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APOLLO

GUIDANCE, NAVIGATION AND CONTROL

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E-1142 (Rev. 37)

(UNCLASSIFIED TITLE)

SYSTEM STATUS REPORT

October 1965

MIT INSTRUMENTATION LABORATORY

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E-1142

(Unclassified Title)

SYSTEM STATUS REPORT

ABSTRACT
(Unclassified)

The System Status Report is distributed monthly on the 15th. This month's revision of E-1142 (Rev. 37) contains, in general, the following for the Block I and Block II Command Module and Lunar Excursion Module equipment: configuration weights, centers of gravity, moments of inertia, power requirements, status of computer programs, and reliability values.

by Apollo Staff

October 15, 1965

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Section 1

INTRODUCTION

1.1 Introduction

The following information is included in this month's report:

(1) Command Module, Block I
100 Series: Weights, power requirements
Zero Series: Centers of gravity and moments of inertia

(2) Command Module, Block II
Integrated Guidance, Navigation, and Control Configuration:
Weights, power requirements and reliability values.

(3) Lunar Excursion Module
LEM Integrated Guidance and Control Configuration:
Weights, power requirements and reliability values.

The definition of what constitutes Block I, Block II, and LEM hardware is contained in the Glossary, Section 5.

1.2 Accuracy

The accuracy of numerical values reported in this revision should not be considered to be within the tolerances implied by the significant figures quoted. The reported values, although based upon the most current information, are subject to normal changes as design and development phases approach completion.

Section 2

BLOCK I COMMAND MODULE DATA

2.1 Introduction

MIT received direction, NASA letter EG44-364-65-598, to develop and design a storage compartment for the Block I eyepieces. The storage compartment will be placed in the area vacated by the M&DV. The condition annunciator assembly should be part of the compartment structure. MIT, in compliance, is identifying the Optical Eyepiece Storage Assy as part of Block I - 100 Series hardware.

2.2 Weights

Table 2.1 presents the weights of all Block I (100 series) flight systems equipment, grouped according to specific location within the Command Module. Weights are reported to the component level and to the nearest tenth of a pound.

Given component weights are identified as estimated, calculated, or measured in order of increasing accuracy. These terms are defined by North American Aviation as follows: estimated weights (E) are based on rough calculations; calculated weights (C) are based on detailed calculations made from final production drawings that will be used to build flyable equipment; measured weights (M) are actual weights of equipment built to the production drawings.

North American Aviation will provide and be responsible for cold plate weights that are not integral with guidance and control equipment.

2.2.1 Weight Status Reporting.

Table 2.1 also offers a comparison of present 100 series component weight values with those listed in System Status Report, E-1142 (Rev. 36) September 15, 1965. All weight changes are explained in paragraph 2.2.

2.2.2 Control Weight (100 Series).

Column (a) in Table 2.1 contains the total control weight for the Apollo 100 series G&N equipment as specified in letter EG-151-44-65-55 (February 10, 1965) from Mr. R. W. Young, ASPO, to Mr. M. Trageser, MIT/IL.

2.2.3 Design Load Weight (100 Series).

Column (d) of Table 2.1 contains the "not to exceed" design load weights for individual Block I 100 series G&N subsystems. These weights were assigned per ICD MH01-01256-416, signed June 3, 1965.

2.3 Reported Block I 100 Series Weight Changes

2.3.1 Optical Subsystem (+1.0 lb)

The increase is due to the measured weight of the hardware in System 121 (Reference KIC Report AA-65-236).

2.3.2 Optical Eyepiece Storage Assy (+5.0 lb)

The addition of the Optical Eyepiece Storage Assy to the Block I configuration has resulted in an increase in weight. (For further information see paragraph 2.1).

2.3.3 Condition Annunciator (+0.8 lb)

The Condition Annunciator Assy is part of the eyepiece storage compartment structure. Added support hardware resulted in a weight increase. (See paragraph 2.1)

2.3.4 SXT Eyepiece (-0.2 lb)

The decrease is due to the measured weight of the hardware in System 121 (Reference KIC Report AA-65-236).

2.3.5 SCT Eyepiece (+0.1 lb)

The increase is due to the measured weight of the hardware in System 121 (Reference KIC Report AA-65-236).

2.3.6 Eye-Relief Eyepieces (-0.8 lb)

By direction from MSC in EG 44-292-65-469 the SXT Long Eye-Relief Eyepiece is no longer identified with Block I Optics and therefore will not be reported.

2.3.7 Control Electronics (-0.1 lb)

This is the measured weight of the hardware in System 110.

2.3.8 G&N Indicator Control Panel (+0.1 lb)

This is the measured weight of the hardware in System 110.

2.3.9 Lens Cleaning Kit (-0.3 lb)

Due to action items 26A-01-MSC and 26A-04-MIT, MIT will no longer report the Lens Cleaning Kit. NAA will provide an

TABLE 2.1 CURRENT WEIGHT STATUS OF BLOCK I 100 SERIES COMMAND MODULE (LBS AT 1G)

ITEM	(a) Control Weight †	(b-a)	(b) Status 9/65	(c-b)	(c) Status 10/65	(d) Design Load Wt. ϕ 7/65
LOWER EQUIPMENT BAY						
G & N Systems						
CDU ASSY			14.1(M)	0.0	14.1(M)	16.0
Optical Subsystem						
SXT						
SCT			46.6(M)	+1.0	47.6(M)	
Optical Base and Gearing						
NVB and Resilient Mounts			25.7(M)	0.0	25.7(M)	155.0*
Bellows Assy			12.7(M)	0.0	12.7(M)	
IMU			61.2(M)	0.0	61.2(M)	
Coolant Hoses (two)			0.9(M)	0.0	0.9(M)	
Power Servo Assy			65.4(M)	0.0	65.4(M)	
G & N Interconnection Assy			26.1(M)	0.0	26.1(M)	120.0
Optical Shroud			3.1(M)	0.0	3.1(M)	4.5
G & N to S/C Interface Assy			87.0(E)	0.0	87.0(E)	100.0
AGC (no spares)						
Optical Eyepiece Storage Assy			0.0(M)	+5.0	5.0(E)	--
Condition Annunciator			1.2(E)	+0.8	2.0(E)	2.0
SXT Eyepiece			1.7(M)	-0.2	1.5(M)	
SCT Eyepiece			2.7(M)	+0.1	2.8(M)	7.2
SCT Long Eye-Relief Eyepiece			1.6(M)	-0.8	0.8(M)	
DISPLAYS AND CONTROLS						
D & C Electronics			2.6(M)	0.0	2.6(M)	5.0
Control Electronics			1.9(M)	-0.1	1.8(M)	4.0

TABLE 2.1 CURRENT WEIGHT STATUS OF BLOCK I 100 SERIES COMMAND MODULE (LBS AT 1G) (CONTINUED)

