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APOLLO

GUIDANCE AND NAVIGATION

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E-1142 (Rev. 36)

(UNCLASSIFIED TITLE)

SYSTEM STATUS REPORT

September 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. 36) 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

September 15, 1965

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1.1 Introduction

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

(1) Command Module, Block I
100 Series: Weights and power requirements
Zero Series: Centers of gravity and moments of inertia
Guidance and Navigation Lunar Land Mission: Status of computer and reliability values.

(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 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.

2.1.1 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. 35) August 15, 1965. All weight changes are explained in paragraph 2.2.

2.1.2 Control Weight (100 Series).

Column (a) in Table 2.1 contains the total control weight for

Table 2.1 Current Weight Status of Block I (100 Series) Command Module (lbs at 1 g)

Item	100 Series Control Weight (a)	(b-a)	100 Series Status 8/65 (b)	(c-b)	100 Series Status 9/65 (c)	100 Series Design§ Load Wt. 1/65 (d)
G&N SYSTEMS						
CDU Assy			14.1 (M)	0.0	14.1 (M)	16.0
Optical Subsystem						
SXT						
SCT			46.6 (M)	0.0	46.6 (M)	
Optical Base & Gearing						
NVB & 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			59.7 (M)	+5.7	65.4 (M)	120.0
G&N Interconnect. Assy			27.3 (E)	-1.2	26.1 (M)	
G&N to S/C Interface Assy						
AGC (no spares)			87.0 (E)	0.0	87.0 (E)	100.0
Optical Shroud			3.1 (E)	0.0	3.1 (M)	4.5
LOWER EQUIPMENT BAY						
D&C						
D&C Electronics			2.6 (M)	0.0	2.6 (M)	5.0
Control Electronics			1.9 (M)	0.0	1.9 (M)	4.0
G&N Ind. Control Panel			10.5 (E)	+0.3	10.8 (M)	15.0
IMU Control Panel			2.9 (M)	0.0	2.9 (M)	5.0
Condition Annunciator Assy			1.2 (E)	0.0	1.2 (E)	2.0
D&C/AGC			23.0 (M)	0.0	23.0 (M)	26.0
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
MAIN PANEL AREA						
D&C/ AGC			25.2 (E)	0.0	25.2 (E)	26.0

Table 2.1 Current Weight Status of Block I (100 Series) Command Module (lbs at 1 g) (cont)

Item	100 Series Control Weight (a)	(b-a)	100 Series Status 8/65 (b)	(c-b)	100 Series Status 9/65 (c)	100 Series Design§ Load Wt. 1/65 (d)
LOOSE STORED ITEMS						
Optical Eyepieces						
SXT			1.7 (M)	0.0	1.7 (M)	7.2
SCT			2.7 (M)	0.0	2.7 (M)	
Eye Relief Eyepieces			1.6 (M)	0.0	1.6 (M)	
Optics Cover			1.6 (C)	0.0	1.6 (C)	2.5
Horizontal Hand Holds			1.0 (E)	0.0	1.0 (E)	1.0
Lens Cleaning Kit			0.1 (E)	+0.2	0.3 (E)	
Total	430.0†	-9.6	420.4	+5.0	425.4	

* This Design Load weight is figured to include only 1/2 the weight of the Bellows Assembly.

† 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 2.1.2.

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

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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.

2.1.3 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.

2.2 Reported Block I 100 Series Weight Changes

2.2.1 Power Servo Assy (+5.7 lb)

The original foam potting in the trays did not adhere consistently to the tray frames. This problem was solved by changing the potting material from urethane foam to a solid polyurethane compound, which is approximately twice as heavy as the molded foam. Tray weights increased accordingly.

2.2.2 G&N Interconnect Assy (-1.2 lb)

This is now a measured rather than an estimated weight.

2.2.3 G&N Indicator Control Panel (+0.3 lb)

This is now a measured rather than an estimated weight.

2.2.4 Lens Cleaning Kit (+0.2 lb)

This kit is not specially defined but it will contain one or more appropriate cloths for cleaning the accessible surface of the optics lens. A more realistic value is 0.3 lb.

