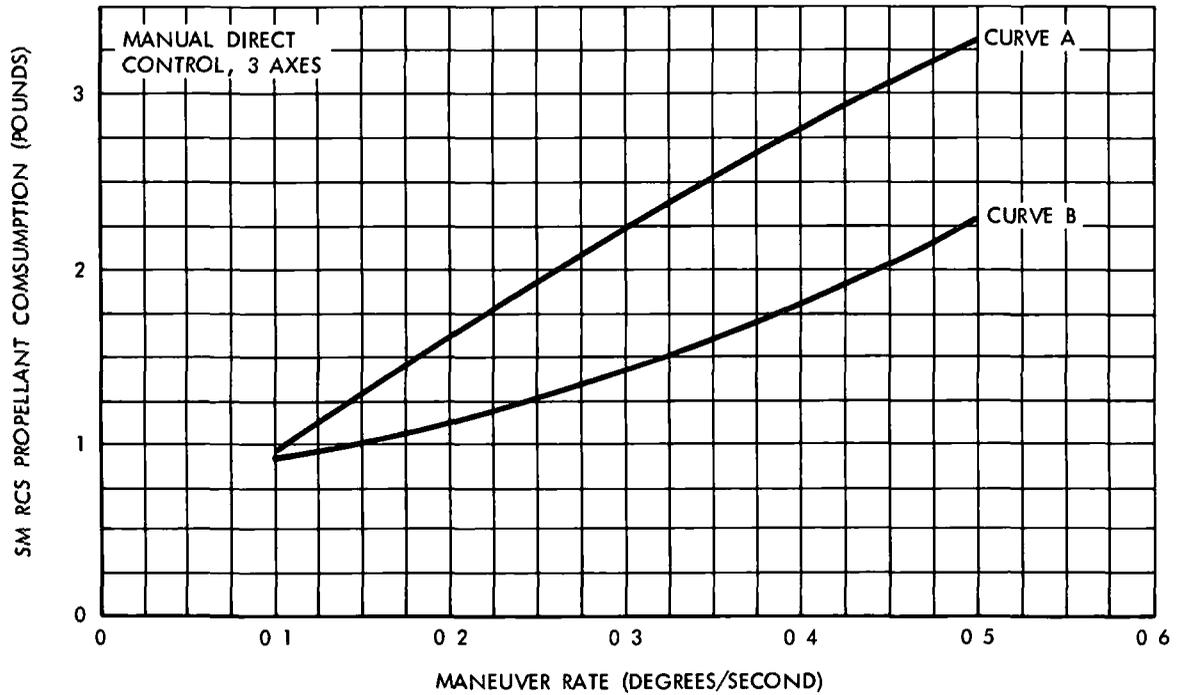
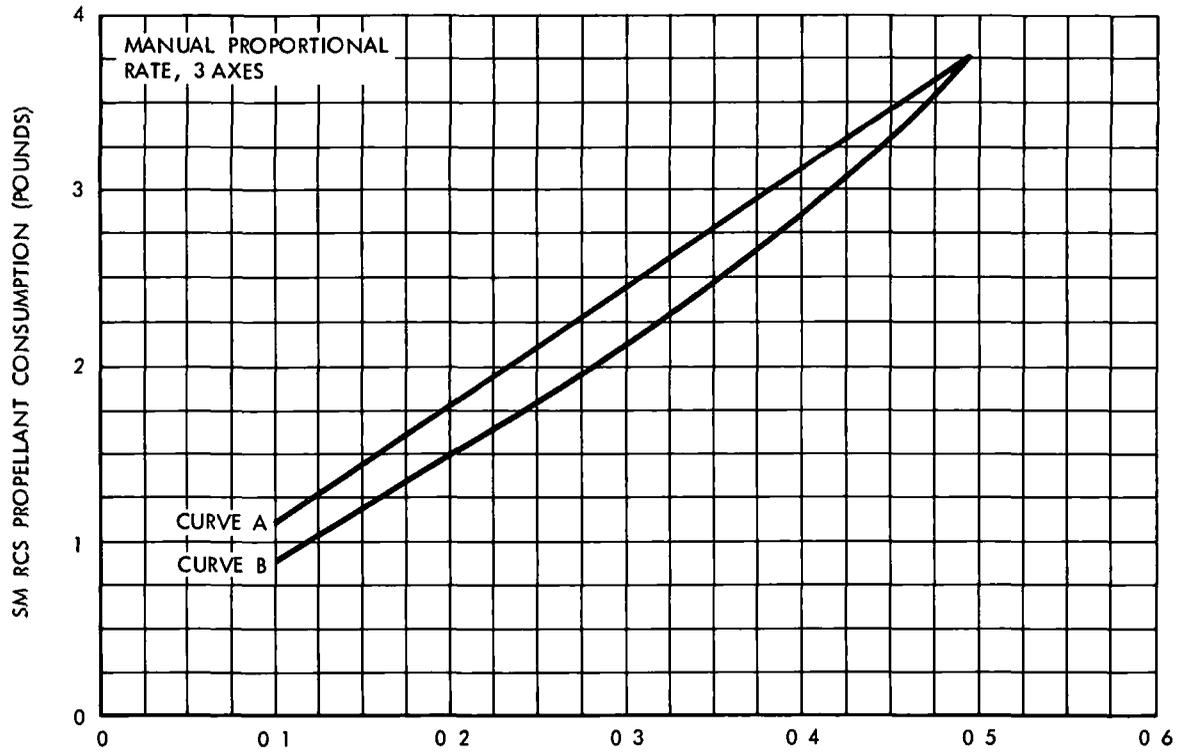


Figure 5-1 Attitude Maneuver Propellant Requirements, Service Module RCS Manual Control

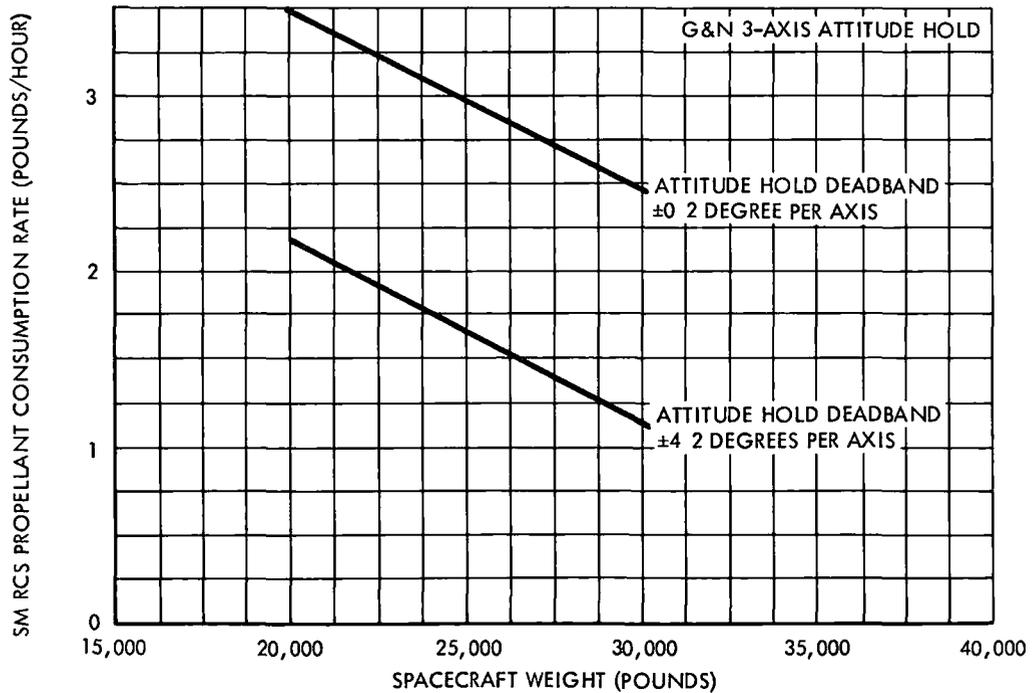
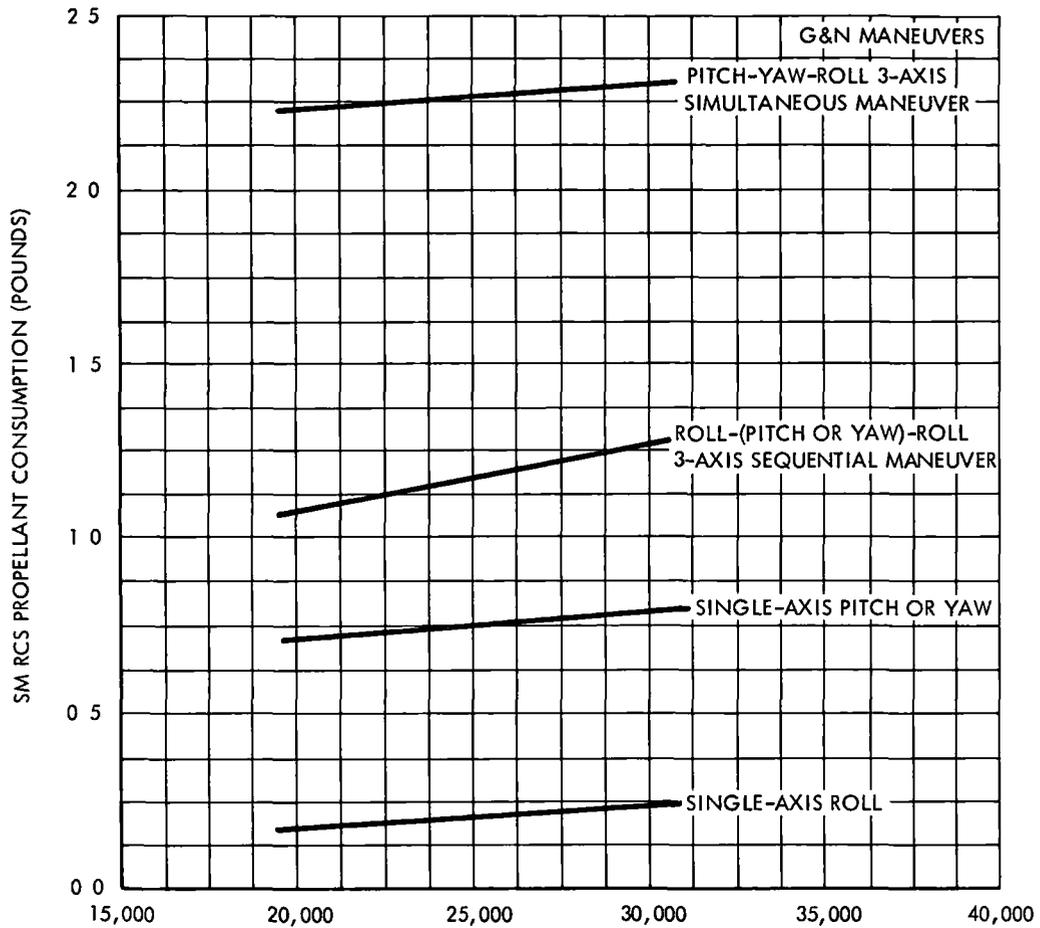


Figure 5-2 Attitude Maneuver and Hold Propellant Requirements, G&N Control Service Module RCS

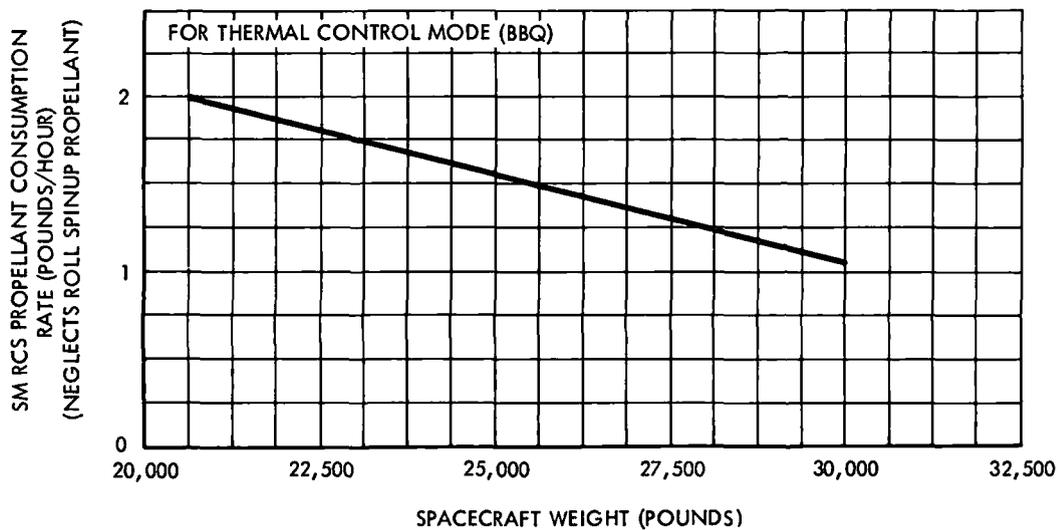
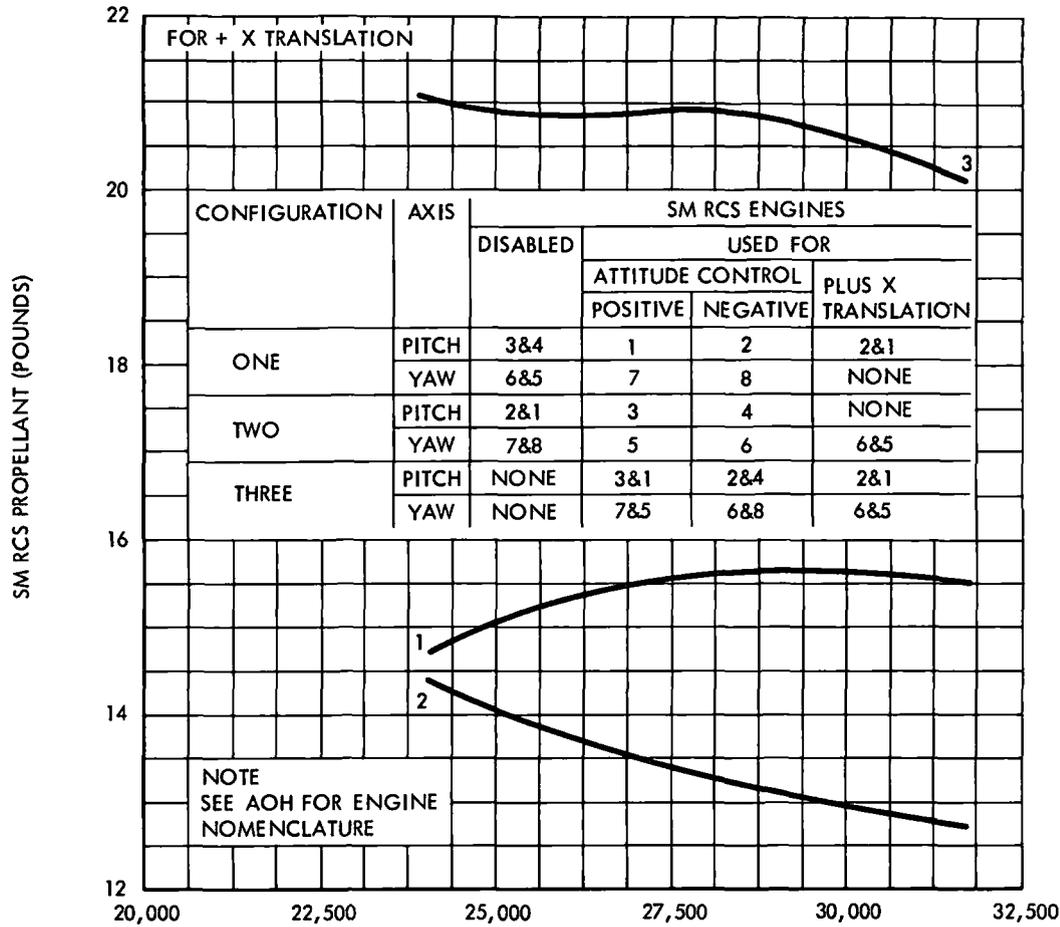


Figure 5-3 Service Module RCS Propellant Consumption Requirements for Settling SPS Propellant

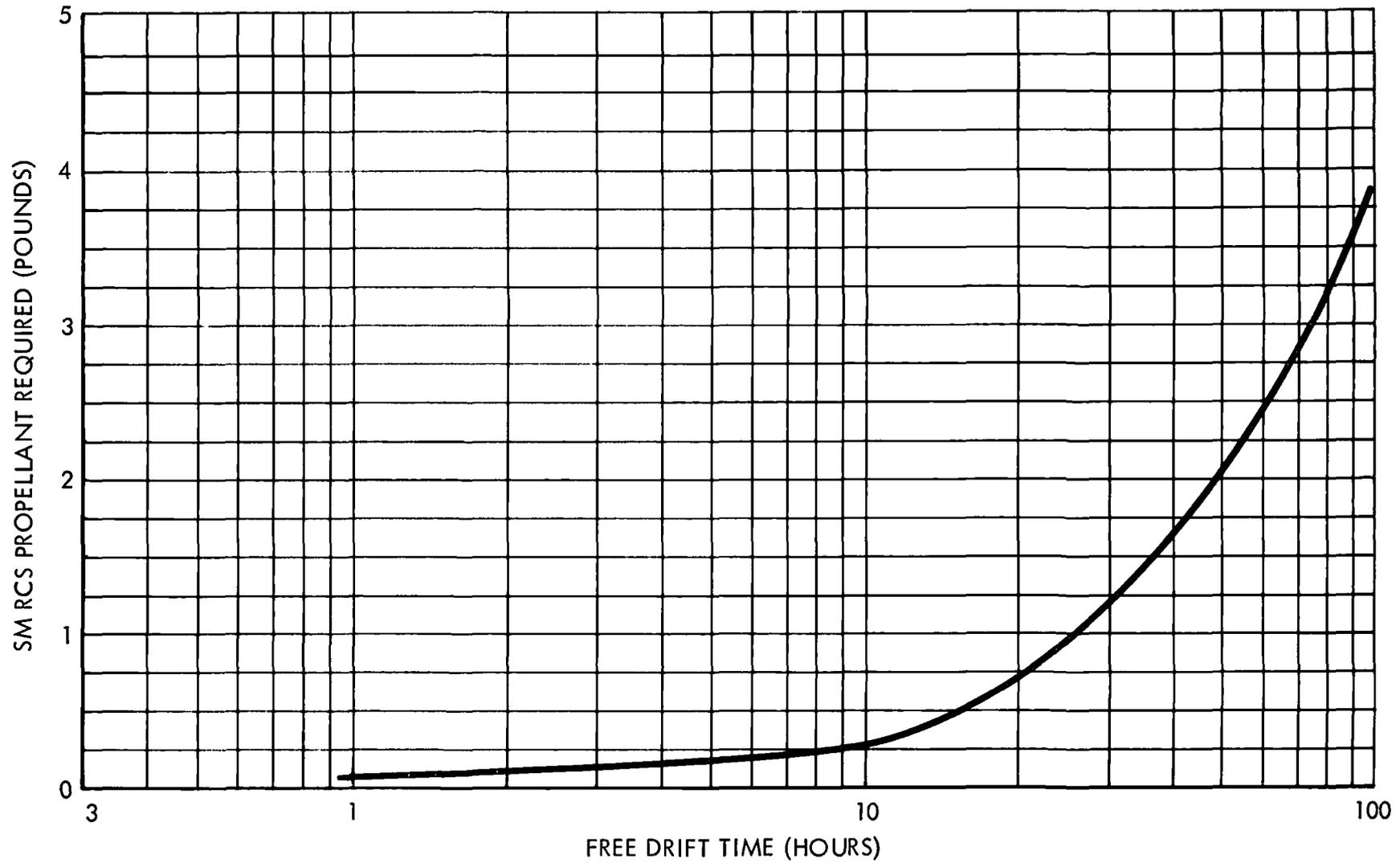


Figure 5-4 Service Module RCS Propellant Requirements for Damping Out Free Drift Rate Caused by Dynamic Disturbances



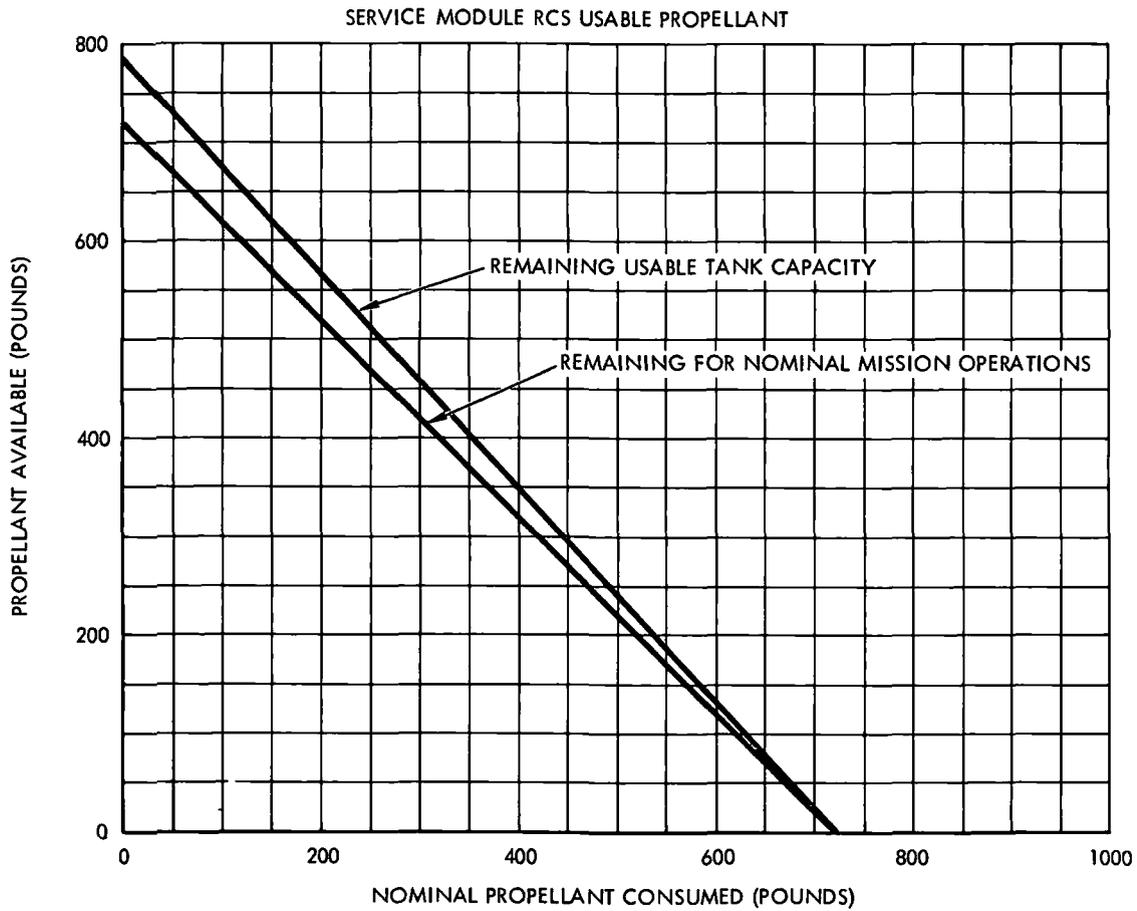
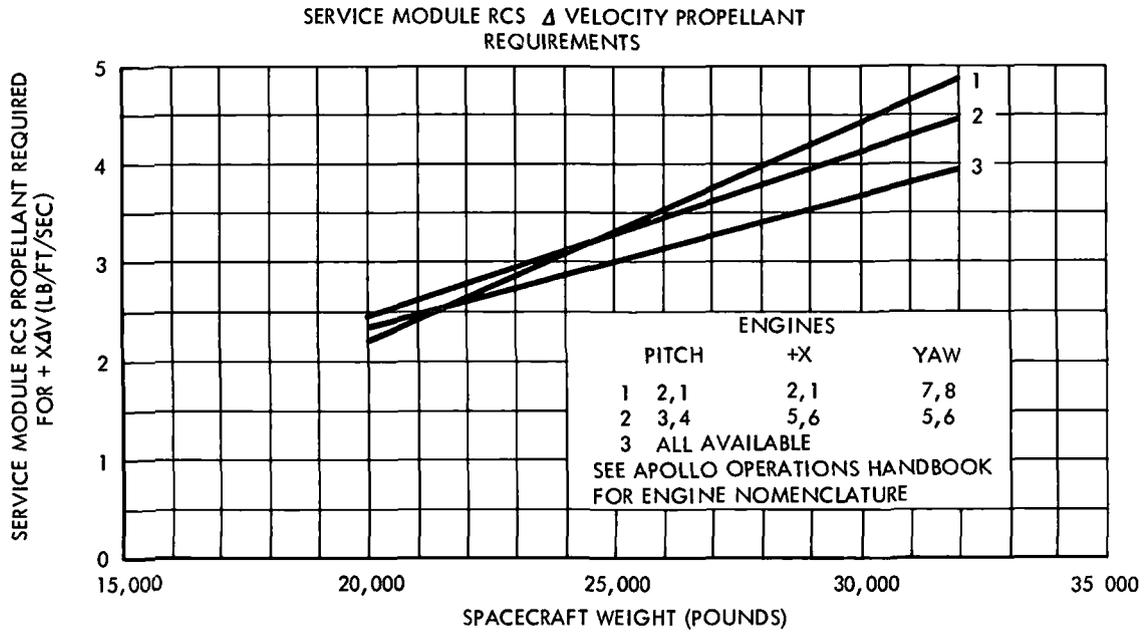
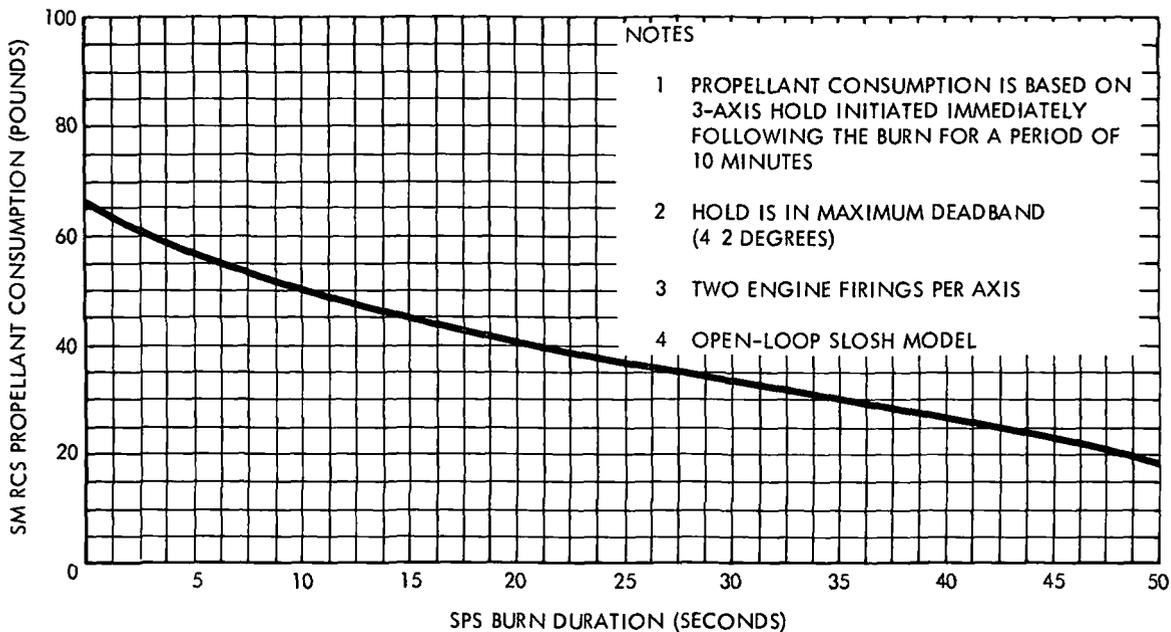
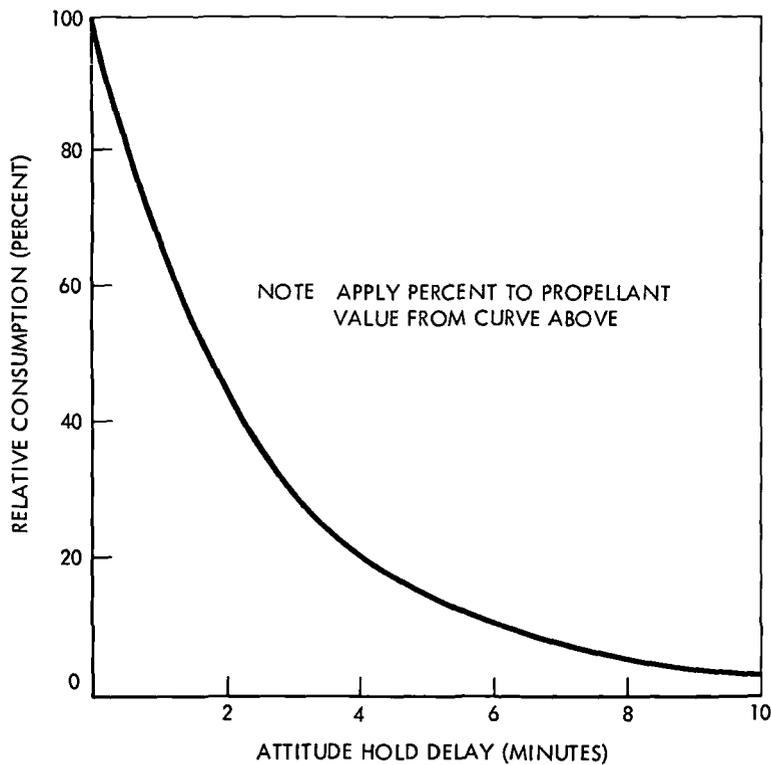


Figure 5-5 Service Module Δ Velocity Propellant Requirements

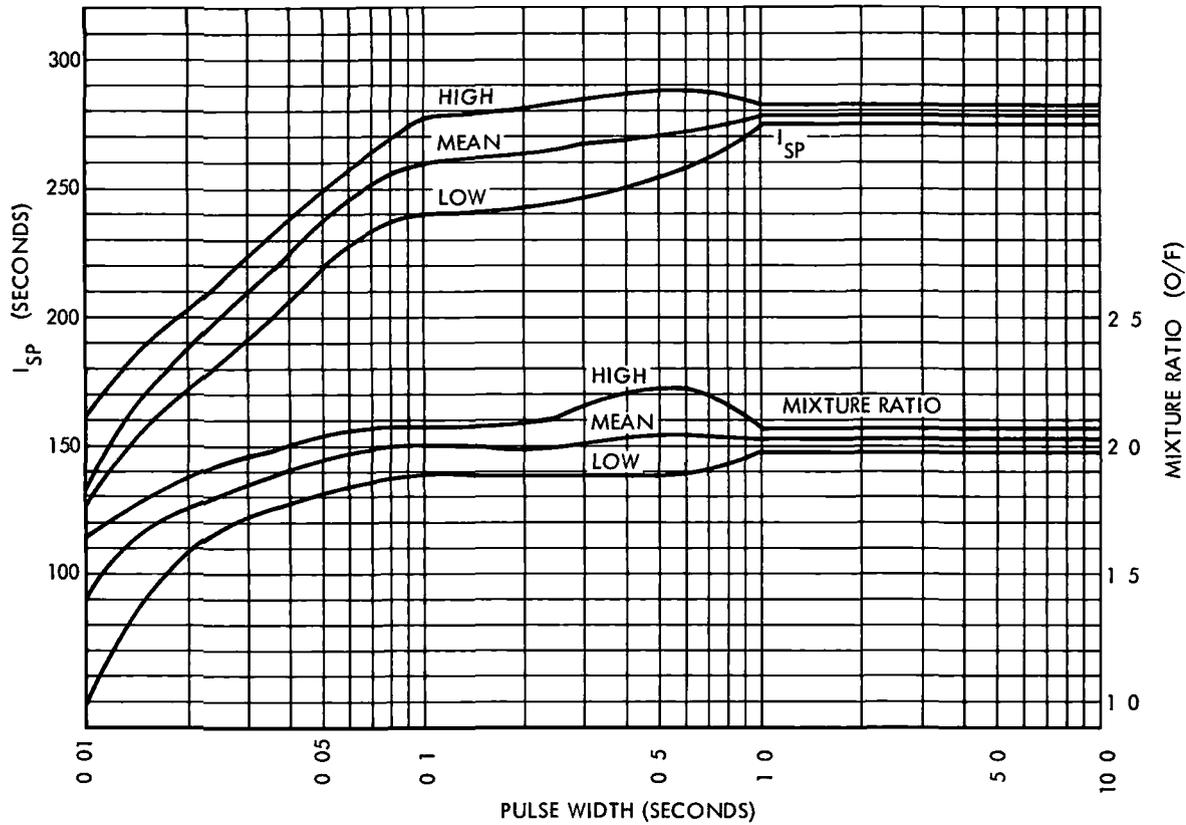


SM RCS PROPELLANT REQUIREMENTS FOLLOWING AN SPS BURN



RELATIVE SM RCS PROPELLANT CONSUMPTION VERSUS DELAY IN ATTITUDE HOLD FROM END OF SPS BURN

Figure 5-6 Attitude Hold Propellant Requirements Following an SPS Burn



STEADY-STATE PERFORMANCE CHARACTERISTICS AT PULSE WIDTHS GREATER THAN 1.0				
	THRUST (LB)	I_{SP} (SEC)	PROPELLANT FLOW RATE (LB/SEC)	MIXTURE RATIO (OXIDIZER/FUEL)
HIGH	100.7	283.0	0.361	2.072
AVERAGE	99.6	278.0	0.357	2.022
LOW	98.0	275.6	0.352	1.979

Figure 5-7 Specific Impulse and Mixture Ratio



6 0 BUILDING BLOCKS

The complete list of building blocks appears at the end of this discussion. Each of the building blocks in this section has been organized under the following outline (where "X" indicates applicable block number)

X 1 Introduction

X 2 Operational data

- X 2 1 General information
- X 2 2 Mission functional flow
- X 2 3 Operational timeline segment
- X 2 4 Attitude maneuvers
- X 2 5 Duty cycles
- X 2 6 Electrical power
- X 2 7 Propellant consumption

X 3 Performance data

- X 3 1 General information
- X 3 2 Parametric data

In some cases, however, not every element of the outline applies to a given block, and therefore, the nonapplicable portions have been intentionally omitted, where necessary, to reduce document size

The nature and scope of each of the outline elements are briefly discussed in the following paragraphs

X 1 Introduction

A narrative summary of the nature and purpose of the block event makes up the introduction. It is essentially a description of the basic content of Paragraphs X 2 and X 3, besides describing the interfaces between data. Included is a general discussion of event limits and constraints. Detailed discussions in the appropriate sections of Paragraphs X 2 and X 3 will be referenced. Included also are any pertinent assumptions, problems, etc., to provide an understanding of "what the block is all about."



X 2 Operational Data

X 2 1 General Information A narrative summary of the scope of operational data, extending the discussion provided in Paragraph X 1 is presented. The data provided and associated interfaces, limits, assumptions, problems, etc., are dealt with. Also included is a discussion of the interface between operational and performance data.

X 2 2 Mission Functional Flow Diagram This diagram summarizes the flow logic of the block event, it contains key times and is correlated to the operational timeline.

X 2 3 Operational Timeline Segment A listing of major events, crew tasks, operations, maneuvers, etc. in time sequence with durations shown is delineated. Included are a source of the time data and applicable remarks involving constraints.

X 2 4 Attitude Maneuvers A list of required maneuvers, as applicable, correlated to the timelines, and showing the maneuvering mode, rate, and associated propellant makes up this section. Additional information is provided in Section 5 0.

X 2 5 Duty Cycles A listing of the percentage utilization of the critical components tabulated in Section 3 0 which indicates their ON-OFF actuation times for the block event is given. Distinctions are made between intermittent and continuous functions.

X 2 6 Electrical Power A presentation of the average Δ power from the common level in Section 3 0 in terms of a-c and d-c components is included. In some blocks a time history is also provided.

X 2 7 Propellant Consumption A presentation of the command module or service module RCS propellant required to accomplish the block event is made. In certain blocks, SPS propellant is also provided or discussed. Additional details are contained in Section 5 0.

X 3 Performance

X 3 1 General Information A narrative summary of the scope of performance data extending the discussion provided in Paragraph X 2 is presented. The data provided and associated interfaces, limits, constraints, assumptions, problems, etc. are noted. Also included is a discussion of the interface between performance and operational data as applicable.



X 3 2 Parametric Data A presentation of performance data showing parametric effects of the key variables is set forth

BUILDING BLOCK IDENTIFICATION

BB-1	Ascent	BB-14	Subsystem Status Checks
BB-2	LET Jettison		EPS
BB-5	Post-Insertion		ECS
BB-6	CSM/S-IVB Separation		SPS
BB-7	IMU Alignment		SM-RCS
BB-8	Navigation Sightings		CM-RCS
	Landmark	BB-15	Subsystem Maintenance
	Celestial		Fuel Cell Purging
BB-9	Drifting Flight		Battery Charging
	AM-1 Powered Down		SPS Propellant Feedline
	AM-2 Powered Up	BB-16	AGC Update
BB-10	Crew Maintenance		MSFN/Updata Link Mode
	Meal Preparation		MSFN/Voice Mode
	Waste Management	BB-17	Experiments
BB-11	Attitude Control	BB-18	Cabin Depressurization
	AM-1 G&N	BB-24	Pre-Deorbit
	AM-2 SCS	BB-25	SPS Deorbit and Entry
	AM-3 Manual TVC		AM-1 G&N
BB-12	SPS ΔV		AM-2 SCS
	AM-1 G&N	BB-26	SM RCS Deorbit and Entry
	AM-2 SCS	BB-35	Parachute Descent/Impact
	AM-3 Manual TVC	BB-37	Postlanding Operations
BB-13	RCS Translation	BB-41	Radiator Loss, EPS and SPS
	AM-1 Translation	BB-42	LES Aborts
	Control	BB-44	Launch Aborts, SPS
	AM-2 Direct Ullage	BB-45	Water Boiler Failure

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BUILDING BLOCK 1 ASCENT

1 1 INTRODUCTION

The primary purpose of the Saturn IB launch vehicle is to inject the spacecraft into earth orbit to verify spacecraft, crew operations, and subsystem performance for an orbital mission of up to 14-days duration. Also, the launch vehicle subsystems and performance must be verified for subsequent operational Saturn IB vehicle missions.

Only data pertinent to crew, spacecraft, and LET operations and design are included. Limitations and constraints on ascent which are imposed by spacecraft design are the primary considerations and are included in Section 1 3.

The MSFC Launch Vehicle Reference Trajectory in NASA Technical Memorandum X-53349, dated 19 October 1965, is used as the reference for data contained in this block.

1 2 OPERATIONAL DATA

1 2 1 General Information

To ensure an operational spacecraft in orbit, the launch vehicle must stay below spacecraft design limitations during ascent. These trajectory constraints are based on design trajectories used for structural and thermal design of the spacecraft.

One of the major spacecraft functions during ascent is the launch escape tower (LET) jettison operation. These data, pertinent to LET jettison, are included in Building Block 2.

1 2 2 Design Considerations

The constraints imposed by spacecraft design on the ascent phase are included in Table 6-1, which shows a comparison of the current reference trajectory nominal values of structural and thermal boost parameters and the spacecraft (LET, command module, service module, SLA) design values.



Table 6-1 Comparison of Reference Trajectory Values and Design Values

Parameter	Reference Trajectory	Design Values
Maximum acceleration, η_x (at S-IB inboard engine cutoff)	4 114	4 9
Maximum dynamic pressure, \bar{q}	668 lb/ft ²	740 lb/ft ²
Maximum $\bar{q}\alpha$	4127 deg-lb/ft ²	5224 deg-lb/ft ²
Aerodynamic heating indicator ($AHI = \int_0^t \rho V^3 dt$)	Nominal = 133 6 x 10 ⁶ lb/ft +3 σ = 144 x 10 ⁶ lb/ft	Nominal = 199 x 10 ⁶ lb/ft +3 σ = 135 x 10 ⁶ lb/ft
Maximum aerodynamic heat rate indicator ($\Delta AHI_{max} = \rho V^3$)	Nominal = 2 25 x 10 ⁶ lb/ft-sec +3 σ = 2 58 x 10 ⁶ lb/ft-sec	Nominal = 2 13 x 10 ⁶ lb/ft-sec +3 σ = 2 35 x 10 ⁶ lb/ft-sec
*Values from MSFC Launch Vehicle Reference Trajectory in NASA TM X-53349		

As noted in Table 6-1, the current reference trajectory structural parameters (η_x , \bar{q} , and $\bar{q}\alpha$) are well below the design values

The reference trajectory aerodynamic heating indicator (AHI) and maximum ΔAHI are both above design values. Based on current aeroheating and thermal response design methods, (1) portions of the service module shell, EPS radiators, and spacecraft LEM adapter (SLA) vertical ordnance splice would probably exceed design temperature limits, and (2) the environmental control system (ECS) radiators, the SLA circumferential ordnance splice ($X_A = 584$ inches), and the SLA structure below the lunar excursion module (LEM) attachment cover would possibly exceed design temperature limits. Each of these components is heat-rate sensitive, therefore, a reduction in the maximum ΔAHI is desired.

Because of the complexity of spacecraft temperature evaluation, particularly during the rapidly changing atmospheric environment during boost, the thermal response design methods used to determine critical



component temperatures may be conservative by up to 20 percent. Since this uncertainty in temperature predictability exists, aerodynamic heat rate or heat-load indicators should not be used as limit lines for abort criteria. Therefore, this type of information has not been included.

During the initial launch phase the average easterly wind component between sea level and 12,000 feet must be limited to approximately 25 feet per second. This constraint is imposed to insure against land impact in the event of low altitude LES aborts.

The Block I spacecraft design for Saturn IB launches is capable of sustaining the bending loads associated with the wind profile shown in Figure 6-1. Ascent should not be performed when the winds exceed this profile unless the existing wind direction is in a favorable quadrant (i.e., tailwind and/or right cross-wind) with respect to the planned flight azimuth.

1 2 3 Mission Functional Flow Diagram

The mission functional flow, shown in Figure 6-2, represents diagrammatically the sequential operations associated with performing ascent to vehicle insertion including stabilization in earth orbit.

1 2 4 Operational Timeline Segment

The operational timeline from S-IB engine ignition to post orbit insertion checks, showing discrete operations during ascent, is included in Table 6-2.

1 2 5 Attitude Operations

The attitude ground rules are based on the NASA reference trajectory and are included herein for block completeness.

- 1 Vertical rise for 10 seconds
- 2 Tilt maneuver from 10 seconds to Mach = 0.7
- 3 Zero lift ($\alpha = 0$) from Mach = 0.7 until 10 seconds before S-IB outboard engine cutoff
- 4 Inertial attitude of the vehicle held constant from 10 seconds before S-IB outboard engine cutoff until LET jettison
- 5 Subsequent to LET jettison, the vehicle attitude controlled through the use of iterative guidance mode closed-loop guidance



1 2 6 Subsystem Duty Cycles

The duty cycles for ascent are presented in Table 6-3 and include the LET jettison operation (Building Block 2)

1 2 7 Electrical Power

The average power levels for Building Blocks 1 and 2 are

$$P_{AC} \text{ (nominal)} = 338.4 \text{ watts}$$

$$P_{DC} \text{ (nominal)} = 2235.6 \text{ watts}$$

1 3 PERFORMANCE DATA

1 3 1 General Information

This section contains data associated with the LET jettison operation and the lifetime of insertion orbits. Partial tradeoffs of LET jettison weight and jettison time are presented, however, Building Block 2 contains the LET weight and performance data. Launch vehicle weight and performance data are not included.

1 3 2 Parametric Data

The following partial tradeoffs show the effect of payload capability as a function of LET jettison weight and jettison time.

$$\frac{\partial \text{Payload}}{\partial \text{LET jettison weight}} = -0.146 \text{ lb/lb}$$

$$\frac{\partial \text{Payload}}{\partial \text{LET jettison time}^*} = -11.26 \text{ lb/sec}$$

Figure 6-3 is included to show the lifetime of insertion orbits as a function of the ballistic number (W/C_{DA}) which can be determined from Figure 6-4. A range of apogee altitudes up to 400 nautical miles and perigee altitudes up to 120 nautical miles is included. The lifetimes are based on decay to 60 nautical miles. These data are useful in determining the insertion orbit altitude requirements to insure adequate mission duration.

*Time from nominal jettison



Table 6-2 Operational Timeline Segment, Ascent (Duration 00 11 57)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
-00 00 04	S-IB engine ignition	G	
-00 00 03	Scan critical displays	G	
00 00 01	Monitor AGC	G	
00 00 00	Liftoff	G	
	Scan critical displays to verify liftoff		
00 00 01	Verify AGC program changes from 05 to 11 of DSKY	G	
00 00 02	Verify automatic start of event timer Report clock start to MSFN	G	
00 00 10	Roll/pitchover maneuver	G	
00 00 12	Monitor FDAI	G	Note Attitude ball indications against entry symbol @ are as follows Up to liftoff Roll 165 deg Pitch 58 deg Yaw 10 deg
00 00 13	Report roll/pitch maneuver to MSFN	G	Roll maneuver complete Roll 180 deg Pitch 58 deg Yaw 0 deg Yaw and roll should remain 0 degrees and 180 degrees respectively as pitch gradually changes from 58 to 0 to 310 5 degrees at orbital insertion Large differences from this attitude program would constitute an abort cue
00 00 14	Scan critical displays	G	
00 00 30	Complete launch vehicle roll program	G	
00 00 52	Launch vehicle gravity tilt maneuver	G	
00 01 01	Disable automatic oxidizer dump capability	G	
00 01 01	Prepare command module RCS for 61 seconds to tower jettison profile	G	
00 01 08	Report Ox Dump Auto disabled and command module RCS propellant switches set to ON	G	



Table 6-2 Operational Timeline Segment, Ascent
(Duration 00 11 57) (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 01 10	Enable main deploy auto	G	
00 01 20	Max q	G	
00 01 50	Prepare angle of attack/SPS PC indicator to indicate SPS PC	G	
00 01 57	Report AOA/SPS PC set to SPS-PC	G	
00 02 00	Receive MSFN staging GO/NO GO report	G	
00 02 17	Start evaporative cooling in suit heat exchanger and water-glycol evaporator	G	
00 02 20	Prepare for staging Deactivate abort system 2 engine out and launch vehicle rates auto abort capability	G	
00 02 21	Cutoff S-IB inboard engine	G	
00 00 27	Stage S-IB/S-IVB Monitor S-IB engine cutoff	G	
00 02 29	Ignite S-IVB ullage	G	
00 02 29	Monitor launch vehicle attitude parameters	G	
00 02 32	Determine S-IB/S-IVB separation	G	
00 02 33	Ignite S-IVB engine	G	
00 02 40	Start SPS gimbal motors	G	
00 02 43	Report SPS gimbal motors started	G	
00 02 51	AGC program change	G	
00 02 53	Jettison launch escape tower	G	
00 03 12	IMU switches to FINE ALIGN MODE	G	
00 03 20	Receive MCC report on SPS abort to orbit capability	G	
00 10 07	Orbit insertion Determine S-IVB engine shutdown	G	
00 10 57	Perform preliminary post-insertion checks and report to MSFN	G	
00 11 57	Perform post insertion DSKY procedures	G	



Table 6-3 Subsystem Duty Cycles, Ascent
(Duration 0 1686 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCKS 1 AND 2
Stabilization and control				
RGP			0	100
BMAG		1	0	100
FDAI			0	100
AS/GPI		1	0	100
Rotation controller		1	0	100
SCS control panel		1	0	100
ECA pitch		1	0	100
ECA roll		1	0	100
ECA yaw		1	0	100
ECA auxiliary		1	0	100
ECA display		1	0	100
Electronics display		1	0	100
TVC	2	Operate	0	100
Guidance and navigation				
AGC OPERATE		A	0	100
STANDBY		F	100	0
IMU OPERATE		A	0	100
STANDBY		F	100	0
Displays and controls		A	0	100
Communications				
VHF/FM transmitter			0	100
VHF/AM equipment		Transmit	0	40
		Standby	0	60
		Receive	100	0
S-Band transponder			0	100
S-Band power amplifier		High	0	100
C-Band transponder		Interrogate	0	100
Audio center		High	0	100
		Low	100	0
Data storage		Operate	0	100
UHF-updata link			0	100
2-KMC switch			0	100
Audio center diode switch		High	30	100
Flight qualification recorder			0	100
Displays and controls				
Digital event timer	2	Operate	0	100
		Standby	100	0
SES floodlights	3	Fixed	0	100
	3	Variable	100	100
CS floodlights	3	Fixed	0	100
	3	Variable	0	100
Service propulsion system				
Gimbal actuator motors		Idle	0	79
Pilot valve (SCS)	4		0	100
Injector prevalues	2		0	100



Table 6-3 Subsystem Duty Cycles, Ascent
(Duration 0 1686 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCKS 1 AND 2
Environmental control system				
Cabin fans	2		1 at 100	2 at 100
*Sequential events control system				
MESC			0	100
ELSC			0	100
*PAC and PDC values for this block do not include power requirements of the SECS Power consumption information was not available				

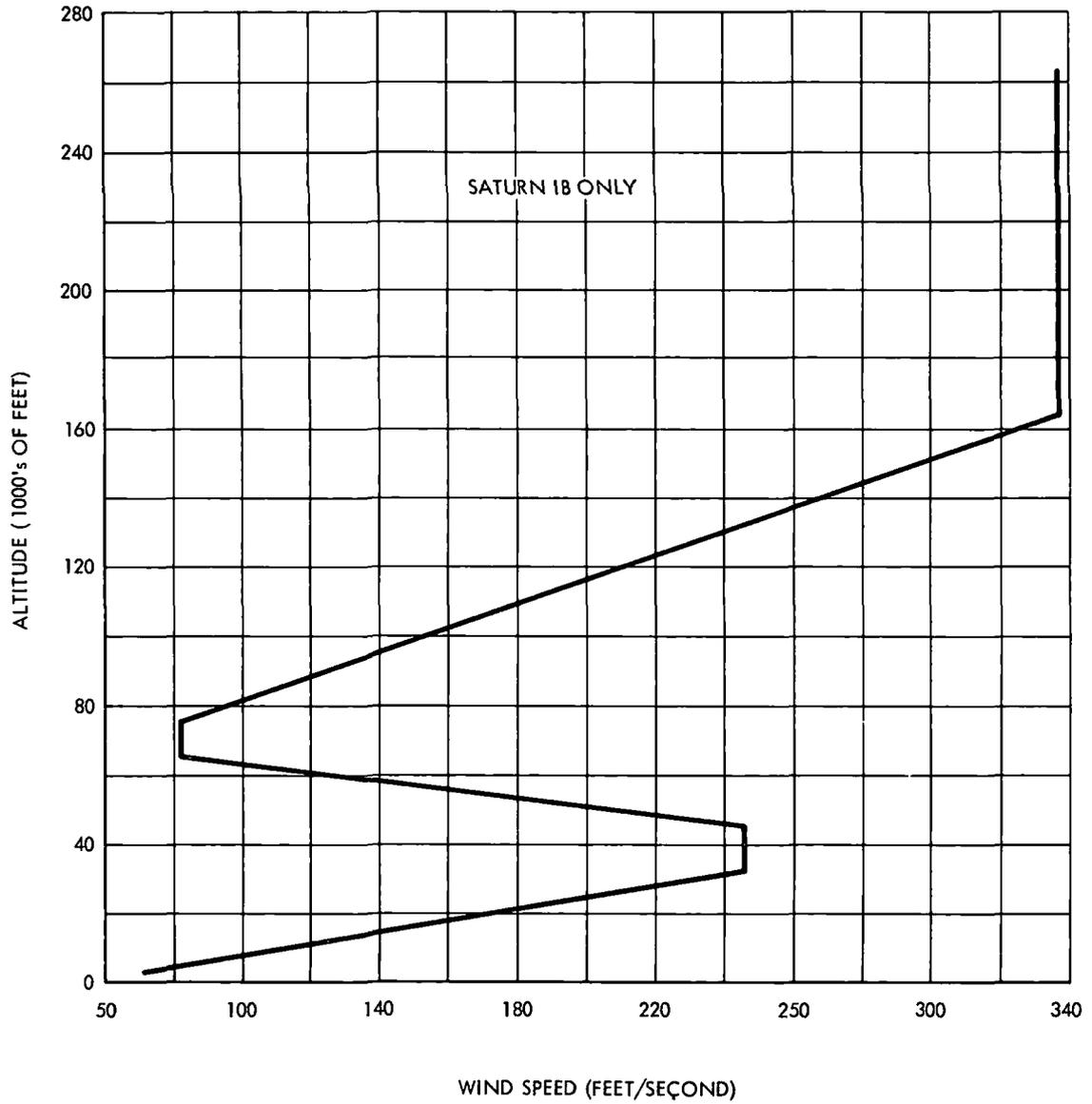


Figure 6-1 Block I Spacecraft 95 Percentile Scalar Wind Speed Envelope (Quasi Steady-State) for Cape Kennedy

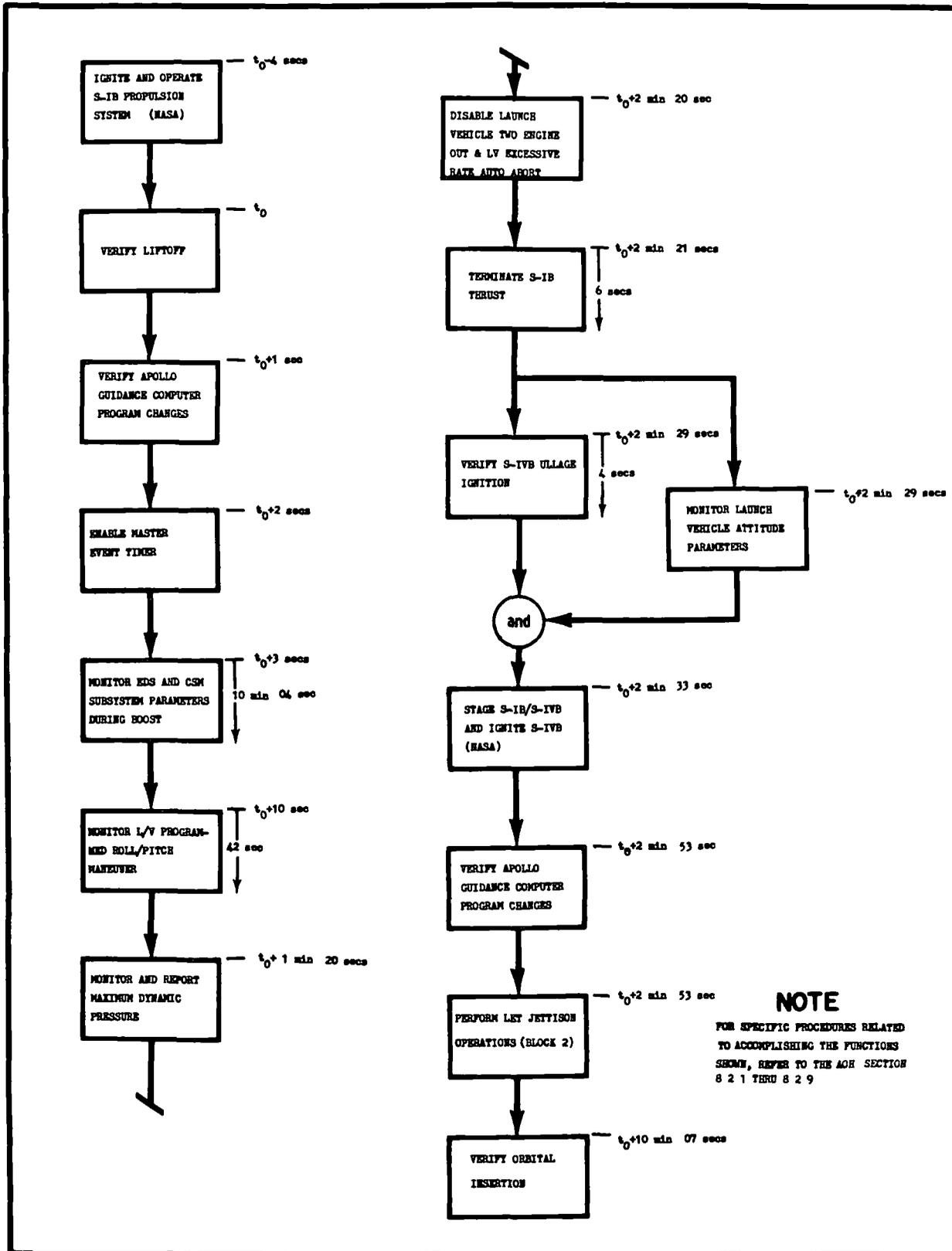


Figure 6-2 Building Block 1 Ascent

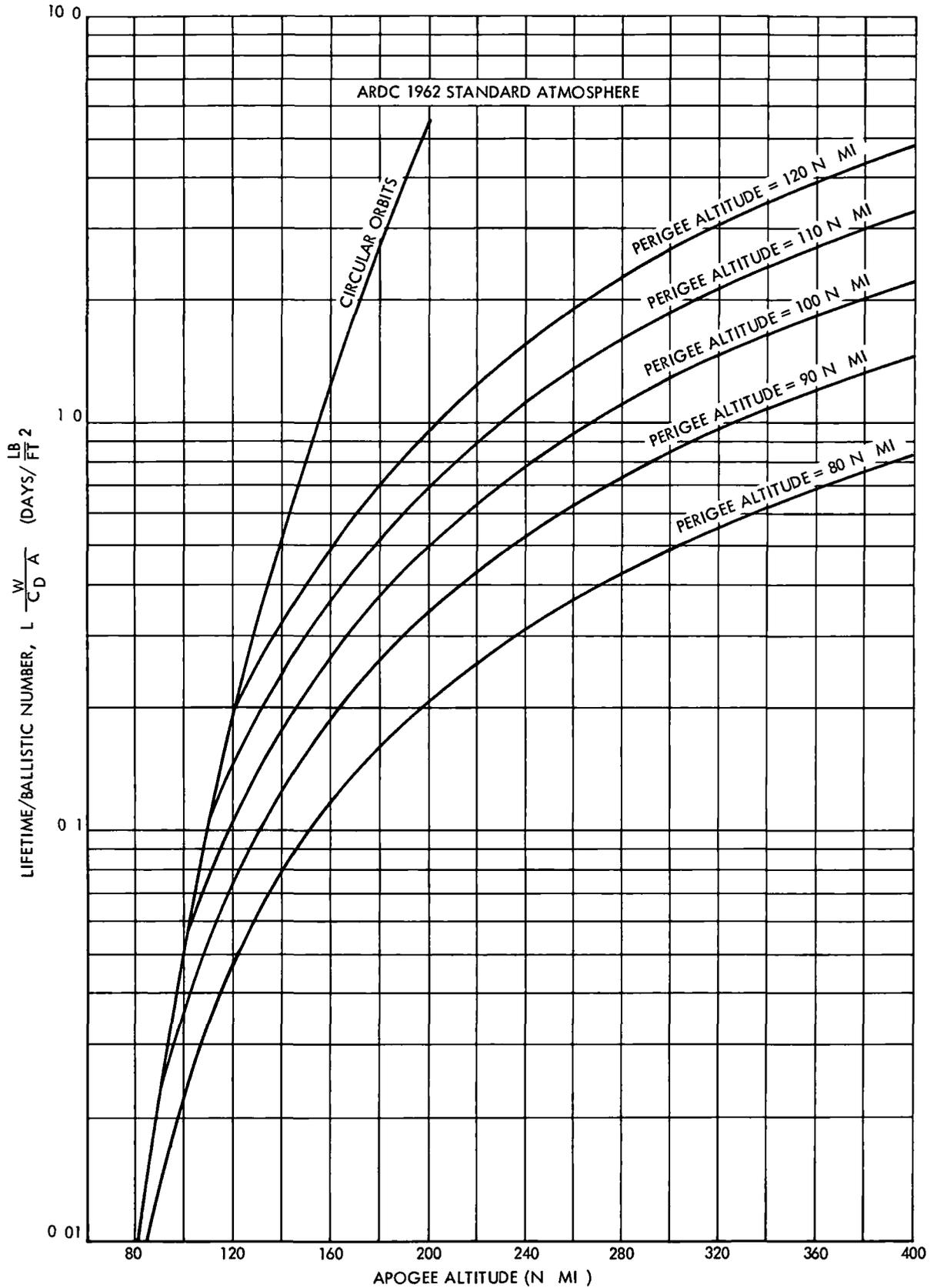


Figure 6-3 Orbital Lifetime in Circular or Elliptical Earth Orbits

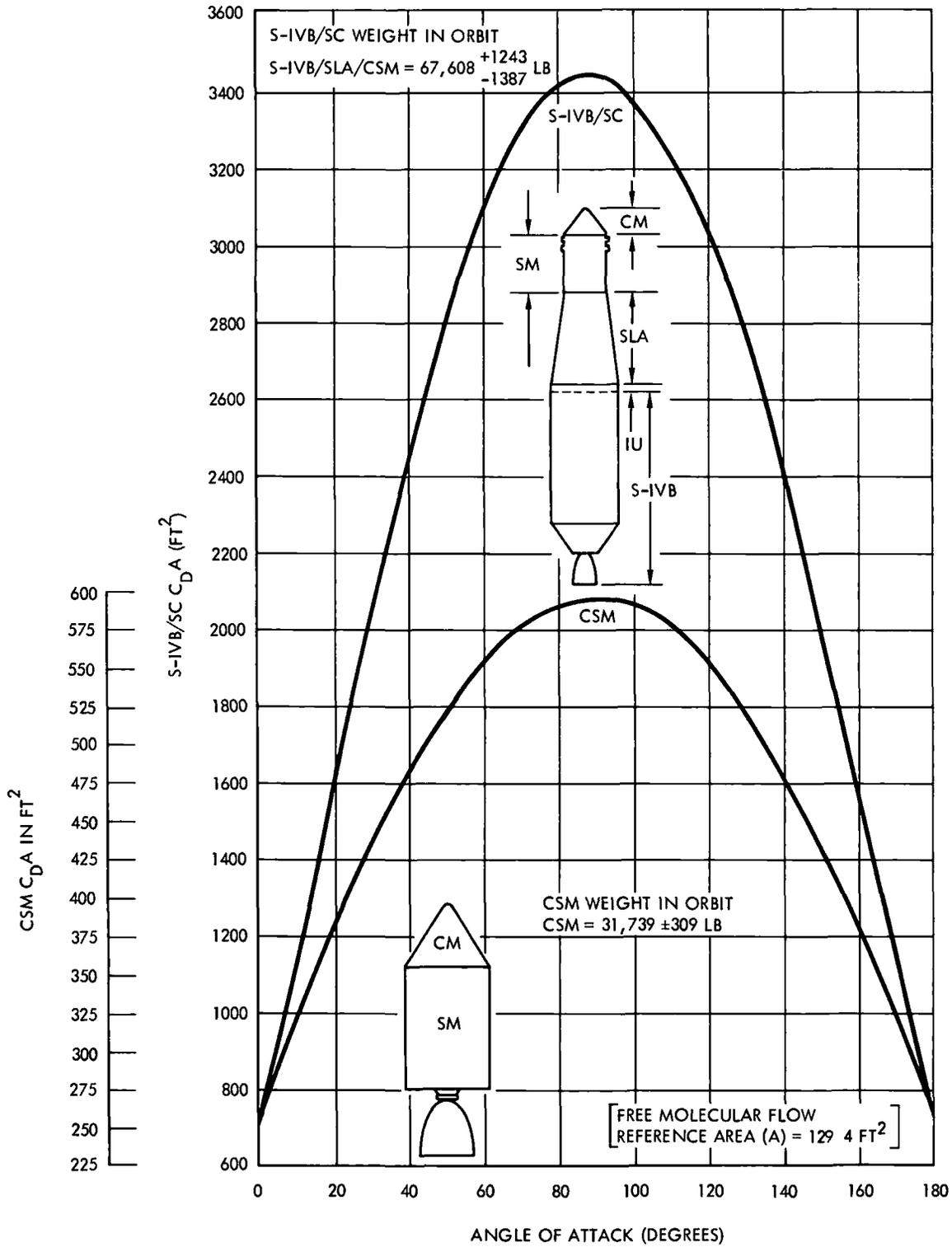


Figure 6-4 S-IVB/SC and CSM $C_d A$ Versus Angle of Attack



BUILDING BLOCK 2 LAUNCH ESCAPE TOWER JETTISON

2 1 INTRODUCTION

During a nominal Saturn IB Block I spacecraft launch, the launch escape tower (LET) and boost protective cover (BPC) are jettisoned by the astronaut at a predetermined time. The LET plus BPC jettison time occurs early during the S-IVB stage flight (approximately 20 seconds after S-IVB ignition).

The significant aspects of the LET jettison operation are the constraints imposed on the jettison time. Tower jettison should not be performed before the dynamic pressure is below 1 lb/ft^2 due to inability of the spacecraft to safely separate from the launch vehicle during service module aborts at higher dynamic pressure. In addition, unnecessary delay in jettison time requires consumption of S-IVB flight performance propellant reserves which are allocated for other boost dispersions.

The nominal jettison mode, using the LET solid propellant jettison motor, is considered to be an inplane jettison with the LET plus BPC passing up and over the boost stage. The jettison motor provides necessary propulsion to safely separate and miss the launch vehicle/spacecraft by a minimum distance of 170 feet, assuming worst case boost dispersion initial conditions at LET jettison.

In the event of a jettison motor malfunction, the LES main motor is used as a backup for LET plus BPC jettison. The backup mode jettison is also manually performed by the astronaut and the time required to accomplish the backup mode jettison is a function of the reaction time of the astronaut. The main motor provides jettison capability in excess of the jettison motor.

2 2 OPERATIONAL DATA

2 2 1 General Information

The primary function of the launch escape subsystem (LES) is to provide abort capability during ascent until the service module can perform aborts. The LET should be jettisoned as soon as service module abort capability exists, since maintaining the LET longer than necessary reduces payload capability (or S-IVB flight performance reserves).



The LET should be jettisoned as closely as possible to the predetermined time when the dynamic pressure subsides to 1 lb/ft², based on a +3σ maximum dynamic pressure trajectory, for the following two reasons

- 1 Due to the service module RCS thrust-to-weight ratio, spacecraft/booster separation can not be safely performed when the dynamic pressure is greater than 1 lb/ft²
- 2 A delay in jettison from the predetermined time reduces S-IVB flight performance reserves (FPR) by the following partial expression

$$\frac{\partial \text{S-IVB FPR}}{\partial \text{LET jettison time}} = -11.26 \text{ lb/sec}$$

2 2 2 Mission Functional Flow Diagram

The mission functional flow, shown in Figure 6-5, represents diagrammatically the necessary operation associated with performing LET jettison. Since the time interval to perform this function is relatively short, the correlation to a timeline segment is meaningless. However, the flow diagram attempts to demonstrate some relative time duration for the operation.

2 2 3 Operational Timeline Segment

The timeline associated with LET jettison is included as a part of the timeline for Building Block 1.

2 2 4 Attitude Operations

The inertial attitude of the booster is held constant from 10 seconds before S-IB outboard engine cutoff to LET jettison. This launch vehicle constraint is imposed so as not to produce adverse dynamic effects during S-IB/S-IVB separation and the LET jettison operation.

2 2 5 Subsystem Duty Cycles

The duty cycles for LET jettison are included as a part of the ascent phase duty cycles in Building Block 1.

2 2 6 Electrical Power Profile

The LET electrical power is included in Building Block 1.



2 3 PERFORMANCE

2 3 1 General Information

The performance of the LES is adequate to safely separate and pass clear of the boost stage during a nominal or backup jettison

2 3 2 Trajectory Data

- 1 LET weight (LET includes BPC) -

= 8517 lbs (from NAA Weight Control)

- 2 LET plus BPC trajectory relative to booster (primary mode) - The LET plus BPC trajectory relative to the boost stage after a normal jettison is presented in Figure 6-6 The trajectory is initiated at a worst-case attitude, altitude, velocity, flight path angle booster dispersion to produce the minimum miss-distance LET plus BPC trajectory

- 3 LET plus BPC trajectory relative to booster (backup mode) - The LET plus BPC trajectory relative to the boost stage after a back-up mode jettison is also presented in Figure 6-6 This trajectory is also initiated at a worst-case attitude, altitude, velocity, flight path angle booster dispersion to produce the minimum miss-distance LET plus BPC trajectory

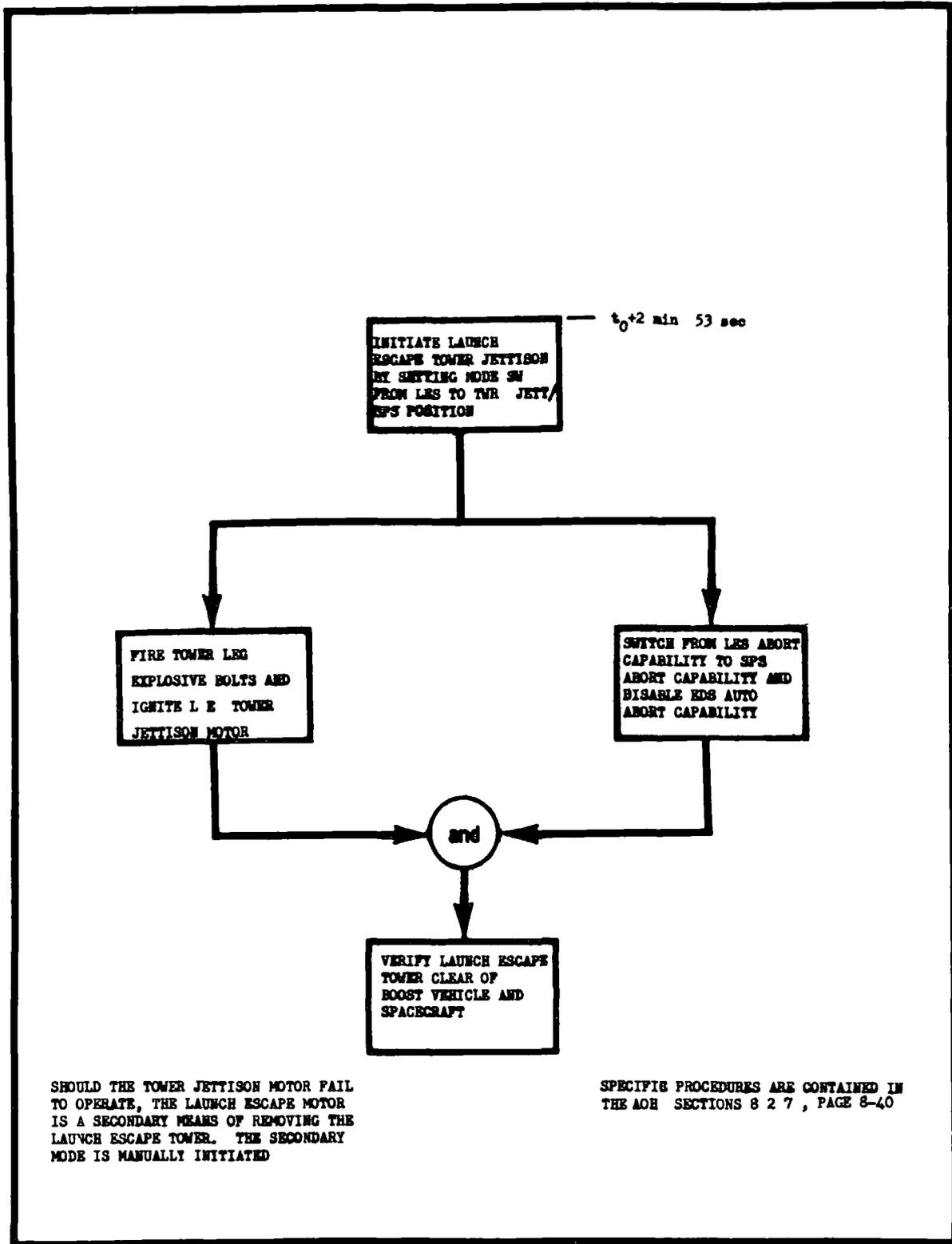


Figure 6-5 Building Block 2 LET Jettison

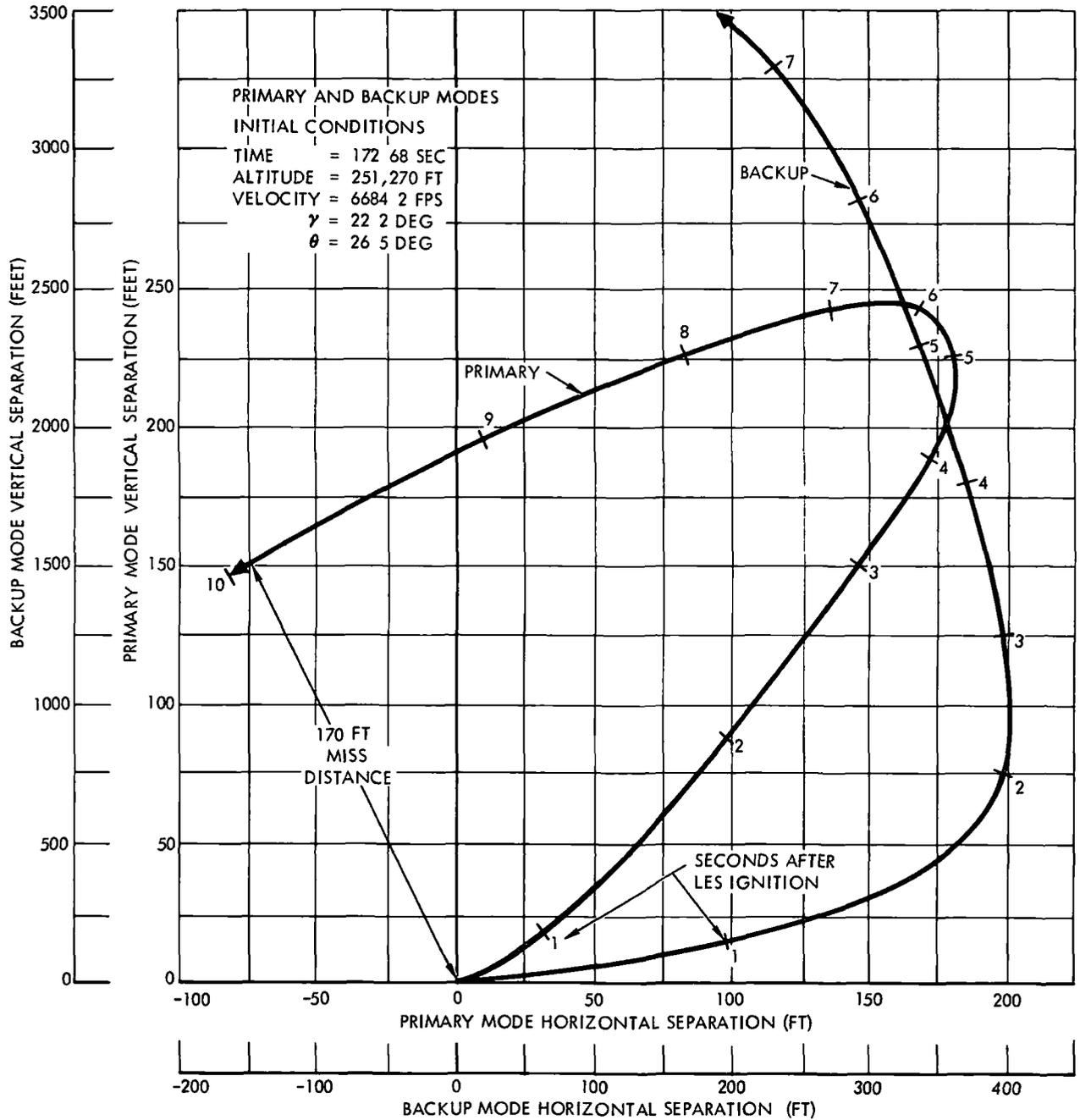


Figure 6-6 LES-BPC Trajectory Relative to Booster After Normal Jettison

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BUILDING BLOCK 5 POST-INSERTION

5 1 INTRODUCTION

Post-orbital insertion commences with confirmation of safe earth orbit through on-board displays and MSFN contact. The block consists of those operations and events which are required immediately after the ascent phase of the mission is completed and includes systems and equipments that are shut down and/or activated for the orbital phase of the mission. For a nominal ascent, the post-orbital insertion phase begins approximately 10 minutes after liftoff and has a duration of approximately 10 to 15 minutes.

5 2 OPERATIONAL DATA

5 2 1 General Information

The primary purpose of this block is to present the operations and events which are necessary to prepare the spacecraft for the orbital phase of the mission.

5 2 2 Operational Timeline Segment

See Table 6-4

5 2 3 Subsystem Duty Cycles

See Table 6-5

5 2 4 Electrical Power

The average delta power levels are

$$P_{AC} \text{ (nominal)} = 335.3 \text{ watts} \quad P_{DC} \text{ (nominal)} = 992.5 \text{ watts}$$



Table 6-4 Operational Timeline Segment, Post-Insertion

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS	
00 00	Determine S-IVB engine shutdown (00 02)		Reference AOH pages 8-41 to 8-46 For a nominal ascent post-orbital insertion begins at 10 07 from liftoff	
00 00	Obtain orbital parameters from AGC (01 30)			
00 00	Deactivate flight qualification recorder and rewind DSE (00 05)			
00 02	Monitor FDAI to determine vehicle attitude and stabilization (00 15)			
00 05	Reset fuel cell reactant isolation valves (00 02)			
00 07	Prepare telecommunications equipment for normal orbital operation (00 05)			
00 15	Perform C/W lamp test (00 15)			
00 20	Deactivate SPS gimbal motors (00 05) and secure SPS injector prevalues			CAUTION Gimbal motors must not remain ON longer than 10 minutes
00 30	Perform initial ECS EPS SPS status checks (05 00)			
Approximately 00 45	Receive MSFN report on ascent PCM playback requirements and biomedical status of crew (≈00 20)			a If MSFN did not receive adequate real time PCM during ascent play back recorded PCM over next station pass See Step 74, page 8-43 of AOH
Approximately 01 00	Monitor programmed S-IVB pitch maneuver to local horizontal attitude (≈00 20)			
Approximately 01 30	Receive orbit confirmation from MSFN (≈00 15)			
Approximately 02 00	Deactivate holding voltage from CM RCS propellant isolation valves (00 05)			
02 05	Prepare C/W system for normal orbital operation (00 02)			
02 10	Perform SCS-G&N attitude reference comparison (03 30)			
05 40	Power down SCS and secure CM propellant jettison logic and digital event timer (00 15)		See Step 66, pages 8-42 and 8-43 of AOH	
05 40	Perform CM and SM RCS status checks (01 00)			



Table 6-4 Operational Timeline Segment, Post-Insertion (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
05 40	Power down EPS and begin charging battery C (00 30)		
06 00	Prepare ECS controls (Commander's station) for normal orbital operation (00 20)		See Step 77 of AOH
06 40	Ingress to LEB (00 30)		
07 10	Lock postlanding vent valves (00 10)		The postlanding vent valves are located in the forward tunnel area and are locked to prevent inadvertent opening of valves during flight
07 10	Detach secondary rotation control from couch (00 05)		
07 20	Obtain secondary rotation control and install in LEB (00 15)		
07 35	Prepare work shelf (00 30)		
08 05	Install COAS (00 20)		
08 15	Obtain tools from tool set (00 15)		
08 30	Ingress to LHEB and prepare attenuator panel and suit circuit return air check valve for normal orbital operation (01 35)		See Step 77 of AOH
10 05	Replenish water-glycol accumulator quantity (00 20)		See Item 80 page 8-44 of AOH
10 25	Ingress to LEB remove and stow G&N optics cover (00 45)		
11 10	See Block 7 for preparation of G&N station for use		



Table 6-5 Subsystem Duty Cycles, Post-Insertion

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 5
Stabilization and control				
RGP		1	0	100
BMAG		1	0	100
FDAI		1	0	100
AS/GPI		1	0	100
ΔV display		1	0	100
Rotation controller		1	0	100
SCS control panel		1	0	100
ECA Pitch		1	0	100
ECA Roll		1	0	100
ECA Yaw		1	0	100
ECA Auxiliary		1	0	100
ECA Display		1	0	100
Electronics display		1	0	100
TVC	2	Operate	0	OFF at 01 00
Guidance and navigation				
AGC OPERATE		A	0	100
STANDBY			100	0
IMU OPERATE		A	0	100
STANDBY			100	0
Displays and controls		A	0	100
Communications				
VHF/FM transmitter			0	100
VHF/AM equipment		Transmit	0	40
		Receive	100	0
		Standby	0	60
S-band transponder				100
S-band power amplifier		High	0	To 06 20
S-band power amplifier		Low	0	ON at 06 25



Table 6-5 Subsystem Duty Cycles, Post-Insertion (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 5
C-band transponder		High	0	100
Audio center		High	0	100
		Low	100	0
Data storage		Normal	0	OFF at 02 00
UHF-Updata link			0	100
2-kmc switch			0	100
Audio center diode switch		High	30	100
Flight qualification recorder			0	OFF at 01 30
Displays and controls				
Digital event timer		Operate	0	100
		Standby	100	0
SES floodlights		Fixed	0	100
		Variable	100	100
CS floodlights		Fixed	0	100
		Variable	100	100
Service propulsion system				
Gimbal actuator motors		Idle	0	OFF at 00 20
Pilot valves (SCS)			0	100
Injector Prevalves			0	OFF at 00 20
			0	OFF at 00 20
Environmental control system				
Cabin fans	2		1 at 100	2 at 100
Sequential events control system				
Master events sequence controller			0	OFF at S-IVB separation
Emergency detection system			0	OFF at S-IVB separation

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BUILDING BLOCK 6 CSM/S-IVB SEPARATION

6 1 INTRODUCTION

Separation of the CSM/S-IVB, as classified in this block, may be conducted at any time after post-insertion (refer to BB-5). Subsystem status checks are conducted after post-insertion and before CSM/S-IVB separation on the electrical power subsystem (EPS), service propulsion subsystem (SPS), and the service module reaction control subsystem (RCS). For details of these status checks, refer to BB-14. The actual duration of this block is that time from the performance of those operations required in preparing for the actual CSM/S-IVB separation through the completion of service module RCS +X thrusters firing. For this block, the firing time is established as that necessary to achieve a separation velocity of 3 fps. CSM maneuvers after separation, as required for SLA photography, are not included in the block. The block duration is 0 102 hour.

6 2 OPERATIONAL DATA

6 2 1 General Information

Several preparatory actions are necessary before separation. However, the actual physical separation is preceded by activating the ordnance train which severs the service module from the SLA, releases the SLA panels, initiates the pyrotechnic thrusters that open the panels, and effectively dead-faces the electrical circuits between the CSM and instrument unit (IU) by pyrotechnically separating the connectors.

Upon initiation, panel deployment occurs at the following rates. The panels acquire an outward angular velocity of 37-46 degrees per second in 0 09 seconds (the minimum acceptable angular velocity is 33 5 degrees per second). The panels reach their fully deployed position of 34-45 degrees in slightly over one second.

The actual SM/S-IVB separation is accomplished by means of the service module RCS, controlled by the translation hand control. The ΔV required for separation depends on exact mission requirements. In a normal mission, it is primarily dictated by CSM/S-IVB recontact avoidance requirements. Current ground rules are that the S-IVB be prevented from venting for a minimum of 1 hour after separation, which should help minimize recontact considerations, aided by the crew monitoring the relative position of the S-IVB.



CSM/S-IVB separation must be performed during daylight hours if SLA photography is scheduled and should occur early enough to provide the crew adequate time to complete SLA photography before darkness is entered

6 2 2 Mission Functional Flow

See Figure 6-7

6 2 3 Operational Timeline Segment

See Table 6-6

6 2 4 Attitude Operations

In preparatory operations for CSM/S-IVB separation, the SCS attitude control is energized, and the attitude reference is aligned to the IMU gimbal angles. The S-IVB terminates pitch (used in the local vertical mode) and assumes inertial attitude, with S-IV venting inhibited.

For CSM/S-IVB separation with the CSM active and the S-IVB passive, the S-IVB attitude is maintained inertially fixed to a 10 degree deadband during the CSM separation from the S-IVB controlled by MSFN.

The CSM/S-IVB separation is accomplished by firing the service module RCS +X thrusters by manipulating the primary translation control counter-clockwise to the abort detent for approximately 1.7 seconds before physical separation from the inertially stabilized S-IVB. While the translation control is in the abort detent position, the CSM attitude is not controlled. Upon confirmation of physical separation, the primary translation control is manipulated to the +X position at which time the CSM stabilization and control subsystem (SCS) initiates attitude control to a maximum deadband of 5 degrees until the desired separation velocity (approximately 3 fps) is attained.

6 2 5 Subsystem Duty Cycles

See Table 6-7

6 2 6 Electrical Power

The average Δ power levels are as follows

P_{AC} (nominal) = 166.6 watts

P_{DC} (nominal) = 216.6 watts



6 2 7 Propellant Consumption

From Section 5 0, a 12-foot/second +X translation consumes a total of 33 pounds of SM RCS propellant



Table 6-6 Operational Timeline Segment,
CSM/S-IVB Separation (Duration 00 06 08)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 00 00	Arm master event sequence controller (MESC) Monitor systems status from t-15 seconds and confirm S-IVB venting is inhibited		If SLA photography is scheduled following separation the camera should be unstowed S IVB cyclic venting (oxidizer venting) which is capable of imparting a velocity of 12 fps in the +X direction is inhibited by MSFN during S-IVB separation
00 00 04	Power up SCS		Refer to AOH Paragraph 8 6 3 5
00 00 10	Set digital event timer to reach 00 00 at S-IVB separation		
00 01 16	Activate TVC power		
00 01 20	Prepare ΔV remaining counter for CSM/S IVB separation rate of 3 fps		
00 01 44	Prepare rate gyros for CSM/S-IVB separation		
00 02 00	Prepare attitude set dials for CSM/S-IVB separation		
00 03 30	Align FDAI		
00 05 00	Check FDAI Note cessation of pitching motion and pitch angle reading		
00 05 46	Initiate CSM/S-IVB sequences Activate data storage equipment (DSE)		A 1 7 second engine firing is performed before separation from the S IVB to ensure a positive separation
00 05 58	Check event timer for -00 minutes 02 seconds		
00 06 01	Manipulate primary translation control counterclockwise to abort detent Check event timer for 00 minutes 00 seconds		
00 06 03	Manipulate primary translation control to +X position upon confirming positive separation		
00 06 08	Hold until ΔV remaining reads 00000		Perform subsequent maneuvers as required for SLA photography



Table 6-7 Subsystem Duty Cycles, CSM/S-IVB Separation

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 6
Stabilization and control				
FDAI		4	0	100
AS/GPI		4	0	100
ECA pitch		4	0	100
ECA yaw		4	0	100
ECA roll		4	0	100
ECA auxiliary		4	0	100
ECA display		4	0	100
ΔV display		4	0	100
Electronics display		4	0	100
Guidance and navigation				
IMU OPERATE		A	0	100
IMU STANDBY		E	100	0
SM RCS				
RCS engine coils	4	Automatic	0	1
Communications				
VHF/FM transmitter			0	100
VHF/AM equipment		Transmit	0	60
		Standby	0	40
		Receive	100	0
Audio center		High	0	100
		Low	100	0
Audio center diode switch		High	30	60

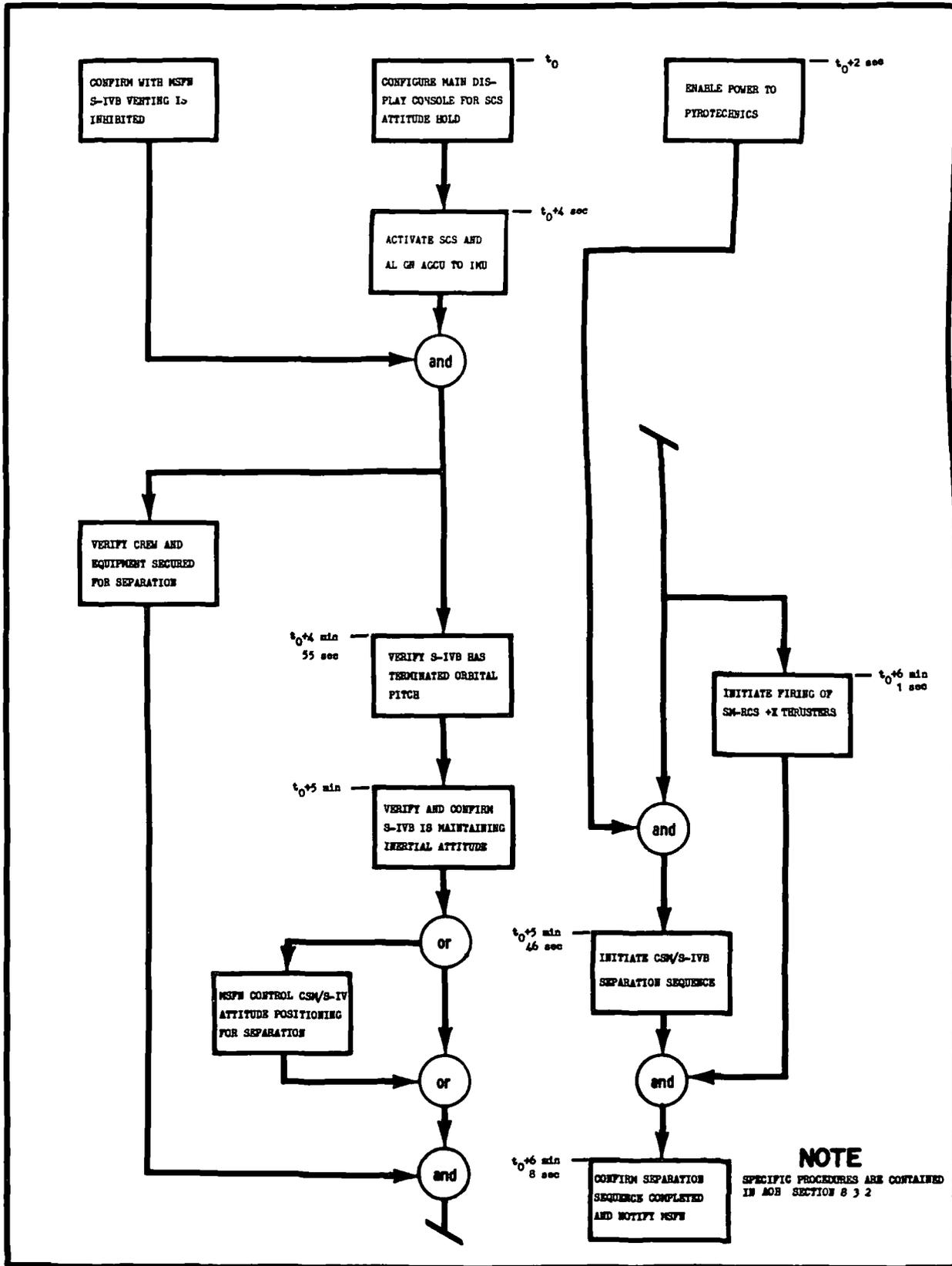


Figure 6-7 Building Block 6 CSM/S-IVB Separation



BUILDING BLOCK 7 IMU ALIGNMENT

7 1 INTRODUCTION

During the major portion of the Block I manned missions, the IMU will be in a standby condition. Prior to the SPS burns and the earth landmark navigation sightings and during other periods when G&N control or comparative data may be necessary, the IMU must be switched to an OPERATE condition and must be aligned to the desired inertial orientation. Also, during periods when the IMU has been in continuous operation for relatively long periods after an initial alignment, its alignment must be updated to offset possible error buildup.