ITEM	(a) Control Weight †	(b-a)	(b) Status 9/65	(c-b)	(c) Status 10/65	(d) Design Load Wt. ϕ 7/65
DISLPAYS & CONTROLS (contd)						
G & N Indicator Control Panel			10.8(M)	+0.1	10.9(M)	15.0
IMU Control Panel			2.9(M)	0.0	2.9(M)	5.0
Horizon Photometer Electronics			2.2(C)	0.0	2.2(C)	4.0
Signal Conditioner Assy			3.9(C)	0.0	3.9(C)	8.0
D & C/AGC			23.0(M)	0.0	23.0(M)	26.0
MAIN PANEL AREA						
D & C/AGC			25.2(E)	0.0	25.2(E)	26.0
LOOSE STORED ITEMS						
Optics Cover			1.6(C)	+0.5	2.1(M)	2.5
Horizontal Hand Holds	(Two)		1.0(E)	0.0	1.0(E)	1.0
Lens Cleaning Kit			0.3(E)	-0.3	0.0(M)	---
TOTAL	430.0 †	-4.6	425.4	+6.1	431.5	---
Bare Guidance Systems - IMU, AGC, IMU portions of the CDU's and IMU support electronics					200.6	---

† Total Control Weight specified in letter EG-151-44-65-55 (February 10,1965), from Mr. R. W. Young, ASPO, to Mr. M. Trageser, MIT/IL. See Paragraph 2.2.2. This weight assignment does not include recognition of the Optical Eyepiece Storage Assembly.

ϕ Design Load Weights are taken from ICD MH01-01256-416 (signed June 3, 1965, submitted by MIT in Letter AG-478-65).

* This Design Load Weight includes only ½ the weight of the Bellows Assembly

optics cleaning kit for Block I and Block II Command Modules, subject to MIT approval of the cleaning materials.

2.4 Block I (Zero Series) Weight, Center of Gravity, and Moment of Inertia Data.

At the present time, since Block I (100 series) G&N equipment is not available inhouse and ACE is not contractually obligated to perform moments of inertia calculations or measurements, MIT is using Block I zero series information and final production drawings to calculate the Block I (100 series) moments of inertia and centers of gravity. These data will appear in future reports. Table 2.2 summarizes Block I (zero series) data.

Table 2.2. Block I (Zero Series) Weight and Balance Data

Weight (lb)	Center of Gravity (in)	Moments of Inertia* (slug ft^2)
408.9	X 55.1 Y -0.3 Z 37.3	I_{xx} 146.8 I_{yy} 418.1 I_{zz} 282.1

*Values determined with respect to the basic X, Y, Z axes of the Command Module.

2.5 Command Module Power Requirements (100 Series)

The power requirements of the Command Module 100 series G&N equipment on the primary +28 VDC power supply are shown in Fig. 2.1 which presents the magnitude and location of dissipated power values on

a subassembly level. This assumes an 8.27-day mission, as defined by the Apollo Mission Planning Task Force (AMPTF) for power profile computation, and is based on a 28 VDC input at the connectors. The values shown are average values. (Ref: GAEC Report No. LED-540-12, October 30, 1964.)

Table 2.3 shows the magnitude and location of power dissipation for the established G&N activities, each operating at a different power level.

Table 2.4 shows the energy requirements for each G&N activity on a power level basis. The table is based upon MIT letter AG-679-6, "G&N Power Profile Status," dated August 14, 1963. The vertical column to the left indicates the various G&N activities (phases of operation) for the model 8.27-day mission submitted by the AMPTF (GAEC Report No. LED-540-12, October 30, 1964). The column also indicates the power requirement and operating time for each specific activity. The top row indicates the power requirement and operating time for each G&N power consuming equipment. The table sums up the energy consumption for each G&N activity and each G&N power consuming equipment.

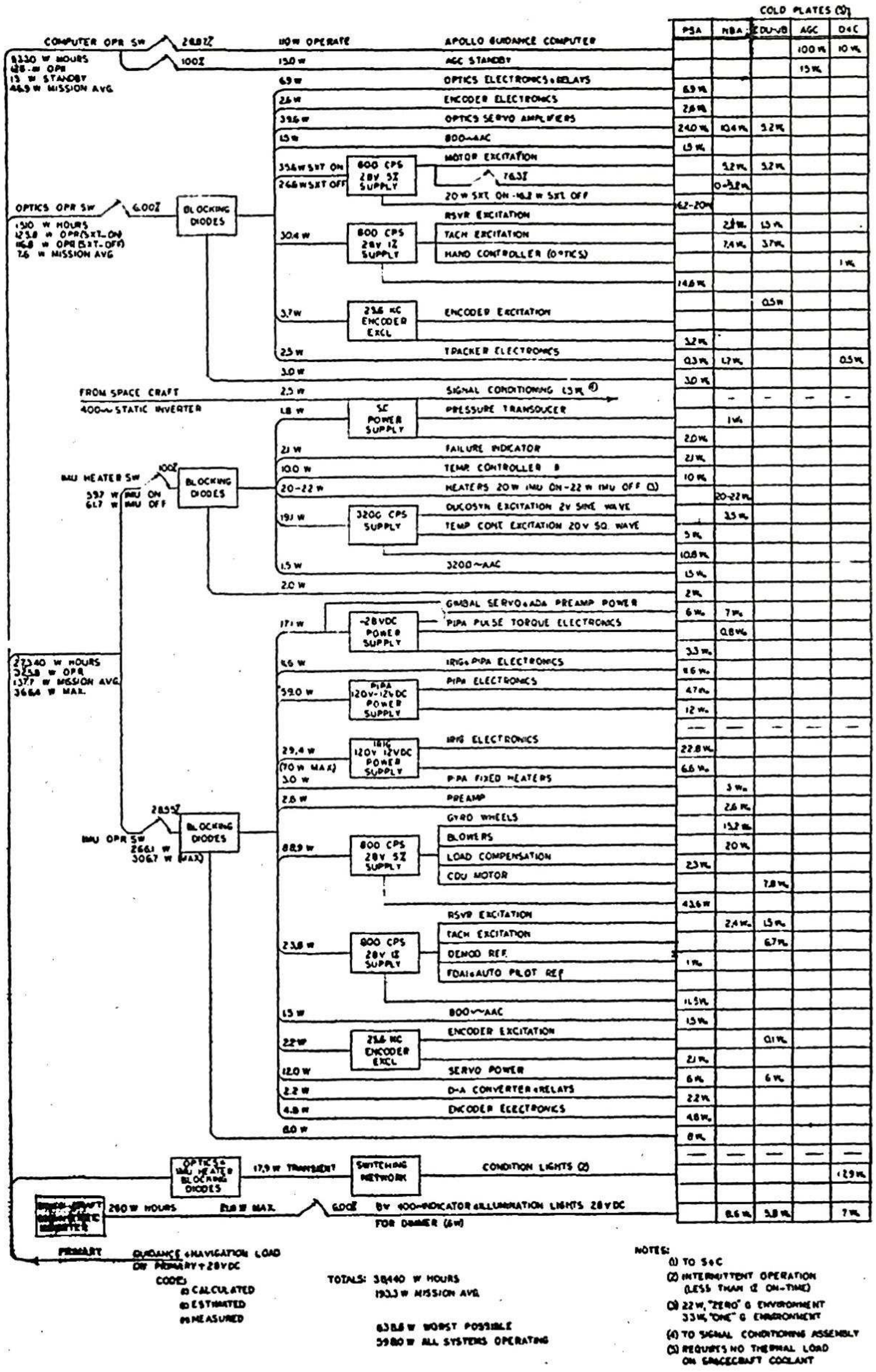

Fig. 2-1 Electrical load on primary + 28 vdc power supply for Block I (100 Series) systems.