2.3 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	I_{xx} 146.8
	Y -0.3	I_{yy} 418.1
	Z 37.3	I_{zz} 282.1

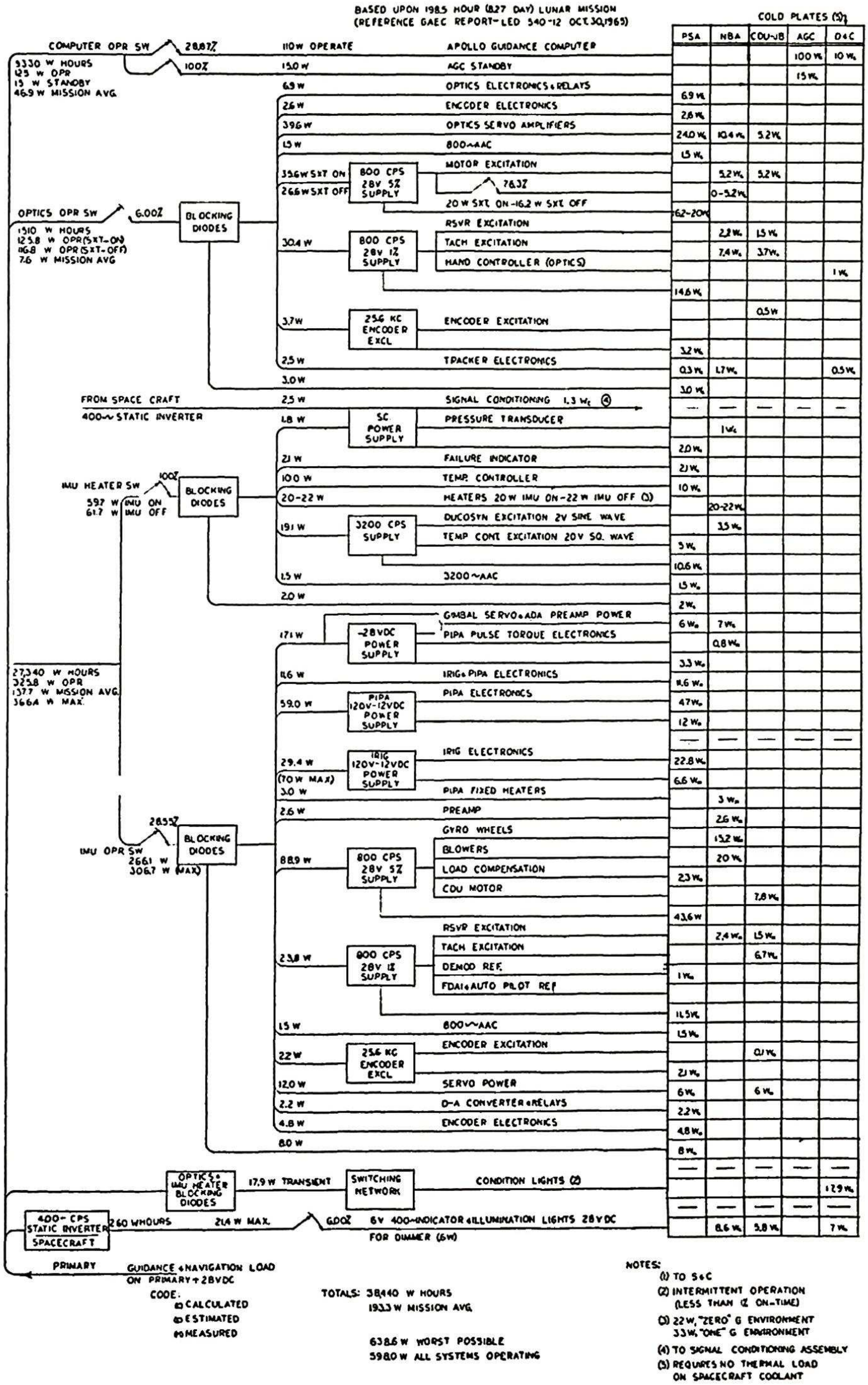
*Values determined with respect to the basic X, Y, Z axes of the Command Module.

2.4 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

COMMAND MODULE
BLOCK I (100 SERIES)

BASED UPON 1985 HOUR (82.7 DAY) LUNAR MISSION
(REFERENCE GAEC REPORT-LED 540-12 OCT. 30, 1965)



PSA	NBA	CDU-UB	AGC	D&C
			100 W	10 W
			15 W	
6.9 W				
2.6 W				
24.0 W	10.4 W	5.2 W		
1.5 W				
	5.2 W	5.2 W		
	0-5.2 W			
16.2-20 W				
	2.2 W	1.5 W		
	7.4 W	3.7 W		
				1 W
14.6 W				
		0.5 W		
3.2 W				
0.3 W	1.7 W			0.5 W
3.0 W				
—	—	—	—	—
	1 W			
2.0 W				
2.1 W				
10 W				
	20-22 W			
	3.5 W			
5 W				
10.6 W				
1.5 W				
2 W				
6 W	7 W			
	0.8 W			
3.3 W				
11.6 W				
47 W				
12 W				
—	—	—	—	—
22.8 W				
6.6 W				
	3 W			
	2.6 W			
	15.2 W			
	20 W			
2.3 W				
		7.8 W		
43.6 W				
	2.4 W	1.5 W		
		6.7 W		
1 W				
11.5 W				
1.5 W				
		0.1 W		
2.1 W				
6 W		6 W		
2.2 W				
4.8 W				
8 W				
—	—	—	—	—
				17.9 W
—	—	—	—	—
	8.6 W	5.8 W		7 W