Building Block 7 covers the complete nominal IMU alignment. The alignment of the IMU while still attached to the S-IVB is shown in addition to the unconstrained SC IMU alignment in the Mission Functional Flow Diagram, Figure 6-9, and the Operational Timeline Segment, Table 6-8. However, for generation of the electrical power profile and consumables, the IMU alignment is assumed to occur after S-IVB separation.

Building Block 7 starts with the preparation of the LEB navigation station and with the selection or confirmation of the G&N being powered up and ends with the satisfactory completion of an optional IMU fine alignment check.

7 2 OPERATIONAL DATA

7 2 1 General Information

To perform an alignment of the IMU, the navigator selects the required computer program (initial or update IMU alignment) and the target stars. If the initial alignment program is selected, the IMU gimbal angles are zeroed and the spacecraft is maneuvered for the coarse-align sightings on two target stars. The navigator centers each star in the SCT optical field of view and initiates a MARK command. After each sighting, a star code number is entered into the computer. The computer records the optics angles and the time and uses these data to calculate the coarse-align stable platform orientation. After the computer has coarse-aligned the stable platform, it maneuvers the spacecraft to obtain the fine-align stars. With the optical subsystem in the computer mode and the SCT slaved to the SXT trunnion axis, the computer will point the optics LOS toward the target star for final alignment measurements. The two fine-align stars are separately



acquired in the center of the SXT field of view, and the MARK command initiated after each star is centered. By using the measured optical angles, the fine align star components are transformed into stable platform axes by the computer, which compares the existing stable platform orientation with the desired orientation and executes commands to torque the platform to the desired position. A final check on the alignment can be performed by sighting on two additional stars.

- 1 If an update alignment is to be performed, the required computer program is initiated and the spacecraft is maneuvered for performing fine-align sightings. Upon completion of the sightings, the stable platform is torqued to the desired position.
- 2 For thrusting maneuvers that require the G&N to be operational for control or monitor purposes, the IMU alignment normally is to be completed no less than 15 minutes prior to the planned thrusting maneuver to allow time for the AGC thrusting program.
- 3 The IMU should be in the OPERATE condition for at least 15 minutes prior to being fine-aligned in order to allow the G&N power servo assembly (PSA) to stabilize.
- 4 An IMU coolant check is to be performed prior to an IMU alignment. In addition, a daily coolant check is to be performed on days when an IMU alignment is not made.
- 5 An IMU orientation determination must be performed by using the G&N optics and sighting two known stars after switching the IMU from a STANDBY to an OPERATE condition, after loss of stabilization resulting from IMU gimbal-lock, or after a severe power transient.
- 6 The AGC mode switch should be switched to ON before the IMU-MNA and -MNB circuit breakers are closed.

7 2 2 Mission Functional Flow

See Figure 6-8

7 2 3 Operational Timeline Segment

See Table 6-8



Table 6-8 Operational Timeline Segment, IMU Alignment

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
$t_0 - 00 00 00$	Prepare LEB nav station and power up G&N (00 04 00)	E	Reference AOH Paragraph 8 6 3 3 Time duration shown is for initial preparation of LEB navigation station after orbital insert on. For subsequent periods involving the preparation of the LEB navigation station subtract 3 minutes since certain activities are presumed to occur only once (e.g. the workshelf is presumed to be positioned for use after orbit insertion until prior to entry) Requires coordinated effort between crewman in LEB and crewmen in couches 1 and 3 The AGC mode switch should be switched to ON before the IMU MNA and IMU MNB circuit breakers are closed
$t_0 - 00 04 00$	Prepare optics for use—unstow and mount SCT and SXT eyepieces (00 03 15)	E	Long relief optics eyepieces are recommended for use by crewman wearing PGA while short relief optics eyepieces are recommended for use by crewman wearing CWG
$t_0 + 00 07 15$	Perform C&WS test (00 00 40)	E	Reference AOH Paragraph 8 4 17 1
$t_0 + 00 07 33$	Perform G&N status check (00 03 11)	E	
$t_0 + 00 11 06 = t_1$	Perform IMU alignment		
	Case I Pre S IVB/CSM separation (00 15 33)		
t_0	Perform S IVB/IMU alignment (00 15 33)		Reference AOH Paragraph 8 3 1 3
	Program AGC for S IVB/IMU alignment (00 01 03)	E	Since the AGC and IMU are not expected to be powered down during the period that the spacecraft is constrained to the S IVB a S IVB/IMU alignment will normally consist of an update alignment (fine alignment) to correct for accumulated system drift errors and to demonstrate astronaut capability to perform an IMU alignment



Table 6-8 Operational Timeline Segment, IMU Alignment (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t ₁ +00 01 03	Perform acquisition of star 1 in SCT (00 01 00)	E	Time duration shown is for obtaining code book and locating and selecting program code Opportunities for performing an S IVB/IMU alignment are periodically provided by the S IVB adopting a preprogrammed attitude facilitating star sightings necessary to the IMU alignment program
t ₁ +00 02 03	Identify target star in SCT field of view (00 01 00)	E	
t ₁ +00 03 03	Center star 1 in SXT and perform mark (00 01 00)	E	
t ₁ +00 04 03	Enter star 1 identification code into the AGC (00 00 30)	E	
t ₁ +00 04 33	Perform acquisition of star 2 in SCT (00 01 00)	E	
t ₁ +00 05 33	Identify target star in SCT field of view (00 01 00)	E	
t ₁ +00 06 33	Center star 2 in SXT and perform mark (00 01 00)	E	
t ₁ +00 07 33	Enter star 2 identification code into the AGC (00 00 30)	E	
t ₁ +00 08 03	Monitor star data test—data within limits (00 00 30)	E	
t ₁ +00 08 33	Monitor IMU fine alignment (00 00 30)	E	The desired final IMU orientation (prelaunch IMU orientation) is stored in the AGC. This orientation will not result in gimbal lock for any of the preprogrammed S-IVB attitudes
t ₁ +00 09 03	Perform IMU fine alignment check (00 06 30)	E	Complete at t ₁ +00 15 33
00 11 06=t ₂	Case II Post S IVB/CSM separation (00 42 16)		
t ₂	Power up SCS and perform FDAI self-test (00 02 00)	E	Reference AOH Paragraph 8 6 3 5



Table 6-8 Operational Timeline Segment, IMU Alignment (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
			The BMAG power switch is pre-umed to remain in the AC2 position for the entire mission thus eliminating the need for a 40 minute warmup period that would occur if the BMAG's had to be powered up from OFF to AC2
$t_2 + 00 02 00$	Perform IMU orientation determination (00 16 33)		Reference AOH Paragraph 8 6 4 2
$t_2 + 00 02 00$	Program AGC for IMU orientation determination (00 01 03)	E	Time duration shown is for obtaining code book and locating and selecting program code
$t_2 + 00 03 03$	Monitor coarse alignment of IMU to caged position (00 01 00)	E	
$t_2 + 00 04 03$	Perform SCS attitude maneuver to acquire two target stars within SCT field of view (00 03 00)	G	Reference BB 11 Paragraph 11 2 2 Spacecraft attitude must be adjusted so as to allow two stars to be visible through the SCT and vehicle residual rates (free drift established) must be less than 0.2 degrees per second in each axis
			The IMU remains caged during the maneuver and G&N attitude error signals are disabled by the coarse align mode
$t_2 + 00 07 03$	Manually acquire star 1 in SCT and perform mark (00 05 00)	E	Time duration shown includes the inspection of the starfield chart
$t_2 + 00 12 03$	Enter star 1 identification code into the AGC (00 00 30)	E	
$t_2 + 00 12 33$	Manually acquire star 2 in SCT and perform mark (00 05 00)	E	Time duration shown includes the inspection of the starfield chart
$t_2 - 00 17 33$	Enter star 2 identification code into the AGC (00 00 30)	E	
$t_2 + 00 18 03$	Monitor star data test—data within limits (00 00 30)	E	



Table 6-8 Operational Timeline Segment, IMU Alignment (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
$t_2+00\ 18\ 33$	<u>Note</u> AGC program should now be performed which defines and stores (1) desired final IMU inertial orientation and (2) desired final spacecraft attitude Upon the completion of this AGC program resume the IMU alignment operations (Duration is variable use Δt)		If the IMU precedes a ΔV maneuver approximately 15 minutes would be required for the program If it precedes a navigation sighting allow approximately 10 minutes In either case contact with MSFN is required which will require an undetermined duration of time
$t_2+\Delta t+00\ 18\ 33$	Perform CSM/IMU alignment (00 23 43)		Reference AOH Paragraph 8 6 5 12
$t_2+\Delta t+00\ 18\ 33$	Program AGC for CSM/IMU alignment (00 01 03)	E	Time duration shown is for obtaining code book locating and selecting program code
$t_2+\Delta t+00\ 19\ 36$	Select G&N attitude control maximum deadband (00 00 40)	E	Reference BB 11 Paragraph 11 1 1
$t_2+\Delta t+00\ 20\ 16$	Monitor coarse alignment of IMU to caged position (00 01 00)	E	
$t_2+\Delta t+00\ 21\ 16$	Monitor AGC display of IMU gimbal angles (00 00 30)	E	AGC will display present IMU gimbal angles preferred at the termination of the maneuver to the desired final spacecraft attitude specified and stored in the AGC by a previously selected program
$t_2+\Delta t+00\ 21\ 46$	Initiate and monitor G&N auto maneuver to final attitude (00 06 00)	G	Reference BB 11 Paragraph 11 1 2 and 11 1 1 Presumes no intermediate orientation required to avoid IMU gimbal lock
$t_2+\Delta t+00\ 27\ 46$	Perform acquisition of star 1 in SCT (00 01 00)	E	
$t_2+\Delta t+00\ 28\ 46$	Identify target star in SCT field of view (00 01 00)	E	
$t_2+\Delta t+00\ 29\ 46$	Center star 1 in SXT and perform mark (00 01 00)	E	
$t_2+\Delta t+00\ 30\ 16$	Enter star 1 identification code into the AGC (00 00 30)	E	
$t_2+\Delta t+00\ 31\ 16$	Perform acquisition of star 2 in SCT (00 01 00)	E	
$t_2+\Delta t+00\ 32\ 16$	Identify target star in SCT field of view (00 01 00)	E	



Table 6-8 Operational Timeline Segment, IMU Alignment (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
$t_2 + \Delta t + 00\ 33\ 16$	Center star 2 in SXT and perform mark (00 01 00)	E	
$t_2 + \Delta t + 00\ 34\ 16$	Enter star 2 identification code into the AGC (00 00 30)	E	
$t_2 + \Delta t + 00\ 34\ 16$	Monitor star data test—data within limits (00 00 30)	E	
$t_2 + \Delta t + 00\ 35\ 16$	Monitor IMU fine alignment (00 00 30)	E	
$t_2 + \Delta t + 00\ 35\ 46$	Perform IMU fine alignment check (00 06 30)	E	Complete at $t_2 + \Delta t + 00\ 42\ 16$
Time source code	<p>E = Engineering estimate (derived from statistical analysis (e.g. the computer formula or data provided by cognizant engineering groups such as alignment time of FDAI etc.))</p> <p>G = Guess (an approximation based upon the engineering assumption of a realistic time limit)</p>		



7 2 4 Attitude Maneuvers

Whenever the IMU is in operation, limitations are imposed upon allowable orientations and sequences by gimbal-lock considerations. Gimbal-lock is approached when the outer gimbal axis is within 30 degrees of the inner gimbal axis. The outer gimbal axis, which is fixed with respect to the spacecraft body axis, points in the spacecraft X-Z plane 33 degrees from the +X axis toward the -Z axis. Essentially, the spacecraft should not be maneuvered to an attitude which will align the inner circle of either red area on the FDAI ball under the navigation axis marker. Specifically, the following maneuvers should be avoided: (1) yaw maneuver greater than ± 75 degrees when the roll angle is 0 degree or 180 degrees and (2) a pitch maneuver greater than ± 42 degrees or -108 degrees when the roll angle is ± 90 degrees.

During coarse IMU alignment, fine IMU alignment, and fine IMU alignment check, it is required that the spacecraft attitude be inertially constrained so that a suitable star field is in the optics field of view. In most cases, acceptable star patterns may be observed without an orientation maneuver. At most, a roll maneuver may be required to make a selected star field visible through the G&N optics.

Fine IMU alignments and fine alignment checks prior to a thrusting maneuver are made in the ΔV attitude unless the star field is not visible through the G&N optics. If this is the case, an intermediate attitude will be required between coarse alignment and the ΔV .

During periods of star sightings for an IMU alignment, with the spacecraft attached to the S-IVB, attitude is maintained fixed with respect to the local horizontal. The spacecraft X-Z plane is coincident with the trajectory plane, with the +X axis within 1 degree of local horizontal and pointing in the direction of motion. The -Z axis has a positive projection on the downward local vertical.

When detached from the S-IVB, a SCS attitude maneuver (proportional rate roll maneuver) may be required to adjust the spacecraft attitude so that a selected star field is visible through the G&N optics. Proportional rate maneuvers may be performed at rates between 0.1 and 0.65 deg/sec, however, it is improbable that the lower limit can be commanded in practical situations. For scheduling purposes, proportional rate maneuvers are presumed to be performed at a minimum rate of 0.2 deg/sec.

G&N attitude control will be used for IMU fine alignments and IMU fine alignment checks. G&N attitude maneuver rates are limited by the G&N digital autopilot program to 0.5 deg/sec in pitch, roll, and yaw.



Attitude impulse control (minimum impulse) may be required to accomplish fine adjustment of the spacecraft attitude for IMU alignments. Use of minimum impulse excites rates of approximately 0.010 deg/sec minimum to 0.05 deg/sec maximum.

7.2.5 Duty Cycles

Separate S-IVB/CSM and CSM alignments are given in the duty cycles (Tables 6-9 and 6-10).

7.2.6 Electrical Power Profile

See Figure 6-9. The average Δ power levels are the following:

Attached to S-IVB	Unattached
P_{AC} (nominal) = 21.4 watts	P_{AC} (nominal) = 128.0 watts
P_{DC} (nominal) = 506.4 watts	P_{DC} (nominal) = 567.0 watts

7.2.7 Propellant Consumption

- 1 Case I Pre-S-IVB/CSM separation (no CSM propellants were consumed)
- 2 Case II Post S-IVB/CSM separation

Approximately 4-3 pounds of RCS propellant is used for the specific sequence in this block, as shown in Figure 6-10.

7.3 PERFORMANCE

- 1 Post S-IVB/CSM separation

SC minimum deadband for G&N attitude hold, 0.5 deg

SC minimum deadband for SCS attitude hold, 0.2 deg

SC maximum deadband for G&N attitude hold, 5.0 deg

SC maximum deadband for G&N attitude hold, 4.2 deg

Minimum impulse rate, 0.01 deg/sec minimum
0.05 deg/sec maximum



2 Pre-S-IVB/CSM separation

Minimum deadband (S-IVB-IU), 1 deg

Attitude rate for maneuvers, 0 5 deg/sec

3 Optics subsystem

Field of view of SCT (magnification 1 1), 60 deg

Field of view of SXT (magnification 28 1), 1 8 deg

Total field of view for SCT, approximately 90 deg

Control speed

Mode	High	Medium	Low
Manual resolved/computer mode			
Trunnion	8 8 deg/sec	1 05	0 105
Shaft	8 8 deg/sec	1 05	0 105
Manual direct			
Trunnion	8 8 deg/sec	1 05	0 105
Shaft	17 3 deg/sec	2 06	0 206

Zero optics mode (time to zero shaft trunnion axis, and AGC counter), 60 sec



Table 6-9 Subsystem Duty Cycles, IMU Alignment,
Pre-S-IVB/CSM Separation (Duration 0 444 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 7
Guidance and navigation				
AGC OPERATE		B	0	100
STANDBY		F	100	0
IMU OPERATE		B	0	100
STANDBY		F	100	0
Optics		B	0	100
Displays and controls		B	0	100



Table 6-10 Subsystem Duty Cycles, IMU Alignment, Post-S-IVB/CSM Separation (Duration 0 890 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 7
Stabilization and control				
3 RGP		2 3 and 6	0	31 1in2 5 62in3 41 2in6
4 BMAG		2 3 and 6	0	31 1in2 5 62in3 41 2in6
1 FDAI		2 3 and 6	0	31 1in2 5 62in3 41 2in6
1 AS/GPI		2 3 and 6	0	31 1in2 5 62in3 41 2in6
2 ΔV display			0	
6 Rotation controller		2 3 and 6	0	31 1in2 5 62in3 41 2in6
CB SCS control panel		2 3 and 6	0	31 1in2 5 62in3 41 2in6
1 Pitch ECA		2 3 and 6	0	31 1in2 5 62in3 41 2in6
1 Roll ECA		2 3 and 6	0	31 1in2 5 62in3 41 2in6
1 Yaw ECA		2 3 and 6	0	31 1in2 5 62in3 41 2in6
1 Aux ECA		2 3 and 6	0	31 1in2 5 62in3 41 2in6
1 Display ECA		2 3 and 6	0	31 1in2 5 62in3 41 2in6
1 Display electronics		2 3 and 6	0	31 1in2 5 62in3 41 2in6
2 TVC OPERATE 1			0	
5 STANDBY 2		2 3 and 6	0	31 1in2 5 62in3 41 2in6



Table 6-10 Subsystem Duty Cycles, IMU Alignment,
Post-S-IVB/CSM Separation (Duration 0 890 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 7
Guidance and navigation				
AGC OPERATE		B	0	100
STANDBY		F	100	0
IMU OPERATE		B	0	100
STANDBY		F	100	0
Optics		B	0	100
Displays and controls		B	0	100
Service module RCS				
Propellant quantity gauging			0	
Engine heaters			62 5	Same as BB-9
RCS engine coils		Automatic	0	0 0568
He isolation valves			0	
Propellant isolation valves			0	
Command module RCS				
Isolation valves			0	
RCS engine coils			0	

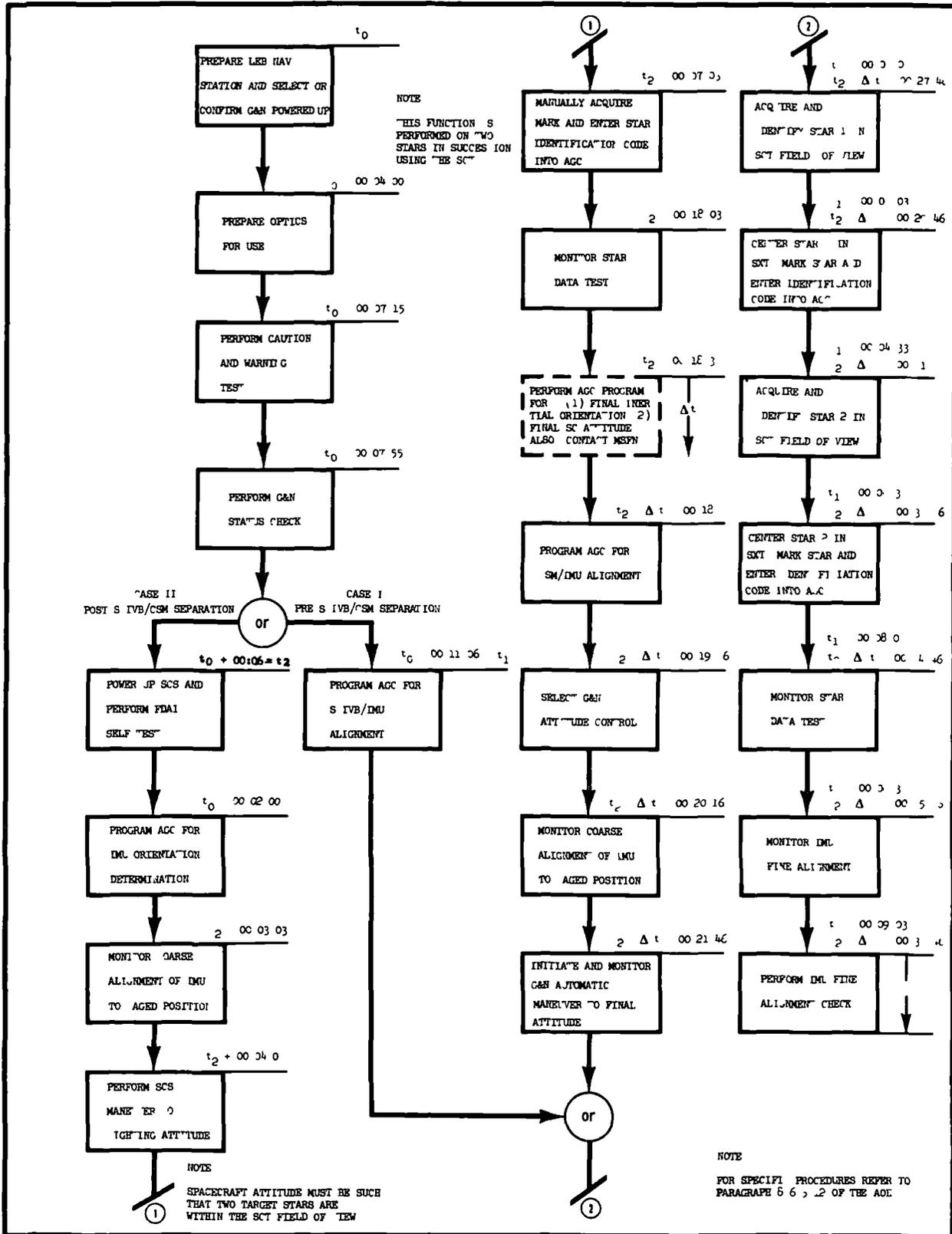


Figure 6-8 Building Block 7 IMU Alignment

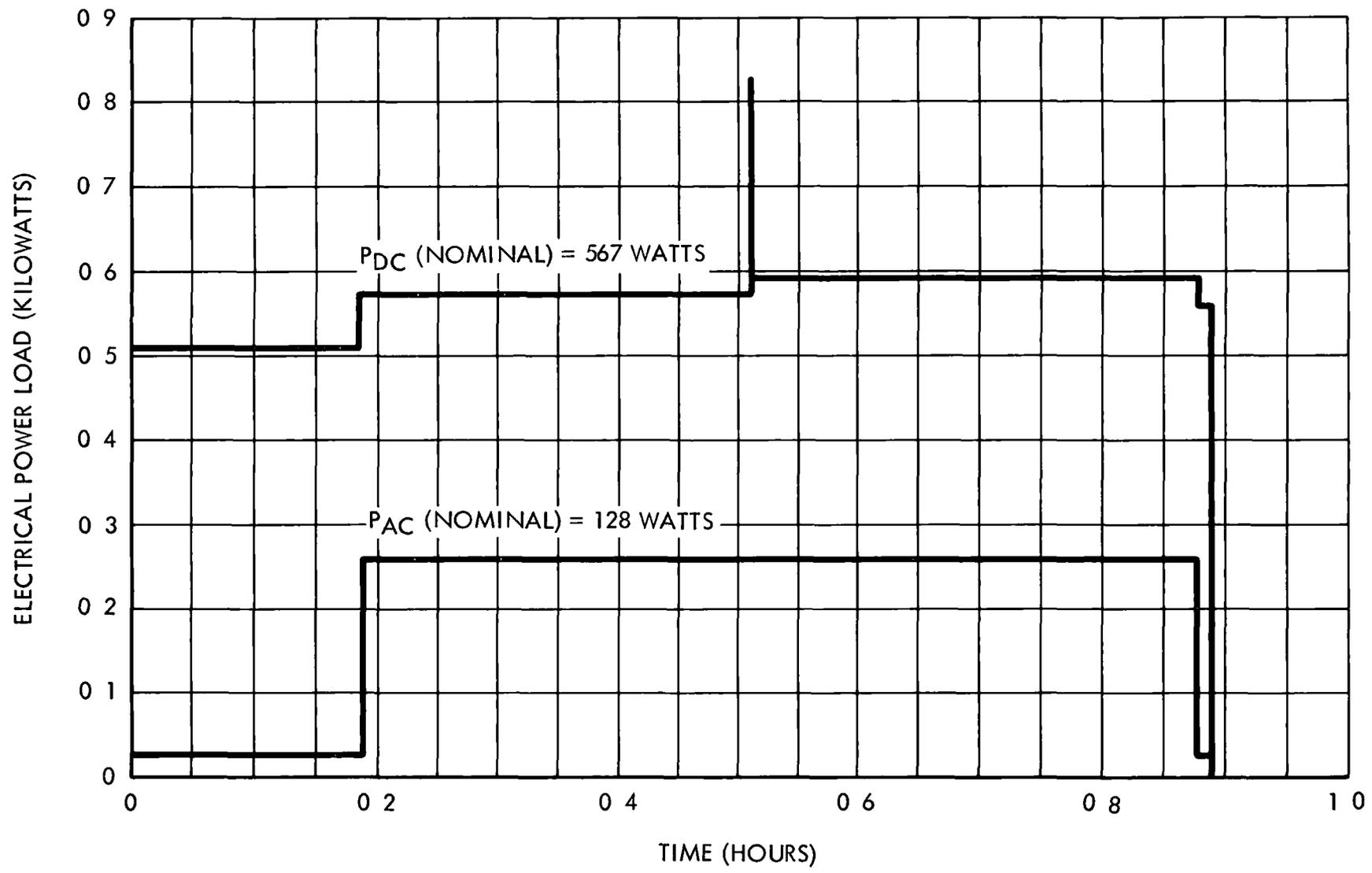


Figure 6-9 Electrical Power Profile (Delta)

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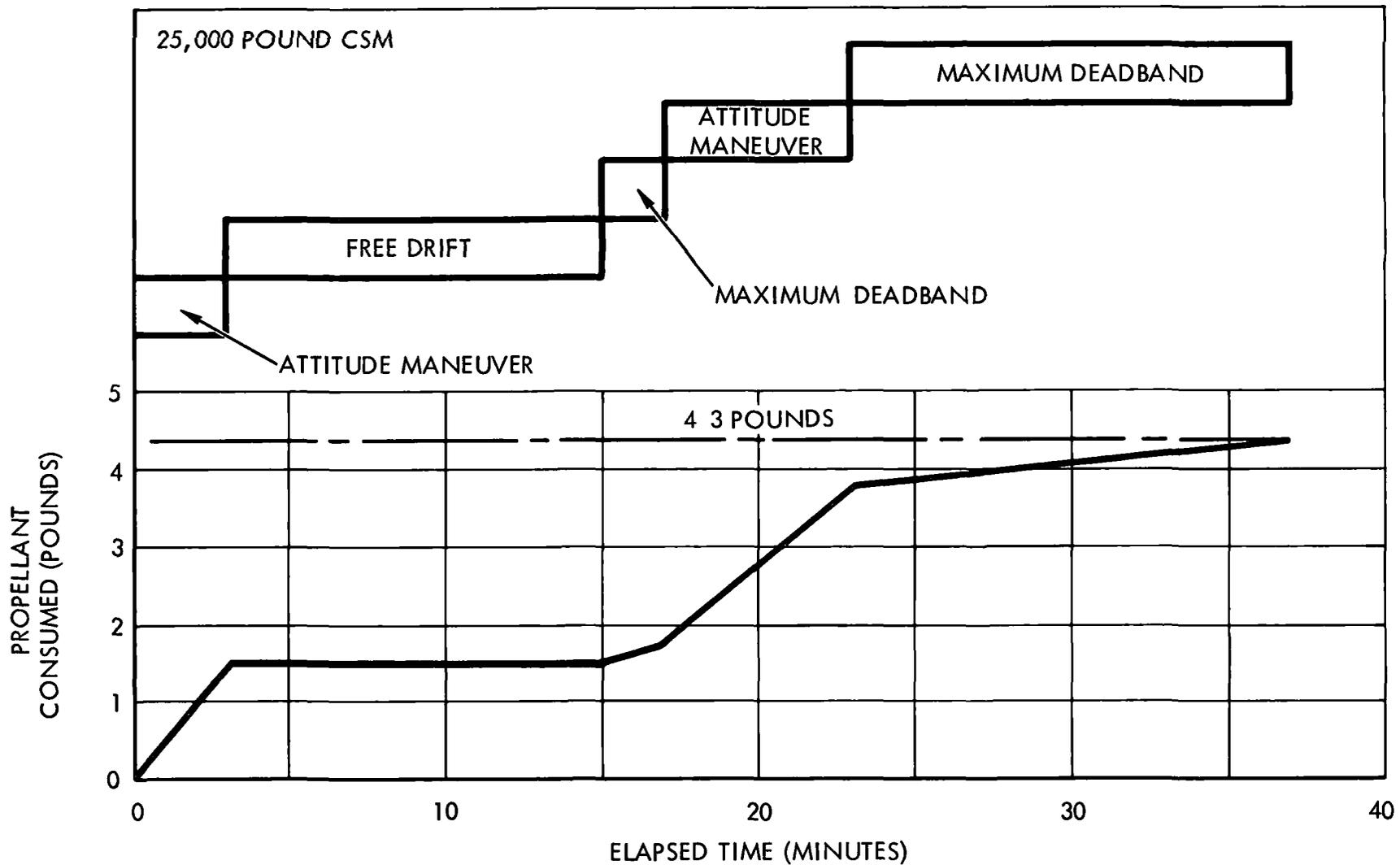


Figure 6-10 Service Module RCS Propellant Profile

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BUILDING BLOCK 8 NAVIGATION SIGHTINGS

8 1 LANDMARK NAVIGATION SIGHTINGS

8 1 1 Introduction

Earth landmark navigation sightings will be used for the purpose of onboard orbital determination. Section 8 1 covers earth landmark navigation sightings with the CSM still attached to the S-IVB, in addition to the unconstrained spacecraft earth landmark navigation sightings. However, the generation of duty cycles, electrical power profile, and consumables are based on earth landmark navigation sightings occurring after the spacecraft has separated from the S-IVB.

Section 8 1 starts with the presumption that an IMU alignment (refer to BB-7) has been accomplished, and ends with the confirmation of the AGC calculation of updated position and velocity with MSFN.

8 1 2 Operational Data

8 1 2 1 General Information

For earth landmark sightings the navigator will delay calling the G&N landmark tracking program until all presighting tasks have been performed and the vehicle attitude rates have reduced to approximately minimum impulse level. Once the landmark tracking program is called the vehicle will be placed under SCS attitude hold with free drift in pitch. The pitch rate will be approximately equal to earth rate. The vehicle will remain satisfactory for landmark sightings for a minimum of 10 minutes.

During earth landmark navigation sightings, certain information must be obtained by looking through the scanning telescope (SCT). Optics coverage is shown in Figure 6-11. Due to the short time available to perform an earth orbit landmark sighting (48 seconds maximum, 20 seconds minimum), it is not advisable to obtain the required information in any other manner. The information that must be obtained by looking through the SCT is as follows:

- 1 Landmark Recognition Limit. The point at which the landmark must be recognized so that sufficient time remains to acquire, track, and accurately obtain "marks" before the landmark passed from the SCT field of view.



- 2 Distance from Orbital Plane Based on the standard attitude described for navigation sightings, the distance the landmark is from the orbital plane must be determined when the landmark is first recognized. Landmarks within 13 nautical miles of the orbital plane should be avoided since they would pass through the "blind zone" of the SCT. If such landmarks are required, the "blind zone" region could be moved by rolling the spacecraft.
- 3 Landmark Definition Limit The point at which the landmark definition is fine enough to allow accurate "marks". It is presently accepted that the landmark will have sufficient definition when the angle between the line-of-sight to the landmark and the vehicle's local vertical is less than 45 degrees.

It is recommended that three marks be accomplished during each land navigation sighting.

8 1 2 2 Mission Functional Flows

See Figure 6-12

8 1 2 3 Operational Timeline Segment

See Table 6-11. The operational timeline segment schedules the spacecraft operations and crew activities required to perform earth landmark navigation sightings. The level of detail includes only those operations required to aid in defining total event duration, duty cycles, and consumable profiles. Estimated duration times for the crew operations are included.

8 1 2 4 Attitude Maneuvers

The first paragraph under Attitude Maneuvers in BB-7, IMU Alignment, is also applicable to this block.

During periods of earth landmark navigation sightings, with the spacecraft attached to the S-IVB, attitude is preprogrammed to remain fixed in regard to the local horizontal. In this attitude the spacecraft X-Z plane is coincident with the trajectory plane, with the +X axis within one degree of the local horizontal, pointing in the direction of motion. The +Z axis has a positive projection on the downward local vertical. Earth landmarks within 13 nautical miles of the orbital plane should not be used as they will pass through the "blind zone" of the SCT (typically shown in Figure 6-13), otherwise, a roll maneuver would be required to avoid the blind zone.



Table 6-11 Operational Timeline Segment for Landmark Navigation Sightings and Celestial Navigation Sightings

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
LANDMARK NAVIGATION SIGHTING			
	<p>Note Section 8.1 of this block should be preceded by the operations detailed in Block 7 IMU Alignment Para 7.4.4</p>		<p>If the spacecraft has separated from the S-IVB this operation also includes the power-up of the SCS (See Case II of Block 7 Paragraph 7.4.4)</p> <p>The IMU should be aligned to the prelaunch orientation as this orientation will not result in IMU gimbal lock during earth landmark navigation sightings</p> <p>If the IMU has been in continuous operation since the last IMU alignment (prelaunch orientation) perform an IMU update (fine) alignment</p>
<p>$t_0 + 00\ 00\ 00$</p>	<p>Select SCS attitude control maximum dead-band (00 00 40)</p>	<p>E</p>	<p>Omit this operation if the spacecraft is constrained to the S-IVB</p> <p>Reference BB-11 Paragraph 11.3.1</p>
<p>$t_0 + 00\ 00\ 40$</p>	<p>Perform SCS attitude maneuver to FDAI attitude ball reference (00 06 00)</p>	<p>G</p>	<p>Reference AOH, paragraph 8.6.5.7 and BB-11 paragraph 11.3.2</p> <p>This operation is unnecessary if the spacecraft is constrained to the S-IVB with the IU of the S-IVB providing attitude control satisfactory for earth landmark navigation sightings</p>
<p>$t_0 + 00\ 06\ 40$</p>	<p>Select SCS attitude hold with free drift in pitch (00 00 10)</p>	<p>E</p>	<p>The spacecraft should be maneuvered to a FDAI total attitude with respect to the FDAI body axis symbol of 0 degrees in roll 340 degrees in pitch and 0 degrees in yaw</p> <p>Reference BB-11 Paragraph 11.3.1</p>
<p>$t_0 + 00\ 06\ 50$</p>	<p>Perform earth orbit landmark navigation sightings (00 17 00 minimum estimate)</p> <p>Select AGC program for landmark tracking navigation measurement (00 01 00)</p>	<p>G</p>	<p>Reference AOH Paragraph 8.3.1.6 or 8.6.5.14</p> <p>Select program at an appropriate time prior to desired landmark acquisition</p>



Table 6-11 Operational Timeline Segment for Landmark Navigation Sightings and Celestial Navigation Sightings (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t ₀ + 00 07 50	Perform AGC-assisted or manual acquisition of landmark and perform mark (00 05 00)		<p>Time duration shown is for obtaining code book and locating and selecting program code</p> <p>The proper selection of earth track charts may be facilitated by MSFN communicating (via voice communications) the spacecraft ground track to the flight crew</p> <p>Procedures detailed in AOH Paragraphs 8 6 7 3 through 8 6 7 5 may be used to help select the proper earth track chart</p> <p>Adjust pitch attitude as required using attitude impulse control so that a local vertical mode is approximated (Reference B-11 Paragraph 11 4 2)</p> <p>Time duration shown includes the initial selection and inspection of proper earth track chart</p>
t ₀ + 00 12 50	Enter landmark geographical data into the AGC (00 00 30)	E	
t ₀ + 00 13 20	Monitor AGC display of orbital parameter changes (00 00 30)	E	
t ₀ + 00 13 50	Repeat last three steps if additional sightings are to be performed (variable duration)	G	<p>A specific duration is not assigned because of dependency upon such real time CONTINGENCIES as favorable lighting conditions spacecraft orbital position with respect to land masses availability of suitable landmarks cloud coverage subsequent mission operations etc Assuming optimum conditions exist a reasonable minimum duration for this operation is 10 minutes</p> <p>If onboard orbital determination is to be demonstrated it is recommended that earth orbit navigation sightings be performed during the two orbits prior and three orbits subsequent to any orbital maneuver, plane changes or retrograde affecting the orbit A minimum</p>



Table 6-11 Operational Timeline Segment for Landmark Navigation Sightings and Celestial Navigation Sightings (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
$t_1 + 00 23 50$	Confirm AGC calculation of updated position and velocity with MSFN (00 05 00)	G	of three sightings as equally spaced as possible should be performed during each sighting orbit Complete at 00 28 50 The MSFN confirmation is not included in the duty cycle or electrical power profile
CELESTIAL NAVIGATION SIGHTING			
$t_1 + 00 00 00$	Select or confirm SCS powered-up with FDAI self-test performed (00 02 00)	E	Reference AOH Paragraph 8 6 3 5 The BMAG power switch is presumed to remain in the AC2 position for the entire mission thus eliminating the need for a 40-minute warmup period that would occur if the BMAG's had to be powered-up from OFF to AC2
$t_1 + 00 02 00$	Select or confirm SCS attitude control (maximum deadband) (00 00 40)	E	Reference Block 11 Paragraph 11 2 1
$t_1 + 00 02 40$	Perform SCS attitude maneuver to external reference (00 06 00)	G	Reference AOH Paragraph 8 6 5 8 and Block 11 Paragraph 11 2 2 External references are stars and/or lunar landmarks Spacecraft should be maneuvered to the gross orientation required for the precise orientation of the spacecraft using the SCT with a lunar landmark used as a reference
$t_1 + 00 08 40$	Prepare or confirm AGC and optics ready for use (00 04 00) Select or confirm AGC powered-up Activate optics power Unstow and mount SCT and SXT eyepieces Perform AGC condition lamps status check	E	Section 8 2 of this block does not require the IMU to be erected and aligned
$t_1 + 00 12 40$	Perform precise spacecraft orientation using the SCT (00 05 00)	G	Reference AOH Paragraph 8 6 5 10 and Block 11 Paragraph 11 3 2 Lunar landmark used as reference



Table 6-11 Operational Timeline Segment for Landmark Navigation Sightings and Celestial Navigation Sightings (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t ₁ + 00 17 40	Perform celestial (lunar landmark/star) navigation sighting (00 10 00)	E	Reference AOH Paragraph 8 6 5 11
t ₁ + 00 17 40	Select AGC program for lunar land landmark/star navigation measurement (00 01 00)	E	Time duration shown is for obtaining code book locations and selecting program code
t ₁ + 00 18 40	Locate and identify lunar landmark in SXT FOV (00 01 00)	E	
t ₁ + 00 19 40	Center lunar landmark in SXT FOV (00 01 00)	E	Adjust spacecraft attitude as required using attitude impulse control to center lunar landmark in the SXT FOV (Reference Block 11 Paragraph 11 3 2)
t ₁ + 00 20 40	Perform acquisition of target star in SCT FOV (00 01 00)	E	
t ₁ + 00 21 40	Center target star in SCT FOV (00 01 00)	E	
t ₁ + 00 22 40	Superimpose star on landmark in SXT FOV and perform mark (00 01 00)	E	Superimpose star and landmark by using OPTICS HAND CONTROLLER to move the star and the MINIMUM IMPULSE CONTROL (attitude impulse control) to move the landmark (Reference Block 11 Paragraph 11 3 2) The star and the landmark must be superimposed near or on the center of the field of view or the R line
t ₁ + 00 23 40	Monitor AGC display of optics angles and time of mark (00 01 00)	E	
t ₁ + 00 24 40	Confirm MSFN receipt of optical data (00 03 00)	G	Complete at t ₁ + 00 27 40

TIME SOURCE CODE E = ENGINEERS ESTIMATE (Derived from statistical analysis e g the computer formula or data provided by cognizant engineering groups such as alignment time of FDAI etc)

G = GUESS (An approximation based upon the engineering assumption of a realistic time limit)



During earth landmark navigation sightings that occur after spacecraft separation from the S-IVB, the spacecraft attitude may be constrained such that the +X axis is pitched 20 degrees below the local horizontal and the X-Z plane coincident with the trajectory plane. This attitude increases the optical coverage of the earth's surface and enables the predetermined landmarks to be tracked as they pass through the large field of view of the SCT without excessive spacecraft maneuvering.

If a proportional rate maneuver is required (because of cloud coverage, landmarks in blind zone, etc.) to adjust the CSM attitude for tracking landmarks, proportional rate maneuvers (see BB-11) are specified between 0.1 and 0.65 degrees per second. However, it is improbable that the lower limit can be commanded in practical situations. For scheduling purposes, proportional rate maneuvers are presumed to be performed at a minimum rate of 0.2 degree per second.

If minimum impulse is required to accomplish fine adjustment of spacecraft attitude for landmark navigation sightings, use of minimum impulse (see Block 11) excites rates of from 0.01 to 0.05 degrees per second.

8 1 2 5 Duty Cycles

See Table 6-12

8 1 2 6 Electrical Power Profile

The average delta power levels are as follows

$$P_{AC} \text{ (Nominal)} = 158.6 \text{ watts}$$

$$P_{DC} \text{ (Nominal)} = 336.7 \text{ watts}$$

8 1 2 7 Service Module RCS Propellant Consumption

Approximately 2.2 pounds of service module/RCS propellant are consumed during this block, as shown in Figure 6-14.



Table 6-12 Subsystem Duty Cycles, Navigation Sightings, Landmark~Post-S-IVB/CSM Separation Only (Duration 0 481 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 8 1
Stabilization and Control				
RGP		3 and 2	0	10 4 in 3 89 6 in 2
BMAG		3 and 2	0	10 4 in 3 89 6 in 2
FDAI		3 and 2	0	10 4 in 3 89 6 in 2
AS/GPI		3 and 2	0	10 4 in 3 89 6 in 2
Δdisplay			0	
Rotation controller		3 and 2	0	10 4 in 3 89 6 in 2
SCS control panel		3 and 2	0	10 4 in 3 89 6 in 2
ECA pitch		3 and 2	0	10 4 in 3 89 6 in 2
ECA roll		3 and 2	0	10 4 in 3 89 6 in 2
ECA yaw		3 and 2	0	10 4 in 3 89 6 in 2
ECA auxiliary		3 and 2	0	10 4 in 3 89 6 in 2
ECA display		3 and 2	0	10 4 in 3 89 6 in 2
Electronics display		3 and 2	0	10 4 in 3 89 6 in 2
TVC OPERATE			0	
STANDBY		3 and 2	0	10 4 in 3 89 6 in 2
Guidance and navigation				
AGC OPERATE		C	0	100
STANDBY		F	100	0
IMU OPERATE		C	0	100
STANDBY		F	100	0
Optics		C	0	100
Displays and controls		C	0	100
Service Module RCS				
Engine heaters			62 5	Same as BB-9
RCS engine coils		Automatic	0	0 0677
He isolation valves			0	
Propellant isolation valves			0	
Command Module RCS				
Isolation valves			0	
RCS engine coils			0	



8 1 3 Performance

The performance data for spacecraft maneuvers and the optics subsystem are the same as those shown in BB-7, IMU Alignment

8 2 CELESTIAL NAVIGATION SIGHTINGS

8 2 1 Introduction

For the initial Block I manned mission, celestial navigation sightings will be used for the demonstration of lunar landmark/star navigation angular measurements Paragraph 8 2 presumes that the lunar landmark/star navigation sighting will be conducted over a ground tracking station, so that telemetry of the spacecraft position, time, and the optics angles may be received by MSFN for analysis

Paragraph 8 2 starts with the selection or confirmation of the stabilization and control subsystem (SCS) being powered up and ends with the confirmation of MSFN receipt of optical data

8 2 2 Operational Data

8 2 2 1 General Information

For Block I missions, the celestial navigation sightings will be an abbreviated sequence for experimental analysis only The IMU is not required to be erected and aligned for this sequence

8 2 2 2 Mission Functional Flow

See Figure 6-12

8 2 2 3 Operational Timeline Segment

See Table 6-11 The operational timeline segment schedules the spacecraft operation and crew activities required to perform celestial (lunar landmark/star) navigation sightings The level of detail includes only those operations which are required to aid in defining total event duration, duty cycles, and consumable profiles Estimated duration times for the crew operations are included

8 2 2 4 Attitude Maneuvers

Paragraph 8 1 2 4 also is applicable to this section



Demonstration of lunar landmark/star navigation angular measurement requires that the SCT/SXT shaft drive axis (SDA) be pointed at the lunar landmark and that the SXT line-of-sight to the star fall within 45 degrees of the SDA (Note The SDA is fixed relative to the spacecraft) Generally, a 3-axis maneuver will be required to achieve the proper attitude

8 2 2 5 Duty Cycles

See Table 6-13

8 2 2 6 Electrical Power Profile

The average delta power levels are as follows

$$P_{AC} \text{ (Nominal)} = 151.9 \text{ watts}$$

$$P_{DC} \text{ (Nominal)} = 145.1 \text{ watts}$$

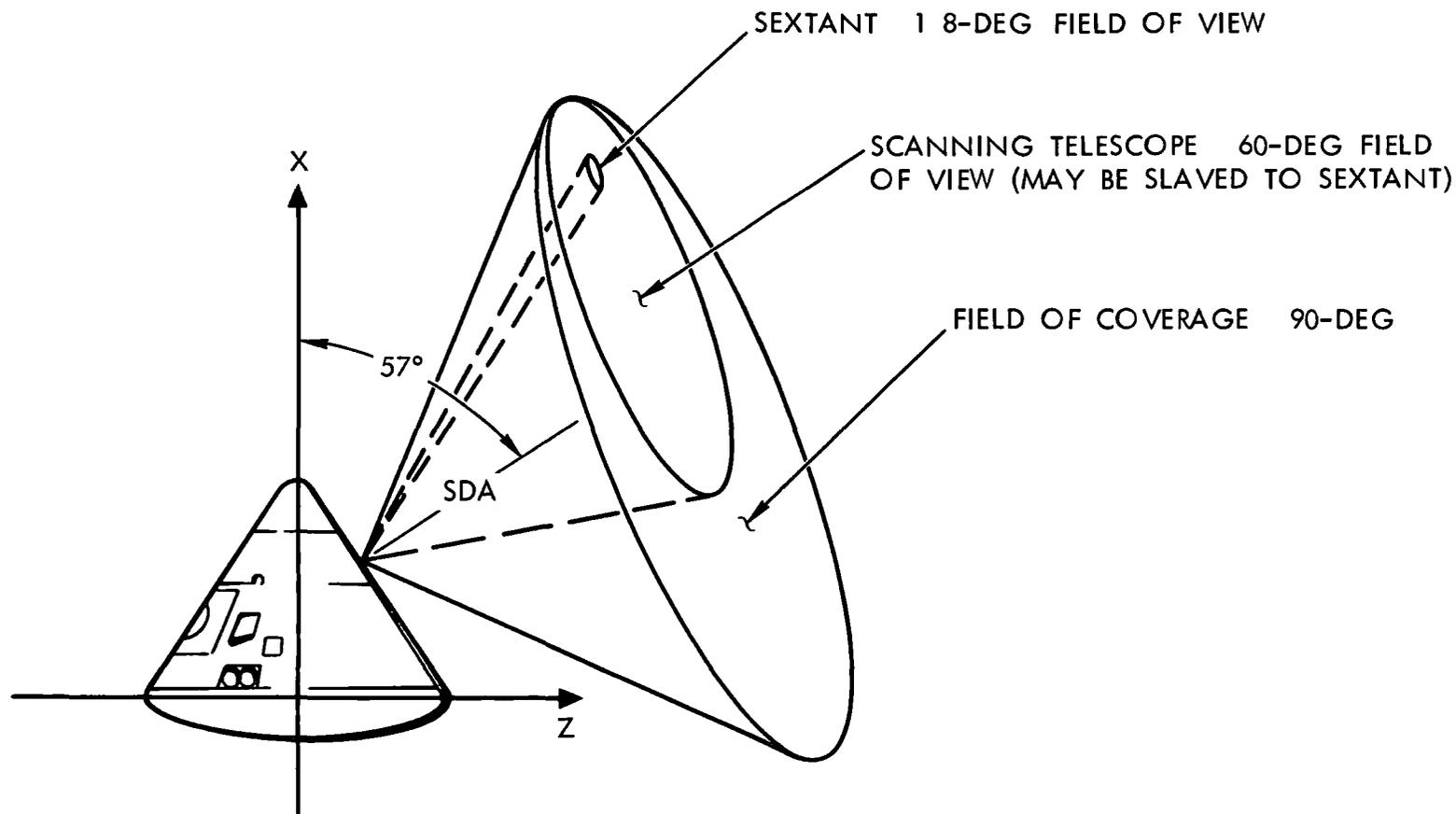
8 2 2 7 Propellant Consumption

Approximately 2.5 pounds of service module RCS propellant are consumed during this block as shown in Figure 6-15



Table 6-13 Subsystem Duty Cycles, Navigation Sightings, Celestial Post-S-IVB/CSM Separation Only (Duration 0 461 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 8 2
Stabilization and control				
RGP		3 and 2	0	10 85 in 3 89 15 in 2
BMAG		3 and 2	0	10 85 in 3 89 15 in 2
RDAI		3 and 2	0	10 85 in 3 89 15 in 2
AS/GPI		3 and 2	0	10 85 in 3 89 15 in 2
ΔV display Rotation controller		3 and 2	0	10 85 in 3 89 15 in 2
RCS control panel		3 and 2	0	10 85 in 3 89 15 in 2
ECA pitch		3 and 2	0	10 85 in 3 89 15 in 2
ECA roll		3 and 2	0	10 85 in 3 89 15 in 2
ECA yaw		3 and 2	0	10 85 in 3 89 15 in 2
ECA auxiliary		3 and 2	0	10 85 in 3 89 15 in 2
ECA display		3 and 2	0	10 85 in 3 89 15 in 2
Electronics display		3 and 2	0	10 85 in 3 89 15 in 2
TVC OPERATE STANDBY		3 and 2	0	10 85 in 3 89 15 in 2
Guidance and navigation				
AGC OPERATE		E	0	68 65
STANDBY		F	100	31 35
IMU OPERATE			0	0
STANDBY		F	100	0
Optics		F and E	0	31 35 in F 68 65 in E
Displays and controls		F and E	0	31 35 in F 68 65 in E
Service Module RCS				
Propellant quantity gauging			0	
Engine heaters			62 5	
RCS engine coils		Automatic	0	0 0717
He isolation valves			0	
Propellant isolation valves			0	
Command Module RCS				
Isolation valves			0	
RCS engine coils			0	



NOTE THE SCANNING TELESCOPE 60-DEG FIELD OF VIEW IS AVAILABLE ANYWHERE WITHIN THE 90-DEG FIELD OF COVERAGE

Figure 6-11. Optics Coverage

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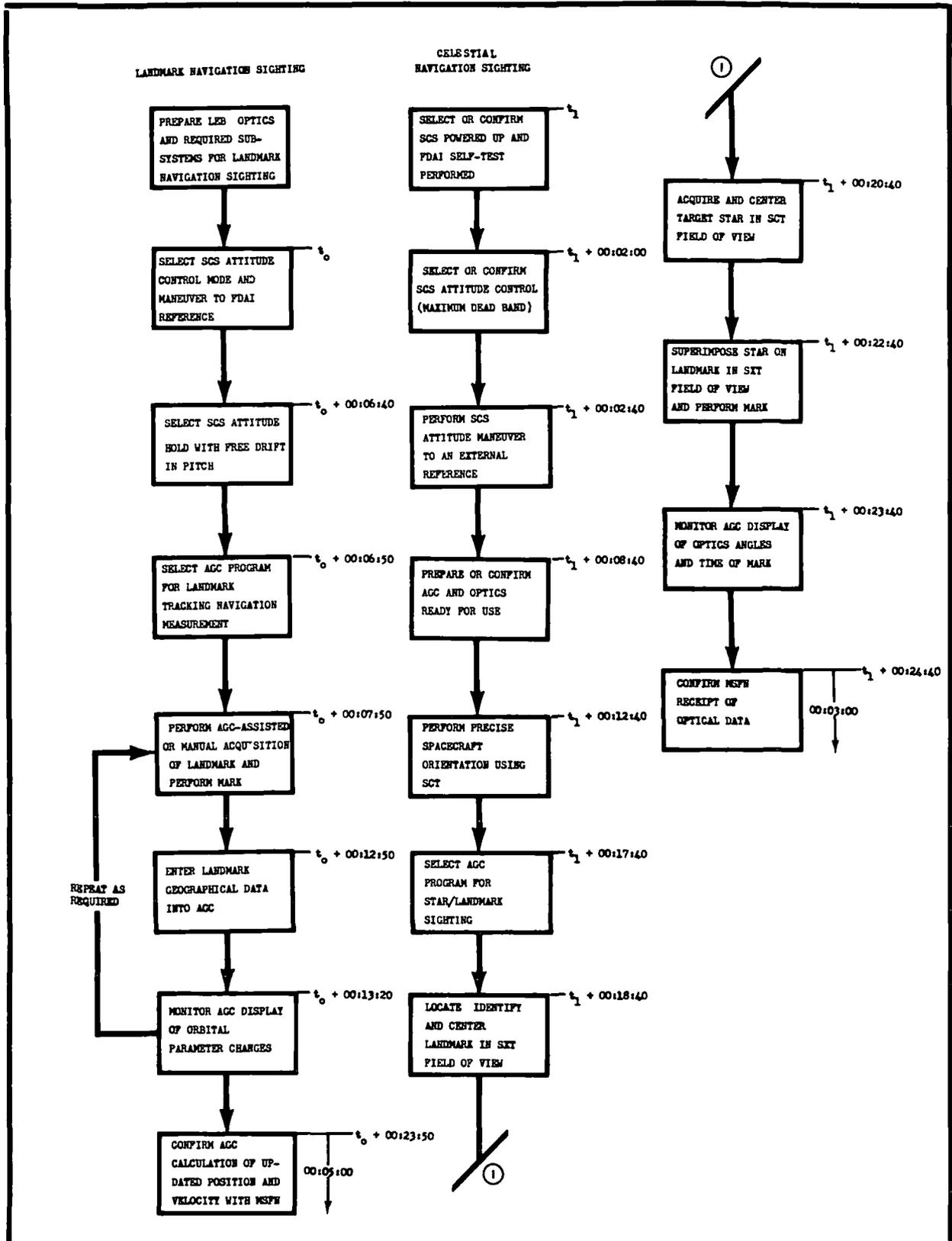


Figure 6-12 Building Block 8 Navigation Sightings



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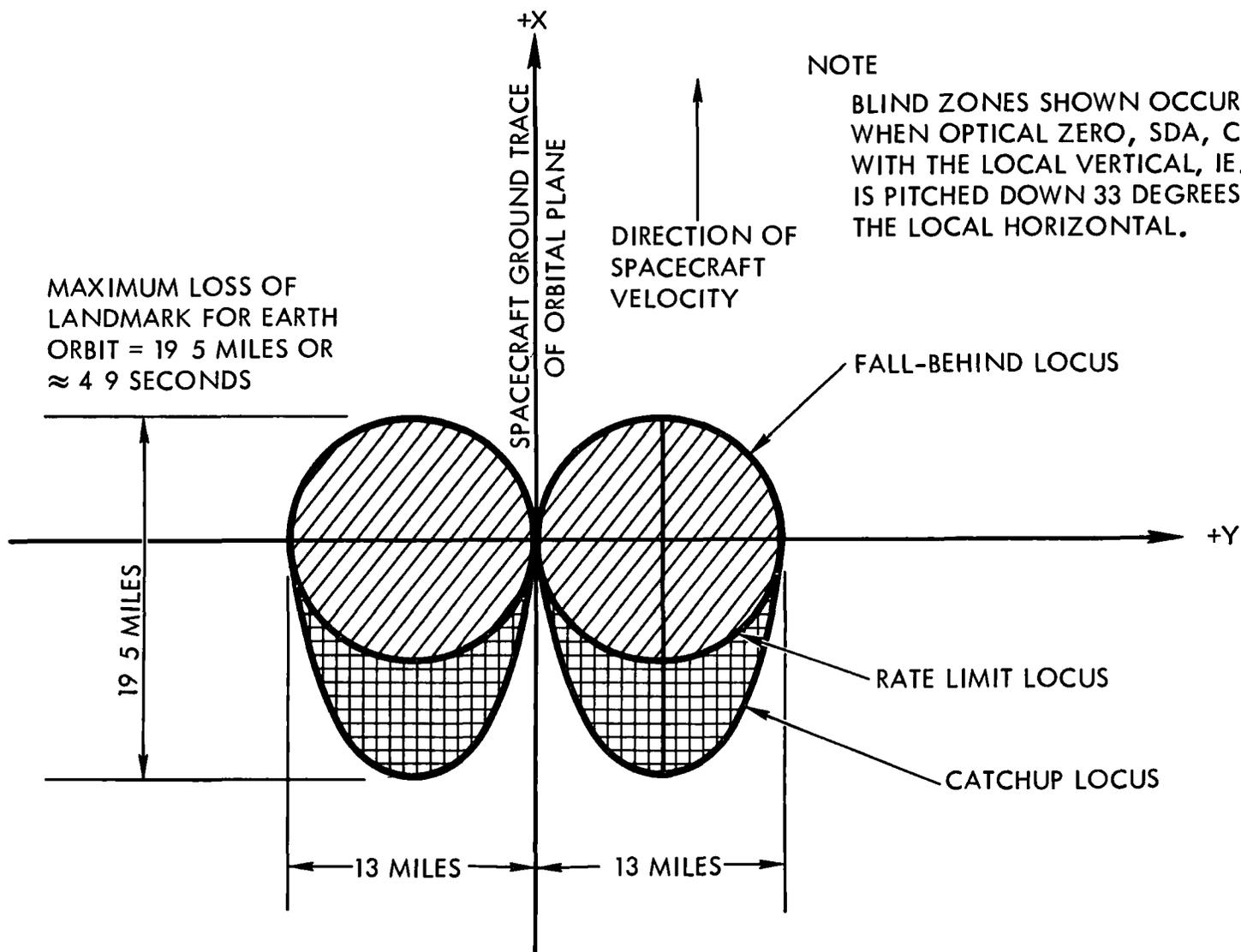


Figure 6-13 Optics Blind Zones

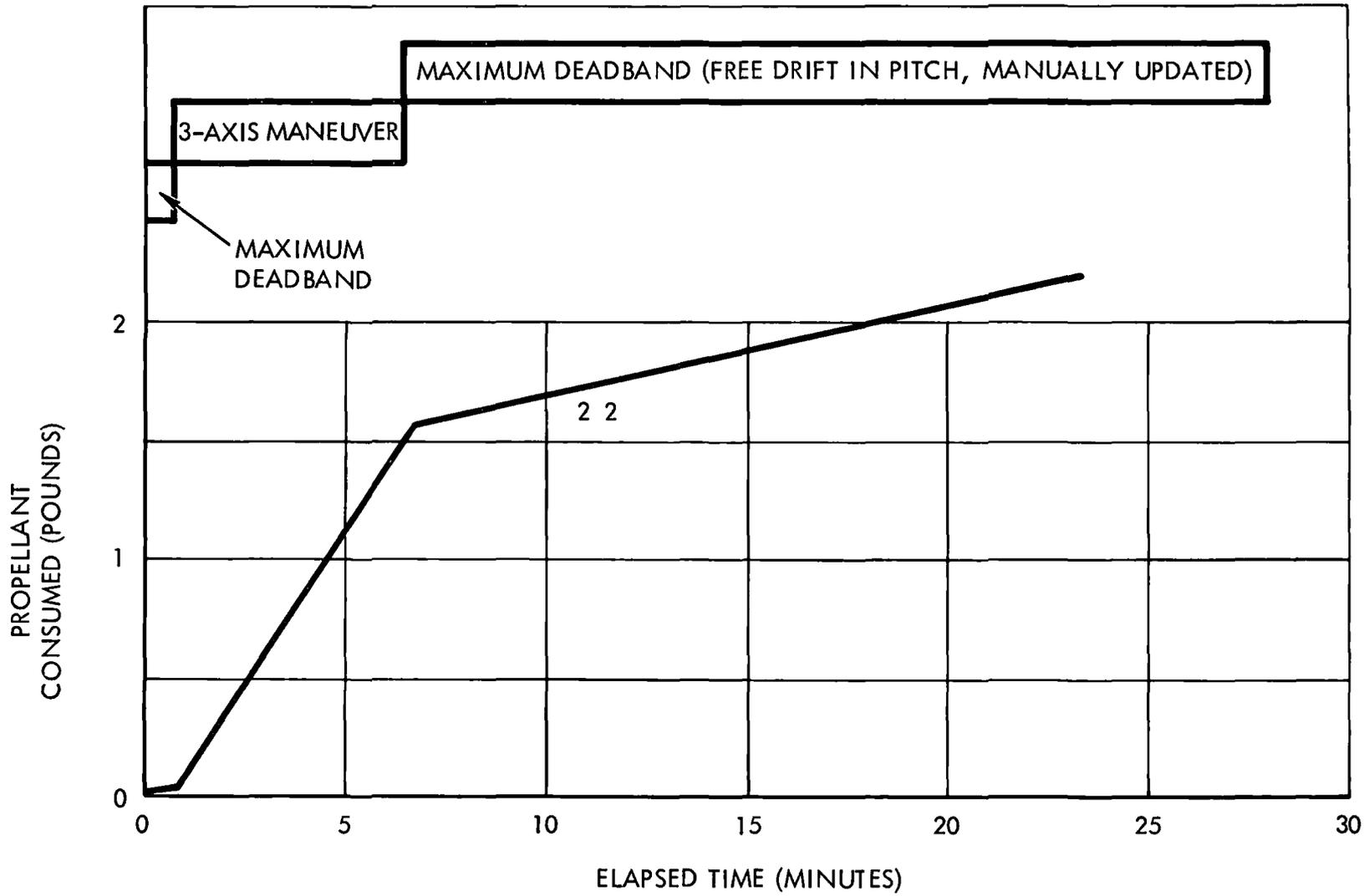


Figure 6-14 RCS Propellant Consumption, Landmark Navigation Sightings





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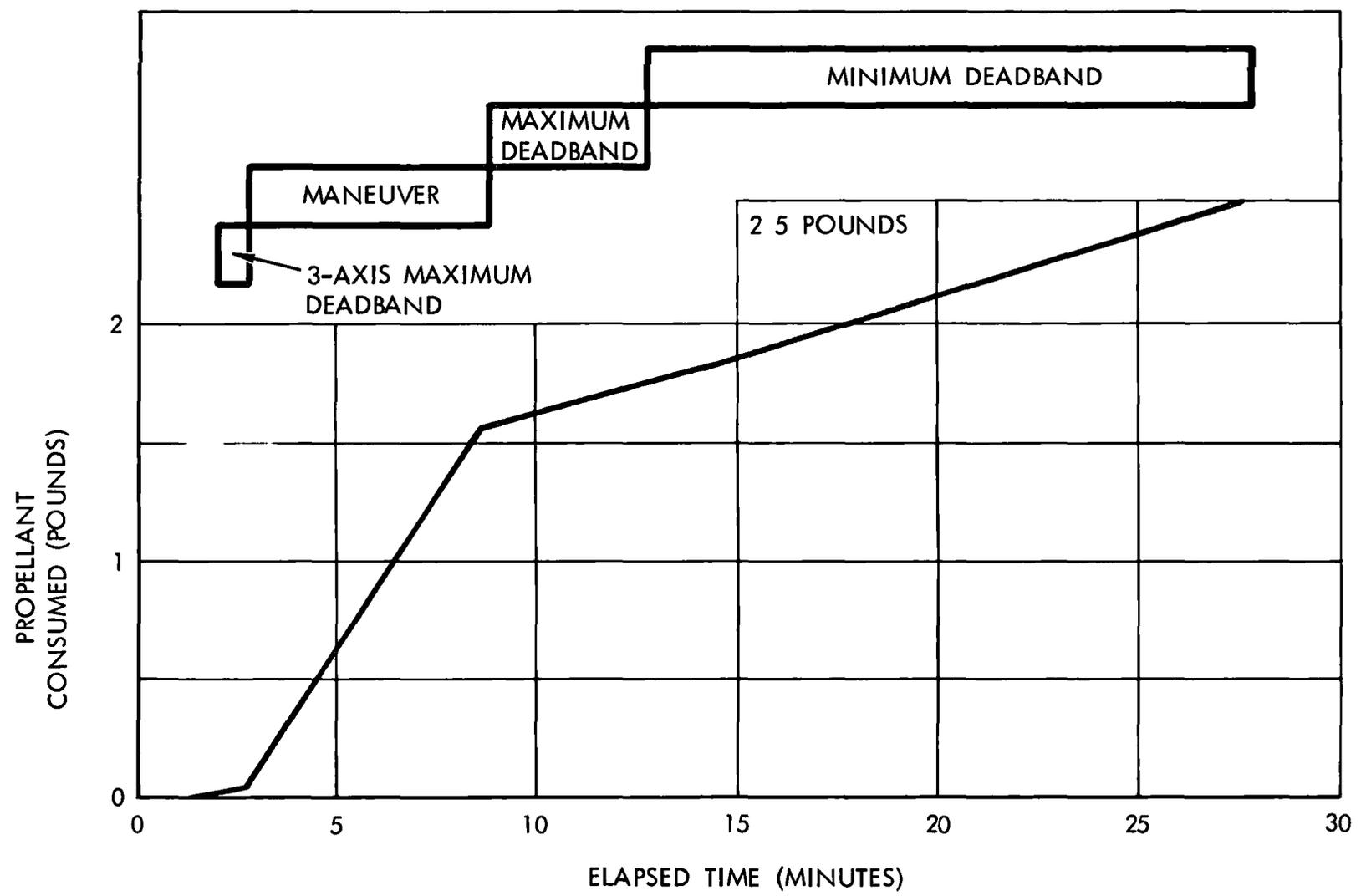


Figure 6-15 RCS Propellant Consumption, Celestial Navigation Sightings



BUILDING BLOCK 9 DRIFTING FLIGHT

9 1 ALTERNATE MODE 1, DRIFTING FLIGHT, POWERED DOWN

9 1 1 Introduction

This building block comprises a representative 24-hour segment of the earth orbit mission phase. During this mission segment, only those routine events and functions necessary to safe mission continuation are performed. Normal functioning of all spacecraft subsystems is presumed, but equipment for which no operational requirement exists are turned off or placed in standby modes to conserve electrical power, even if the minimum power levels stated in the Apollo fuel cell specification for three fuel cell operation are not maintained. No spacecraft test objectives or experiment accomplishments are included. No provision has been made for biasing the attitude drift rates during this 24-hour period. Crew and MSFN monitoring of environmental control subsystem (ECS) radiator outlet and inlet temperatures will detect the need for an attitude rate bias maneuver. The frequency with which such a maneuver might be required has not yet been determined. No attitude maneuver to improve MSFN communication capabilities are included.

No entry procedures into this building block are shown. The entry is not time-critical, and the accomplishment of a check-list following the completion of any other building block will assure correct spacecraft operating configuration. No exit procedure is called out, as termination of this building block will be through the preparation for, or entry into, another building block.

9 1 2 Operational Data

9 1 2 1 General Information

The operations outlined in the representative 24-hour operational timeline segment (Table 6-14) reflect the following assumptions:

- 1 VHF voice communications with MSFN will occur once per revolution
- 2 High data bit-rate PCM telemetry signals will be transmitted over every MSFN station capable of receiving them



- 3 The C-band transponder is ON approximately one hour per day and is being interrogated 45 minutes per day
- 4 The UHF updata link and the three audio centers (low-power mode) are operated continuously
- 5 Preservation of periodic subsystem status check scheduling is maintained between this block and the preceding and following building blocks
- 6 The specification minimum power level for three fuel cell operation is not observed, under the assumption that ground tests will verify safe operation at lower power levels

9 1 2 3 Operational Timeline Segment

See Table 6-14

9 1 2 4 Attitude Maneuvers

No attitude maneuvers will be performed unless biasing of the spacecraft attitude drift rates, as indicated by ECS radiator outlet and inlet temperature readings, becomes necessary

9 1 2 5 Duty Cycles

Equipment duty cycles, as a delta to the common level listed in Section 3 0, are shown in Table 6-15. When this building block is used for periods of time differing from multiples of 24 hours, deviations from the average duty cycles shown (particularly in the case of telecommunications equipment) should be anticipated.

9 1 2 6 Electrical Power

The average delta power levels are as follows

$$P_{AC} \text{ (nominal)} = 26.5 \text{ watts}$$

$$P_{DC} \text{ (nominal)} = 39.8 \text{ watts}$$

The minimum transient power level is 578.7 watts ac and 416.2 watts dc. This represents a fuel cell load of 1335 watts, with corresponding total current and bus voltage readings of 42.0 amps and 31.0 volts, respectively.

9 1 2 7 Propellant Consumption

No propellants are required unless attitude rate biasing becomes necessary.



Table 6-14 AM-1 Representative 24-Hour Timeline,
Drifting Flight, Powered Down

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 00 00	Commander start sleep period		
00 00 00	Navigator doff PGA (05 00)		
00 20 00	Perform EPS status check (02 00)		
00 22 00	Perform ECS status check (01 00)		
00 30 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
00 52 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
01 00 00	Perform check on batteries A B and C (01 00)		
01 00 00	Perform fuel cell oxygen purge (07 00)		
01 20 00	Perform EPS status check (02 00)		
01 22 00	Perform ECS status check (01 00)		
02 05 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
02 10 00	Accept voice PLA retrofire data from MSFN (02 00)		
02 14 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
02 20 00	Perform EPS status check (02 00)		
02 22 00	Perform ECS status check (01 00)		
03 32 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
03 00 00	Perform SPS status check (02 00)		
03 15 00	Navigator start eat period warm meal (45 00)		
03 15 00	Systems engineer start eat period warm meal (45 00)		
03 20 00	Perform EPS status check (02 00)		
03 22 00	Perform ECS status check (01 00)		
03 32 45	Perform SM RCS status check (02 00)		
03 42 00	Perform voice confirmation of satisfac- tory status with MSFN (03 00)		



Table 6-14 AM-1 Representative 24-Hour Timeline,
Drifting Flight, Powered Down (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
03 49 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
04 00 00	Navigator start sleep period		
04 00 00	Perform SPS status check (02 00)		
04 20 00	Perform EPS status check (02 00)		
04 22 00	Perform ECS status check (01 00)		
04 30 00	Perform fuel cell hydrogen purge (05 00)		
05 06 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
05 06 45	Perform SM RCS status check (02 00)		
05 15 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
05 20 00	Perform EPS status check (02 00)		
05 21 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
05 22 00	Perform ECS status check (01 00)		
06 00 00	Replace CO ₂ absorber element (10 00)		
06 20 00	Perform EPS status check (02 00)		
06 22 00	Perform ECS status check (01 00)		
06 36 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
06 38 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
06 43 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
07 00 00	Perform CM RCS status check (01 00)		
07 15 00	System engineer start eat period, hot meal (45 00)		
07 20 00	Perform EPS status check (02 00)		
07 22 00	Perform ECS status check (01 00)		
07 27 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		



Table 6-14 AM-1 Representative 24-Hour Timeline,
Drifting Flight, Powered Down (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
07 30 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
07 37 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
07 48 00	Systems engineer don PGA (07 00)		
07 55 00	Commander end sleep period		
07 55 00	Commander doff PGA (05 00)		
08 00 00	Systems engineer start sleep period		
08 00 00	Perform check on batteries A, B, and C (01 00)		
08 00 00	Perform fuel cell oxygen purge (07 00)		
08 08 00	Select VHF/FM transmitter ON (00 15) Select VHF/AM TRANSMIT/RECEIVE Select VHF/AM TRANSMIT/RECEIVE		
08 20 00	Perform EPS status check (02 00)		
08 22 00	Perform ECS status check (01 00)		
08 26 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
08 30 00	Commander start eat period hot meal (45 00)		
09 01 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
09 03 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
09 06 00	Accept voice PLA retrofire data from MSFN (02 00)		
09 10 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
09 20 00	Perform EPS status check (02 00)		
09 22 00	Perform ECS status check (01 00)		
09 42 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
10 00 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
10 20 00	Perform EPS status check (02 00)		



Table 6-14 AM-1 Representative 24-Hour Timeline,
Drifting Flight, Powered Down (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
10 22 00	Perform ECS status check (01 00)		
10 39 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
10 42 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
10 48 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
11 00 00	Perform SPS status check (02 00)		
11 20 00	Perform EPS status check (02 00)		
11 22 00	Perform ECS status check (01 00)		
11 30 00	Perform fuel cell hydrogen purge (05 00)		
12 00 00	Navigator end sleep period		
12 00 00	Commander start eat period cold meal (45 00)		
12 00 00	Navigator start eat period hot meal (45 00)		
12 02 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
12 03 00	Perform SM RCS status check (02 00)		
12 15 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
12 20 00	Perform EPS status check (02 00)		
12 22 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
12 22 10	Perform ECS status check (01 00)		
12 51 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
13 06 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
13 20 00	Perform EPS status check (02 00)		
13 22 00	Perform ECS status check (01 00)		
13 34 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
13 49 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		



Table 6-14 AM-1 Representative 24-Hour Timeline,
Drifting Flight, Powered Down (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
13 56 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
14 20 00	Perform EPS status check (02 00)		
14 21 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
14 22 00	Perform ECS status check (01 00)		
14 40 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
15 00 00	Perform fuel cell oxygen purge (07 00)		
15 06 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
15 07 00	Perform SM RCS status check (02 00)		
15 09 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
15 20 00	Perform EPS status check (02 00)		
15 22 00	Perform ECS status check (01 00)		
15 30 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
15 53 00	Navigator doff PGA (07 00)		
15 55 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
16 00 00	Systems engineer end sleep period		
16 00 00	Systems engineer doff PGA (05 00)		
16 00 00	Commander start eat period warm meal (45 00)		
16 00 00	Navigator start eat period cold meal (45 00)		
16 00 00	Systems engineer start eat period warm meal (45 00)		
16 15 00	Perform check on batteries A, B, C (01 00)		
16 16 00	Perform status check on pyrotechnic batteries A and B (02 00)		



Table 6-14 AM-1 Representative 24-Hour Timeline,
Drifting Flight, Powered Down (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
16 18 00	Perform status check on inverters 1 and 2 (02 00)		
16 19 00	Perform CM RCS status check (01 00)		
16 20 00	Perform EPS status check (02 00)		
16 22 00	Perform ECS status check (01 00)		
16 24 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
16 34 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
16 36 00	Perform first daily MSFN-spacecraft status briefing (13 00)		
16 44 00	Confirm daily status with MSFN for continuation of mission flight to revolution Recovery Zone 1 (01 00)		
16 45 00	Accept voice PLA retrofire data from MSFN (02 00)		
17 20 00	Perform EPS status check (02 00)		
17 22 00	Perform ECS status check (01 00)		
17 29 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
17 53 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
18 00 00	Replace CO ₂ absorber element (10 00)		
18 06 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
18 16 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
18 20 00	Perform EPS status check (02 00)		
18 22 00	Perform ECS status check (01 00)		
18 30 00	Perform fuel cell hydrogen purge (05 00)		
18 37 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
19 02 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		



Table 6-14 AM-1 Representative 24-Hour Timeline,
Drifting Flight, Powered Down (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
19 03 30	Perform SM RCS status check (02 00)		
19 13 00	Perform SPS status check (02 00)		
19 17 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
19 20 00	Perform EPS status check (02 00)		
19 22 00	Perform ECS status check (01 00)		
19 29 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
19 50 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
20 20 00	Perform EPS status check (02 00)		
20 22 00	Perform ECS status check (01 00)		
20 47 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
21 02 00	Select VHF/FM transmitter ON (00 15) Select VHF antenna position Select VHF/AM TRANSMIT/RECEIVE		
21 20 00	Perform EPS status check (02 00)		
21 22 00	Perform ECS status check (01 00)		
21 24 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
21 45 00	Commander start eat period warm meal (45 00)		
21 45 00	Navigator start eat period warm meal (45 00)		
21 45 00	Systems engineer start eat period cold meal (45 00)		
22 00 00	Perform check on batteries A B, and C (01 00)		
22 00 00	Perform fuel cell oxygen purge (07 00)		
22 20 00	Perform EPS status check (02 00)		
22 22 00	Perform ECS status check (01 00)		
22 38 00	Perform second daily MSFN-spacecraft status briefing (05 00)		
23 00 00	Perform SPS status check (02 00)		



Table 6-14 AM-1 Representative 24-Hour Timeline
Drifting Flight, Powered Down (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
23 20 00	Perform EPS status check (02 00)		
23 22 00	Perform ECS status check (01 00)		
23 32 00	Perform SM RCS status check (02 00)		
23 42 00	Select VHF/FM transmitter OFF (00 10) Select VHF/AM RECEIVE ONLY		
23 53 00	Commander don PGA (07 00)		
24 00 00	Commander start sleep period		



Table 6-15 Duty Cycles, Drifting Flight

Subsystem	Component	Component Mode	Percent Duty		
			AM-1	AM-2	
SCS	Rate gyro package	Monitor	0	100	
	BMAG's	Monitor	0	100	
	FDAI	Monitor	0	100	
	AS/GPI	Monitor	0	100	
	Rotation controller	Monitor	0	100	
	SCS control panel	Monitor	0	100	
	ECA pitch	Monitor	0	100	
	ECA roll	Monitor	0	100	
	ECA yaw	Monitor	0	100	
	ECA auxiliary	Monitor	0	100	
	ECA display	Monitor	0	100	
	Electronics display	Monitor	0	100	
	Communications	VHF/FM transmitter		50 0	100
		VHF/AM equipment	Transmit	2 0	2 0
		Standby	48 0	98 0	
		Receive	-50 0	-100	
S-Band transponder			0	100	
S-Band power amplifier		Low	0	100	
C-Band transponder		Interrogate	3 0	3 0	
		Noninterrogate	1 0	97 0	
Data storage		Standby	0	100	
Voice recorders			5 0	5 0	
EPS	Hydrogen purge solenoids		0 2	0 2	
	Oxygen purge solenoids		0 4	0 4	
Cryogenics	Hydrogen tank heaters		13 7	15 0	
	Hydrogen tank fans		13 7	15 0	
	Oxygen tank fans		14 6	16 0	
Instrumentation	Data storage electronics assembly		5 0	5 0	
	Digital event timer	Operate	3 0	3 0	
Displays and Controls		Standby	3 0	-3 0	
	CW lamp test		0 2	0 2	
	Floodlights (lower equipment bay)	Fixed	2 0	2 0	
		Variable	25 0	25 0	
	Floodlights (Commander's station)	Variable	100	100	
SPS	Propellant utilization gauging		0 8	0 8	
	Feedline heaters		50	50	



9 2 ALTERNATE MODE 2, DRIFTING FLIGHT, POWERED UP

9 2 1 Introduction

The information contained in Paragraph 9 1 1 applies, except that some equipment, notably telecommunications, are operated continuously to ensure electrical power demands equalling or exceeding the specified minimum values for three fuel cell operation

9 2 2 Operational Data

9 2 2 1 General Information

The operations outlined in the Operational Timeline Segment (Table 6-16) reflect the following assumptions

- 1 The assumptions stated in 1, 4, and 5 of Paragraph 9 1 2 1
- 2 VHF-FM high data-bit rate PCM telemetry signals will be transmitted continuously
- 3 The C-band transponder will be ON continuously, although only 45 minutes of operation in the interrogated mode for MSFN tracking is considered necessary
- 4 The S-band transponder will be operated continuously with the power amplifier in the low mode

9 2 2 2 Operational Timeline Segment

See Table 6-16

9 2 2 3 Attitude Maneuvers

No attitude maneuvers will be performed unless biasing of the spacecraft attitude drift rates, as indicated by ECS radiator outlet and inlet temperature readings, becomes necessary

9 2 2 4 Duty Cycles

Equipment duty cycles are presented in Table 6-15. When this building block is used for periods of time differing from multiples of 24 hours, the deviations from the average duty cycles shown will be less than in the case of AM-1 (Paragraph 9 1 2 5), because a greater proportion of the loads are continuous



9 2 2 5 Electrical Power

The average delta power levels are

$$P_{AC} \text{ (nominal)} = 269 \text{ 34 watts} \quad P_{DC} \text{ (nominal)} = 128 \text{ 97 watts}$$

The minimum transient power level is 846 0 watts ac and 514 1 watts dc
This represents a fuel cell load of 1810 watts, with corresponding total
current and bus voltage readings of 58 0 amps and 30 1 volts, respectively

9 2 2 6 Propellant Consumption

No propellants are required unless attitude rate biasing becomes
necessary



Table 6-16 AM-2 Representative 24-Hour Timeline,
Drifting Flight, Powered Up

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 00 00	Commander start sleep period		
00 00 00	Navigator doff PGA (05 00)		
00 20 00	Perform EPS status check (02 00)		
00 22 00	Perform ECS status check (01 00)		
00 34 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
01 00 00	Perform check on batteries A B and C (01 00)		
01 00 00	Perform fuel cell oxygen purge (07 00)		
01 20 00	Perform EPS status check (02 00)		
01 22 00	Perform ECS status check (01 00)		
02 07 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
02 10 00	Accept voice PLA retrofire data from MSFN (02 00)		
02 20 00	Perform EPS status check (02 00)		
02 22 00	Perform ECS status check (01 00)		
03 00 00	Perform SPS status check (02 00)		
03 15 00	Navigator start eat period warm meal (45 00)		
03 15 00	Systems engineer start eat period warm meal (45 00)		
03 20 00	Perform EPS status check (02 00)		
03 22 00	Perform ECS status check (01 00)		
03 32 45	Perform SM RCS status check (02 00)		
03 42 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
04 00 00	Navigator start sleep period		
04 00 00	Perform SPS status check (02 00)		
04 20 00	Perform EPS status check (02 00)		
04 22 00	Perform ECS status check (01 00)		
04 30 00	Perform fuel cell hydrogen purge (05 00)		



Table 6-16 AM-2 Representative 24-Hour Timeline,
Drifting Flight, Powered Up (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
05 06 45	Perform SM RCS status check (02 00)		
05 15 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
05 20 00	Perform EPS status check (02 00)		
05 22 00	Perform ECS status check (01 00)		
06 00 00	Replace CO ₂ absorber element (10 00)		
06 20 00	Perform EPS status check (02 00)		
06 22 00	Perform ECS status check (01 00)		
06 38 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
07 00 00	Perform CM RCS status check (01 00)		
07 15 00	Systems engineer start eat period hot meal (45 00)		
07 20 00	Perform EPS status check (02 00)		
07 22 00	Perform ECS status check (01 00)		
07 30 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
07 48 00	Systems engineer don PGA (07 00)		
07 55 00	Commander end sleep period		
07 55 00	Commander doff PGA (05 00)		
08 00 00	Systems engineer start sleep period		
08 00 00	Perform check on batteries A, B and C (01 00)		
08 00 00	Perform fuel cell oxygen purge (07 00)		
08 20 00	Perform EPS status check (02 00)		
08 22 00	Perform ECS status check (01 00)		
08 30 00	Commander start eat period hot meal (45 00)		
09 03 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
09 06 00	Accept voice PLA retrofire data from MSFN (02 00)		
09 20 00	Perform EPS status check (02 00)		



Table 6-16 AM-2 Representative 24-Hour Timeline,
Drifting Flight, Powered Up (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
09 22 00	Perform ECS status check (01 00)		
10 20 00	Perform EPS status check (02 00)		
10 22 00	Perform ECS status check (01 00)		
10 42 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
11 00 00	Perform SPS status check (02 00)		
11 20 00	Perform EPS status check (02 00)		
11 22 00	Perform ECS status check (01 00)		
11 30 00	Perform fuel cell hydrogen purge (05 00)		
12 00 00	Navigator end sleep period		
12 00 00	Commander start eat period cold meal (45 00)		
12 00 00	Navigator start eat period hot meal (45 00)		
12 03 00	Perform SM RCS status check (02 00)		
12 15 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
12 20 00	Perform EPS status check (02 00)		
12 22 00	Perform ECS status check (01 00)		
13 20 00	Perform EPS status check (02 00)		
13 22 00	Perform ECS status check (01 00)		
13 49 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
14 20 00	Perform EPS status check (02 00)		
14 22 00	Perform ECS status check (01 00)		
15 00 00	Perform fuel cell oxygen purge (07 00)		
15 07 00	Perform SM RCS status check (02 00)		
15 09 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
15 20 00	Perform EPS status check (02 00)		
15 22 00	Perform ECS status check (01 00)		
15 53 00	Navigator don PGA (07 00)		



Table 6-16 AM-2 Representative 24-Hour Timeline,
Drifting Flight, Powered Up (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
16 00 00	Systems engineer end sleep period		
16 00 00	Systems engineer doff PGA (05 00)		
16 00 00	Commander start eat period warm meal (45 00)		
16 00 00	Navigator start eat period cold meal (45 00)		
16 00 00	Systems engineer start eat period warm meal (45 00)		
16 15 00	Perform check on batteries A B and C (01 00)		
16 16 00	Perform status check on pyro batteries A and B (02 00)		
16 18 00	Perform status check on inverters 1 and 2 (02 00)		
16 19 00	Perform CM RCS status check (01 00)		
16 20 00	Perform EPS status check (02 00)		
16 22 00	Perform ECS status check (01 00)		
16 36 00	Perform first daily MSFN-spacecraft status briefing (13 00)		
16 44 00	Confirm daily status with MSFN for continuation of mission flight to revolution, Recovery Zone 1 (01 00)		
16 45 00	Accept voice PLA retrofire data from MSFN (02 00)		
17 20 00	Perform EPS status check (02 00)		
17 22 00	Perform ECS status check (01 00)		
18 00 00	Replace CO ₂ absorber element (10 00)		
18 16 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
18 20 00	Perform EPS status check (03 00)		
18 22 00	Perform ECS status check (01 00)		
18 30 00	Perform fuel cell hydrogen purge (05 00)		
19 00 00	Perform CM RCS status check (01 00)		
19 03 30	Perform SM RCS status check (02 00)		



Table 6-16 AM-2 Representative 24-Hour Timeline,
Drifting Flight, Powered Up (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
19 13 00	Perform SPS status check (02 00)		
19 20 00	Perform EPS status check (02 00)		
19 22 00	Perform ECS status check (01 00)		
19 50 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
20 20 00	Perform EPS status check (02 00)		
20 22 00	Perform ECS status check (01 00)		
21 20 00	Perform EPS status check (02 00)		
21 22 00	Perform ECS status check (01 00)		
21 24 00	Perform voice confirmation of satisfactory status with MSFN (03 00)		
21 45 00	Commander start eat period warm meal (45 00)		
21 45 00	Navigator start eat period warm meal (45 00)		
21 45 00	Systems engineer start eat period cold meal (45 00)		
22 00 00	Perform check on batteries A B and C (01 00)		
22 00 00	Perform fuel cell oxygen purge (07 00)		
22 20 00	Perform EPS status check (02 00)		
22 22 00	Perform ECS status check (01 00)		
22 38 00	Perform second daily MSFN-spacecraft status briefing (05 00)		
23 00 00	Perform SPS status check (02 00)		
23 20 00	Perform EPS status check (02 00)		
23 22 00	Perform ECS status check (01 00)		
23 32 00	Perform SM RCS status check (02 00)		
23 53 00	Commander don PGA (07 00)		
24 00 00	Commander start sleep period		



BUILDING BLOCK 10 CREW MAINTENANCE

10 1 INTRODUCTION

Building Block 10 describes food preparation, meal intake, personal hygiene, housekeeping, and waste management during a 24-hour period. The food provided for the astronauts furnishes a balanced diet of approximately 2650 calories per day for each crew member, it is prepared in several forms: dehydrated, freeze-dry, and bulk. The foods are for the most part highly nutritious, concentrated, and vacuum-packed in plastic bags of special design. Personal hygiene includes body cleansing, defecation, and urination.