Table 2-IV. Block I (100 Series) Command Module Energy Consumption Profile for 8.27-Day Lunar Orbit Mission

MODE	G&N Activity	Energy Consumption (kwh)							
		(1) AGC Operate 125.0 watts 57.38 hours	(2) AGC Standby 15.0 watts 141.31 hours	(3) Optics Sextant ON 125.8 watts 9.08 hours	(4) Optics Sextant OFF 116.8 watts 2.83 hours	(5) IMU Operate 325.8 watts 56.73 hours	(6) IMU Standby 61.7 watts 141.96 hours	(7) D&C Operate 21.4 watts 11.91 hours	Total
A	Accomplish & Confirm Course Correction Major Maneuvers Inactivity & Monitor 450.8 watts 45.12 hours	5.640	—	—	—	14.700	—	—	20.340
B	IMU Alignments Sextant Sightings (Midcourse Navigation) 598.0 watts 9.08 hours	1.135	—	1.142	—	2.958	—	0.194	5.429
C	Landmark Tracking (Low-Orbit Navigation) 589.0 watts 2.83 hours	0.354	—	—	0.330	0.922	—	0.060	1.666
D	Inactivity & Monitor 186.7 watts 0.35 hours	0.044	—	—	—	—	0.022	—	0.066
E	Sextant Sightings (Midcourse Navigation) 333.9 watts 0.30 hours	0.038	—	0.038	—	—	0.019	0.006	0.101
F	Inactivity & Monitor 76.7 watts 141.31 hours	—	2.119	—	—	—	8.719	—	10.838
	Total 198.55 hours	7.211	2.119	1.181	0.330	18.580	8.760	0.260	38.440

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Table 2-III. Nominal Power Dissipation (watts) vs G&N Activity for Block I (100 Series) Systems

MODE	G&N Activity (power levels)	NBA		CDU JB		PSA		AGC	Thermal Load on S/C Coolant	D&C and S&C	Optics External	Electrical Load
		IMU	D&C and OBA	IMU	D&C and OBA	IMU	OBA					
A	Accomplish & Confirm Course Corrections Inactivity & Monitor Major Maneuvers (1, 5)	74.5	0.0	22.1	0.0	228.5	0.0	115.0	440.1	10.7	0.0	450.8
B	IMU Alignments Sextant Sightings (Midcourse Navigation) (1, 3, 5, 7)	74.5	40.7	22.1	21.9	228.5	76.1	115.0	578.8	18.7	0.5	598.0
C	Landmark Trackings (Low-orbit Navigation) (1, 4, 5, 7)	74.5	35.5	22.1	21.9	228.5	72.3	115.0	569.8	18.7	0.5	589.0
D	Inactivity & Monitor (1, 6)	25.5	0.0	0.0	0.0	36.2	0.0	115.0	176.7	10.0	0.0	186.7
E	Sextant Sightings (Midcourse Navigation) (1, 3, 6, 7)	25.5	40.7	0.0	21.9	36.2	76.1	115.0	315.4	18.0	0.5	333.9
F	Inactivity & Monitor	25.5	0.0	0.0	0.0	36.2	0.0	15.0	76.7	0.0	0.0	76.7

1. AGC Operate 125.0 watts
2. AGC Standby 15.0 watts
3. Optics Operate SXT On 125.8 watts
4. Optics Operate SXT Off 116.8 watts
5. IMU Operate 325.8 watts
6. IMU Standby 61.7 watts
7. D&C Operate 21.4 watts

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Section 3

BLOCK II COMMAND MODULE DATA

3.1 Introduction

MIT received a NASA direction (EG 131-5-65-374) redefining the ground rules to be used in reporting the command module primary guidance navigation, and control systems reliabilities. In compliance, MIT has extended the operating time from earth launch until LEM powered descent.

The Block II Command Module computer program, which contains S&C functions, is in the process of being calculated and will be reported when the values become established.

As a result of action item 26A-08-MSC, MIT will provide a storage unit for eyepieces in the Block II command module similar to the Block I (100 Series) unit. There is no provision for the Condition Annunciator Assembly as part of the compartment structure.

3.2 Reliability

The operating times and associated mission success probabilities in Table 3.1 are based upon the Apollo Mission Planning Task Force (AMPTF) time line listed in GAEC Report LED-540-12, dated 30 October 1964.

3.3 Weights for the Block II Command Module

Table 3.2 shows the weights of the Block II Command Module Integrated Guidance and Control System.

In general the data conforms to the information contained in paragraphs 2.2, 2.2.1, and 2.2.2.

3.3.1 Design Load Weights

Column (d) of Table 3.2 contains the "not to exceed" design load weights for individual Block II G&N subsystems. These weights were assigned per ICD MH01-01356-416, signed 16 July 1965.

3.4 Reported Block II Weight Changes

3.4.1 SXT Eyepiece (-0.2 lb)

The decrease is due to the measured weight of the hardware in System 121 (Reference KIC Report AA-65-236).

3.4.2 SCT Eyepiece (+0.1 lb)

The increase is due to the measured weight of the hardware in System 121 (Reference KIC Report AA-65-236).

3.4.3 Optical Subsystem (+1.0 lb)

The increase is due to the measured weight of the hardware in System 121 (Reference KIC Report AA-65-236).

3.4.4 AGC (-5.0 lb)

A more extensive weight analysis has been performed on the AGC during the reporting period. Also, the results of thermal test and analysis have indicated that adequate thermal environment for the electronic components could be met with a change from aluminum to magnesium in some of the structure. The present

estimate reflects this change and includes the estimate for conformal or foam potting of modules and case.

3.4.5 Power Servo Assy (+7.9 lb)

The original estimate was based on the use of foam encapsulation of header wiring (total wire and potted volume = 180 cu.in. approx.). Because of the foam adhesion problems in Block I, the potting material was changed from foam to solid polyurethane to avoid potential potting separation. This caused an increase of 2.0 lb. The rest of the estimated increase is a result of final layout and concurrent stress analysis of the header. The thickness of the header under the modules was increased from .080" to .100". A pattern of ribs, at full header height = 1.75" enclosing module groups, was added to reduce header stresses below the yield point and to limit deflections (Maximum stresses and deflections occur when the header is evacuated prior to filling with dry nitrogen, and during flight when the spacecraft pressure equals zero and internal PSA pressure equals one atmosphere). This additional structure is responsible for the balance of the weight increase.

3.4.6 PIPA Electronics Assembly

After the original estimate, design refinement of the twelve modules contained in the assembly showed that module weights should be increased from 3% to 35% The net increase in total module weight equals 0.5 lb. The balance of the increase is in the cover. A stress analysis was made of the final layout. The cover flange was made thicker to reduce deflections in the area of the compression seal. A "waffle" rib pattern was added to the cover to reduce stresses and deflections under a differential pressure of one atmosphere. See the pressure discussion of the C/M PSA.