NOTES:
(1) TO S&C
(2) INTERMITTENT OPERATION (LESS THAN 1% ON-TIME)
(3) 22 W, "ZERO" G ENVIRONMENT
33 W, "ONE" G ENVIRONMENT
(4) TO SIGNAL CONDITIONING ASSEMBLY
(5) REQUIRES NO THERMAL LOAD ON SPACECRAFT COOLANT

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 of which consists of various power levels of operation.

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.

2.5 Status of Command Module AGC Program

The Block I Command Module program status (Table 2.5) reflects the lunar landing mission exclusive of the stabilization and control function.

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.

Table 2.3 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

Table 2.4 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

Table 2.5 Current Memory Capacity of Command Module AGC Programs (9/15/65)

Item	Memory Words
List Processing Interpreter	1762
AGC Executive	318
AGC Waitlister	190
AGC Self-Check	889
G&N System Test	1699
Display & Keyboard	2847
Input/Output Control	1769
Navigation	1775
Powered Flight Guidance & Attitude Control	1052
Prelaunch Alignment	782
In-Flight Alignment*	925
Re-Entry	1543
Re-Start and First Start	468
Mission Sequencing (202)	960
Miscellaneous	497
	17476

*Estimated

Section 3

BLOCK II COMMAND MODULE DATA

3.1 Introduction

There is an expected weight increase in the PSA, and PIPA Electronics Assy. This increase is now being evaluated and will be contained in the October System Status Report (Rev. 37, E-1142).

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.

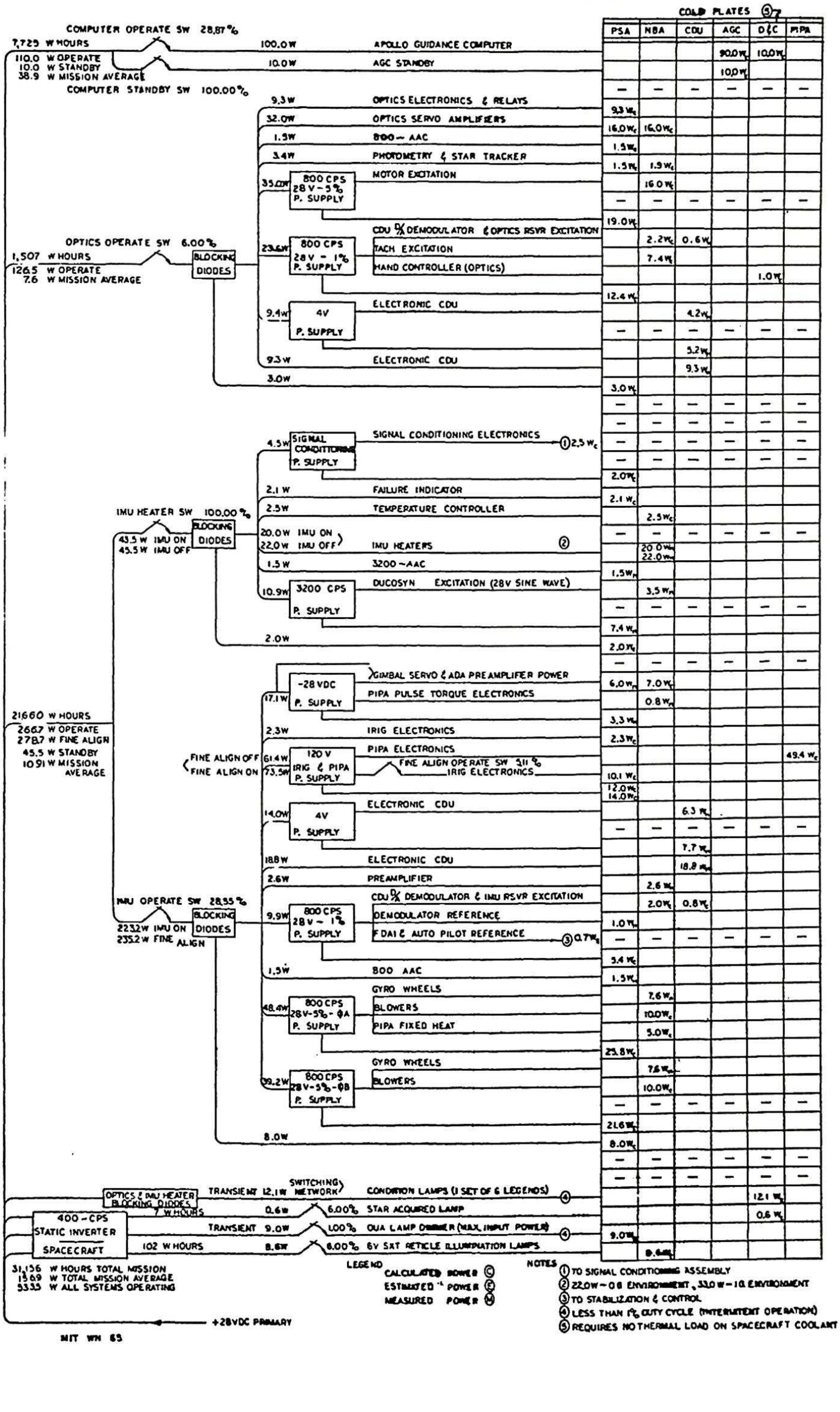
The power requirements of the Block II Command Module PGNCS equipment on the primary +28 VDC power supply (shown in Fig. 3.1) will be updated to reflect the power drawn by LEM on the Command Module bus during the trans-lunar phase. The October System Status Report will contain this revision.