The waste management system (WMS) consists of two basic subsystems: urine/feces/emesis and vacuum cleaner. The function of the WMS is to control and/or dispose of waste solids, liquids, and gases in the command module. The waste solids consist of feces, emesis (vomitus), food particles, and debris. The waste liquids consist of urine, mucus, or any spilled water for biological use.

The urine/feces/emesis subsystem will allow the crewman to urinate and dump the waste liquids overboard. It will also receive urine from the Apollo Block I pressure garment assembly (PGA) urine collection bag. The urine/feces/emesis subsystem will receive the feces, hold them in a fecal/emesis bag, and draw any odor into the environmental control subsystem. Utilization of the PGA urine collection bag is available any time the PGA is worn (i.e., from spacecraft ingress to postlanding).

The vacuum cleaner subsystem will gather debris, food, and other particulate matter in fecal/emesis debris bags. Filled bags will be stored in the waste storage compartment. The waste gases and odors will be removed by the CO₂ and odor absorber filters. The spacecraft WMS function is available from the time of earth orbit insertion until just prior to entry.

Table 6-17 summarizes crew maintenance functions.

Table 6-17 Crew Maintenance Functions

Function	Description	Quantity	Frequency per 24 Hours	Duration (min)
Nutrition				
Kind and quality of food	Dehydrated freeze-dry or bulk packaged in plastic bags	2650 calories/man/day	See paragraph 10 2 5 for details of operations and times involved	
Meals	Meal (hot warm or cold)	1 5 lb/man/day	3	35 5 to 44 5
	Snack		1	28 5
Water	Hot and cold water for meal preparation Drinking water	6 lb/man/day	as needed	
Personal Hygiene				
	Body cleansing per man		2	
	Defecation per man		1	10 to 20
	Urination per man		4 to 6 times	5 to 6
Waste Management				
Urine/feces/emesis subsystem	Receives and contains feces and draws odors into ECS Allows the crewman to urinate and dump the urine overboard Receives urine from PGA urine collection bag and from USVMS if available		Contingent upon the frequency of other functions requiring action of this system	
Vacuum cleaner subsystem	Used to gather debris food and other particulate matter			

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10 2 OPERATIONAL DATA

10 2 1 General Information

10 2 1 1 Meal Preparation

- 1 All three crewmen may eat at the same time if convenient. The major meal-preparation limitation is the limited volume of hot water available for any one meal period.
- 2 The preparation of a snack does not require hot water.
- 3 A snack may be substituted for a hot meal if required operational activities prevent hot meal preparation.
- 4 Each crewman will be provided with three meals (hot, warm, or cold) and one snack during each 24-hour period.
- 5 Meals will be scheduled starting no earlier than four hours after the start of the mission. Thereafter, the meals for each crewman will be scheduled every four to eight hours, as operational activity permits.
- 6 No food or water port is provided in the Block I helmet, therefore, during suited periods, the crewmen cannot eat or drink. This system limitation does not affect crew safety.

10 2 1 2 Drinking Water

- 1 Water consumption is considered to be a crew-preference function.
- 2 Water at cabin ambient temperature, only, is available to the crewmen from the drinking assembly until water stored in the 72-inch plastic tubing is exhausted (4 cc of water must be removed at an average initial temperature of 78 F).

10 2 1 3 Personal Hygiene

- 1 Body cleansing is assumed to be performed two times a day per man.
- 2 Defecation is assumed to occur once per day per man.
- 3 Urination is assumed to occur four to six times a day per man.



10 2 1 4 Urine Disposal

- 1 During periods when crewmen are constrained in their couches and are wearing the PGA, the suit urine collection bag (capacity 1200 cc) is used Dumping into the WMS occurs at the first opportunity after getting out of the couches
- 2 The urine receptacle with its flexible hose can be used without removing the fecal canister from storage
- 3 The urine steam vent heater is turned on after earth orbit insertion and remains on until just prior to entry
- 4 The vacuum cleaner unit will be used at any time it is necessary to remove debris or liquid from the cabin environment

10 2 2 Operational Timeline Segment

A description of crew procedures and timelines for meal preparation and waste management are contained in the AOH Subsections 6 5, 6 6, and 8 4 13

Food preparation and consumption involve the sequence of steps shown in AOH Subsection 10 6 Estimates of the time required to accomplish each step are given

10 2 3 Electrical Power Profile

The electrical components utilized in the WMS are the blower and the urine dump heater Since the electrical power for the urine dump heater is activated at earth orbit insertion and remains ON until entry, it is included as part of the comon level power profile In a similar manner, the WMS blower power profile will be reflected in the ECS power profile for Building Block 9 Electric power requirements for the WMS are included as a part of the basic life-sustaining requirements during drifting flight

10 2 4 Consumables Usage

- 1 The daily intake of water for each astronaut is assumed to be about 6 pounds per day
- 2 One cfm of O₂ at 3 5 to 5 0 psi is required for the operation of the urine/feces/emesis subsystem
- 3 Five cfm of O₂ at -0 176 psi is required for the operation of the vacuum cleaner subsystem
- 4 Waste storage area is not vented (cancelled by MCR No 1595)



10 2 5 Details of Crew Maintenance Operations

10 2 5 1 Meal Preparation

Task	Duration (min)		
	Hot	Warm	Cold
Obtain food packages from food compartment	2	2	2
Prepare food package for usage	2	2	2
Rehydrate food as required	1	1	1
Knead food as required	8 5	4 5	4 5
Consume food	15	15	10
Prepare used food bags for storage	4	4	4
Stow used food bags	2	2	2
Clean up LEB	10	10	10
Total	44 5	40 5	35 5

10 2 5 2 Snack Preparation

Task	Duration Times (min)
Obtain and prepare snack	4 5
Eat snack	8
Dispose of waste	6
Clean up	10
Total	28 5

10 2 5 3 Waste Management Functions

Function	Duration Times (min)
Urination	
Suited	6 0
Unsuited	5 0
Urine dump	2 0
Defecation	
Suited	10 0 to 20 0
Unsuited	10 0 to 20 0
Vacuuming	0 5

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BUILDING BLOCK 11 ATTITUDE CONTROL

11 1 INTRODUCTION

This block presents the function of maneuvering the spacecraft to a desired inertial attitude and then maintaining the attitude. To accomplish this function, the spacecraft has redundant subsystems, therefore, this block is presented in three sections (alternate modes). The guidance and navigation (G&N), stabilization and control subsystem (SCS), and manual attitude controls are designated Alternate Modes 1, 2, and 3 respectively. This breakdown reflects the source of the attitude error signal in the outer control loop, i.e., IMU, BMAG-AGCU loop or visual reference.

The maneuvering and holding function will be handled together in each of the alternate modes. The decision as to the type of attitude hold to use is of more concern to the mission planner than the method used to perform a maneuver. Four control system configurations are available: hold attitude about all three axes (hold mode), maintain attitude about two axes and free drift about one axis ("barbecue" mode), establish a mode where pitch and yaw are held (approximately) and a deliberate roll rate is initiated and maintained (wobble mode), and drift free about all three axes (drifting mode). Table 6-18 presents a gross comparison of certain electrical power, reaction control subsystem (RCS) fuel, and equipment operating time costs for the approaches presented. The G&N and SCS three-axis attitude-hold modes are discussed under Alternate Modes 1 and 2. The two free-drifting modes are described under Building Block 9. The "barbecue" and wobble modes are special cases and are presented to illustrate the flexibility of the control systems. Following the brief descriptions of the three attitude-controlled cases presented in Table 6-18.

11 1 1 Hold Mode (AM 1 and 2)

In this mode, a three-axis attitude hold is established and maintained by either the on-board attitude references (IMU or BMAG-AGCU loop) which close the outer control loop. This mode is most expensive in terms of electrical power, RCS propellant, and system operating time. It should only be used when the mission requires that a specific and relatively accurate inertial attitude hold be established and maintained. Both of these attitude reference systems must be updated periodically. Also, in both Alternate Modes 1 and 2, provisions were made to select an allowable attitude error deadband, wide (maximum) or narrow (minimum). The selection of the deadband is dependent on mission requirements.



Table 6-18 Comparison of Attitude Modes

Mode	Attitude Accuracy		Equipment Time	RCS Fuel	Electrical Power
	Deg	Axes			
Three-axis hold					
G&N	+5	3	Greatest	Greatest	Greatest
SCS	+5	3	High	Greatest	High
"Barbecue"					
SCS	+5	2			
only	+180	1	High	High	High
Wobble					
SCS	+20	2			
only	+180	1	Minimum	Minimum	Minimum
Free drift (1)					
Monitor	+180	3	High	None	High
Free drift (2)	+180	3	None	None	None

11 1 2 "Barbecue" Mode

This mode was developed to satisfy spacecraft thermal constraints which developed after the control system design base was established. For this special case, the SCS attitude control mode is used. The vehicle is oriented to the desired initial attitude, and the free-axis control jets are disabled by opening their circuit breakers after the desired rate of rotation has been established in that axis. The BMAG for that axis is rate caged by its backup rate switch to prevent the BMAG from going into and out of its attitude stops as the vehicle rotates about its axis. Equipment operating times and electrical power required will be the same as for the three-axis attitude-hold mode although a slight RCS propellant saving is realized.

11 1 3 Wobble Mode

In this mode, two axes are established in an attitude hold as a side effect of spinning the vehicle about the third axis. The control system may



be turned off after the mode is established. A significant savings in equipment operating time, RCS propellant, and electrical power can result. The limitation to this mode is that the resulting attitude error is three times greater than the "barbecue" mode (half-cone angles of 14 degrees versus 5 degrees).

11 2 ALTERNATE MODE 1, G&N ATTITUDE CONTROL

11 2 1 Introduction

In this mode, the inertial measurement unit (IMU) maintains the primary inertial attitude reference. Attitude changes are commanded (1) by Apollo guidance computer (AGC) programs by entering the verb 70 (manual attitude maneuver) in the display keyboard (DSKY) and maneuvering the spacecraft with the hand controller, or (2) by manually dialing the coupling display units (CDU). This mode will only cover maneuvers that are preprogrammed in the AGC. MIT R507 contains a complete listing of the AGC programs and subroutines. The G&N subsystem is described in Section 2 2 of the Apollo Operations Handbook. Paragraph 2 2 1 1 3 in the handbook contains a discussion of the attitude control mode. The following were assumed:

- 1 Initial conditions are of nominal magnitude. Requirements developing from contingency conditions cannot be solved with the data presented.
- 2 The spacecraft is in an orbit of at least 100 nautical miles.
- 3 The basic assumptions stipulated for each maneuver and hold function described in Section 5 0 (Propellant Consumption) apply to those functions in this building block.
- 4 Spacecraft mass characteristics are presented in the Data Specification, Revision D.
- 5 The SCS (BMAG-AGCU Loop) inertial attitude reference will maintain a backup inertial attitude reference during G&N attitude control.

11 2 2 Operational Data

11 2 2 1 Functional Flow Diagram

Figure 6-16 is a functional flow diagram for Alternate Mode 1.



11 2 2 2 Operational Timeline Segment

The timeline (Table 6-19) is composed of an attitude maneuver initiated from a G&N attitude-hold condition of maximum deadband and a low-energy slosh condition (defined in Section 5 0). The AGC is in a program which commands a three-axis, 60-degree reorientation of the spacecraft. This program is similar to an IMU alignment (BB-7).

11 2 2 3 Subsystem Duty Cycles

Table 6-20 contains the G&N duty cycles.

11 2 2 4 Electrical Power

The average Δ power levels are

$$P_{AC} = 144.9 \text{ watts} \quad P_{DC} = 448.1 \text{ watts}$$

11 2 2 5 RCS Propellant Consumption

Figure 6-17 is a time history of the propellant consumption.



Table 6-19 Operational Timeline Segment, G&N Attitude Control, Alternate Mode 1

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t + 00 00 00	<p>Perform G&N attitude maneuver (00 06 30)</p> <p>Check AGC DSKY flashes verb-noun to request proceed and displays present ICPU/IMU gimbal angles (00 00 10)</p> <p>Align AGCU and FDAI if desired (00 03 00 see Remarks)</p> <p>Set attitude set thumbwheels to values displayed on DSKY (Ref)</p> <p>Set G&N/SCS switch on MDC to SCS (Ref)</p> <p>Set attitude set OFF switch on MDC to ATTITUDE SET (Ref)</p> <p>Hold FDAI align pushbutton in until FDAI stops driving and error needles are nulled (Ref)</p> <p>Check angles displayed under FDAI navigation axis symbol agree with AGC DSKY display (Ref)</p> <p>Set attitude set OFF switch on MDC to OFF (Ref)</p> <p>Set G&N/SCS switch on MDC to G&N (Ref)</p> <p>Key in proceed V33E on AGC DSKY (00 00 05)</p> <p>Check AGC DSKY flashes verb-noun to request proceed and displays desired final ICPU/IMU gimbal angles (00 00 10)</p>	<p></p> <p>E</p> <p>E</p> <p>E</p> <p>E</p>	<p>Presumes AGC and the IMU are energized with the IMU inertially stabilized at an orientation known to the AGC</p> <p>Presumes SCS is energized</p> <p>Presumes the final spacecraft attitude desired has been stored in the AGC by the calling program</p> <p>The attitude maneuver routine normally is automatically selected by the AGC program requiring the G&N to have attitude control</p> <p>Assumed not desired but shown for reference</p>



Table 6-19 Operational Timeline Segment, G&N Attitude Control, Alternate Mode 1 (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t + 00 06 35	Set attitude set thumbwheels to values displayed on AGC DSKY if desired (00 01 00 see Remarks)	E	Assumed not desired but shown for reference If desired set attitude set thumbwheels to the values displayed on the AGC DSKY to prepare the attitude reference subsystem for a backup or manual attitude control situation When switched to SCS attitude control the attitude reference subsystem will display attitude errors on the FDAI which if nulled by the astronaut with his manual rotation control will bring the spacecraft to the same final attitude that the G&N would have commanded
	Key in proceed V33E on AGC DSKY when ready to maneuver (00 00 05)	E	
	Check FDAI attitude changes at 0.5 degrees per second to the ICDU angles displayed on the AGC DSKY (00 06 00)	G	Couch 1 function Assumes three-axis maneuver through 180 degrees
	Check that ICDU's are driven and the spacecraft follows (00 00 05)	E	Performed by crewman at lower equipment bay navigation station concurrently with preceding operation
	Check IMU-CDU difference indicator indicates random spacecraft motion within selected deadband (00 05 50)	G	Same as preceding remark
	Check that ICDU's stop at required angles (00 00 05)	E	Same as preceding remark
	Perform G&N attitude hold (00 15 38)		Reference AOH Paragraph 8 6 5 3
	Select or confirm that AGC program is 00 (00 00 10)	E	Presumes no major AGC program is in progress and that the IMU is inertially stabilized
	Select desired attitude deadband (maximum or minimum) (00 00 02)	E	Maximum deadband normally selected minimum deadband selected for celestial navigation sightings
	Configure SM RCS for desired quadrant operation (00 00 10)	G	
Set G&N/SCS switch on MDC to G&N (00 00 02)	E		



Table 6-19 Operational Timeline Segment, G&N Attitude Control, Alternate Mode 1 (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
	Set attitude/monitor/entry switch to ATTITUDE (00 00 02)	E	
	Press V44E on AGC DSKY (00 00 05)	E	
	Verify ISS Att Control Mode light is on (00 00 02)	E	
	Confirm attitude hold by monitoring the FDAI or external references (00 00 05 plus assumed 15 minutes of attitude hold)	E	A subsequent attempt to perform a SCS attitude maneuver can not be satisfactorily accomplished with this switch configuration
<p>Time Source Code E = Engineering Estimate Derived from statistical analysis (E G the computer formula or data provided by cognizant engineering groups such as alignment time of FDAI etc)</p> <p> G = Guess An approximation based upon the engineering assumption of a realistic time limit</p>			



Table 6-20 Subsystem Duty Cycles, G&N Attitude Control, Alternate Mode 1 (Duration 0 3685 Hours)

COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	BLOCK 11
Stabilization and Control						
RGP		6			0	100
BMAG		6			0	100
FDAI		6			0	100
AS/GPI		6			0	100
ΔV display					0	
Rotation controller		6			0	100
Control panel		6			0	100
ECA pitch		6			0	100
ECA roll		6			0	100
ECA yaw		6			0	100
ECA auxiliary		6			0	100
ECA display		6			0	100
Electronics display		6			0	100
TVC OPERATE					0	
TVC STANDBY		6			0	100
Guidance and Navigation						
AGC OPERATE		A			0	100
AGC STANDBY		F			100	0
IMU OPERATE		A			0	100
IMU STANDBY		F			100	0
Optics		F			0	0
Displays and controls		A			0	100
Service Module RCS						
Propellant quantity gaging					0	
Engine heaters					62.5	
Engine coils		Automatic			0	0.01954*
Helium isolation valves					0	
Propellant isolation valves					0	
Command Module RCS						
Isolation valves					0	
Engine coils					0	
Consists of						
(1) 6 minutes of G&N attitude maneuver						
3-axis maneuver at 0.5 deg/sec achieved by 1/3 second SM RCS firing to start rotation and 1/3 second SM RCS firing to stop maneuver = 0.01854-percent utilization						
(2) 15 minutes of G&N attitude hold						
Minimum impulse firing assumed at 0.001-percent utilization						



11 2 3 Performance Data

All preprogrammed maneuvers are executed by the AGC at an attitude rate of 0.5 degrees per second. The angular acceleration for the initiation and termination of body rates is from ± 1.0 to ± 1.5 degrees per second², depending on the spacecraft mass characteristics. Due to the magnitude of the maneuver rate (0.5 degrees per second), the damping characteristics of the control system, the initiation and termination transients are insignificant to the mission planner.

In this mode, a choice of ± 5.0 degrees (maximum) or ± 0.5 degrees (minimum) attitude error deadbands are available. The spacecraft will limit cycle within these deadbands at an approximate rate of 0.02 degrees per second.

11 2 4 Functional Modification

The general G&N attitude maneuver of G&N attitude hold presented in the timeline segment of Table 6-19 can be modified as required by the particular mission by performing the following tasks:

- 1 Determine attitude change and duration of the attitude hold
Check for possible gimbal lock
- 2 Determine the attitude error deadband required
- 3 Determine the time of the last SPS burning operation to determine propellant sloshing conditions
- 4 With data collected in Tasks 1, 2, and 3, calculate maneuver and hold duration
- 5 Review functional flow and crew tasks to determine and make time allowances for crew operations
- 6 Calculate the RCS propellant consumption and electrical power profile from parametric data presented in Sections 3.0 and 5.0 of this document

11 3 ALTERNATE MODE 2, SCS ATTITUDE CONTROL

11 3 1 Introduction

In this mode, the BMAG-AGCU loop maintains the primary inertial attitude reference. Attitude changes are commanded by maneuvering the spacecraft with the rotation control in proportional rate.

The SCS is described in Section 2.3 of the AOH. Paragraphs 2.3.1.1.2 and 2.3.1.3.2 of the AOH contain discussions of the attitude control and attitude maneuver modes.



The assumptions listed in 11 2 1 for AM-1 apply to this function

11 3 2 Operational Data

11 3 2 1 Functional Flow Diagram

Figure 6-18 contains the Alternate Mode 2 functional flow

11 3 2 2 Operational Timeline Segment

The operational timeline segment (Table 6-21) schedules the spacecraft operations and crew activities required to perform an SCS attitude maneuver of 72 degrees from a low energy slosh condition and an attitude hold of one hour in the SCS minimum attitude error deadband

11 3 2 3 Subsystem Duty Cycles

Table 6-22 contains the stabilization and control subsystem duty cycles

11 3 2 4 Electrical Power

The average delta power levels are

$$P_{AC} = 157.2 \text{ watts} \quad P_{DC} = 444.7 \text{ watts}$$

11 3 2 5 RCS Propellant Consumption

Figure 6-19 is a time history of the propellant consumption



Table 6-21 Operational Timeline Segment, SCS Attitude Control, Alternate Mode 2

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t + 00 00 00	Perform SCS attitude maneuver (00 17 42)		Reference AOH paragraphs 8 6 5 6 8 6 5 7 or 8 6 5 8
	Select or confirm SCS powered-up (00 02 00 if powered-down)	E	Reference AOH paragraph 8 6 3 5 The BMAG power switch is presumed to remain in the AC2 position for the entire mission thus eliminating the need for a 40-minute warmup period that would occur if the BMAG's had to be powered-up from OFF to AC2
	Configure SM RCS for desired quadrant operation (00 00 10)	G	
	Align AGCU and FDAI to IMU gimbal angles if G&N is operating (00 03 00)	E	Reference AOH paragraph 8 6 5 4 The G&N may or may not be energized during an SCS attitude maneuver however for at least the first SCS attitude maneuver it is assumed that the IMU will be erected and aligned for attitude reference comparison For subsequent SCS attitude maneuvers and if not required for test objective demonstration the G&N may be powered-down
	Determine required roll pitch and yaw angles (00 05 00)	G	Use MSFN and/or on-board mission timeline data to determine desired roll pitch and yaw angles
	Set attitude set thumbwheels to the desired angles (00 01 00)	E	This operation is required for a SCS attitude maneuver to an attitude set reference only (Reference AOH paragraph 8 6 5 6)
	Compare desired attitude with present attitude and determine magnitude and direction of changes required (00 00 10)	G	If a SCS attitude maneuver to an external reference is to be performed adjust couch 1 seat back to docking position
	Unpin rotation control (00 00 02)	E	
	Set attitude set OFF switch to ATTITUDE SET (00 00 02)	E	This operation is required for a SCS attitude maneuver to an attitude set reference only (Reference AOH paragraph 8 6 5 6)



Table 6-21 Operational Timeline Segment, SCS Attitude Control, Alternate Mode 2 (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t + 00 11 26	<p>Set limit cycle/off switch to OFF (00 00 02)</p> <p>Using rotation control command proportional rates in the appropriate directions and in the same ratio as the magnitudes of the angular changes required (00 00 05)</p>	<p>E</p> <p>E</p>	<p>Assume three-axis maneuver at 0.2 degrees per second through 72 degrees (6-minute duration) After the rates are established exercise care to avoid possible inadvertent SM RCS firings If very low rates are used for large angle maneuvers the SCS channel switches may be set to OFF then to ON as each attitude error indicator nulls out (Not applicable to an SCS attitude maneuver to an external reference reference AOH paragraph 8 6 5 8)</p> <p>On large angle changes the FDAI attitude ball should be the primary reference and the attitude error indicators secondary As the errors become less than 5 degrees the attitude error indicators become the primary reference (Not applicable to an SCS attitude maneuver to an external reference reference AOH paragraph 8 6 5 8)</p>
t + 00 17 26	<p>Set attitude deadband switch to MIN during the maneuver (00 00 02)</p> <p>Restore rotation control to neutral as the FDAI attitude ball nears the correct attitude (00 00 05)</p> <p>Perform any required minor attitude adjustments (00 00 05)</p> <p>Set limit cycle/off switch to LIMIT CYCLE (00 00 02)</p> <p>Use external reference as required to confirm attitude acquired (00 00 05)</p> <p>Set attitude deadband switch to MAX (00 00 02)</p> <p>Repin rotation control (00 00 02)</p>	<p>E</p> <p>E</p> <p>G</p> <p>E</p> <p>G</p> <p>E</p> <p>E</p>	



Table 6-21 Operational Timeline Segment, SCS Attitude Control, Alternate Mode 2 (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t + 00 17 41	<p>Perform SCS attitude hold (01 15 00)</p> <p>Perform SCS G&N attitude reference comparison (00 05 00)</p> <p>Record SM RCS propellant quantity at the start of attitude hold (00 07 00)</p> <p>Configure SM RCS for single ± jet per axis operation (00 01 00)</p> <p>Monitor limit cycling in attitude hold by reference to attitude error indicators for malfunction cues (01 00 00)</p> <p>Record SM RCS propellant quantity at the completion of the attitude hold (00 07 00)</p> <p>Time Source Code</p> <p>E = Engineering Estimate Derived from statistical analysis (E G the computer formula or data provided by cognizant engineering groups such as alignment time of FDAI etc)</p> <p>G = Guess An approximation based upon the engineering assumption of a realistic time limit</p>	<p>E</p> <p>E</p> <p>E</p> <p>G</p>	<p>Reference AOH paragraph 8 6 5 2</p> <p>Reference AOH paragraph 8 6 5 1</p> <p>Presumes G&N is powered-up with the IMU erected and aligned. Omit if G&N is powered-down</p> <p>This operation should be performed as closely as possible to the completion of the preceding SCS attitude maneuver</p> <p>Performed concurrently with preceding operation</p> <p>Assume 1-hour of SCS attitude hold</p> <p>SM-RCS firings should all be pulses of approximately 18 milliseconds duration spaced 200 to 300 seconds apart after the spacecraft attitude has settled out within the selected deadband</p>



Table 6-22 Subsystem Duty Cycles, SCS Attitude Control, Alternate Mode 2 (Duration 1 544 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 11
Stabilization and Control				
RGP		3 2	0	6 57 in 3 93 43 in 2
BMAG		3 2	0	6 57 in 3 93 43 in 2
FDAI		3-2	9	6 57 in 3 93 43 in 2
AS/GPI		3-2	0	6 57 in 3 93 43 in 2
ΔV display Rotation Controller		3-2	0	6 57 in 3 93 43 in 2
Control panel		3 2	0	6 57 in 3 93 43 in 2
ECA pitch		3-2	0	6 57 in 3 93 43 in 2
ECA roll		3-2	0	6 57 in 3 93 43 in 2
ECA yaw		3 2	0	6 57 in 3 93 43 in 2
ECA auxiliary		3-2	9	6 57 in 3 93 43 in 2
ECA display		3 2	0	6 57 in 3 93 43 in 2
Electronics display		3 2	0	6 57 in 3 93 43 in 2
TVC OPERATE TVC STANDBY		3-2	0	6 57 in 3 93 43 in 2
Guidance and Navigation				
AGC OPERATE		A	0	100
AGC STANDBY		F	100	0
IMU OPERATE		A	0	100
IMU STANDBY		F	100	0
Optics		F	0	0
Displays and controls		A	0	100
Service Module RCS				
Propellant quantity gaging			0	7 56
Engine heaters			62 5	
RCS engine coils		Automatic	0	0 02438
He isolation valves			0	
Propellant isolation valves			0	
Command Module RCS				
Isolation valves			0	
RCS engine coils			0	



11 3 3 Performance Data

The attitude maneuvers are commanded by displacement of the rotation control into the proportional rate regime. The resulting rate will vary from a minimum of 0.2 degrees per second to a maximum of 0.65 degrees per second, depending on the displacement of the hand controller. The spacecraft has a maximum angular acceleration of 1.0 to 1.5 degrees per second², depending on the spacecraft mass configuration and number of RCS engines enabled. Due to the maximum rate that can be commanded and the damping characteristics of the SCS, maneuver start and terminal transient can be assumed to be step functions and therefore are of no consequence to the mission planner.

The attitude error deadbands available are maximum ± 4.2 to 5.0 degrees and minimum ± 0.2 to 0.5 degrees.

11 4 ALTERNATE MODE 3, MANUAL ATTITUDE CONTROL MODE

This alternate mode includes two methods of inducing attitude rate to the spacecraft, direct rotation and minimum attitude impulse. Each of these methods has a specific operational requirement. Direct rotational control is provided for emergency or backup conditions. For emergency conditions, attitude maneuvers can be commanded about any one axis or all three axes at any rate desired. This function also provides an electrical backup for firing the RCS engines if the control system malfunctions. Minimum attitude impulse provides the ability to command minute attitude rates about any one axis or all three spacecraft axes. This function is required for optical sighting operations. (See BB-7, IMU Alignment, and BB-8, Navigational Sightings.)

11 4 1 Direct Rotational Control

11 4.1 1 Introduction

Direct rotational control is commanded by rotating the rotation control about the desired axes to its hard stops. Just before engaging the hardstops, a switch closes and applies a direct command to the RCS direct coils. Rate feedback is not used to cancel stick movement, but the BMAG-AGCU loop is closed and maintains an attitude reference up to its limits.

11 4 1 2 Operational Data

11 4 1 2 1 Spacecraft constraints None

11 4 1 2 2 Functional Flow Diagram Figure 6-20 contains the Alternate Mode 3 functional flow diagram.



11 4 1 2 3 Operational timeline segment The timeline segment (Table 6-23) describes an example maneuver of 72 degrees at a rate of 5 degrees per second

11 4 1 2 4 Subsystem duty cycles Table 6-24 contains the RCS attitude control mode duty cycles

11 4 1 2 5 Electrical power The average delta power levels are

$$P_{AC} = 157.2 \text{ watts} \quad P_{DC} = 442.7 \text{ watts}$$

11 4 1 2 6 Propellant consumption RCS propellant consumption data presented in Section 5.0 were used to calculate the following service module RCS propellant consumed to execute the direct rotational maneuver of Table 6-23

Time T+ (hr min sec)	Event	Propellant Consumed (lb)
00 11 32	Perform 32.0 degrees pitch maneuver at a 5.0-degree per second rate	0.75
	Perform 40 degrees roll maneuver at a 5.0-degree per second rate	0.25
	Total service module RCS Propellant	1.0

11 4 1 3 Performance Data

The attitude rate that can be commanded by direct rotational control is limited only by human endurance and RCS propellant supply. At a rate of 20 degrees per second about the roll axis and 5.0 degrees per second about the pitch or yaw axis, the inertial references start to accumulate error due to gyro slue rate limitations.

The attitude rate determines at an angular acceleration of 1.0 to 1.5 degrees per second². This angular acceleration is a function of the spacecraft's mass configuration.

Maneuver start and stop transients are dependent on pilot technique and the attitude reference (FDAI or landmark) used to close the outer control loop.



Table 6-23 Operational Timeline Segment,
Manual Attitude Control, Alternate Mode 3

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
DIRECT ROTATION CONTROL			
	Perform direct rotation control (00 11 59)		Reference AOH paragraph 8 6 1 2g Direct rotation control is used to backup proportional rotation control for any SCS attitude maneuver Direct rotation control should only be used when automatic control in any single axis is not possible due to failure in the G&N and/or SCS systems
t+00 00 00	Perform same operations of Section 11 3 2 SCS Attitude Maneuver except as indicated below		Reference BB-11 Section 11 3 2
t+00 11 24	Set direct RCS switch to DIRECT RCS (00 00 02)	E	
t+00 11 26	Set all SCS channel switches to OFF (00 00 06)	E	
t+00 11 32	Unpin rotation control (00 00 02)	E	
t+00 11 34	Deflect rotation control into the stop in the appropriate direction of desired attitude change (00 00 05)	E	Assume two-axis maneuver at 5 degrees per second through 72 degrees (14 4-second duration) Pitch 32-degree roll 40 These control signals appear as acceleration signals directly to the RCS engines Caution should be exercised so as not to hold the rotation control in the stop too long as too high a rate will develop
t+00 11 44	Apply equal and opposite direct rotation command as each axis approaches the desired attitude (00 00 05)	E	
t+00 11 49	Set all SCS channel switches that were previously on to their ENABLE positions (00 00 06)	E	
t+00 11 55	Set direct RCS switch to OFF (00 00 02)	E	
t+00 11 57	Repin rotation control (00 00 02)	E	



Table 6-23 Operational Timeline Segment,
Manual Attitude Control, Alternate Mode 3 (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
ATTITUDE IMPULSE CONTROL			
	Perform attitude impulse control (00 05 10)		<p>The attitude impulse control (G&N) optics control panel) provides the capability for commanding low rotational rates (0 010 degrees per second) about all three axes</p> <p>Attitude impulse control is available only in SCS or G&N attitude control modes and is used primarily for precise attitude maneuvers during navigational sighting periods</p>
t+00 00 00	Perform operations same as in Sections 11 2 1 or 11 3 1 G&N Attitude Hold or SCS Attitude Hold respectively except as indicated below		Reference Block 11 Sections 11 2 1 or 11 3 1
t+00 03 00	Confirm that switch is set to LIMIT CYCLE (00 00 02)	E	<p>If the attitude impulse control is used with the limit cycle off switch set to OFF a continuous RCS engine firing occurs instead of a pulsed firing thus resulting in excess propellant being used</p> <p>Assume the requirement for attitude impulse control occurs 3 minutes after establishing attitude hold</p>
t+00 03 02	Set attitude impulse enable switch to ON (00 00 02)	E	When the attitude impulse enable switch is ON electrical relay action removes all rate, attitude error and rotation control inputs to the SCS electronics
t+00 03 04	Displace the attitude impulse control in the direction of desired attitude change		<p>After the attitude impulse control is enabled and displaced an electrical switch closure in the control and a RCS network combination generate one pulse (18±4 milliseconds) which is applied to the RCS jet selection logic</p> <p>One pulse is generated for each attitude impulse switch closure (control displacement)</p>



Table 6-23 Operational Timeline Segment,
Manual Attitude Control, Alternate Mode 3 (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t+00 05 04	Apply opposite and an equal number of attitude impulse control displacements as each axis approaches the desired attitude		Attitude impulse control does not provide proportional control and attitude hold is not available when the attitude impulse control is returned to neutral Assume a single-axis maneuver of 2-minutes duration Confirm desired attitude acquired by viewing external reference through G&N optics
t+00 05 08	Set attitude impulse enable switch to OFF (00 00 02)	E	
Time Source Code E= Engineering Estimate (Derived from statistical analysis e g the computer formula or data provided by cognizant engineering groups such as alignment time of FDAI etc)			



11 4 1 4 Function Modification

The maneuver described in the attitude timeline segment (Table 6-23) can be modified to any other direct rotational function by using the task list in Paragraph 11 2 3

11 4 2 Attitude Impulse Control

11 4 2 1 Introduction

The attitude impulse control located on the G&N optics control panel provides the capability for commanding low-rotational rates about all three axes. Attitude impulse control is available only in SCS or G&N attitude control modes and is used only for precise attitude maneuvers during navigational sighting periods. After the control is enabled and displaced, a switch closure in the control will cause one pulse of 18 ± 4 milliseconds, which is applied to the RCS jet selection logic. One pulse is generated for each attitude impulse switch closure. It is not a proportional control and attitude hold is not available. When the control is enabled, relay action removes all rate attitude error, and rotational control inputs to the SCS electronics. Switching is defined in Paragraph 2 3.2 2 3.

11 4 2 2 Operational Data

11 4 2 2 1 Mission Functional Flow Figure 6-20 is a diagram of the mission functional flow.

11 4 2 2 2 Operational Timeline Segment Table 6-6 contains the operational timeline segment.

11 4 2 2 3 Subsystem Duty Cycles Table 6-24 shows the subsystem duty cycles.

11 4 2 2 4 Electrical Power The electrical power usage will depend on which attitude hold mode has been selected. Refer to 11 2 2 4 if G&N is selected and to 11 3 2 5 if SCS is selected.

11 4 2 2 5 RCS Propellant Consumption The timeline segment does not describe an actual attitude change due to the function simplicity. Each attitude impulse fires the RCS engines about one axis 18 ± 4 milliseconds for each switch closure. This 18 ± 4 milliseconds duration consumes approximately 0.01 pounds of service module RCS propellant.



Table 6-24 Subsystem Duty Cycles, Manual Attitude Control, Alternate Mode 3, Direct Rotation Control (Duration 0 1998)

COMPONENT	QUANTITY	MODE	INPUT POWER UNIT		PERCENT DUTY CYCLE	
			AC (WATTS)	DC (WATTS)	COMMON LEVEL	BLOCK 11
Stabilization and Control						
RGP		2 and 3			0	98 in 2 2 in 3
BMAG		2 and 3			0	98 in 2 2 in 3
FDAI		2 and 3			0	98 in 2 2 in 3
AS/GPI		2 and 3			0	98 in 2 2 in 3
ΔV display					0	
Rotation controller		2 and 3			0	98 in 2 2 in 3
Control panel		2 and 3			0	98 in 2 2 in 3
ECA pitch		2 and 3			0	98 in 2 2 in 3
ECA roll		2 and 3			0	98 in 2 2 in 3
ECA yaw		2 and 3			0	98 in 2 2 in 3
ECA auxiliary		2 and 3			0	98 in 2 2 in 3
ECA display		2 and 3			0	98 in 2 2 in 3
Electronics display		2 and 3			0	98 in 2 2 in 3
TVC OPERATE					0	
TVC STANDBY		2 and 3			0	98 in 2 2 in 3
Guidance and navigation						
AGC OPERATE		A			0	100
AGC STANDBY		F			100	0
IMU OPERATE		A			0	100
IMU STANDBY		F			100	0
Optics		F			0	0
Displays and controls		A			0	100
Service Module RCS						
Propellant quantity gaging					0	
Engine heaters					62 5	
RCS engine coils		direct			0	1 392
Helium isolation valves					0	
Command Module RCS						
Isolation valves					0	
RCS engine coils					0	

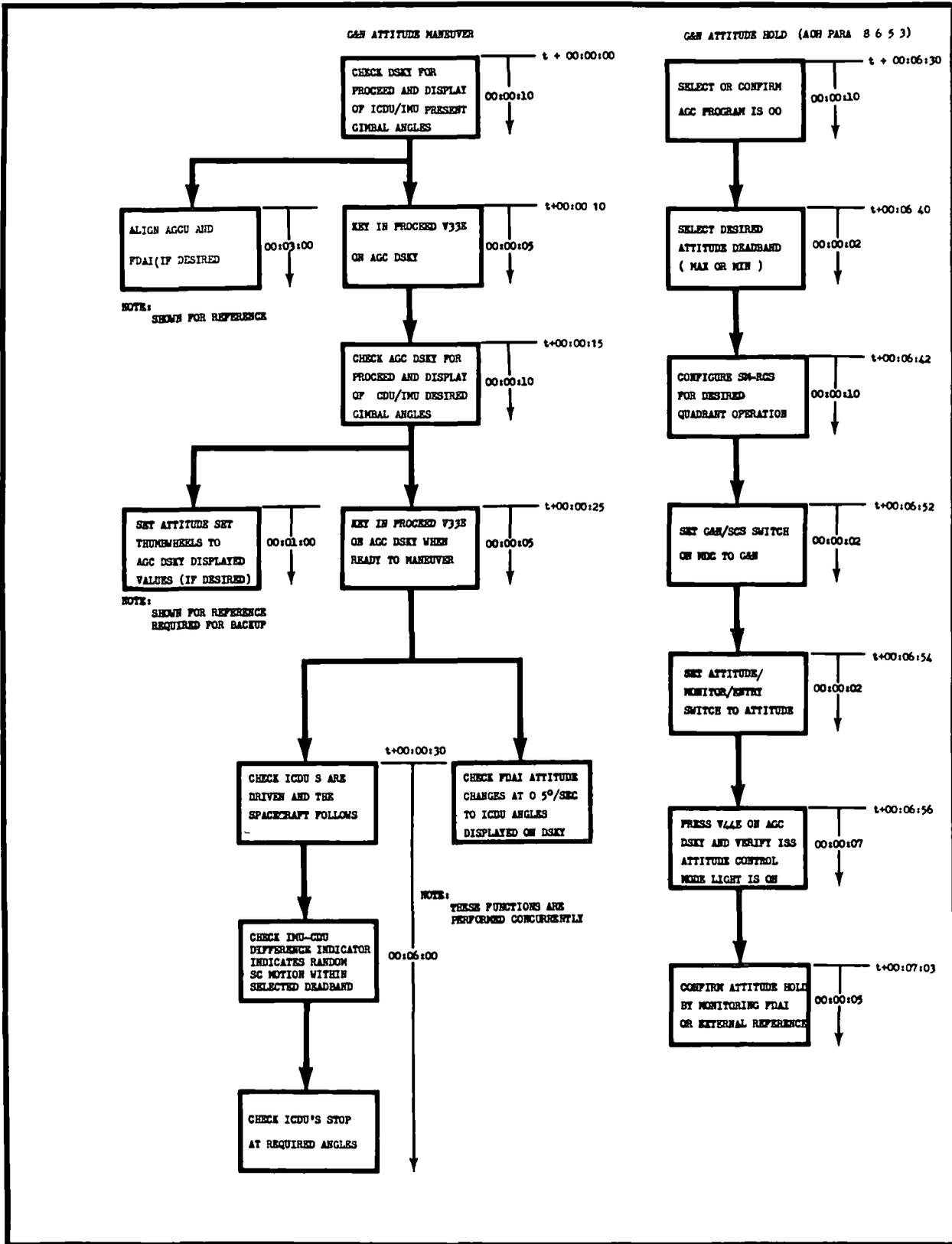


Figure 6-16 Building Block 11 G&N Attitude Control Mode (AM-1)

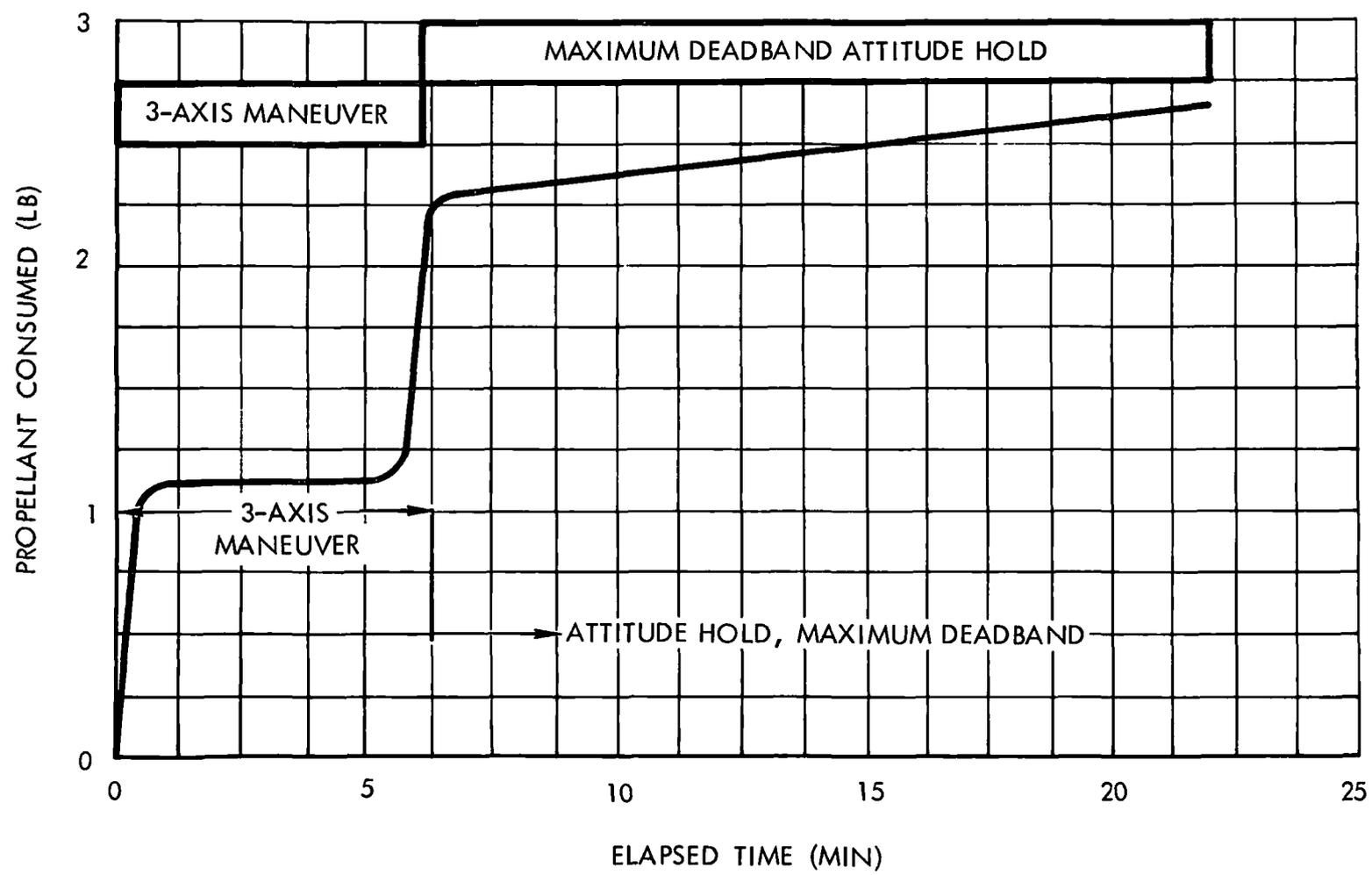


Figure 6-17 AM-1 G&N Attitude Control RCS Propellant Consumption

6-113

SID 66-1177

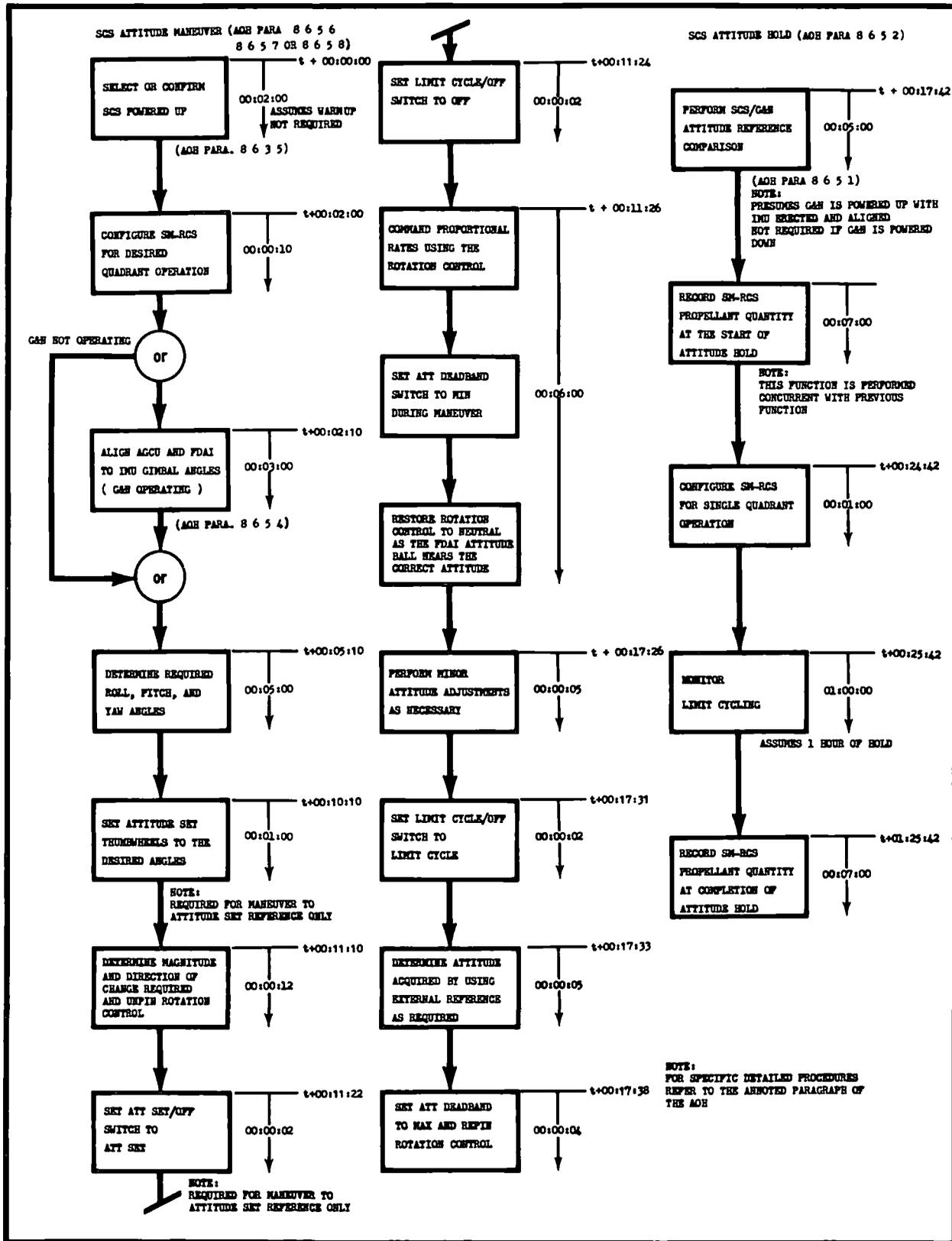


Figure 6-18 Building Block 11 SCS Attitude Control Mode (AM-2)

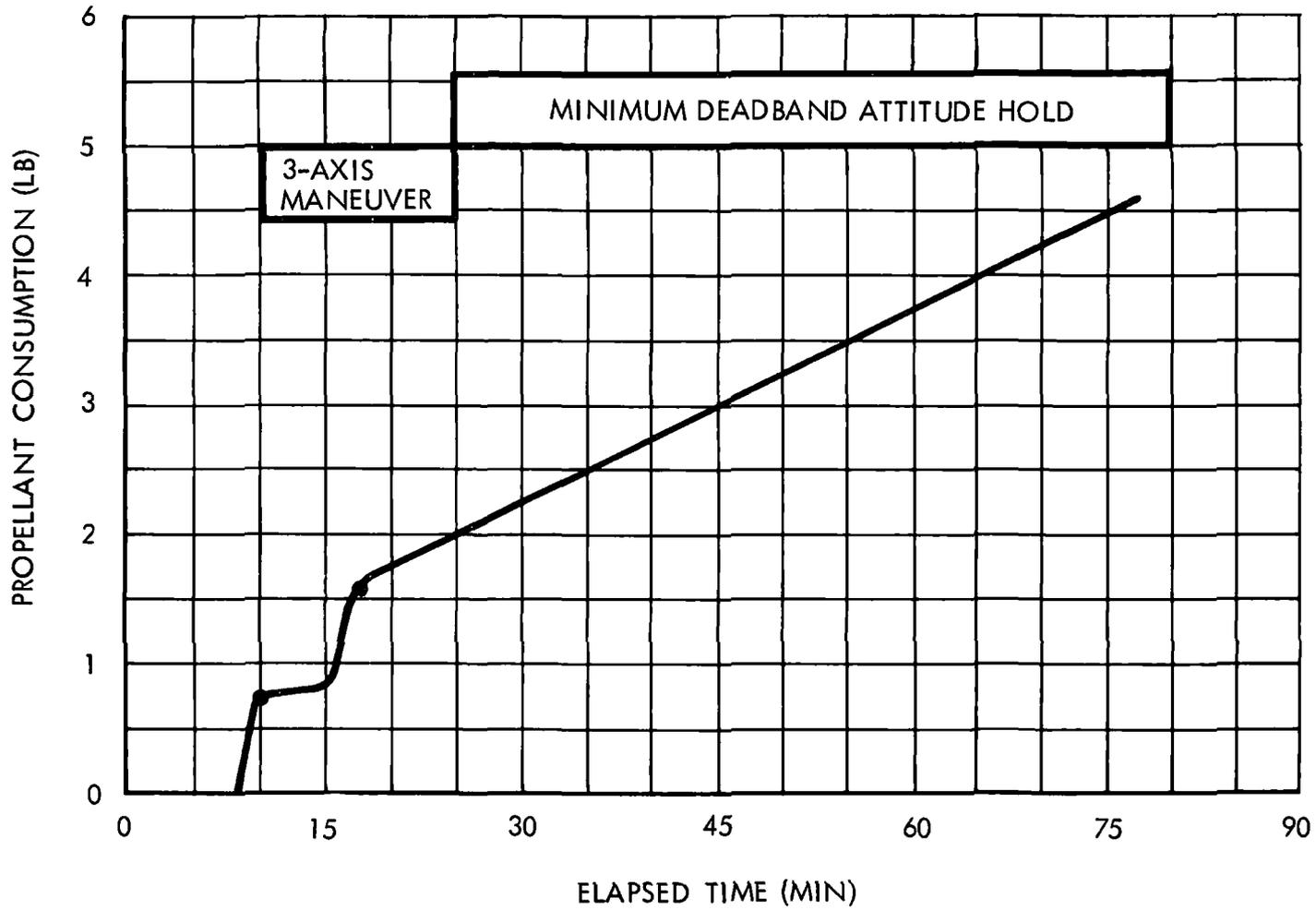


Figure 6-19 AM-2 SCS Attitude Control RCS Propellant Consumption

6-115

SID 66-1177



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SPACE and INFORMATION SYSTEMS DIVISION

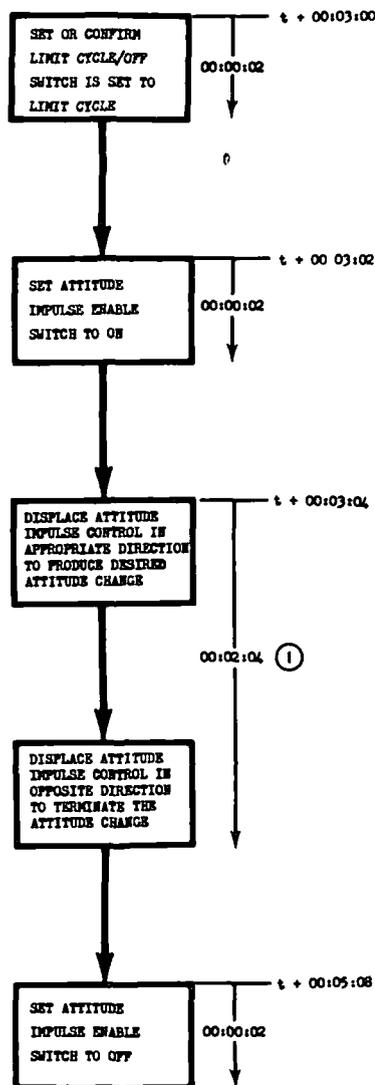
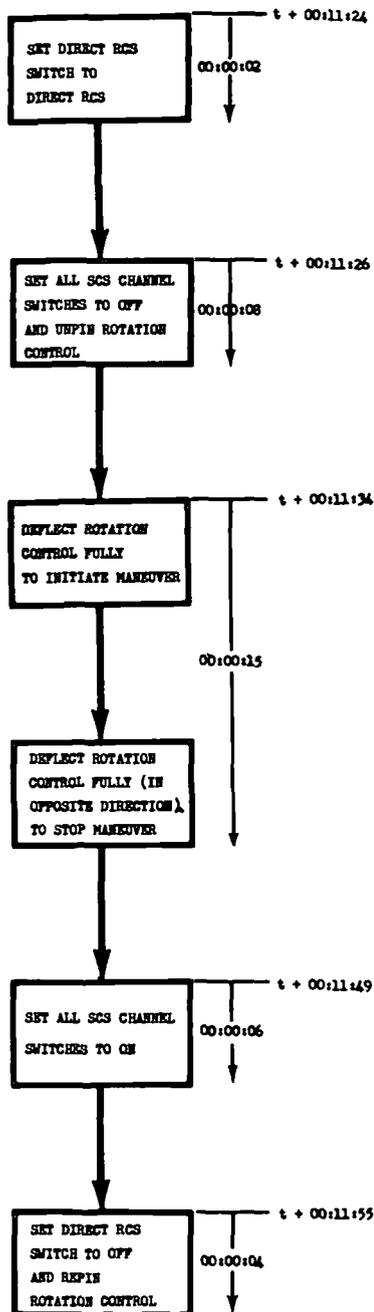


DIRECT ROTATION CONTROL (AGS PARA 6 6 1 2g)

NOTE:
WITH THE SPACECRAFT CONFIGURED FOR AN SCS ATTITUDE MANEUVER, THE FUNCTIONS DEPICTED BELOW ARE REQUIRED TO PERFORM DIRECT ROTATION CONTROL.

ATTITUDE IMPULSE CONTROL

NOTE:
WITH THE SPACECRAFT CONFIGURED FOR GAN OR SCS ATTITUDE HOLD, THE FUNCTIONS DEPICTED BELOW ARE REQUIRED TO EFFECT ATTITUDE IMPULSE CONTROL.



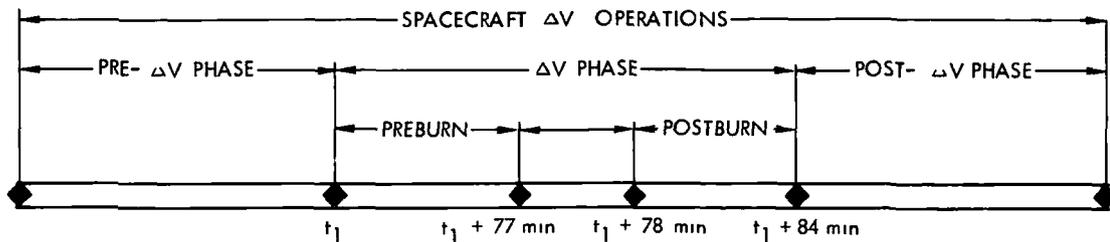
①
EACH DISPLACEMENT OF THE ATTITUDE IMPULSE CONTROL PRODUCES A SINGLE CONTROL SIGNAL OF 16 ± 4 MILLISECONDS DURATION TO THE APPROPRIATE RCS ENGINE THROUGH THE JET SELECTION LOGIC

Figure 6-20 Building Block 11 Manual Attitude Control Mode (AM-3)

BUILDING BLOCK 12 SPS ΔV

12 1 INTRODUCTION

The SPS ΔV is more correctly defined as a spacecraft ΔV using the SPS since all spacecraft subsystems are involved in ΔV operations. This event, as described herein, is initiated by powering up (from STANDBY to OPERATE) the G&N system and is terminated by the completion of a postburn checklist. Three phases are applicable as shown herewith.



The ΔV phase includes a mandatory preburn timeline, an open-ended burn timeline and a postburn timeline. Basic event times shown are related to the detailed timeline segment in Subsection 12 2 3. Additional pertinent comments are as follows:

12 1 1 Alternate Modes

Three modes are applicable to this block: the AM-1 G&N ΔV mode, the AM-2 SCS ΔV mode and the AM-3 manual TVC mode. Since this block reflects normal subsystem usage only, all systems will be available regardless of the mode chosen to perform a particular ΔV . Therefore, timeline differences are non-critical between modes and the timeline is represented as a single continuous timeline with appropriate options.



12 1 2 Block Interfaces

The data contained herein are generally applicable to any ΔV including the SPS deorbit (Building Block 25). The timeline reflects information pertaining to the following subordinate blocks or related subsystems:

IMU alignment	7
Landmark navigation sightings	8
Attitude control	11
RCS translation	13
Subsystem status checks (except CM RCS)	14
Subsystem maintenance	15
AGC update	16
Communications	Section 4 0

The detailed information pertaining to these events is provided in the individual building block data packages. In practice, however, these blocks must be considered a part of Building Block 12 in order to assure full recognition of all applicable operational and performance information.

12 2 OPERATIONAL DATA

12 2 1 General Information

The functional logic has been prepared showing recommended modes of ΔV operations during the mandatory ΔV timeline. A basic timeline was prepared with reference information for each of the three modes included herein.

Duty cycles and power profiles have only minor differences from mode to mode, and therefore all recommended combinations have been generally covered in a single timeline presentation.

Spacecraft status prior to the mandatory ΔV procedures will be accounted for by in-flight decision logic and pre- ΔV status confirmation procedures. These procedures will cover all spacecraft systems functionally and materially related to the overall ΔV operation and have been referenced to the AOH. The mandatory ΔV operations include only those systems



involved in starting and controlling the propulsion systems. Most currently known operational limits and constraints have been covered within the operational timeline write-up.

12 2 2 Mission Functional Flow

A flow diagram, (Figure 6-21) is provided to depict sequentially the functions required to perform an SPS ΔV maneuver. Relative time is depicted on the flow diagram for a specific set of initial conditions and assumptions. (Refer to the operational timeline for mission time and the nominal time required to perform a function or to complete the entire maneuver.)

12 2 3 Operational Timeline Segment

The operational timeline segment of Table 6-25 includes only those operations which are required to aid in defining total event duration, duty cycles, and consumable profiles.

Since the SPS burn building block was presumed not to be a time-fixed trajectory event, mission times are shown in the operational timeline segment as nonspecific times (denoted as t_1 , t_2 , $t_3 + 00 05 00$, etc.) to aid in real-time mission planning. It should be noted that where operational events could not be precisely fixed in time with respect to preceding or subsequent operations, because of dependency upon trajectory-oriented variables such as required SC/MSFN communications contacts (AGC update, confirmation of thrusting parameters, etc.) and burn duration, they are indicated by the change in the mission-time subscript.

The operational timeline segment is confined in scope to considering the G&N system as a requisite part of all modes of accomplishing a ΔV .

12 2 4 Duty Cycles

Duty cycles are presented in Tables 6-26 and 6-27 as is also the mode time for critical components of the ΔV related subsystems. The duty cycles shown are for combinations of AM-1, AM-2 and AM-3.

12 2 5 Electrical Power Profile

Electrical power usage for a SPS ΔV maneuver, which is representative of AM-1, AM-2, and AM-3, is shown in Figure 6-22.



Table 6-25 Operational Timeline Segment, SPS ΔV

Mission Time From t ₁ Hr min sec	Duration Hr min sec	Event/Operation	Time Source	Remarks
Assumed to occur some time before t ₁	0 30 00	Determine necessity for ΔV maneuver Evaluate status of present sequence of events Assess criteria for flight plan modification Dispersions in powered maneuver Known flight crew constraints	E	For information only NASA responsibility MCC/flight crew determine necessity for trajectory redesign or modification based upon updated criteria trajectory parameters total parameters and total flight plan
Assumed to occur some time before t ₁	1 00 00	Select optimum ΔV maneuver plan Perform crew preparation Awaken and brief any sleeping crewman Perform shirtsleeve-to-PGA mode change Perform PGA verification test Perform go, no-go check of critical systems Perform EPS d-c voltage-amperage check Verify EPS fuel cell purge status Perform SM RCS status check Perform SPS status check Perform ECS status check Perform C&WS lamp check Select or confirm spacecraft configured for ΔV Select trajectory modification plan	E	For information only NASA responsibility References AOH Paragraphs 8 4 12 2, 8 4 15 8 4 4 1 8 4 6 If at the time of a scheduled ΔV maneuver more than 6 hr will have elapsed since the last O ₂ or H ₂ fuel cell purge the appropriate purge is to be accomplished at this time References AOH Paragraphs 8 4 3 1 8 4 2 1 Reference AOH Paragraph 8 4 8 1 Reference AOH Paragraph 8 4 17 1 See mission time t ₁ +1 06 16 for TVC selection variables and recommendations MCC/flight crew determine that trajectory modification plan (i.e. type of



Table 6-25 Operational Timeline Segment, SPS ΔV (Cont)

Mission Time From t ₁ Hr min sec	Duration Hr min sec	Event/Operation	Time Source	Remarks
				ΔV SPS engine ignition time etc) including contingencies, satisfying the maximum number of mission objectives within known constraints
t ₁ 0 0 0	0 02 00	Select or confirm G&N powered up	E	<p>The AGC mode switch should be switched to ON before the IMU-MNA and -MNB circuit breakers are closed</p> <p>The IMU-MNA and -MNB circuit breakers should be closed at least 60 minutes prior to a ΔV References AOH Paragraphs 8 6 3 9 1 1</p> <p>If G&N is determined to be inoperative (IMU and/or AGC inoperative) omit subsequent operations involving those systems (i.e. AGC update IMU orientation determination AGC pre-thrusting program IMU alignment AGC thrusting program) and proceed with either a SCS ΔV or MTVC</p>
t ₂ 0 02 00	0 05 00	<p>Perform update of AGC</p> <p>Update navigation state vector</p> <p>Receive ΔV maneuver data</p>	E	<p>MSFN/SC voice and/or updata link communications coverage required Reference AOH Paragraph 8 6 7 1</p> <p>Spacecraft attitude must be such as to allow CSM antenna coverage for communications If CSM attitude is unsatisfactory, power us SCS and employ attitude impulse to bias CSM rates as necessary</p> <p>AGC mode switch must be placed to ON</p> <p>If AGC update is to be made via the updata link place AGC UPTEL switch in ACCEPT position</p>



Table 6-25 Operational Timeline Segment, SPS ΔV (Cont)

Mission Time From t ₁ Hr min sec	Duration Hr min sec	Event/Operation	Source	Remarks
				If orbital track will not afford MSFN station coverage with digital updata link capability proceed with AGC update via voice communications with MSFN and manual entry of data into AGC
0 07 00	0 02 00	Select or confirm SCS powered up	E	Required only if spacecraft is in spin stabilized mode
0 09 00	0 16 33	Perform IMU orientation determination	E	<p>If G&N has not been powered down since last IMU alignment this step is unnecessary Reference AOH Paragraph 8 6 4 2</p> <p>CSM attitude must be such as to allow two stars to be visible through the G&N optics and vehicle rates must be less than 0 2 degree/second in each axis</p> <p>If constraint above is exceeded powerup SCS and employ G&N attitude control to satisfactorily adjust CSM attitude and rates prior to performing IMU orientation determination</p>
0 25 33	0 10 00	Perform AGC pre-thrusting program	E	<p>This procedure should be performed at least twice for each thrusting maneuver once after the initial MSFN update of the AGC and once prior to the burn while in contact with MSFN for final confirmation of thrusting parameters</p> <p>Reference AOH Paragraph 8 8 2</p> <p>Depending upon the trajectory modification plan adopted either an AGC pre-thrusting orbit change or SPS minimum impulse program will be performed</p>



Table 6-25 Operational Timeline Segment, SPS ΔV (Cont)

Mission Time From t_1 Hr min sec	Duration Hr min sec	Event/Operation	Time Source	Remarks
t_3 0 35 33	0 05 00	Perform confirmation of thrusting parameters with MSFN	E	<p>MSFN/SC voice communications coverage required Reference AOH Paragraph 8 8 2</p> <p>Spacecraft attitude must be such as to allow CSM antenna coverage for communications If CSM attitude is unsatisfactory power up SCS and employ attitude impulse to bias CSM rates as necessary</p> <p>MSFN monitors AGC downlink telemetry of computed perigee altitude apogee altitude and ΔV required Flight crew coordinates evaluation of AGC computed parameters with MSFN</p>
0 40 33	0 02 00	Select or confirm SCS powered up (00 02 00)	E	<p>The BMAG power switch is presumed to remain in the AC2 position for the entire mission eliminating the need for a 40-minute warm-up period that would occur if the BMAG's had to be powered up from OFF to AC2</p> <p>Reference AOH Paragraph 8 6 3 5</p>
0 42 33	0 23 43	<p>Perform CSM/IMU alignment to thrusting attitude</p> <p>Maneuver CSM to thrusting attitude</p> <p>Perform IMU fine alignment</p> <p>Perform IMU fine alignment check</p>	E	<p>The IMU must be inertially stabilized at a known orientation prior to performing this operation Reference AOH Paragraph 8 6 5 12</p> <p>The G&N and SCS must be powered up</p> <p>An AGC program has been previously selected which has specified and stored in the AGC</p> <ol style="list-style-type: none"> 1 Desired final IMU orientation 2 Desired final vehicle attitude



Table 6-25 Operational Timeline Segment, SPS ΔV (Cont)

Mission Time From t ₁ Hr min sec	Duration Hr min sec	Event/Operation	Time Source	Remarks
1 06 16	0 06 00	Configure main display console for TVC mode	E	<p>Reference AOH Paragraphs 8 8 2 8 7 1</p> <p>The TVC selection variables are listed as follows</p> <p>Attitude Control</p> <p>A-1 G&N Auto A-2 SCS Auto A-3 Manual (Rate Damped) to G&N ball A-4 Manual (Rate Damped) to external reference A-5 Manual (Acceleration) to G&N ball A-6 Manual (Acceleration) to external reference</p> <p>Magnitude Control</p> <p>B-1 G&N Auto B-2 SCS Auto B-3 Direct On-Off</p> <p>Depending upon the trajectory modification plan adopted the main display console will be configured for one of the following recommended TVC selections</p> <p>* A-1 B-1 † A-1 B-2 † A-1 B-3 † A-2 B-2 A-2 B-3 † A-3 B-1 A-3 B-2 A-3 B-3 * A-4 B-2 * A-4 B-3 A-5 } not recommended A-6 }</p> <p>* Designates desired flight test configuration</p> <p>** Designates required flight test to satisfy test objectives</p>

Table 6-25 Operational Timeline Segment, SPS ΔV (Cont)

Mission Time From t_1 Hr min sec	Duration Hr min sec		Time Source	Remarks
1 06 16 (cont)		Initiate AGC thrusting program		<p>This operational time-line segment presumes that the G&N is operative and that the G&N will be used to monitor the performance of a SCS velocity change or a manual TVC to the docking window reference, in addition to controlling a G&N velocity change Reference AOH Paragraphs 8 2 2 and 8 7 1</p> <p>Depending upon the trajectory modification plan adopted an AGC thrusting orbit change an SPS minimum impulse or a G&N standby SPS monitor program will be performed</p>
1 12 16	0 04 00	Perform initial trim of SPS engine gimbals Start SPS engine gimbal motors Manually set initial trim of SPS engine gimbals	E	Reference AOH, Paragraphs 8 8 2 and 8 7 1
t_4 1 16 16	0 00 15	Perform ullage	E	<p>A normal ullage involves 4 +X SM RCS jets for 15 seconds</p> <p>Reference AOH Paragraphs 8 8 2 and 8 7 1</p> <p>Depending upon the trajectory modification plan adopted either the test objective demonstration of direct ullage will be performed or a normal ullage will be performed by manually initiating a +X command with the translation control</p>
	0 01 00	Perform SPS burn	G	Perform SPS burn as selected prior to t_1 and/or as configured for at mission time $t_1 + 1 06 16$ Reference AOH Paragraphs 8 8 2 and 8 7 1



Table 6-25 Operational Timeline Segment, SPS ΔV (Cont)

Mission Time From t ₁ Hr min sec	Duration Hr min sec		Time Source	Remarks
t ₅ 1 17 16	0 06 00	Perform post-SPS burn checklist Switch off SPS engine gimbal motors Establish random drift Perform systems status checks and consumable logging Compare parameters with MSFN	E	If SPS burn was a G&N velocity change switch from G&N ΔV to G&N attitude control before establishing random drift Reference AOH Paragraphs 8 8 2 8 7 1 and 8 4 2
Assumed to occur sometime after t ₁ + 1 23 16	0 02 00	Power down G&N and SCS	E	Power down G&N and SCS only if it is determined that an additional SPS burn is not required within the next 60 minutes Reference AOH Paragraphs 8 6 3 2 and 9 6 3 6 9 6 3 6
Assumed to occur sometime after t ₁ + 1 23 16	2 00 00	Perform EPS battery charge	E	Perform EPS battery charge if not constrained by time availability Reference AOH Paragraph 8 4 5

Time source code

- E = Engineering estimate Derived from statistical analysis (e g the computer formula or data provided by cognizant engineering groups such as alignment time of FDAI etc)
- G = Guess An approximation based upon the engineering assumption of a realistic time limit



Table 6-26 Subsystem Duty Cycles, AM-1 G&N ΔV Mode and AM-3 Manual TVC Mode (Duration 1 391 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 12
Stabilization and Control				
RGP		2 3 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
BMAG		2 3 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
FDAI		2 3 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
AS/GPI		2 3, 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
ΔV display		5	0	7 48 in 5
Rotation controller		2 3 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
SCS control panel		2 3, 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
ECA pitch		2 3 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
ECA roll		2, 3 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
ECA yaw		2 3, 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
ECA auxiliary		2, 3, 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
ECA display		2 3, 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5



Table 6-26 Subsystem Duty Cycles, AM-1 G&N ΔV Mode and AM-3 Manual TVC Mode (Duration 1 391 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BB-12
Electronics display		2 3 6 and 5	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 5
TVC OPERATE		6 and 5	0	44 8 in 6 7 48 in 5
STANDBY			0	
Guidance and navigation				
AGC OPERATE		A and B	0	51 75 in A 48 25 in B
AGC STANDBY		F	100	0
IMU OPERATE		A and B	0	51 75 in A 48 25 in B
IMU STANDBY		F	100	0
Optics		B	0	48 25 in B
Displays and controls		A and B	0	51 75 in A 48 25 in B
Service module RCS				
Propellant quantity gauging			0	
Engine heaters			62 5	same as BB 9
RCS engine coils		Automatic	0	0 0351
He isolation valves			0	
Propellant isolation valves			0	
Command module RCS				
Isolation valves			0	
RCS engine coils			0	
Service propulsion system				
Propellant utilization valve			0	20 65
Propellant utilization gauging system			0	20 65



Table 6-26 Subsystem Duty Cycles, AM-1 G&N ΔV Mode and AM-3 Manual TVC Mode (Duration 1 391 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BB-12
Injector prevalves	2		0	20 65
He solenoid valve	2		0	20 65
Feedline heaters	26		0	50 00
Pilot valves (SCS)	4		0	1 198
Gimbal actuator motors		Idle	0	5 09
		ΔV	0	1 198



Table 6-27 Subsystem Duty Cycles, AM-2 SCS ΔV Mode and AM-3 Manual TVC Mode (Duration 1 391 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 12
Stabilization and control				
RGP		2, 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
BMAG		2 3, 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
FDAI		2 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
AS/GPI		2 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
ΔV display		4	0	7 48 in 4
Rotation controller		2, 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
SCS control panel		2 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
ECA pitch		2 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
ECA roll		2 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
ECA yaw		2 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
ECA auxiliary		2 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
ECA display		2 3 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4



Table 6-27 Subsystem Duty Cycles, AM-2 SCS ΔV Mode and AM-3 Manual TVC Mode (Duration 1 391 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 12
Electronics display		2 3, 6 and 4	0	37 9 in 2 3 59 in 3 44 8 in 6 7 48 in 4
TVC OPERATE		6 and 4	0	44 8 in 6 7 48 in 4
STANDBY			0	
Guidance and navigation				
AGC OPERATE		A and B	0	51 75 in A 48 25 in B
AGC STANDBY		F	100	0
IMU OPERATE		A and B	0	51 75 in A 48 25 in B
IMU STANDBY		F	100	0
Optics		B	0	48 25 in B
Displays and controls		A and B	0	51 75 in A 48 25 in B
Service Module RCS				
Propellant quantity gauging			0	
Engine heaters			62 5	Same as BB-9
RCS engine coils		Automatic	0	0 0351
He isolation valves			0	
Propellant isolation valves			0	
Command module RCS				
Isolation valves			0	
RCS engine coils			0	
Service propulsion system				
Propellant utilization valve			0	20 65
Propellant utilization gauging system			0	20 65



Table 6-27 Subsystem Duty Cycles, AM-2 SCS ΔV Mode and AM-3 Manual TVC Mode (Duration 1 391 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 12
Injector prevalves	2		0	20 65
He solenoid valves	2		0	20 65
Feedline heaters	26		0	50 00
Pilot valves (SCS)	4		0	1 198
Gimbal actuator motors		Idle	0	5 09
		ΔV	0	1 198



12 2 6 Propellant Consumption

For information regarding SPS propellant availability and usage, refer to Subsection 12 3 For SM RCS propellant consumption, the following assumptions have been made

- 1 Drifting flight - unless a maneuver is scheduled
- 2 IMU alignment requirements as covered in Building Block 7
- 3 Attitude-hold is a 3-axis minimum deadband
- 4 Ullage uses four +X jets
- 5 SPS burn uses attitude-hold with a minimum deadband in roll plus TVC

Based on these assumptions, propellant consumption for this specific case is as follows

Time	Maneuver	Propellant (lb)
$t_1 + 43$ minutes	IMU alignment	4 3
$t_1 + 67$ minutes	Attitude-hold	0 5
$t_1 + 77$ minutes	Ullage	21 0
$t_1 + 77$ minutes	SPS burn	
Total		25 8

The propellant-consumed values are not to be used except for this specific case

12 3 PERFORMANCE DATA

12 3 1 General Information

In an ideal sense, the spacecraft "performance" applicable to Building Block 12 would include all subsystem operations during the three phases shown in Paragraph 12 1 However, this amount of data would be prohibitive and unreasonable for modular mission analysis, even though the operational timeline segment reflects some consideration of all applicable performance data The applicable performance data are described in Subsection 12 3 3 It must be realized, however, that the enormity of general performance data



applicable to ΔV operations can be encompassed only by reference to the CSM System, Master End-Item and End-Item Specifications (SID-313, 1237, and 1080) and to other detailed reference sources

The performance data include only that information which is considered useful in modular mission planning and which is not conveniently available in existing primary references. General SPS and RCS model data including SCS mode and rate usage are provided in Section 5.0 and in Building Block 11.

12.3.2 Scope of Data

Performance data have been limited to ΔV capability involving G&C, SPS, and SM RCS. Ranges for parametric data have been limited to (1) burns - minimum impulse and 150 seconds in duration, (2) usable SPS propellant - 8,000 lb, (3) CSM weight - 30,000 lb, and (4) ΔV - 3,000 ft/sec. Performance data cover the nominal ranges of ΔV magnitude and accuracy and reflect consideration for (1) spacecraft weight limits and c.g. offsets, (2) propellant limits, (3) rate limits, and (4) gimbal angle limits.

12.3.3 Description of Performance Data Provided

12.3.3.1 SPS Steady-State Performance

The SPS rocket engine ratings and performance data in a vacuum are given as follows:

Operating life (minimum)	= 600 seconds
Thrust, nominal	= 21,500 pounds
Specific impulse average nominal	= 311.2 seconds
minimum (-3 sigma)	= 307.4 seconds
Propellant flow rate, total (start)	= 69.09 pounds/ second
Fuel flow rate (start)	= 23.03 pounds/ second
Oxidizer flow rate (start)	= 46.06 pounds/ second

The flight engine is currently capable of a minimum of 36 starts for a 600-second operational life. The total impulse provided by the SPS, based on approximately 7,500 pounds of usable propellant, is 2,321,000 pound-seconds nominal, minus 4,500 pound-seconds for each engine start.



12 3 3 2 SPS Propellant Requirements

Spacecraft weight is plotted against characteristic velocity for nominal and minimum values of specific impulse in Figure 6-23. A sample path traces a typical solution for propellant weight when initial weight, specific impulse, and characteristic velocity change are given. The arrows indicate the direction of flow, starting with an initial value for weight W_1 . It is important to note that the characteristic velocity (V_c) scale does not represent values of ΔV remaining aboard the spacecraft but is intended to serve as a reference only on which increments (ΔV_c) may be taken as shown by the example.

In order to account for the 4500 pound-second loss for each SPS engine start, 14.4 pounds of propellant must be added to the propellant requirements for each firing. The total propellant requirements are limited to the total usable propellant available.

12 3 3 3 SPS Small-Impulse Operation

The SPS engine is capable of accepting a shutdown signal at any time after receipt of a start signal. A nominal minimum pulse bit of 12,000 pound-seconds is developed when the engine is fired for a period of 0.6 seconds. The run-to-run minimum impulse-bit tolerance is ± 300 pound-seconds (1 sigma). Impulse value as a function of start-to-shutdown signal duration (FS1 to FS2), estimated from qualification tests generated at AEDC, is shown in Figure 6-24. Propellant consumption for small impulse firings, including the 14.4 pound engine start loss, is given by the equation $W_p = (\text{Impulse} + 4500)/I_{sp}$.

12 3 3 4 SPS Engine Start and Shutdown Transients

The SPS engine start and shutdown transients are given in Figure 6-25, with percentage of rated thrust as a function of elapsed time from the start and shutdown command signals (FS1 and FS2). Rated thrust is based on nominal inlet conditions. These data were estimated from AEDC qualification tests. The start transient total impulse from FS1 to 90-percent rated thrust is limited to the range from 100 pound-seconds (minimum) to 400 pound-seconds (maximum). The run-to-run tolerance on start transient impulse is ± 100 pound-seconds (1 sigma).

The SPS engine shutdown impulse from FS2 to 10-percent rated thrust is limited to the range from 8000 pound-seconds (minimum) to 12,000 pound-seconds (maximum). The run-to-run tolerance on the shutdown impulse is ± 300 pound-seconds (1 sigma).



12 3 3 5 SPS Engine Gimbal Angles

The engine gimbal angles for an SPS firing are a measure of thrust vector alignment, through the center of gravity, with the body axis. The position of the center of gravity depends on the SPS fuel remaining aboard the spacecraft. Figure 6-26 presents the gimbal angles for fuel remaining based on an SPS oxidizer-to-fuel ratio of $(2.00 \pm 0.02)/1$.

12 3 3 6 SM RCS Ullage Maneuver Performance

The SPS propellant settling requirements are presented in Section 5.0 for two- and four-SM RCS-engine operation. The settling times include the 1-second overlap due to delay of RCS shutdown after the SPS start signal. The curve for normal settling with four RCS engines includes thrust modulation necessary for attitude control requirements. The change in axial characteristic velocity is graphed as a function of total spacecraft weight in Section 5.0.