TABLE 3.2. CURRENT WEIGHT STATUS OF BLOCK II COMMAND MODULE (LBS AT 1G)

ITEM	(a) Control Weight †	(b-a)	(b) Status 9/65	(c-b)	(c) Status 10/65	(d) Design Load Wt. ϕ 7/65
LOWER EQUIPMENT BAY						
GN&C Systems						
CDU Assy			35.7(E)	0.0	35.7(E)	50.0
Optical Subsystem						
SXT						
SCT			46.6(M)	+1.0	47.6(M)	
Optical Base & Gearing						
NVB & Mounts			14.9(E)	0.0	14.9(E)	
Bellows Assy			12.7(E)	0.0	12.7(E)	150.0
IMU			41.3(M)	0.0	41.3(M)	
Coolant Hoses (two)			0.9(M)	0.0	0.9(M)	
Power Servo Assy			41.5(E)	+7.9	49.4(E)	58.0
PIPA Electronics Assy			7.9(E)	+1.1	9.0(E)	12.0
G & N Interconnect Harness Assy			30.0(E)	0.0	30.0(E)	40.0
AGC			70.0(E)	-5.0	65.0(E)	80.0
Optical Shroud			3.1(M)	0.0	3.1(M)	4.5
Optical Eyepiece Storage Assy			0.0(M)	+5.0	5.0(E)	---
SXT Eyepiece			1.7(M)	-0.2	1.5(M)	
SCT Eyepiece			2.7(M)	+0.1	2.8(M)	7.0
SCT Long Eye-Relief Eyepiece			0.8(M)	0.0	0.8(M)	2.0
DISPLAYS AND CONTROLS						
G & N Indicator Control Panel			12.1(E)	0.0	12.1(E)	17.0
D & C/AGC			17.5(E)	0.0	17.5(E)	25.0
Signal Conditioner Assy			6.5(E)	0.0	6.5(E)	8.0

TABLE 3.2. CURRENT WEIGHT STATUS OF BLOCK II COMMAND MODULE (LBS AT 1G) (CONTINUED)

ITEM	(a) Control Weight †	(b-a)	(b) Status 9/65	(c-b)	(c) Status 10/65	(d) Design Load Wt.ϕ 7/65
MAIN PANEL AREA						
D & C/AGC			17.5(E)	0.0	17.5(E)	25.0
LOOSE STORED ITEMS						
Horizontal Hand Holds (two)			1.0(E)	0.0	1.0(E)	1.0
Lens Cleaning Kit			0.3(E)	-0.3	0.0(M)	---
TOTAL	400.0 †	-35.3	364.7	+9.6	374.3	---
Bare Guidance Systems - IMU, AGC, IMU portions of the CDU's and IMU support electronics					166.9	

† Total Control Weight specified in Letter EG-151-44-65-55 (10 February 1965) from Mr. R. W. Young, ASPO, to Mr. M. Trageser, MIT/IL. See Paragraph 2.2.2. This weight assignment does not include recognition of the Optical Eyepiece Storage Assembly.

ϕ Design Load Weights are taken from ICD MH01-01356-416 (signed 16 July 1965, at meeting 22A).

Table 3.1 Reliability Estimates For Variations of AMPTF Design Reference Mission (Probability of success of CSM PGNCS from earth launch until LEM powered descent. Elapsed time of approximately 69 hours.)

PGNCS Subsystem	Operate Failure Rate Per 10^6 hrs	Operate Time (hrs)	Standby Failure Rate Per 10^6 hrs	Standby Time (hrs)	Failures Per 10^6 Missions	Success Probability
IMU	129	13.8	7.8	55.6	2214	0.99779
IMU Electronics	110	13.8	6.3	55.6	1868	0.99813
CDU (IMU)	171	13.8	0	55.6	2360	0.99764
Optics	94	9.1	0	59.1	855	0.99914
Optics Electronics	77	9.1	0	59.1	701	0.99929
CDU (Optics)	114	9.1	0	59.1	1037	0.99896
AGC	357	13.8	96.4	55.6	10,286	0.9901
DSKY (2)	14.6	13.8	0	55.6	202	0.99979*
D&C	22	13.8	0	55.6	304	0.99969
Total					19,827	0.9805

*Success requires that only one of redundant pair of DSKYs, not fail.

3.4.7 Optical Eyepiece Storage Assembly (+5.0 lb)

The addition of the Optical Eyepiece Storage Assy to the Block II Configuration has resulted in an increase in weight. (For further information see section 3.1).

3.4.8 Lens Cleaning Kit (-0.3 lb)

Due to action items 26A-01-MSC and 26A-04-MIT, MIT will no longer report the Lens Cleaning Kit. NAA will provide an optics cleaning kit for Block I and Block II Command Modules, subject to MIT approval of the cleaning materials.

3.5 Power Requirements

The power requirements of the Block II Command Module G&N equipment on the primary +28 VDC power supply are shown in Fig. 3.1, which presents the magnitude and location of dissipated power values on a subassembly level. This chart assumes an 8.27-day lunar orbit mission as defined by the Apollo Mission Planning Task Force (AMPTF) for power profile computation and is based on a 28 VDC input at the connectors. These values are average values (Ref: GAEC Report LED-540-12, October 30, 1964).

Table 3.3 shows the magnitude and location of power dissipation for the established G&N activities, each operating at different power levels.

Table 3.4 shows the energy requirements for each G&N activity on a power level basis. The table is based on MIT letter AG 679-6. "G&N Power Profile Status," dated August 14, 1963. The vertical column to the left indicates the various G&N activities (phases of operation) for the model 8.27-day lunar orbit mission submitted by AMPTF (GAEC Report LED-540-12, October 30, 1964). This column also indicates the power

requirement and operating time of each G&N activity. The top row indicates the power requirement and operating time for each G&N power consuming equipment. The total power consumption for each G&N activity and each G&N power consuming equipment is also given.