12 3 4 Parametric Data

See Figures 6-23 through 6-26

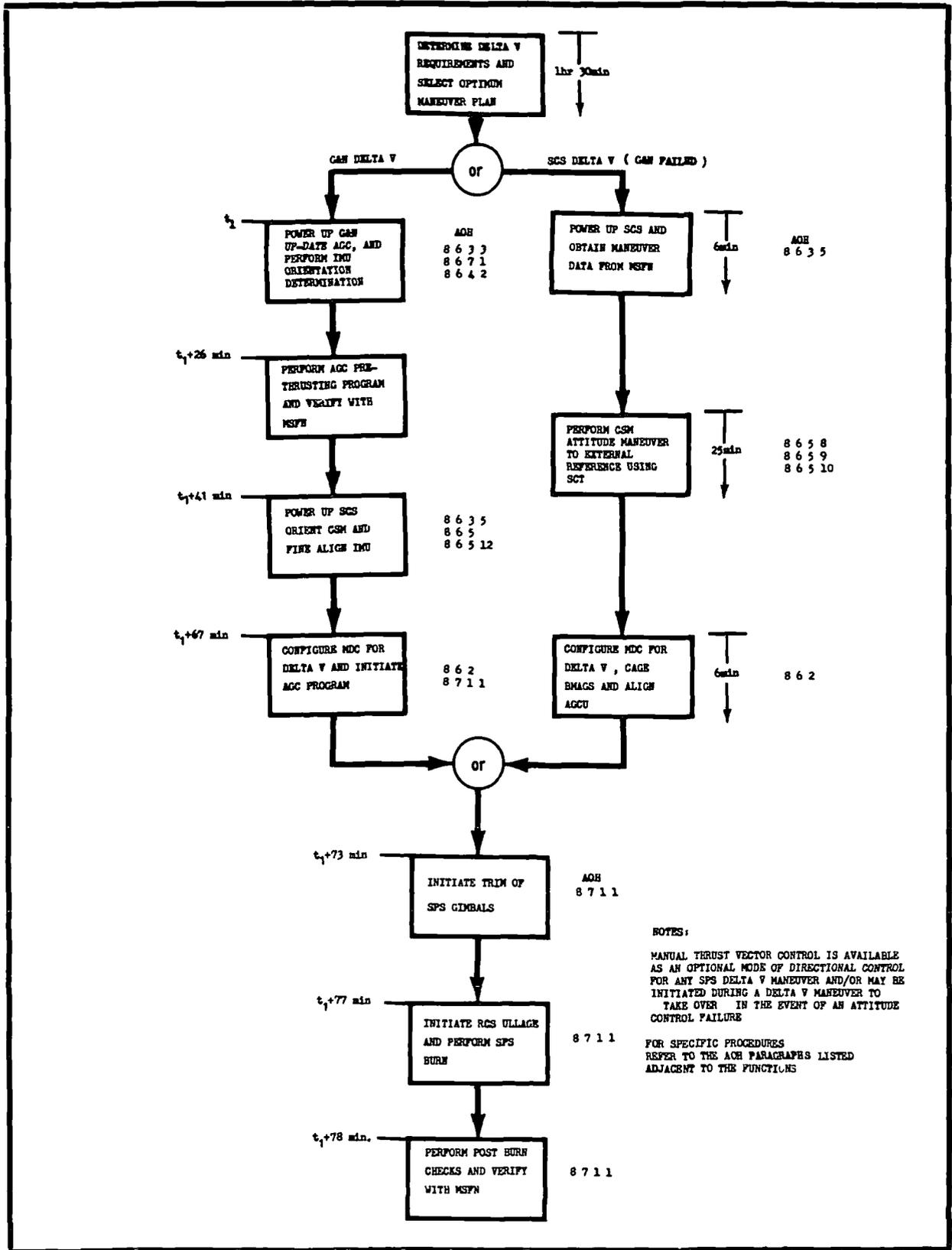


Figure 6-21 Block 12 SPS ΔV

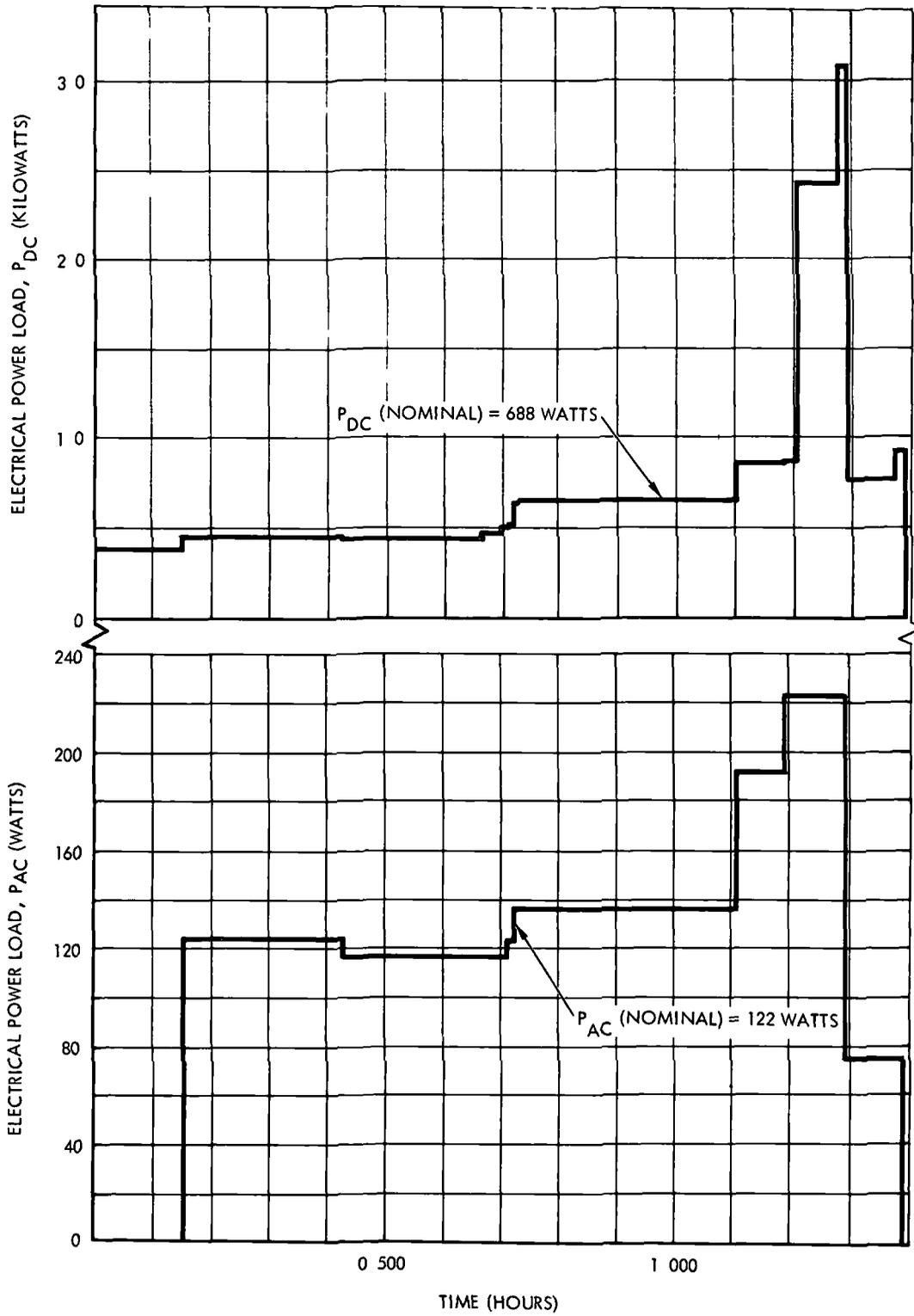


Figure 6-22 Electrical Power Profile (Delta)

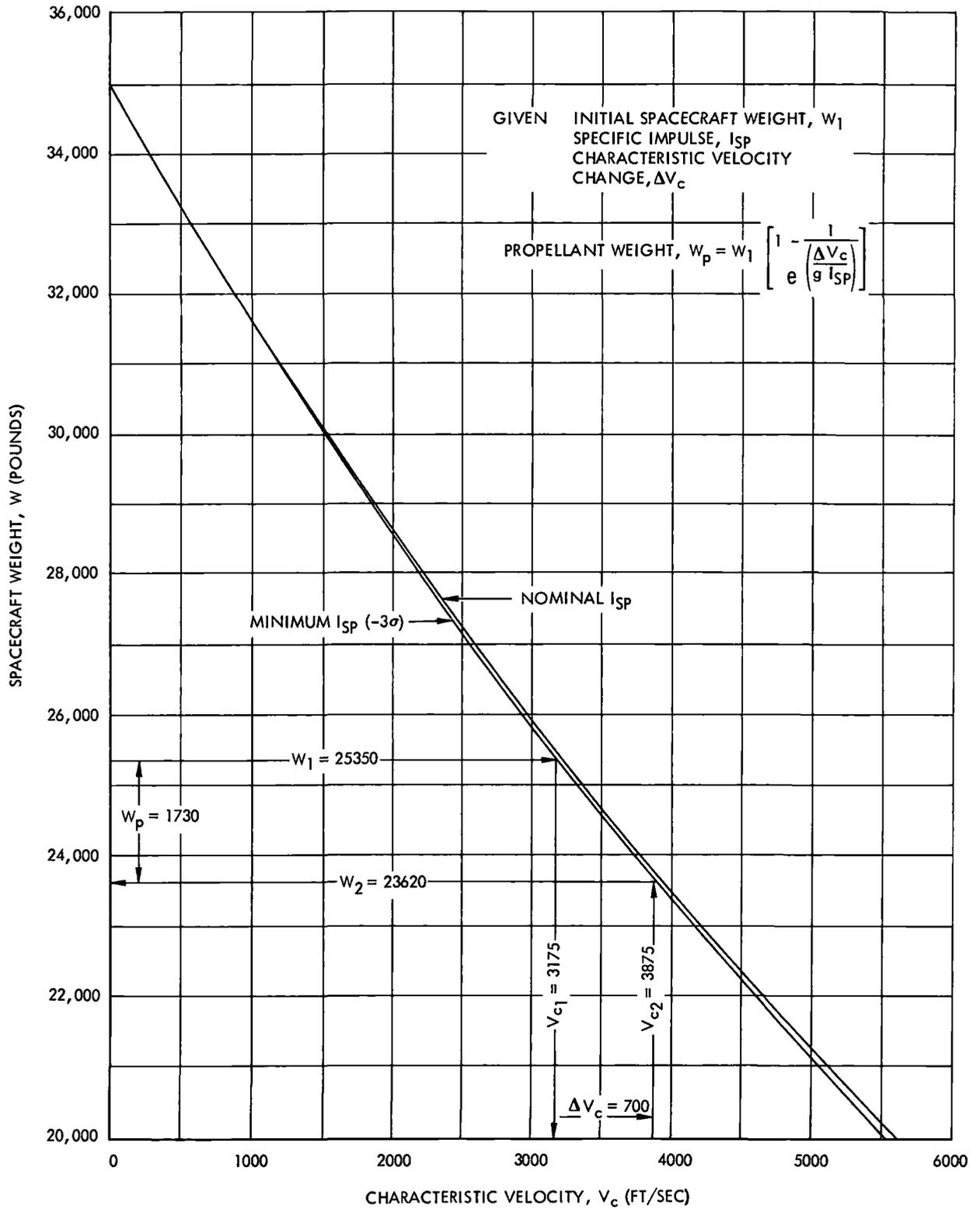


Figure 6-23 SPS Propellant Requirements

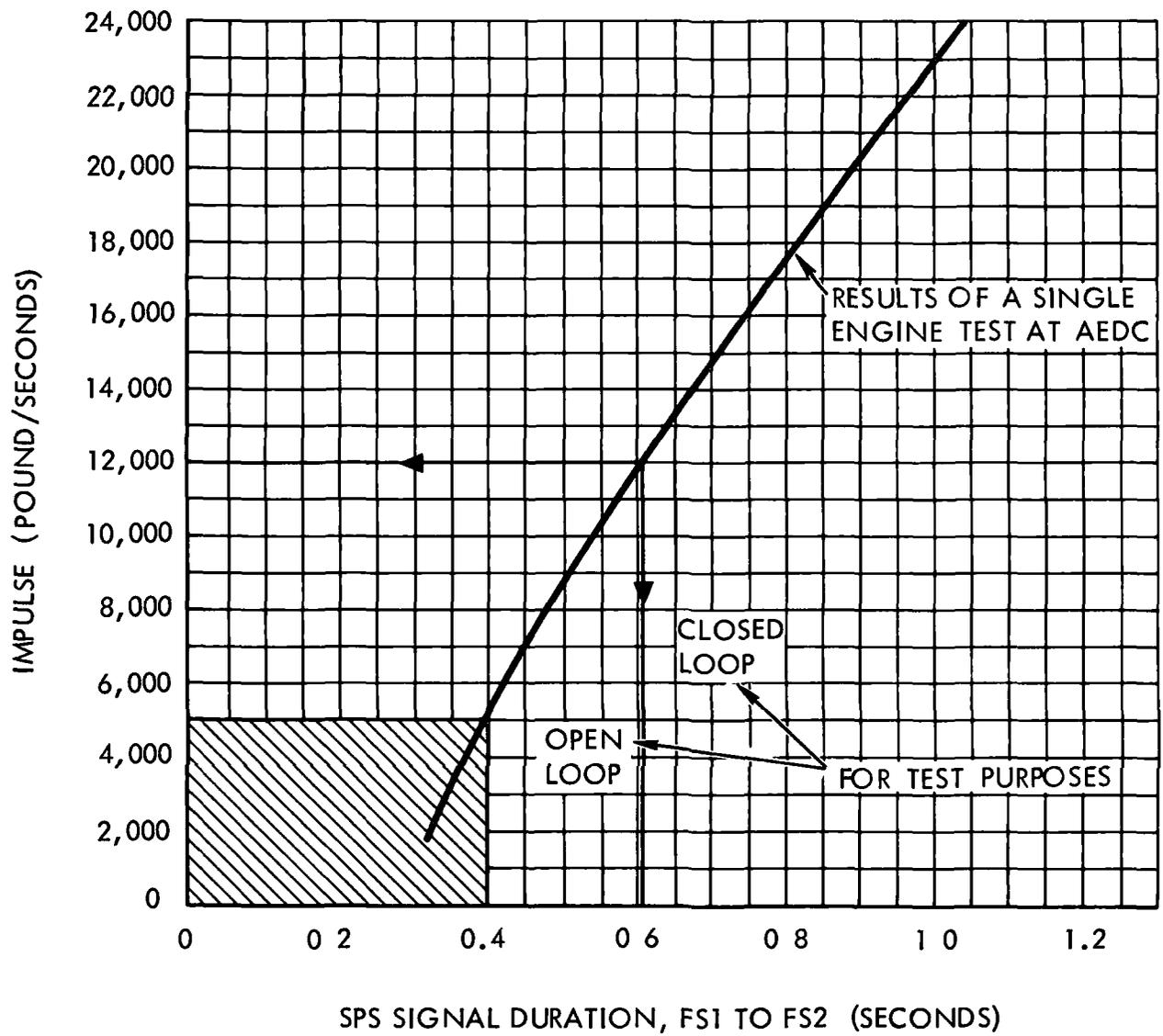


Figure 6-24 SPS Small Impulse Firings for Open-Loop Operation

6-140

SID 66-1177

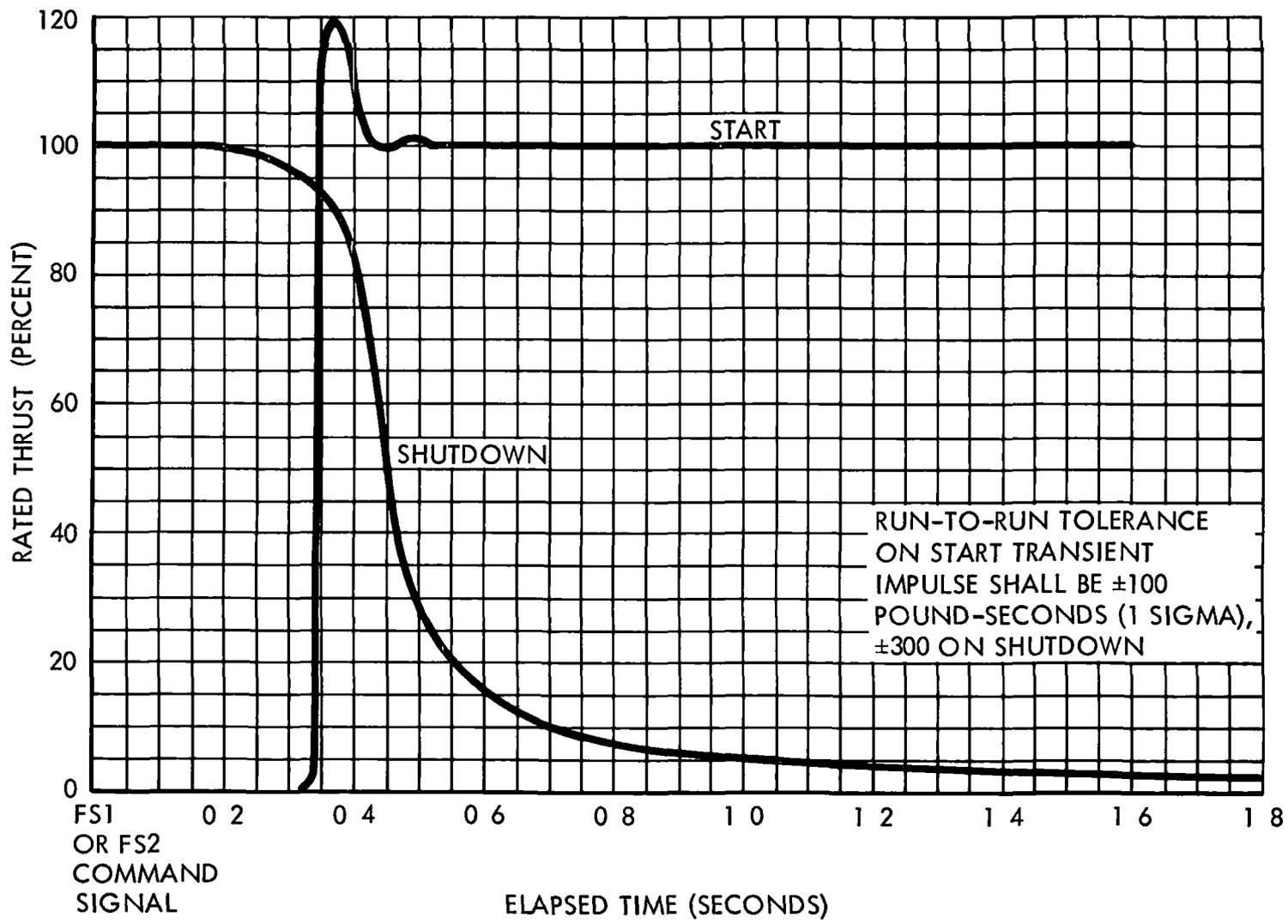
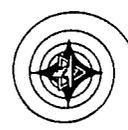


Figure 6-25 SPS Engine Start and Shutdown Transients

6-141

SID 66-1177



6-142
SID 66-1177

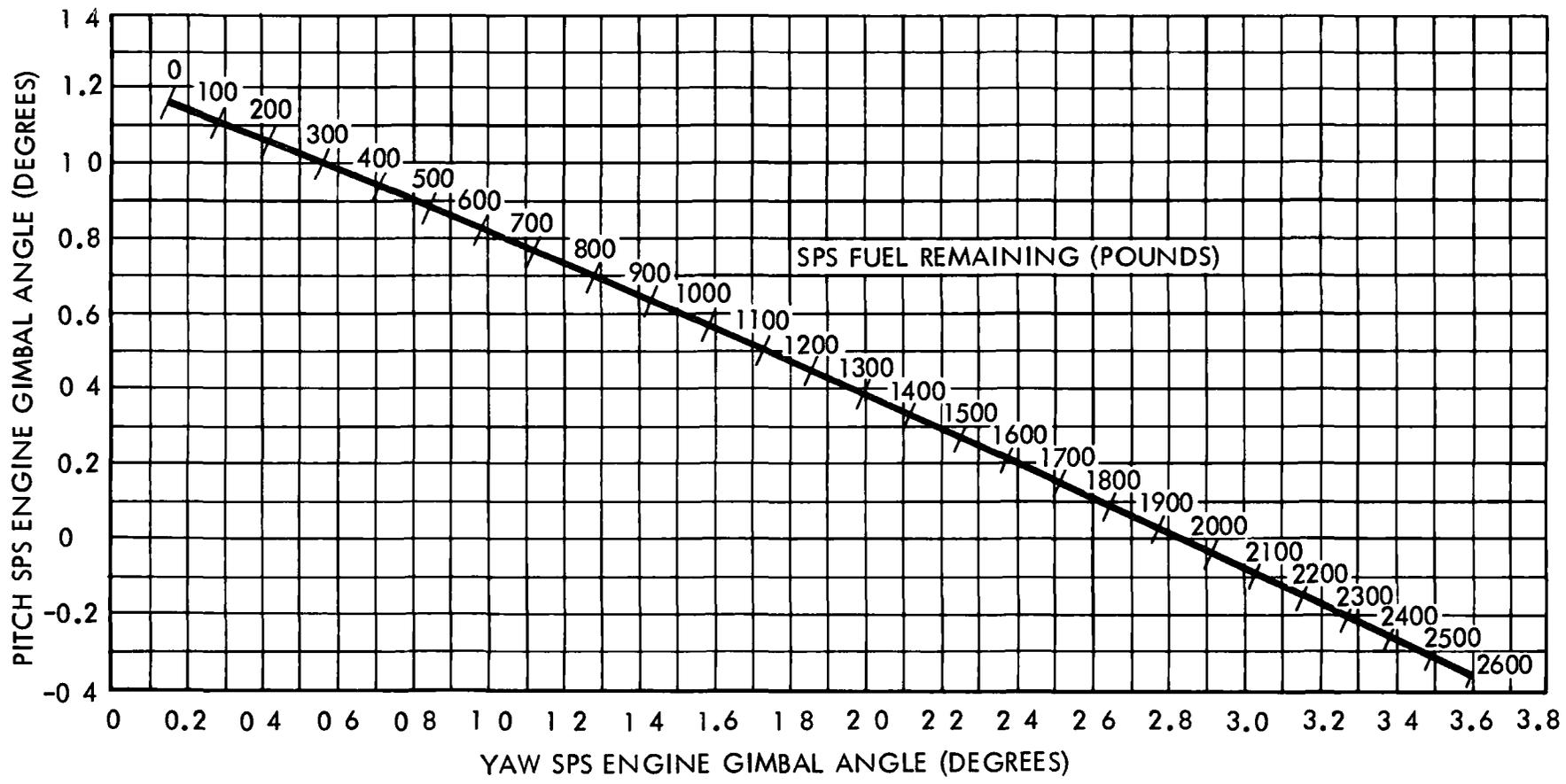


Figure 6-26 SPS Engine Gimbal Angles Versus Fuel Remaining



BUILDING BLOCK 13 RCS TRANSLATION

The two alternate modes of RCS translation are defined by the method of initiation. Those RCS translations initiated when the hand translation control is manipulated are designated alternate Mode 1, Translation Control. The +X RCS translation maneuver (initiated when the direct ullage button on the ΔV control panel is pushed) is designated Alternate Mode 2, Direct Ullage. Due to the similarity of these two modes and their limited supporting roles in mission operations only the timeline segment for alternate Mode 1 with its subsystem duty cycles, power, and propellant consumptions will be presented.

Translation is available at any time after S-IVB separates from the spacecraft and prior to when the command module separates from the service module. The effect on the normal mission operation of a translation maneuver will be reflected in the RCS propellant expended, electrical power, and a small velocity change. It should be noted that once the command module has separated from the SM, the command module does not have RCS translation capability.

Alternate Modes 1 and 2 are discussed in paragraph 2 3 1 3 2 of the AOH.

13 1 ALTERNATE MODE 1, TRANSLATION CONTROL

13 1 1 Introduction

The translation control has two RCS translation functions. The first function (primary) provides the ability for the SC to be translated along all three of its axes in both the plus and minus directions. These commands are not proportional, operation is through the switch closure only and is available during all modes of operation prior to command module-service module separation. During normal translation, switch closure within the translation control provides commands to the jet selection logic which fire the appropriate RCS engine for the desired direction of translation and for attitude control. The commands are directed to the automatic RCS engine coils. The translational control manipulations and the resulting actions are:

Push and pull handle in and out commands the $\pm X$ translation

Push handle up and down commands the $\pm Z$ translation

Push handle right and left commands the $\pm Y$ translation



The $\pm X$ translation control is used for SPS propellant settling in the SPS ΔV sequence (Table 6-28)

The second function is activated by turning the translation control counter clockwise into the detent position. The resulting SC operations will depend on the mission phase at the time of command. For example, during the ascent phase this function will initiate aborts, but after S-IVB shutdown it commands separation ullage. The separation ullage sequence is part of the normal mission procedure which induces $+X$ translation by activating the RCS engines direct coils. This inhibits attitude control since the direct coils hold the RCS engine valve open thus overcoming the attitude control pulsing of the automatic coils.

13 1 2 Operational Data

13 1 2 1 Operational Timeline Segment

The operational timeline (Table 6-28) is an abridged segment for a G&N ΔV . In this procedure the translation control is pushed to initiate the ullage maneuver. If the RCS failed to fire, the astronaut would then press the direct ullage button. The functions of the direct ullage button are discussed under Alternate Mode 2. This segment is presented to illustrate the primary function of the translation control and its negligible effect on the subsystem duty cycles.

13 1 2 2 Subsystem Duty Cycles

Table 6-29 contains the subsystem duty cycles.

13 1 2 3 Electrical Power

The average delta power levels are

$$P_{AC} \text{ (nominal)} = 306.2 \text{ watts} \quad P_{DC} \text{ (nominal)} = 2876.2 \text{ watts}$$

The electrical power required to operate one RCS engine automatic coil = 118 watts and direct coil = 34 watts.

13 1 2 4 Propellant Consumption

The service module propellant consumed for a given RCS translation is a function of the translation duration and the number of SM RCS engines fired. Two engines are fired for $\pm Y$ and $\pm Z$ translation and four engines for $\pm X$ translation (see Section 5.0).



Table 6-28 Operational Timeline Segment, RCS Translation

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
			<p>Preparatory requisites for this operation are</p> <p>SPS ΔV preparation (Refer to Block 12)</p> <p>Determination ullage acceleration duration requirements</p>
00 00 00	Unlock prime translation control (00 02)	SID 65- 1231A	
00 00 30	Monitor digital event timer on MDC-5 for ullage initiation cue		<p>Note</p> <p>At T-25 seconds register 3 on MDC-14 should be 00000 until ullage commences and then will display accumulated ullage velocity in fps</p>
00 00 32	Push and hold translation controller to +X command when event timer reads 00 15 (00 14)		<p>When event timer reads 00 00 the navigator presses ENTER on MDC-14 if 14 seconds of ullage have occurred this will initiate SPS ignition signal which in turn activates a 1-second time delay that terminates +X translation</p>
00 00 47	Release translation controller to null position (approximately 1 second after SPS ignition (00 01)		<p>Securing requisites refer to BB-12 which include locking translation controller and propellant consumption determination</p>



Table 6-29 Delta Duty Cycles, RCS Translation, Alternate Mode 1

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	DUTY CYCLE
Stabilization and Control				
RPG			0	100
BMAG		5	0	-100
FDAI			0	100
AS/GPI		5	0	-100
ΔV display		5	0	-100
Rotation controller			0	100
SCS control panel		5	0	-100
ECA pitch		5	0	100
ECA roll		5	0	-100
ECA yaw		5	0	-100
ECA aux			0	100
ECA display		5	0	100
Electronics display		5	0	-100
TVC operate			0	0 or 100
TVC STANDBY			0	0
Guidance and Navigation				
AGC operate		A	0	-100
IMU operate		A	0	-100
Displays and controls		A	0	-100
Communications				
VHF/FM transmitter			0	100
C-band transponder			0	100
Data storage operate			0	100
Reaction Control				
RCS Engine coils (16) automatic			0	100
Engine coils direct			0	0
Helium isolation valves (8)			0	100
Propellant isolation valves (8)			0	100
Service Propulsion				
Propellant utilization gaging system			0	100
Injector pre valves			0	100
Helium solenoid valves			0	100
Feedline heaters			0	100
Pilot valves			0	100
Gimbal actuator motors idle			0	100



13 1 3 Performance Data

Each SM RCS engine nominally develops 100 pounds of thrust (See Figure 2 41 of the AOH for a nominal thrust rise and decay estimate) If four engines are ignited for a translation, the SC will accelerate at 0 04 to 0 08 ft/sec², depending on SC mode

The minimum RCS impulse duration, assuming average human response, is on the order of 200 milliseconds The maximum translation duration is a function of the available propellant A propellant allowance must be made to assure RCS translation ability for separation of the service module from the command module

13 2 ALTERNATE MODE 2, DIRECT ULLAGE

13 2 1 Introduction

Direct ullage is accomplished by using the direct ullage button on the ΔV control panel When pressed, switch closures command the four +X direct RCS engine coils to initiate translation along the +X axis Direct ullage is available at any time prior to separation of the command module from the service module It is primarily a backup operation in the event of normal translation failure Ullage will continue as long as the direct ullage button is pressed Attitude errors will develop about the pitch and yaw axes due to the direct coil override of attitude control pulse of the automatic engine coils

13 2 2 Operation and Performance Data

The operation and performance data presented in paragraphs 13 1 2 1 and 13 1 3 also are valid for Alternate Mode 2

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BUILDING BLOCK 14 SUBSYSTEM STATUS CHECKS

14 1 INTRODUCTION

Building Block 14 presents subsystem status checks. Table 6-30 depicts the types of checks, by subsystem, that must be performed, either periodically or in relation to discrete mission events. Therefore, the status check duration of necessity becomes mission-related and each status check is effectively a building block for planning purposes.

These events, along with their specific checks, are defined further in the status check matrix (Table 6-31), which contains a definition of routine status checks on a subsystem-by-subsystem basis.

Specific subsystem requirements necessary as prerequisites to completing a given check are presented, e.g., the service propulsion subsystem fuel and oxidizer quantity check requires a delta velocity duration of 4.5 seconds or greater. The mission planner, utilizing Tables 6-30 and 6-31, can insert in his planning, as a function of a discrete mission event, that portion of the matrix which is pertinent to performing a specific status check. This information can be added laterally or vertically in compiling an overall mission plan.

14 2 GROUND RULES

Ground rules associated with the performance of each status check are included to assist in mission planning. They are listed on a subsystem basis and are itemized as follows:

14 2 1 Electrical Power Subsystem (EPS)

- 1 Flight and postlanding (F/PL) batteries
 - a Should be checked hourly during battery charging as a part of the routine status check
 - b Should have the voltage level checked prior to a delta velocity
 - c Should have the frequency of the voltage level check readjusted after each Δ velocity



- 2 Routine (periodic) checks begin at earth orbit insertion
- 3 During ascent and entry
 - a The MSFN will monitor EPS status
 - b Crew restraints and g-loads make manipulation of EPS indicator switches prohibitive
- 4 Prior to S-IVB separation and CSM separation the voltage level of the pyro batteries should be checked to assure the proper power level to perform the separation function
- 5 Post S-IVB separation and at daily intervals throughout the mission the pyro batteries voltage level is to be verified

14 2 2 Service Propulsion Subsystem (SPS)

- 1 The propellant quantity gauging subsystem operates only during engine firings longer than 4 5 seconds
- 2 A self-test of the SPS propellant utilization gauging subsystem (PUGS) should be performed only as a fault isolation procedure
- 3 The PUGS should be checked during any Δ velocity maneuver that is programmed for a time duration greater than 10 seconds
- 4 Propellant quantity readouts should be recorded for any burn which is longer than 4 5 seconds Readout and recording should be compared with the MSFN's recorded values
- 5 Propellant consumption rate data should be obtained from MSFN after the second SPS burn and again prior to the SPS deorbit burn
- 6 MSFN should be relied upon to verify SPS status during ascent
- 7 Routine (periodic) checks begin at earth orbit insertion

14 2 3 Environmental Control Subsystem (ECS)

- 1 Routine (periodic) checks begin at earth orbit insertion
- 2 Lithium hydroxide filter elements will be replaced every 12 hours or when the CO₂ partial pressure indicates 7 6 mmHg



- 3 Cabin atmosphere will be "scrubbed" prior to pressure garment assembly (PGA) mode change (doff cycle)
- 4 A PGA verification check is required each time a crewman dons his suit
- 5 The redundant component test every 12 hours should be performed to verify backup capability of critical items to insure crew safety
- 6 Eight to 12 hours prior to CSM separation the cabin and space suit circuits should be subjected to maximum cooling conditions (cold soak) to insure tolerable heat levels during entry

14 2 4 Service Module Reaction Control Subsystem (SM-RCS)

- 1 Except during status checks or attitude hold, quad A is to be selected for constant gauge display after launch escape tower jettison
- 2 Post S-IVB separation attitude-hold modes require propellant consumption determination for efficiency evaluation
- 3 During SPS burn and ullage maneuvers directly preceding a burn, the SPS demand for crew member attention supersedes the SM-RCS requirements for monitoring
- 4 Quantity checks are to be performed by taking successive readings for each quad by using the pressure, temperature, and volume (PTV) method
- 5 Routine (periodic) checks begin at earth orbit insertion

14 2 5 Command Module Reaction Control Subsystem (CM-RCS)

- 1 During ascent, only CM-RCS subsystem A is to be checked, MSFN will verify the status of subsystem B
- 2 During entry, CM-RCS subsystem A status is to be displayed (the system in use) MSFN will verify the status of subsystem B (the reserve system)
- 3 The CM-RCS engine valve pre-heat function is to be checked at earth orbit insertion
- 4 Routine (periodic) checks begin at earth orbit insertion



Table 6-30 Summary of Subsystem Status Checks

Check	Subsystem				
	EPS	SPS	ECS	RCS	
				SM	CM
Periodic					
Every hour	X		X		
Every orbit				X	
Every 4 hours		X		X	
Every 6 to 8 hours	X				
Every 12 hours			X		X
Every 24 hours	X			X	
Special					
Ascent monitoring	X	X			X
Pre-LET jettison		X			
Post-LET jettison		X			
Earth orbit insertion					X
Pre-S-IVB separation	X	X		X	X
Post-S-IVB separation	X	X		X	
Pre-delta velocity	X	X	X	X	
Delta V (less than 5 seconds)		X			
Delta V (5 to 10 seconds)		X			
Delta V (more than 10 seconds)		X			
Post-delta velocity		X		X	
Pre-CSM separation	X		X	X	X
Post-CSM separation	X				X
Entry and descent	X				X
Power-up/power-down	X				
Auxiliary display check	X				
See Table 6-31 for planning data and times					



14 3 OPERATIONAL TIMELINE

There are no significant timeline segments for subsystem status checks. Each check is a variable factor in its own right that must be evolved during mission planning. Related operational procedures are helpful in detailing the individual status checks in terms of crew functions and duration. This information, together with the frequency and duration of performance, will define the specific timeline for each status check. Table 6-31 contains a cross-reference of each check by subsystem and duration.



Table 6-31 Subsystem Status Checks, Periodic and Special

Checks ⁽¹⁾	Subsystem Check and Approximate Duration				
	EPS	SPS	ECS	SM RCS	CM RCS
Periodic					
Every hour	1 min 30 sec ⁽²⁾		1 min ⁽²⁾		
Every orbit				1 min ⁽³⁾	
Every 4 hours		1 min ⁽²⁾		5 min ⁽²⁾ 2 min ⁽¹⁰⁾	
Every 6 to 8 hours	30 sec ⁽⁴⁾ H ₂ 1 min/cell ⁽⁵⁾ O ₂ 2 min/cell				
Every 12 hours			10 min ⁽⁸⁾ 10 min ⁽⁹⁾		1 min ⁽²⁾
Every 24 hours	1 min 25 sec ⁽⁶⁾⁽⁷⁾				

(1) Earth orbit insertion denotes beginning of all periodic checks (Number following note indicates applicable Apollo Operations Handbook section for detailed operational procedure)

(2) Perform routine status checks (8 4 2 8 4 3 8 4 4 8 4 8)

(3) Monitor package temperatures each orbit in the shade (8 4 3 1)

(4) Charge status of F/PL batteries A B and C becomes part of 1-hour check when batteries are charging (8 4 4 1)

(5) Monitor fuel cell purging (8 4 6)

(6) Check open circuit voltage of pyrotechnic batteries

(7) Monitor inverter 2 voltage and frequency Check inverter 3

(8) Perform redundant component operational check (8 4 9)

(9) Replace CO₂-odor filter earlier if CO₂ partial pressure requires (8 4 10)

(10) Determine propellant consumption rate (8 4 3 2)



Table 6-31 Subsystem Status Checks, Periodic and Special (Cont)

Check ⁽¹⁾	Subsystem Check and Approximate Duration				
	EPS	SPS	ECS	SM RCS	CM RCS
Special					
Earth orbit insertion					10 5 min ⁽²¹⁾
PGA verification			2 min 4 sec ⁽¹⁶⁾		
PGA mode changes			TBD ⁽¹⁷⁾		
Ascent monitoring	3 min ⁽²⁾	30 sec ⁽²⁵⁾ 30 sec ⁽⁸⁾			1 min ⁽⁻⁰⁾
Pre-S-IVB separation	1 5 min ⁽¹⁾ 1 min 25 sec ⁽³⁾	1 min ⁽¹⁾		6 min ⁽¹⁾	
Post-S IVB separation	1 min 25 sec ⁽⁵⁾ 1 min ⁽⁶⁾	1 min ⁽¹⁾		6 min ⁽¹⁾ TBD ⁽¹⁸⁾	
Pre delta velocity	30 sec ⁽⁷⁾	1 min ⁽¹⁾	2 min 4 sec ⁽²⁴⁾	6 min ⁽¹⁾	
Post-delta velocity		1 min ⁽¹⁾ 4 0 min ⁽¹⁰⁾⁽¹²⁾		6 min ⁽¹⁾	
Delta v (less than 5 sec)		3 sec ⁽⁹⁾⁽¹¹⁾			
Delta v (5 to 10 sec)		5 to 10 sec ⁽⁹⁾⁽¹¹⁾⁽¹³⁾			
Delta v (greater than 10 sec)		10 sec ⁽⁹⁾⁽¹¹⁾⁽¹²⁾			
Power up/power down	30 sec ⁽⁷⁾ 1 min ⁽¹⁹⁾				
Auxiliary display check	1 5 min ⁽⁴⁾				
Pre-CSM separation	1 min ⁽¹⁾ 1 min 25 sec ⁽³⁾ 1 min ⁽⁶⁾	10 sec ⁽¹⁴⁾	1 min ⁽¹⁵⁾	6 min ⁽¹⁾	1 min ⁽²²⁾ 1 min ⁽²³⁾
Post-CSM separation	30 sec ⁽⁷⁾				1 min ⁽²³⁾
Entry and descent	3 min ⁽⁶⁾				1 min ⁽²⁰⁾

- (1) Perform routine status checks (8 4 2 8 4 3 8 4 4)
- (2) Check amperage of fuel cell 1 and voltage/amperage of A C bus 1 phase A (8 4 4 4 8 4 4 2)
- (3) Check open circuit voltage of pyrotechnic batteries
- (4) Check auxiliary display functions (8 4 17)
- (5) Charge status of F/PL batteries A B and C 1 hour before delta V (8 4 4 1)
- (6) Check d c voltage of main bus A and voltage/frequency of a-c bus 1 phase A (8 4 4 1 8 4 4 2)
- (7) Check d-c voltage buses A and B and voltage/frequency buses 1 and 2 each phase (8 4 4 1 8 4 4 2)
- (8) Check fuel and oxidizer pressure engine inlet fuel and oxidizer pressure and helium event indicators before tower jettison (8 4 2)
- (9) Check fuel and oxidizer tank pressure and oxidizer inlet pressure (8 4 2 1)
- (10) Record propellant quantity readouts (8 4 2 2)
- (11) During burn check injector valve meter positions and helium pressure control subsystem
- (12) Check PUGS and manage oxidizer quantity as required (8 4 2 2)
- (13) Check PUGS during thrusting (8 4 2 2)
- (14) Check propellant consumption rate data with MSFN after second burn and before deorbit burn (8 4 2 2)
- (15) Check cabin and space suit circuit settings for cold soak operations (8 4 8)
- (16) Perform check each time astronaut dons pressure garment assembly (8 4 12 2)
- (17) Perform check when astronaut changes from PGA to shirtsleeves and vice versa (8 4 12)
- (18) Check consumption rate (8 4 3 2)
- (19) D-C main bus A and B voltage and fuel cell amperage and voltage (8 1 5 1)
- (20) Check subsystem A (8 4 3 3)
- (21) Check engine valve preheat function
- (22) Perform routine status check at least 2 hours before CSM separation and monitor engine valve temperatures (8 4 3 3)
- (23) Perform status checks and check fuel and oxidizer tank pressures with system pressurized (8 4 3 3)
- (24) If crewman was unsuited verify PGA as required (8 4 12 2)
- (25) Check Post LET jettison injector valve event indicators oxidizer flow event indicator helium tank temperature and pressure and nitrogen tank pressures (8 4 2)

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BUILDING BLOCK 15 SUBSYSTEM MAINTENANCE

15 1 FUEL CELL PURGING

15 1 1 Introduction

Fuel cell purging is a system management function which is performed periodically during the mission. The hydrogen and oxygen reactants used in the fuel cells are not 100 percent pure, nor are the impurities consumed during the fuel cell operation. As a result, over a period of time the accumulated impurities cause a slight decrease in fuel cell efficiency. To eliminate the impurities, an excess flow of reactant is allowed to enter the fuel cell when a purge valve (solenoid operated) is opened, allowing venting of the gases overboard. Each fuel cell is equipped with an oxygen-purge valve and a hydrogen-purge valve. Each valve contains an orifice designed to allow a specific amount of gas flow. The valves are activated electrically by control switches located on the main display console (MDC) in the command module (MDC Panel 18).

15 1 2 General Information

Purging on each side (hydrogen and oxygen) of each power plant shall be accomplished every seven hours. The purges shall be staggered so that a hydrogen purge shall follow an oxygen purge by three and one-half hours. The present purging cycle of seven hours is based upon the maximum normal power output of 1420 watts per fuel cell module. Recent information from the vendor indicates that the purging interval may be extended without detrimental effect on the powerplant. The time between purges would be based upon the ratio of the present maximum of 1420 watts/fuel cell module to the actual maximum gross power demand times seven hours. Thus, if the actual maximum gross power demand is 633 watts/fuel cell module, the nominal purge interval of seven hours would be increased $1420/633$ to 15.7 hours.

Another approach to determination of purging requirements would be for the manned space flight network to maintain a power profile in real time and then request purge after 29.82 kilowatts of power production. This procedure would minimize the quantity of reactants required for purging.

The purging operation in no way inhibits the normal reaction process. During purging, the powerplant continues to consume reactants in the quantities required to produce the power demanded by the spacecraft electrical loads.



The hydrogen solenoid-purge-valve orifice limits the hydrogen purge flow rate to 0.75 lb/hr (hydrogen and steam). The oxygen solenoid-purge-valve orifice limits the oxygen-purge-flow rate to 0.6 lb/hr. Each rate is in addition to the normal consumption flow prevalent at the time.

A fuel cell module shall be purged regardless of the purging schedule if the current outputs of three modules vary 5 amperes between the lowest and the highest.

The duration of each hydrogen purge is 80 seconds, and of each oxygen purge, 120 seconds.

15.1.3 Operational Timeline Segment

See Table 6-32

15.1.4 Duty Cycles

See Tables 6-33 and 6-34

15.1.5 Electrical Power Profile

No P_{AC} is consumed during purging. The P_{DC} (nominal) = 0.414 watt.

15.2 BATTERY CHARGING

15.2.1 Introduction

The two sources of energy for the command service module electrical power subsystem (EPS) are the cryogenic storage subsystem (CSS) and seven batteries. Three of these batteries are rechargeable in flight. The other four are used to power redundant pyrotechnic and service module control circuits which are isolated from the main electrical power subsystem. The four pyrotechnic batteries cannot be recharged in flight. The three batteries which can be recharged in flight are the entry and post-landing batteries A, B, and C. These batteries, located in the lower equipment bay of the command module, are an integral part of the spacecraft EPS. They supplement the fuel cell modules during mission peak load periods, compensate for the fuel cell modules' slow reaction in responding to rapid load changes during these peak load periods, and provide command module electrical power after command module service module (CM-SM) separation. A solid-state battery charger satisfies the in-flight charging requirements of the three batteries. Since charging times are a function of battery energy depletion, this building block has a variable time span which will be described in the following paragraphs. Detailed descriptions of the batteries and the battery charger may be found in the AOH, Section 2.



Table 6-32 Operational Timeline Segment, Subsystem Maintenance

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
-3 00 00	Perform fuel cell 1 oxygen purge (00 02 00)		There are no equipment constraints
-2 58 00	Verify normal operation of fuel cell (00 00 20)		Scheduling may be the only constraint
-2 57 40	Perform fuel cell 2 oxygen purge (00 02 00)		Reference AOH (Section 8 and Section 2)
-2 55 40	Verify normal operation of fuel cell (00 00 20)		
-2 55 20	Perform fuel cell 3 oxygen purge (00 02 00)		
2 53 20	Verify normal operation of fuel (00 00 20)		
	End oxygen purge		
T = Liftoff	After liftoff the first hydrogen purge will commence 3 5 hr from the beginning of fuel cell 1 oxygen purge		Notes Purge one cell at a time only one side at a time
+0 30 00	Perform fuel cell 1 hydrogen purge (00 01 20)		Alternate oxygen purge every 3 5 hours with hydrogen purge
00 31 20	Verify normal operation of fuel cell (00 00 20)		Although purging is scheduled every 7 hours the fuel cell with the lowest current output should be purged if a 5-ampere discrepancy is noted during normal operation (hydrogen for 80 seconds oxygen for 120 seconds) regardless of the schedule
00 31 40	Perform fuel cell 2 hydrogen purge (00 01 20)		
	Verify normal operation of fuel cell (00 00 20)		
00 33 20	Perform fuel cell 3 hydrogen purge (00 01 20)		
	Verify normal operation of fuel cell (00 00 20)		
	End hydrogen purge		
04 00 00	Perform fuel cell 1 oxygen purge (00 02 00)		
04 02 00	Verify normal operation of fuel cell (00 00 20)		
04 02 20	Perform fuel cell 2 oxygen purge (00 02 00)		
04 04 20	Verify normal operation of fuel cell (00 00 20)		



Table 6-32 Operational Timeline Segment, Subsystem Maintenance (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
04 04 40	Perform fuel cell 3 oxygen purge (00 02 00)		
04 06 40	Verify normal operation of fuel cell (00 00 20)		
	End oxygen purge		



Table 6-33 Subsystem Duty Cycles, Subsystem Maintenance
Fuel Cell Purging (7-Hour)

Subsystem Component (Mode)	Pulses (Total)	Pulse Width (Hr)	Cycle Period (Hr)	First Cycle Start (T + Hr)
Electrical Power				
Fuel cell 1 hydrogen purge valve	1	0 022	7 000	0 000
Fuel cell 2 hydrogen purge valve	1	0 022	7 000	0 028
Fuel cell 3 hydrogen purge valve	1	0 022	7 000	0 056
Fuel cell 1 oxygen purge valve	1	0 033	7 000	3 500
Fuel cell 2 oxygen purge valve	1	0 033	7 000	3 539
Fuel cell 3 oxygen purge valve	1	0 033	7 000	3 578
Note The next purging cycle begins at T + 7 000				7 000
Fuel cell 1 hydrogen purge valve Same cycle as above	1	0 022	7 000	7 000
T = Start of fuel cell 1 hydrogen purge				

Table 6-34 Subsystem Duty Cycles, Subsystem Maintenance
Fuel Cell Purging (24-Hour)

Subsystem Component (Mode)	Pulses (Total)	Pulse Width (Hr)	Cycle Period (Hr)	First Cycle Start (T + Hr)
Electrical Power				
Fuel cell 1 hydrogen purge valve	4	0 022	7 000	1 000
Fuel cell 2 hydrogen purge valve	4	0 022	7 000	1 028
Fuel cell 3 hydrogen purge valve	4	0 022	7 000	1 056
Fuel cell 1 oxygen purge valve	3	0 033	7 000	4 500
Fuel cell 2 oxygen purge valve	3	0 033	7 000	4 539
Fuel cell 3 oxygen purge valve	3	0 033	7 000	4 578
T = Start of 24-hour period				



15 2 2 General Information

The system-management rules pertaining to battery charging have one objective to maintain batteries A, B, and C in a fully charged condition at all times. Only one battery can be charged at a time. The batteries must be disconnected from the main d-c buses to be charged. The first charging period after liftoff is for battery C. While the S-IVB is still attached to the CSM, battery C is idle, whereas batteries A and B are powering the master events sequence control (MESAC) circuits A and B, respectively. The duration of charging cycles is based upon estimated battery-energy depletion during the ascent phase, and on similar estimates during ΔV maneuvers. Crew judgment will be required to manage charging time so that all three batteries are maintained at the same level. Thus, in the event of a battery failure, the remaining batteries will have a maximum charge.

Operational limitations with battery charging are primarily a matter of scheduling. For example, if two ΔV maneuvers occur two hours apart, it is unlikely that the three batteries will be completely recharged for the second burn. Time between the de-orbit burn and CM-SM separation also will not permit battery charging. The battery-vent valve shall remain open throughout the mission. It shall be closed only if cabin oxygen is escaping through a cracked battery case.

Batteries A, B, and C shall be removed from the main buses as soon as possible after their fuel-cell-supplementing function is no longer required.

15 2 3 Operational Timeline Segment

The following ground rules and operational procedures were used in determining the battery charging timeline shown in Table 6-35. Batteries A, B, and C are checked

Once every 6-8 hours

1 \pm 0.5 hour prior to each ΔV

Periodically during battery charging

Batteries A, B, and C shall be recharged (as time permits)

After earth-orbit insertion

After each ΔV maneuver (except de-orbit)

Prior to de-orbit burn



Table 6-35 Operational Timeline Segment, Subsystem Maintenance

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 18 00	<p>T_1 = Liftoff</p> <p>Charge battery C (03 00 00) (Charge battery C until just after S-IVB separation)</p>		<p>Batteries cannot be charged while connected to main bus The MAIN BUS TIE switch must be OFF to provide complete circuit from charger to battery</p>
00 05 00	<p>T_2 = S-IVB separation</p> <p>Charge battery A (03 00 00) Monitor charging current frequently</p>		<p>When battery charger output decreases to approximately 0.6 amperes battery may be considered fully charged</p>
03 05 00	<p>Charge battery B (03 00 00) Monitor charging current frequently</p>		<p>Monitor charging current frequently If necessary repeat charging cycle until batteries A B and C are fully charged</p>
06 05 00	<p>Charge battery C (03 00 00) Monitor charging current frequently</p>		
09 05 00	<p>Charge battery A (03 00 00) Monitor charging current frequently</p>		<p>Batteries should be maintained in fully charged condition throughout the mission to ensure maximum capacity at CM SM separation</p>
12 05 00	<p>Charge battery B (03 00 00)</p>		
00 05 00	<p>T_3 = End SPS thrusting</p> <p>Charge battery A (02 00 00)</p>		<p>Repeat charging cycle until batteries A B and C are fully charged</p>
02 05 00	<p>Charge battery B (02 00 00)</p>		
04 05 00	<p>Charge battery C (02 00 00)</p>		<p>Reference AOH (Section 8 and Section 2)</p>
00 00 00	<p>T_4 = After battery check indicates a battery not fully charged</p> <p>Charge affected battery (as required)</p>		



Batteries A, B, and C shall be recharged as required when EPS checks indicate a discharged condition

The pyro batteries shall be checked once every 24 hours and prior to CM SM separation

15 2 4 Duty Cycles

See Table 6-36

15 2 5 Electrical Power

The average delta power levels are

$$P_{AC} \text{ (nominal)} = 41.0 \text{ watts}$$

$$P_{DC} \text{ (nominal)} = 36.0 \text{ watts}$$

15 2 6 Performance

Battery charger and battery performance data may be found in the AOH, Section 2. Figure 6-27 presents data on battery discharge and time required for battery recharge. The initial charging current is a function of the amount by which a battery has been discharged. For example, an initial current of 2.0 amps indicates a battery discharge of 4.0 ampere-hours. The amount of energy required by the charger to attain a 0.24-amp charge as a function of battery discharge is presented in this enclosure. For example, if the battery has been discharged by 4.0 ampere-hours, the charger will require approximately 8.6 ampere-hours. Charging time is a function of battery discharge. For example, a battery that has been discharged by 4.0 ampere-hours will require approximately 8.5 hours of charge.

15 3 SPS PROPELLANT FEED-LINE TEMPERATURE CONTROL

15 3 1 Introduction

The SPS propellant feed-line (external Aerojet and internal NAA transfer lines) temperatures are to be maintained within the temperature range of 40 to 120 F. Heaters are installed as follows: between the engine interface and the fuel tank, seven heaters will be installed at strategic locations; between the engine interface and the oxidizer tank, seven heaters will be installed at strategic locations; on the engine side of the NAA-Aerojet interface, 12 heaters will be installed at strategic locations.

Table 6-36 Battery Charging Duty Cycles

Subsystem Component (Mode)	Pulses (Total)	Pulse Width (Hr)	Cycle Period (Hr)	First Cycle Start (T + Hr)
Electrical power				
Battery charger (initial duty cycle) Commence as soon as possible after earth orbit insertion verification				
Charge battery C As soon as possible after S-IVB separation, cease charging battery C and commence charging battery A	$T_1 = \text{liftoff}$ 1	3 000	3 000	$T_1 + 0 300$
Charge battery A	1	3 000	3 000	$T_2 + 0 083$
Charge battery B	1	3 000	3 000	$T_2 + 3 083$
Charge battery C	$T_2 = \text{S-IVB separation}$ 1	3 000	3 000	$T_2 + 6 083$
Charge battery A	1	3 000	3 000	$T_2 + 9 083$
Charge battery B	1	3 000	3 000	$T_2 + 12 083$
Battery charger (post ΔV duty cycle)				
Charge battery A	$T_3 = \text{end SPS thrusting}$ 1	2 000	2 000	$T_3 + 0 083$
Charge battery B	1	2 000	2 000	$T_3 + 2 083$
Charge battery C	1	2 000	2 000	$T_3 + 4 083$
Battery charger (after battery check indicates a battery not fully charged)				
Change affected battery	$T = \text{crew discretion}$ 1	As required		
When time permits, each charging cycle should be continued until charging current is 0 6 amperes (battery considered as charged)				

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Seven thermocouples sense the temperatures at selected points two in the fuel feed line between the fuel tank and the interface, two in the oxidizer feed line between the oxidizer tank and the interface, one in the Aerojet oxidizer line between the interface and the oxidizer valve, one on the engine, and one in the Aerojet fuel line between the interface and the fuel valve, which is the only one wired to a temperature gauge on MDC Panel 20 (This gauge was formally the helium tank temperature gauge, modified to display the SPS engine fuel line temperature) All seven thermocouple temperature readings are telemetered to MSFN All 26 heaters are energized by a single OFF-ON switch on MDC Panel 19

Operation of the heaters will be at the discretion of the crew and/or by direction from MSFN

15 3 2 General Information

The fuel line temperature gauge is calibrated and marked to display temperature in degrees F The upper and lower extremes of the operating range are redlined at 120 and 40 F, respectively Continuous monitoring by MSFN and the crew will determine whether an attitude change for solar heating will be required to maintain propellant temperature Two possible conditions could require an attitude change (1) heater OFF, temperature rises to 100 F, (2) heaters ON, temperature drops to 50 F In either case, an attitude maneuver is the only possible corrective action Since the heater systems were designed for a duty cycle of 50 percent during cold soak, the need for attitude maneuvers is not anticipated

15 3 3 Duty Cycle

The heater duty cycle is estimated at 50 percent for the entire mission

15 3 4 Electrical Power

The 26 heaters are wired in such a way that the total watts required at 25 volts is 31.6 Each heater is rated at 2 watts when 25 vdc are applied Estimated power requirements for the 26 heaters at 28 vdc is 33 watts

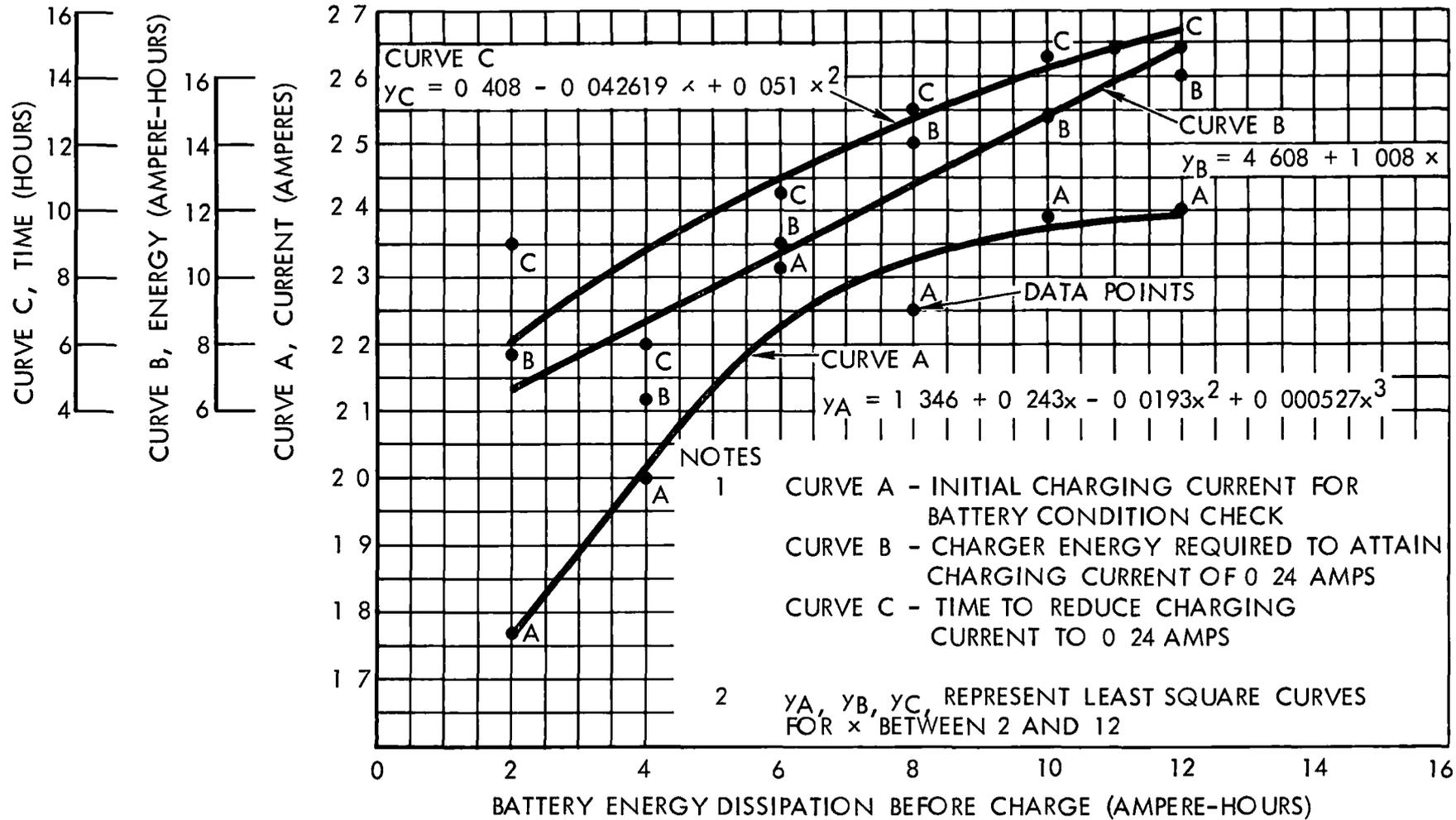


Figure 6-27 Battery Charging Characteristics



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BUILDING BLOCK 16 AGC UPDATE

16 1 INTRODUCTION

AGC updates are performed by two methods, both involving MSFN communications, i e , (1) MSFN/updata link mode (automatic) and (2) MSFN/voice mode (manual) AGC updates in both of these modes are performed to establish a reference for aim parameters related to all thrusting maneuvers and G&N programs MSFN/UDL is the prime mode used for AGC updating MSFN/voice is used as a backup mode only

16 2 OPERATIONAL DATA

16 2 1 General Information

The AGC should be updated no earlier than 90 minutes, or no later than 30 minutes, prior to initiation of a maneuver It should also be updated approximately every three to five orbits following tracking intervals, if required

The primary means of updating the AGC is with the VHF updata link, the VHF/AM transceiver, and the VHF/FM transmitter The S-band equipment may be used for backup

At least three MSFN stations should be allowed to track the spacecraft before each AGC update in order to establish the flight parameters The C-band equipment is utilized for this purpose with the S-band equipment available for backup

It is assumed that when an AGC update is to be performed that satisfactory MSFN coverage exists For the MSFN/UDL mode the station will have VHF/AM, VHF/FM, and UHF update capabilities For the MSFN/voice mode only VHF/AM capability is necessary It is recommended that the MSFN/UDL mode be used whenever possible

Insufficient time exists for voice mode AGC update after deorbit, except for minor corrections such as target impact changes Therefore, it is recommended that the mode of updating the AGC be preplanned as automatic for deorbits



The AGC update program may be selected at any time during the mission, except when another program is in progress

16 2 2 Mission Functional Flow

See Figure 6-28

16 2 3 Operational Timeline Segment

See Table 6-37

16 2 4 Subsystem Duty Cycles

See Table 6-38

16 2 5 Electrical Power

The average delta power levels are the following

Power	MSFN/UDL	MSFN Voice
P_{AC} (Nominal)	46 0 watts	0 0 watts
P_{DC} (Nominal)	262 2 watts	260 7 watts

16 2 6 Propellant Consumption

None

16 3 PERFORMANCE DATA

Refer to Section 4 0, Communications



Table 6-37 Operational Timeline Segment, AGC Update

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
	MSFN/UDL MODE		
00 00 00	Power up the AGC (00 01 11)		A crew member must be in the LEB to perform required operations
	Activate the VHF/FM transmitter and select HBR PCM Switch VHF/AM from REC to T/R Select the desired VHF antenna (00 00 49)		
00 02 00	Place UPTTEL switch to the ACCEPT position (00 00 05)		
00 02 05	Record from MSFN aim parameters required for verification for the pre-thrust program (00 02 00)		
00 04 05	Place UPTTEL switch to the BLOCK position (00 00 05)		
00 04 10	Verify AGC update program termination of DSKY (00 00 05)		
00 04 15	Power down AGC Activate the VHF/AM in the receive mode and deactivate the VHF/FM equipment (00 00 30)		
	MSFN/VOICE MODE		
00 00 00	Switch the VHF/AM transceiver from REC to T/R Select the desired VHF antenna (00 00 30)		A crew member must be in the LEB
00 02 00	Record from MSFN aim parameters required for verification for the pre-thrust programs (00 02 00)		
00 04 00	Record vehicle position velocity and time parameters into the AGC (00 02:00)		
00 08 00	Verify that the UPTTEL switch is in the BLOCK position (00 00 05)		
00 08 05	Verify AGC update program termination on the DSKY (00 00 10)		
00 08 15	Switch the AGC from ON to STANDBY Switch the VHF/AM transceiver from T/R to REC (00 00 30)		



Table 6-38 Subsystem Duty Cycles, AGC Update

Component	MSFN/UDL Mode (Block Duration 0 071 Hour)			MSFN/Voice Mode (Block Duration 0 138 Hour)	
	Percent Duty Cycles			Percent Duty Cycles	
	Mode	Common Level	Block 16	Common Level	Block 16
Guidance and navigation					
AGC	D	0	100	0	100
	F	100	0	100	0
Communications					
VHF/FM transmitter		0	100	0	0
VHF/AM equipment	Transmit	0	40	0	40
	Standby	0	60	0	60
	Receive	100	0	100	0

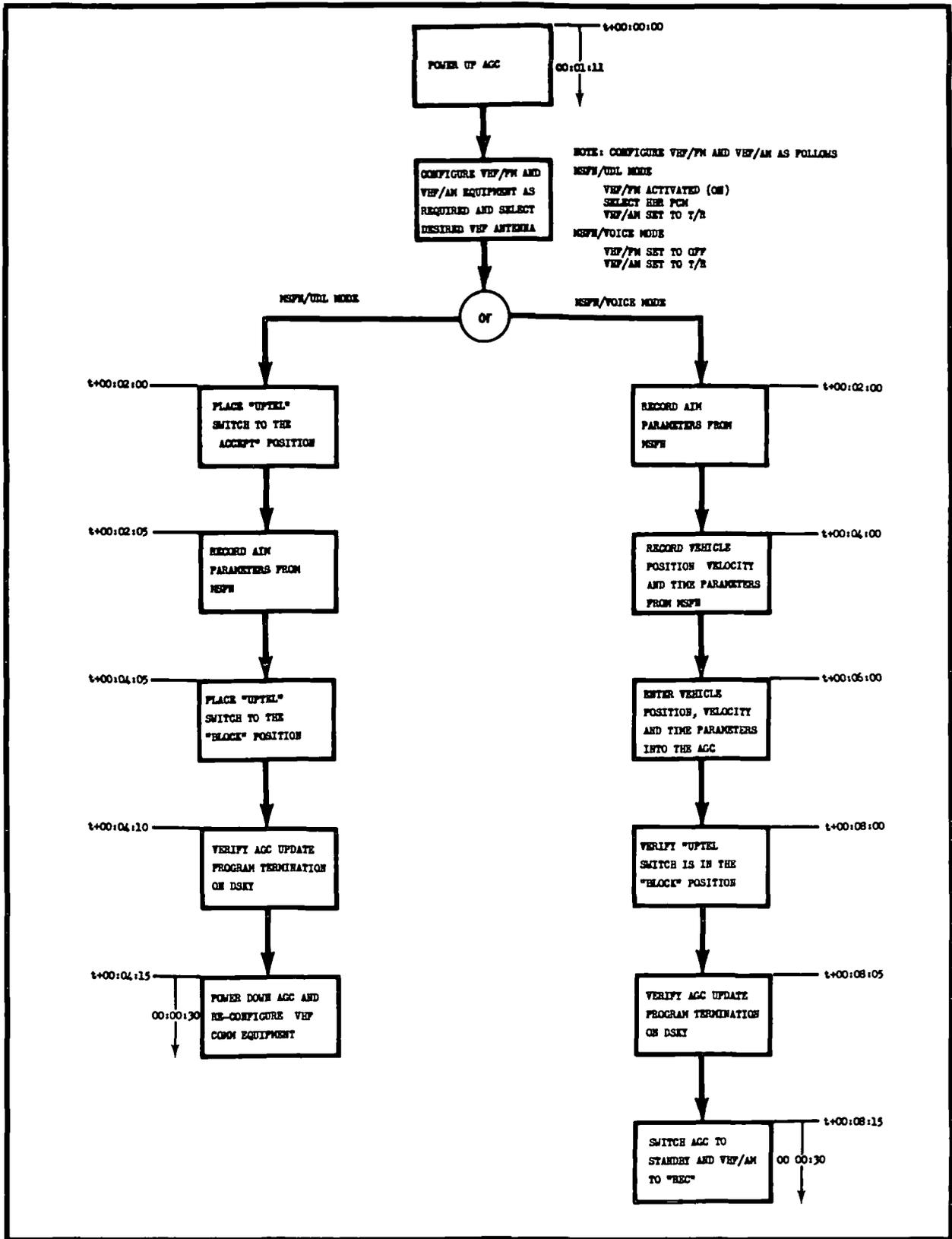


Figure 6-28 Building Block 16 AGC Update

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BUILDING BLOCK 17 EXPERIMENTS

17 1 INTRODUCTION

In-flight experiments are classified as medical (M), scientific (S), or technology (T) and are summarized in Table 6-39. Experiment storage volumes are defined in Figure 6-29. A detailed list of equipment stowed in each volume is presented in Table 6-40.

17 2 M-1A CARDIOVASCULAR REFLEX CONDITIONING

17 2 1 Introduction

The purpose of experiment M-1A is to evaluate the effect of lower body vascular supports in the prevention of blood pooling during re-entry and to increase effective circulating blood volume.

17 2 2 General Information

The experiment will be conducted by a preselected crewmember. The constant wear garment (CWG) which is in two pieces permits easy donning of tights without disturbance of biomedical sensors. The subject will remove the lower portion of the CWG and stow in the clothing compartment of the left-hand equipment bay (LHEB). The tights are donned as close as possible to reentry time. Operational requirements make it necessary to don the tights at least 1.5 hours prior to reentry. Donning will require approximately 4.5 to 7.0 minutes.

17 2 3 Operational Timeline Segment

Time (min sec)	Function	Δ Time (min sec)
T +00 00	Remove lower vascular supports from stowage (Volume A)	00 20
T +00 20	Do off lower constant wear garment	01 00
T +01 20	Don lower vascular supports	04 00
T +05 20	Don lower constant wear garment	01 30
T +06 50	Cycle complete	



Table 6-39 Summary of Flight Experiments

Paragraph No	Experiments		Title	Requirements Per Experiment Cycle	
	Number			Astronauts Participating	Remarks
	Old	New			
17 2	M-1A	M-048	Cardiovascular reflex conditioning	One preselected crewman	Lower vascular supports sized to test subject
17 3	M-3A	M-003	In-flight exercise	Any one crewman	Isometric and isotonic exercise
17 4	M-4A	M-004	In-flight phonocardiogram	Commander and navigator	Data recorded on MDAS Power 9 92 watt-hours
17 5	M-5A	M-005	Bio-assays body fluids	Two preselected crewmen	Experiment limited by number of sample bags (stowage volume)
17 6	M-6A	M-006	Bone demineralization		No in-flight interface
17 7	M-9A	M-009	Human otolith function	Any one crewman	No ΔV is permitted during experiment power 9 81 watt-hours
17 8	M-11	M-011	Cytogenetic blood studies		No in-flight interface
17 9	S-5A	S-005	Synoptic terrain photography	Any one crewman	Light window 9 00 a m to 3 00 p m local time
17 10	S-6A	S-006	Synoptic weather photography	Any one crewman	Light window 9 00 a m to 3 00 p m local time
17 11	T-3	T-003	In-flight nephelometer (aerosol particle analyzer)	Any one crewman	APA has limited internal power supply
17 12	MDAS		Medical data acquisition system		Records M-4A data plus bio-medical data



Table 6-40 Experiment Equipment Stowage

Equipment	Stowage Volume * and Quantity										Utilization
	A	B	C	D	E	S	T	1	2		
MDAS			1								M-3A and M-4A
Octopus cable				1							M-3A and M-4A
70-mm camera and ring sight	1										S-5A S-6A and operational
70-mm film packs	3	8									4 packs for S-5A and S-6A 7 packs for operational
Spot meter	1										S-5A S-6A and operational
Exposure dial	1										S-5A S-6A and operational
250-mm lens (70-mm camera)	1										S-5A S-6A and operational
16-mm camera	1										M-9A and operational
16-mm camera power cable	1										M-9A and operational
16-mm film packs	4	7									2 packs for M-9A 9 packs for operational
10-mm lens (16-mm camera)	1										Operational
18-mm lens (16-mm camera)	1										Operational
25-mm lens (16-mm camera)	1										M-9A
Goggles		1									M-9A
Mouthpiece		1									M-9A
Camera bracket								1			M-9A
Lower body vascular supports	1										M-1A
Nephelometer					1						T-3
Urine sample and volume measurement system (USVMS)							2				M-5A
USVMS receivers (spares)							2				M-5A
USVMS filter							1				M-5A (One filter in drain line)
Sample bags									115		M-5A
Secondary sample stowage bags									21		M-5A
Mixing bags									2		M-5A
Roll-on cuffs									30		M-5A
Bungee cord										1	M-3A

*Refer to Figures 17-1 and 17-2



17 3 M-3A IN-FLIGHT EXERCISE

17 3 1 Introduction

The purpose of experiment M-3A is to determine the benefits of exercise during spaceflight

17 3 2 General Information

The experiment consists of isometric and isotonic exercises to be performed by all three crew members. Each crew member will exercise three times per day. The isometric exercises will most likely be performed in the couches but could take place anywhere in the command module. The isotonic exercise will take place in the center couch by means of a bungee cord. The bungee has Velcro for operational stowage. Each day one crewman's biomedical data will be recorded for 10 minutes: (a) two minutes before exercise, (b) five minutes during isotonic exercise, and (c) three minutes during recovery.

17 3 3 Operational Timeline Segment

Time (min sec)	Function	Δ Time (min sec)
T ₀ +00 00	Ingress LEB	00 03
T ₀ +00 03	Unstow bungee and place in operational stowage	01 00
T ₀ +01 03	Move octopus cable to proper subject	00 30
T ₀ +01 33	Move T-adapter to proper subject	00 30
T ₀ +02 03	Conduct isometric exercise	05 00
T ₁ +00 00	Assume isotonic exercise position	02 00
T ₁ +02 00	Activate tape recorder	00 10
T ₁ +02 10	Sit dormant	02 00
T ₁ +04 10	Remove bungee from operational stowage	00 10
T ₁ +04 20	Perform isotonic exercises	05 00
T ₁ +09 20	Rest and recover	03 00



Time (min sec)	Function	Δ Time (min sec)
T ₁ +12 20	Deactivate tape recorder	00 10
T ₁ +12 30	Stow bungee in operational stowage	00 10
T ₁ +12 40	Release couch harness	00 15
T ₁ +12 55	Complete cycle	

17 4 M-4A IN-FLIGHT PHONOCARDIOGRAM

17 4 1 Introduction

The purpose of experiment M-4A is to obtain functional status information on the astronaut's heart during prolonged spaceflight. An in-flight phonocardiographic recording of the heart sounds will be compared with a simultaneous recording of the highest electrocardiogram (EKG) signal to determine the time interval between electrical activation of the heart muscle (myocardium) and the onset of ventricular systole (heart contraction).

17 4 2 General Information

Performance of the experiment depends upon the prior connection of the octopus cable to the medical data acquisition system (MDAS) and to the power source. The biomedical instrumentation interfaces with the MDAS by means of a T-adaptor installed at the cobra cable/spacecraft electrical interface of each crew position. There will be three T-adaptors. The octopus cable is connected to the T-adaptor of the crewman to be recorded, and the telemetry input biomedical switch is set to either crewman. Test subjects will be the commander and the navigator.

17 4 3 Operational Timeline Segment

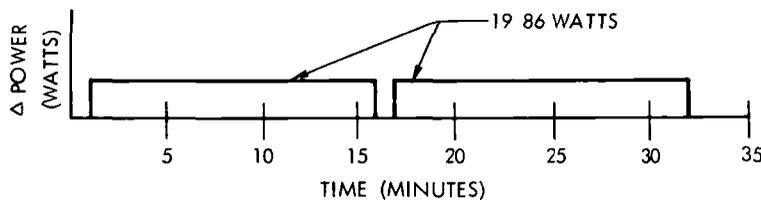
Time (min sec)	Function	Δ Time (min sec)
T ₀ +00 00	Connect octopus cable to T-adaptor of crewman to be recorded	00 50
T ₀ +00 50	Perform required electrical switching for recording of data	00 10
T ₀ +01 00	Record data	15 00



Time (min sec)	Function	Δ Time (min sec)
T ₀ +16 00	Biomedical tape recorder selector switch to OFF	00 10
T ₀ +16 10	Transfer cable to T-adapter of next subject	00 50
T ₀ +17 00	Perform required electrical switching for recording of data	00 10
T ₀ +17 10	Record data	15 00
T ₀ +32 10	Biomedical tape recorder selector switch to OFF	00 10
T ₀ +32 20	Cycle complete	

17 4 4 Electrical Power Profile

The electrical power profile is depicted below One M-4A operational cycle uses 9 92 watt-hours



17 5 M-5A BIO-MEDASSAYS BODY FLUIDS

17 5 1 Introduction

The purpose of experiment M-5A is the identification of body changes that occur within the astronauts during weightlessness This is accomplished by a careful postflight analysis of body fluids collected during flight Urin-
 analysis will yield medical information on such biochemical constituents as body steroids, catecholamines, enzymes, and salts This experiment uses a radioactive aqueous solution for the urine volume/sample correlation The radioactive tracer is tritium in nondangerous quantities



17 5 2 General Information

Two crewmen will participate in the experiment. Each has a personal urine-sampling and volume-measuring system (USVMS) unit. All urine eliminations will be collected by means of these urine-sampling devices, and a tritium tracer will be introduced. A 75 cc sample is taken at each micturition, and the remainder is dumped overboard. The tritium radioactivity cannot penetrate its container, whether it is the accumulator on the USVMS or the sample bag. The potential experimental limitations are the quantity of sample bags (115), the supply of tritium in the USVMS, and the available entry stowage volume. After completion of experiment, crew will use operational WMS for voiding.

17 5 3 Operational Timeline Segment

Time (min sec)	Function	Δ Time (min sec)
T ₀ +00 00	Place bio-assay bag in operational stowage, LEB	01 15
T ₀ +01 15	Ingress to aft equipment bay from LEB	01 00
T ₀ +02 15	Obtain urine-sampling devices from stowage, aft bay	00 45
T ₀ +03 00	Ingress to LEB from aft equipment bay	01 00
T ₀ +04 00	Prepare urine-sampling device for use	02 05
T ₁ +00 00	Obtain and stow urine sample, LEB	12 05
T ₂ +00 00	Secure urine-sampling device, LEB	02 20
T ₂ +02 20	Ingress to aft equipment bay from LEB	01 00
T ₂ +03 20	Stow urine-sampling device in aft equipment bay	00 55
T ₂ +04 15	Ingress to LEB from aft equipment bay	01 00
T ₂ +05 15	Place bio-assay bag in boost/entry stowage, aft equipment bay	01 30
T ₂ +06 45	Complete cycle	



17 6 M-6A BONE DEMINERALIZATION

The purpose of experiment M-6A is to determine the effect of weightlessness and immobilization during spaceflight on the demineralization of certain bones within the body of each astronaut

This experiment has no in-flight interface

17 7 M-9A HUMAN OTOLITH FUNCTION

17 7 1 Introduction

The purpose of experiment M-9A is to determine the effect of prolonged weightlessness on the astronaut's orientation sensation. Of particular interest is the ability of space crews to orient themselves in a weightless environment, especially in darkness.

17 7 2 General Information

All three crewmen act as test subjects. Testing is accomplished in the center couch and utilizes the 16-mm sequence camera as well as the otolith-test equipment. Testing is conducted once daily on each subject, at approximately the same time each day. Testing requires approximately five minutes per subject, not including the preliminary preparation of equipment or stowage of equipment prior to reentry. Testing may be conducted in the CWG or in the vented pressure garment assembly (PGA). The visor must be open to accept the test goggle. Window shades must be drawn and floodlights turned to full bright. Couch lights must be adjusted to avoid glare in the camera lens. The experiment may not be conducted during, nor within five minutes subsequent to, any ΔV . No attitude maneuvers are required for the experiment.

17 7 3 Operational Time Line Segment

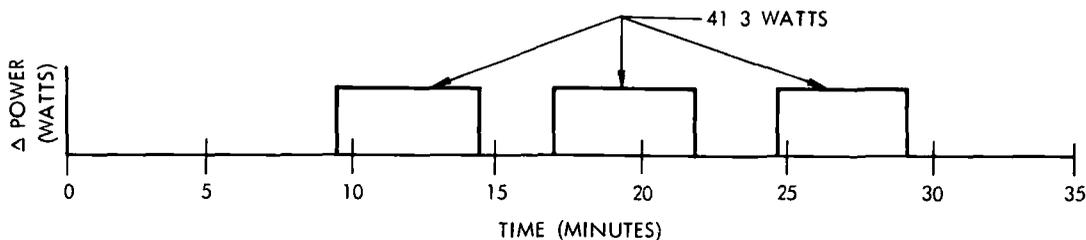
Time (min sec)	Function	Δ Time (min sec)
$T_0 +00 00$	Unstow and assemble sequence camera, electric cable, and mounting brackets, route and secure power cable	05 20
$T_0 +05 20$	Place camera and bracket in operational stowage	01 00
$T_0 +06 20$	Unstow otolith kit and place in operational stowage	02 20



Time (min sec)	Function	Δ Time (min sec)
T ₁ +00 00	Prepare for experiment, mount camera, and don test goggles	01 13
T ₁ +01 13	Window shades installed, floodlights, full, camera ON, conduct experiment	04 45
T ₁ +05 58	Camera OFF, floodlights dimmed, camera and goggles to temporary stowage	01 15
T ₁ +07 13	Change test subjects	00 21
T ₁ +07 34	Don test goggles	00 50
T ₁ +08 24	Camera ON, conduct experiment	04 45
T ₁ +13 00	Camera OFF, floodlights dimmed, camera and goggles to temporary stowage	01 15
T ₁ +14 24	Change test subjects	00 46
T ₁ +15 10	Don test goggles	00 50
T ₁ +16 00	Camera ON, conduct experiment	04 45
T ₁ +20 45	Camera OFF, floodlights dimmed, camera and goggles to temporary stowage	00 37
T ₂ +00 00	Stow otolith test equipment	01 10
T ₂ +01 10	Disassemble sequence camera, mounting bracket, and power cable, return to stowage	05 20
T ₂ +06 30	Cycle complete	

17 7 4 Electrical Power Profile

The electrical power profile for M-9A is presented below One cycle uses approximately 9 81 watt-hours



17 8 M-11 CYTOGENETIC BLOOD STUDIES

The purpose of experiment M-11 is to conduct preflight and postflight analyses to determine whether space environment produces cellular changes in the blood of astronauts. These changes, which are important to the medical and scientific point of view, may not be apparent from routine monitoring procedures.

This experiment has no in-flight interface.

17 9 S-5A SYNOPTIC TERRAIN PHOTOGRAPHY

17 9 1 Introduction

The purpose of experiment S-5A is to obtain photographs of selected areas of the earth from orbital altitude. These photographs are required for research in geology, geophysics, geography, and oceanography.

17 9 2 General Information

This experiment comprises the photographing of certain areas and features along the spacecraft flight path. Service module RCS propellant required for spacecraft orientation to conduct S-5A and S-6A is approximately 0.5 pound per cycle. Photographs will also be taken from other camera angles. They may be taken by any crewmember and from any window. A total of four magazines — two color, one black-and-white, one infrared — will be provided for both Experiments S-5A and S-6A. It is not known what film will be used for each experiment. A written log of each photograph, including time, object, magazine number, and frame number, will be maintained. Attitudes and rates are not critical as long as motions do not disturb the taking of photographs, however, data on attitudes and rates will be useful.



as backup information for target location Photography may be conducted from 9 00 a m to 3 00 p m local time (approximately 22 5 minutes per orbit are available)

17 9 3 Operational Timeline Segment

Time (min sec)	Function	Δ Time (min sec)
T ₀ +00 00	Unstow 70-mm camera and film magazines (Volume A)	01 00
T ₀ +01 00	Stow camera and film magazines in operational stowage	01 00
T ₀ +02 00	Ingress crew couch	00 06
T ₁ +00 00	Remove 70-mm camera and film magazines from operational stowage	00 45
T ₁ +00 45	Exchange film magazine as required	00 10
T ₁ +00 55	Photograph targets, Interior lights OFF	00 45
T ₁ +01 40	Return camera and film magazines to operational stowage	01 00
T ₂ +00 00	Egress crew couch	00 06
T ₂ +00 06	Remove 70-mm camera and film magazines from operational stowage	01 00
T ₂ +01 06	Stow camera and film magazines (Volume A)	00 10
T ₂ +01 16	Cycle complete	

17 10 S-6A SYNOPTIC WEATHER PHOTOGRAPHY

17 10 1 Introduction

The purpose of experiment S-6A is to obtain selective, high-quality photographs of cloud patterns taken from orbital altitude These photographs will be used for studies of weather-system structures around the earth

17 10 2 General Information

This is the same as 17 9 2

17 10 3 Operational Timeline Segment

This is the same as the material of 17 9 3

17 11 T-3 IN-FLIGHT NEPHELOMETER

17 11 1 Introduction

The purpose of experiment T-3 is to determine and obtain a quantitative evaluation of the size, concentration, and distribution of particles present in the command module crew compartment. In-flight measurements will be made of particles in the 0.3- to 10-micron size, using an aerosol particle analyzer (APA).

17 11 2 General Information

The experiment may be conducted anywhere in the spacecraft. Specific instances and locations are after PGA donning or doffing, food preparation, waste-management functions, lithium hydroxide canister change, and prolonged periods of sun-shafting. The power supply is self-contained, and once the APA is activated, operation is fully automatic. The duty cycle for the T-3 experiment is approximately every four hours (six cycles daily). The experiment is to be performed periodically until the APA internal power supply is exhausted. Data readouts must be logged as they appear on the instrument indicator.

17 11 3 Operational Timeline Segment

Time (min sec)	Function	Time (min sec)
T ₀ +00 00	Unstow APA and transfer to operational stowage	00 30
T ₁ +00 00	Transfer APA to area to be sampled	00 30
T ₁ +00 30	Start automatic sampling, record data from five samplings, advance filter in APA	02 30
T ₁ +03 00	Return APA to stowage	00 30
T ₂ +00 00	Transfer APA to operational stowage	00 30
T ₂ +00 00	Cycle complete	



17 12 MEDICAL DATA ACQUISITION SYSTEM

17 12 1 General Information

The MDAS is used to record the phonocardiogram (M-4A) and biomedical data. The biomedical data are used to evaluate Experiments M-3A and M-4A. Additionally, timing signals are provided to the onboard voice recorder. The MDAS is installed in Volume C and receives signals and power through the octopus cable. The power is obtained at a connector in Volume A. The tape recorder provides a seven-channel tape record of physiological signals related to the medical experiments. The following data are to be recorded:

- a Impedance pneumograph
- b Electrocardiogram (EKG)
- c Phonocardiogram (PCG)
- d Unassigned channel
- e Oral temperature/blood pressure pump
- f Systolic and diastolic markers
- h Time code

17 12 2 Operational Timeline Segment

Time (min sec)	Function	Δ Time (min sec)
T ₀ +00 00	Unstow octopus cable (Area D)	00 15
T ₀ +00 15	Connect octopus cable to biomedical tape recorder	00 10
T ₀ +00 25	Verify main power switch OFF	00 02
T ₀ +00 27	Route octopus cable, and attach to Velcro tabs	02 00
T ₀ +02 27	Connect octopus cable to electric power (Area A)	00 10
T ₀ +02 37	Connect octopus cable to any crewman's T-adaptor	00 10
T ₀ +02 47	Prepare biomedical tape recorder for service	01 05



Time (min sec)	Function	Δ Time (min sec)
T ₁ +00 00	Disconnect octopus cable from crewman's T-adapter, electric power and biomedical tape recorder, prepare cable for stowage	02 00
T ₁ +02 00	Stow octopus cable (Area D)	00 15
T ₁ +02 15	Cycle complete	

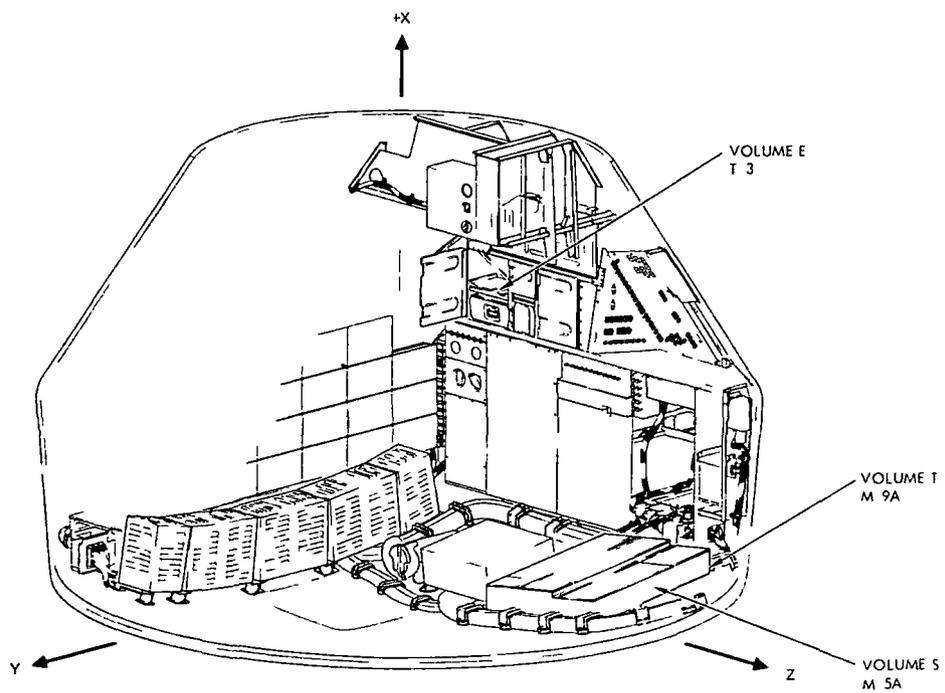
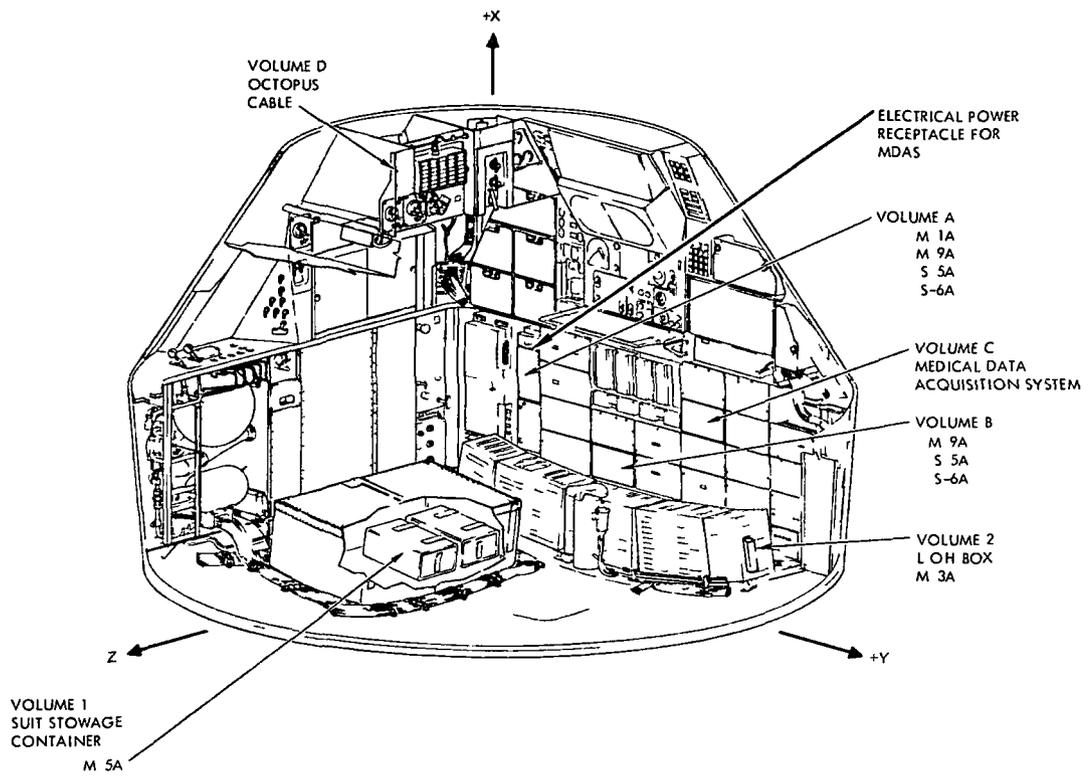


Figure 6-29 Experiment Equipment Location

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BUILDING BLOCK 18 CABIN DEPRESSURIZATION

18 1 INTRODUCTION

The objective of cabin depressurization is to demonstrate depressurized cabin operation including command service module (CSM) subsystem, crew compatibility, and interface

Scheduled mobility tasks will be performed after the command module pressure stabilizes at ambient. The crew, while in pressurized suits, will be required to set up and secure the optics, perhaps perform an Inertial Measurement Unit (IMU) alignment (time permitting), change the lithium hydroxide canister, and move to various locations in the command module

Figure 6-30 depicts the substance of pertinent data in performing the step method of cabin depressurization. The step method is recommended in order to verify both normal and emergency repressurization capability early in the block. The block duration including crew-mobility requirements is approximately 2.5 hours.

18 2 OPERATIONAL DATA

18 2 1 General Information

Upon receiving a go-ahead from Mission Control, the command module will be manually depressurized. The depressurization schedule is planned for the use of a step method. The schedule is as follows: the command module will be depressurized from 5.0 to 3.8 psia. Depressurization will be stopped, and the command module will be pressurized normally by using only the cabin pressure regulator up to 4.0 psia. The repressurization will be stopped at 4.0 psia, and depressurization will again be resumed. The command module will be depressurized to 2.75 psia before repressurization is again started. This second repressurization is accomplished by using only the emergency oxygen inflow control. The command module is repressurized to 3.25 psia. At this time repressurization is stopped, and the depressurization is resumed and allowed to proceed to ambient (0.0 psia).

Precautionary measures which are conducive to crew safety but cannot be readily taken by the crew in their pressurized configuration should be scheduled prior to depressurization. Both inverters should be turned on before beginning depressurization sequence.



18 2 2 Operational Timeline (See Table 6-41)

The time required for command module depressurization is approximately 25 minutes. Re-pressurization from outside ambient to five psia requires approximately one hour using the cabin pressure regulator and the emergency oxygen inflow control.

18 2 3 Duty Cycles - Block Duration Approximately 2 5 hours

Equipment	Common Level	Block 18
Inverter 2 (at no load)	0	85 percent

Includes approximately one hour for crew-mobility studies

18 2 4 Electrical Power

The average Δ power levels are

$$P_{AC}(\text{nominal}) = 0.0 \quad P_{DC}(\text{nominal}) = 95.2 \text{ watts}$$

18 3 PERFORMANCE DATA

18 3 1 Oxygen Used During Depressurization

- 1 Oxygen drawn from automatic section of cabin pressure, regulated during pressure buildup from 3.8 to 4.0 psia
1.3 lb/hr for 17 minutes = 0.37 lb
 - 2 Oxygen consumed during pressure buildup from 2.75 to 3.25 psia using emergency flow regulator
0.67 lb/min for 1.5 minutes = 1.00 lb
 - 3 Metabolic oxygen consumed by three astronauts
0.23 lb/hr for 18.5 minutes = 0.07 lb
- Total oxygen during depressurization 1.44 lb

18 3 2 Oxygen Used During Re-pressurization (Duration Approximately One Hour)

- 1 Emergency flow regulator 0.67 lb/min for 5 minutes = 3.35 lb
- 2 Re-pressurization control valve 0.12 lb/min for 0 to 5 psi (approximate) = 5.40 lb



3	Automatic section of cabin pressure regulator 1 3 lb/hr for 3 5 to 5 ps ₁ (approximate)	= 0.40 lb
4	Cabin leakage - varying linearly with pressure 0 2 lb/hr for 5 ps ₁ (approximate)	= <u>0 15 lb</u>
	Subtotal	9 30 lb
5	Metabolic oxygen consumed by three astronauts 0 23 lb/hr for 1 hour	= <u>0 23 lb</u>
	Total oxygen during repressurization	9 53 lb



Table 6-41 Operational Timeline Segment, Cabin Depressurization

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
	(Depressurization)		
00 00 00	Verify following Surge tank pressure 900 ±50 Psia Oxygen supply tank pressure 900 ±50 Psia CM cabin pressure 5 ±0 2 Psia		Cabin fans should be turned OFF if inverters 1 and 2 are ON
00 00 06	Close emergency oxygen inflow control valve Open cabin pressure relief valve		At 4 8 psia the pressure regulator valve opens to maximum flow rate
00 00 16	Monitor cabin pressure for 3 8 psia then close cabin pressure relief valve		
00 17 21	Monitor cabin pressure for 4 0 psia		If cabin pressure does not increase to 4 0 psia open repressurization rate control valve When 4 0 psia is reached continue procedure At 3 5 psia pressure regulator valve automatically shuts off
00 17 28	Monitor cabin pressure for 2 75 psia		
00 17 38	At 2 75 psia close pressure relief valve		
00 17 40	Observe pressure stabilization at 2 75 psia		
00 17 43	Open emergency oxygen inflow control valve		
00 19 13	Monitor cabin pressure for 3 25 psia		
00 19 14	At 3 25 psia close emergency oxygen inflow valve		
00 19 19	Observe pressure stabilization at 3 25 psia		
00 19 20	Open pressure relief valve		
00 25 00	Monitor cabin pressure exponential decay to 0 0 psia		



Table 6-41 Operational Timeline Segment, Cabin Depressurization (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
	(Repressurization)		
00 00 00	Close cabin pressure relief valve		
00 00 02	Open emergency oxygen inflow control valve		
00 00 07	Open repressurization rate control valve		
00 00 12	Monitor surge tank pressure for 150 psia		
00 00 15	Close emergency oxygen inflow control valve		
00 00 20	Manually adjust repressurization rate control valve to maintain 150 psia in surge tank		Automatic section of regulator will open at 3 5 psia
	Monitor cabin pressure for 4 8 psia then close repressurization rate control valve cabin pressure will stabilize at 5 0 psia		
*01 00 00			*This repressurization time is approximate

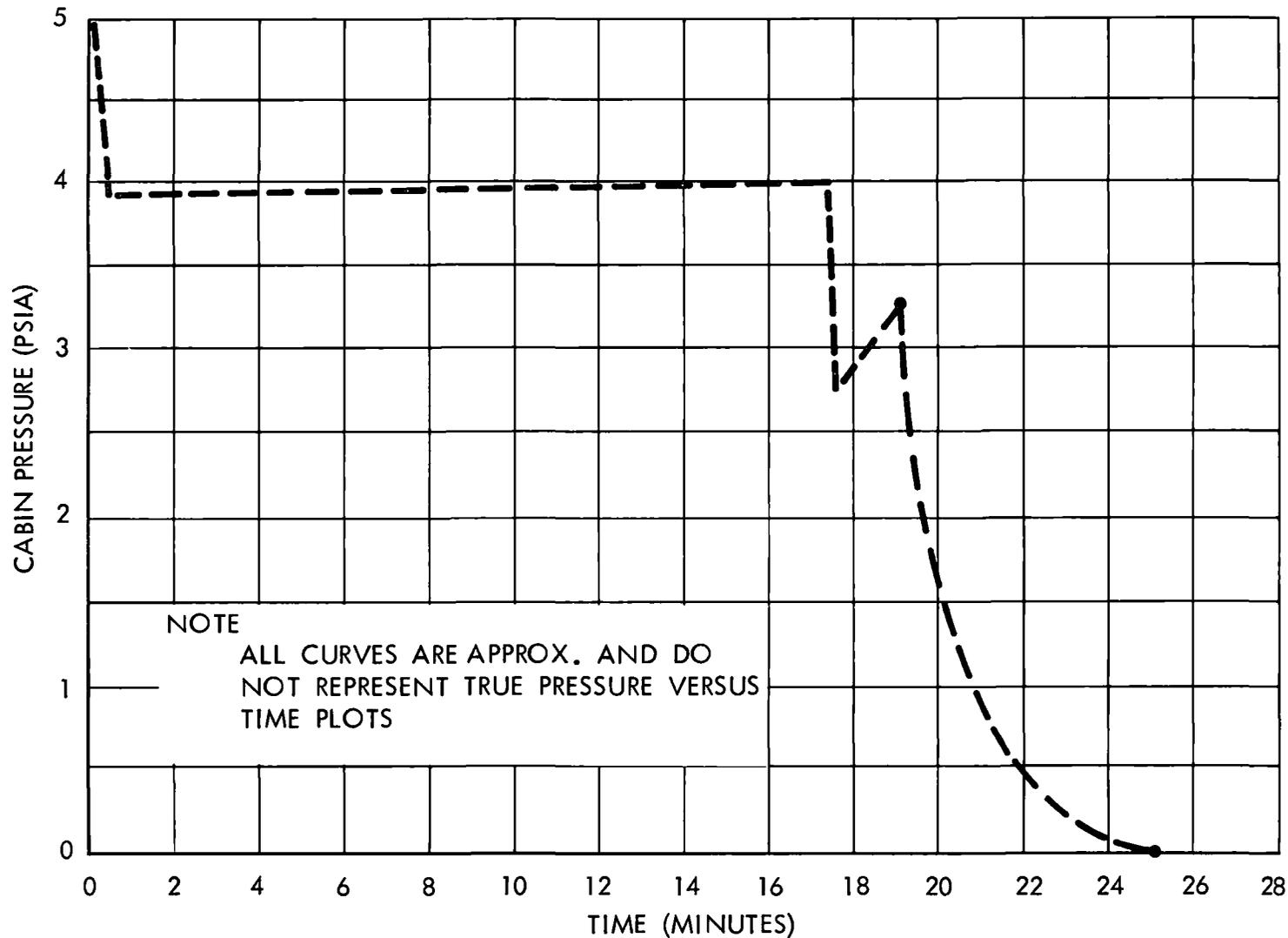


Figure 6-30 Cabin Pressure Versus Time

6-196

SID 66-1177



BUILDING BLOCK 24 PRE-DEORBIT

24 1 INTRODUCTION

Building Block 24 lists all the functions and events which must be completed before the retro maneuver is initiated. The intent of the building block is to provide a sequence which the mission planner can superimpose on any mission timeline. The required functions are the following:

An attempt to cool down the command module cabin to 70 F

System checks

Gear stowage

Heating CM RCS engines to 100 F

Preparing the ECS

24 2 OPERATIONAL DATA

24 2 1 Operational Timeline Segment

Table 6-42 shows the spacecraft operations and crew activities required to configure the spacecraft for atmospheric entry. The level of detail includes only those operations which are required to aid in defining total event duration, duty cycles, and consumable profiles. Estimated duration times for the crew operations are included.