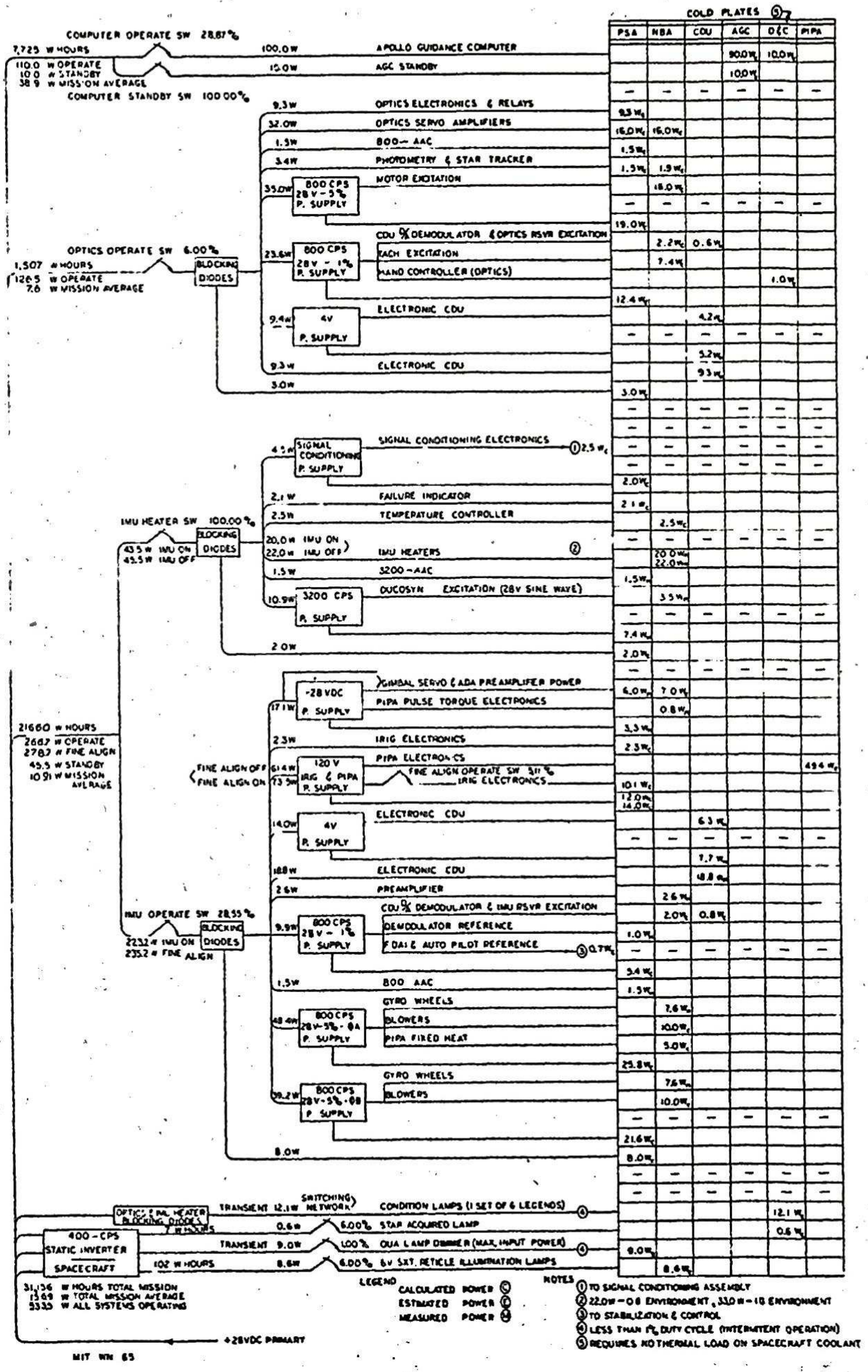

Fig. 3-1 Electrical load on primary + 28 vdc power supply for Block II Command Module.

Table 3-IV. Block II Command Module Energy Consumption Profile for 8.27-Day Lunar Orbit Mission

MODE	G&N Activity	Energy Consumption (kwh)						
		(1) AGC Operate 110.0 watts 57.38 hours	(2) AGC Standby 10.0 watts 141.31 hours	(3) Optics Operate 126.5 watts 11.91 hours	(4) IMU Operate 266.7 watts 56.73 hours	(5) IMU Standby 46.0 watts 141.96 hours	(6) D&C Operate 22.1 watts 11.91 hours	Total
A	Accomplish & Confirm Course Corrections Major Maneuvers Inactivity & Monitor 376.7 watts 45.12 hours	4.963	—	—	12.034	—	—	16.997
B	IMU Alignments Sextants Sightings (Midcourse Navigation) Landmark Trackings (Low-orbit Navigation) 525.3 watts 11.61 hours	1.277	—	1.469	3.096	—	0.257	6.099
C	Inactivity & Monitor 156.0 watts 0.35 hours	0.039	—	—	—	0.016	—	0.055
D	Sextant Sightings (Midcourse Navigation) 304.6 watts 0.30 hours	0.033	—	0.038	—	0.014	0.007	0.092
E	Inactivity & Monitor 56.0 watts 141.31 hours	—	1.413	—	—	6.500	—	7.913
	Total 198.55 hours	6.312	1.413	1.507	15.130	6.530	0.264	31.156

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Table 3-III. Nominal Power Dissipation (watts) vs G&N Activity for Block II Systems

MODE	G&N Activity (power levels)	NBA		CDU		PSA		AGC	Thermal Load on S/C Coolant	D&C and S&C	Electrical Load
		IMU	OBA	IMU	OBA	IMU	OBA				
A	Accomplish & Confirm Course Corrections Inactivity & Monitor Major Maneuvers (1, 4)	78.6	0.0	32.8	0.0	154.3	0.0	100.0	365.7	10.7	376.7
B	IMU Alignments Sextant Sightings (Midcourse Navigation) Landmark Tracking (Low-orbit Navigation) (1, 3, 4, 6)	78.6	32.8	44.9	18.7	154.3	62.7	100.0	491.5	33.8	525.3
C	Inactivity & Monitor (1, 5)	28.0	0.0	0.0	0.0	18.0	0.0	100.0	146.0	10.0	156.0
D	Sextant Sightings (Midcourse Navigation) (1, 3, 5, 6)	28.0	43.7	0.0	18.7	18.0	62.7	100.0	271.5	33.1	304.6
E	Inactivity & Monitor (2,5)	28.0	0.0	0.0	0.0	18.0	0.0	10.0	56.0	0.0	56.0

1. AGC Operate 110.0 watts
2. AGC Standby 10.0 watts
3. Optics Operate 126.5 watts
4. IMU Operate 266.7 watts
5. IMU Standby 46.0 watts
6. D&C Operate 22.1 watts

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Section 4

LUNAR EXCURSION MODULE DATA

4.1 Introduction

MIT has initiated several weight reduction actions in an effort to meet the control weight requirements as assigned by MSC in letter EG 151-44-65-55. These possibilities have been reported to NASA.

The current estimates of the LEM Primary Guidance, Navigation and Control System power requirements are shown in Fig. 4.1. This illustration contains the latest information regarding the LEM standby mode operating on the Command Module bus during the translunar phase.

4.2 Reliability

The operating times and associated mission success probabilities in Table 4.1 are based upon the Apollo Mission Planning Task Force (AMPTF) time line listed in GAEC Report No. LED-540-12, dated 30 October 1964, which uses the interval of LEM operation from earth launch to LEM lunar touchdown.

4.3 Weights for LEM PGNCS

Lunar Excursion Module weights are presented in Table 4.2. In general, the data conform to the information contained in paragraphs 2.1, 2.2.1, and 2.2.2.

4.4 Reported LEM Weight Changes

Table 4.1 Reliability Estimate for LEM G & N Based on AMPTF Design Reference Mission
(Probabilities for LEM PGNCS from earth launch until LEM touchdown.)