24 2 2 Subsystem Duty Cycles

See Table 6-43.

24 2 3 Electrical Power

The average Δ power levels are as follows:

$$P_{AC} = 34.5 \text{ watts} \quad P_{DC} = 64.7 \text{ watts}$$



24 2 4 Propellant Consumption

The RCS propellant consumed to perform this three-axis maneuver at
0 2 deg/sec is one pound of service module RCS



Table 6-42 Operational Timeline Segment, Pre-Deorbit

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t +00 00 00	<p>Initiate crew cabin chilldown using the ECS (00 01 00)</p> <p>Establish CM cold soak attitude if required (10 29 00 maximum)</p> <p>Power up SCS (00 02 00)</p> <p>Perform SCS attitude maneuver to CM cold soak attitude (00 06 00)</p> <p>Power down SCS and establish free drift (00 02 00)</p> <p>Perform crew maintenance as required (02 00 00)</p> <p>Perform subsystem status checks as required (00 02 00)</p> <p>Perform communications functions as required (See Block 9 AM-1)</p> <p>Perform subsystem maintenance, as required (00 15 00)</p>	<p>E</p> <p>E</p> <p>G</p> <p>G</p> <p>G</p> <p>G</p> <p>G</p> <p>G</p>	<p>Reference AOH paragraph 8 4 11</p> <p>Chilldown of the crew cabin should begin at least 8 to 12 hours prior to entry</p> <p>The crew cabin should be chilled down to approximately 70 F at entry interface penetration</p> <p>Current analysis indicates that the ECS may not have the capacity to reduce the CM ambient temperature to the required level before entry therefore it is probable that a spacecraft attitude hold will be required at an orientation which results in a cold soak of the CM</p> <p>Omit this operation if not required</p> <p>Reference AOH paragraph 8 6 3 5</p> <p>Reference Block 11 Section 11 3 2</p> <p>Assume three-axis maneuver at 0 2 degrees per second through 72 degrees of CM cold soak attitude</p> <p>Reference AOH paragraphs 8 6 3 6 and 8 6 4 1</p> <p>Adjust attitude as required to avoid exceeding ECS and EPS radiator constraints</p> <p>Reference Block 10</p> <p>Reference Block 14</p> <p>Reference AOH paragraph 8 5 1</p> <p>Reference Block 15</p>



Table 6-42 Operational Timeline Segment, Pre-Deorbit (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
	Don and check PGA CWG and MIA gear as required (00 30 00)	E	Reference AOH paragraphs 8 4 12 and 8 4 15
	Perform deorbit stowage (01 00 00)	G	Involves simultaneous action of all three crewmen All items of loose equipment and material will be returned to storage before deorbit thrusting preparation
t +10 29 00	End crew cabin chulldown (00 01 00)	E	Assumes crew cabin ambient temperature has been reduced to 70 F or less
t +10 30 00	Replace unhinged attenuation panel and prepare ECS (00 05 00)	G	Reference AOH paragraphs 8 4 16 and 8 8 12
t +00 35 00	Perform ΔV preparation (01 17 00)	E	Reference Block 12
t +11 34 00	Perform CM RCS preheating (00 13 00)	E	Reference AOH paragraph 8 8 1 3
t +11 47 00	Prepare ECS for CM/SM separation (00 01 00)	E	Two crewmen active simultaneously
t +11 49 00	Power up EPS for SPS ΔV	E	Reference Block 12
t +11 52 21	Perform deorbit burn		Reference Block 25 or 26



Table 6-43 Subsystem Duty Cycles, Pre-Deorbit (Duration 12 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 24
Stabilization and Control				
RGP		3 2 6	0	0 209 in 3
BMAG		and 5	0	2 2 in 2
FDAI			0	2 6 in 6
AS/GPI			0	0 433 in 5
ΔV display		5	0	0 433
Rotation controller		3 2 6	0	
SCS control panel		and 5	0	
ECA pitch			0	0 209 in 3
ECA roll			0	2 2 in 2
ECA yaw			0	2 6 in 6
ECA aux			0	0 433 in 5
ECA display			0	
Electronics display			0	
TVC OPERATE		6 and 5	0	2 6 in 6 0 433 in 5
TVC Standby			0	
Guidance and navigation				
AGC OPERATE		A and B	0	3 0 in A 2 8 in B
AGC Standby		F	100	94 2
IMU OPERATE		A and B	0	3 0 in A 2 8 in B
IMU Standby		F	100	94 2
Optics		B	0	2 8
Displays and controls		A and B	0	3 0 in A 2 8 in B
Communications				
				See BB-9 AM-1
Electrical power				
H ₂ purge solenoids			0	See BB-9
O ₂ purge solenoids			0	See BB-9
Service module RCS				
Engine heaters			62 5	
RCS engine coils		Auto- matic	0	0 2345
He isolation valves			0	
Propellant isolation valves			0	
Command module RCS				
Isolation valves			0	
RCS engine coils		Auto- matic	0	0 902
Service Propulsion System				
Propellant utilization valve			0	1 196
Propellant utilization gauging system			0	1 196
Injector prevalues 2			0	1 196



Table 6-43 Subsystem Duty Cycles, Pre-Deorbit (Duration 12 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 24
H _e solenoid valves 2			0	1 196
Feedline heaters 26			0	See BB-9
Pilot valves (SCS) 4			0	0 0695
Gimbal actuator motors		Idle	0	0 295



BUILDING BLOCK 25 SPS DEORBIT AND ENTRY

25 1 AM-1 G&N (PRIMARY)

25 1 1 Introduction

This building block comprises that segment of the Apollo manned earth orbital mission between orientation for the SPS deorbit burn and apex cover jettison. The major events associated with the block include the orbital ejection attitude, the coast and maneuver to CM-SM separation attitude, module separation, coast and maneuver to the entry attitude, and the atmospheric flight phase to the beginning of the recovery phase (apex cover jettison). The SPS deorbit burn may be accomplished by any of the following modes (indicated in the preferred order), G&N ΔV , SCS ΔV , and Manual Thrust Vector Control (MTVC) ΔV . Since this spacecraft represents the first manned flight, it is presumed that G&N operation is desirable to either control the deorbit ΔV (G&N ΔV mode) or monitor the performance of the deorbit ΔV (SCS or MTVC ΔV mode). This subsection (AM-1) is confined to the G&N operative mode, with normal functioning of all subsystems assumed throughout the subsection. Subsection 25 2 (AM-2) covers the G&N inoperative modes.

25 1 2 Operational Data

25 1 2 1 General Information

The flow diagram provides an overall view of the related events occurring between orbit ejection and apex cover jettison, followed by the timeline segment, which provides specific event durations. Major interfaces, noted where applicable, occur with BB-12 (SPS ΔV), BB-24 (Pre-Deorbit), and BB-35 (Parachute Descent). Trajectory limits and considerations applicable to this segment of the mission are itemized in Paragraph 25 1 2 2. Performance data of Paragraph 25 1 3 are referenced by figure numbers, where applicable, to specific operational considerations.

25 1 2 2 Trajectory Limits and Considerations

- 1 The spacecraft deorbit attitude must be consistent with horizon visibility requirements. The G&N is pre-programmed to maneuver the spacecraft to a head-up ejection attitude which may be checked by means of Figures 6-31 and 6-32.



- 2 The deorbit ΔV should be budgeted to the hybrid entry corridor (HEC) mean (Figures 6-33 and 6-34) with provision for a minimum coast-to-entry time of 7 minutes, 19 seconds (The recommended minimum coast period is 10 minutes) The minimum coast period is imposed by crew task operations and spacecraft maneuvers required between end deorbit burn and entry A minimum period of 3 minutes 50 seconds, out of the total minimum coast-to-entry time, should be allotted for accomplishment of crew tasks and spacecraft maneuvers required between CM-SM separation and entry (See timeline segment, Tables 6-44 and 6-45)
- 3 A constant inertial attitude should be maintained during the deorbit burn
- 4 A minimum of 10 seconds should be allotted for attitude rate damping following all maneuvers
- 5 The nominal CM-SM separation attitude is approximately 60 degrees with respect to the velocity vector, with the spacecraft positive X axis directed up and forward (see Figure 6-35) in the orbital plane
- 6 The required separation ΔV to obtain a non-collision probability of 0.9999 or a separation distance of 3200 feet between the command and service modules at the 400,000-foot entry altitude may be obtained from Figures 6-35 and 6-36 for a given time between ignition of four service module RCS jets and entry
- 7 The spacecraft should maintain an inertially fixed attitude during the separation
- 8 A minimum delay of 5 seconds is required for module clearance after severance of CM-SM ties during which time the command module should maintain a constant inertial attitude
- 9 A roll rate should be imparted to the service module to null RCS thrust misalignment effects
- 10 The command module must be oriented to assure blunt-face (or heat shield) forward trim at entry The permissible excursion envelope of angle of attack and sideslip at entry is given in Figure 6-37.
- 11 Lift vector orientation should be such that full positive lift is obtained and maintained until 0.2 g's



Table 6-44 Operational Timeline Segment, SPS Deorbit and Reentry, AM-1

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t_0	Perform SPS ΔV deorbit burn		<p>CM pre-entry chilldown should be initiated approximately 10 hours before the scheduled deorbit maneuver (Reference Block 24)</p> <p>The CM RCS engines must have been warmed to at least 100 F before CM-SM separation</p> <p>The procedures for the deorbit burn are those of the nominal ΔV burn of Block 12 No time can be assigned this operation because of the multiplicity of variables</p> <p>Reference AOH Section 8 for details</p>
t_1	<p>Perform pre-CM-SM separation procedures (03 51)</p> <p>Prepare EPS for separation Set C&W mode to CM Select AGC program for separation attitude and maneuver parameters Align FDAI for backup to automatic maneuver to separation attitude Maneuver spacecraft to separation attitude monitor maneuver on FDAI Prepare CM RCS pressurize only - no detailed checks Verify final separation attitude Activate master events sequence controller (MESC) and arm pyrotechnics</p>	CS	Does not include time to damp fuel slosh oscillations
$t_1+03 51$	<p>Perform CM-SM separation (00 18)</p> <p>Set CM-SM separation switches to SEP Set RCS transfer switch to CM Report to MSFN</p>	CS	
$t_1+04 09$	<p>Perform postseparation operations (01 50)</p> <p>Perform EPS check Perform CM RCS pressure checks Monitor FDAI for final attitude after separation and rate damping (Reference Block 16) AGC up-date</p>		



Table 6-44 Operational Timeline Segment,
SPS Deorbit and Reentry, AM-1 (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t ₁ +05 59	Perform preentry operations (01 20) Program AGC for pre-entry maneuver Prepare attitude reference system for backup manual maneuver Visually observe SM separation distance and report to MSFN Monitor FDAI Configure main display console for entry Activate flight qualifications and tape recorders	CS	
t ₁ +07 19	Perform entry monitor operations Report entry interface penetration Monitor DSKY Verify 0.05 g Verify 0.2 g Engage ELS battery circuit breakers		The exact time is a function of spacecraft trajectory



Table 6-45 SPS Deorbit Minimum Coast Time
(Based on Required Functions)

Event/Operations	Estimated Minimum Time (Sec)
<p>Preseparation (end deorbit burn to physical separation of CM-SM)</p> <p>Secure CSM systems and communicate with MSFN</p> <p>Program AGC for CM-SM separation and monitor DSKY displays</p> <p>Monitor G&N controlled maneuver to CM-SM separation attitude</p> <p>Prepare MDC and AGC for CM-SM separation</p> <p>Prepare pyros and caution/warning system for CM-SM separation</p> <p>Prepare EPS for CM-SM separation</p> <p>CM-SM separation</p> <p style="text-align: right;">Total</p>	<p style="text-align: right;">30</p> <p style="text-align: right;">40</p> <p style="text-align: right;">45</p> <p style="text-align: right;">60</p> <p style="text-align: right;">15</p> <p style="text-align: right;">15</p> <p style="text-align: right;"><u>5</u></p> <p style="text-align: right;">210*</p>
RECOMMENDED MINIMUM TIME = 5 Minutes	
<p>Postseparation preentry (physical separation of CM-SM to 400,000-foot entry altitude)</p> <p>Perform AGC automatic update and coordinate with MSFN</p> <p>Program AGC for entry attitude maneuver and monitor DSKY</p> <p>*Monitor G&N controlled maneuver to entry attitude</p> <p>Monitor SC rates and AGC entry programming</p> <p style="text-align: right;">Total</p>	<p style="text-align: right;">60</p> <p style="text-align: right;">15</p> <p style="text-align: right;">90</p> <p style="text-align: right;"><u>60</u></p> <p style="text-align: right;">225</p>
RECOMMENDED MINIMUM TIME = 5 Minutes	
<p>*This time does not include allowance for possibility of damping fuel slosh oscillations</p> <p>*1-180 degree single-axis maneuver at 4 deg/sec</p> <p>**2-180 degree sequential maneuvers at 4 deg/sec</p>	



- 12 The primary entry control mode (closed-loop ranging with manual G&N using a single RCS) should be used for lift vector orientation control from 0 2 g's to an approximate earth-fixed velocity of 1000 fps, at which time the bank angle command will remain fixed at the last commanded value until drogue parachute deployment (refer to BB-35)
- 13 Bank angle maneuvers during closed-loop ranging should be restricted to positive lift ($|\phi| \leq \pm 90$ degrees) in order to maintain backup manual monitoring and control capability with assurance of safe entry (avoid exceeding the 10-g acceleration load limit)

25 1 2 3 Mission Functional Flow

The flow diagram (Figure 6-38) is provided to give an overall view of the SPS deorbit functions. The diagram interfaces directly with BB-12 (SPS ΔV) and BB-24 (Pre-Deorbit). Functions for this building block are shown sequentially and terminate with the apex cover jettison, interfacing directly with BB-35 (Parachute Descent).

25 1 2 4 Operational Timeline Segment

The operational timeline segment (Table 6-44) presents the specific time durations of the events shown in the functional flow diagram. The table also outlines the various procedures incorporated in each event and includes pertinent comments. The interfaces are identical to those given in the preceding Paragraph 25 1 2 3.

It is assumed that the SPS deorbit is not a time-fixed trajectory event and the operational timeline segment accordingly indicates nonspecific mission times as an aid in real-time mission planning. Where operational events could not be precisely fixed in time with respect to preceding or succeeding operations because of dependency upon trajectory-oriented variables such as required SC/MSFN communications (AGC update, confirmation of thrusting parameters, etc.) and burn duration, they are indicated by a change in mission time subscript.

25 1 2 5 Attitude Maneuvers

The spacecraft attitude at SPS ignition for deorbit should be constrained to maintain the spacecraft X-Z plane coincident with the orbital plane and positive plus X axis pointing in a retrograde direction at an angle to the local horizontal so that the horizon is visible in the forward window. The ejection attitude, θ_{ej} , as a function of orbital altitude consistent with horizon visibility requirements is given in Figure 6-31 for the pre-programmed head-up retro attitude (positive Z axis down = 180 degrees). This attitude is



held inertially fixed from RCS ullage ignition through SPS cutoff. The assumptions pertinent to Figure 6-31 are a fiftieth percentile man, horizon centered in the forward field-of-view (angle between the spacecraft positive X axis and the line-of-sight, ψ , is 23.85 degrees), and a mean spherical earth model with a radius of 3440 nautical miles.

Following completion of the post-burn checklist and checks of subsystems, the spacecraft should be maneuvered to a separation thrust attitude directed in a manner which will provide maximum separation distance between the command and service modules at the 400,000-foot entry altitude. The positive X axis should be directed 60 ± 20 degrees above the velocity vector in the orbital plane with the positive Z axis also in the orbital plane and the negative Y axis along the angular momentum vector, $\vec{r} \times \vec{v}$.

After completion of the separation and checks of subsystems, the command module should be maneuvered to the 0.05-g entry attitude, i_e , within the permissible attitude envelope (Figure 6-39). The command module attitude is held inertially fixed from completion of the maneuver to 0.05 g's. At 0.05 g's, the command module attitude should be such that the X-Z plane is coincident with the orbital plane, the positive axis having a positive component on the upward local vertical, and the positive X axis directed at an angle, α , above the velocity vector and within the attitude limits of Figure 6-37.

At 0.05 g's (obtained from the DSKY), the pitch and yaw channels will be manually switched to the rate stabilization mode, and the cross-coupling of yaw with roll will be enabled. The roll channel will remain in the attitude hold mode.

The manual G&N attitude mode (closed-loop ranging mode) which controls the orientation of the lift vector is used from 0.2 g's to an earth-fixed velocity of approximately 1000 fps, at which time the bank command will remain fixed at the last commanded value until drogue parachute deployment. The bank angle, however, should be limited to ± 90 degrees (positive-lift maneuvers) once the G&N ranging has begun. All stabilization and attitude control of the command module is terminated at drogue parachute deployment.

25.1.2.6 Duty Cycles

The primary method for accomplishing retrograde thrusting for this spacecraft is to perform SPS engine thrusting with the thrust vector and ΔV controlled by the G&N. The power duty cycle chart shows this primary mode.



Duty cycles are given in two parts in Table 6-46. Part A covers the portion between initiation of the SPS deorbit burn and securing the system following termination of the burn, and interfaces directly with BB-24. Part B covers the remainder of the SPS deorbit and entry phase.

25 1 2 7 Electrical Power

The average power levels are as follows

Duty Cycle	P_{AC} (watts)	P_{DC} (watts)
Part A	201.6 (delta)	896.0 (delta)
Part B	590.9 (total)	861.8 (total)

For the electrical power of Part B, the equipment loads associated with this portion of the block should be summed from a power level of zero watts and should not be added to the common-level power.

25 1 2 8 Propellant Consumption

SPS propellant consumption may be determined from the data presented in Subsection 5-3 and BB-12.

The command module RCS propellant available for stabilization and control between CM-SM separation and drogue parachute deployment is 112.5 pounds per system (refer to Paragraph 25 1 3 2, Spacecraft Subsystem Limits, Item 8). Propellant penalties associated with off-trim attitude of the command module at the 0.05-g entry threshold are presented in Figure 6-39 showing lines of constant propellant consumption for combinations of angle of attack and angle of sideslip. These data were derived for a nominal state vector at CM-SM separation and a single RCS. The propellant numbers apply to that segment of the trajectory between CM-SM separation and a point after 0.05 g's where pitch and yaw rates are contained within the rate deadbands (see Paragraph 25 1 3 2, Spacecraft Subsystem Limits, Item 7).

Representative command module RCS propellant time histories are presented in Figure 6-40 for nominal and off-nominal single RCS entries. The propellant expended during the preentry phase (nominal, 5 pounds, off-nominal, 9 pounds) has been added to the respective curves. A parametric representation of the propellant consumption during this mission phase would be prohibitive due to the variables involved.



Table 6-46 Subsystem Duty Cycles, SPS Deorbit and Reentry
(Duration 0 100 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 25
PART A				
Stabilization and control				
RGP		5 and 6	0	} 8 33 in 5 91 67 in 6
BMAG			0	
FDAI			0	}
AS/GPI			0	
ΔV display		5	0	} 8 33 in 5
Rotation controller			0	
SCS control panel			0	} 8 33 in 5 91 67 in 6
ECA pitch			0	
ECA roll			0	}
ECA yaw			0	
ECA aux			0	}
ECA display			0	
Electronics display			0	}
TVC OPERATE			0	
Guidance and navigation				
AGC OPERATE		A	0	100
AGC STANDBY			100	0
IMU OPERATE		A	0	100
IMU STANDBY			100	0
Displays and controls		A	0	100
Service propulsion system				
Propellant utilization valve				100
Propellant utilization gauging system			0	100
Injector prevalues		2	0	100
He solenoid valves		2	0	100
Feedline heaters		26	0	BB-9
Pilot valves (SCS)		4	0	5
Gimbal actuator motors		ΔV	0	8 33
PART B				
Stabilization and control				
RGP			7	100
BMAG			7	100
FDAI			7	100
AS/GFI			7	100
Rotation controller			7	100
SCS control panel			7	100
ECA pitch			7	100
ECA roll			7	100
ECA yaw			7	100
ECA aux			7	100
ECA display			7	100
Electronics display			7	100



Table 6-46 Subsystem Duty Cycles, SPS Deorbit and Reentry
(Duration 0 100 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 25
Guidance and navigation				
AGC OPERATE		A		100
IMU OPERATE		A		100
Displays and controls		A		100
Crew systems				
Personal communications				100
Biomedical instrumentation				100
Communications				
VHF/FM transmitter				100
VHF/AM equipment		Standby		100
S-band transponder				100
S-band power amplifier		High		100
C-band transponder		Interrogate		10
		Noninterrogate		90
Audio center		Low		100
Signal conditioner				100
PCM telemetry				100
Premodulation processor				100
Central timing				100
UHF-Updata link				100
Flight qualification recorder				Initiated at t + 0 109
2-KMC switch				100
Audio center diode switch		Low		100
Electrical power				
Power distributions sensors				100
Instrumentation				
CM				100
SM				Initiated at t = 0 terminates at t + 0 092
Gas chromatograph				100
Displays and controls				
Digital event timer		Operate		100
CW detection unit				100
Master alarm indicator				100
CW matrix indicator				100
SES floodlights		Fixed		100
		Variable		100
CS floodlights		Fixed		100
		Variable		100



Table 6-46 Subsystem Duty Cycles, SPS Deorbit and Reentry
(Duration 0 100 Hours) (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 25
Environmental control				
Suit compressor		Low		100
Glycol pump				100
Cabin fans	2			2 at 100
Glycol temperature control				100
Glycol temperature control valve				100
Cabin temperature control				100
Cabin temperature control valve				100
Backpressure control				100
Backpressure control valve				100
Wetness control				100
Power supply				100
O ₂ flow transducer				100
Pressure transducers	3			100
Backpressure sensor				100
Glycol transducers	2			100
Steam duct heater				100
Potable H ₂ O tank potentiometer				100
Waste H ₂ O tank potentiometer				100
Cyclic accumulator valve				1 6
Potable H ₂ O assembly				4 0
Urine line heater				100
Suit sensors				100
Cyclic accumulator control				1 6
Suit circuit				
Backpressure control				100
Glycol valve				100
Wetness control				100
Glycol diverter valve				100
Water control valve				100
Backpressure valve				100
Sequential events				
Logic				100



25 1 3 Performance Data

25 1 3 1 General Information

Paragraph 25 1 3 contains the performance trade-off data associated with the SPS deorbit maneuver and subsequent mission events to jettison of the apex cover. Interfaces are identical to those of Paragraph 25 1 2 (Operational Data) and are noted where applicable. All maneuvers are performed within the limits enumerated in Paragraph 25 1 3 2.

Orientation to the ejection attitude is performed automatically by the G&N to a head-up retro position consistent with the horizon visibility requirement. The ejection attitudes, though attained automatically, are included here for reference and are given as a function of orbital altitude (Figure 6-31) and as a function of true anomaly for an 85- to 230-nautical-mile elliptical orbit (Figure 6-32). These figures are based on the assumption of the horizon (relative to a mean spherical earth model) centered in the forward window field-of-view of a fiftieth percentile man.

The position of the deorbit retro maneuver is dependent upon the target location, entry flight mode (range), coast range or time, and ejection ΔV . The ejection ΔV requirements are determined by the horizon visibility requirement in conjunction with the HEC (Figure 6-33). Consideration must also be given to worst-case ejection attitude errors to determine minimum and maximum ΔV requirements. Investigations of three-sigma attitude errors resulting from hard-over failure ($\Delta\theta_{ej} = \pm 18$ degrees) indicate that the ΔV associated with the nominal ($L/D = 0.34$) HEC overshoot and undershoot boundaries should include the possibility of such failure to ensure attainment of entry conditions within the corridor (see Figure 6-34). The ejection ΔV budget should therefore be based on the HEC mean-line. Budgeting the ΔV to the HEC mean-line will ensure the attainment of entry conditions within the limits indicated in Figure 6-31 for the 85- 230-nautical-mile orbit. Curves relating to minimum coast times, superimposed on the figure, are based on crew task requirements (440 seconds) and the recommended value (600 seconds). (See Table 6-45.)

Following the deorbit burn, the spacecraft coasts and maneuvers to the required attitude for CM-SM separation. Performance associated with this phase of the mission includes the time requirements for performing the pre-separation functions necessary to prepare and maneuver the spacecraft for this event. Table 6-45 presents the best estimate of a minimum time required to accomplish the necessary pre-separation tasks. This estimate (3 minutes, 30 seconds) does not allow for the possibility of having to damp fuel slosh oscillations before separation. The recommended minimum time for mission planning is, therefore, 5 minutes to allow for this possibility (which may be more or less than the additional time of 1 minute, 30 seconds).



The separation attitude is based upon crew safety considerations, i.e., a noncollision probability of 0.9999 and a maximum separation distance between the command and service modules at the 400,000-foot entry altitude. Spacecraft maneuvers are at the rate of 4 degrees per second (see Paragraph 25.1.3.2, Spacecraft Subsystem Limits, Item 4) to the separation attitude indicated on the inset of Figure 6-35. The attitude is dependent upon the combined effects of thrust vector orientation, the amount of service module RCS propellant expended with the -X translation jets, and the coast time remaining between the separation and 400,000-foot entry altitude. The estimated minimum time required to accomplish necessary pre-entry tasks and spacecraft maneuvers is given in Table 6-45 as 3 minutes, 45 seconds. The recommended minimum time for mission planning in the phase is 5 minutes. This recommended time is based on minimizing the service module RCS propellant provisions critical to the service module RCS retro case (see BB-26) and, therefore, maintains a consistent time period for both retro cases.

The CM-SM separation ΔV requirements are shown in Figure 6-35 for a representative jettisoned service module weight of 15,000 pounds as a function of the time between service module translation jet ignition and the 400,000-foot entry altitude for the nominal thrust pitch attitude and a noncollision probability of 0.9999. For this noncollision probability, a separation distance of 3200 feet or greater is attained between the command and service modules at the 400,000-foot entry altitude. The effect of the separated service module weight is shown in Figure 6-36. The effect of the jettisoned service module weight on the required ΔV is approximately linear, except in the extremely short preentry separation times which require large separation ΔV 's. High service module weights at jettison can impose a maximum possible separation ΔV (see intersection with continuous thrusting limit of Figure 6-36), but actually establish an absolute minimum time to jettison the service module before entry (exclusive of required crew tasks and spacecraft maneuvers). A jettisoned service module weight of approximately 20,000 pounds, for example, would impose an absolute minimum preentry time of 1.65 minutes, less than half the time required to complete the post-separation and preentry crew tasks and maneuvers (see Table 6-45).

Following the separation, a minimum delay of 5 seconds is required to assure module clearance. During the coast-to-entry period, the command module must be oriented to the entry trim attitude, which consists of blunt-face forward with full positive lift (head-down) within the permissible attitude envelope (Figure 6-37), which defines the maximum allowable excursions in angle of attack and sideslip for assurance of the blunt-face forward trim. The blunt-face (or heat shield), forward aerodynamic trim characteristics in the hypersonic entry flight regime are given in Figure 6-41, and the relationship between command module center of gravity and aerodynamic trim is illustrated in Figure 6-42.



Entry within the HEC is dependent upon the deorbit conditions and ejection ΔV (nominally budgeted to the HEC mean line) Conditions at entry (400,000-foot altitude) which result from the prescribed ejection attitude (Figures 6-31 and 6-32) and ΔV (Figure 6-34) are presented as functions of the true anomaly for an 85- to 230-nautical mile elliptical orbit in Figures 6-43 (inertial entry velocity) and 6-44 (inertial entry flight path angle) The related coast ranges and coast times are given in Figures 6-45 and 6-46, respectively These figures all indicate the effect of the three-sigma error of ± 18 degrees in ejection attitude on the entry conditions The entry conditions obtained as a consequence of such an error in ejection attitude, while within the HEC, could result in an overshoot or undershoot of the predicted touchdown area Where applicable, the minimum time restrictions for crew activities and the recommended total minimum coast time restrictions are indicated on the figures

The primary entry mode (AM-1) of manual G&N consists of full positive lift ($\phi = 0$ degrees) maintained to an acceleration load factor level of 0.2 g's where closed-loop ranging is begun The entry ranging mode is terminated at an earth fixed velocity of approximately 1000 fps, at which time the bank command will remain fixed at the last commanded value until drogue parachute deployment

The command module RCS is used for stabilization and control from module separation to drogue parachute deployment Representative propellant consumption time histories for this mission segment are given in Figure 6-40 Command module electrical energy is provided by three zinc-silver oxide batteries The electrical energy limits for three, two, and one batteries are indicated in Figure 6-47, with notation for nominal deorbit and postlanding energy requirements The figure also indicates the total entry energy requirements for preentry CM-SM separation times of 0, 5, 10, and 15 minutes Additional electrical energy information is given in Paragraph 25.1.2.7

25.1.3.2 Spacecraft Subsystem Limits and Capabilities

- 1 The SPS operating life (minimum) is 600 seconds
- 2 The deorbit thrusting attitude, θ_{ej} , is limited to the head-up retro position ($\phi = 180$ degrees for the horizon visible in the forward window as pre-programmed in the G&N)
- 3 The G&N automatic maneuver rates will be 4.0 degrees per second for abort or entry maneuvers only Otherwise, all AGC controlled maneuvers will be accomplished at 0.5 degrees per second (three axes)



- 4 G&N attitude maneuver-commanded rate limits are as follows

Maneuver	Limit (deg/sec)
Roll (CSM)	7 2
Roll (CM)	15 0
Pitch and yaw (CSM, CM)	4 0

- 5 The G&N is pre-programmed to command the CM-SM separation maneuver (at 4 0 degrees per second) to an attitude whereby the positive X axis will be in the direction of motion and pitched up at an angle of 60 degrees above the velocity vector and whereby the negative Y axis will be along the orbital angular momentum, $\vec{r} \times \vec{V}$

- 6 The SCS effective maneuver rate limits are as follows

Maneuver	Limit (deg/sec)
Roll	17 0
Pitch and Yaw	5 0

- 7 The SCS rate and attitude deadband limits (three-axes) are the following

Deadbands	Maximum Limit	Minimum Limit
Rate	± 2.0 deg/sec	± 2.0 deg/sec
Attitude	± 5.0 deg	± 0.2 deg

- 8 The command module RCS propellant weight is 270 pounds, of which 225 pounds are considered usable, i e , 112.5 pounds per system are available for control of the command module between CM-SM separation and drogue parachute deployment
- 9 The total command module electrical energy (three batteries) available is 3480 watt-hours
- 10 The g-meter readability is $G \pm 0.5$ g, and the ΔV display accuracy is ± 1.0 fps



- 11 The structural design limits are 20 g's all axes
- 12 The thermal protective subsystem (TPS) limits are as follows

$$147^\circ \leq \alpha \leq 162^\circ$$

Bondline, $T_b = 600$ F

Cabin wall, $T_{cw} = 200$ F

Windows, $T_w = 1680$ F

Cabin air, $T_{ca} = 100$ F

Parachute compartment, $T_{pc} = 160$ F

- 13 The service module RCS operating life (maximum) is 1000 seconds - 500 seconds for continuous operation (single burn)
- 14 The command module RCS operating life (minimum) is 200 seconds

25 2 AM-2 SCS (G&N INOPERATIVE)

25 2 1 Introduction

This subsection encompasses the same mission segment as that of Subsection 25 1. Only data pertinent to that portion of the mission where the G&N is inoperative are given here. The SCS provides for manual control of the spacecraft and thrust vector forces, with the added capability for rate stabilization. Interfaces with other building blocks are identical to those of Subsection 25 1. Detailed description of the SCS and its capabilities is given in the AOH.

25 2 2 Operational Data

25 2 2 1 General Information

Operational data for AM-2 are essentially the same as those of Subsection 25 1. All trajectory limits and considerations of Subsection 25 1, except for those pertaining specifically to the G&N, are applicable to Subsection 25 2 2. Additions are itemized in Paragraph 25 2 2 2.

25 2 2 2 Trajectory Limits and Considerations

- 1 All orientation maneuvers must be performed manually with the aid of the control panel displays before SCS attitude hold is commanded.
- 2 The SCS does not provide automatic thrust-on. The thrust-on switch on the ΔV display provides this command for the SCS ΔV mode. Thrust is automatically terminated when the ΔV remaining



counter indicates zero. If engine ignition fails to occur when the thrust-on switch is pressed, the NORMAL/OFF/DIRECT-ON switch may be moved to DIRECT-ON, in which case thrust is terminated by returning the switch to the OFF position.

- 3 Manual ΔV (MTVC) will be used only as backup to a G&N or SCS ΔV . MTVC is primarily used to limit excessive rate changes which may be created by malfunctions of these systems.
- 4 Entry ranging cannot be accomplished with the backup SCS entry mode. Atmospheric penetration is made with full positive lift ($\phi = 0$ degrees), which should be maintained to 0.2 g's but not later than 1.0 g. After 0.2 g's, the secondary entry mode may be (a) constant roll rate, (b) any constant positive-lift bank angle, or (c) any constant positive-lift bank angle with time to reverse bank.
- 5 Orientation to the spacecraft deorbit attitude is achieved manually and may be a head-up or head-down attitude consistent with the horizon visibility requirement.

25 2 2 3 Mission Functional Flow

See Figure 6-38

25 2 2 4 Operational Timeline Segment

See Table 6-47

25 2 2 5 Attitude Maneuvers

The spacecraft attitude at SPS deorbit should be constrained to maintain the spacecraft X-Z plane coincident with the orbital plane, and the positive plus X axis should be pointed in a retrograde direction at an angle to the local horizontal so that the horizon is visible in the forward window. The ejection attitude, θ_{ej} , is attained manually and may be such that the pilot's head is either up or down. The head-up ejection attitude consistent with horizon visibility requirements is given in Figure 6-31 as a function of orbital altitude. Identical information for the head-down ejection attitude is shown in Figure 6-48. Whichever retro attitude is selected, it must be held inertially fixed from RCS ullage ignition through SPS cutoff. Assumptions pertinent to both figures are identical to those of Paragraph 25 1 2 5.

Maneuvers after the retro-fire are identical to those of Subsection 25 1 2 5, except that they are performed manually with the SCS. The entry attitude should be such that heat shield forward trim is assured with full positive lift ($\phi = 0$ degrees) maintained to 0.2 g's but not later than 1.0 g,



after which the secondary mode is employed (see Paragraph 25 2 2 2, Item 4)

25 2 2 6 Duty Cycles

The SCS ΔV mode provides backup for the G&N ΔV as well as thrust vector control. The power duty cycle chart (Table 6-48), shows this secondary mode. Duty cycles are given in two parts. Part A covers the portion between initiation of the SPS deorbit burn and securing the system following termination of the burn, and interfaces directly with BB-24. Part B covers the remainder of the deorbit and entry phase and is identical to Part B of Paragraph 25 1 2 6.

25 2 2 7 Electrical Power

The average power levels are as follows

Duty Cycle	P _{AC} (watts)	P _{DC} (watts)
Part A	202.6 (delta)	504.0 (delta)
Part B	590.9 (total)	801.8 (total)

25 2 2 8 Propellant Consumption

See Subsection 5-3, BB-12, and Paragraph 25 1 2 8

25 2 3 Performance Data

This paragraph contains the performance data associated with the AM-2 (G&N inoperative) SPS deorbit maneuver and subsequent mission events to jettison of the apex cover. Building block interfaces are identical to AM-1 (Subsection 25 1). All maneuvers are performed within the limits and constraints of Paragraphs 25 1 2 2 and 25 2 2 2.

Orientation for orbital ejection is performed manually with the aid of the control panel displays to a retro attitude consistent with the horizon visibility requirements. These attitudes are given in Figures 6-31 and 6-48 as functions of the orbital altitude for head-up and head-down attitudes, respectively. Similar data are given in Figure 6-32 as a function of the true anomaly for an 85- to 230-nautical-mile orbit. The same assumptions as for AM-1 (Paragraph 25 1 3) apply.



Table 6-47 Operational Timeline Segment, SPS Deorbit and Reentry, AM-2

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
0			1 Entry using the SCS is a backup procedure to the primary entry mode under G&N control 2 The preentry chill down should be initiated approximately 10 hours before the deorbit burn 3 The CM RCS engine injection valves must have been warmed to at least 100 F before separation
0	Perform SPS deorbit burn		4 See BB-12 for procedures If the G&N is operative it should be used as backup for the SCS
t	Perform procedures for CM-SM separation and entry (06 22)		5 The procedures are identical to those delineated in the standard SPS deorbit procedures



Table 6-48 Subsystem Duty Cycles, SPS Deorbit and Reentry, Part A
(Duration 0 100 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE		
			COMMON LEVEL	BLOCK 25	
Stabilization and control					
RGP		3 and 4	0	} 8 33 in 4 91 67 in 3	
BMAG		3 and 4	0		
FDAI		3 and 4	0		
AS/GPI		3 and 4	0		
ΔV display		4	0	8 33	
Rotation controller		3 and 4	0	} 8 33 in 4 91 67 in 3	
SCS control panel		3 and 4	0		
ECA pitch		3 and 4	0		
ECA roll		3 and 4	0		
ECA yaw		3 and 4	0		
ECA auxiliary		3 and 4	0		
ECA display		3 and 4	0		
TVC OPERATE		3 and 4	0		
Service propulsion system					
Propellant utilization valve			0		100
Propellant utilization gauging system			0	100	
Injector prevalues	2		0	100	
He solenoid valves	2		0	100	
Feedline heaters	26		0	BB-9	
Pilot valves (SCS)	4		0	5	
Gimbal actuator motors	ΔV		0	8 33	



The position of the deorbit retro maneuver is dependent upon the target location, the backup entry mode selected (see Paragraph 25 2 2 2, Item 4), the ejection ΔV , and the coast range, all of which must be determined prior to deorbit. The deorbit ΔV requirements are determined by the horizon visibility constraint in conjunction with the HEC of Figure 6-33. As in AM-1, worst-case ejection attitude errors must be considered, and the ejection ΔV budget should be based on the HEC mean-line. For head-up deorbit, the ΔV envelope of Figure 6-34 applies. The ΔV envelope for the head-down retro is given in Figure 6-49. The effect of ejection attitude errors is not shown on the latter figure.

Following the deorbit burn, maneuvers to separation and entry are similar to AM-1 (see Paragraph 25 1 3), except that they are performed manually with the aid of the control panel displays. Entry conditions following a head-up retro maneuver from an 85- to 230-nautical-mile orbit are given in Paragraph 25 1 3. Similar data for entry conditions following the head-down retro are given in Figures 6-50 (inertial entry velocity) and 6-51 (inertial entry flight path angle). Coast ranges and times associated with the head-down retro are given in Figures 6-52 and 6-53, respectively.

Entry ranging with the G&N inoperative cannot be accomplished, and a secondary entry mode must be selected. The secondary mode is a matter of choice and may consist of one of two basic types. The initial penetration should be made within the attitude trim envelope of Figure 6-37 with full positive lift ($\phi = 0$ degrees), which should be maintained to a g-level of 0.2, following which a constant roll rate initiated after 0.2 g's but no later than 1.0 g may be employed or any constant positive-lift bank angle may be employed. The latter mode may be altered by using any constant positive-lift bank angle with time to reverse bank for the purpose of minimizing cross range dispersions. Use of half lift ($\phi = 60$ degrees) with time to reverse bank will keep the touchdown area approximately in the center of the footprint. Open-loop impact footprints associated with various entry flight path angles are given in Figure 6-54 for an inertial entry velocity of 25,570 fps. Entry range, time, and stagnation point heating characteristics are presented in parametric form in Figures 6-55, 6-56, and 6-57, respectively, for an open flight mode of constant bank angle equal to zero degrees (full positive lift). These data are given in the critical entry region (shallow entry angles) near the 3500-nautical-mile overshoot boundary.

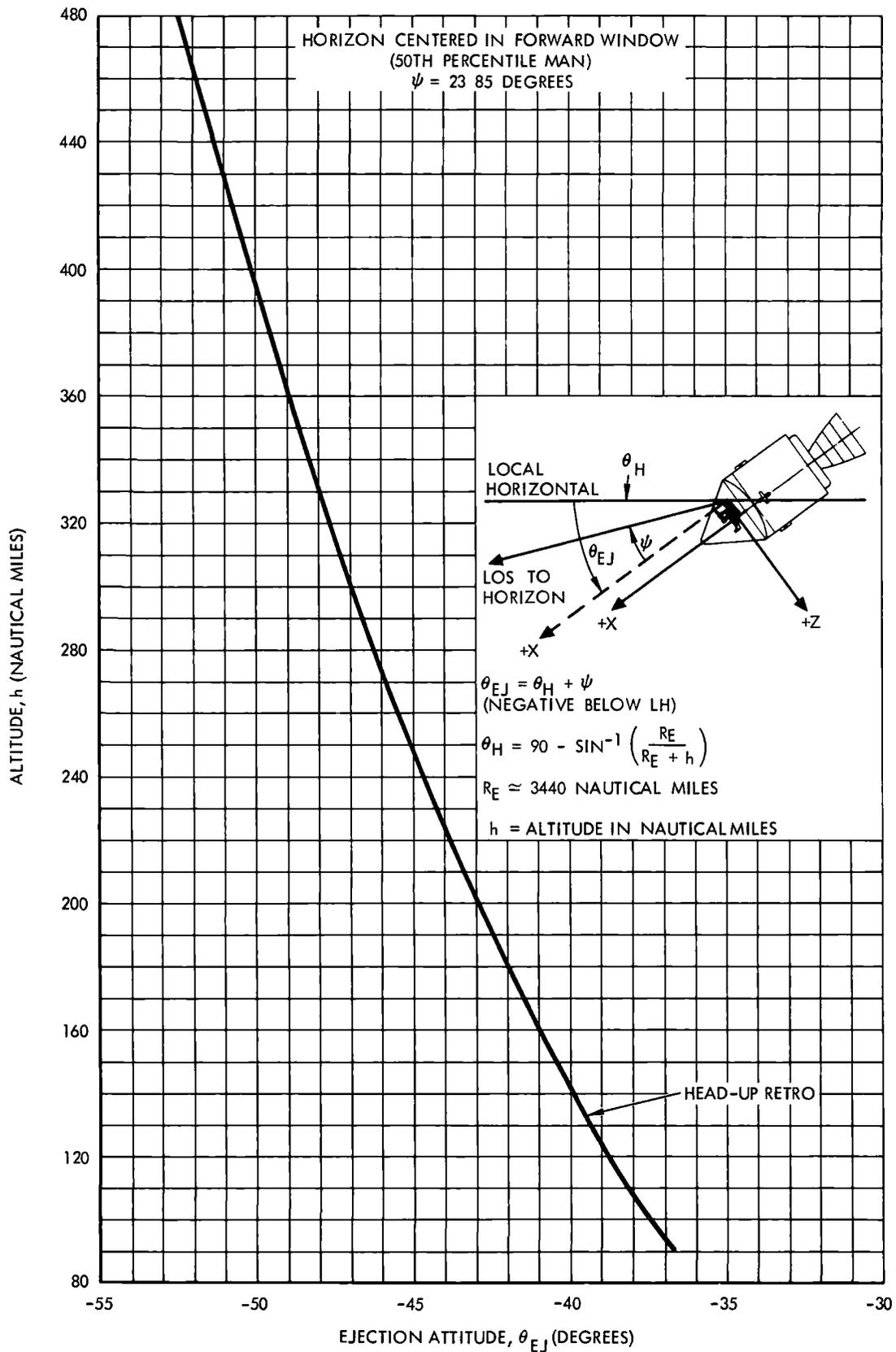


Figure 6-31 Ejection Attitude as a Function of Orbital Altitude

85/230 NM ELLIPTICAL ORBIT HORIZON CENTERED IN FORWARD WINDOW
(50TH PERCENTILE MAN)

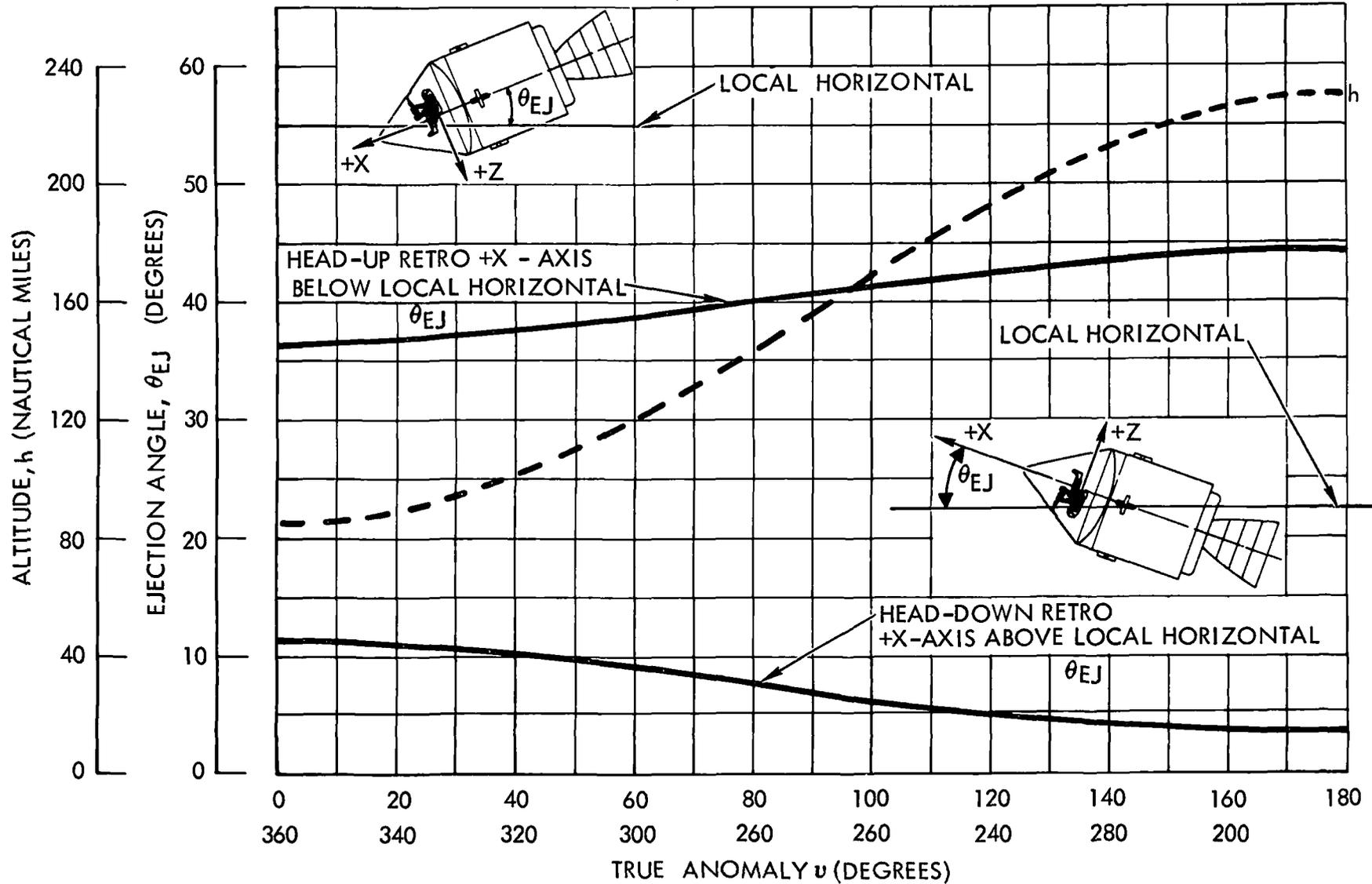


Figure 6-32. Orbital Retro Attitude and Altitude as a Function of True Anomaly

6-225

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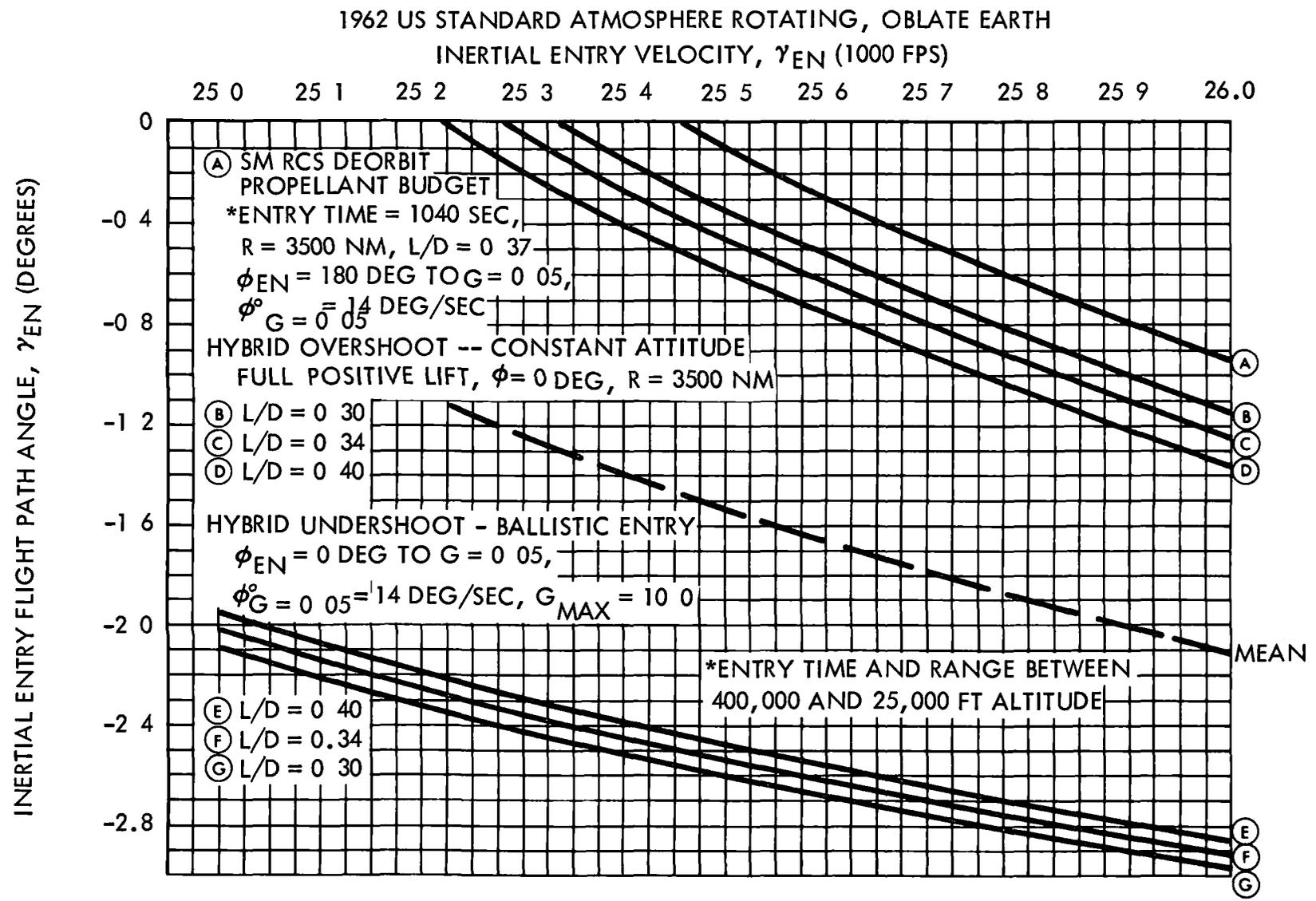


Figure 6-33. Entry Corridor Boundaries

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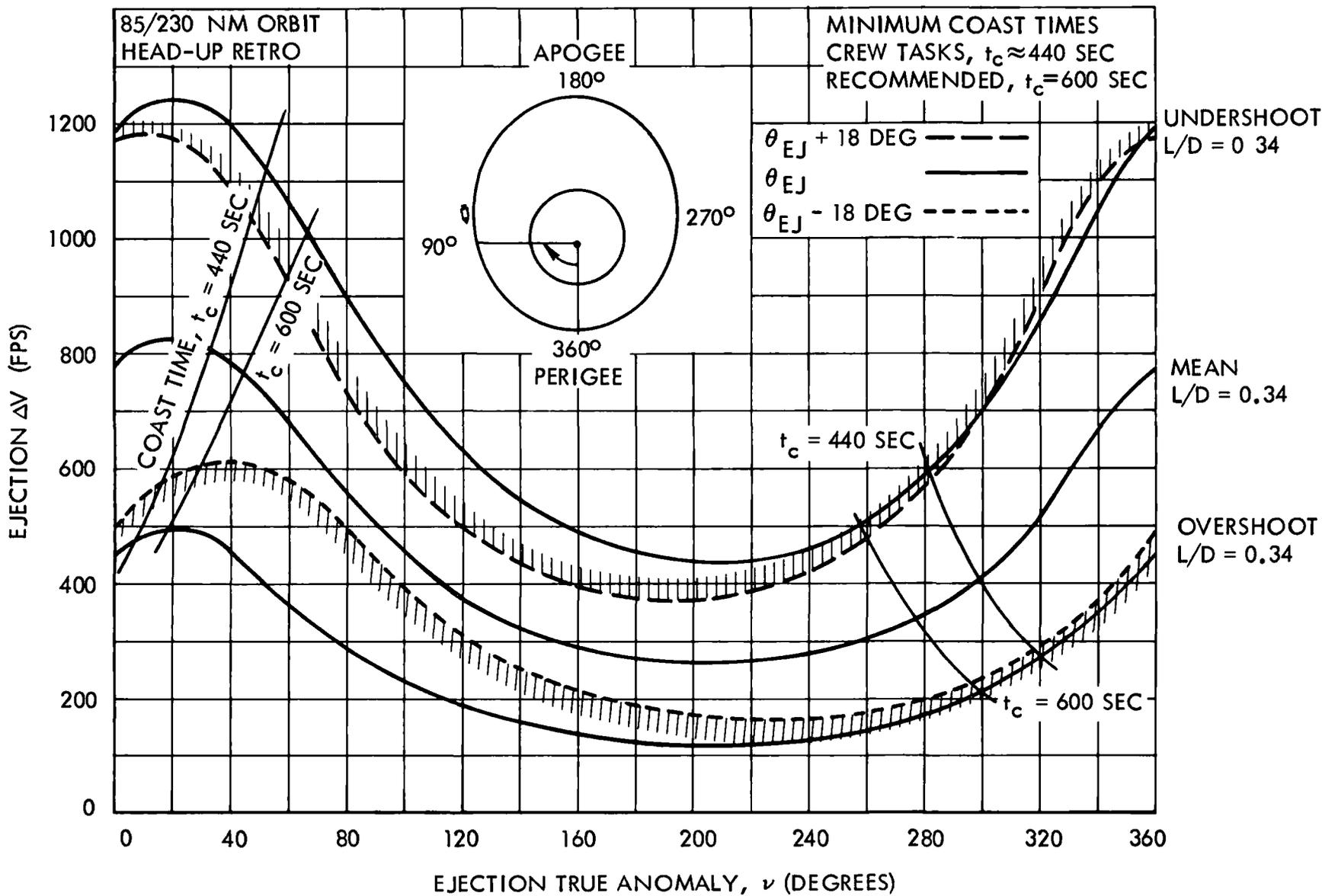


Figure 6-34. Ejection ΔV Envelope for Elliptical Orbit

6-227

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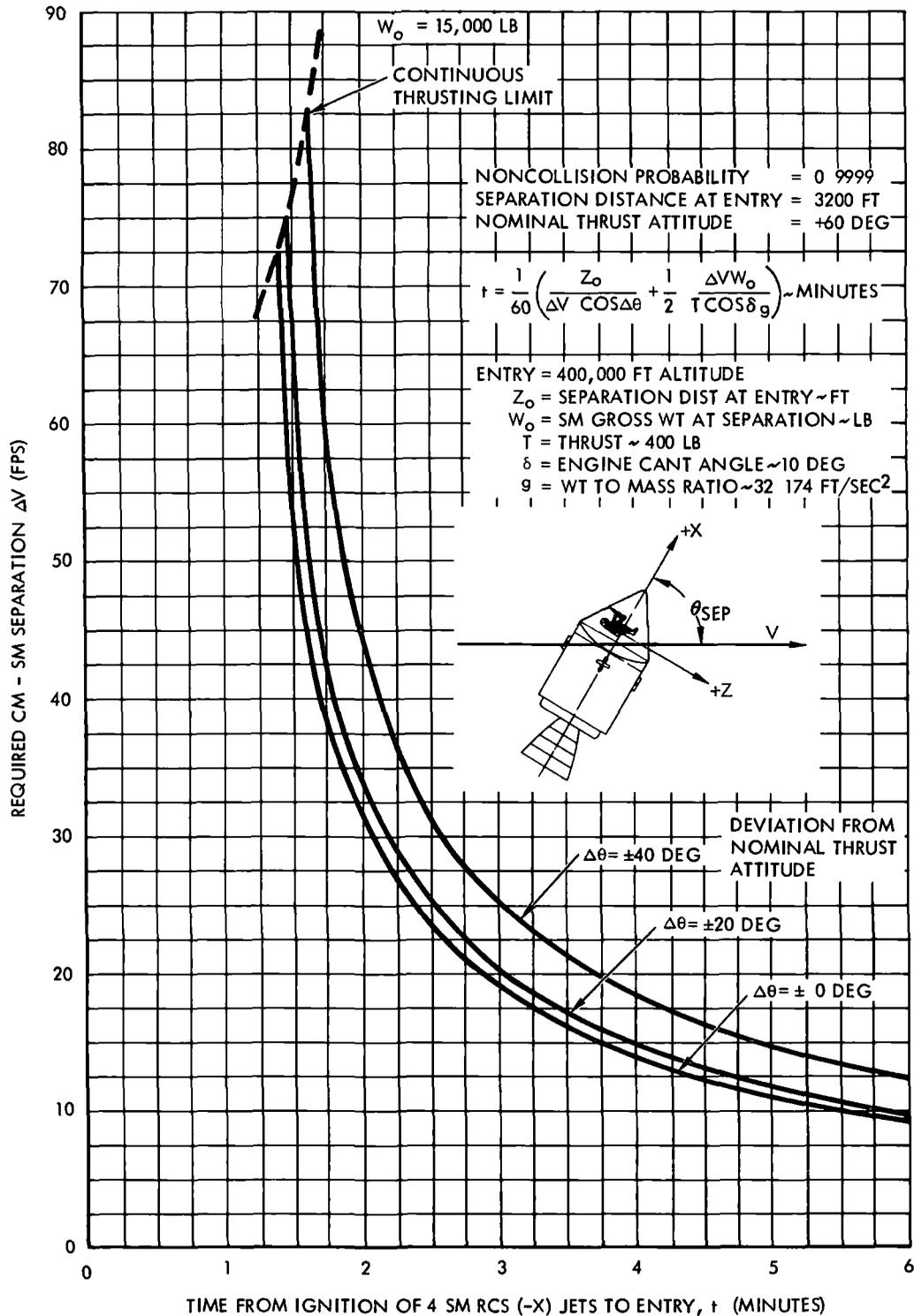


Figure 6-35 CM-SM Separation ΔV Requirements, Effect of Thrust Deviation

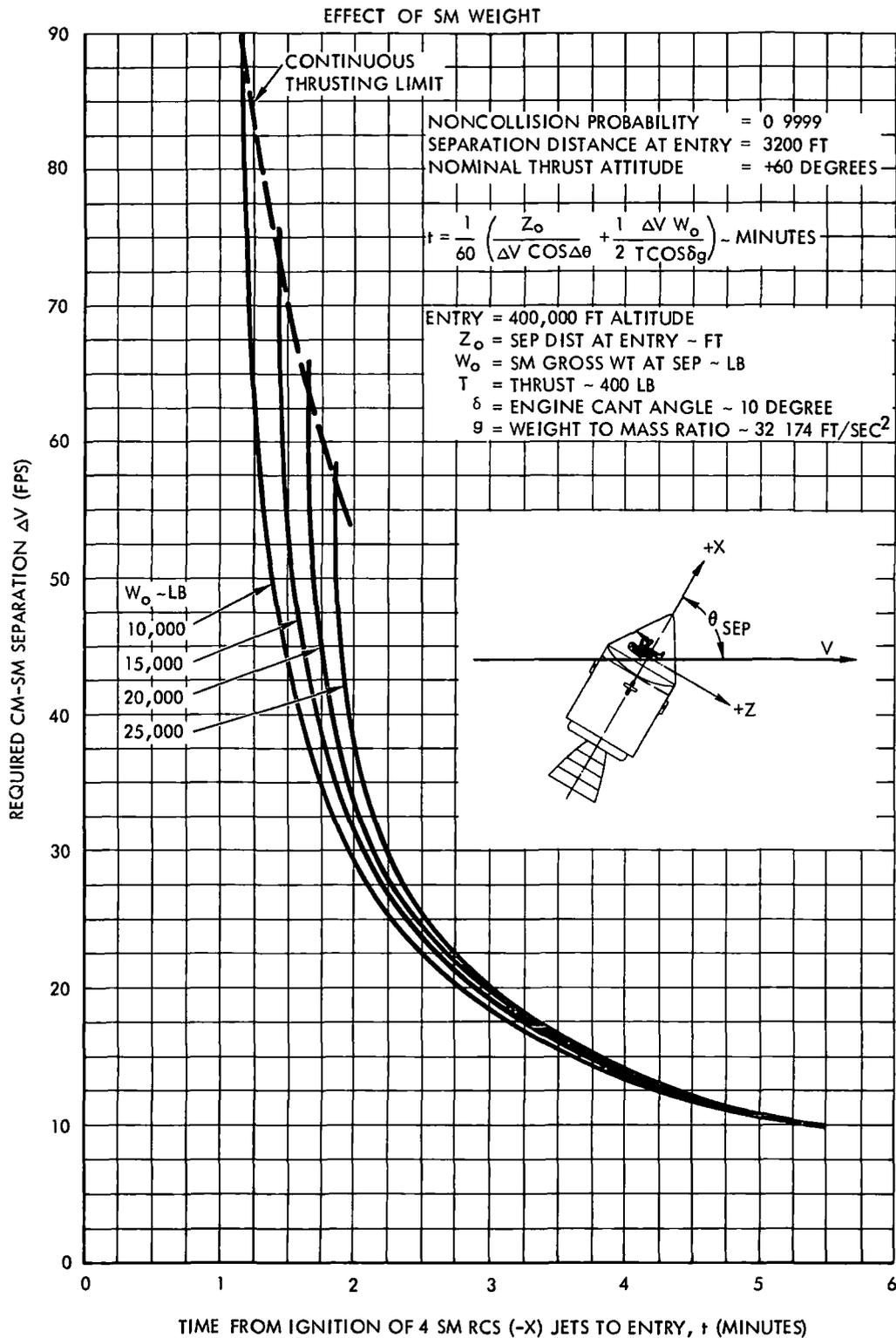


Figure 6-36 CM-SM Separation ΔV Requirements, Effect of Service Module Weight

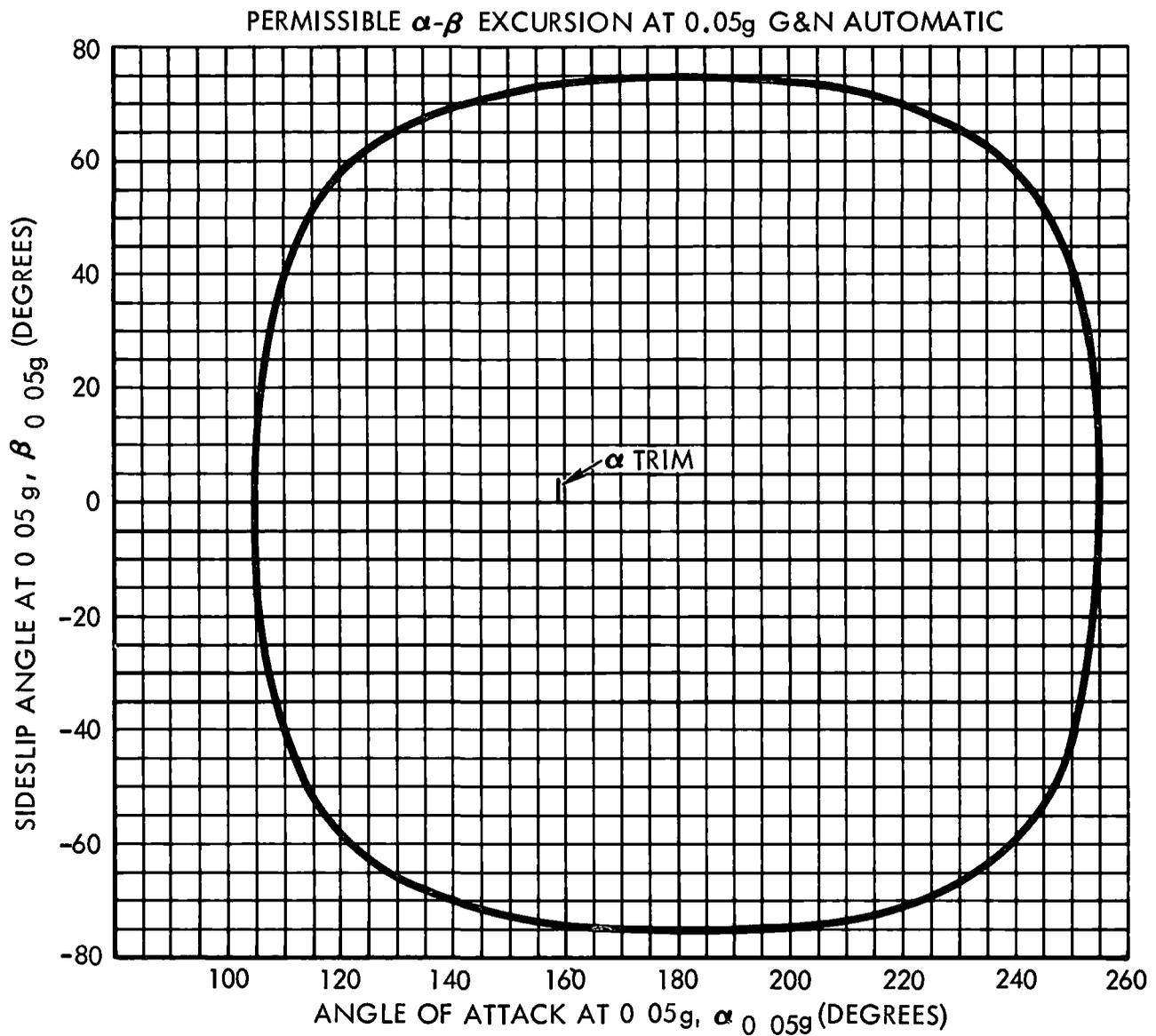


Figure 6-37 Command Module Entry Attitude Envelope

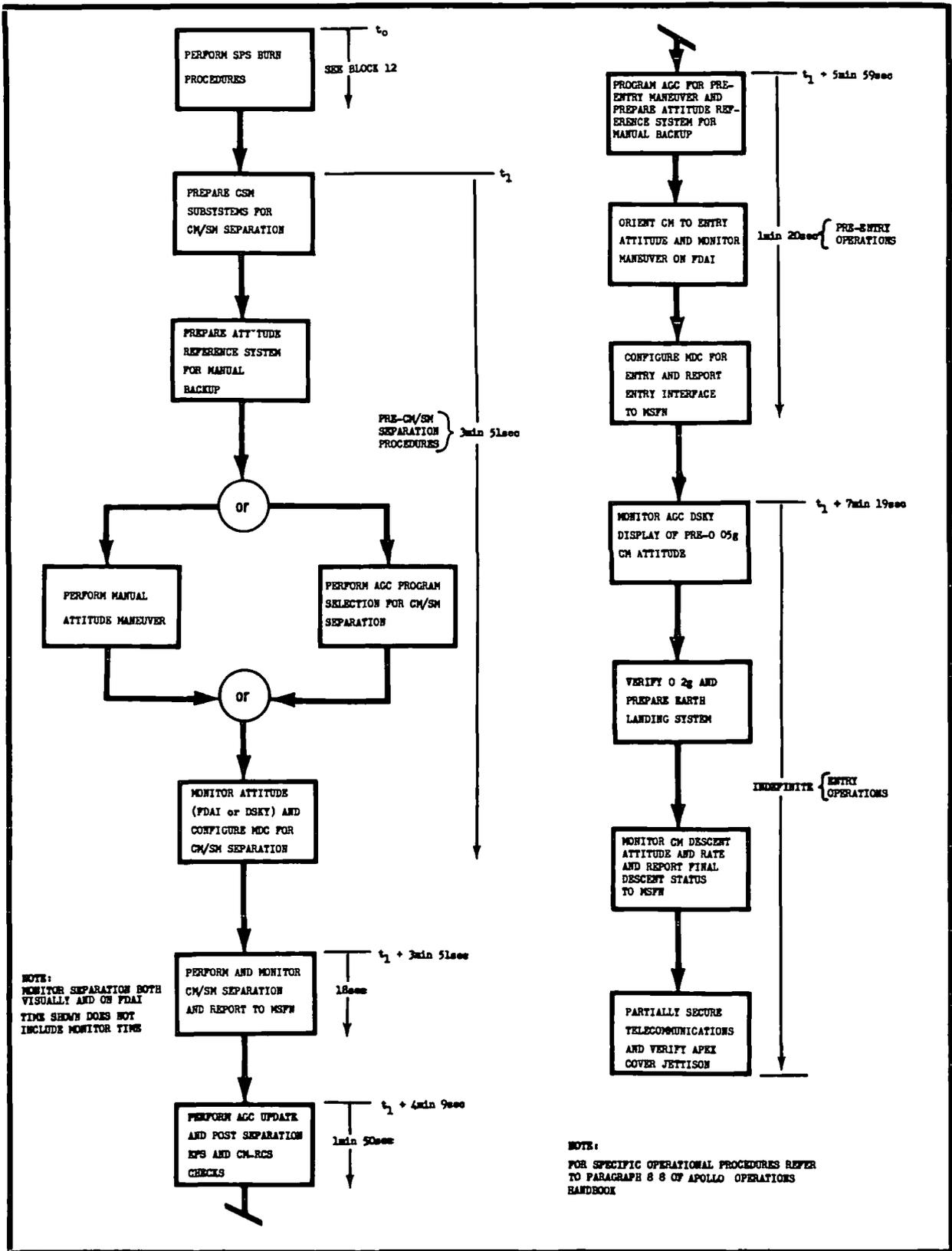


Figure 6-38 Block 25 SPS Deorbit

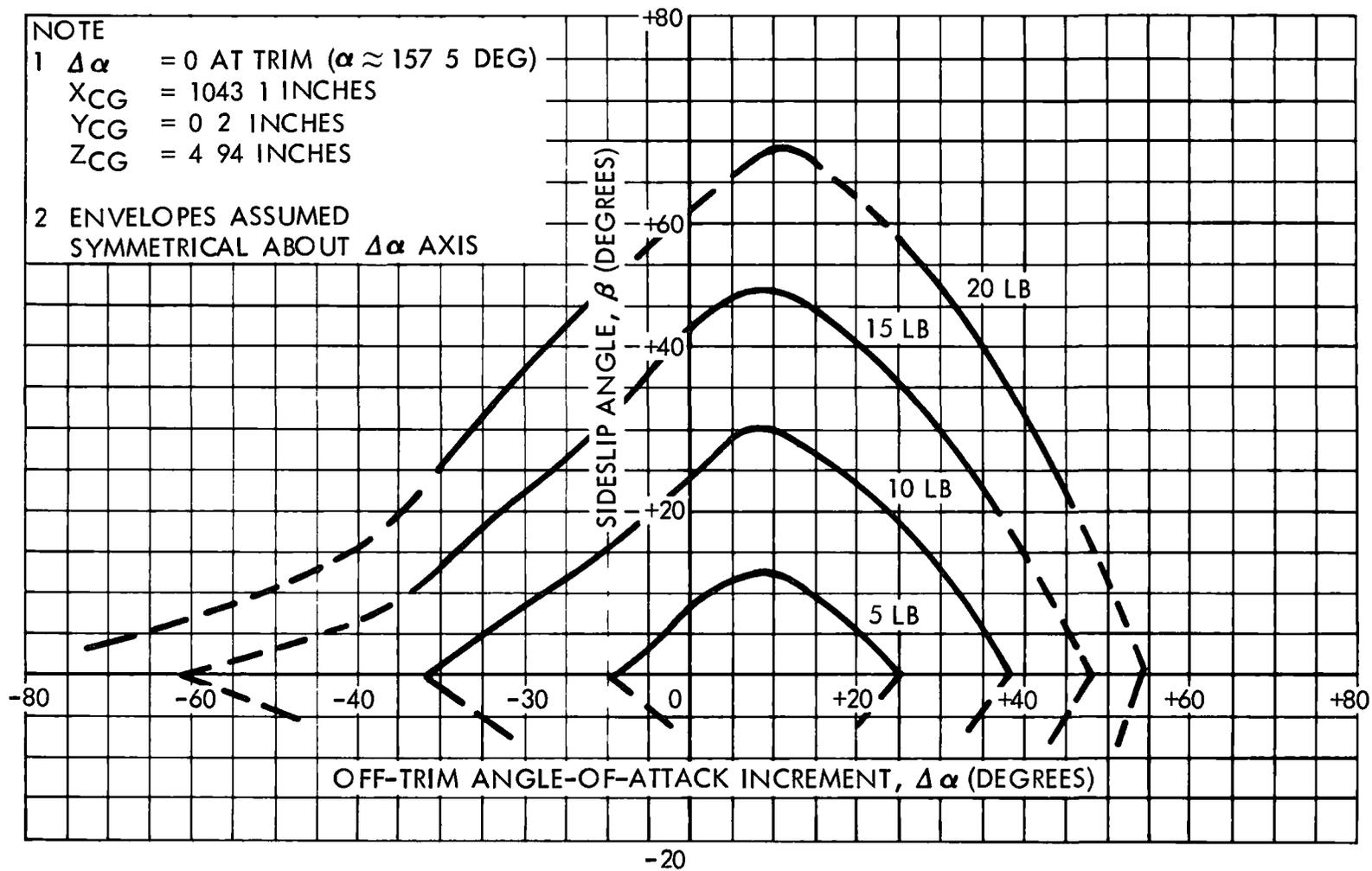


Figure 6-39. Propellant Penalty Envelopes, Single RCS Nominal Entry

6-232

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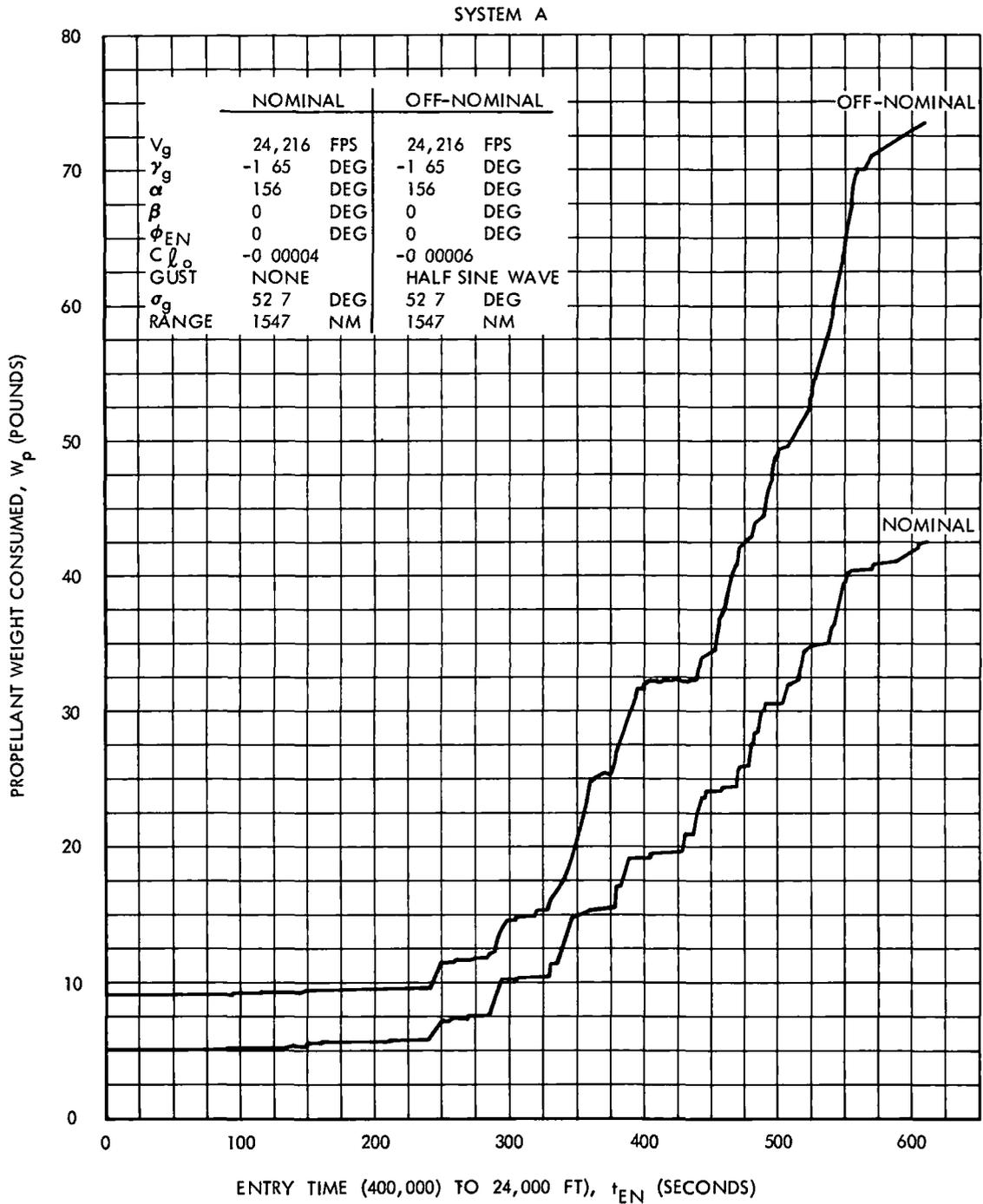


Figure 6-40 Command Module RCS Propellant Time Histories, Single System

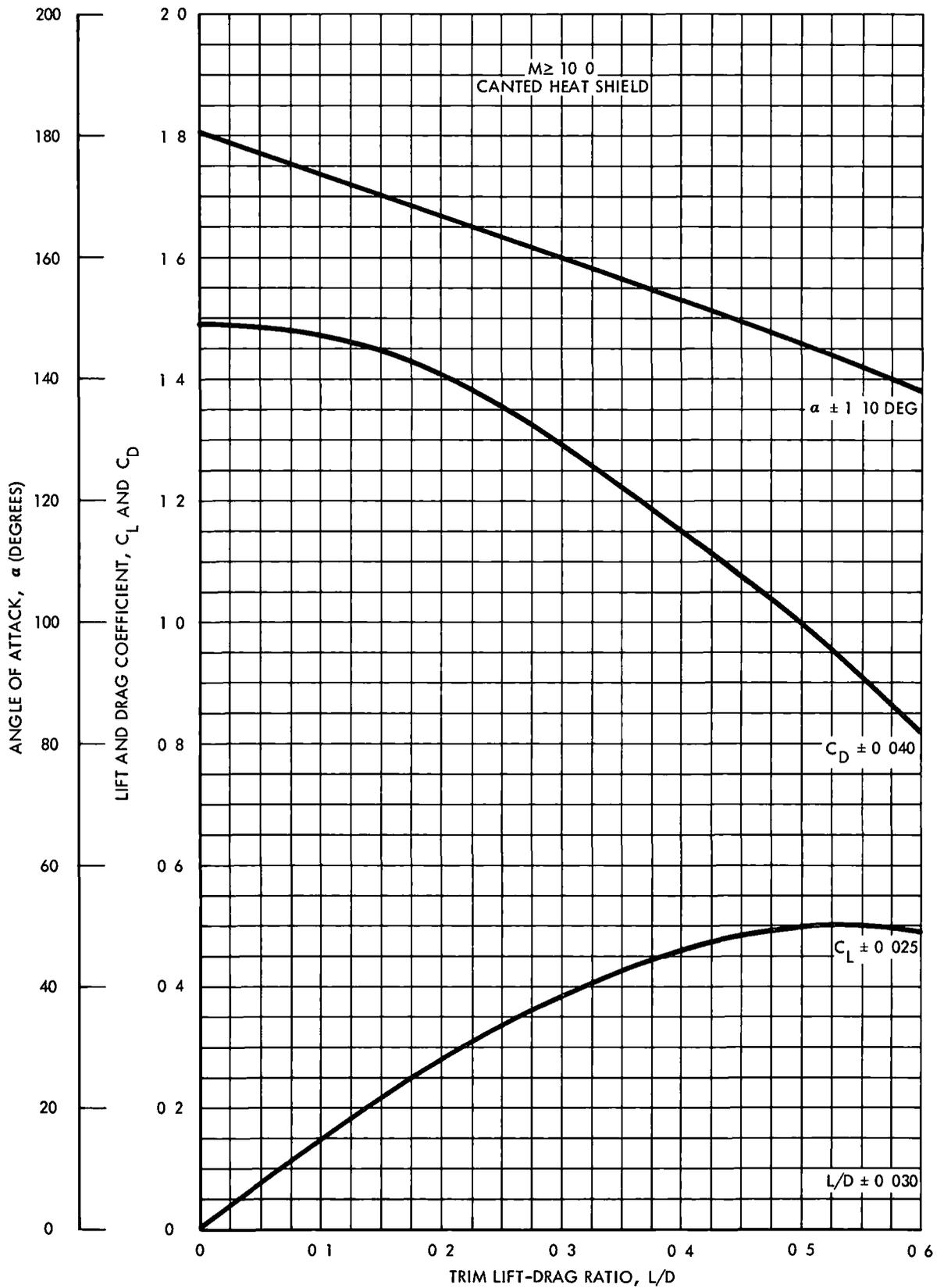


Figure 6-41 Command Module Trim Aerodynamics

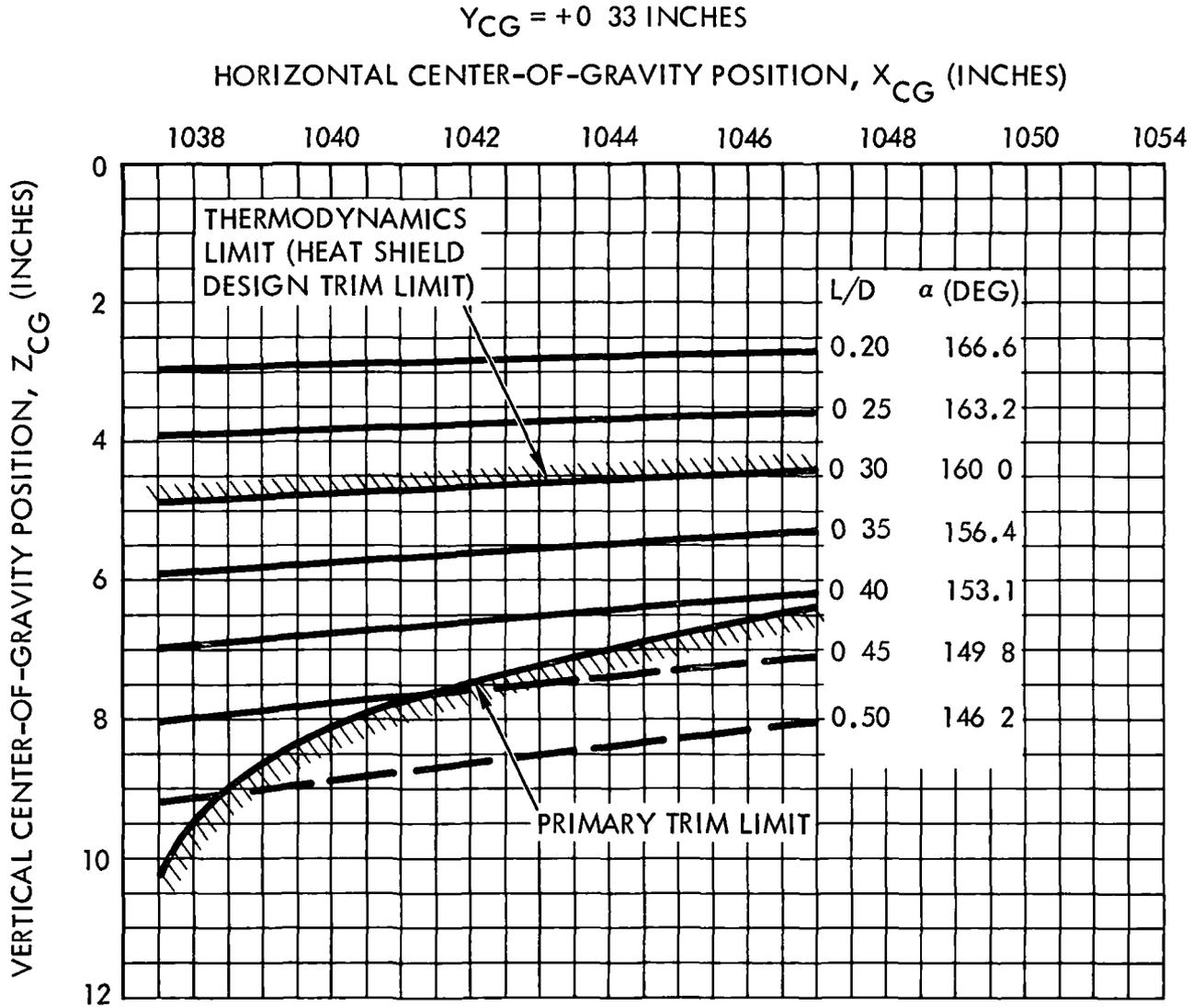


Figure 6-42 Command Module Center of Gravity Requirements



85/230 NM ORBIT HEAD-UP RETRO

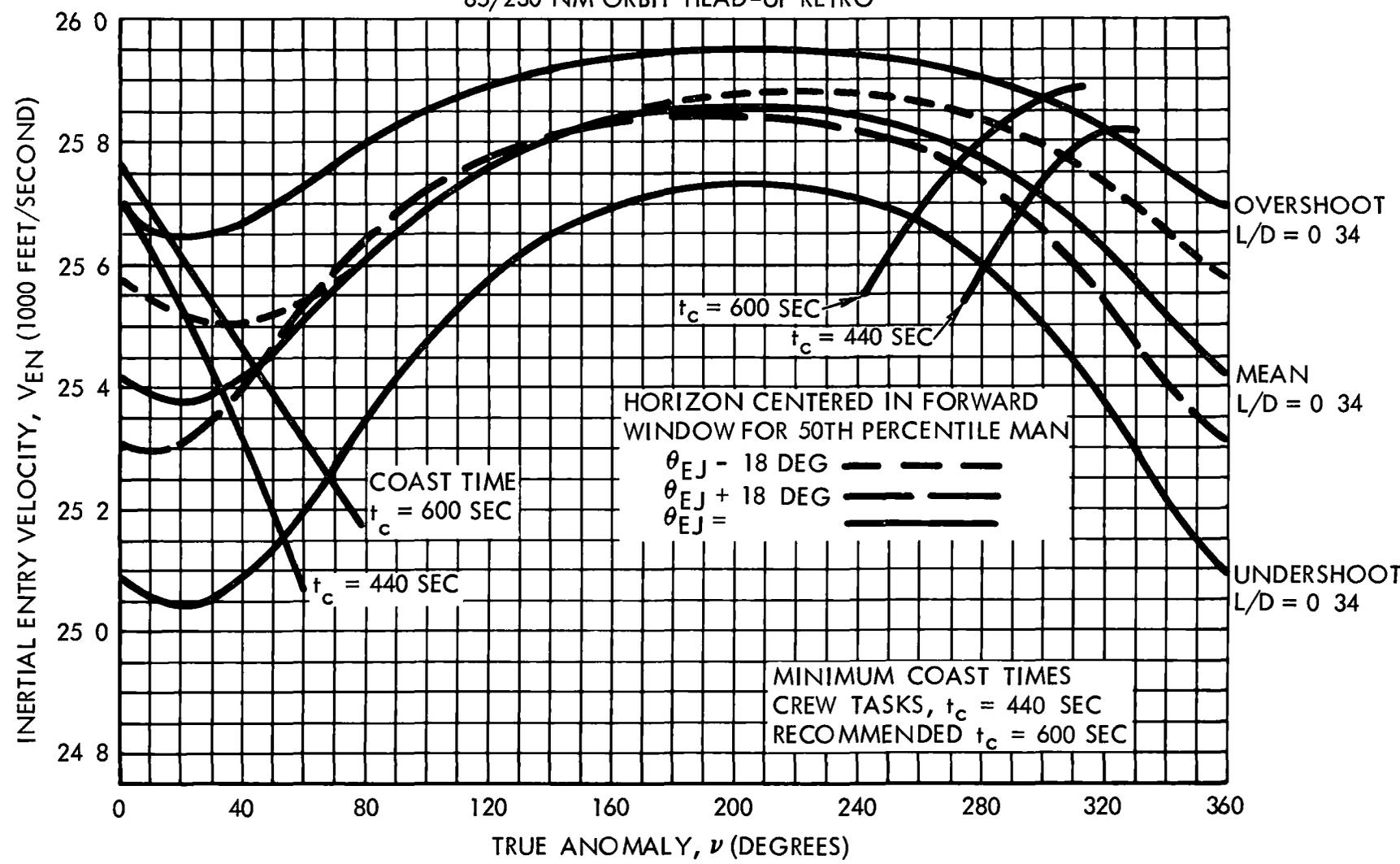


Figure 6-43. Hybrid Entry Corridor, Entry Velocity

6-236

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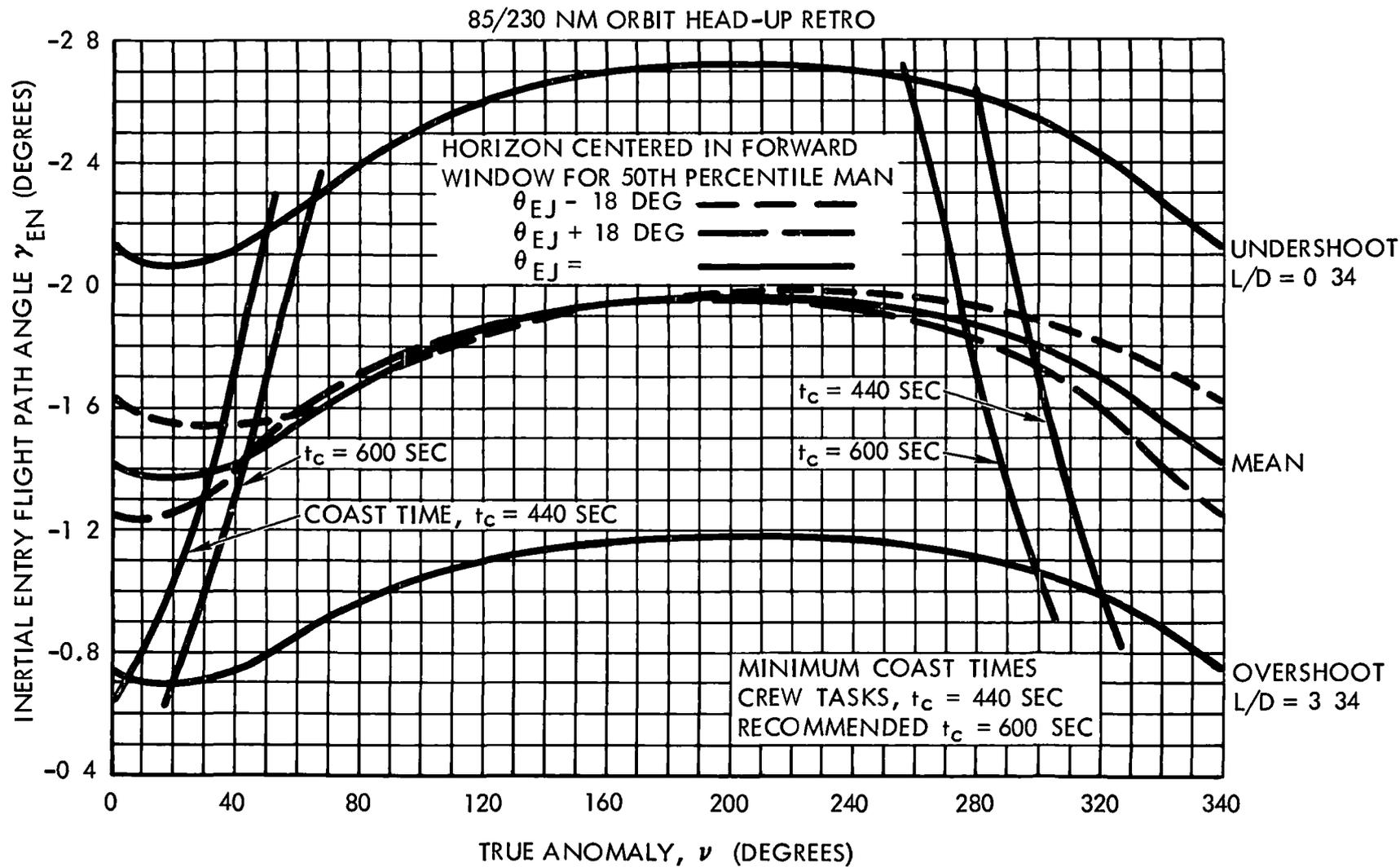
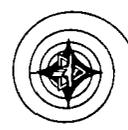