PGNCS Subsystem	Operate Failure Rate Per 10^6 hrs	Operate Time (hrs)	Standby Failure Rate Per 10^6 hrs	Standby Time (hrs)	Failures Per 10^6 Missions	Success Probability
IMU	129	3.25	7.8	66.2	936	0.9991
IMU Electronics	105	3.25	6.3	66.2	758	0.9993
CDU (IMU)	183	3.25	0	0	595	0.9995
Optics	38	3.25	0	0	124	0.99988
Optics Electronics	38	3.25	0	0	124	0.99988
CDU (Optics)	122	3.25	0	0	397	0.9997
AGC	357	3.25	0	0	1160	0.9989
DSKY	245	3.25	0	0	796	0.9992
D & C	7	3.25	0	0	42	0.99998
Total					4932	0.995

TABLE 4.2 CURRENT WEIGHT STATUS OF LEM PGNCS (LBS AT 1G)

Item	(a) Control Weight †	(b-a)	(b) Status 9/65	(c-b)	(c) Status 10/65	(d) Design Load Wt. ϕ 9/65
LEM GN&C SYSTEMS						
IMU			41.3(M)	0.0	41.3(M)	43
Nav Base			4.0(E)	0.0	4.0(E)	8
AOT			23.1(E)	0.0	23.1(E)	25
Button Box			2.0(E)	0.0	2.0(E)	3
PTA			14.8(E)	0.0	14.8(E)	17
Harness "B"			4.5(E)	0.0	4.5(E)	8
DSKY			17.5(E)	0.0	17.5(E)	20
LGC			70.0(E)	-5.0	65.0(E)	75
CDU			36.8(E)	0.0	36.8(E)	42
PSA			20.1(E)	0.0	20.1(E)	32
Signal Conditioner Assy			7.2(E)	-3.1	4.1(E)	
Harness "A"			19.0(E)	-4.4	14.6(E)	22
Lens Cleaning Kit			0.3(E)	0.0	0.3(E)	0.5
Total	240.0 †	+20.6	260.6	-12.5	248.1	---
Bare Guidance Systems - IMU, LGC, IMU portions of the CDU's and IMU support electronics					160.6	---

†Total Control Weight specified in Letter EG-151-44-65-55 (10 February 1965), from Mr. R. W. Young, ASPO, to Mr. M. Trageser, MIT/IL. See Section 2.2.2.

ϕDesign load weights based upon MIT answer (AG-824-65, dated 9 September 1965) to GAEC Submittal of ICD LIS-490-10001.

4.4.1 LGC (-5.0 lb)

A more extensive weight analysis has been performed on the LGC during the reporting period. Also the results of thermal test and analysis have indicated adequate thermal environment for the electronic components could be met with a change from aluminum to magnesium in some of the structure. The present estimate reflects this change and includes the estimate for conformal or foam potting of the modules and case.

4.4.2 Signal Conditioner Assy (-3.1 lb)

This item is still very early in the design cycle. The estimate is based upon the weight density per signal processed in the Block I Command Module signal conditioner. The estimate assumes approximately 35 signals required for support of operational LEMs. For development flight LEMs, a larger signal conditioner processing about 55 signals will be required weighing about two pounds heavier.

4.4.3 Harness "A" (-4.4 lb)

Last month's estimate provided for considerable EMI filtering to be provided in the junction box associated with the "A" harness. The latest estimates for these filters involving condensers only on power and signal lines results in an estimated reduction in the junction box of the amount stated. The weight is, of course, sensitive to many considerations of the installed equipment, its environment, and the EMI specifications.

4.5 Power Requirements

The power requirements of the Lunar Excursion Module PGNCS on the primary +28 VDC powersupply are shown in Fig. 4.1 which presents

the magnitude and location of dissipated power values on a subassembly level. The estimate for LEM power is based upon the 8.27-day lunar mission as defined by the Apollo Mission Planning Task Force (AMPTF) for power profile computation (Ref: GAEC Report LED-540-12, dated October 30, 1964).

Table 4.3 shows the energy requirements for each G&N activity on a power level basis. The table is also based upon GAEC Report LED-540-12. The vertical column on the left indicates the various G&N activities (phases of operation). This column also indicates the power requirements and operating time for each activity. The top row indicates the power requirements and operating time of each G&N power consuming equipment. The table sums up the energy consumption for each G&N power consuming equipment and each G&N activity.

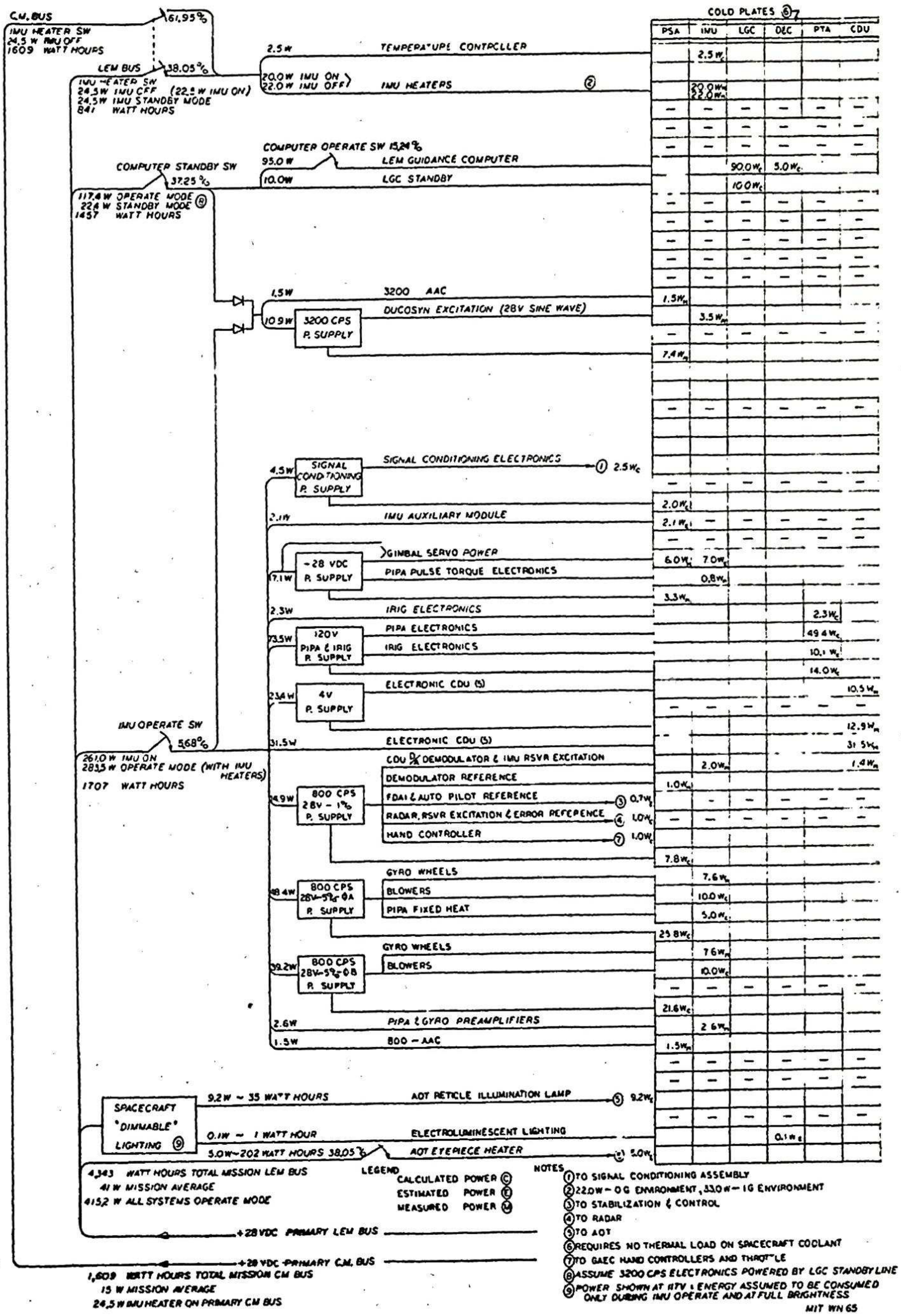

Fig. 4-1 Electrical load on primary + 28 vdc power supply for Lunar Excursion Module.

Table 4.3 Lunar Excursion Module Power Profile Based on GAEC Report LED-540-12

Total Mission Time 106.02 Hours

LEM PGNCS on +28 VDC LEM Bus

MODE	LEM Activity	Energy Consumption (kwh)							
		(1) LGC Off 0.0 watts 0.84 hours	(2) LGC Operate 117.4 watts 6.02 hours	(3) LGC Standby 22.4 watts 33.48 hours	(4) IMU Operate 283.5 watts 6.02 hours	(5) IMU Standby 24.5 watts 34.32 hours	(6) OMU (AOT) Operate 9.2 watts 3.83 hours	(7) AOT Eyepiece heater 5 watts 40.34 hours	(8) Total
I	Inactivity 29.4 watts 0.84 hours	0.000	-	-	-	0.021	-	0.004	0.025
II	Inactivity Alignment Midcourse Measurements 415.1 watts 3.83 hours	-	0.450	-	1.086	-	0.035	0.019	1.590
III	Guidance During Major Event 405.9 watts 2.19 hours	-	0.257	-	0.621	-	-	0.011	0.889
IV	Inactivity 51.9 watts 33.48 hours	-	-	0.750	-	0.820	-	0.167	1.737
	Total 40.34 hours	0.000	0.707	0.750	1.707	0.841	0.035	0.202	4.242

LEM PGNCS on +28 VDC CM Bus

MODE	LEM Activity	(1) LGC Off 0.0 watts 65.68 hours				(5) IMU Standby 24.5 watts 65.68 hours			Total
I_o	Inactivity 24.5 watts 65.68 hours	0.000	-	-	-	1.609			1.609

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Section 5

GLOSSARY AND SYSTEM DEFINITION

Apollo Guidance Computer (AGC)

CM Block I

A single complete flight computer containing all logic, memory associated power supplies, and all interface circuits except those identified with the CDU's. Does not contain the associated displays and controls.

Consists of one case containing factory replaceable electronic modules. Includes cover for moisture-proofing, but does not include the necessary cold plate or the G&N to S/C Interface Assembly which is located in the adjacent area.

CM Block II and LEM

Many modules have been redesigned and repackaged in a separate case. The CDU's are on the same side of the cold plate as the AGC. Memory capacity is increased over Block I.

Alignment Optical Telescope (AOT)

CM Block I and CM Block II

Not in CM; see Optical Subsystem.

LEM

A three-position periscope with single-degree-of-freedom, manually read reticule for alignment of the IMU. Includes the weight of the bellows assembly and a regular eyepiece.

Bellows Assembly

CM Block I

Consists of two flexible metal bellows forming pressure seal between CM & optical subsystem for penetration of hull for optics.

CM Block II

Same except for two elastomeric seals and transition pieces.

LEM

Same except for one elastomeric seal.

Computer Control and Reticle Dimmer Assy (Button Box)

CM Block I and CM Block II

Not defined in the Command Module.

LEM

Located on GAEC Supplied Hardware protecting the AOT. Contains illuminated push button controls mark "x", mark "y", and reject mark. Also has an AOT reticle dimmer.

Condition Annunciator Assembly

CM Block I

Visually displays G&N system status. This function was previously part of the Map & Data Viewer. The current proposal is to include this into the optics eyepiece storage unit.

CM Block II

Not identified as a separate item. Incorporated as part of the Indicator Control Panel.

LEM

Not identified as part of LEM.

Coupling Data Unit (CDU) Assembly

The CDU provides the necessary signal interface among the IMU gimbal angles, optics gimbal angles, radar gimbal angles, angle registers in the AGC, the spacecraft autopilot attitude error signals, and the tracking radar command error signals.

CM Block I

Five interchangeable gear boxes each with necessary motor tachometer resolver synchros, and encoder with mounting frame work. Does not include associated electronics which are located in the PSA.

CM Block II

Functionally similar to Block I except the instrumentation is all electronic and also provides for simultaneous A/D and D/A functions. Includes all support electronics (including special power supply) and header mounted adjacent to the AGC.

LEM

Interchangeable with CM Block II CDU's except for the headers which contain different module interwiring.

Cold Plates

CM Block I, Block II, and LEM

Cold plates for the IMU are built into the IMU. Necessary cold plates for electronics are part of the equipment supplied by the spacecraft manufacturer.

Control Electronics Assembly

CM Block I

Consists of one power transformer, one relay and diode module and a bracket end connector mounted behind G&N indicator control panel to support display and control functions. Includes moisture-proofing.

CM Block II

Not required in Block II. These functions are now incorporated into the PSA.

LEM

Not required in LEM.

Coolant Hoses

CM Block I

Consists of: (1) three steel-flex coolant hoses between IMU and spacecraft, (2) line transition piece, (3) bracket assembly screws and clamp, and (4) entrapped coolant.

CM Block II

Consists of: (1) two steel-flex coolant hoses, between IMU and spacecraft and (2) entrapped coolant.

LEM

Not identified as part of LEM.

DSKY (D&C/AGC)

CM Block I

Number displays and keyboard control associated with the operation of the AGC. Two functionally identical and parallel

operating units in each CM system, one in lower equipment bay and one on main panel between left and center couches.

CM Block II

Mechanically and electrically similar to Block I but smaller configuration because of smaller relays. The Block II display and keyboard controls will be sealed by encasing the unit in a container and using pressurized 0-rings.

LEM

Identical to Block II except only a single unit is required.

D&C Electronics Assembly

CM Block I

Consists of a chassis, a relay and diode module, a demod. elect. module, a saturable reactor, a time delay module, a connector, and wiring and is mounted behind the G&N Indicator Control Panel. Used to support display and control functions. Connectors will be moisture-proofed.

CM Block II

Not required in Block II. These functions now incorporated in the PSA.

LEM

Not used in LEM.

G&N Indicator Control Panel

CM Block I

Consists primarily of controls and displays for the operation of the optics, IMU temperature control, panel brightness control,

and attitude impulse control. It includes display and control elements, panel, panel wiring, supporting hardware, and moisture-proofing.

CM Block II

Consists of controls and displays for optics, condition lamps, telemetry, and Master Alarm. Also contains Attitude impulse switch and hand controller. Has integral illuminated computer instructions.

G&N Interconnection Assembly

CM Block I

Consists of PSA End Connector Assembly and interconnect wiring harness, which electrically ties together the assemblies that constitute a completely integrated system. This term does not include weights of harness support brackets, which are an NAA responsibility, nor the G&N to S/C Interface Assembly weight.

CM Block II

Not in Block II.

LEM

Consists of two harness assemblies. Harness "A" provides interconnection in the CDU, AGC, and PSA areas. In order to solve EMI problems, there is a filter, located in the distribution box. Harness "B" connects the IMU and PTA areas. The estimated weights include connectors, distribution box, wire, insulation, shielding, and cable clamps.

G&N Interconnect Harness Assembly

CM Block I

Not required.