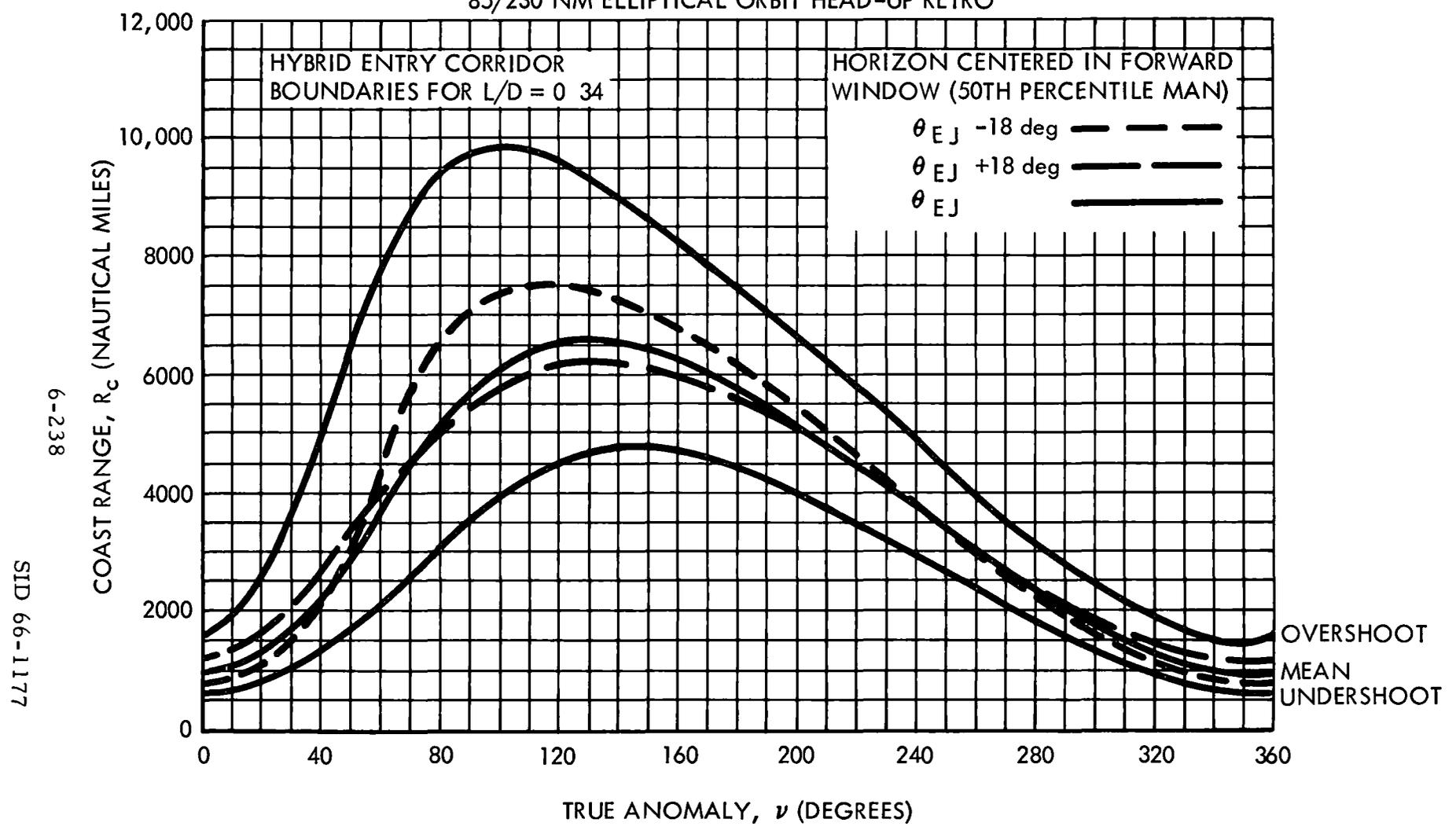
Figure 6-44 Hybrid Entry Corridor, Entry Flight Path Angle

6-237

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85/230 NM ELLIPTICAL ORBIT HEAD-UP RETRO



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Figure 6-45 Coast Range as a Function of True Anomaly



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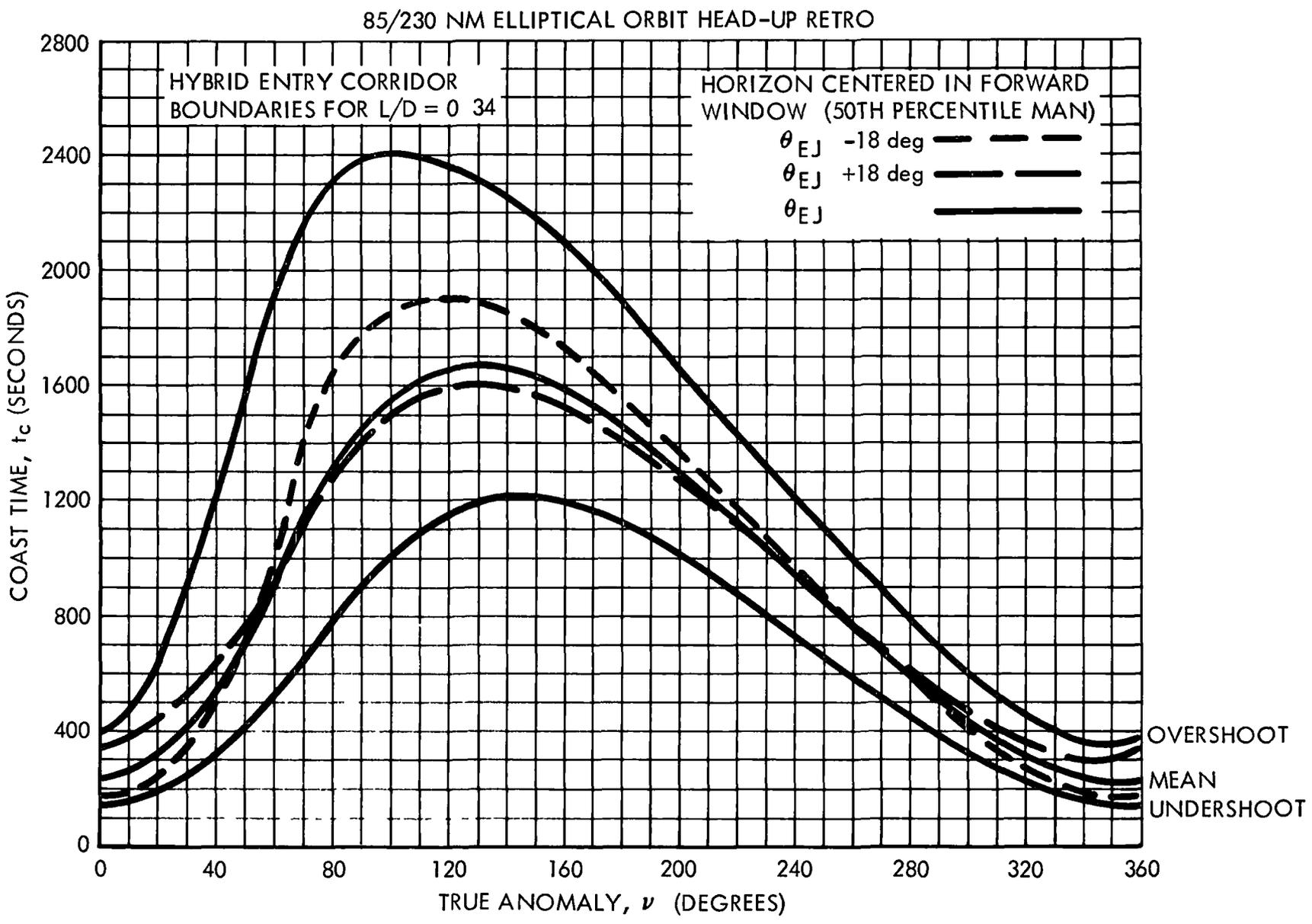


Figure 6-46 Coast Time as a Function of True Anomaly

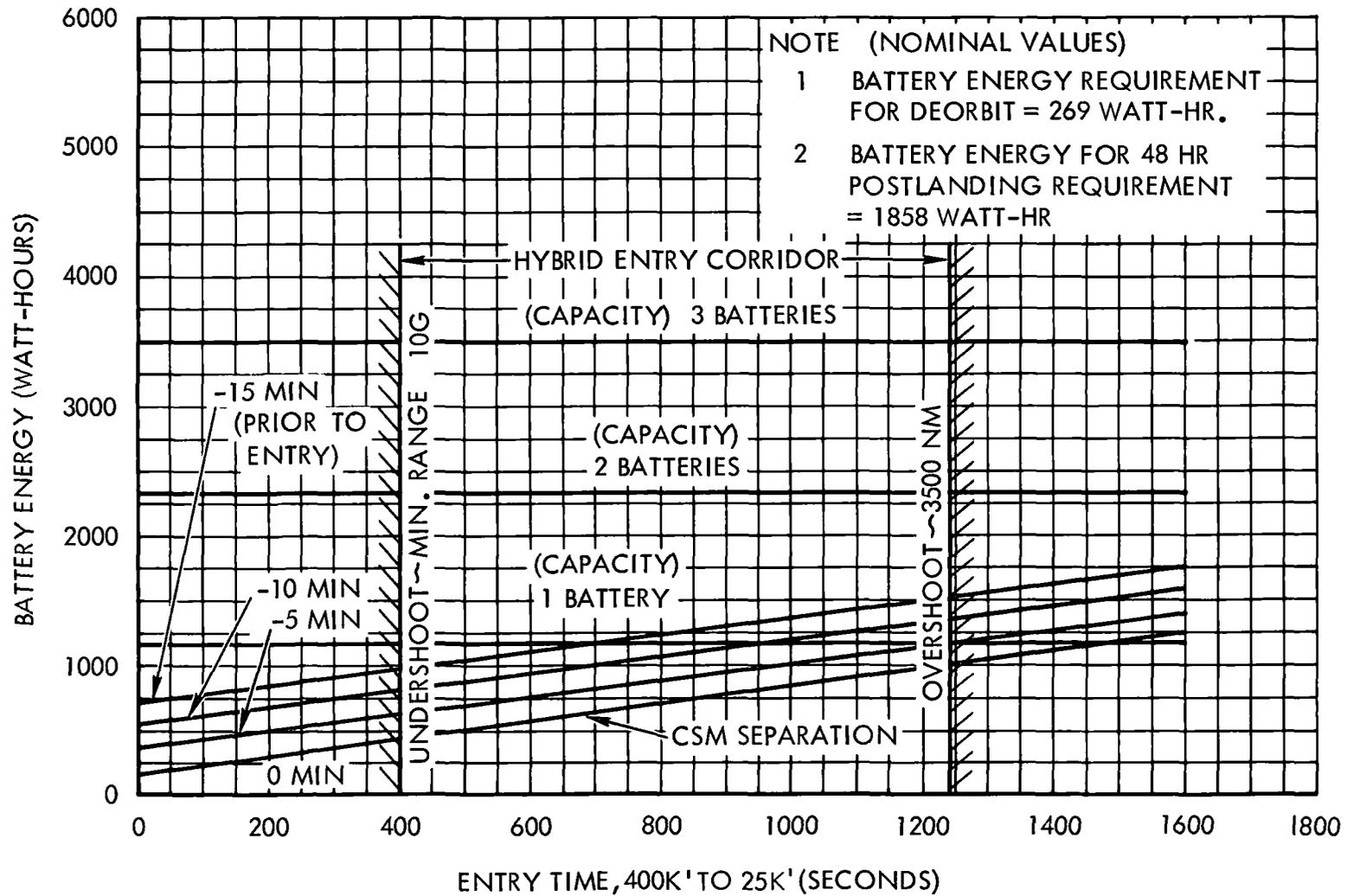


Figure 6-47 Command Module Battery Energy Capability



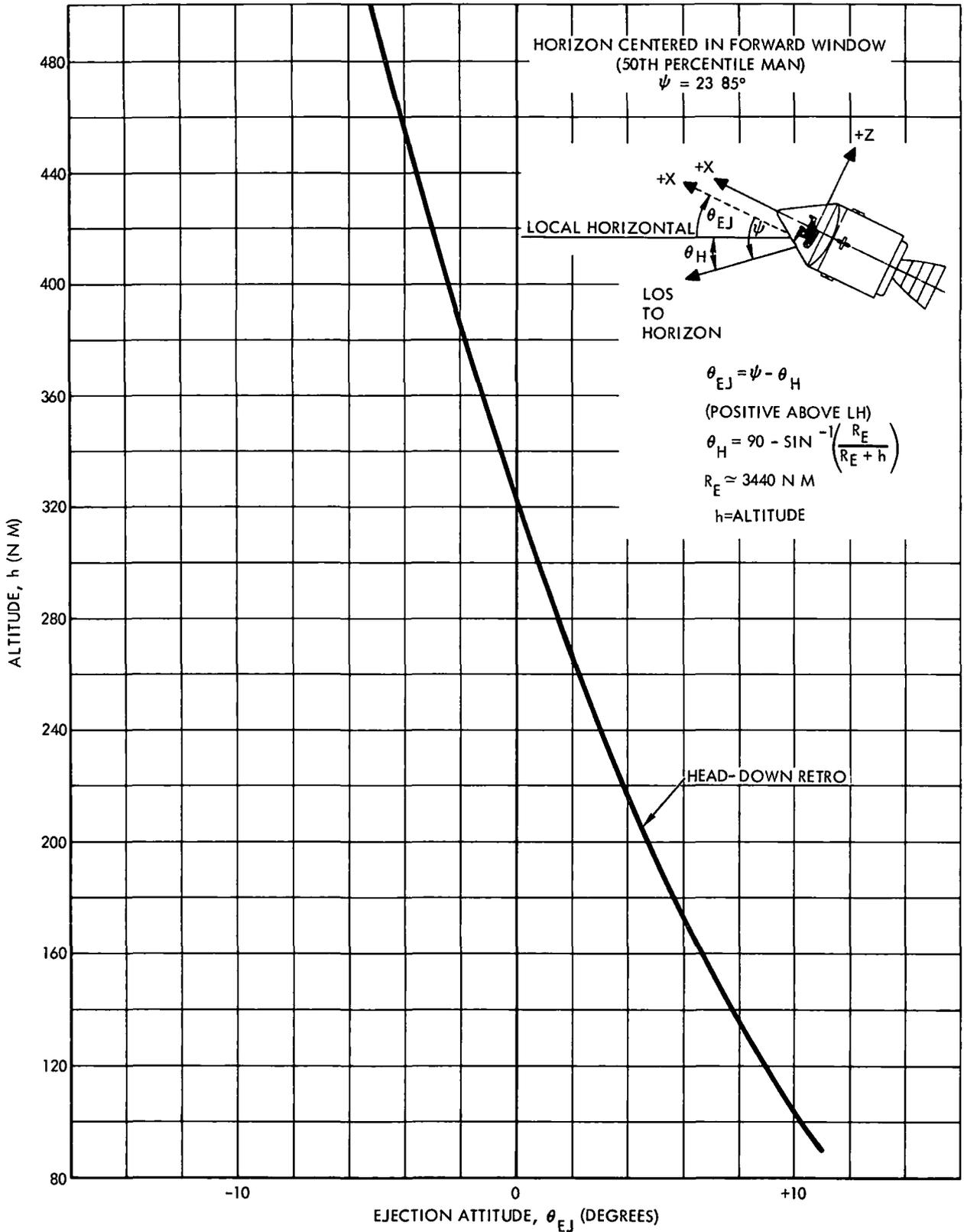


Figure 6-48 Ejection Attitude as a Function of Orbital Altitude

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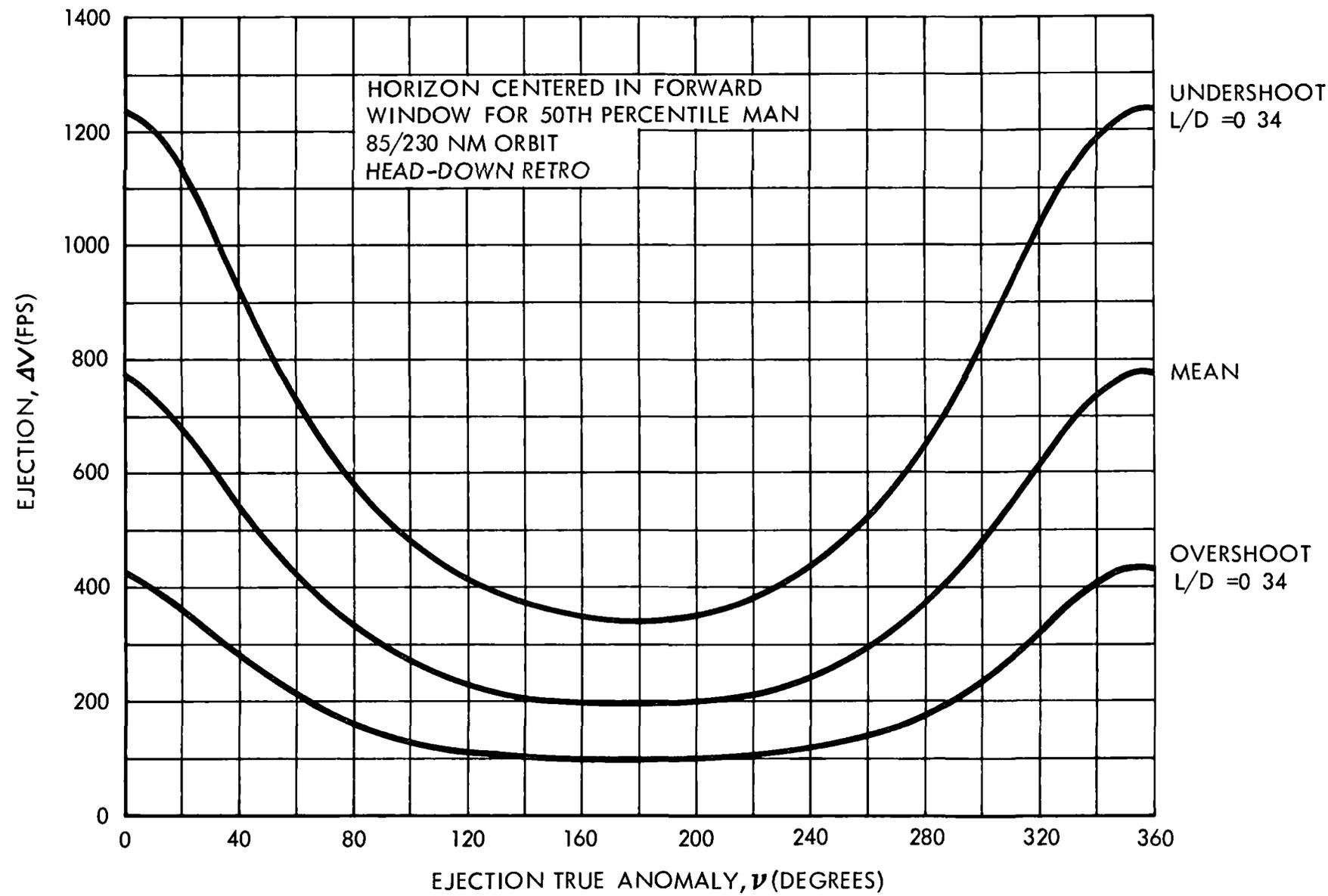
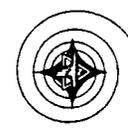


Figure 6-49 Hybrid Entry Corridor, Ejection ΔV Envelope

6-242

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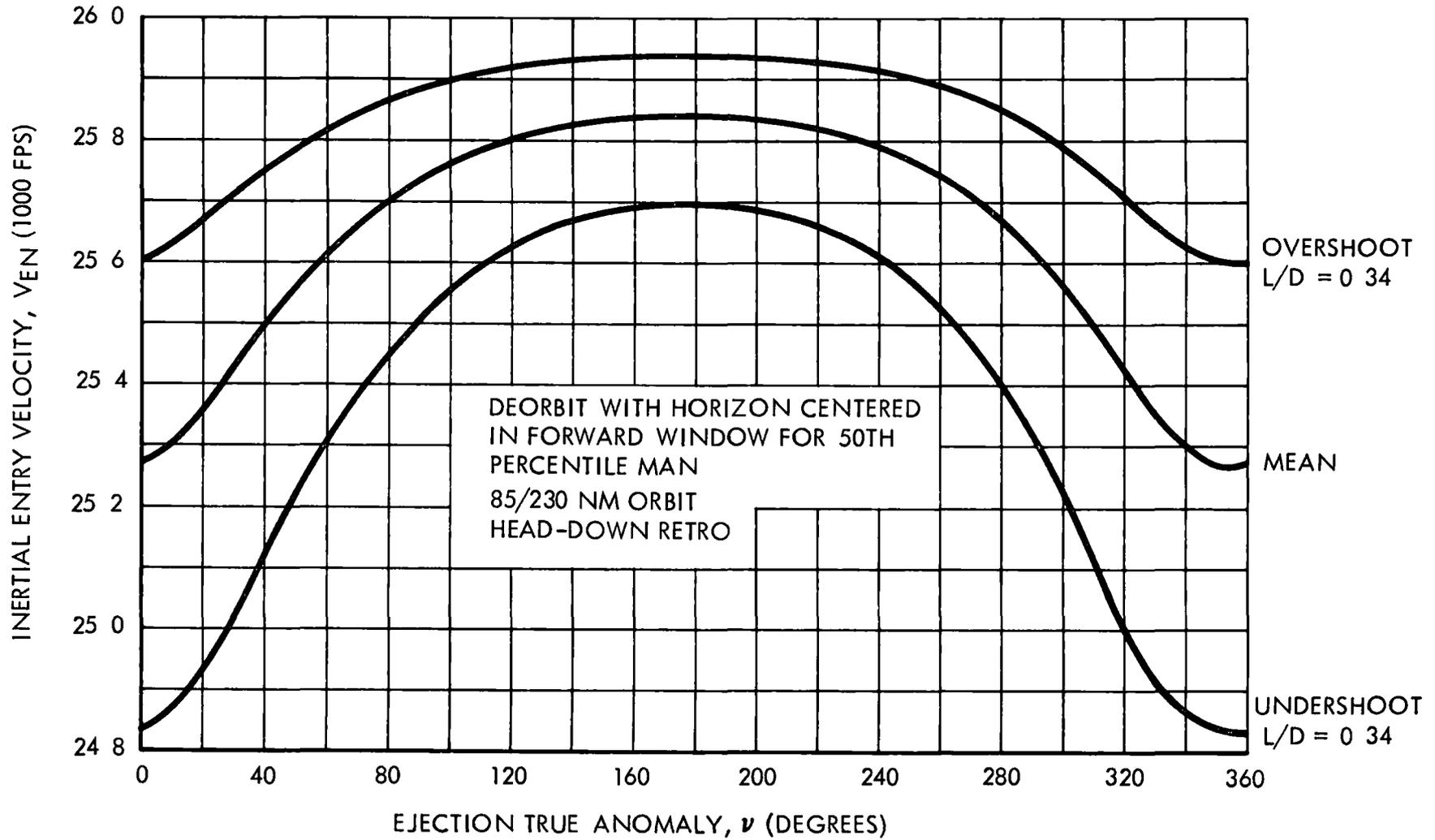


Figure 6-50 Hybrid Entry Corridor, Entry Velocity



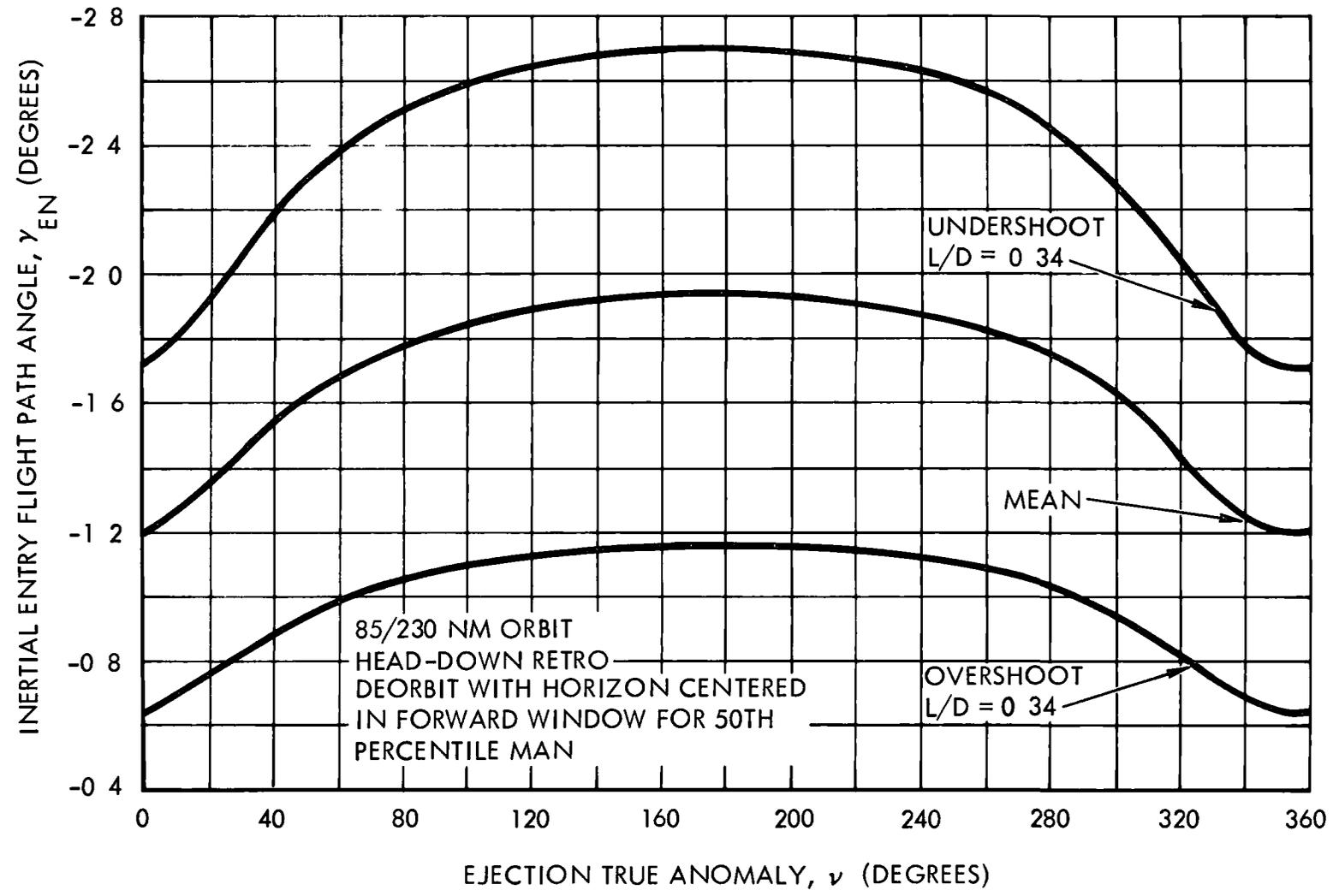
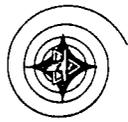


Figure 6-51 Hybrid Entry Corridor, Entry Flight Path Angle

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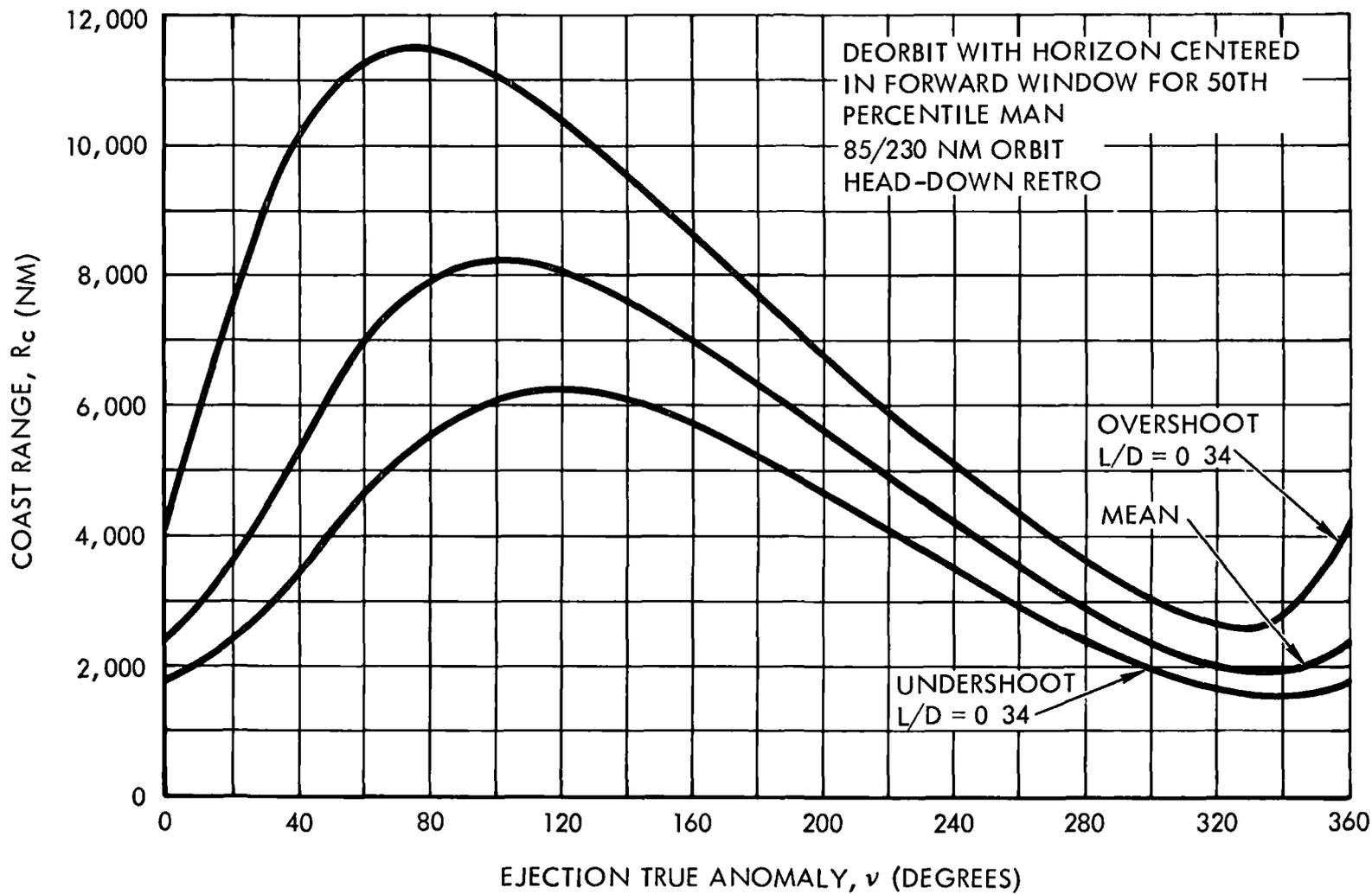


Figure 6-52 Hybrid Entry Corridor, Coast Range

6-245

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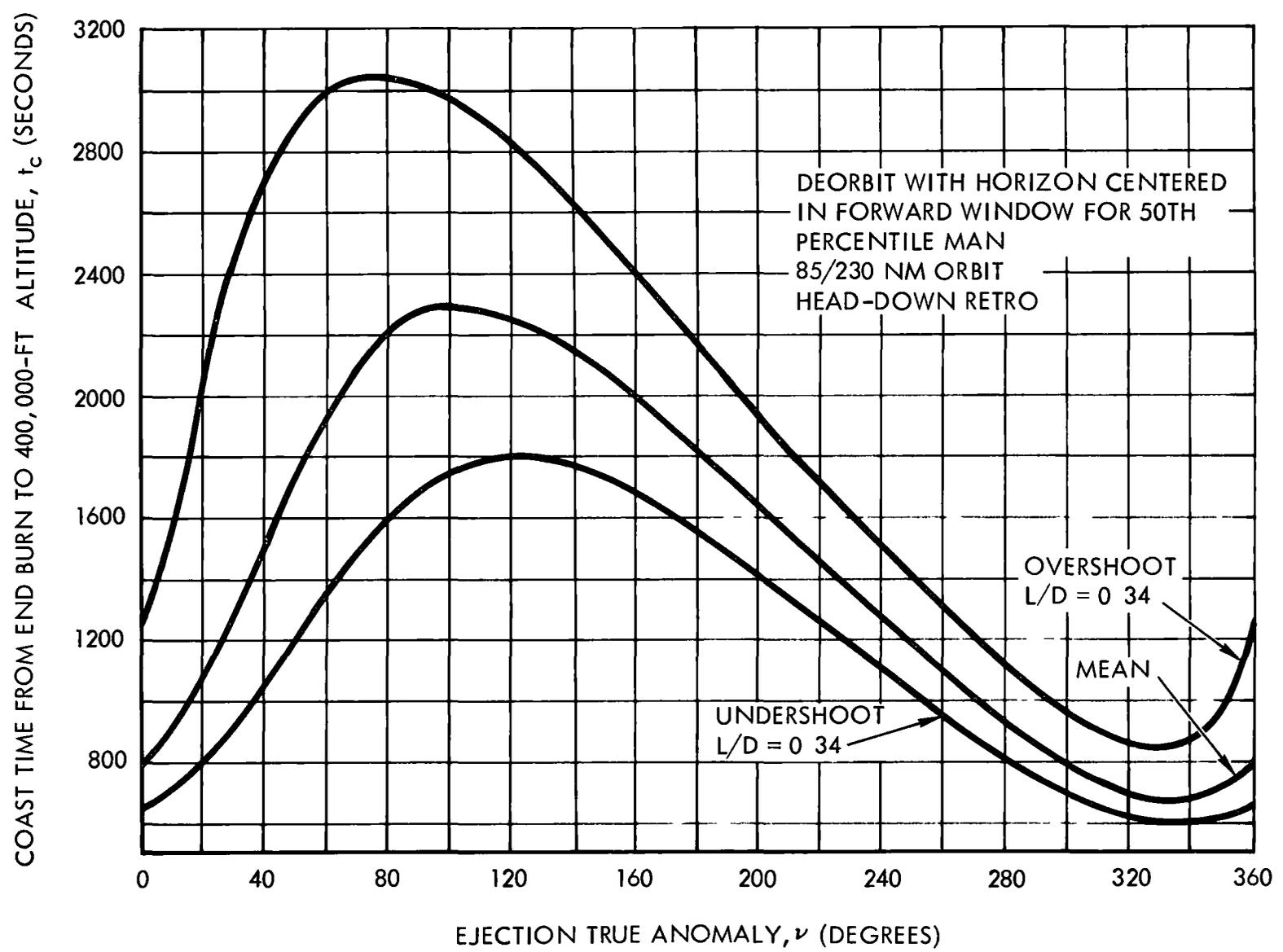


Figure 6-53 Hybrid Entry Corridor, Coast Time

6-246

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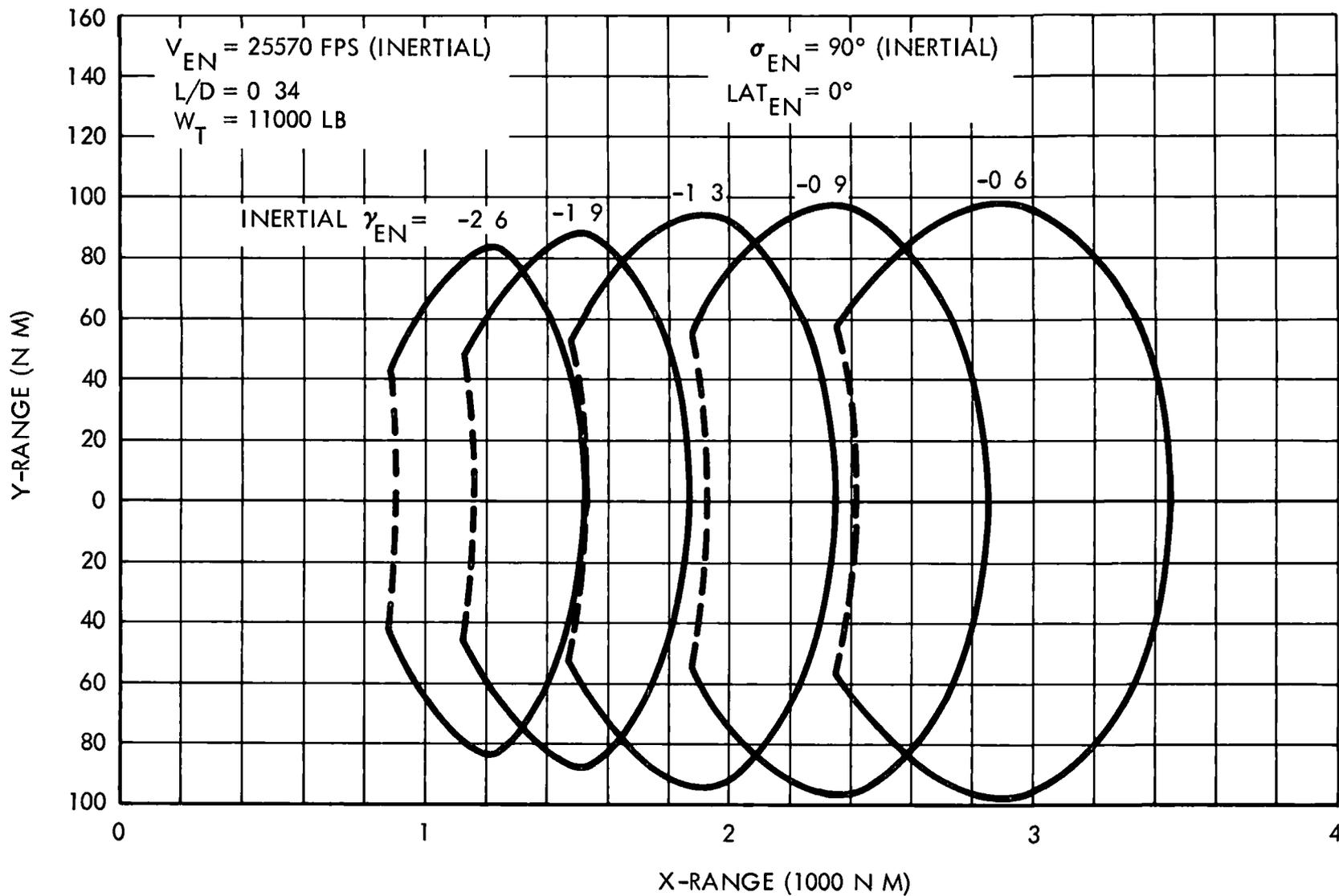


Figure 6-54 Command Module Entry Open-Loop Footprints

6-247

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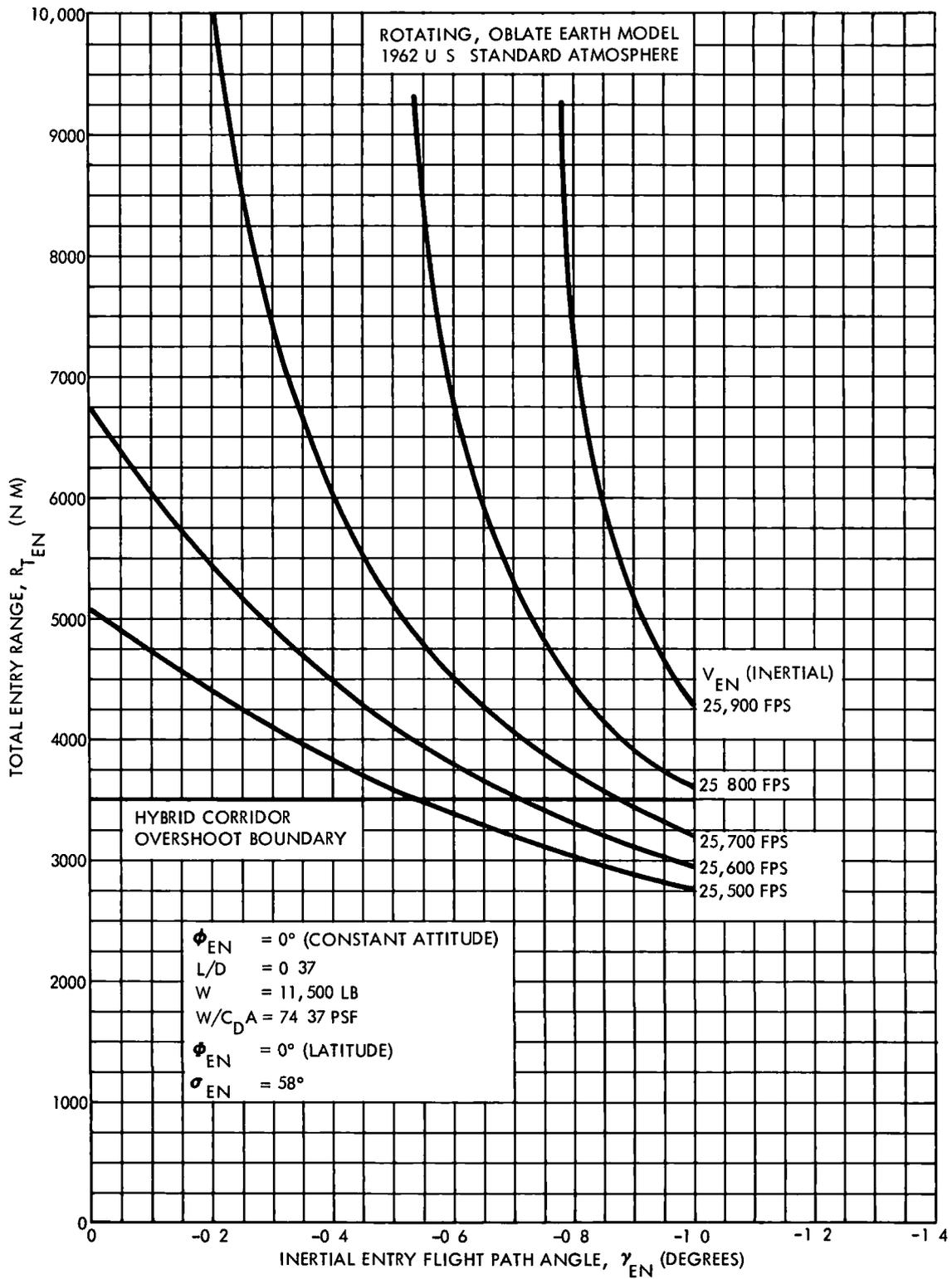


Figure 6-55 Entry Range as a Function of Entry Flight Path Angle

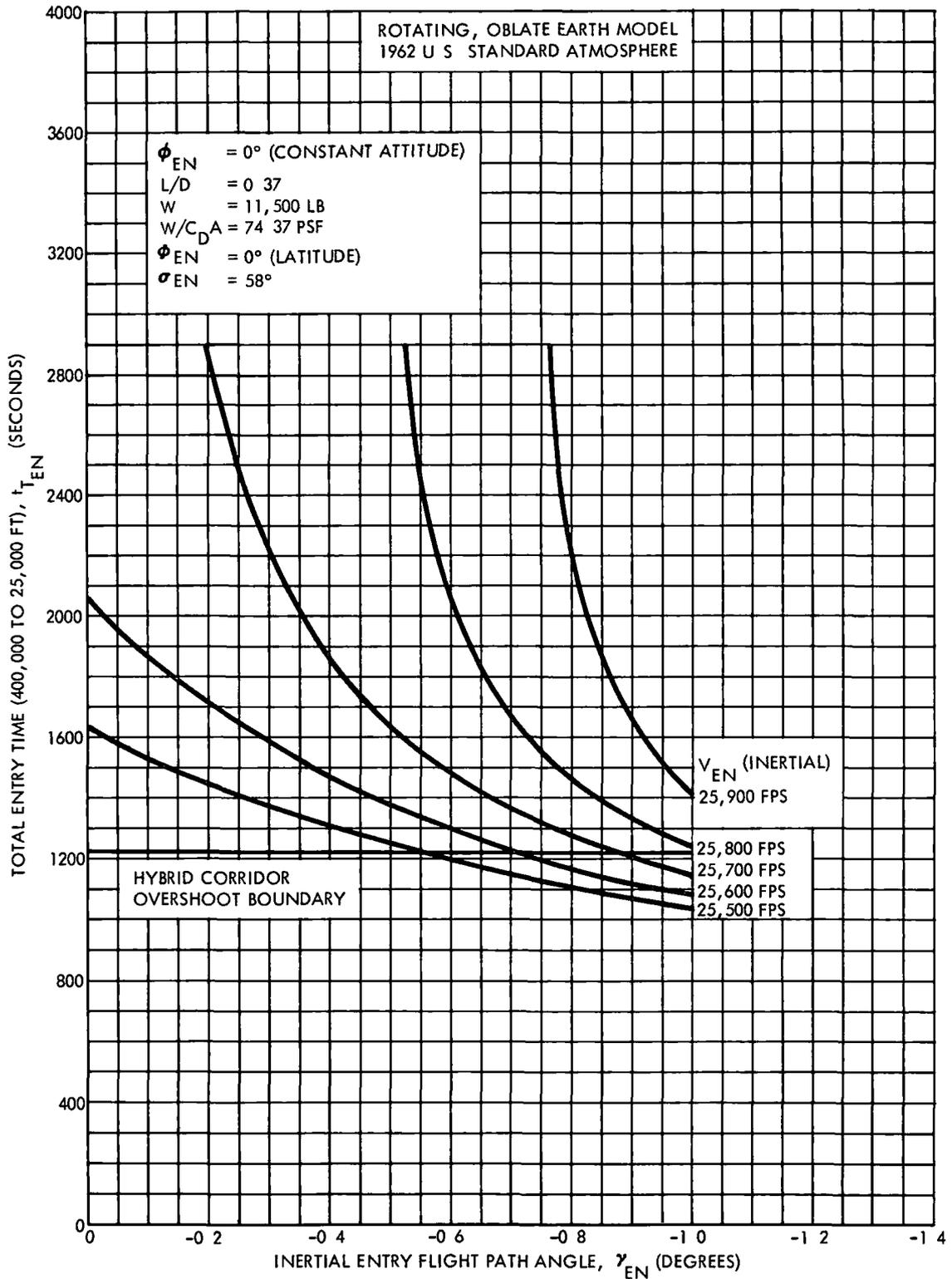


Figure 6-56 Entry Time as a Function of Entry Flight Path Angle

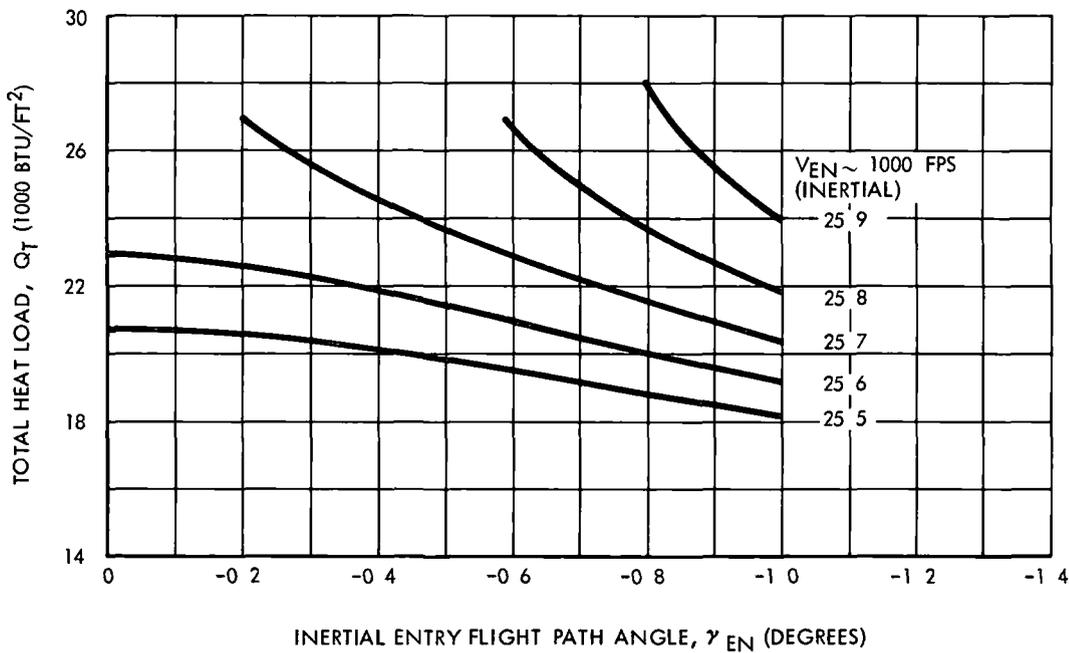
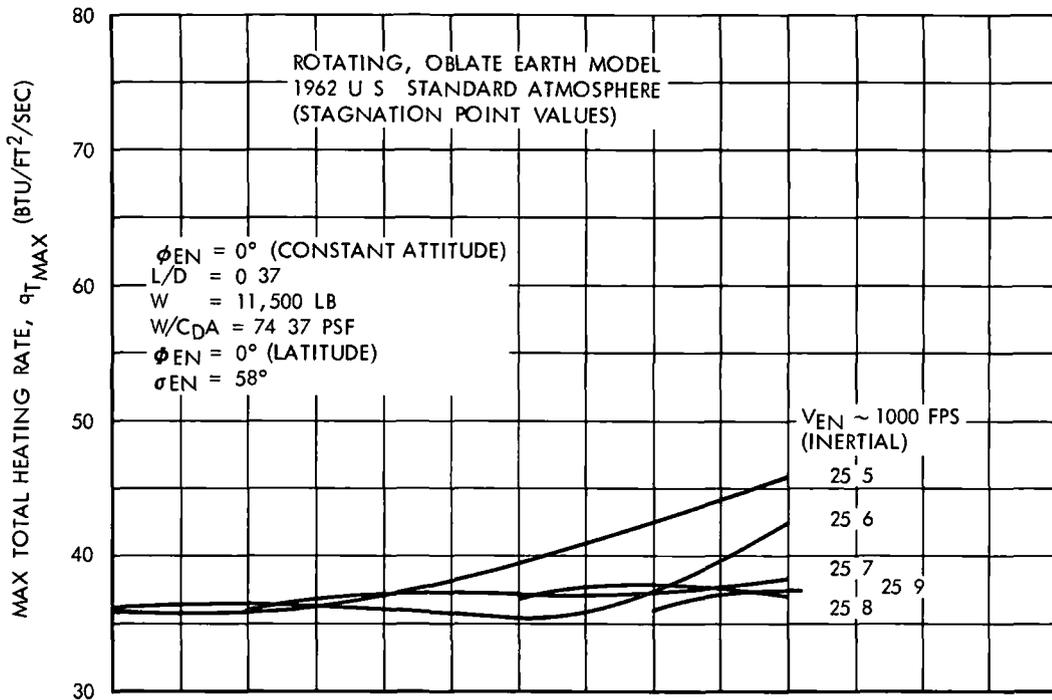


Figure 6-57 Entry Heating as a Function of Entry Flight Path Angle



BUILDING BLOCK 26
SERVICE MODULE RCS DEORBIT AND ENTRY

26 1 ALTERNATE MODE 1, GUIDANCE AND NAVIGATION (PRIMARY)

26 1 1 Introduction

This block presents operational and performance data for that phase of the mission resulting from the contingency of an SPS failure where the service module RCS provides the thrust to deorbit. This phase commences with the decision for deorbit using the service module RCS and terminates at the jettison of the apex cover which initiates the parachute descent phase. The major events associated with this block are decision to deorbit with service module RCS, deorbit maneuver, module separation, and the atmospheric flight phase to the beginning of the recovery phase (apex cover jettison).

26 1 2 Operational Data

26 1 2 1 General Information

Major interfaces with other blocks occur with Building Blocks 24 (Pre-Deorbit), 13 (RCS Translation), and 35 (Parachute Descent). BB-24 does not reflect the malfunction in the subsystem to justify using the service module RCS for the ejection maneuver. Neither will the operational data reflect any subsystem malfunction, except that the SPS was not used for the ejection maneuver.

26 1 2 2 Trajectory Limits and Considerations

All limits and considerations listed in BB-25 (Paragraph 25 1 2 1) apply to this block with the additions and exceptions that follow:

- 1 The minimum time required for the deorbit preparation will depend upon when and where the decision to deorbit with the service module RCS is made. Normally, 1.5 hours are required for crew activities before the ejection maneuver.
- 2 If the spacecraft is not within ± 20 degrees of apogee at the end of the deorbit preparation, the ejection maneuver must be delayed to at least the next apogee.



- 3 The apogee chosen for the deorbit maneuver must be compatible with the range safety, communication and tracking coverage, and water impact
- 4 The spacecraft deorbit attitude must be consistent with the minimum energy solution (direct retrograde)
- 5 The minimum required deorbit ΔV should be based on attaining the overshoot boundary defined by an entry range of 3500 nautical miles achieved with a flight mode consisting of full negative lift to 0 2g followed by a roll to full positive lift and maintaining full positive lift thereafter
- 6 Lift vector orientation should be such that full negative lift is obtained and maintained to at least 0 2 but not past 1 5g

Trajectory limits and considerations 3 through 10 of BB-25 apply directly to this block

The spacecraft subsystem limits for this block are identical to those presented in BB-25, Paragraph 25 1 3b

26 1 2 3 Mission Functional Flow

Figure 6-58 is a diagram of the Alternate Mode 1, Guidance and Navigation, mission functional flow

26 1 2 4 Operational Timeline Segment

Table 6-49 contains the operational timeline segment for Alternate Mode 1

26 1 2 5 Attitude Maneuvers

The spacecraft attitude at RCS ignition for deorbit should be constrained to maintain the spacecraft X-Z plane coincidental with the orbital plane and the +X axis pointing in a retrograde direction at angle above the local horizontal equal to half of the range angle traversed during the thrusting maneuver. A preliminary estimate of the range angle can be obtained using the following equation. It is assumed that the flight path angle in orbit is small and the change in flight path angle is negligible

$$\beta = \Delta t \frac{V_I}{r} (57 296)$$



Table 6-49 Operational Timeline Segment,
Service Module RCS Deorbit and Entry

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t_0			<p>This is a backup procedure to the SPS deorbit</p> <p>The CM pre-entry chutdown should be initiated approximately 10 hours before the deorbit maneuver</p> <p>The CM RCS engines injector valves must have been warmed to at least 100 F before CM-SM separation</p>
t_2	Perform SM RCS deorbit burn		<p>The procedures for the deorbit burn are included in the SM RCS translation control timeline of BB-13. A definite time cannot be associated with this operation because of the multiplicity of variables</p> <p>The G&N cannot control a burn of this duration</p>
t_4	Perform all necessary procedures for CM-SM separation and entry		<p>The procedures are identical to those delineated in the SPS deorbit timeline of BB-25</p>



where

β = range angle in degrees

V_I = inertial velocity in orbit

r = radius to vehicle

Δt = thrusting time

This technique is used to best simulate the optimum retrograde attitude consistent with the minimum energy solution

If the +Z axis is oriented pointing away from the earth (head down) the horizon will be visible through the pilot's forward window. Figure 6-59 presents the location of the pilot's forward window for a fiftieth percentile man.

The attitude maneuvering to attain the proper module separation attitude is identical as that presented in Paragraph 25 1 2 of BB-25

After the damping the separation transients, the command module must be oriented so that the resulting attitude at the entry acceleration threshold (0.05 g) falls within the blunt face forward trim limits shown in Figure 6-37 with the +Z axis pointing toward the earth. The required local body pitch attitude at 0.05 g is given by

$$\theta_{0.05 \text{ g}} = (360 - \alpha_T) + \gamma_{0.05 \text{ g}}$$

where

$\theta_{0.05 \text{ g}}$ = required local pitch angle at 0.05 g

α_T = hypersonic trim angle of attack

$\gamma_{0.05 \text{ g}}$ = flight path angle at 0.05 g

The hypersonic aerodynamic trim characteristics are shown in Figure 6-41. The negative lift should be maintained to 0.2 g but not past 1.5 g.

The attitude maneuvers after 0.2 g are identical to those presented in Paragraph 25 1 2 5 of BB-25



26 1 2 6 Duty Cycles

The duty cycles for this block are presented on Table 6-50 in two parts. Part A covers the portion between initiation of the service module RCS deorbit burn and securing the system following termination of the burn and interfaces directly with BB-24. Part B covers the remainder of the deorbit and entry phase, and is identical to Part B of Paragraph 25 1 2 6.

26 1 2 7 Electrical Power Profile

The following is Δ power usage from the common level

Part	P_{AC} (watts)	P_{DC} (watts)
A	168 0	716 0
B	590 9	861 8

26 1 2 8 Propellant Consumption

Service module RCS propellant consumption can be found in Section 5 0. A representative off-nominal command module RCS propellant consumption curve is presented in Figure 6-60.

26 1 3 Performance Data

Performance trade-off data associated with the RCS deorbit maneuver and mission events to jettison of the apex cover follow. Interfaces are identical to those in Paragraph 26 1 2 and are noted where applicable. All maneuvers are performed within the limits and constraints enumerated in Paragraph 26 1 2.

Orientation to the ejection attitude is performed manually to a retro position consistent with minimum ΔV requirements. The optimum attitudes are shown in Figure 6-61 as a function of the true anomaly of two elliptical orbits, 85/230 and 85/130.

Overshoot boundaries and the required ejection ΔV for an 85/230-nautical-mile elliptical orbit are presented in Figure 6-62. All overshoot boundaries shown are based on a maximum entry range (400,000 to 25,000 feet) of 3500 nautical miles but with different entry flight modes. The constant positive lift overshoot is the most desirable, but its ΔV requirements are high. The overshoot defined by a full negative lift entry to 0.2 g, then applying a constant bank rate is the least restrictive with regard to ΔV and the rolling (constant bank rate) entry mode is the only mode that may be used. The overshoot defined by a negative lift of 0.2 g, then roll to



full positive lift and maintain is used because it permits the use of the G&N for closed-loop entry ranging after 0.2 g

Performance trade-off data for mission events after the RCS ejection maneuver are identical to those presented in Paragraph 25.1.3 of BB-25



Table 6-50 Subsystem Duty Cycles, Service Module RCS Deorbit and Entry

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 26
PART A				
Stabilization and control				
RGP		5	0	100
BMAG		5	0	100
FDAI		5	0	100
AS/GPI		5	0	100
ΔV display		5	0	100
Rotation controller		5	0	100
SCS control panel		5	0	100
ECA pitch		5	0	100
ECA roll		5	0	100
ECA yaw		5	0	100
ECA auxiliary		5	0	100
ECA display		5	0	100
TVA OPERATE		5	0	100
Guidance and navigation				
AGC OPERATE		A	0	100
IMU OPERATE		A	0	100
Displays and controls		A	0	100
Propulsion				
SM RCS engine direct	4			100
PART B				
The power duty cycle for Part B of this Block is identical to that of BB-25 AM-1				

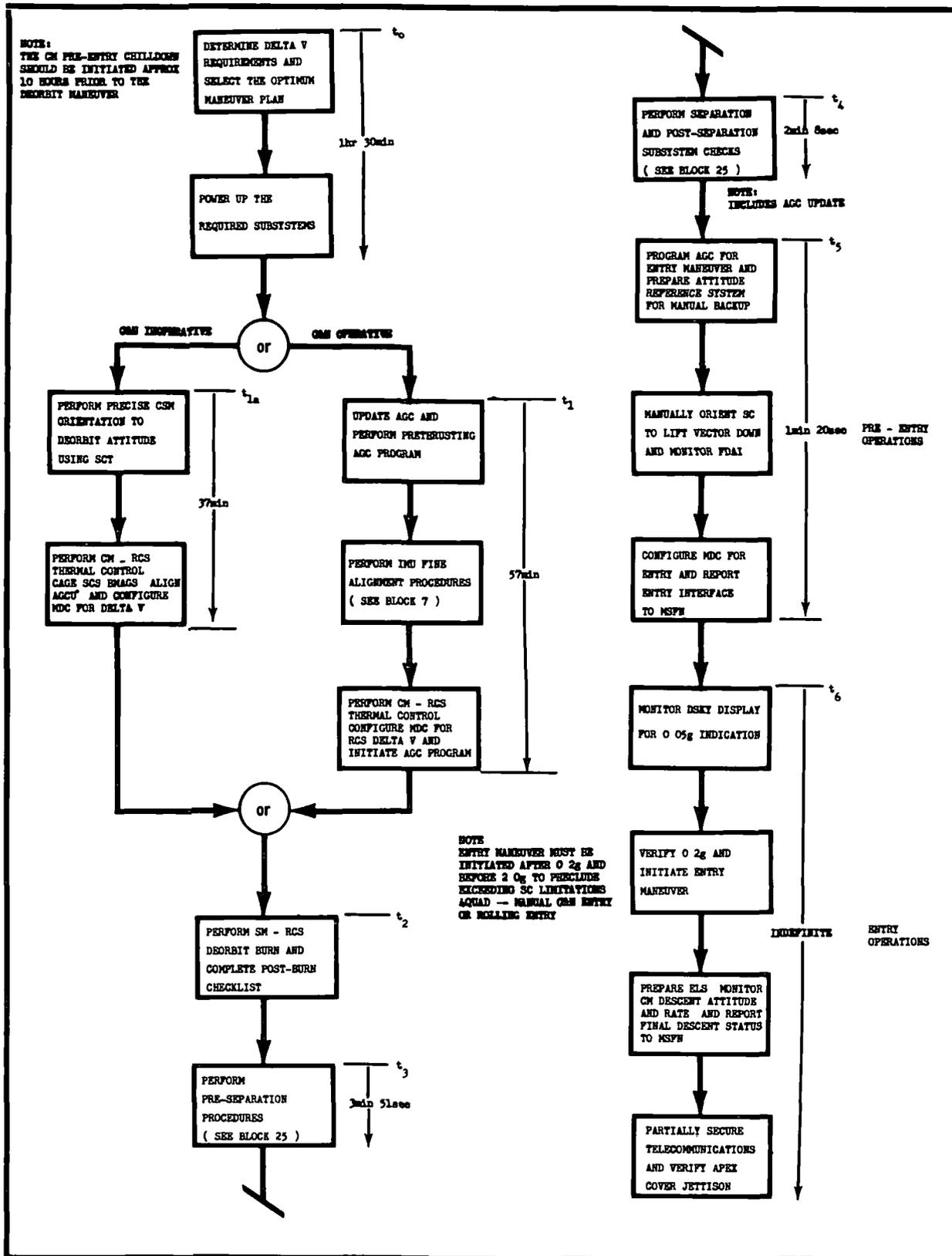


Figure 6-58 Building Block 26 Service Module RCS Deorbit

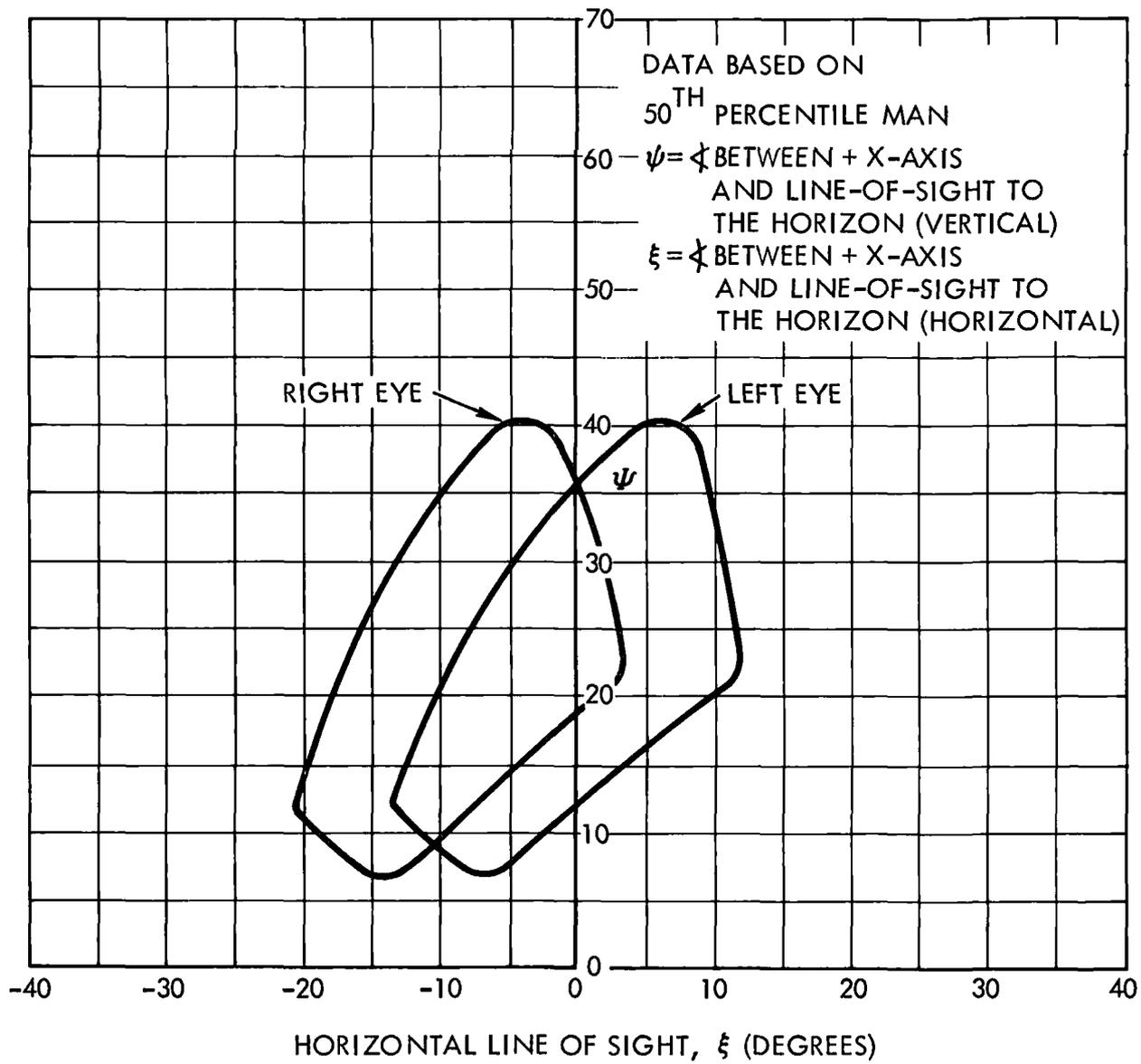


Figure 6-59. Forward Window Field of View

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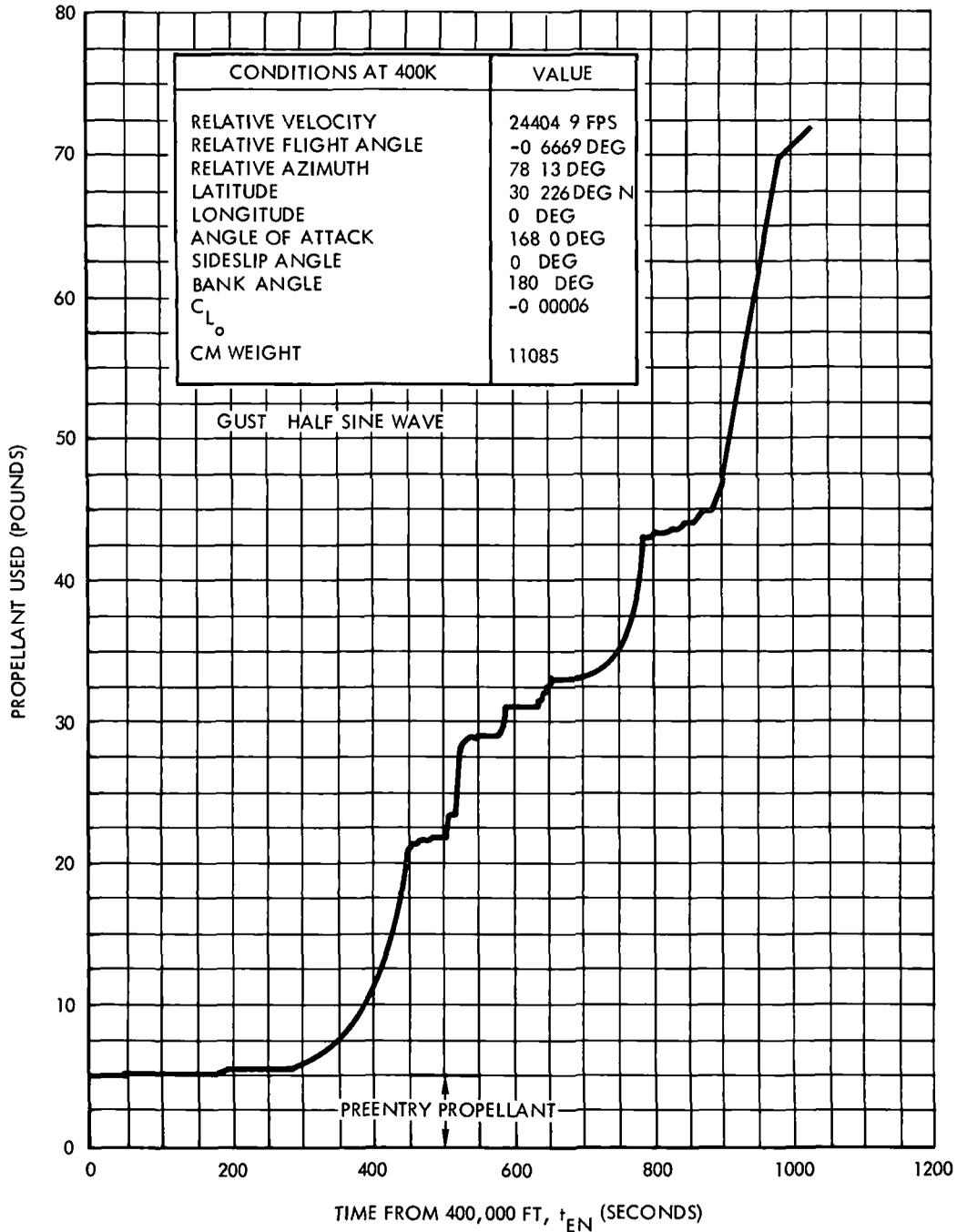


Figure 6-60 Off Nominal RCS Deorbit Propellant Time History

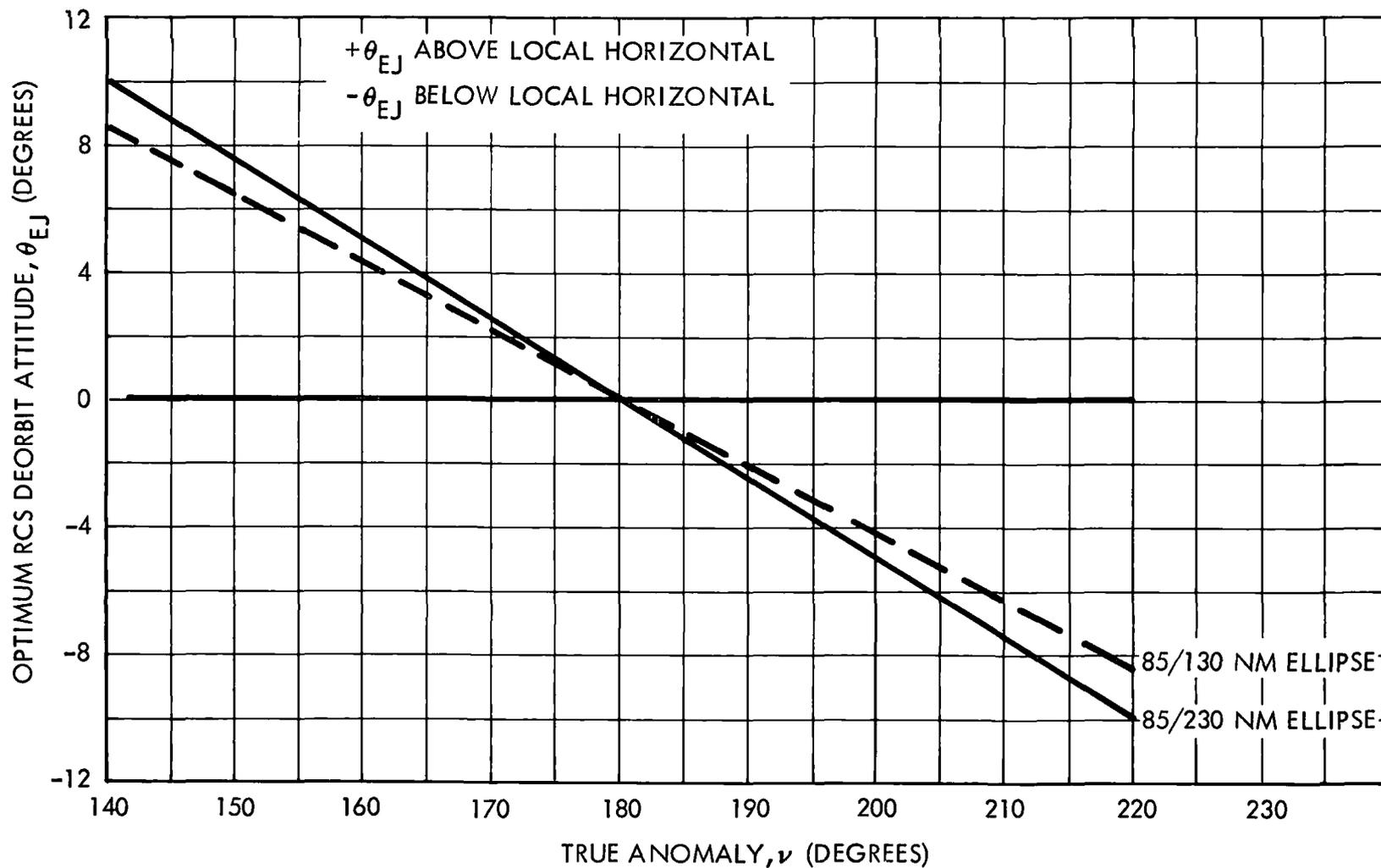
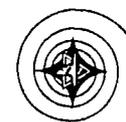


Figure 6-61 Optimum RCS Deorbit Attitude As a Function of True Anomaly

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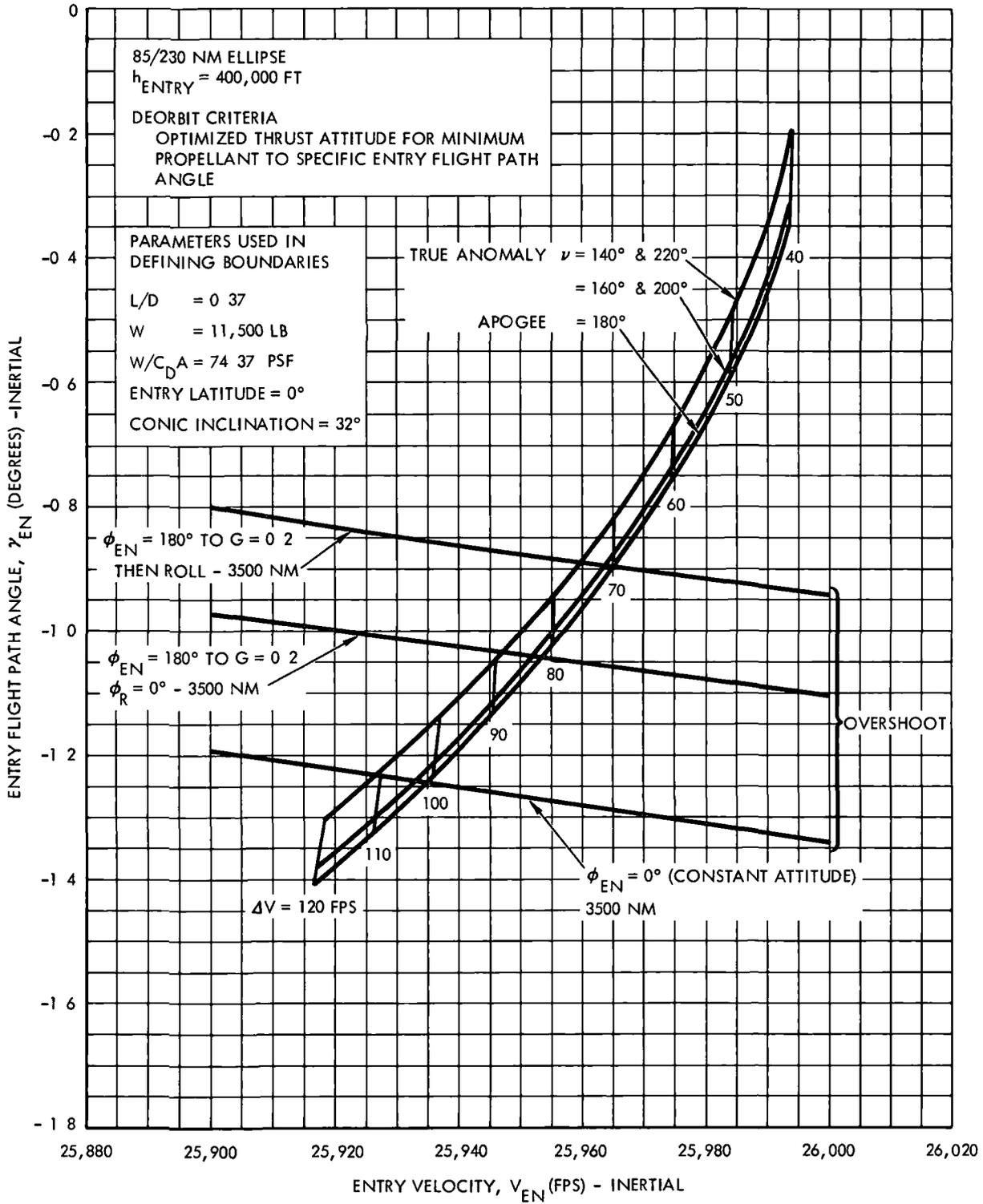


Figure 6-62 Entry Interface Format



BUILDING BLOCK 35 PARACHUTE DESCENT AND IMPACT

There are two modes of operation for parachute descent normal descent and abort mode Paragraph 35 1 contains a description of the normal descent mode It may be used for all descent operations except Mode I aborts (as defined in BB-42) Paragraph 35 2 presents data applicable to abort modes

35 1 PARACHUTE DESCENT (NORMAL)

35 1 1 Introduction

As shown on the operational flow logic chart (Figure 6-63), Block 35 1 starts with the arming of the earth landing subsystem (ELS) logic circuit at 50,000 feet and ends with the deployment of recovery aids However, the discussion of attitude starts with the closing of the high-altitude baroswitches (approximately 23,500 feet) The attitude operations sequence between 50,000 and 23,500 feet can be found in BB-25 and BB-26 The main parachute release function can be found in BB-37, Postlanding Operations The duty cycle, power profile, and consumable sections were written to include all systems operable during the approximately 465-second span from 50,000 feet to touchdown

35 1 2 Operational Data

35 1 2 1 General Information

Opening of the high- and low-altitude baroswitches define the abort mode and control the ELS functions The opening of these baroswitches inhibit ELS operations and the closing initiates the operations The high-altitude baroswitch (25,000 foot design) controls the LES tower jettison, apex cover jettison, and drogue mortar fire The low-altitude baroswitch (10,750-foot design) controls the drogue release and pilot mortar fire Baroswitch tolerance and venting log data are presented in Paragraph 35 1 4 The impact system attenuating struts allow strut stroking when the load threshold exceeds the strut core capability The crew will unlock the electro-mechanical lockout device located on the four x-x struts The lockout may be actuated by activating a switch on the main display console or by manually unlocking each strut In addition, there is automatic breakout provided on each lockout device in case the crew is unable to perform this function



35 1 2 2 Mission Functional Flow

The operational flow for parachute descent operations is shown in Figure 6-63. For this data book, impact and crew attenuation are included in BB-35 while flotation and uprighting are included in BB-37, Postlanding Operations.

35 1 2 3 Operational Timeline Segment

The timeline is shown in Table 6-51. It is to be emphasized that the parachute descent phase of the mission is altitude oriented rather than time oriented. That is, the drogue chutes are deployed two seconds after baroswitches S1 and S2 close but there is a +1000-foot tolerance on the baroswitches in addition to the venting lag of -1100 to -2300 feet. Similarly, with the drogue chute release and main chute deployment, the operations are controlled by baroswitches S3 and S4 — not by a specific time increment.

35 1 2 4 Attitude Maneuvers

No pre-programmed automatic attitude maneuvers or attitude controls are planned for the parachute descent operation utilizing the SCS or G&N control. Command module attitude from 50,000 to 25,000 feet is included in Building Blocks 25 and 36. During parachute descent, the command module is suspended at an angle of approximately 27.5 degrees from the +X axis to the local vertical.

35 1 2 5 Duty Cycles

The duty cycles presented in Table 6-52 are total duty cycles and are not associated with the common-level power. For electrical power profile, the equipment loads associated with this block should be summed from a power level of zero watts and should not be added to the common level power. The block duration is 0.129 hours (465 seconds).

35 1 2 6 Electrical Power Profile

The average power levels are P_{AC} (nominal) = 482.7 watts and P_{DC} (nominal) = 869.0 watts and should not be added to the common level.

35 1 2 7 Propellant Consumption

Of the 225 pounds of command module RCS propellant aboard, approximately 43 pounds will be consumed during the nominal entry phase. This leaves 182 pounds to be dumped after main parachute disreefing.