CM Block II

Consists of eight cables that electrically tie together the assemblies that make up the G&N system and interface with the spacecraft.

LEM

Not required.

G&N to S/C Interface Assembly

CM Block I

Cable interconnection between the spacecraft wiring channel, the computer connector, and the PSA end connector. Contains no active electronics. The weight of this item is included with the computer.

CM Block II

Not in Block II.

LEM

Not in LEM.

Horizon Photometer

CM Block I and Block II

An earth horizon brightness photometer and automatic star tracker used for navigation measurements against the earth's illuminated limb. The sensors are incorporated into the head of the SXT, the weight of which includes this function. The PSA includes all support electronics for Block II and some of the support electronics for Block I.

LEM

Not a part of LEM.

Horizon Photometer Electronics

CM Block I

Additional horizon photometer and star tracker electronics mounted on an auxiliary header and attached to the right-hand wall in the lower equipment bay.

CM Block II

All electronics are located in the PSA or on the sextant head.

LEM

Not required.

Horizontal Hand Holds

CM Block I and CM Block II

Hand holds on the G&N Panel for use during navigation sightings. These Hand Holds are a part of the body tethering system for the S/C and will be removed during flight.

LEM

Not defined in LEM.

Inertial Measurement Unit (IMU)

CM Block I

Size 14 IMU (14-inch case diameter) gimbal assembly including all parts inside hermetic case, entrapped coolant, and heat exchanger insulation.

CM Block II and LEM

Size 12.5 IMU is functionally similar to the Block I IMU but not physically interchangeable. Redesigning has eliminated the ADA's, and it now uses a single torque motor per gimble assy.

IMU Control Panel

CM Block I

Consists of panel, wiring, attitude error meter, CDU transfer switch, manual alignment switch, CDU mode control switches, connector, supporting hardware, and associated moisture-proofing.

CM Block II

Does not exist in Block II. Moding is done by AGC program and AGC push buttons.

LEM

Does not exist in LEM.

Lens Cleaning Kit

CM Block I, CM Block II and LEM

Not specifically defined but appropriate cloths for cleaning the accessible surfaces of the optics lens.

Long-Eye-Relief Eyepiece

CM Block I

Consists of a SCT eyepiece to provide eye relief of at least 1.6 inches for closed visor operation. Used in place of normal eyepiece of SCT.

CM Block II

A Block I long-eye-relief eyepiece for the SCT only.

LEM

Not part of LEM.

NVB and Mounts

CM Block I

Rigid beryllium structure supporting the IMU and the optical subsystem with its associated hardware. The NVB is attached to the spacecraft using flexible resilient mounts to prevent spacecraft strains from distorting the NVB and the alignment between the IMU and optics. These mounts also provide shock and vibration attenuation.

CM Block II

A polyurethane filled aluminum skinned structure functionally similar to Block I but lighter and will provide for mounting the size 12.5 IMU. The Block II NVB is attached to the spacecraft by use of strain isolation hardmounts and will have a transition piece as a result of the re-orientation of the NVB so that the IMU axes will be parallel to the Command Module axes.

LEM

A toroidal aluminum ring with: (1) four tubular aluminum posts to provide for IMU mounting, (2) four tubular aluminum posts for AOT mounting, and (3) three aluminum inserts to provide strain isolation ball mounting to the GAEC structure.

Optical Eyepieces

CM Block I and CM Block II

Removable SXT eyepiece and SCT eyepiece.

LEM

Included as part of the AOT.

Optical Eyepiece Storage Assy

CM Block I

A polyurethane filled structure will provide storage for three optical eyepieces: SXT normal eye-relief, SCT normal eye-relief, and SCT long eye-relief eyepieces. The condition annunciator assembly is part of the compartment structure. The weight also includes a protective cover or door. The assembly is located in the area vacated by the M&DV.

CM Block II

Block II eyepiece storage is not clearly defined.

LEM

Not identified as part of LEM. See AOT.

Optical Subsystem

CM Block I and CM Block II

Consists of SXT, SCT, Optical Base, and associated hardware defined as follows:

SXT: Sextant: A two-line-of-sight, narrow-field, two-degree-of-freedom sextant and its attached gearing. The horizon photometer and automatic star tracker sensors are incorporated into the SXT head. (See Horizon Photometer Electronics.)

SCT: Scanning Telescope: A single-line-of-sight, wide-field-of-view, two-degree-of-freedom articulation optical instrument and its attached gearing.

Optical Base: Base for SXT and SCT with associated gearing.

LEM

Not in LEM; see AOT.

Optical Shroud & Cover Assembly

CM Block I

Consists of the optical shroud and protective cover.

CM Block II

Contains only the optical shroud.

LEM

Does not exist in LEM.

PIPA Electronics Assembly

CM Block I

Does not exist separately in Block I.

CM Block II

Consists of electronics which directly support the function of the PIPA loop, including the calibration modules, containing selected components, assigned to each IMU. This sealed assembly is located in the Block I CDU location.

LEM

Not required - (see Pulse Torque Assembly).

Power Servo Assembly (PSA)

CM Block I

Includes most of the support electronics: power supplies; IMU, Optics, and CDU servos; IMU temperature control; accelerometer and gyro pulse torquing; and horizon photometer and automatic star tracker electronics. Consists of 10 trays and replaceable modules which plug into the PSA end connector assembly. Includes a beryllium front tow plate.

CM Block II

Similar in function to Block I except that CDU servos are deleted. Electronics to support the PIPA loop have been transferred. See "PIPA Electronics Assembly." Consists of a single plane matrix header with a cold plate mounted on top with the modules plugging from beneath. Many of the modules have been redesigned and repackaged.

LEM

Consists of electronics similar to those identified in the Block II PSA minus various electronics modules. Does not include optics and photometry electronics associated with the Block I and II PSA's. Also, the LEM PSA does not include electronics for the PIPA and IRIG loops. See "Pulse Torque Assembly."

PSA End Connector Assembly

CM Block I End Connector weight is reported in the G&N to S/C Interconnection.

Electrical interconnection between the PSA trays, the G&N Interconnection Assy, and the G&N to S/C Interface Assy. The

End Connector weight is reported in the G&N to S/C Interconnection Assembly weight.

CM Block II and LEM

Not identified as a separate item; will be part of the PSA matrix header.

PSA Covers

CM Block I

Ten connector covers, gaskets, and mounting screws (one for each tray) for moisture-proofing. Weight included in PSA weight value.

CM Block II and LEM

Cover required for moisture-proofing during flight. Weight is reported in PSA weight value.

Pulse Torque Assembly

CM Block I

Does not exist separately in Block I.

CM Block II

Not required (see PIPA Electronics Assembly).

LEM

This assembly consists of electronics contained in the PIPA and IRIG loops, including the pulse torque power supply and PIPA and IRIG calibration modules. The PIPA calibration modules, containing selected components, are assigned to each IMU. This sealed assembly is located adjacent to the IMU in LEM.

Signal Conditioner Assembly

CM Block I

Conditions signals for telemetry.

CM Block II

These modules are located in the same volume now occupied by the Block I lower equipment bay DSKY.

LEM

Same as for Block I. This assembly is located on top of the LEM PSA.

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