Table 6-51 Operational Timeline Segment, Parachute Descent and Impact

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 00 00	Arm earth landing system (ELS) logic circuit (00 05)	CS	For details of this time segment see AOH pages 8-81 to 8-82 Arming the ELS is normally accomplished at approximately 50 000-foot altitude
00 00 05	Confirm CM descent status with MSFN (00 30)	G	If the spacecraft cannot be stabilized with the RCS the apex cover jettison and drogue chute deployment should be manually accomplished This should not occur prior to descending to the 45 000-foot altitude
00 00 46	High-altitude baroswitches close	RT	The baroswitches are assumed to close at 23 500 feet nominal altitude The range is 24 900 to 21 700 feet
00 00 46 4	Apex cover jettison Confirm by sound denoting pyrotechnic firing	A	If the apex cover is not automatically jettisoned by 21 500 feet it must be accomplished manually
00 00 48	Automatic deployment of drogue chute Note sound denoting drogue mortar firing	A	If the drogue chutes are not deployed automatically 1 6 seconds after apex cover jettison they must be deployed manually
00 00 57	Automatic drogue chute disreef Visually confirm disreef	A	If communication with MSFN is available apex cover should jettison drogue and main chutes should deploy and disreef should be reported as they occur
00 01 39	Automatic release of drogue chutes and deployment of main pilot chutes Note sound denoting deployment	RT	Main chutes should deploy between 9 450- and 10,950-foot altitude This should be manually accomplished at 9 100 feet if necessary
00 01 49	Automatic main chute disreef Visually confirm disreef	A	
00 01 49	Close cabin pressure relief valve (00 05)		
00 01 49	Secure nonessential equipment (01 00)	G	
00 01 54	Prepare to burn RCS fuel (00 20)	G	Reference AOH for details



Table 6-51 Operational Timeline Segment, Parachute Descent and Impact (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 02 14	Burn RCS fuel (02 20)	CS	This is the maximum time required for a full load of propellant If the propellant fails to burn, all RCS engines (except the plus pitch) should be manually activated Helium pressure should drop to 290 psi after propellant exhaustion
00 02 30	Prepare couch attenuation system for impact (00 05)	CS	Backup for lockouts which do not unlock will be accomplished manually by pulling the lockout attenuator pin
00 03 10	Turn on VHF recovery beacon (00 10)	G	
00 04 32	Purge RCS engines (00 30)	CS	If the RCS propellant tanks do not purge set the helium dump switch to DUMP and activate the RCS engines
00 05 17	Place propellant jettison switch OFF (00 05)	G	The helium pressure gauge should read zero at the conclusion of dump
00 05 22	Place cabin relief valve on boost entry (00 05)		
00 07 00	Prepare postlanding bus for use (00 10)		
00 07 10	Isolate main d-c buses (00 10)		
00 07 45	Touchdown	RT	
	<p style="text-align: center;"><u>Time Source Code</u></p> <p>A = AOH CS = Crew systems G = Best guess RT = Preliminary reference trajectory</p>		



Table 6-52 Subsystem Duty Cycles, Parachute Descent and Impact

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 35
Stabilization and control				
RGP		7		100
BMAG		7		100
FDAI		7		100
AS/GPI		7		100
Rotation control		7		100
SCS control panel		7		100
ECA pitch		7		1 pulse pulse width = 10 sec initiate at t = 0
ECA roll		7		100
ECA yaw		7		100
ECA auxiliary		7		100
ECA display		7		100
Electronics display		7		100
TVC	2	Operate		1 pulse pulse width - 10 sec initiate at t = 0 OFF at t = 10 sec
Guidance and navigation				
AGC		Operate		100
IMU		Operate		100
LEB floodlights	2	Fixed		0
	2	Variable		0
SES floodlights	3	Fixed		100
	3	Variable		100
CS floodlights	3	Fixed		100
	3	Variable		100
Reaction control				
CM RCS	12	Direct		1 pulse for 140 seconds start at t + 132 sec
Environmental control				
Suit compressor		High		100
Glycol pump				100
Cabin fans	2			100
Glycol temperature control				100
Glycol temperature control valve				100
Cabin temperature control				100
Cabin temperature control valve				100
Backpressure control				100
Backpressure control valve				100
Power supply				100
O ₂ flow transducer				100
Pressure transducers				100
Glycol transducers				100
Glycol evaporator control valve				10
Steam duct heater				100
Potable H ₂ O tank potentiometer				100



Table 6-52 Subsystem Duty Cycles, Parachute Descent and Impact (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 35
Waste H ₂ O tank potentiometer				100
Cyclic accumulator valve				1 7
Potable H ₂ O supply assembly				4 0
Urine line heater				100
Suit sensors				100
Cyclic accumulator control				1 7
Suit circuit				
Backpressure control				100
Glycol valve				100
Wetness control				100
Glycol diverter valve				100
Water control valve				100
Backpressure valve				100
Sequential events				
Logic				100
Crew systems				
Personal communications				100
Biomedical instrumentation				100
Impact				
Lockout solenoid release				1 pulse initiate at t + 2 min 30 sec pulse width = 1 sec
Communications				
VHF/FM transmitter				one 10-sec pulse initiated at t = 0
VHF/AM equipment		Transmit/ receive		
C-band transponder		Interrogated		Off at 01 47 sec
Audio center		High Low		Same duty cycles as VHF/AM equipment
PCM telemetry				100
Data storage				100
Premodulator processor		Normal		100
Central timing				100
UHF-Update link				100
Flight qualification recorder				100
2-KMC switch				100
VHF recovery beacon				53 2-sec pulses period = 5 sec first pulse at t = 200 sec
Audio center diode switch		High		100
Electrical power				
Power distribution sensors				100



Table 6-52 Subsystem Duty Cycles, Parachute Descent and Impact (Cont)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 35
Instrumentation				
CM				100
Displays and controls				
Digital event timer		Operate Standby		100 0
CW detection unit				100
Master alarm indicator				100
CW matrix indicator				50

35 1 3 Performance

35 1 3 1 General Information

For aborts above 100,000 feet and for normal entry operations, Table 6-53 indicates the dynamic pressure (q) and pressure altitudes at which events occur. The altitude variations are a result of venting lag and baroswitch tolerances. The U S Standard Atmosphere, 1962, was assumed for all calculations.

Table 6-53 Dynamic Pressure and Pressure Altitudes

Mode of Operation	High Baroswitch		Drogue Fire		Low Baroswitch	
	(h in ft)	(q in psf)	(h in ft)	(q in psf)	(h in ft)	(q in psf)
2 drogues and 3 mains						
Nominal	23,500	100	22,700	100	10,200	46
Maximum	24,900	100	24,100	100	10,950	46
Minimum	21,700	100	20,900	100	9,450	46
1 drogue and 2 mains						
Maximum	24,900	100	24,100	100	10,600	64
Minimum	21,700	100	20,900	100	9,100	64

The load capability of the command module structure and ELS performance attributes are as follows:

Item	Structural Capability (lb)	Maximum Loads Generated (lb)
Drogue mortar	10,000	9,100
Drogue parachute attachment	20,000	20,000
Pilot mortar	9,000	9,000
Main parachute attachment	42,000	34,000



These values are based on a 11,000-pound recoverable weight configuration which corresponds to a launch control weight of 11,500 pounds. Shortly before this writing, NAA briefed NASA on the effects of command module weight increase. The results of this briefing and subsequent NAA/NASA negotiations are not available and are not included in this section.

The ELS is required to perform satisfactorily within the boundaries of the flight envelope defined in Figure 3, page 67, of NAA S&ID Specification MC901-0001, Revision F. This envelope is shown in Figure 6-64. These requirements apply to a recoverable weight configuration of 11,000 pounds.

The capability to perform satisfactorily within the limits of Figure 6-64 were demonstrated in the nine NAA aerial drop tests. The main parachutes decelerate the command module to a maximum two-parachute rate of 34 feet per second and a nominal three parachute rate of 27 feet per second at impact.

The command module was designed to withstand loads and deformations resulting from impact at the velocities and impact angles shown in Figure 6-65.

The capability to perform satisfactorily within these limits has been demonstrated in impact tools at S&ID, Downey. The impact weight was 10,400 pounds which corresponds to a launch control weight of 11,500 pounds.

35 2 PARACHUTE DESCENT (ABORTS)

35 2 1 General Information

A detailed description of the four abort modes can be found in BB-42. The purpose of this section is to describe the sequence of events which occur when the command module is in its parachute descent phase. The duty cycles, electrical power profile, and propellant consumption sections have not been included in the abort mode of this block.

35 2 2 Operational Data

35 2 2 1 General Information

The normal sequence of events for aborts is covered in BB-42, LES Aborts. To assure water impact on low-altitude aborts, the commander will inhibit deployment of the main chutes until an indicated altitude of 3300 feet is attained. Conversely, if an altitude of 3300 feet is attained before the 14-second timer releases the drogues and deploys the main parachutes, the main deploy switch may be used to deploy the main parachutes immediately.



after drogue parachutes are deployed For aborts below 31,000 feet, see Paragraph 42 3 2 in BB-42, LES Aborts

35 2 2 2 Mission Functional Flow

Figure 6-63 contains a diagram of the abort mode functional flow

35 2 2 3 Operational Timeline Segment

The Mode I timeline in BB-42 indicates manual release of drogue parachutes and deployment of main parachutes at time t_1 Assuming an altitude of 3300 feet at this time, touchdown would occur approximately 115 seconds later

Mode II also indicates drogue parachute release and main parachute deployment at time t_1 However, the release is automatic and the altitude is approximately 10,750 feet The remaining sequence of events may be found by entering the normal parachute descent timeline (Table 6-51) at "Automatic release of drogue chutes " and substituting t_1 for 00 01 39 The remaining descent time from this point is 00 06 06 Modes III and IV both indicate apex cover jettison at $t_1 + 0.5$ seconds, where t_1 is defined as the time of high-altitude baroswitch closing Each of these blocks would continue the timeline from Table 6-51, where t_1 would coincide with "High-Altitude Baroswitches close " As indicated in Table 6-51, approximately 7 minutes is required for descent from 23,500 feet to touchdown

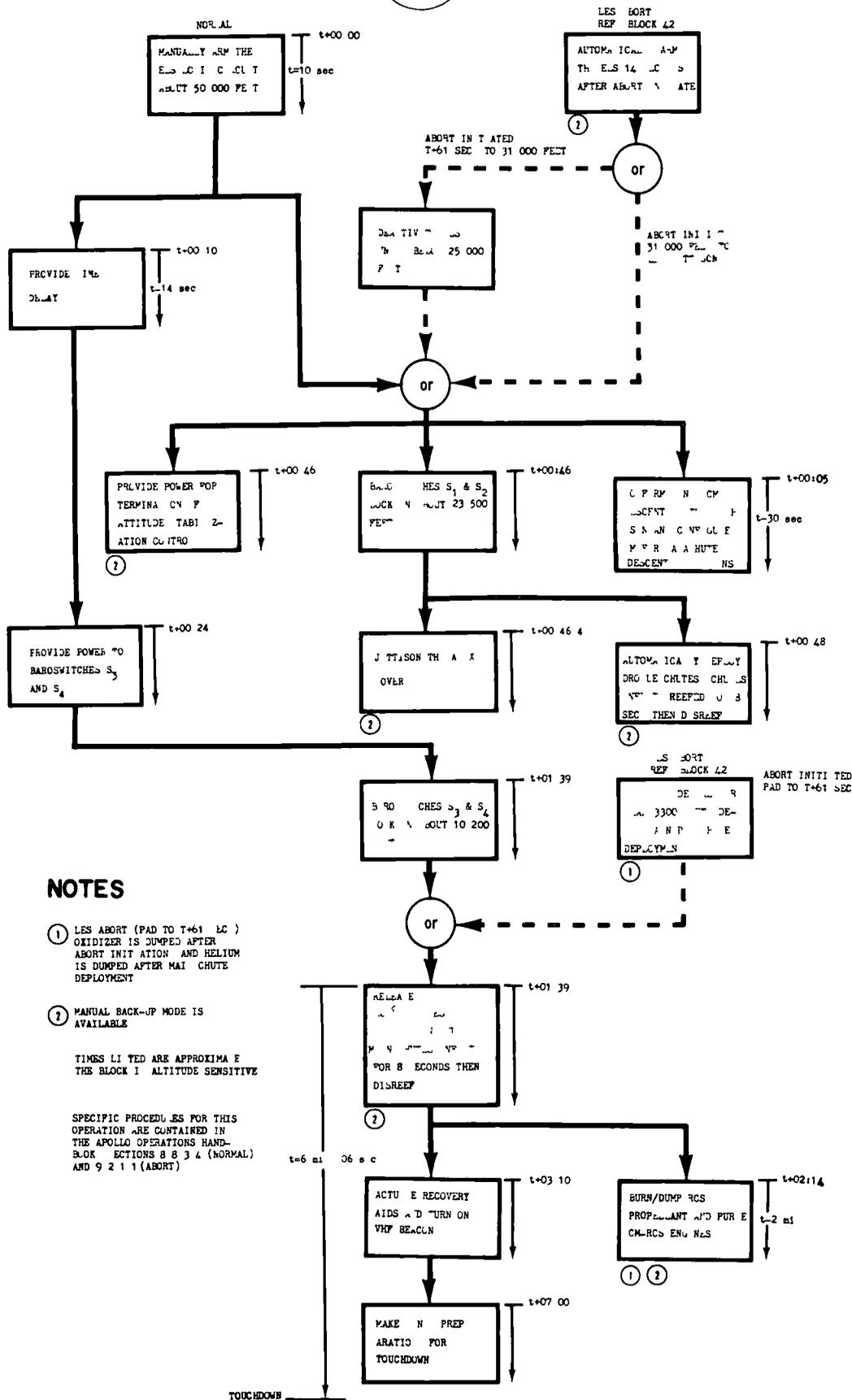
35 2 3 Performance Data

For aborts between 31,000 and 100,000 feet Table 6-54 indicates the dynamic pressures and pressure altitudes at which events occur The altitude variations are a result of venting lag and baroswitch tolerances



Table 6-54 Dynamic Pressure and Pressure Altitudes (Aborts Between 31,000 and 100,000 Feet)

Mode of Operation	High Baroswitch		Drogue Fire		Low Baroswitch	
	(h in ft)	(q in psf)	(h in ft)	(q in psf)	(h in ft)	(q in psf)
<u>2 drogues and 3 mains</u>						
Nominal	23,300	180	22,200	182	10,200	46
Maximum	24,900	180	23,800	182	10,950	46
Minimum	21,500	180	20,400	182	9,450	46
<u>1 drogue and 2 mains</u>						
Maximum	24,900	180	23,800	182	10,600	70
Minimum	21,500	180	20,400	182	9,100	80



NOTES

- ① LES ABORT (PAD TO T+61 SEC) OXIDIZER IS DUMPED AFTER ABORT INITIATION AND HELIUM IS DUMPED AFTER MAIN CHUTE DEPLOYMENT
 - ② MANUAL BACK-UP MODE IS AVAILABLE
- TIMES LISTED ARE APPROXIMATE THE BLOCK IS ALTITUDE SENSITIVE
- SPECIFIC PROCEDURES FOR THIS OPERATION ARE CONTAINED IN THE APOLLO OPERATIONS HANDBOOK SECTIONS 8 2 3 4 (NORMAL) AND 9 2 1 1 (ABORT)

Figure 6-63 Building Block 35 Parachute Descent Operations

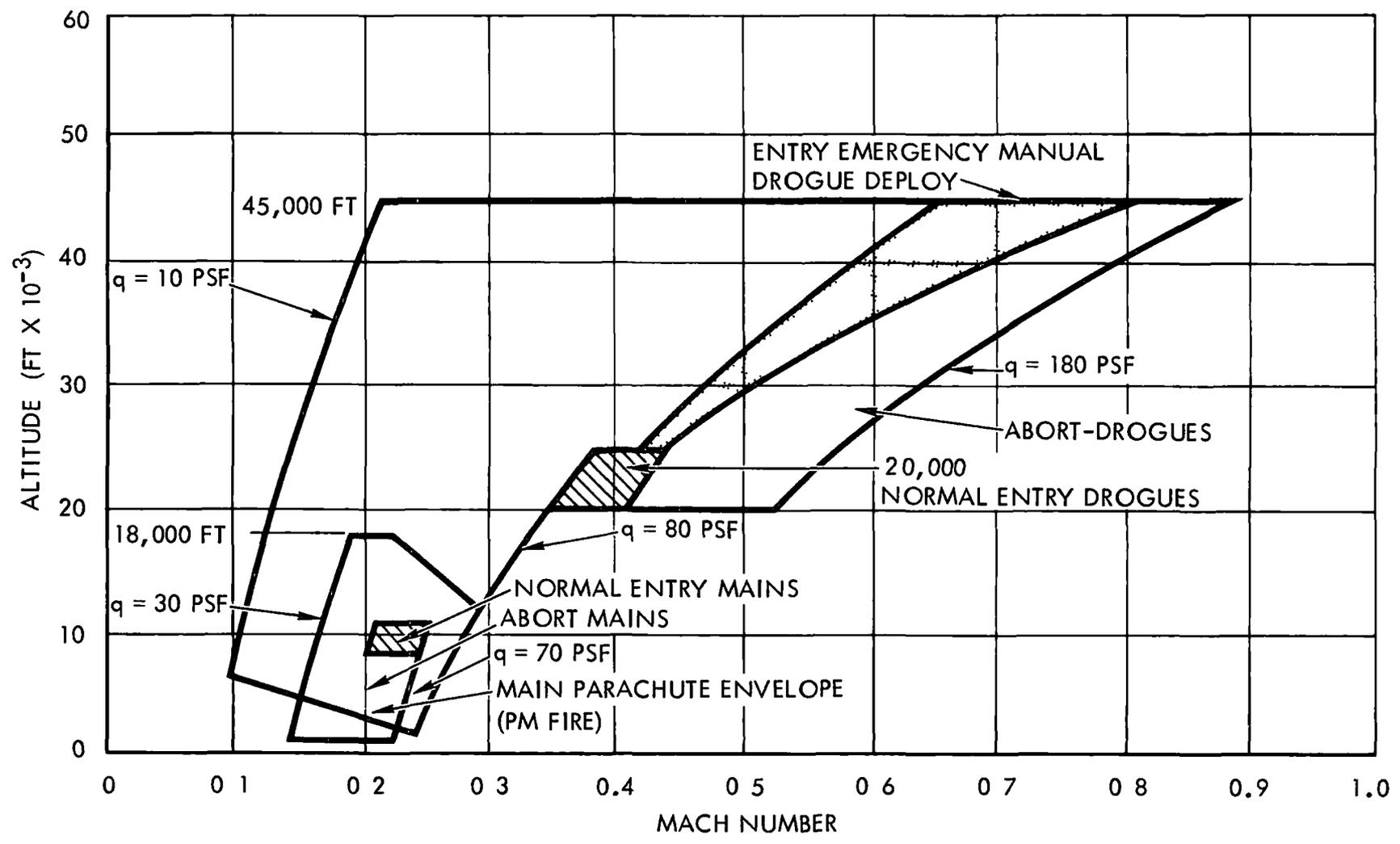


Figure 6-64 Earth Recovery Subsystem Flight Requirements

6-275
SID 66-1177

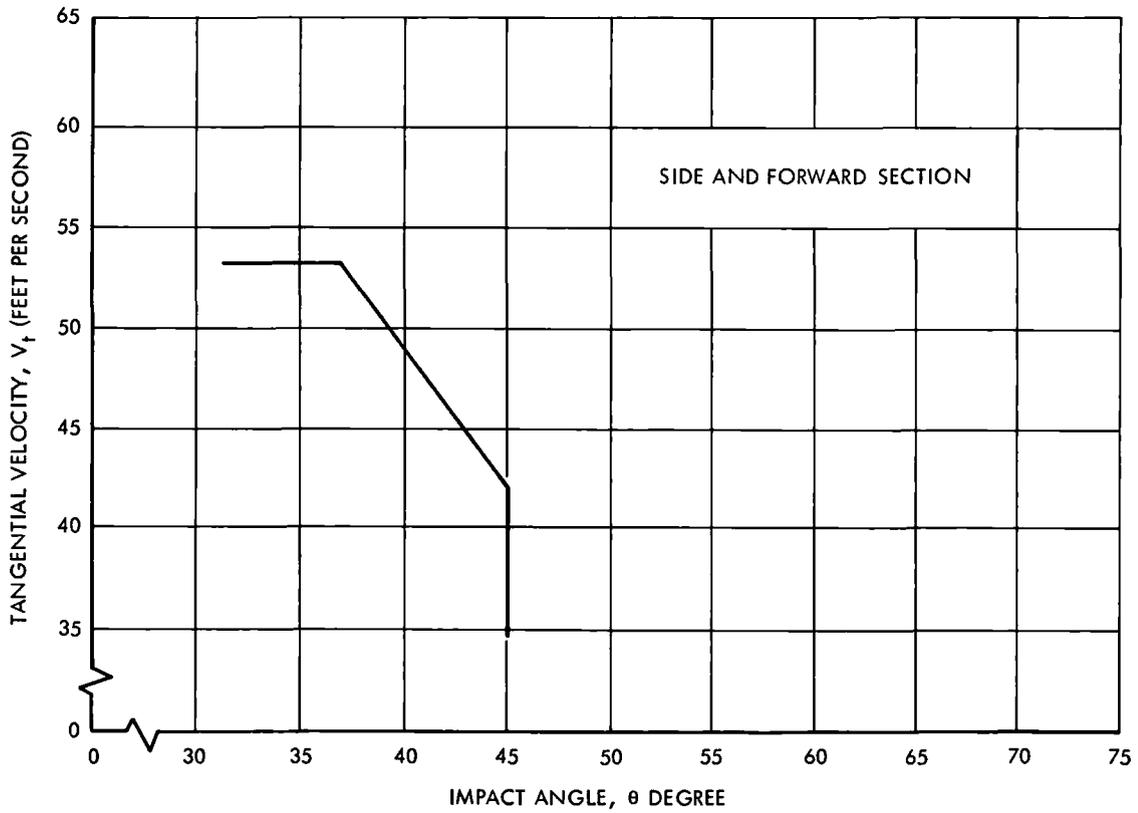
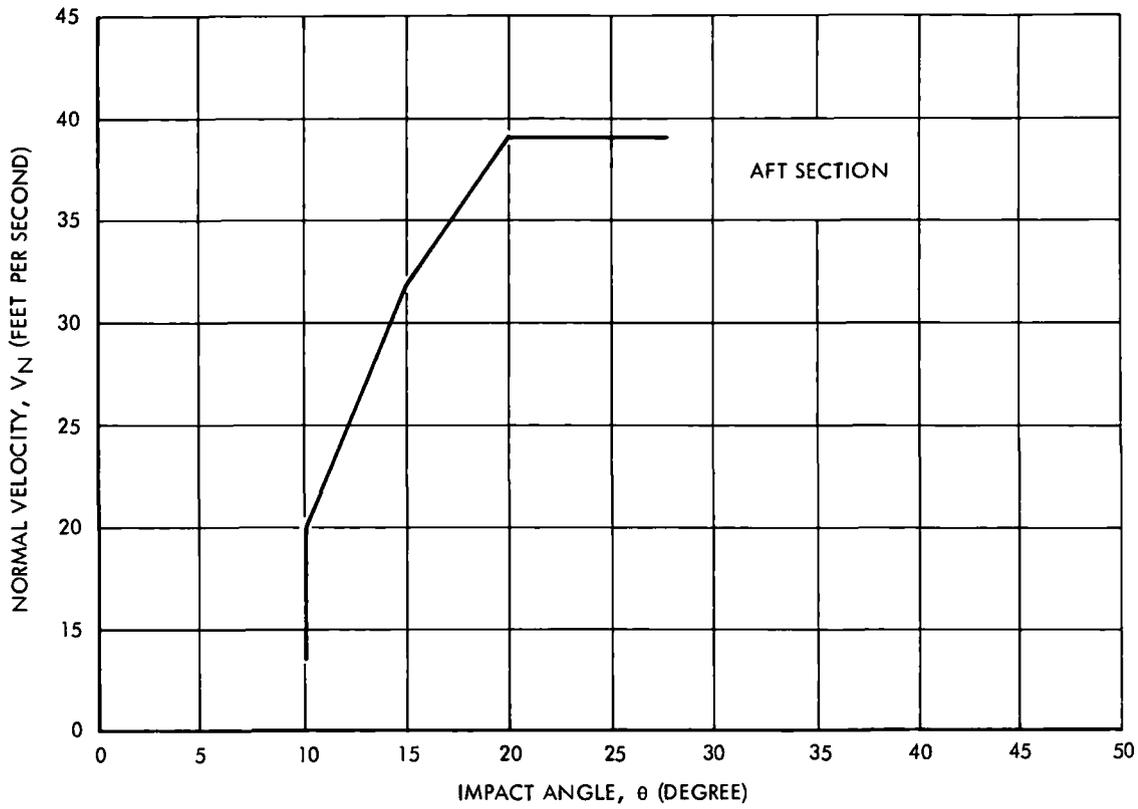


Figure 6-65 Command Module Water Impact Criteria



BUILDING BLOCK 37 POSTLANDING OPERATIONS

37 1 INTRODUCTION

Postlanding operations are initiated by the release of the main parachutes at touchdown. The operations are considered complete at the time when the crew and command module are retrieved. Of prime importance during the postlanding operation phase is the command module uprighting subsystem, which must be activated if the command module assumes a stable II position. For purposes of establishing an electrical power profile, Paragraph 37 2 5, the command module was assumed to require two uprightings: one at t+20 seconds and one at t+24 hours.

37 2 OPERATIONAL DATA

37 2 1 General Information

Postlanding operations consist of uprighting the command module with the flotation uprighting subsystem (if necessary), deploying the HF antennas, providing location aids (flashing light and sea dye marker), ensuring adequate environmental control (post landing vent [PLV] duct and fan, pressure garment removal, pressure relief valves), and contacting recovery forces.

The uprighting sequence described in this block is that which has been tested and is presently being used. At the time of this writing, S&ID is investigating an alternate design sequence which would require the simultaneous inflation of all three bags.

The command module side hatch should not be opened until shortly before recovery, to minimize the possibility of the module filling with water.

The top hatch will only be used for egress or ventilation in emergencies due to the danger of inverting the command module.

Flotation bag 3 (+Z axis) will be inflating only if Bag 1 and/or Bag 2 fail to inflate.

The VHF and HF antennas are limited by their range by functions of line-of-sight, altitude, atmospheric state, etc. The circuit margin data may be found in Paragraph 37 3, Performance Data.



37 2 2 Functional Flow

See Figure 6-66

37 2 3 Operational Timeline Segment

See Table 6-55 The time sequence shown does not include uprighting of the command module, since the probability of stable II position is less than that of stable I position. However, for the electrical power profile, two uprightings were assumed, one at t+20 seconds and one at t+24 hours, as indicated in the Remarks column.

37 2 4 Subsystem Duty Cycles

See Table 6-56 The duty cycles presented are total duty cycles and are not associated with the common level.

37 2 5 Electrical Power Profile

The equipment loads associated with this block should be summed from a power level of zero watts and not added to the common level power. There is no a-c power required for this block. If no uprightings are required, the average d-c power level is approximately 63 watts. If two uprightings are required as shown in the duty cycles, the average d-c power level would be 68 watts.

37 3 PERFORMANCE DATA

The VHF recovery circuit margin summary ground rules are as follows:

Range 300 NM

Frequency	Simplex voice	296.8 megacycles
	Beacon	243.0 megacycles

Circuit Margins

VHF recovery (voice)	CM to aircraft	Nominal	+ 3.66 db
		Worst case	- 1.35 db
VHF recovery (voice)	Aircraft to CM	Nominal	+ 0.04 db
		Worst case	- 1.46 db
VHF recovery (beacon)	CM to aircraft	Nominal	+ 21.02 db
		Worst case	+ 18.90 db



Range Conversion Factor - The change in circuit margin due to a range other than 300 nautical miles is equal to $20 \log (300/R)$, where R = new range in nautical miles

37 4 EQUIPMENT SUMMARY

The cabin ventilating blower is a two-speed fan capable of providing air circulation, 150 cubic feet per minute during a 12-hour daytime period, and 100 cubic feet per minute during a 12-hour night period. The blower is capable of operation for a 48-hour period.

In addition to the 18 pounds of survival kit water, the capability for producing 25 pounds of desalinated sea water will be provided by three desalter kits.



Table 6-55 Operational Timeline Segment, Postlanding Operations

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 00 00	Release main parachutes (00 02)	CS	
00 00 00	Close cabin pressure relief valves (00 05)	G	
00 00 20	Evaluate CM attitude in water (00 10)	G	If the CM is inverted inflate flotation bag 1 (+Y axis) then inflate bag 2 (-Y axis) If the vehicle fails to upright inflation of bag 3 is then initiated Five minutes are required for each inflation
00 00 30	Secure postlanding vent duct in extended position and place vent fan on high (01 04)	CS	If the CM is shipping water prepare for CM abandonment Initiate recovery devices as time permits
	Set up HF communications and deploy sea dye marker (00 20)	CS	If touchdown occurs near or after sunset the flashing light should be activated until sunrise
	Attempt contact with recovery forces	CS	The duty cycle for the HF transmitter is 2 minutes transmit on SSB 2 minutes receive on SSB and 8 minutes beacon on SSB until contact with the recovery forces is established
00 00 50	Set master events controller (MESC) to safe (00 04)		
00 01 34	Remove PGA's (05 00)		
00 06 34 to 48 hrs	Continue attempts at contacting recovery forces		If the CM capsizes it may be necessary to fill the flotation bags even though they may have been previously used to right the CM Less than 5 minutes will be required for each bag The side hatches should be removed just prior to rescue to minimize possibility of shipping water



Table 6-56 Subsystem Duty Cycles, Postlanding Operations
(Duration 48 Hours)

COMPONENT	QUANTITY	MODE	PERCENT DUTY CYCLE	
			COMMON LEVEL	BLOCK 37
<u>Communications</u>				
HF/SSB AM transceiver		Transmit		16
		Beacon		67
		Receive		16
Audio center		High		99
		Low		0
		Standby		0
Audio center diode switch		High		99
		Low		99
VHF recovery beacon				99
<u>Crew</u>				
Personal communications				100
<u>Flotation</u>				
Pumps	2			2 pulses pulse duration 0.167hrs
Solenoid valves	2			First pulse at t + 20 secs second at t + 24 hrs
<u>Environmental control</u>				
PLV fan		High		50
		Low		50
PLV gate valves	2			3 pulses of 1 2 sec 1st pulse at t+15 sec 2nd pulse at t + 24 hrs 3rd pulse at 24 hrs 15 min
PLV attitude sensor switch relay				One pulse at t + 24 hrs duration of 15 min

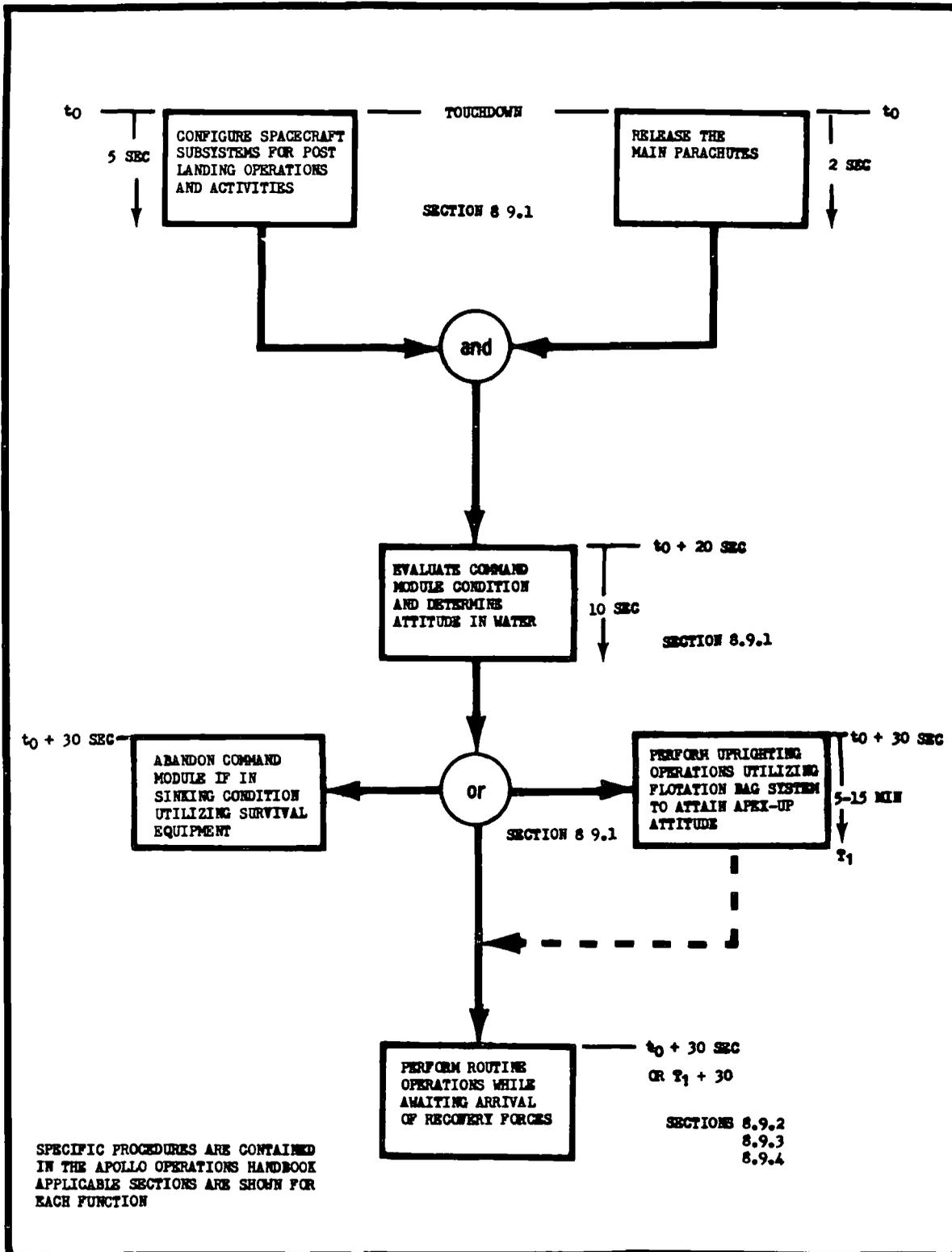


Figure 6-66 Building Block 37 Postlanding Operations



BUILDING BLOCK 41 RADIATOR LOSS, EPS AND ECS

41 1 RADIATOR LOSS, ELECTRICAL POWER SUBSYSTEM

Qualification tests of the EPS Block I radiator assembly have successfully demonstrated the heat rejection capabilities of the radiator assembly. The tests performed were within solar and deep-space simulated environments while heat rejection loads were applied at steady-state and transient conditions. The radiator heat rejection capabilities exceed those required by the Block I mission to the extent that the total radiating area of the radiator assembly has been reduced in size by approximately 33 percent, as recommended in the test report.

The configuration of the radiator area is such that three independent coolant (glycol/water) loops are routed through each panel. There are no shutoff valves or manual controls associated with the independent loops which serve individual fuel cell modules. Consequently, the only way to stop flow through any one loop is to shut down the fuel cell module associated with that loop.

Temperature instrumentation consists of fuel cell skin temperature displayed on Panel 17, a mechanical indicator on Panel 17 which will display a flag when the temperature of the coolant returning from the radiators is below -30 degrees F, and down link PCM telemetry (not displayed to the crew) for each loop's radiator outlet temperature at a rate of one signal per second.

41 1 1 EPS Radiator Loss Contingencies

Contingencies contemplated are

- 1 radiator freezing
- 2 ruptured lines to and from the radiators
- 3 failed glycol pump
- 4 ruptured radiator channels due to meteoroid puncture or other unknown reasons
- 5 inability of radiator to cope with out-of-tolerance waste heat



41 1 2 General Information

41 1 2 1 Radiator Freezing

Radiator freezing could occur if power production by the fuel cells were reduced to a level which would not produce enough waste heat to utilize the total radiator area as originally designed. In reducing the effective area by 33 percent on Block I radiators, the capabilities to reject waste heat in excess of those required by Block I spacecraft is also reduced. Solar soak or increased electrical power load are possible corrective actions.

41 1 2 2 Ruptured Lines

Nominal pressures are assumed, thus no ruptured lines are anticipated. If experiences, a ruptured line will permit loss of coolant in the affected loop and will eventually require shutdown of the affected fuel cell. There is no known corrective action.

41 1 2 3 Failed Glycol Pump

Failure of a glycol pump will require shut down of the affected fuel cell. There is no known corrective action.

41 1 2 4 Ruptured Radiator Channels

The degree of leakage will determine how long after rupture the fuel cell will require shutdown. If severe damage results from penetration by a meteoroid large enough to damage more than one radiator channel, it can be assumed that mission abort will be in order.

41 1 2 5 Inability of Radiator to Cope with Out-of-Tolerance Waste Heat

This remote contingency is possible if a combination of factors adversely affecting the radiators exists, such as a breakdown of thermal coating such that solar absorptivity is increased and infrared emissivity is decreased. Other possibilities include simultaneous high power production, solar soaking, partially blocked radiator, malfunctioning glycol pump, malfunctioning fuel cell temperature controls, etc.

Corrective Action consists of reducing electrical load, changing spacecraft attitude, and monitoring results. If corrective action fails to correct the condition, the fuel cell of the affected loop is to be shut down.



41 2 RADIATOR LOSS, ENVIRONMENTAL CONTROL SYSTEM

For the purpose of this Block, it is assumed that the ECS radiator sustains a failure in the form of freezing or by a leak in one or more sections in the panel, but limiting the failure to one panel

41 2 1 Determination of the Problem

First indication of this type of failure would be displayed by the caution and warning system, low glycol temperature light, radiator outlet temperature gauge, glycol accumulator quantity gauge, or glycol pressure discharge gauge. Troubleshooting procedures would be accomplished as detailed in AOH Paragraphs 9 1 6 6, 9 1.6 9 and 9 1 6 10. Essentially a freezing radiator would probably first be indicated by low radiator outlet temperature. If not corrected it might subsequently result in loss of cooling capability of the frozen radiator. A leaking section in the radiator panel would show as reduced glycol accumulator quantity and glycol pump discharge pressure and might be corrected by isolating the leaking radiator section. A radiator section leak would cause permanent loss of heat rejection capability or possibly mission abort if not corrected.

41 2 2 Remedial Procedures and Recommended Actions (as required for a degraded mission)

A frozen radiator section or panel would be corrected by orienting the CSM so as to thaw the frozen section.

A leaking radiator section would be mitigated by closing the isolating valve of the leaking section, orienting the active radiator sections for optimum heat rejection, replenishing glycol loss in coolant loop from glycol reservoir, setting the suit and cabin heat exchanger temperature controls for maximum rejection of gas heat through suit circuit heat exchanger water boiler function, and managing the command module electrical load to be consistent with degrade heat rejection rates.

41 2 3 Mission Constraints

The water boiler and suit heat exchanger evaporator will supplement the radiator heat rejection rate. However, due to possible increased water consumption rates and reduced water production rates, the mission might have to be limited to the restrictions imposed by essential cooling requirements and water usage. Increased attitude management for optimum heat



rejection will increase service module RCS propellant consumption, which would take priority over less essential attitude requirements. Electrical loads in the command module would have to be reduced to the powered-down mode and – possibly during any high external thermal load excursions – the loads would have to be reduced to emergency levels which might entail subsequent stabilization activation or warmup periods. This could cause minimum MSFN communication periods and deletion of some experiments contributing to the thermal load of the command module.



BUILDING BLOCK 42 LES ABORTS

42 1 INTRODUCTION

Launch escape subsystem (LES) aborts are performed using four modes of operation as a function of the altitude region at which the abort is initiated. The altitude regions in the four modes are as follows:

- 1 Mode I Pad to 61 seconds ($h \approx 24,000$ feet)
- 2 Mode II 61 seconds to $h \approx 31,000$ feet
- 3 Mode III $h \approx 31,000$ feet to $h \approx 100,000$ feet
- 4 Mode IV $h \approx 100,000$ feet to launch escape tower jettison

A detailed description of the sequencing for the four modes is included in Paragraph 42 2.

This block will include that portion of the abort phase from initial separation to main chute deployment. BB-35 and BB-37 should be referred to for the descent and recovery phases after main chute deployment.

The major sequence of events for the four LES abort modes are as follows:

	Description of Abort Sequence
Mode I	<ol style="list-style-type: none"> 1 Automatic initiation (manual prior to liftoff) with manual backup 2 Automatic sequencing to abort initiation +16 seconds (drogue deployment) 3 Manual deployment of main parachutes if altimeter reads 3300 feet (altitude decreasing) or less. If altimeter reading is greater than 3300 feet, main parachute is delayed until 3300 feet is attained.



	Description of Abort Sequence
Mode II	<ol style="list-style-type: none"> 1 Automatic initiation with manual backup 2 All abort events up to main chute deployment are initiated by time delay relays 3 The closing of the low-altitude baroswitch initiates the main parachute sequence
Mode III	<ol style="list-style-type: none"> 1 Automatic initiation with manual backup 2 All events to canard deployment automatic on time-delay relays 3 When 23,500 feet is reached, the high altitude baroswitch initiates automatic sequencing of LET jettison, apex cover jettison, and drogue chute deployment 4 When 10,750 feet is reached, the low altitude baroswitch initiates automatic sequencing for main chute deployment and command module RCS propellant dumping
Mode IV	<ol style="list-style-type: none"> 1 Automatic initiation with manual backup 2 Following LES motor burnout, the crew utilizes the command module RCS to produce a launch escape vehicle pitch rate of 5 degree per second. When the 5 degree per second pitch rate is established, the command module RCS pitch channel is manually disabled 3 The high and low-altitude baroswitches automatically initiate landing sequences as in the Mode III abort

42 2 OPERATIONAL DATA

42 2 1 General Information

The basic function of the LES is to separate and propel the command module safely away from the booster at any time from the pad until LES jettison in the event of a launch vehicle or spacecraft malfunction. Major abort functions for each mode are discussed below to give the reasons for the different sequencing in the four altitude regions.

42 2 1 1 Mode I, pad to 61 seconds, $h \approx 24,000$ feet

- 1 The problem associated with aborts in this altitude region is the requirement to assure command module water landing. Water landing is assured by the following abort procedures
 - a The LES pitch control motor is used to provide a downrange trajectory
 - b The main parachutes are not deployed until the indicated altitude of the abort trajectory decreases to 3300 feet (actual altitude of 3300 to 2500 feet)
- 2 Due to the limited amount of time in low altitude aborts, the command module RCS oxidizer is dumped automatically. Sufficient time is not available to dump the fuel, but the fuel tanks are depressurized before landing. RCS helium purge/dump begins after drogue chute deployment

42 2 1 2 61 seconds to $h \approx 31,000$ feet

- 1 After 61 seconds of boost, adequate range from the pad has been achieved to preclude land landing without the requirement for main chute deployment at 3300 feet. In this abort region, the high altitude baroswitches may be either open or closed at $t + 14$ seconds. If closed, the LET will be jettisoned, followed by apex cover jettison 0.4 seconds later. If open, the sequence will be delayed until baroswitch closure at approximately 23,500 feet during descent. For purposes of timing, the baroswitches were assumed closed.
- 2 The pitch control motor is disabled by the astronaut's moving the RCS DUMP switch to RCS CMD AUTO position for all aborts after 61 seconds since it produces high vehicle structural loads in the high dynamic pressure flight region.
- 3 There is sufficient time to dump/purge the command module RCS propellant while on the main parachutes for aborts after 61 seconds.
- 4 The crew couch attenuating struts are unlocked manually during descent on main parachutes to assure stroking of the couch struts as a backup to moving the couch switch to UNLOCK. This function is performed in Modes II, III, and IV aborts. A Mode I abort will not allow sufficient time to manually unlock the struts.



42 2 1 3 Mode III, $h \approx 31,000$ feet to $h \approx 100,000$ feet

- 1 Due to the open condition of the high altitude baroswitches for aborts initiated at approximately 31,000 feet or above, the ELS sequence is delayed until about 23,500 feet is reached during descent
- 2 The LET is jettisoned at approximately 23,500 feet
- 3 The main parachutes are deployed at approximately 10,750 feet to assure safe landing velocities

42 2 1 4 Mode IV, $h \approx 100,000$ to LET jettison

- 1 In this altitude region, the crew is required to establish a launch escape vehicle pitch rate of 5 degrees per second as soon as practical following the abort. This pitch rate eliminates the possibility of vehicle capture in the apex forward attitude. The apex forward capture stable trim region exists only above $Mach \approx 3.8$
- 2 The LET jettison and chute deployment procedures are the same as those in Mode III

42 2 2 Mission Functional Flow

See Figure 6-67

42 2 3 Operational Timeline Segment

See Table 6-57. This timeline is divided into four different timelines representing the four abort sequences dependent upon the altitude region at which the abort is performed.

42 2 4 Attitude Maneuvers

A launch escape vehicle pitch rate of 5 degrees per second is established following abort initiation for aborts initiated above 100,000 feet. Once this rate is established, the command module RCS pitch channel is disabled. The RCS yaw and roll channels are left operational until ELS initiation at approximately 23,500 feet.

42 3 PERFORMANCE DATA

42 3 1 General Information

The LES has the performance capability to safely separate and propel the command module safely away from the booster at any time from the



launch pad to LET jettison. The performance of the LES is automatic in all but low aborts (Mode I). The crew enhances performance through back-up and manual inputs. The manual functions are dependent on the altitude region where the abort is performed.



Table 6-57 Operational Timeline Segment, LES Aborts

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
MODE I (PAD TO T + 61 SECONDS)			
00 00 00	Abort initiation		<p>Prerequisites are launch preparation which is accomplished per AOH Paragraph 8 1 7</p> <p>Abort is initiated automatically by the EDS or manually by twisting translation control counter clockwise The booster engines are inhibited from cut off until T+40 seconds</p>
00 00 00 1	<p>LES main motor and pitch control motor ignition</p> <p>CM/SM umbilical deadfaced</p> <p>Main d c bus tied to batteries</p> <p>CSM Separation</p> <p>CSM RCS oxidizer dump begins</p> <p>Digital event timer reset to zero</p>		
00 00 10	Unlock EDS panel and deactivate caution and warning tone	Estimate	If canards fail to deploy automatically or the CM RCS automatic dump function fails do not use manual backup control for it may disturb the SECS normal timer functions and possibly incur greater risk to crew safety.
00 00 11	Canards deployed		
00 00 12 4	End of RCS oxidizer dump		
00 00 14	LET and BPC jettison		
00 00 14 4	Apex cover jettison		
00 00 16	Automatic deployment of drogue chutes		
00 00 17	Drogue parachute line stretch (if main chutes have not been deployed before this time)		If altimeter reads 3300 feet or less the main parachutes are deployed immediately if the altimeter reads above 3300 feet the auto deploy function for the main parachutes is set to the manual deploy function and when altimeter decreases to 3300 feet the auto deploy function is enabled or the parachutes are deployed



Table 6-57 Operational Timeline Segment, LES Aborts (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 00 18	Begin RCS helium purge/dump		Monitor CM RCS pressure indicator for pressure drop
	Close postlanding battery bus circuit breakers set main bus tie switches to OFF and open SPS gimbal motor circuit breakers		To avoid possible shorting of exposed wiring by sea water after touchdown certain circuits are opened
00 00 25	Automatic drogue chutes disreef (if main parachutes are not deployed before this time)		
t_1	Manual release of drogue chutes and deployment of main pilot chutes		t_1 is the time at which the altimeter reads 3300 feet
$t_1 +$ 00 00 10	Automatic main chute disreef		
(MODE II (61 SECONDS TO APPROXIMATELY 31 000 FEET ALTITUDE))			
00 00 00	Abort initiation		Automatically by the EDS or manually by twisting translation control clockwise
00 00 00 1	Booster engine cutoff		
	Event timer reset		
	CM-SM umbilical deadfaced		
	CM RCS pressurized and control transfer		
	Main d-c bus tied to batteries		
	LES main motor ignition		
	CM-SM separation		
00 00 10	Unlock EDS panel and deactivate caution and warning tone		
00 00 11	Canards deployed		
00 00 14	LET jettison		If the baroswitches have opened prior to 00 00 14 the ELS sequence will be delayed until baroswitch closing at approximately 23 500 feet
00 00 14 4	Apex cover jettison		
00 00 16	Automatic deployment of drogue chutes		
00 00 25	Automatic drogue chute disreef		



Table 6-57 Operational Timeline Segment, LES Aborts (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
t ₁	Automatic release of drogue chutes deployment of main pilot chutes		t ₁ is the time of low altitude baroswitch closing Refer to Block 35 for descent following t ₁
MODE III (31 000 TO 100 000 FEET ALTITUDE)			
00 00 00	Booster engine cutoff		Abort is initiated automatically by the EDS or manually by twisting translation control counter-clockwise
00 00 00 1	Abort initiated		
	Booster engine cutoff		
	Event timer reset		
	CM SM umbilical deadfaced		
	CM RCS pressurized and control transfer		
	Main d-c bus tied to batteries		
	CM-SM separation		
00 00 10	Unlock EDS panel and deactivate caution and warning tone		
00 00 11	Canards deployed		
00 00 14	ELS armed		
t ₁	Barometric switches close at approximately 23 500 feet altitude		
t ₁	LET jettison		
t ₁ + 0 4	Apex cover jettison		Refer to Parachute Descent Block 35 for details from apex cover jettison to touchdown
MODE IV (100 000 FEET ALTITUDE TO LET JETTISON)			
00 00 00	Abort initiated		Abort is initiated automatically by the EDS or manually by twisting the translation control counter-clockwise
	Booster engine cutoff		
	Event timer reset		
	CM SM umbilical deadfaced		
	CM RCS pressurized and control transfer		
	Main d-c bus tied to batteries		
	LES main motor ignited		
	CM-SM separation		



Table 6-57 Operational Timeline Segment, LES Aborts (Cont)

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
00 00 10	Unlock EDS panel and deactivate caution and warning tone		
00 00 11	Canards deployed		
00 00 12	Initiate a pitch rate of 5 deg/sec (approximate time)		Pitch rate is established by manipulation of rotation controller to avoid possible apex forward capture and/or a high g turnaround After CM pitch rate is established the CM RCS pitch channel only is disabled
t_1	High altitude barometric switches close at approx 23 500 feet altitude		
t_1	T jettison		
$t_1 + 0.4$	cover jettison		Refer to Parachute Descent Block 35 for details from apex cover jettison to touchdown

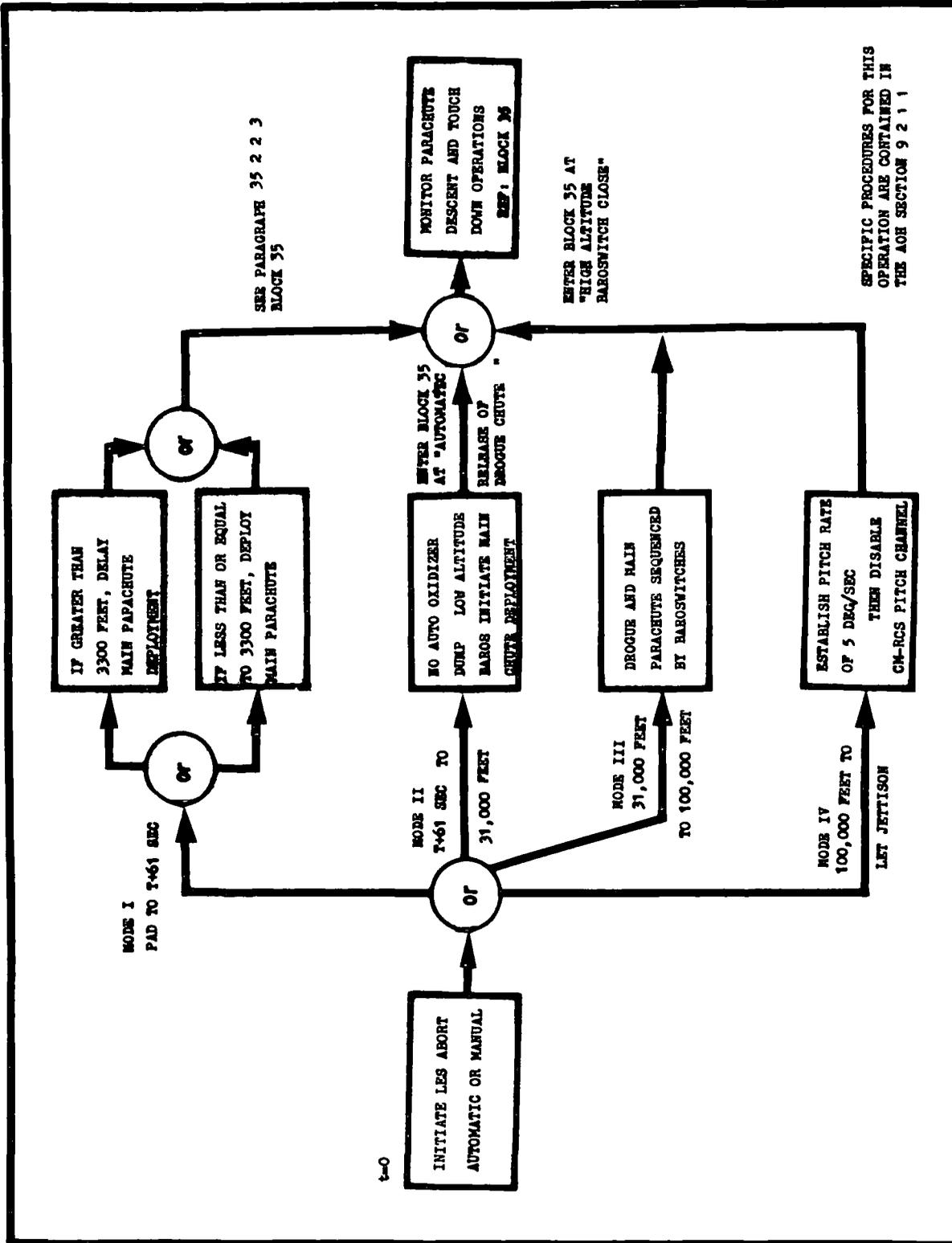


Figure 6-67 Building Block 42 Launch Escape System Aborts



BUILDING BLOCK 44 LAUNCH ABORT, SPS

44 1 INTRODUCTION

This block contains the abort-performance data related to that phase of the mission between launch escape system (LES) jettison and orbit insertion. The primary purpose is to define crew and vehicle operation procedures which are consistent with crew-survival criteria in the event of a booster malfunction. Included are the abort, coast, and entry-flight phases from booster malfunction to drogue deployment. BB-35 and BB-37 should be referenced for the descent and recovery phase following drogue deployment.

Crew-survival criteria for booster malfunctions which occur prior to this phase will be met with the LES (Abort Mode I). BB-42 should be referenced for abort data related to that phase of the mission between launch and LES jettison.

BB-44 includes the following abort and alternate modes: Abort Mode II, Abort Mode III, Alternate Mission Mode IVa, and Alternate Mission Mode IV.

44 2 ABORT MODE II

44 2 1 Introduction

Abort Mode II begins at LES jettison and will result in command module impact areas along the continuous recovery area which is located from 350 nautical miles east of the pad to 3200 nautical miles down range. Mode II terminates when the full positive-lift flight mode results in a range of 3200 nautical miles.

44 2 2 Summary

The following items summarize the major sequence of events for Abort Mode II:

- 1 Subsequent to booster-thrust tailoff the command service module (CSM) S-IVB separation will be performed utilizing the service module RCS to provide sufficient separation distance between the CSM and S-IVB for service propulsion system (SPS) ignition.
- 2 A short-duration SPS burn to assure nonrecontact between the CSM and the S-IVB will be performed.



- 3 Following CM SM separation the command module will maintain a constant full positive vertical lift flight mode to apex-cover jettison

44 2 3 Operational Data

The basic purposes of Abort Mode II are to insure nonrecontact between the booster and the CSM and to insure command module impact within the continuous recovery area (CRA)

44 2 3 1 Trajectory Limits, Initial Conditions, and Considerations

These consist of the following

- 1 All service module boost aborts will be performed manually by the crew
- 2 Service module aborts will insure water recovery in the CRA
- 3 Service module aborts will provide for no CSM-booster recontact
- 4 Vehicle attitudes will be determined visually in the event of a tumbled inertial measurement unit (IMU)
- 5 Minimum coast time from end of SPS burn to entry-threshold penetration will be seconds (Time will be determined)
- 6 The CM SM separation following abort will ensure against CM SM recontact
- 7 Command module will be oriented to within natural blunt-face forward-trim limits upon entry-threshold penetration
- 8 Full positive vertical lift flight mode will be employed during the entry trajectory
- 9 Minimum clearance distance of 45 inches must exist between the booster and the CSM prior to SPS ignition S-IVB thrust tailoff time = 1 85 seconds
- 10 Structural load limits

Location	Rate Limit at LES Jettison (deg/sec)	Rate Limit at S-IVB Cutoff (deg/sec)
S-IVB/IMU interface	133	210
CSM tension ties	108	136
SLA panel restraint cable	60	70



11 Pitch and yaw errors must not exceed degrees to avoid loss of electrical attitude-reference system (The limit will be determined)

12 Emergency detection system (EDS) limits

Rate limit deg/sec (To be determined)

Attitude limit deg (To be determined)

13 Limits for defining abort mode will be determined

44 2 3 2 Mission Functional Flow

See Figure 6-68

44 2 3 3 Operational Timeline Segment

See Table 6-58

44 2 3 4 Attitude Maneuvers

These are not available for abort maneuvers See BB-25 for CM SM separation and command module entry attitudes

44 2 3 5 Duty Cycles, Electrical Power Profile, and Propellant Consumption

These matters will be determined

44 2 4 Performance Data

This section contains the performance trade-off data associated with the boost abort maneuver and subsequent mission phases to apex cover jettison Performance data are presented in a continuous flow due to the interdependency of events occurring from abort to apex cover jettison

1 Decision to Abort through Abort Initiation

Performance associated with this phase of the mission concerns the nature of the booster malfunction and the crew reaction time The required crew functions are obtained from Table 6-53, Operation Timeline Segment Vehicle attitudes and attitude rates at S-IVB-CSM separation are presented in Figure 6-69 as a function of EDS delay time (crew reaction time) for a saturated actuator control signal in the instrument unit A saturated control signal forces the actuator to the hardover position in either pitch or yaw



Table 6-58 Operational Timeline Segment, Launch Abort, SPS

TIME (hr min sec)	TIME EVENT/OPERATION	TIME SOURCE	REMARKS
0			An SPS abort is indicated any time after LET jettison. This occurs at liftoff plus 182 seconds.
0	Commander rotate translation controller fully CCW (00 01)	G	Immediately following abort initiation the booster engine is cut off the event timer is set to zero signal of the abort initiation is given the G&N and direct ullage is started
00 01 7	SLA adapter separated	DG	
00 02 5	Stabilize spacecraft roll by SM RCS and SCS (00 10 5)	DG	In a hardover abort it may require a longer time to roll stabilize the spacecraft
00 13	Perform SPS manual ignition and termination of ullage (t)	G	Termination of ullage is accomplished after SPS ignition by manual rotation of the hand controller to the neutral position
t	Pressurize CM RCS (00 05)	G	The SPS engine may be fired to achieve sufficient altitude to ensure a safe entry or to achieve a degraded orbit depending upon the time of abort initiation
t+00 05	Perform CM SM separation (00 11)		See BB-25 for details. The remainder of the operations and events for entry is similar to the normal procedures



at the maximum rate of 8 degrees per second. Figure 6-70 presents the attitude and attitude rates at S-IVB/CSM separation as a function of EDS delay time for a loss of hydraulic pressure. For a loss of hydraulic pressure, it was assumed that the effective torque generating thrust vector simultaneously slews the actuator to both pitch and yaw stops in 0.5 seconds.

2 Abort Initiation to Atmospheric Entry

This section pertains to the coast phase from abort initiation to atmospheric entry. The major events which occur during this phase include attitude orientation for CSM-booster separation, CM-SM separation, and for CM orientation for atmospheric entries.

The CSM-booster separation attitude cannot be defined without knowledge of the booster malfunction. As indicated in section (1) the attitudes of the booster for various malfunctions vary significantly with the crew reaction time. Reference to Block 25 identifies the attitudes for CM-SM separation and CM entry.

The allowable time during which the required maneuvers must be performed is presented on Figure 6-73 as a function of flight time at abort for the reference 85/130 nautical-mile boost trajectory. The figure includes coast times for free-fall aborts and for aborts with a short duration (11 sec) SPS thrust period at an attitude consistent with the reference boost trajectory at the time of abort. Coast times are presented to entry interfaces of 300,000 and 400,000 feet altitude and to the threshold g-level. Apogee of the conics resulting from aborts near LES jettison is less than the 400,000 feet entry interface. The figure indicates approximately 100 seconds additional time is obtained with the powered abort mode.

3 Atmospheric Entry to Apex Cover Jettison

The performance trade-off data associated with this phase were obtained assuming a rotating, oblate Earth model encompassed by the 1962 U.S. Standard atmosphere. A CM weight of 11,000 pounds was assumed with an aerodynamic trim lift-drag ratio of 0.34. On each figure data is included for free-fall aborts and for short duration SPS powered aborts.

The steepest entry (400,000 feet) flight path angle resulting from boost abort is -12.5 degrees at an abort time of $\cong 290$ seconds as indicated in Figure 6-74. The figure also shows that the entry velocity corresponding to this abort time is a relatively slow 10,500 fps. Altitude at the threshold g-level is shown in Figure 6-75.



as a function of flight time at abort. The figure indicates that the altitude at which the entry threshold is attained varies by approximately 40,000 feet for the abort times investigated.

Entry time from 400,000 feet to apex cover jettison is illustrated on Figure 6-76 as a function of flight time at abort. Entry time increases asymptotically with abort time. The figure is misleading for aborts near LES jettison in that it indicates a minimum entry time of 240 seconds results from boost abort. When utilizing the data it must be realized that apogee of the conics resulting from aborts near LES jettison is less than 400,000 feet and therefore no entry time is given. The abort time which results in a 400,000 feet apogee corresponds to the zero slope on the curve.

Maximum load factor data resulting from boost aborts are shown on Figure 6-77. The figure illustrates the maximum load factor obtained during entry trajectories resulting from aborts at various flight times. The highest maximum load factor (12.5g's) results from an abort at approximately 400 seconds booster flight time.

Utilization of AM-II is based on the criteria that recovery occurs in the CRA which is defined as $350 \text{ nautical mile} \leq \text{CRA} \leq 3200 \text{ nautical mile}$ along the launch azimuth. Figure 6-78 illustrates the total range from launch to apex cover jettison and indicates AM-II is applicable for aborts occurring at the flight times examined.

Heating data are presented in Figures 6-79 and 6-80 for SM boost aborts. The total heat load (Figure 6-79) and maximum heat rate (Figure 6-80) for aborts occurring at flight times investigated do not exceed the thermal limitations defined in Block 25.

44 3 ABORT MODE III

44 3 1 Introduction

Abort Mode III begins when the constant full positive vertical-lift flight mode results in an impact area 3200 nautical miles from the launch site. For near nominal S-IVB boost trajectories, Abort Mode III capability exists at orbit insertion.

44 3 2 Summary

The following items summarize the major sequence of events for Abort Mode III.

- 1 This is the same as 44 2 2 (1)
- 2 This is identical to 44 2 2 (2)



- 3 Following CM SM separation, the command module will maintain a constant half-lift flight mode to apex-cover jettison in the discreet recovery area (DRA)
- 4 If required, an SPS fixed-attitude retrograde burn will be performed to position the half-lift impact area within the DRA

44 3 3 Operational Data

The basic purpose of Abort Mode III is to insure nonrecontact between the S-IVB and the CSM and to insure command module impact in the DRA

44 3 3 1 Trajectory Limits, Initial Conditions, and Considerations

These consist of the following items

- 1 This is the same as 44 2 1 (1)
- 2 Service module aborts will be performed to insure water recovery in the DRA
- 3-7 These are the same as those of 44 3 1 3 through 7
- 8 A constant half-lift flight mode will be employed during entry trajectory
- 9-13 These items are identical to those of 44 3 1, 9 through 13

44 3 3 2 Mission Functional Flow

See Figure 6-70

44 3 3 3 Operational Timeline Segment

See Table 6-58

44 3 3 4 Duty Cycles, Electrical Power Profile, and Propellant Consumption

These matters will be determined

44 4 ALTERNATE MISSION MODE IVa

44 4 1 Introduction

Alternate Mission Mode IVa capability exists when there is sufficient CSM propulsion capability available to achieve an acceptable CSM orbit



within a minimum perigee (75 nautical miles) Mode IVa is characterized by the necessity of performing two SPS burns to achieve an acceptable CSM orbit

44 4 2 Summary

The following items summarize the major sequence of events for Alternate-Mission Mode IVa

- 1 This is the same as 44 2 2, item 1
- 2 The first SPS burn is performed approximately two minutes following S-IVB cutoff and results in high positive flight-path angles
- 3 The second SPS burn is performed at apogee and results in an alternate orbit

44 4 3 Operational Data

The basic purpose of Alternate Mission Mode IVa is to prevent mission termination and to provide for an alternate mission

44 4 3 1 Trajectory Limits, Initial Conditions, and Considerations

These comprise the following matters

- 1 This is the same as 44 2 3, item 1
- 2 Service module aborts will be performed to ensure orbit with perigee of 75 nautical miles
- 3 These are the same as 44 2 3, 3 and 4
- 4 See BB-25 for applicable data
- 5 See BB-25 for applicable data
- 6 See BB-25 for applicable data
- 7 See BB-25 for applicable data
- 8-11 These are identical to 44 2 3, 9 through 12
- 12 The SPS has the capability to abort to orbit with perigee of 75 nautical miles after seconds mission-flight time (Time will be determined)



44 4 3 2 Mission Functional Flow

See Figure 6-70

44 4 3 3 Operational Timeline Segment

See Table 6-58

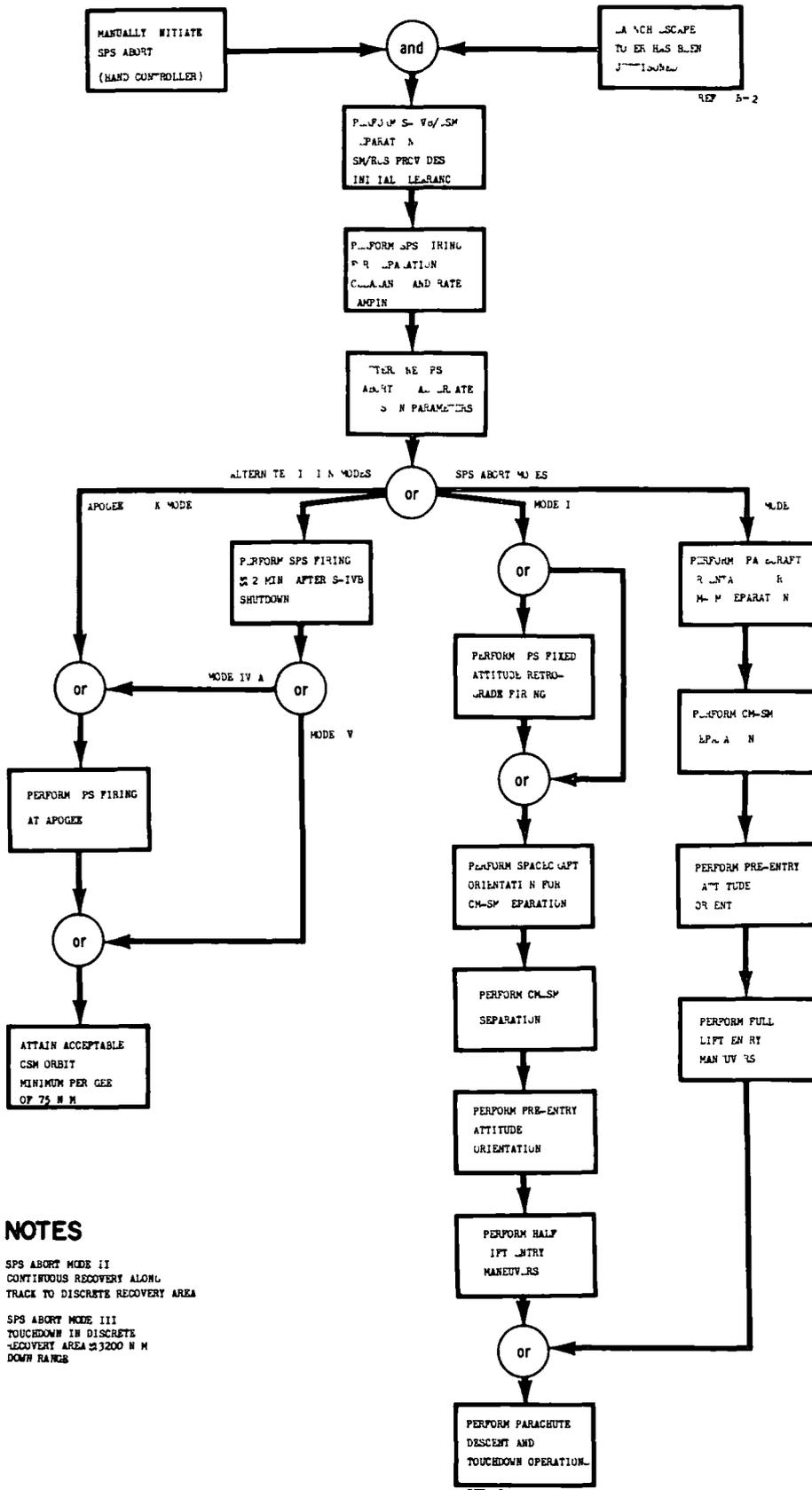
44 4 3 4 Duty Cycles, Electrical Power Profile, and Propellant Consumption

See BB-25 for applicable data

44 5 ALTERNATE MISSION MODE IV

44 5 1 Introduction

Alternate Mission Mode IV is identical to Alternate Mission Mode IVa except that only one SPS burn is required to achieve an acceptable CSM orbit. The SPS burn will be performed approximately two minutes following S-IVB cutoff.



NOTES

SPS ABORT MODE II
CONTINUOUS RECOVERY ALONG
TRACK TO DISCRETE RECOVERY AREA

SPS ABORT MODE III
TOUCHDOWN IN DISCRETE
RECOVERY AREA 23200 N M
DOWN RANGE

Figure 6-68 Building Block 44 SPS Aborts and Alternate Missions

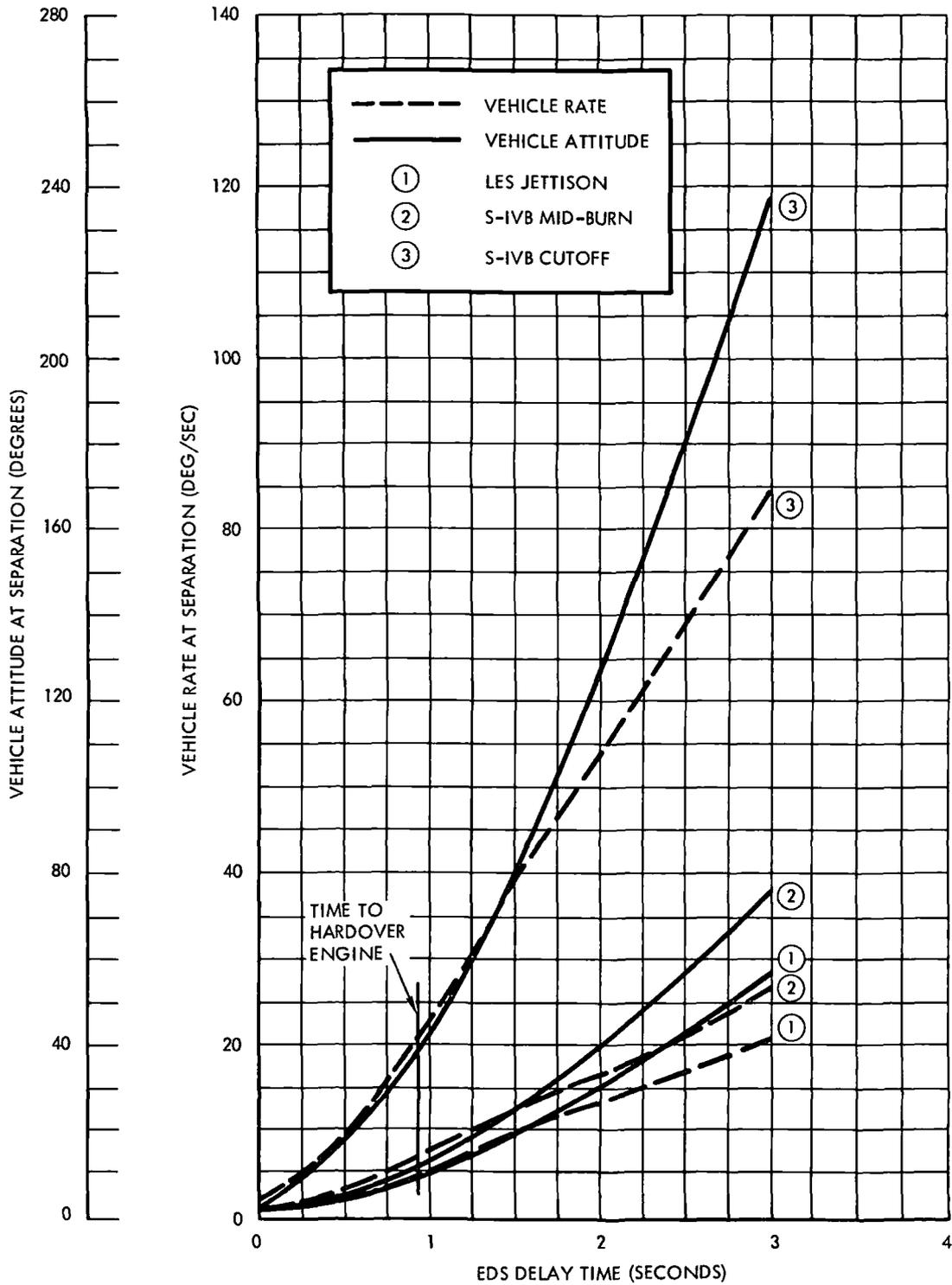


Figure 6-69 CSM/S-IVB Vehicle Dynamics, J-2 Hardover in Pitch or Yaw, Saturated Control Signal

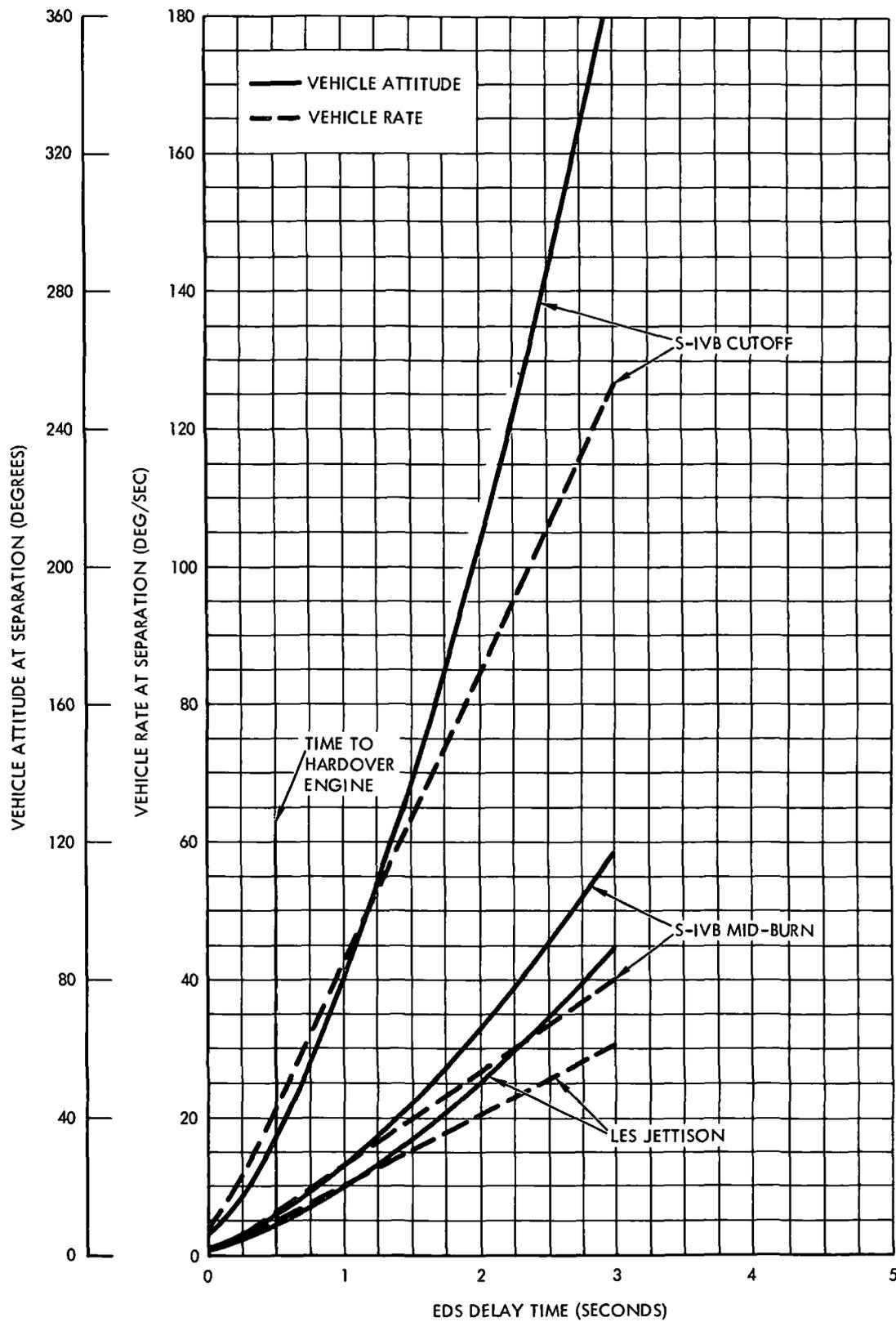


Figure 6-70 CSM/S-IVB Vehicle Dynamics, J-2 Hardover in Pitch and Yaw, Loss of Hydraulic Pressure

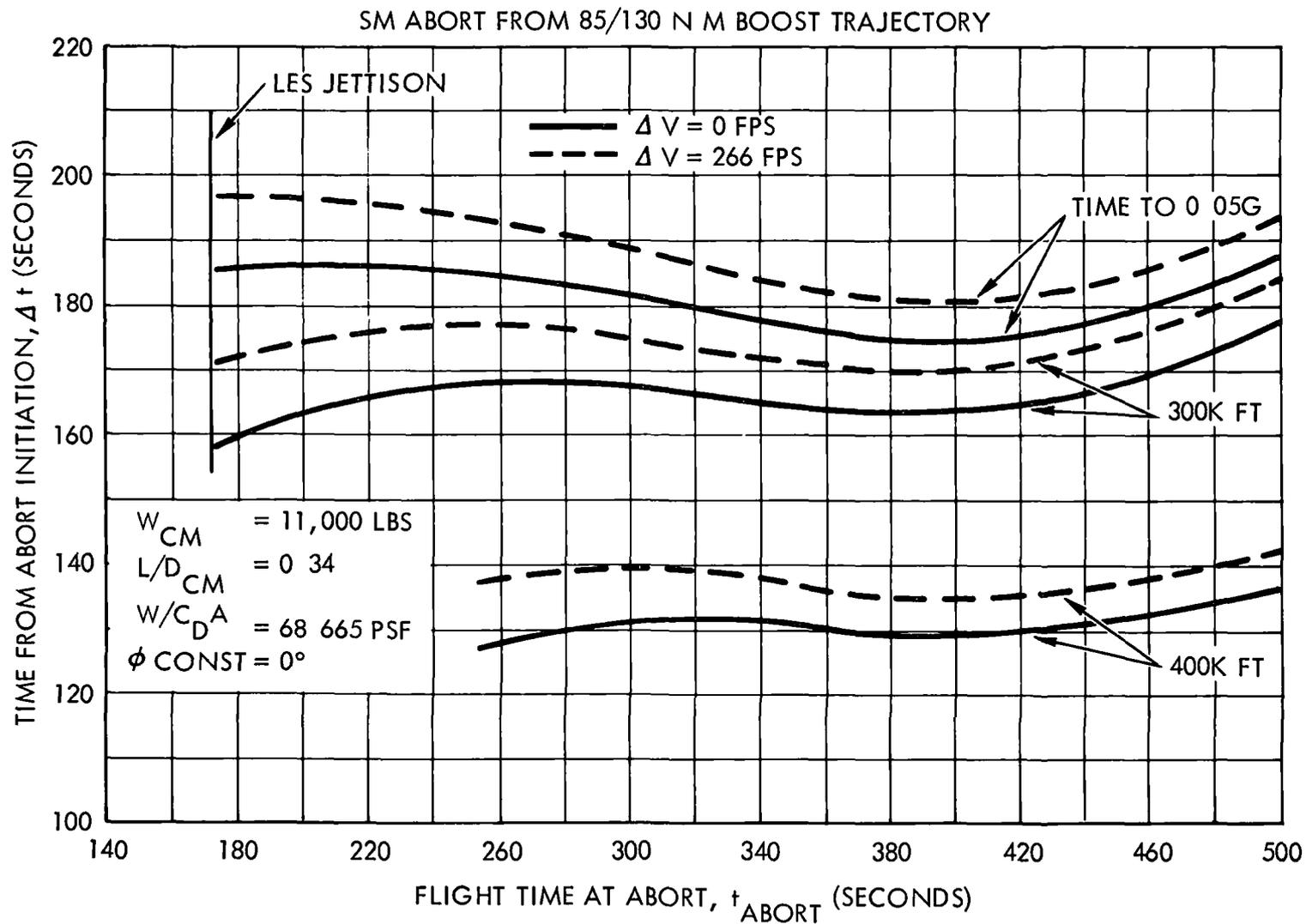


Figure 6-71 Coast Time as a Function of Flight Time at Abort

6-309

SID 66-1177

SM ABORT FROM 85/130 NM BOOST TRAJECTORY
 NOTE ENTRY ASSUMED AT 400K FT

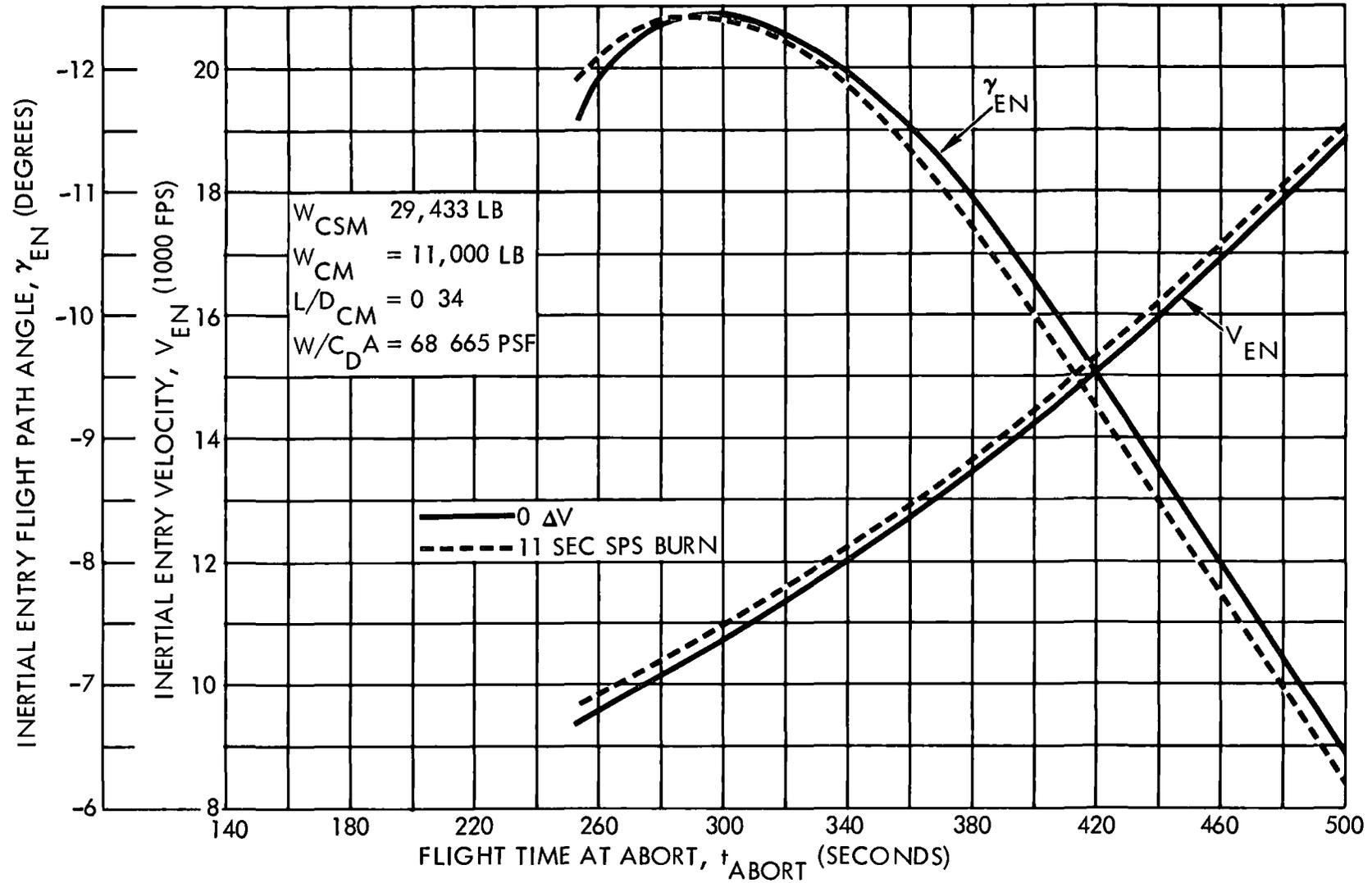


Figure 6-72 Entry Parameters as a Function of Flight Time at Abort

6-310

SID 66-1177



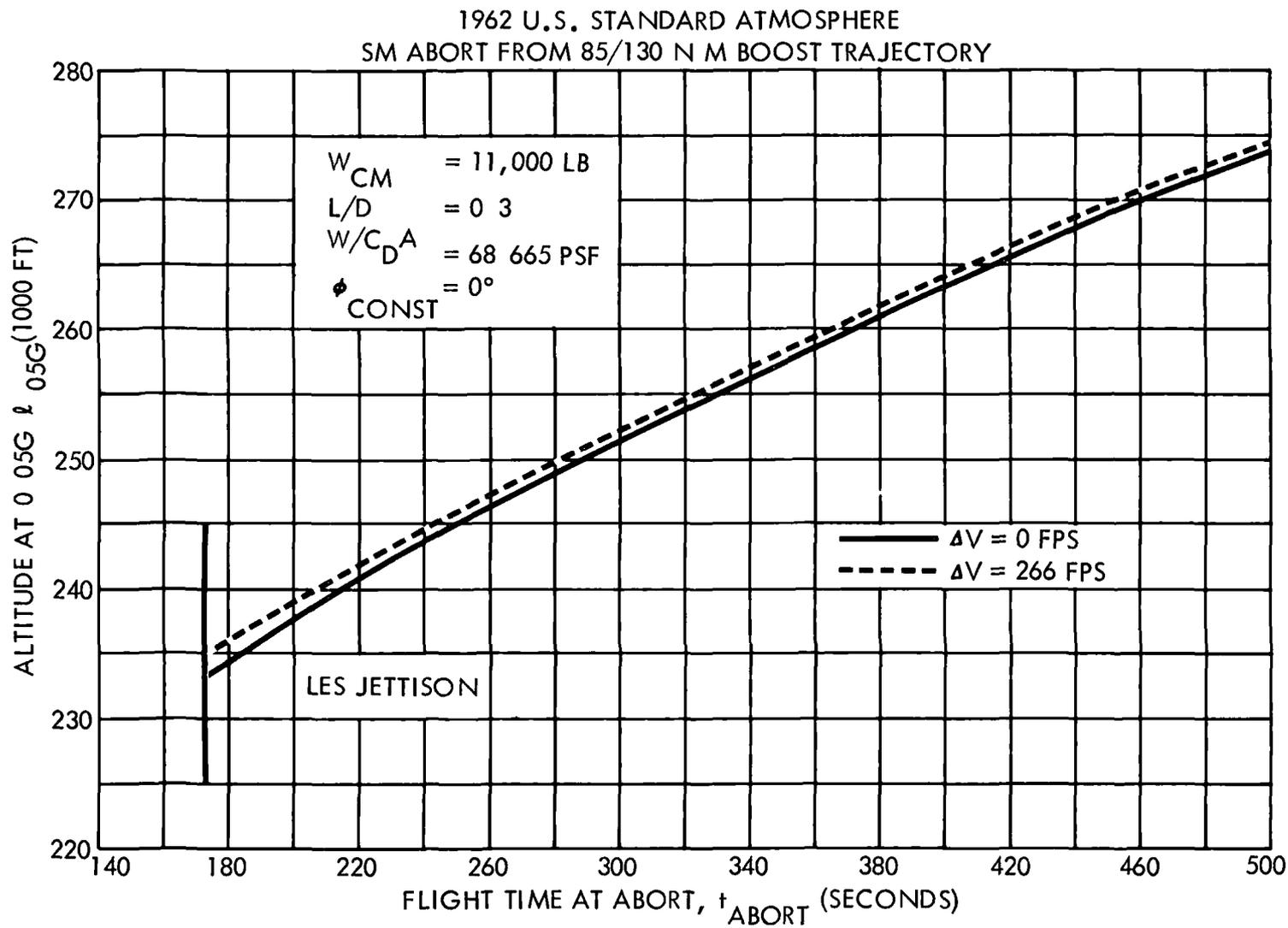


Figure 6-73 Altitude at Entry Threshold as a Function of Flight Time at Abort

6-311

SID 66-1177

1962 U.S. STANDARD ATMOSPHERE
SM ABORT FROM 85/130 NM BOOST TRAJECTORY

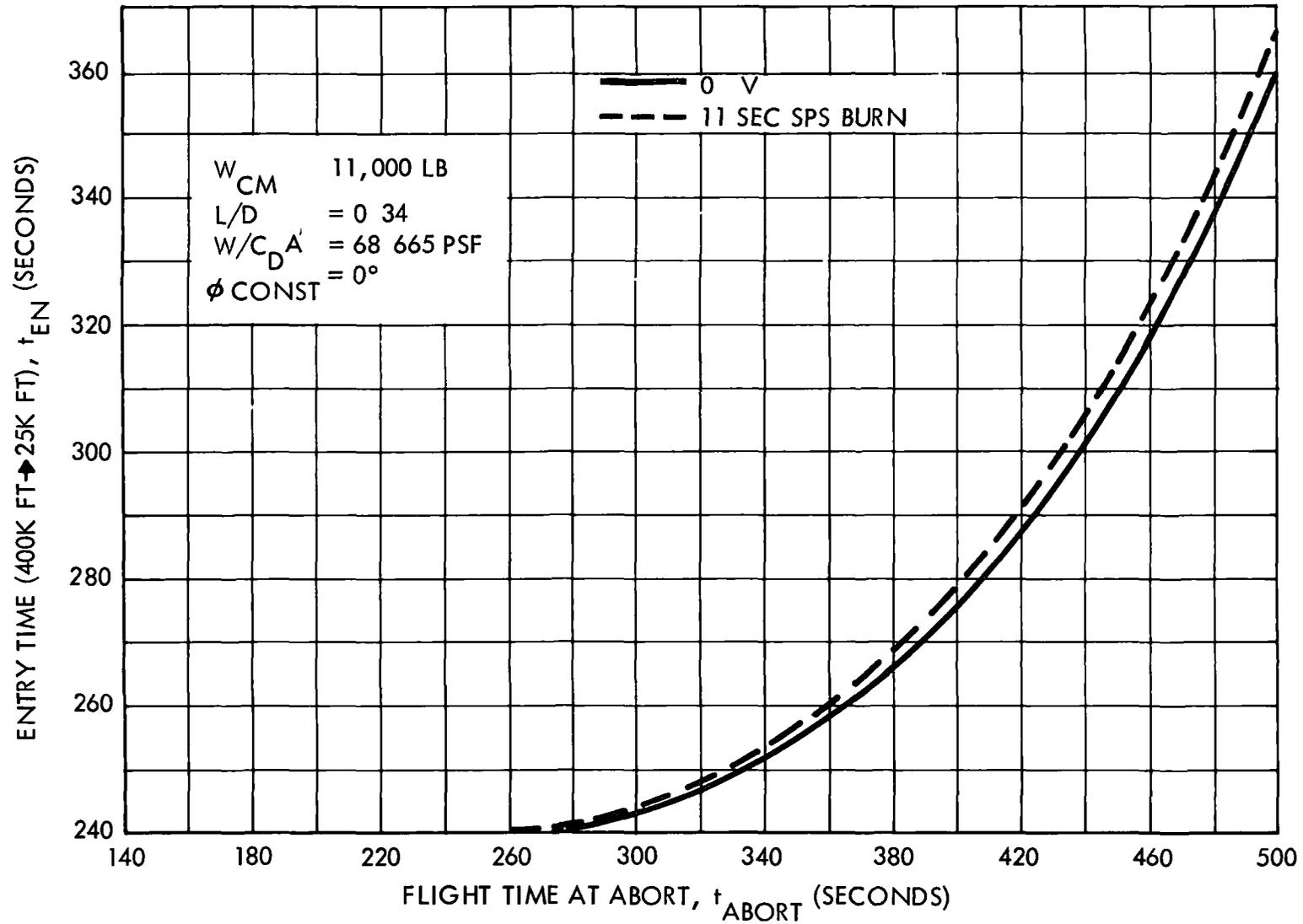


Figure 6-74 Entry Time as a Function of Flight Time at Abort

6-312

SID 66-1177





1962 U S STANDARD ATMOSPHERE
SM ABORT FROM 85/130 N M BOOST TRAJECTORY

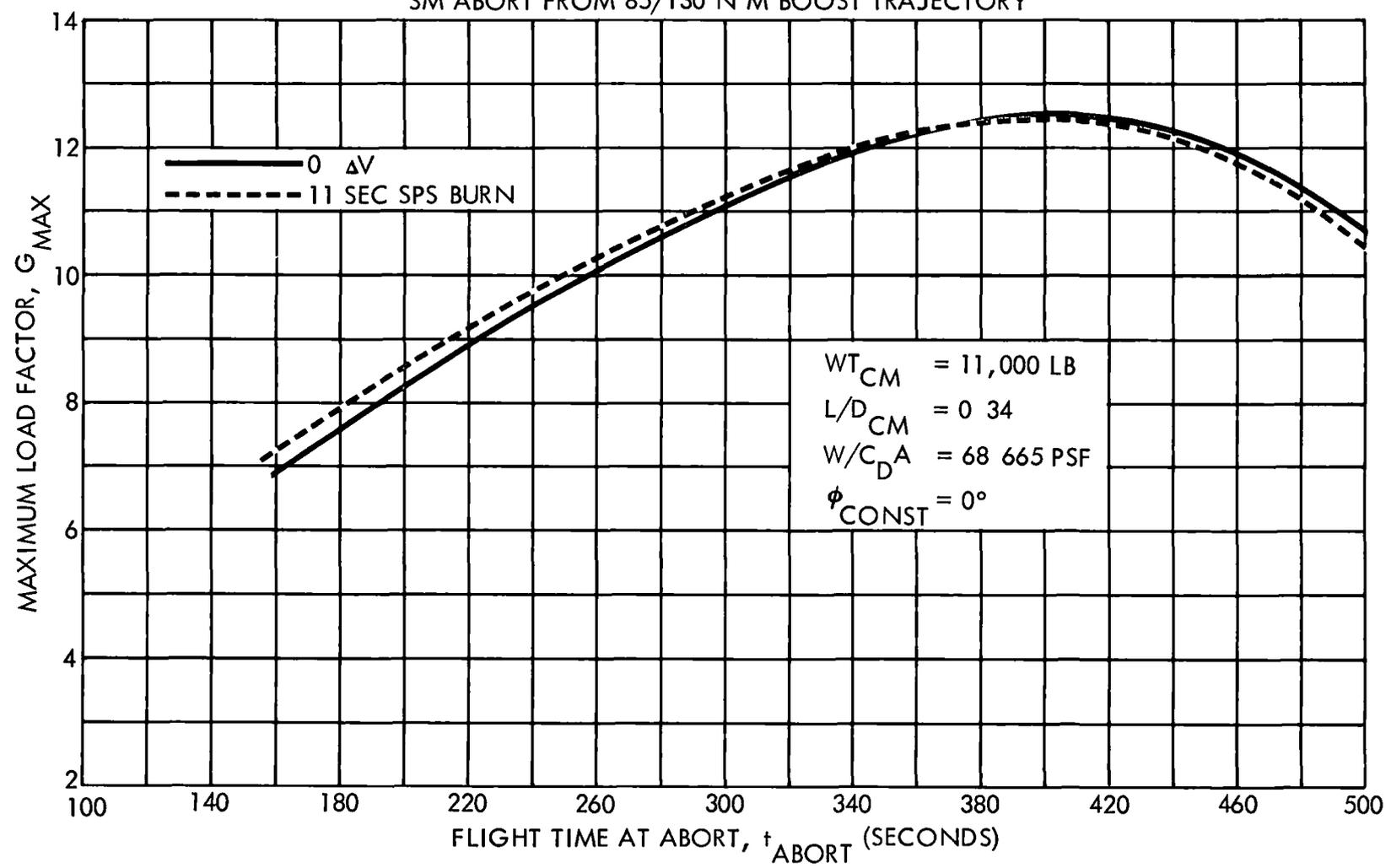


Figure 6-75 Maximum Load Factor as a Function of Flight Time at Abort

6-313

SID 66-1177

1962 U S. STANDARD ATMOSPHERE
SM ABORT FROM 85/130 N M BOOST TRAJECTORY

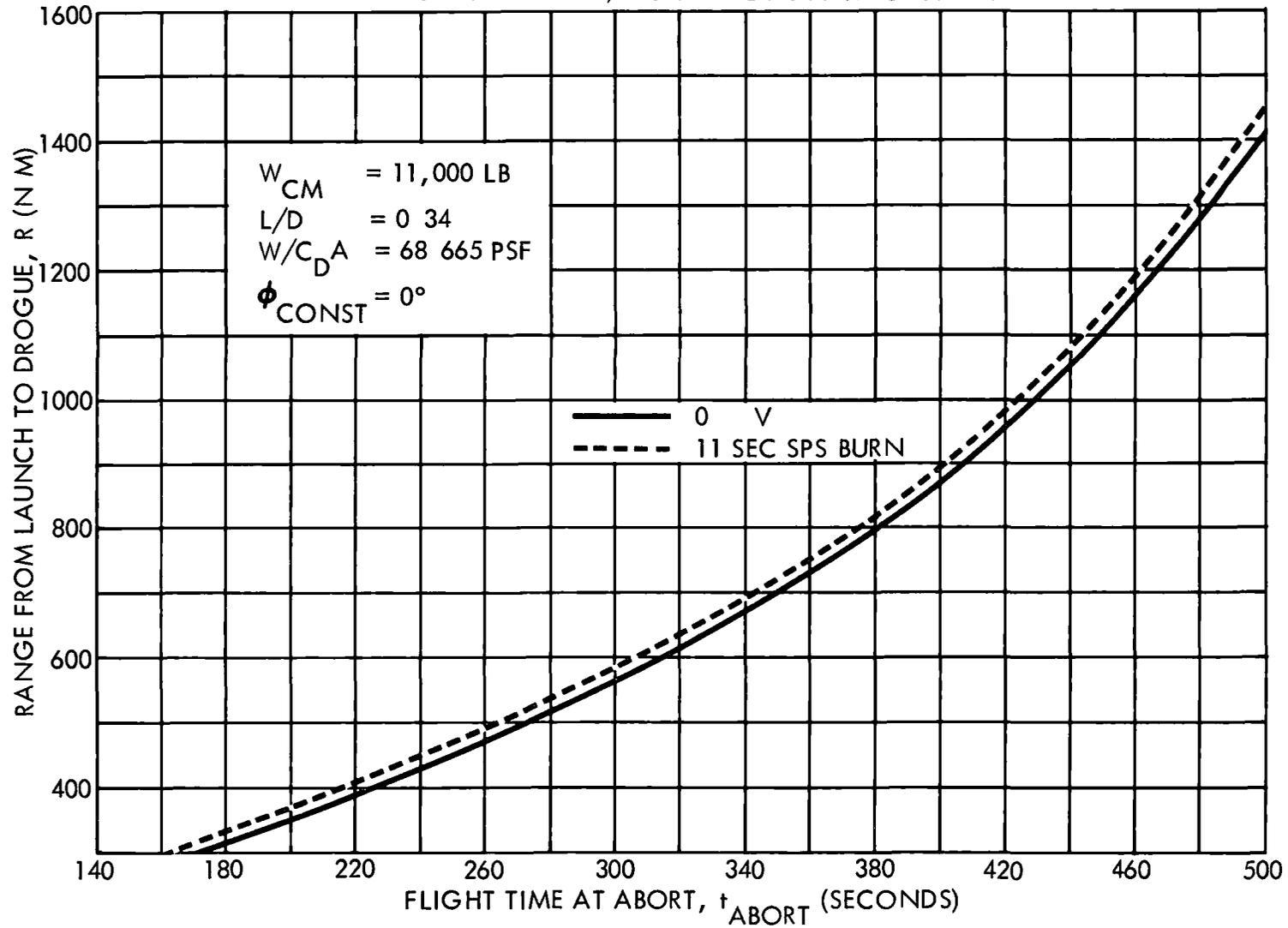


Figure 6-76 Total Range as a Function of Flight Time at Abort

6-314

SID 66-1177



1962 U.S. STANDARD ATMOSPHERE
SM ABORT FROM 85/130 N M BOOST TRAJECTORY

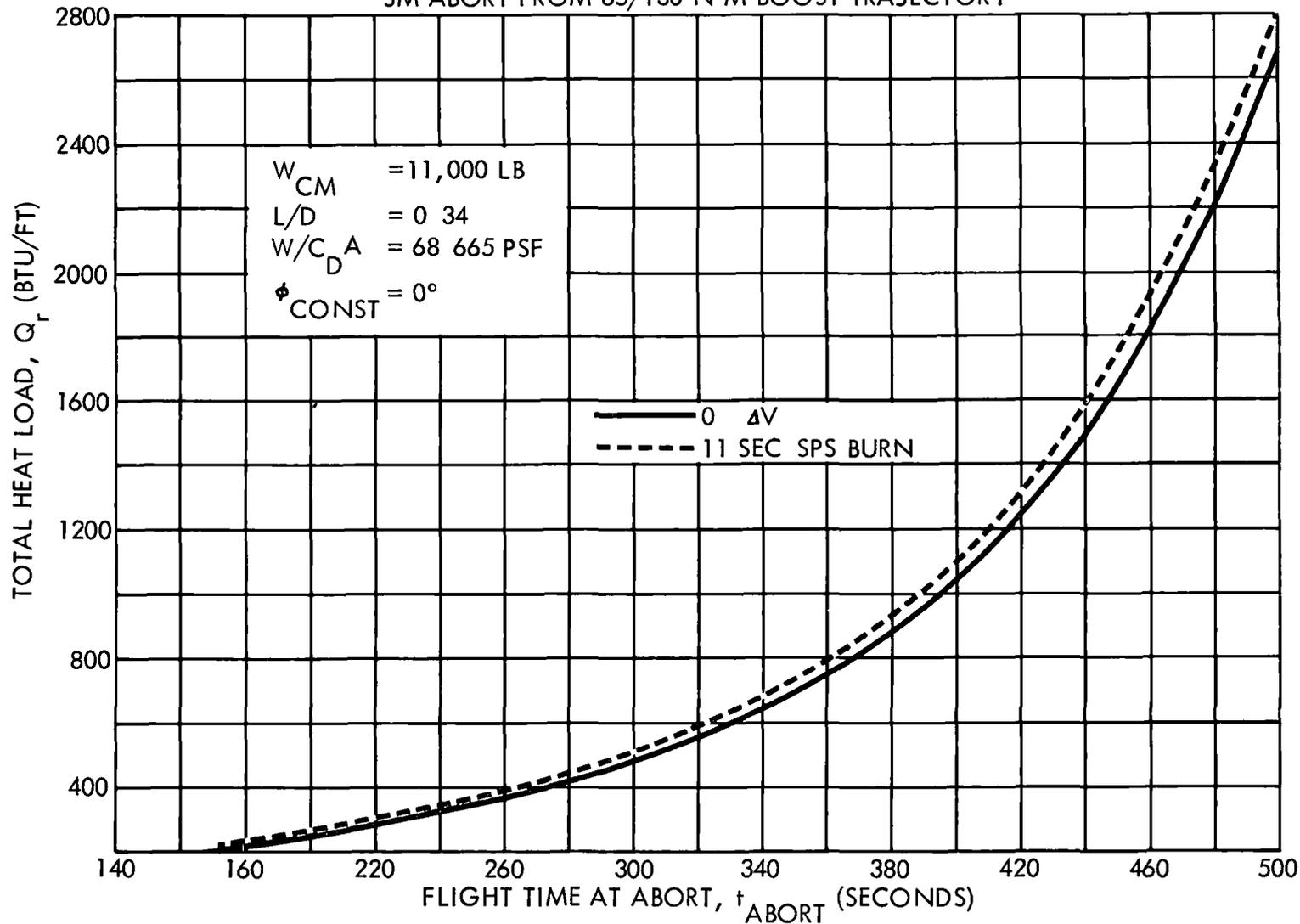


Figure 6-77 Total Heat Load as a Function of Flight Time at Abort

6-315

SID 66-1177



1962 U.S. STANDARD ATMOSPHERE
SM ABORT FROM 85/130 N M BOOST TRAJECTORY

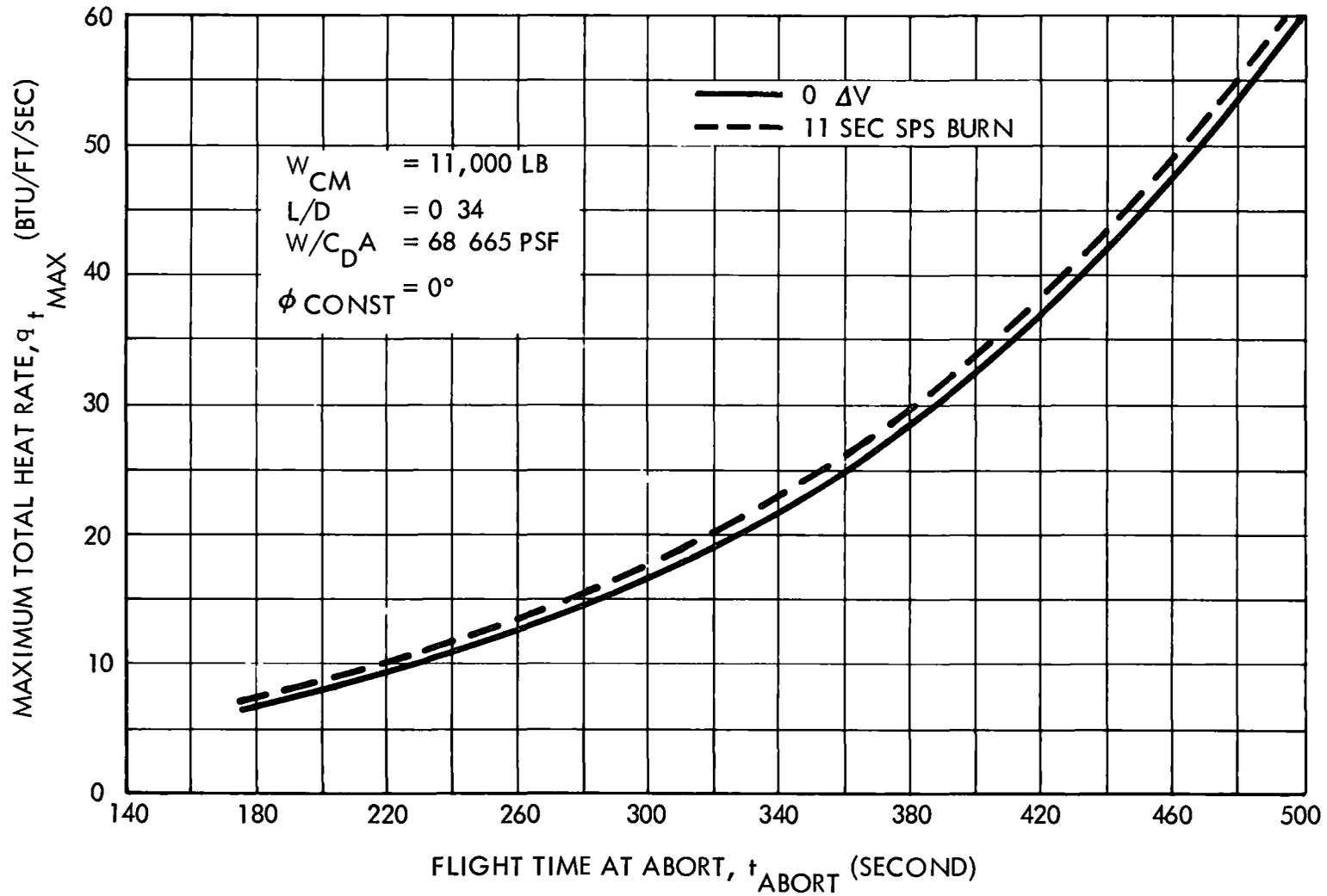


Figure 6-78 Maximum Total Heat Rate as a Function of Flight Time at Abort

6-316

SID 66-1177





BUILDING BLOCK 45 WATER BOILER FAILURE

45 1 INTRODUCTION

It is assumed that the supplemental cooling capability of the water-glycol evaporator and the water boiler incorporated in the environmental control subsystem (ECS) suit circuit has failed. Causes of this type of failure are not specified for the purpose of this block.

45 2 DETERMINATION OF PROBLEM

The extent of water-boiler failure can be determined by monitoring temperature gauges and by switching electrical power loads ON-OFF in accordance with the malfunction procedures detailed in the Apollo Operations Handbook (AOH), Paragraph 9 1 6.

45 3 IMMEDIATE ACTION REQUIRED

In the case of failure, take immediate action by means of these steps:

- 1 Deactivate the inoperative water-glycol evaporator temperature-control valve in the closed position so that there will be full coolant flow through the space radiators. Manually adjust valve if the radiator coolant outlet temperature does drop below the specified level of 40 F.
- 2 Deactivate the inoperative suit-circuit water-glycol evaporator temperature-control circuit and manually close the diverter valve for full coolant flow through heat exchanger.
- 3 Deactivate the cabin heat-exchanger temperature-control circuit and manually set temperature to full heat. This will ensure that the electronic thermal load will receive full coolant flow. Turn cabin fans OFF and don suits.

45 4 RECOMMENDED ACTIONS AS REQUIRED FOR DEGRADED MISSION

For a degraded mission, take action according to the following recommendations:

- 1 In the event a powered-down condition is possible, a reduction in radiator load commensurate to the heat rejection capabilities



is accomplished by a reduction in command module electrical power in accordance with external heat load. In this case, assuming average electrical loads, external thermal loads, metabolic loads and heat-rejection rates, it will be necessary to reduce command module electrical power to approximately 800 watts. With approximately 700 watts being consumed in the service module, the total level at the fuel cells must average 1500 watts.

It is permissible to allow electrical power excursions to 1300 watts if, within one-half hour, it is compensated for by increasing power to 1700 watts. The system can accommodate 100-watt hour excursions if compensated in order to maintain a 1500-watt hour average, which in turn is expected to result in a 40 to 55 F radiator-outlet temperature range. Greater excursions are permissible if the electrical load dissipation in command module is unaffected.

2. In order to compensate for command module electrical power excursions above 800 watts and to maintain an average command module electrical load consistent with the average space radiator heat-rejection rate, it may be necessary to reduce the command module electrical load to less than the electrical load identified in Building Block 9, Apollo Mission 1, powered down drifting flight. The following electrical loads could be turned OFF or reduced without imposing significant constraints:

Components	Power Load Reduction (watts)
Environmental Control Subsystem	
Turn OFF inoperative water-glycol evaporator temperature-control subsystem consisting of the following:	37.2
Backpressure control	
Backpressure-control valve	
Wetness control	
Backpressure sensor	
Glycol-evaporator control valve	
Glycol-temperature control	
Glycol temperature-control valve	



Components	Power Load Reduction (watts)
Turn OFF inoperative suit-circuit evaporative section consisting of the following	42 0
Backpressure control	
Glycol valve	
Wetness control	
Glycol-diverter valve	
Water-control valve	
Backpressure valve	
Deactivate cabin heat-exchanger temperature-control subsystem and place on manual	51 0
Subsystem components are as follows	
Cabin-temperature control	
Cabin temperature-control valve	
Fans (turned OFF)	
Reduce potable and waste water tank quantity instrumentation duty cycles to 50 percent	2 5
Reduce potable water heaters duty cycles to 10 percent for the 35-watt heaters and 40 percent for the 10-watt heaters	7 5
G&N Subsystem	
Turn off AGC from standby mode	15 0
Communications Subsystem	
Reduce VHF/FM transmitter to approximately 25 percent, limit telemetry to selected MSFN stations	15 0
Turn UHF-updata link OFF, use voice only	
Turn 2-KMC antenna switch since S-band transmission is not utilized	15 0
Reduce VHF/AM transmit standby to approximately 2 percent	6 5



Components	Power Load Reduction (watts)
Service Propulsion Subsystem Do not activate propellant-utilization subsystem	0 8
Displays and Controls Reduce lighting cycles to approximately 50 percent of average cycles	8 0
Instrumentation Approximately 110 watts are allocated to this function, it is expected that some nonessential instrumentation may be turned off	

- 3 It will also be operationally necessary to monitor radiator-outlet temperature to ensure that it is between 40 and 55 F The following steps are taken
- a CSM thermal passive-attitude control is maintained
 - b A roll rate of two or more revolutions per hour with random pitch and yaw attitudes is established to stabilize external thermal conditions
 - c These performance predictions assume unsooted ECS radiators



7 0 TEST OBJECTIVES

7 1 INTRODUCTION

This section provides the visibility necessary for test objective accomplishment while real-time mission planning redesign is performed by use of building blocks. Accomplishment of test objectives is not an automatic result of performance of building blocks, because the test objective, test condition, and data requirements are not inherent elements of the building blocks. Therefore, a test objective accomplishment data sheet (TOADS) is provided for each objective which lists the test conditions, related objectives, and data requirements.

Test condition identification in the TOADS guides the mission designer by listing either the building blocks, special tests, or unique procedures which permit test objective accomplishment. Where necessary, the deltas (Δ 's) to a building block, as a result of test objective accomplishment, are identified as well as any lighting or other restrictive conditions. The mission designer is also provided correlation with the applicable procedure of the AOH.

The TOADS, under Data Requirements, provide the mission designer with sufficient guidelines to enable him to program test objective accomplishment to the highest degree desired. These guidelines consist of pulse code modulation (PCM) data rate at either high bit rate (HBR) or low bit rate (LBR), recommendations with respect to use of telemetry (T/M) or data storage equipment (DSE), frequency and duration of data acquisition, identification with respect to maximum and minimum data acquisition requirements, astronaut support, related objectives, etc.

The heart of this section is the two matrices (Building Block/Test Objective Matrix, Figure 7-1, and Test Objective/Test Objective Matrix, Figure 7-2) which both supplement and summarize the TOADS. The logic used in generating these matrices derives from the fact that real-time mission planning redesign will be achieved by call up of the building blocks. The correlation coding of the matrices identifies which building blocks and/or test objectives accomplish or govern the accomplishment of test objectives as well as the results of mission design decisions as regards data acquisition. The matrices can also be used as a test objective accomplishment checklist during the mission. For convenience, a short-form test objective has been used in the matrices.



The basic assumptions which controlled the matrix correlation of test objectives were as follows

- 1 Test objective accomplishment will be achieved by the operational performance of building blocks. Therefore, maneuver and/or mode objectives such as use of proportional rate, wide deadband, etc., are assumed to be achieved during such appropriate mission operations as inertial measurement unit (IMU) alignment, navigation sightings, drifting flight (powered down), etc.
- 2 All potential data sources (maneuver, operation, etc.) for a given test objective are identified to the fullest extent possible. It is not to be assumed that all indicated sources are required for objective satisfaction. However, it is highly desirable that all operations susceptible to variation as a function of astronaut performance be accomplished by as many astronauts as is practical.
- 3 Those objectives which do not occur as a result of a building block are identified as a special test (ST) and related to the domain of the objective or building block most closely associated as a function of time, test conditions, or operation.

No attempt has been made to evaluate the degree of test objective accomplishment possible by performing any given building block or objective once or many times. Because the degree of accomplishment is a function of many variables (quantity of data gathered, validity of specific maneuver or operation, repeatability of test parameters, etc.) which are difficult to positively control before a mission, the evaluation has been left as a post-mission or possibly post-test objective task.

Test objective satisfaction implies that a sufficient quantity of data be gathered to support the analytical requirement. Almost all of the test objectives, as identified by the TOADS, require HBR PCM data (51.2 kbps). As building blocks are called up and the concomitant test objectives are accomplished, the relationship between objective duration, Manned Space Flight Network (MSFN) contact, and analytical (i.e., data) requirements must be closely monitored. Certain revolutions over the North American continent during an earth orbital mission provide approximately 16 minutes of continuous real-time PCM T/M. This latter factor makes these revolutions the most desirable for purposes of test objective accomplishment.

The Measurement Operational Readiness Requirements (MORR), Appendix B of SID 65-304-1, supports test objective accomplishment by identifying the measurements required as well as test objective applicability. The MORR may be used for detailed information with respect to measurement test objective support.



7 2 POTENTIAL PROBLEMS

The basic problem of test objective accomplishment in earth orbit is data acquisition. This in turn can be divided into two elements, both of which should be considered by the mission designer. These two elements are the decision as to what quantity of data is to be acquired (identified in the TOADS as the choice between maximum or minimum data acquisition) and when and/or how the DSE will be used to acquire HBR PCM.

Although almost all of the test objectives could be satisfied by the mere fact of their occurrence (i.e., Demonstrate), quantitative analysis, if desired, requires quantitative data. The data acquisition period varies not only from test objective to test objective but also within a test objective as a function of the extent of analysis desired. An example of the latter would be the test objective for demonstration of IMU alignment whose building block can be regarded as a maneuvering sub-block and an alignment sub-block separated by an Apollo guidance computer (AGC) program. If it is sufficient to solely demonstrate alignment, then the minimum data acquisition need consist only of verbal comment and/or PCM T/M or on-board determination of the desired and actual IMU gimbal alignment. If it is desirable that this operation (or governing test objective) be used as a maximum data acquisition (i.e., acquire data on guidance and navigation (G&N) attitude control, proportional rate, maximum deadband, etc.), then the data acquisition period is synonymous with both sub-blocks if not the entire block. Time-over-station (TOS) is now the governing factor in the mission designer's decisions. Obviously, the mission designer will have to establish a priority ranking between what he needs as against what he can acquire. This means in effect that the mission designer must plan his data acquisition as well as his sequential operations to assure that sufficient data are acquired coincident with the logical flow of the mission.

Use of the DSE to support the data acquisition periods of test objectives performed fully or partially off-station and whose data requirement is HBR PCM necessitates careful planning. The unfavorable playback ratio of 1:1 for DSE recorded HBR PCM can introduce severe data management problems. For this reason, some technique of in-flight data management is recommended. Certain of the long-term test objectives whose data are quasi-static have been suggested as being conducive to a technique of real-time editing during data acquisition in their respective TOADS. A typical example would be a thermal oriented objective whose duration of data acquisition is one hour and requires HBR PCM. These data could be gathered by periodic short-burst operation of the DSE during data acquisition so that total data accumulated can be dumped during one station pass (i.e., 5 seconds of data every 5 minutes for one hour for a total of 300 seconds, assuming an average TOS of 5 minutes). Variations of this technique could be used for long-term dynamic objectives by initiating an



IMU alignment over Hawaii, record on DSE, complete the alignment over Guaymas, dump the DSE to Corpus Christi, and perform the service propulsion subsystem (SPS) ΔV over Antigua

7 3 TEST OBJECTIVE ACCOMPLISHMENT DATA SHEETS

The following data sheets are organized sequentially by the test objective numbers identified in Figure 7-2



- P 1 1 1 Demonstrate astronaut capability to align the IMU using sextant, scanning telescope, and AGC

This objective will be accomplished in conjunction with objective P 2 1 3 Refer to objective P 2 1 3 for accomplishment data

- P 1 1 2 Demonstrate astronaut capability to align the vehicle to a pre-determined inertial attitude by use of the scanning telescope in conjunction with the rotation and attitude impulse controls

This objective will be accomplished in conjunction with objective P 2 1 4 Refer to objective P 2 1 4 for accomplishment data

- P 1 1 3 Demonstrate astronaut ability to determine orbital parameters by earth landmark tracking using the scanning telescope and the AGC

This objective will be accomplished in conjunction with objective P 2 1 5 Refer to objective P 2 1 5 for accomplishment data

- P 1 1 4 Demonstrate astronaut capability to support updating of the AGC from MSFN via updata link and voice modes

This objective will be accomplished in conjunction with objective P 4 1 1 Refer to objective P 4 1 1 for accomplishment data

- P 1 1 5 Deleted

- P 1 1 6 Demonstrate astronaut capability to perform a midcourse star-landmark angle measurement using the sextant

TEST CONDITIONS

No special test conditions or procedures are required other than those identified in BB-8, Celestial Navigation

DATA REQUIREMENTS

Maximum data acquisition requires either continuous HBR PCM T/M or HBR PCM selectively recorded on DSE by the astronauts throughout the initial maneuvering phase of the building block (approximately 18 minutes) and continuous HBR PCM T/M throughout the succeeding celestial sighting phase of the



building block (approximately 10 minutes) Maximum data acquisition only during the second, or celestial sighting, phase of the building block does not assure maximum objective accomplishment Minimum data acquisition requires approximately 10 seconds of LBR PCM, either T/M or DSE for later dump (5 seconds of display keyboard (DSKY) shaft and trunnion data and 5 seconds of DSKY mark data)

Astronaut support for maximum data acquisition requires identification of the lunar landmark used and the star used, and also subjective comment on procedures, controls, etc Astronaut support for minimum data acquisition requires the above plus time required for both building block phases

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that related objectives which could always be accomplished are the ECS objectives P 2 3 1, P 2 3 2, P 2 3 4, and P 2 3 6, the consumables objective P 4 3, the astronaut-supported objectives S 2 3 and S 2 4, and the displays and controls (D&C) objective S 3 3 All G&N, stabilization and control subsystem (SCS), and thermal control objectives require maximum data acquisition Of these latter, the minimum impulse controller objectives P 1 2 2 and P 2 2 5 and the minimum deadband objective P 2 2 1 are the most likely to be accomplished during the sighting Maximum data acquisition through the maneuvering would accomplish the proportional rate objectives P 1 2 1 and P 2 2 4 and the limit cycle objective P 2 2 3 The P 2 4 1 TOADS defines the maximum data acquisition which would be required during the building block to accomplish that objective

- P 1 1 7 Demonstrate astronaut visual observation capability by performing a manual "out-of-window" CSM attitude orientation (simulated deorbit preparations)

TEST CONDITIONS

This objective should be accomplished in both sunlight and earth shadow Maneuver can be accomplished by either AM-2 or AM-3 of BB-11 Accomplishment by both modes is desirable Refer to AOH 12 3 15 and the current Mission Requirements (MR) It is highly desirable that the IMU be ON Use of the IMU constitutes a Δ to BB-11 AM-2 and AM-3 Note that BB-25 AM-2 requires this technique



DATA REQUIREMENTS

Maximum data acquisition requires continuous HBR PCM, either T/M or DSE for later dump, for the duration of the maneuver (approximately 5 minutes) Objective P 2 1 1 would be accomplished both before and after this objective (refer to AOH 8 6 5 1) Minimum data acquisition would consist of the following (1) accomplishment of the attitude orientation, (2) accomplishment of objective P 2 1 1 before and after the attitude orientation, and (3) astronaut logging and transmission of these data

Astronauts should log time required for maneuver and any problems encountered

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that related objectives which could always be accomplished are the attitude reference objective P 2 1 1, the ECS objective P 2 3 1, the consumables objective P 4 3, the astronaut-supported objective S 2 2, S 2 3 and S 2 4, and the D&C objective S 3 3 The proportional rate objectives P 1 2 1 and P 2 2 4 and the wide deadband objective P 2 2 2 require maximum data acquisition Although the IMU objectives P 1 1 1 and P 2 1 3 must be accomplished prior to the maneuver, they are not part of the objective and not required to be accomplished with the objective

- P 1 2 1 Demonstrate astronaut capability to maintain proportional rate control using the rotation and attitude impulse controls and the flight director attitude indicator (FDAI) attitude display (to be demonstrated for both single- and multi-axis maneuvers)

This objective will be accomplished in conjunction with objective P 2 2 4 Refer to objective P 2 2 4 for accomplishment data

- P 1 2 2 Demonstrate astronaut capability, using the SCS/RCS minimum impulse controller, to support G&N optics measurements

This objective will be accomplished in conjunction with P 2 2 5 Refer to objective P 2 2 5 for accomplishment data

- P 1 2 3 Deleted

- P 1 2 4 Deleted



P 1 2 5 Demonstrate astronaut capability to perform all required pre- ΔV operations in preparation for G&N or SCS thrust vector control (TVC)

TEST CONDITIONS

No special test conditions or procedures are required other than performance of BB-12 in earth orbit and BB-25 for deorbit or BB-26 for contingency deorbit

DATA REQUIREMENTS

There are no PCM measurements for this specific test objective. During the building block phase beginning with G&N power up, the related test objectives may be accomplished by either maximum or minimum data acquisition according to their respective TOADS. The duration of this phase of the building block is approximately 82 minutes. Objective P 2 3 5 would be accomplished during an SPS cold soak (see P 2 3 5 TOADS).

Astronaut support for either maximum or minimum data acquisition requires objective comment concerning adequacy of functions, time allotted, etc.

RELATED TEST OBJECTIVE

Examination of the test objective matrix (Figure 7-2) shows that related objectives which could always be accomplished are the ECS objectives P 2 3 1, P 2 3 2, P 2 3 4, P 2 3 5 (during the SPS cold soak), and P 2 3 6, the AGC update objectives P 1 1 4 and P 4 1 1, the communication objectives P 4 2 1, P 4 2 3, and P 4 2 4, the consumables objective P 4 3, and the D&C objective S 3 3. While the IMU objectives P 1 1 1 and P 2 1 3 would be performed, they require continuous maximum data acquisition during an extended period of time for complete satisfaction which the preceding objectives do not. The P 2 4 1 TOADS defines the maximum data acquisition which would be required during the building block to accomplish that objective.

P 1 2 6 Demonstrate astronaut capability to perform a CSM/S-IVB separation and a transposition maneuver



TEST CONDITIONS

No special test conditions or procedures are required beyond performance of BB-6 such that sufficient daylight remains to permit accomplishment of objective P 2 7 (Refer to AOH 12 2 12) The extremely close juxtaposition of objective P 2 7 with this objective (P 2 7 occurring immediately after transposition) makes these almost one objective

DATA REQUIREMENTS

Maximum data acquisition requires continuous HBR PCM T/M throughout the maneuver (approximately 5 minutes) These data could be recorded on DSE for later dump Astronaut objective comment on adequacy of procedures, control modes, etc , would supplement the HBR PCM

Minimum data acquisition would consist solely of the astronaut objective comment as previously noted

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objective which could always be accomplished is the D&C objective S 3 3 The objectives for proportional rate P 1 2 1 and P 2 2 4, translation control P 2 2 6, and direct ullage P 2 2 7 all require maximum data acquisition The wide deadband objective P 2 2 2, which also requires maximum data acquisition, may not be adequately accomplished during separation

P 1 2 7 Spacecraft 014 only

P 1 2 8 Deleted

P 1 3 1 Demonstrate a manual SPS start

TEST CONDITIONS

No special test conditions or procedures are required other than performance of the appropriate procedures of BB-12 The contingency BB-44 requires this technique



DATA REQUIREMENTS

Data acquisition at the time of SPS manual start requires HBR PCM T/M and DSE for later dump. These data are available because of the data requirement for SPS ΔV (see objective P 2 6 1)

Astronaut support requires objective comment with respect to adequacy of techniques, displays and controls, etc. These data may be available in real-time or on DSE for later dump.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objective which could always be accomplished is the D&C objective S 3 3. This manual SPS start objective is one of the test variables which would be accomplished during the SPS objective P 2 6 1.

P 1 4 Deleted

P 1 5 Demonstrate emergency donning of pressure suits

TEST CONDITIONS

No special test conditions or procedures are required other than identified in AOH procedure 12 3 14. This objective would be accomplished as a special test during either AM-1 or AM-2 of BB-9.

DATA REQUIREMENTS

There are no PCM measurements for this specific test objective. Astronaut support requires objective comment, either in real-time, on DSE for later dump, or logged, concerning specific events and techniques of the donning operation as well as elapsed time.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that there are no related objectives.

P 2 1 1 Evaluate and compare the performance of the G&N and SCS attitude reference systems during launch, orbital maneuvers and entry.



TEST CONDITIONS

No special test conditions are required other than performance of BB-1, -5, -7, -8, -11, -12, -25, and -26 with the IMU ON. Performance of this test objective in conjunction with a building block that does not otherwise require IMU ON constitutes a Δ to that building block. Refer to AOH 12 1 3 (procedure 8 6 5 1). It is highly desirable that this test objective be performed before and/or after those objectives as identified in their respective TOADS.

DATA REQUIREMENTS

Maximum data acquisition for related objectives requires HBR PCM, either T/M or DSE for later dump (approximately 5 seconds per data burst). It is highly desirable that maximum data be acquired by HBR PCM on DSE during an attitude hold maneuver of approximately 1-1/2 hours at a data sample rate of 5 seconds every 5 minutes during the maneuver. Maximum data acquisition during entry requires HBR PCM on DSE beginning 5 seconds before entry and ending 5 seconds after entry.

Minimum data acquisition requires astronaut performance of AOH procedure 8 6 5 1 at all points identified for maximum data acquisition except entry. Minimum data acquisition during entry is not desired. Minimum data acquisition requires astronaut data logging and voice transmission of these data.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objective which would always be accomplished is the D&C objective S 3 3. The attitude reference objective supports accomplishment of the vehicle alignment objectives P 1 1 2 and P 2 1 4 and the out-the-window objective P 1 1 7 as defined in the TOADS for those objectives. The remaining objectives (IMU alignment P 1 1 1 and P 2 1 3, orbital determination P 1 1 3, and P 2 1 5, G&N attitude control P 2 1 2, TVC P 2 1 6, and SPS Δ V P 2 6 1) provide several opportunities for gathering attitude reference data either over long periods of time or under dynamic conditions as defined in their TOADS.

P 2 1 2 Demonstrate performance of G&N subsystem in attitude control, Δ V control, and entry guidance



TEST CONDITIONS

No special test conditions or procedures are required other than identified in BB-7, -11, -12, and -25 and contingency BB-26 and -44 Refer to AOH 12 4 2

DATA REQUIREMENTS

Maximum data acquisition requires continuous HBR PCM, either T/M or DSE for later dump These data are required for the durations indicated in the TOADS for the related test objectives Entry guidance requires continuous HBR PCM on DSE beginning 5 seconds before initiation of entry guidance and ending 5 seconds after termination of entry guidance

Minimum data acquisition requires astronaut objective comment with respect to the adequacy of procedures, control modes, etc These data may also supplement maximum data acquisition

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that attitude and ΔV control is accomplished during IMU alignment P 1 1 1 and P 2 1 3 and SPS ΔV P 2 6 1 The related objective which would always be accomplished is TVC P 2 1 6 during ΔV control The minimum deadband objective P 2 2 1 could be accomplished during ΔV control because of the data requirement of P 2 6 1 TOADS but would not be accomplished during attitude control and entry guidance if maximum data acquisition were not achieved The attitude reference objective P 2 1 1 could always be accomplished The remaining objectives (wide deadband P 2 2 2, limit cycle P 2 2 3, and thermal control P 2 4 1) are related to attitude control and entry guidance and would not be accomplished if maximum data acquisition were not achieved

P 2 1 3 Demonstrate performance of the sextant, scanning telescope, and AGC to align the IMU

TEST CONDITIONS

No special test conditions or procedures are required other than those identified in BB-7 Refer to AOH 12 2 1 BB-8, Landmark, requires performance of this operation before BB-8, and BB-12, -25, and -26 include this operation It is highly



desirable that this objective also be accomplished at some time between the end of BB-5 and start of BB-6

DATA REQUIREMENTS

Maximum data acquisition while the CSM is attached to the SIV-B requires continuous HBR PCM T/M for approximately 15 minutes. Maximum data acquisition for alignment after CSM/SIV-B separation requires continuous HBR PCM T/M for approximately 24 minutes. This latter case may require selective use of DSE. It is highly desirable that the CSM maneuvering period prior to alignment also be covered by maximum data acquisition which requires continuous HBR PCM T/M or selective use of DSE for approximately 17 minutes. Minimum data acquisition requires LBR PCM, either T/M or DSE for later dump, as follows: 5-second data burst of DSKY data at end of alignment, and, after gimbals torquing, a 5-second data burst of DSKY data as obtained by AOH procedure 8 6 5 1.

Test objective P 2 1 1 would be accomplished immediately after the alignment by either maximum or minimum data acquisition as defined by P 2 1 1 TOADS.

Astronaut support requires objective comment with respect to task suitability, attitude control mode suitability, adequacy of time allotment, inadequacies in D&C, etc. These data are applicable to both maximum and minimum data acquisition.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which would always be accomplished are the companion objective P 1 1 1, the CSM/SIV-B stabilization objective P 5 1, and the D&C objective S 3 3. Other related objectives which could be accomplished are the attitude reference objective P 2 1 1, and ECS objectives P 2 3 1, P 2 3 2, P 2 3 4, and P 2 3 6, and the astronaut supported objectives S 2 3 and S 2 4. The minimum impulse controller objectives P 1 2 2 and P 2 2 5, attitude control objective P 2 1 2, and wide deadband objective P 2 2 2 require maximum data acquisition during the alignment. The proportional rate objectives P 1 2 1 and P 2 2 4 and the limit cycle objective P 2 2 3 require maximum data acquisition during the pre-alignment maneuvering. The P 2 4 1 TOADS defines the maximum data acquisition which would be required during the building block to accomplish that objective.



P 2 1 4 Demonstrate performance of the scanning telescope in conjunction with the rotation and attitude impulse controls to align the vehicle to a predetermined inertial attitude

TEST CONDITIONS

This is a special test using BB-11 AM-2 after performance of BB-7 Refer to AOH paragraph 8 6 5 10 and the current MR The IMU will be ON during performance of this test objective, and this constitutes a Δ to BB-11 AM-2 It is highly desirable that this objective be accomplished as soon as practicable following CSM/SIV-B separation Normal use of BB-12 AM-2, BB-12 AM-3, and BB-25 AM-2, (i e , G&N OFF) requires this technique

DATA REQUIREMENTS

Maximum data acquisition requires continuous HBR PCM, either T/M or DSE for later dump, for approximately 5 minutes and 10 seconds beginning 5 seconds prior to the misalignment and ending 5 seconds after the realignment Objective P 2 1 1 would be accomplished after the maneuver Minimum data acquisition requires performance of objective P 2 1 1 before misalignment and after realignment as identified by the minimum data acquisition of the P 2 1 1 TOADS

Astronaut objective comment as to adequacy of procedures, time required, etc , may supplement both maximum and minimum data acquisition

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which would always be accomplished are the companion objective P 1 1 2 and the D&C objective S 3 3 Other related objectives which could be accomplished are the attitude reference objective P 2 1 1, the command module habitability portion of the ECS objective P 2 3 1, the consumables objective P 4 3, and the astronaut-supported objectives S 2 3 and S 2 4 The minimum impulse controller objectives P 1 2 2 and P 2 2 5 and the minimum deadband objective P 2 2 1 require maximum data acquisition while aligning the vehicle The proportional rate objectives P 1 2 1, P 2 2 4, which require maximum data acquisition, could be accomplished during misalignment and attitude reacquisition



P 2 1 5 Demonstrate performance of the scanning telescope and the AGC to establish orbital parameters

TEST CONDITIONS

No special test conditions or procedures are required other than performance of BB-8, Landmark Sightings Refer to AOH 12 2 2 It is highly desirable that this objective also be accomplished at some time between the end of BB-5 and start of BB-6

DATA REQUIREMENTS

Maximum data acquisition while the CSM is attached to the SIV-B requires continuous HBR PCM T/M for approximately 7 minutes Repetition sightings would require approximately 10 additional minutes Maximum data acquisition for sightings after separation have the same requirements as above It is highly desirable that the CSM maneuvering period prior to alignment also be covered by maximum data acquisition which requires continuous HBR PCM, either T/M or DSE for later dump, for approximately 6 minutes Minimum data acquisition would consist of a 5-second data burst of LBR PCM, either T/M or DSE for later dump, of all significant DSKY displays

Test objective P 2 1 1 would be accomplished before and after the sighting by either maximum or minimum data acquisition as defined by P 2 1 1 TOADS

Astronaut support requires objective comment with respect to task suitability, attitude control mode suitability, adequacy of time allotment, inadequacies in D&C, target acquisition, etc These data are applicable to both maximum and minimum data acquisition

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which would always be accomplished are the companion objective P 1 1 3, the CSM/SIV-B objective P 5 1, and the D&C objective S 3 3 Related objectives which could be accomplished are the attitude reference objective P 2 1 1, the ECS objectives P 2 3 1, P 2 3 2, P 2 3 4, and P 2 3 6, the consumables objective P 4 3, and the astronaut-supported objectives S 2 3 and S 2 4 The minimum impulse controller objectives P 1 2 2 and P 2 2 5 and the wide deadband objective P 2 2 2 require maximum data acquisition where applicable



during the sightings. The limit cycle objective P 2 2 3 requires continuous maximum data acquisition throughout the sightings. The P 2 4 1 TOADS define the maximum data acquisition which would be required during the building block to accomplish that objective.

P 2 1 6 Demonstrate performance in the G&N and SCS to control the thrust vector.

TEST CONDITIONS

No special test conditions or procedures are required other than performance of BB-12 and -25 or contingency BB-26 and -44. Refer to AOH procedure 12 3 2.

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM T/M beginning 5 seconds prior to the ΔV and ending 5 seconds after completion of the ΔV . This time period is included within the data requirement identified in the P 2 6 1 TOADS.

Astronaut support requires objective comment relative to gimbals positioning, apparent TVC, adequacy of mode, use of center-of-gravity determination data, etc.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which would always be accomplished are G&N ΔV control P 2 1 2 and minimum deadband P 2 2 1. The attitude reference objective P 2 1 1 could be accomplished. This TVC objective is one of the test variables which would be accomplished during the SPS objective 2 6 1.

P 2 2 1 Demonstrate rate damping in all three axes in minimum deadband.

TEST CONDITIONS

No special test conditions or procedures are required other than performance of BB-8, -11, -12, and -25 or contingency BB-26 and -44. It is highly desirable that this objective be performed at more than one level of consumables quantity.



DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM during the appropriate maximum data acquisition periods of the performed building block as identified by the related test objective TOADS

A form of minimum data acquisition would be possible by astronaut monitoring and logging of the FDAI rate indication. This mode of data acquisition is not recommended.

Astronaut support requires objective comment relative to adequacy of mode, FDAI indications, D&C procedures, etc.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the objective is accomplished as a function of the vehicle alignment objectives P 1 1 2, P 2 1 4, the celestial navigation objective P 1 1 6, the TVC objective P 2 1 6, and the SPS objective P 2 6 1. The best opportunity for acquisition at varying consumable quantities is during the various SPS ΔV 's

- P 2 2 2 Demonstrate SCS attitude hold capability in the propellant conservation (wide deadband) configuration

TEST CONDITIONS

No test conditions or procedures are required other than identified in BB-6, -7, -8, and -11. It is highly desirable that this objective be performed at more than one level of consumables quantity. It is also desirable that a special test be performed by using BB-11 AM-2 for approximately one hour. Refer to AOH procedure 12 3 16.

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM during the appropriate maximum data acquisition periods of the performed building block as identified by the related TOADS (see below). Special test maximum data acquisition requires continuous HBR PCM T/M for approximately 5 minutes at the beginning and end of the test and periodically throughout the test at each station contact. These data may be supplemented by periodic one minute bursts on DSE between station contacts. Special test minimum data acquisition requires astronaut logging of the FDAI



at the beginning and end as well as periodically throughout the test

Astronaut support requires objective comment with respect to the adequacy of the mode, D&C, damping, etc

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished as a function of the IMU objectives P 1 1 1 and P 2 1 3, the orbital parameter objectives P 1 1 3 and P 2 1 5, the out-the-window objective P 1 1 7, and the SLA panel objective P 2 7. During the special test, the related objectives which could be accomplished are the ECS objective P 2 3 1, the consumables objective P 4 3, the vibration objective S 2 4, and the D&C objective S 3 3. The limit cycle objective P 2 2 3 would be accomplished if maximum data acquisition is acquired. The proportional rate objectives P 1 2 1 and P 2 2 4 could be accomplished if maximum data acquisition were acquired where appropriate. The P 2 4 1 TOADS define the maximum data acquisition which would be required during the special test to accomplish that objective.

P 2 2 3 Demonstrate convergence to minimum impulse limit cycle rates during attitude hold in the SCS attitude control mode

TEST CONDITIONS

No special test conditions or procedures are required other than those identified in BB-7, -8, and -11. It is highly desirable that this objective be performed at more than one level of consumables quantity.

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM during the appropriate maximum data acquisition periods of the performed building block as identified by the related TOADS (see below).

Astronaut support requires objective comment relative to adequacy of mode, D&C, etc

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished as a function of the IMU objectives



P 1 1 1 and P 2 1 3, the orbital parameter objectives P 1 1 3 and P 2 1 5, the celestial sighting objective P 1 1 6, and the special test of the wide deadband objective P 2 2 2

P 2 2 4 Demonstrate proportional rate control performance using the rotation and attitude impulse controls and the FDAI attitude display (for both single- and multi-axis maneuvers)

TEST CONDITIONS

No test conditions or procedures are required other than those identified in BB-6, -7, -8, and -11. The single axis maneuver (pitch only) may be accomplished during BB-6. Accomplishment of roll only and yaw only requires special planning. The multi-axis maneuver may be accomplished during BB-7, -8, and -11.

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM during the appropriate maximum data acquisition periods of the performed building block as identified by the related TOADS (see below)

Astronaut support requires objective comment relative to controller displacement, FDAI readability, adequacy of mode, D&C, etc. This latter, if supplemented by astronaut logging of FDAI readout, would be a form of minimum data acquisition, but it is not recommended for that purpose.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished as a function of the maneuvering portions of the IMU objectives P 1 1 1 and P 2 1 3, the vehicle alignment objectives P 1 1 2 and P 2 1 4, the celestial sighting objective P 1 1 6, the out-the-window objective P 1 1 7, the separation objective P 1 2 6, the special test of the wide deadband objective P 2 2 2, and the maneuvering portion of the SLA panel objective P 2 7. The companion objective P 1 2 2 would be accomplished during the appropriate maximum data acquisition periods of the above related objectives.

P 2 2 5 Demonstrate performance of the SCS/RCS minimum impulse controller, in supporting G&N optics measurements



TEST CONDITIONS

No special test conditions or procedures are required other than those identified in BB-7 and -8

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM during the appropriate maximum data acquisition periods of the performed building block as identified by the related TOADS (see below)

Astronaut support requires objective comment relative to adequacy of controller, procedures, etc

RELATED OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished as a function of the alignment portions of the IMU objectives P 1 1 1 and P 2 1 3, the vehicle alignment objectives P 1 1 2 and P 2 1 4, the orbital parameters objectives P 1 1 3 and P 2 1 5, and the celestial sighting objective P 1 1 6. The companion objective P 1 2 2 would be accomplished during the appropriate maximum data acquisition periods of the above related objectives

P 2 2 6 Demonstrate translation performance control in all three axes

TEST CONDITIONS

No test conditions or procedures are required other than those identified in BB-6, -11, -12, -13, and -25 or contingency BB-26 and -44. It is highly desirable that translation in Y and Z be performed using BB-13 during accomplishment of P 2 7 after BB-6 because normal mission use of these building blocks does not accomplish anything other than $\pm X$ translation

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM during the appropriate maximum data acquisition periods of the performed building blocks as identified by the related TOADS (see below)

Astronaut support requires objective comment relative to adequacy of control, D&C, mode, etc. A form of minimum data acquisition would be possible by supplementing the above astronaut support by astronaut logging of FDAI readout for residual



rate and cross coupling, but it is not recommended for that purpose

RELATED OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the +X translation portion of this objective is accomplished during the separation objective P 1 2 6 and the SPS objective P 2 6 1. As previously noted, the SLA panel objective P 2 7 permits accomplishment of translation in Y and Z. Related objectives which can be accomplished are the restraint objective S 2 2, the vibration objective S 2 4, and the D&C objective S 3 3.

P 2 2 7 Demonstrate direct ullage maneuver performance

TEST CONDITIONS

No special test conditions or procedures are required other than identified in BB-6, -12, -13, and -25 or contingency BB-24. This objective will be accomplished in BB-6 and may be accomplished in any of the remaining building blocks.

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM during the appropriate maximum data acquisition periods of the performed building block as identified in the related TOADS (see below).

Astronaut support requires objective comment relative to adequacy of procedures and D&C, as well as monitoring/logging of ΔV indication.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished during the separation objective P 1 2 6 and the SPS objective P 2 6 1. Related objectives which can be accomplished are the restraint objective S 2 2, the vibration objective S 2 4, and the D&C objective S 3 3.

P 2 3 1 Demonstrate satisfactory command module cabin habitability and equipment temperature control



TEST CONDITIONS

It is highly desirable that this objective be accomplished during the special test SPS cold and hot soak (BB-12) identified by P 2 6 1 TOADS Refer to AOH procedure 12 3 1 and the current Mission Requirements No further test conditions or procedures other than accomplishment during BB-1, -5, -7, -8, -9, -10, -11, -12, and -25 or contingency BB-26 are required

DATA REQUIREMENTS

Maximum data acquisition requires HBR PCM, either T/M or DSE for later dump These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes throughout the performance of the building blocks or special test previously identified

Astronaut support requires objective comment, periodic or as required, relative to general comfort, ease of movement in command module, monitoring/logging of appropriate D&C, reporting of such control changes as may be required, command module atmosphere, etc Minimum data acquisition requires solely the above astronaut support

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished during the various operations and maneuvers objectives (IMU alignment, vehicle alignment, orbital parameters, celestial sighting, out-the-window, wide deadband special test) as well as pre- ΔV operations objective P 1 2 5, and the ECS objectives P 2 3 3, P 2 3 5, and P 2 3 6 Related objectives which can be accomplished are the suit circuit objective P 2 3 2, the water separator objective P 2 3 4, and the D&C objective S 3 3 Related objectives which require maximum data acquisition for accomplishment are the thermal control objective P 2 4 1 and the ECS radiator objective P 2 4 4 This ECS objective is of special interest during the special test cold and hot soaks of the SPS objective P 2 6 1

P 2 3 2 Demonstrate satisfactory command module suit circuit habitability

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-5, -7, -8, -9, -12, -14, -24, and -25



or contingency BB-26 It is highly desirable that accomplishment encompasses all modes of suit circuit usage Refer to AOH procedure 12 2 8

DATA REQUIREMENTS

Maximum data acquisition requires HBR PCM, either T/M or DSE for later dump These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes throughout the performance of the building blocks identified above

Astronaut support requires objective comment, periodic or as required, relative to general comfort, faceplate fogging, monitoring/logging of appropriate D&C, reporting of such control changes as may be required, suit atmosphere and/or odors, etc Minimum data acquisition requires solely the above astronaut support

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished during the longer period operations (IMU alignment, orbital parameters, celestial sightings, pre- ΔV operations) where high activity of the astronaut while wearing the PGA is of interest Related objectives which can be accomplished are the temperature control portion of objective P 2 3 1, the waste management objective P 2 3 3, the water separator objective P 2 3 4, and the pressure control objective P 2 3 6, as well as the D&C objective S 3 3 This ECS objective is of interest during the special test cold and hot soaks of the SPS objective P 2 6 1

P 2 3 3 Demonstrate performance of the waste management subsystem

TEST CONDITIONS

No special test conditions are required other than accomplishment during BB-9 and -10 It is highly desirable that this test objective be accomplished on a daily basis as indicated below in data requirements Refer to AOH procedure 12 2 4 and the current Mission Requirements



DATA REQUIREMENTS

Maximum data acquisition requires continuous LBR PCM recorded on DSE for later dump for a minimum of 80 minutes per cycle. It is highly desirable that these data (gas chromatograph) be acquired at least twice daily, one cycle of cabin sample and one cycle of suit sample.

Astronaut support requires objective comment relative to use of fecal canister, fecal bags, urine dump, PGA urinal dump, vacuum cleaner, waste stowage, miscellaneous debris, etc.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which would always be accomplished are the ECS habitability objectives P 2 3 1 and P 2 3 2. Related objectives which can be accomplished are the provisioning objective S 2 1 and the D&C objective S 3 3.

P 2 3 4 Demonstrate performance of the water separators

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-5, -7, -8, -9, -12, -14, -17, -24, and -25, or contingency BB-26. It is highly desirable that this objective be accomplished during any period of high physical activity. Refer to AOH procedure 12 2 7.

DATA REQUIREMENTS

Maximum data acquisition requires HBR PCM, either T/M or DSE for later dump. These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes throughout the performance of the building block.

Astronaut support requires objective comment relative to condensation/high humidity, D&C, logging of humidity data from the GFE hydrometer, etc. These data are of particular interest during and after experiment M-3A. Minimum data acquisition requires solely the above astronaut support.



RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished during the longer period operations (IMU alignment, orbital parameters, celestial sightings, pre- ΔV operations) which would involve high physical activity. Related objectives which would always be accomplished are the ECS habitability objectives P 2 3 1 and P 2 3 2 and the condensation objective P 2 4 6. The D&C objective could also be accomplished. This ECS objective may also be of interest after any experiments which involve high levels of astronaut activity.

P 2 3 5 Verify heat rejection of the ECS evaporators

TEST CONDITIONS

It is highly desirable that this objective be accomplished during the special test SPS cold soak (BB-12) identified by P 2 6 1 TOADS. Refer to AOH procedure 12 3 7. No further test conditions or procedures other than indicated in BB-5 and post BB-5 in earth orbit while the CSM is attached to the SIV-B, and BB-24 are required.

DATA REQUIREMENTS

Maximum data acquisition requires HBR PCM, either T/M or DSE for later dump. These data would consist of 5-second data bursts every 2 minutes for a sufficient time to establish the cooling trend (approximately 20 to 30 minutes) during evaporator operations. If required, these data can be reacquired periodically throughout the building block or special test.

Astronaut support requires objective comment relative to procedures, monitoring/logging of D&C data, etc. Minimum data acquisition requires solely the above astronaut support.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) and the building block matrix (Figure 7-1) shows that this objective is accomplished at specific points in the mission in order to control cabin temperature. Related objectives which would accomplish the ECS objective are the deorbit pre- ΔV operations objective P 1 2 5, and the special test cold soak of the SPS objective P 2 6 1. Related objectives always accomplished are



the command module habitability portion of P 2 3 1, the pressure control objective P 2 3 6, and the D&C objective S 3 3

- P 2 3 6 Demonstrate capability of the pressure control circuit to regulate the cabin pressure and the water tank pressure

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-1, -5, -7, -8, -9, -10, -12, -24, -25, and -35 or contingency BB-26 Refer to AOH procedure 12 2 6

DATA REQUIREMENTS

Maximum data acquisition requires HBR PCM, either T/M or DSE for later dump These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes throughout the performance of the building block

Astronaut support requires objective comment relative to water tank pressure, monitoring/logging of D&C data, reporting of such control changes as may be required, procedures, etc Minimum data acquisition requires solely the above astronaut support

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished during the longer period operations (IMU alignment, orbital parameters, celestial sightings, pre- ΔV operations) as well as the ECS evaporator objective P 2 3 5 and the provisioning objective S 2 1 Related objectives which can be accomplished are the ECS objectives P 2 3 1 and P 2 3 2 and the D&C objective S 3 3 This pressure control objective is of special interest after the accomplishment of the depressurization objective S 3 2

- P 2 4 1 Verify CSM thermal control during controlled orientations and obtain data during random drift

TEST CONDITIONS

It is highly desirable that this objective be accomplished during the BB-12 special test cold and hot soaks of the SPS (see P 2 6 1 TOADS) Refer to AOH procedure 12 3 3 and the current Mission



Requirements No further test conditions or procedures other than accomplishment during BB-5, -7, -8, -9, and -11 are required

DATA REQUIREMENTS

Data acquisition requires HBR PCM during the appropriate maximum data acquisition periods of the performed building blocks as identified by the related test objective TOADS. These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes throughout the performance of the building blocks. LBR PCM would also suffice except during the special test (see P 2 6 1 TOADS)

Astronaut support requires periodic monitoring/logging of appropriate D&C as well as periodic monitoring/logging of approximate spacecraft drift rate and attitude with respect to the sun during drifting flight (special test)

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished during the longer period operations and maneuvers (IMU alignment, orbital parameters, celestial sightings, pre- ΔV operations, wide deadband special test) as well as the special test cold and hot soaks of the SPS objective P 2 6 1 and the CSM/SIV-B stabilization objective P 5 1. The related ECS objective P 2 3 1 would always be accomplished. Related objectives which could be accomplished are the service module RCS objectives P 2 4 2 and the ECS and EPS radiator objectives P 2 4 4 and P 2 4 5.

P 2 4 2 Verify service module RCS thermal response characteristics, with RCS thermal control active

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-9 and -14 and the special test period of BB-12 (see P 2 6 1 TOADS). This is not meant to exclude any other building block as a potential data source. Refer to AOH procedure 12 2 10.



DATA REQUIREMENTS

Data acquisition requires periodic HBR PCM, either T/M or DSE for later dump. These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes throughout the performance of the building block or special test. The exact definition of thermal equipment cyclic operation may not be possible other than by post-analysis.

Astronaut support requires periodic monitoring/logging of service module RCS D&C as well as periodic monitoring/logging of approximate spacecraft drift rate and attitude orientation relative to the sun.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related D&C objective S 3 3 would always be accomplished. The thermal control objective P 2 4 1 and the ECS and EPS radiator objectives P 2 4 4 and P 2 4 5 are related through the special test cold and hot soak of the SPS objective P 2 6 1 and could be accomplished with this service module RCS objective

P 2 4 3 Verify command module RCS thermal control

TEST CONDITIONS

No special test conditions or procedures are required other than identified in BB-14 and -25 or contingency BB-26. Refer to AOH procedure 12 4 1. BB-14 would be accomplished at some point between BB-5 and -6. Use of the command module RCS injector valves prior to BB-6 may constitute a Δ to the power load of that portion of the mission.

DATA REQUIREMENTS

Data acquisition requires HBR PCM on DSE for later dump during the appropriate period of the performed building block. Those data would consist of 5-second bursts at approximately one minute intervals.

Astronaut support requires monitoring/logging of minimum and maximum oxidizer valve temperature from the D&C selectable meter as well as logging period of operation. These data may be retained for postmission acquisition or voice-communication during the mission.



RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the only related objective which would always be accomplished is the D&C objective S 3 3

P 2 4 4 Verify ECS radiator heat rejection

TEST CONDITIONS

It is highly desirable that this objective be accomplished during the BB-12 special test cold and hot soaks of the SPS (see P 2 6 1 TOADS) No further test conditions or procedures other than accomplishment during BB-9 are required This is not meant to exclude any other building block as a potential data source Refer to AOH procedure 12 2 3 and the current Mission Requirements

DATA REQUIREMENTS

Data acquisition requires HBR PCM, either T/M or DSE for later dump These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes throughout the performance of the building block or special test where attitude holds are greater than 30 minutes It is desirable that these data be available at least once per revolution LBR PCM would also support this objective, but it is not recommended

Astronaut support requires periodic monitoring/logging of ECS D&C and approximate spacecraft drift rate and attitude as well as reporting changes to control settings

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which could always be accomplished are the temperature control portion of objective P 2 3 1, the service module RCS objective P 2 4 2, and the EPS radiator objective P 2 4 5 The D&C objective would always be accomplished The special test cold and hot soak of the SPS objective P 2 6 1 as well as the thermal control objective P 2 4 1 relates this ECS radiator objective to the EPS radiator objective P 2 4 5



P 2 4 5 Verify electrical power subsystem (EPS) radiator heat rejection

TEST CONDITIONS

It is highly desirable that this objective be accomplished during the BB-12 special test cold and hot soaks of the SPS (see P 2 6 1 TOADS) No further test conditions or procedures other than accomplishment during BB-9 are required This is not meant to exclude any other building block as a potential data source Refer to AOH procedure 12 3 6 and the current Mission Requirements

DATA REQUIREMENTS

Data acquisition requires HBR PCM, either T/M or DSE for later dump These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes throughout the performance of the building block or special test It is desirable that these data be available at least once per revolution

Astronaut support requires periodic monitoring/logging of EPS D&C and approximate spacecraft drift rate and attitude relative to the sun These data should be correlated with power demands

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which could always be accomplished are the service module RCS objective P 2 4 2 and the ECS radiator objective P 2 4 4 The D&C objective S 3 3 would always be accomplished The special test cold and hot soak of the SPS objective P 2 6 1 as well as the thermal control objective P 2 4 1 relates this EPS radiator objective to the ECS radiator objective P 2 4 4 This EPS radiator objective should be correlated with the cryogenic pressure control objective P 2 5 1

P 2 4 6 Obtain data on cabin and secondary structure condensation areas and degree of condensation as a function of CSM attitude and duration

TEST CONDITIONS

It is highly desirable that this objective be accomplished during the BB-12 special test hot soak of the SPS (see P 2 6 1 TOADS) No further test conditions or procedures other than



accomplishment during BB-9 and BB-24 are required. This is not meant to exclude any other building block as a potential data source. Refer to AOH procedure 12 2 5 and the current Mission Requirements.

DATA REQUIREMENTS

There are no PCM measurements in support of this test objective.

Astronaut support requires objective comment relative to degree and location of condensation, possible cause or source, correlation with work activity, approximate spacecraft attitude, etc. Special attention should be given to observations during pre-entry cooldown (BB-24).

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objective always accomplished is the water separator objective P 2 3 4.

- P 2 5 1 Verify automatic and manual operation of the cryogenic pressure control.

TEST CONDITIONS

It is highly desirable that manual operation be scheduled, as a special test, for some continuous 10-hour period as early as possible in the mission during BB-9 AM-1. A recommended period would be the initial SPS cold soak. No further test conditions or procedures other than accomplishment during BB-9 and BB-14 are required. This is not to exclude any other building block as a potential data source for automatic operation. Refer to AOH procedure 12 3 4 and the current Mission Requirements.

DATA REQUIREMENTS

Data acquisition requires LBR PCM, either T/M or DSE for later dump. These data would consist of periodic bursts of any duration ranging from 5 seconds to 5 minutes approximately every 30 minutes throughout the performance of the building blocks. It is highly desirable that the sampling frequency during the special test be at approximately 15-minute intervals. HBR PCM is not required, but it is also acceptable.



Astronaut support requires objective comment with respect to adequacy of procedures, D&C, etc , as well as monitoring/ logging of D&C data approximately once per hour during automatic operation and approximately every 15 minutes during manual operation

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objective always accomplished is the D&C objective S 3 3. The related consumables objective P 4 3 could also be accomplished. This cryogenic pressure control objective is related to the special test cold soak of the SPS objective only because of the requirement for manual operations noted above.

- P 2 5 2 Verify fuel cell water separation and purity during earth orbital environment

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-9, -10, and -14. This is not to exclude any other building block as a potential data source. Refer to AOH procedure 12 3 5.

DATA REQUIREMENTS

Data acquisition requires HBR PCM, either T/M or DSE for later dump. These data would consist of periodic data bursts of any duration ranging from 5 seconds to 5 minutes approximately every 30 minutes throughout the building blocks.

Astronaut support requires objective comment as regards purity and availability of water, adequacy of D&C, monitoring/ logging of fuel cell activity, etc. These data should be available approximately once per hour.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related test objective which would always be accomplished is the D&C objective S 3 3. The related consumables objective P 4 3 could also be accomplished. This fuel cell water objective is related to the cryogenic pressure control objective P 2 5 1 and the provisioning objective S 2 1 because of the requirement for adequate water in the mission.



P 2 6 1 Verify eight SPS duty cycles

TEST CONDITIONS

No test conditions or procedures are required other than those identified in BB-12 and -25, contingency BB-44 and the controlled orientations for the special test cold soak and solar soak identified in the current Mission Requirements. It is highly desirable that the various ΔV 's consist of any or all of the following: Initial ΔV for system performance, restart ΔV for system performance, ΔV following a cold soak, ΔV following a solar soak, long-duration ΔV , minimum impulse ΔV , ΔV at low propellant level, and deorbit ΔV . The cold soak and solar soak burns are identified as a special test within the domain of BB-12 for those TOADS where they impact the accomplishment of those test objectives. In actuality, the possible duration (approximately 12 hours) of these attitude control periods precludes their inclusion as an actual part of BB-12. The cold and hot soaks are most likely a combination of BB-11 to establish a particular orientation followed by BB-9 with selective interpolations of BB-11 to update that orientation. Refer to AOH procedure 12 3 2 and the current Mission Requirements. BB-15 may be performed as required during these special tests. It is highly desirable that all recommended ΔV modes be exercised.

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM T/M and DSE for later dump, if required. These data are to be available from 2 minutes before the ΔV , through the ΔV , to 2 minutes after the ΔV (not over 5 minutes including duration of ΔV). Flight qualification recorder data would also be required for postmission recovery for the time period from 10 seconds before the ΔV to 10 seconds after the ΔV .

Astronaut support requires objective comment relative to adequacy of procedures, D&C, monitoring/logging of any anomalies encountered, etc. These data are to be available in real-time or as close as practical to the conclusion of the ΔV .

In addition to the above, it is highly desirable that MSFN monitor in real-time the following PCM measurements during both the cold and solar soak: oxidizer and fuel feedline temperatures, pitch and yaw gimbal actuator temperatures, and command module side heat shield bondline temperatures. During the solar soak, it is highly desirable that chamber outer skin



and injector manifold temperatures be added to the preceding monitored measurements. These data should be available at least once per revolution.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) as well as the building block matrix (Figure 7-1) shows that almost all test objectives are related in some fashion to this SPS objective. Related objectives which would always be accomplished are the manual start objective P 1 3 1, the G&N ΔV control objective P 2 1 2, the TVC objective P 2 1 6, the minimum deadband objective P 2 2 1, the translation and ullage objectives P 2 2 6 and P 2 2 7, the SPS objectives P 2 6 3 and P 2 6 4, and the D&C objective S 3 3. Objectives which could be accomplished are the attitude reference objective P 2 1 1, the consumables objective P 4 3, and the astronaut supported objectives S 2 2, S 2 3, and S 2 4. The special test cold and hot soaks provide the opportunity for accomplishing the ECS objectives P 2 3 1, P 2 3 2, and P 2 3 5, the thermal control objectives P 2 4 1, P 2 4 2, P 2 4 4, P 2 4 5, and P 2 4 6, and the manual cryogenic pressure control objective P 2 5 1. The relating of operations and maneuvers, such as IMU alignment, vehicle alignment, AGC update, out-the-window, and pre- ΔV operations, is included for consistency with the building block and definition of sequential operations.

P 2 6 2 Deleted

P 2 6 3 Verify operation of the engine redundant bipropellant valve

TEST CONDITIONS

Accomplishment of this objective constitutes a special test during one or more of the ΔV 's of BB-12. Refer to AOH procedure 12 3 2 and the current Mission Requirements. It is highly desirable that ΔV 's be accomplished using both valve bank A only and valve bank B only.

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM to coincide with the data acquisition identified in P 2 6 1 TOADS.

Astronaut support requires objective comment as regards variation in ΔV with single bank operation, adequacy of



procedures as well as D&C, etc. These data to be available in real-time or as close as practical to the conclusion of the ΔV

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objective which would always be accomplished is the D&C objective S 3 3. The related gauging objective P 2 6 4 could be accomplished. This bipropellant valve objective is accomplished as one of the test variables during the SPS objective P 2 6 1.

P 2 6 4 Verify operation and accuracy of primary and auxiliary propellant gauging display

TEST CONDITIONS

Accomplishment of this objective constitutes a special test during one or more of the ΔV 's of BB-12. Refer to AOH procedure 12 3 2 and the current Mission Requirements. Scheduling of this objective during the mission would entail correlating the propellant consumed with point sensor location to assure uncovering of a point sensor during the ΔV selected for objective accomplishment.

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM to coincide with the data acquisition identified in P 2 6 1 TOADS. These data would be gathered with AUXILIARY selected on the gauging display throughout the test period. An alternate method would be to momentarily switch to PRIMARY 2 seconds after crossing each sensor point and then 2 seconds later returning to AUXILIARY.

Astronaut support requires objective comment with regard to anomalies in the D&C, adequacy of procedures, etc. These data are to be available in real-time or as close as practical to the conclusion of the ΔV .

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objective which would always be accomplished is the D&C objective S 3 3. The related objectives which could be accomplished are the bipropellant valve objective P 2 6 3 and



the consumables objective P 4 3 This gauging objective is accomplished as one of the test variables during the SPS objective P 2 6 1

P 2 7 Demonstrate SLA panel deployment

TEST CONDITIONS

No special test conditions or procedures are required other than performance of BB-6, such that sufficient daylight remains to permit photography of the SLA panels Refer to AOH procedure 12 2 11 It is highly desirable that the photographs, which can be taken from the left- or right-hand CSM couches, be taken not only from dead-on but also at various offset angles from the SLA centerline This permits accomplishment of objective P 2 2 6 using BB-13 during the photography

DATA REQUIREMENTS

There are no PCM measurements in support of this objective If BB-13 is used to position the spacecraft for purposes of photography, it is highly desirable that continuous HBR PCM be acquired throughout the maneuvering (approximately 5 minutes) These data would be required in real-time or on DSE for later dump

Astronaut support requires objective comment relative to SLA panel deployment, SIV-B stabilization, adequacy of control mode, etc These data are to be available in real-time or as close as practical to conclusion of the objective

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related proportional rate objectives P 1 2 1 and P 2 2 4, the wide deadband objective P 2 2 2, and the translation objective P 2 2 6 all require maximum data acquisition for accomplishment during the maneuvers The separation objective P 1 2 6 is sequentially related

P 2 8 Deleted

P 2 9 Deleted



P 2 10 Verify biomedical instrumentation adequacy

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-1, -5, -9, and -17 This is not to exclude any other building block as a potential data source Refer to AOH procedure 12 1 4 It is highly desirable that the test pattern, once established, remain constant

DATA REQUIREMENTS

Data acquisition requires HBR PCM, either T/M or DSE for later dump DSE would primarily be used to maintain continuity of test pattern for those periods when the spacecraft is out of station contact These data would be gathered continuously, when required, for any duration ranging from 1 to 5 minutes Supplemental data would be furnished by postmission recovery of the biomedical recorder

Astronaut support requires such objective comment as would permit correlation of the PCM data with work-rest cycles, periods of discomfort, exercise periods, etc These data would be available concurrently with the PCM data

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective could assist in accomplishment of the experiment objective S 6

P 3 MSFC objective

P 4 1 1 Demonstrate updating of the AGC from MSFN via updata link and voice modes

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment of BB-16 Refer to AOH procedure 12 3 8 This objective would also be accomplished as a part of BB-5 (or post-BB-5 operation), -12 and -25, or contingency BB-26 Accomplishment of this objective with BB-12 AM-2 and -3 would constitute a special test, because it is not normally required



DATA REQUIREMENTS

Data acquisition for UHF uplink requires approximately one minute of HBR PCM T/M

Data acquisition for VHF voice uplink requires astronaut objective comment with regard to adequacy of mode, D&C, procedures, etc

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives always accomplished are the companion objective P 1 1 4 and the D&C objective S 33. The communications objectives P 4 2 1 and P 4 2 4 and the acoustic objective S 2 3 could be accomplished

- P 4 2 1 Verify CSM/MSFN S-band telemetry, television, voice, updata, and tracking capability

TEST CONDITIONS

Although the updata portion of this test objective may be accomplished during BB-16, in general, this test objective constitutes a special test because S-band is not required for Block I. BB-9 AM-2 offers the best opportunity for accomplishment, however, this is not meant to exclude any other building block as a potential data source. Use of television during BB-9 constitutes a Δ to that building block. Refer to AOH procedure 12 1 2. It is desirable that some exercise of the S-band high power mode be achieved. This latter is also a Δ to BB-9.

DATA REQUIREMENTS

Data acquisition requires HBR or LBR PCM, when required. These data would consist of any duration ranging from 1 to 5 minutes of simultaneous VHF and S-band T/M. S-band tracking, sequentially in both modes (doppler and PRN), would be acquired simultaneously with C-band tracking. HBR-PCM T/M would be available simultaneously with television transmission of a suitable target (approximately 5 minutes duration).

Astronaut support requires objective comment as regards the adequacy of S-band voice vis-a-vis VHF. These data would be derived from either simultaneous or sequential VHF and S-band voice.



It is desirable that 24 hours of S-band operation, primarily in low power mode, be acquired during the first 48 hours of the mission

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related test objectives which could be accomplished are the AGC update objectives P 1 1 4 and P 4 1 1, the data dump objective P 4 2 2, the CTE update objective P 4 2 3, the acoustic objective S 2 3, the D&C objective S 3 3, and the antenna switching objective S 4

P 4 2 2 Demonstrate the capability of VHF/FM and S-band data dump

TEST CONDITIONS

This test objective would be a special test capable of accomplishment in either BB-5 or AM-2 of BB-9 Refer to AOH procedure 12 3 13

DATA REQUIREMENTS

Data acquisition requires simultaneous VHF/FM and S-band data dump of HBR PCM for approximately one minute as well as simultaneous VHF/FM and S-band data dump of LBR PCM for approximately one minute Alternate data acquisition would be S-band dump of previously transmitted VHF/FM PCM Less desirable would be S-band dump of PCM not previously transmitted, these data would require qualitative analysis

Astronaut support requires objective comment relative to procedures and D&C

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related test objectives which could always be accomplished are the S-band objective P 4 2 1, the acoustic objective S 3 3, and the D&C objective S 3 3 The VHF communications objective P 4 2 4 is related because of the requirement for downlink

P 4 2 3 Verify compatibility of MSFN updata link (UDL) for updating central timing equipment (CTE) by the UHF and S-band links



TEST CONDITIONS

This test objective would be a special test capable of accomplishment in either BB-5 or AM-2 of BB-9. Refer to AOH procedure 12 3 11. If not operationally required, it is desirable that the test update occur sequentially, i.e., update by UHF and then by S-band.

DATA REQUIREMENTS

Data acquisition requires approximately one minute of HBR PCM T/M for each mode.

Astronaut support, other than appropriate switching as necessary, is not required.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related test objectives which could always be accomplished are the S-band objective P 4 2 1 and the VHF communications objective P 4 2 4.

- P 4 2 4 Demonstrate the capability of MSFN and spacecraft crew to maintain VHF communications.

TEST CONDITIONS

No special test conditions or procedures are required other than crew activity as required to maintain VHF communications throughout the mission. Refer to AOH procedure 12 1 1. VHF communications are required for BB-12, -14, -16, and -25 and contingency BB-26. This is not meant to exclude BB-5 and -9, or any other building block as a potential data source.

DATA REQUIREMENTS

Data acquisition requires HBR PCM T/M of any duration ranging from 5 seconds to 5 minutes, as required.

Astronaut support requires objective comment relative to adequacy of procedures, D&C, audio levels, etc.



RELATED TEST OBJECTIVES

Examination of the test objectives matrix (Figure 7-2) shows that the related test objective which would be always accomplished is the D&C objective S 3 3. Related objectives which could be accomplished are the acoustic objective S 3 3 and the CSM/LEM voice objective S 5. The AGC objectives P 1 1 4 and P 4 1 1, the data dump objective P 4 2 2, and the CTE objective P 4 2 3 are related because of the requirement for downlink.

- P 4 3 Obtain data on the use of consumables for a long duration earth orbital mission

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment as required by BB-5, -6, -7, -8, -11, -12, -13, -14, -15, -24, and -25 and contingency BB-26. Refer to AOH procedure 12 2 9.

DATA REQUIREMENTS

Data acquisition requires HBR PCM, either T/M or DSE for later dump. These data would consist of any duration ranging from 5 seconds to 5 minutes, as required.

Astronaut support requires logging consumption of such items as potable water, LiOH canisters, etc. These data would be periodically voice-transmitted to MSFN.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective is accomplished as an element of pre- ΔV operations. This objective may also be accomplished after the IMU alignment objectives P 1 1 1 and P 2 1 3, the vehicle alignment objectives P 1 1 2 and P 2 1 4, the orbital parameter objectives P 1 1 3 and P 2 1 5, the celestial sighting objective P 1 1 6, the out-the-window objective P 1 1 7, the wide dead-band special test objective P 2 2 2, the cryogenic pressure objective P 2 5 1, the fuel cell water objective P 2 5 2, and the SPS objectives P 2 6 1 and P 2 6 4.



P 5 1 Demonstrate CSM/SIV-B attitude stabilization for navigational sightings

TEST CONDITIONS

No special test conditions or procedures are required other than identified in BB-7 and -8 (see P 2 1 3 and P 2 1 5 TOADS)

DATA REQUIREMENTS

Data acquisition is required as identified in P 2 1 3 and P 2 1 5 TOADS

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related test objectives which would always be accomplished are the IMU alignment objectives P 1 1 1 and P 2 1 3 and the orbital parameters objectives P 1 1 3 and P 2 1 5. Related objectives which could be accomplished are the thermal control objective P 2 4 1, the compatibility objective S 1, and the astronaut-supported objectives S 2 3 and S 2 4.

S 1 Demonstrate CSM and launch vehicle compatibility

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment of BB-1, -5, and -6. Refer to AOH procedure 12 1 8.

DATA REQUIREMENTS

There are no specific PCM measurements in support of this test objective. However, it is highly desirable that continuous HBR PCM T/M be available from T-O to insertion in earth orbit.

Astronaut support requires objective comment with regard to vibration, acoustic phenomena, structural or system anomalies, etc. These data would be available in real-time or as close as practical to the time of occurrence.



RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that this objective can be accomplished by the related separation objective P 1 2 6. Related objectives which could be accomplished are the astronaut-supported objectives S 2 2, S 2 3, and S 2 4.

- S 2 1 Obtain data on food provisioning for a long-duration mission

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-10. Refer to AOH procedure 12 2 13.

DATA REQUIREMENTS

Data acquisition requires LBR PCM, either T/M or DSE for later dump. These data would consist of approximately 5 seconds of data once every hour or revolution throughout the mission.

Astronaut support requires objective comment with respect to palatability, flavor alteration, etc. These data would be available coincident with meal periods, if possible, or as soon as practical after the meal period.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that related test objectives which could be accomplished are the waste management objective P 2 3 3, the pressure control objective P 2 3 6 and the fuel cell water objective P 2 5 2.

- S 2 2 Demonstrate adequacy of the couch restraint system

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-1, -12, -25, and -35 or contingency BB-26 and -44. Refer to AOH procedure 12 1 5.



DATA REQUIREMENTS

There are no specific PCM measurements in support of this test objective. Flight qualification recorder data would be required during the building block for postmission recovery.

Astronaut support requires objective comment with regard to comfort, adjustability, D&C access, etc. These data would be available in real-time or as close as practical to the time of acquisition.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which function as data sources for this restraint objective are the out-the-window objective P 1 1 7, the translation and ullage objectives P 2 2 6 and P 2 7 7, the SPS objective P 2 6 1, and the compatibility objective S 1

S 2 3 Obtain data (astronaut-sensed) on acoustic environment

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-1, -7, -8, -9, -11, -12, -13, -14, -17, -25, and -35 or contingency BB-26. Refer to AOH procedure 12 1 7.

DATA REQUIREMENTS

There are no specific PCM measurements in support of this test objective.

Astronaut support requires objective comment with respect to noise level, possible source, possible remedial action if any, etc. These data would be available in real-time or as close as practical to the time of phenomena detection.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which function as data sources for this acoustic objective are the G&N operation and maneuvering objectives, the SPS objective P 2 6 1, and the communications objectives as well as the compatibility objective S 1. The related



objective which could be accomplished with this acoustic objective is the vibration objective S 2 4

- S 2 4 Obtain data (astronaut-sensed) on signs of equipment structure resonant vibration

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment during BB-1, -6, -7, -8, -11, -12, -13, and -25 or contingency BB-26 Refer to AOH procedure 12 1 6

DATA REQUIREMENTS

There are no specific PCM measurements in support of this test objective

Astronaut support requires objective comment with respect to detected vibration, possible source or cause, etc These data would be available in real-time or as close as practical to the time of occurrence

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related objectives which function as data sources for this vibration objective are the G&N operation and maneuvering objectives, the special test wide deadband objective P 2 2 2, the translation and ullage objectives P 2 2 6 and P 2 2 7, the SPS objective P 2 6 1, as well as the compatibility objective S 1 The related objective which could be accomplished with this vibration objective is the acoustic objective S 2 3

- S 3 1 Demonstrate simulated one-man lunar orbit and transearth coast operations

TEST CONDITIONS

This constitutes a special test which could require the performance of any or all of the following BB-7, -8, -9, -11, -12, -13, -14, -15, and -16 Accomplishment of this test objective would require the generation within the mission of its own timeline Refer to AOH procedure 12 3 18



DATA REQUIREMENTS

Data acquisition requires maximum or minimum data acquisition as identified in those TOADS selected as applicable

Astronaut required support would be as identified in those TOADS selected as applicable, as well as objective comment relative to one-man operation

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) permits identification of all the operations which could be accomplished by performance of the aforementioned building blocks

S 3 2 Demonstrate depressurized cabin operation

TEST CONDITIONS

No special test conditions or procedures are required other than performance of BB-18 Refer to AOH procedure 12 3 17

DATA REQUIREMENTS

Data acquisition requires maximum or minimum data acquisition as identified in those TOADS selected for accomplishment during the building block

Astronaut required support would be as identified in those TOADS accomplished during the building block as well as objective comment relative to depressurized cabin operation

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the only directly related objective is the pressure control objective P 2 3 6, which could be accomplished after repressurization

S 3 3 Demonstrate adequacy of displays/controls and compartment lighting

TEST CONDITIONS

No special test conditions or procedures are required other than performance of all building blocks Refer to AOH procedure 12 3 12



DATA REQUIREMENTS

There are no specific PCM measurements in support of this test objective

Astronaut support requires objective comment relative to the test objective as obtained through performance of the building blocks. It is highly desirable that data be obtained by the astronauts by use of a hand-held light meter to provide quantitative data with respect to light levels. All these data should be periodically transmitted to MSFN.

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) and the building block matrix (Figure 7-1) shows that almost all test objectives can function as data sources for the D&C objective

S 4 Demonstrate S-band and C-band antenna switching

TEST CONDITIONS

The S-band portion of this test objective constitutes a special test which would be performed during BB-9 AM-2. The C-band portion of this test would be accomplished during BB-5 and AM-1 or AM-2 of BB-9. This latter does not eliminate the use of any other building block as a possible data source for C-band antenna switching. Refer to AOH procedure 12 3 9. It is highly desirable that the C-band data be obtained in both two-pulse and one-pulse mode.

DATA REQUIREMENTS

Data acquisition requires HBR PCM T/M for both S-band and C-band. S-band data would be continuous during a station pass for the duration required for accomplishment of the objective (up to 5 minutes). C-band data would be accumulated over several station passes (approximately 5 minutes per pass). These latter data require correlation with station-based radar data received by signal strength "steps."

Astronaut support requires monitoring/logging of appropriate D&C, as well as objective comment with regard to S-band voice reception and switching procedures.



RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related test objectives which could always be accomplished are the S-band objective P 4 2 1 and the D&C objective S 3 3

- S 5 Obtain data on CSM/LEM VHF voice communications capability (earth-located LEM VHF prototype)

TEST CONDITIONS

Accomplishment of this objective constitutes a special test during BB-9 AM-2 Refer to AOH procedure 12 3 10 Test control will originate from MSC

DATA REQUIREMENTS

Data acquisition requires continuous HBR PCM T/M for approximately 5 minutes per station pass

Astronaut support requires monitoring/logging of appropriate D&C as well as objective comment relative to intelligibility of voice communications

RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related test objectives which could always be accomplished are the VHF communications objective P 4 2 4, the acoustic objective S 2 3 and the D&C objective S 3 3

- S 6 Conduct medical, scientific, and Department of Defense experiments as assigned to these missions

TEST CONDITIONS

No special test conditions or procedures are required other than accomplishment of BB-17 Refer to AOH Section 11

DATA REQUIREMENTS

Data acquisition is defined in BB-17



RELATED TEST OBJECTIVES

Examination of the test objective matrix (Figure 7-2) shows that the related test objectives which could always be accomplished are the biomedical objective P 2 10 and the acoustic objective S 2 3. The related water separator objective could be accomplished after any experiment which requires high physical activity.

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