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.

BLOCK II GUIDANCE & NAVIGATION LOAD ON PRIMARY + 28 VDC COMMAND MODULE

BASED UPON 198.5 HOUR (8.27 DAY) LUNAR ORBIT MISSION — REFERENCE GSEC REPORT - LED 540-12 OCT. 30, 1964
DESIGN REFERENCE MISSION — APOLLO MISSION PLANING TASK FORCE



MIT WN 65

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)	202/13.8 hrs	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.

3.3 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 2.1, 2.1.1, and 2.1.2.

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 Lens Cleaning Kit (+0.2 lb)

The kit is not specially defined but it will contain one or more appropriate cloths for cleaning the accessible surface of the optics lens. A more realistic value is 0.3 lb.

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 3.2 Current Weight Status of Block II Command Module (lbs at 1 g)

Item	Control Weight (a)	(b-a)	Status 8/65 (b)	(c-b)	Status 9/65 (c)	Design† Load Wt. 7/65 (d)
G&N SYSTEMS						
CDU Assy			35.7 (E)	0.0	35.7 (E)	50.0
Optical Eyepieces						
SXT			1.7 (M)	0.0	1.7 (M)	7.0
SCT			2.7 (M)	0.0	2.7 (M)	
Optical Subsystem						
SXT			46.6 (M)	0.0	46.6 (M)	
SCT						
Optical Base & Gearing			14.9 (E)	0.0	14.9 (E)	
NVB & Mounts			12.7 (E)	0.0	12.7 (E)	
Bellows Assy			41.3 (M)	0.0	41.3	150.0
IMU			0.9 (M)	0.0	0.9 (M)	
Coolant Hoses (two)			41.5 (E)	0.0	41.5 (E)	
Power Servo Assy			7.9 (E)	0.0	7.9 (E)	58.0
PIPA Electronics Assy			30.0 (E)	0.0	30.0 (E)	12.0
Interconnect Harness Assy			70.0 (E)	0.0	70.0 (E)	40.0
AGC			3.1 (M)	0.0	3.1 (M)	80.0
Optical Shroud						4.5
LOWER EQUIPMENT BAY						
D&C						
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
MAIN PANEL AREA						
D&C/AGC			17.5 (E)	0.0	17.5 (E)	25.0

Table 3.2 Current Weight Status of Block II Command Module (lbs at 1 g) (cont)

Item	Control Weight (a)	(b-a)	Status 8/65 (b)	(c-b)	Status 9/65 (c)	Design† Load Wt. 7/65 (d)
LOOSE STORED ITEMS						
Horizontal Hand Holds (2)			1.0 (E)	0.0	1.0 (E)	1.0
Lens Cleaning Kit			0.1 (E)	+0.2	0.3 (E)	0.1
SCT Long Eye-Relief Eyepiece			0.8 (M)	0.0	0.8 (M)	2.0
Total	400.0*	-35.5	364.5	+0.2	364.7	—

* 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 2.1.2.

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

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Table 3.3 shows the magnitude and location of power dissipation for the established G&N activities, each of which consists of various power levels of operation.

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 mission submitted by AMPTF (GAEC Report LED-540-12, October 30, 1964). This column also indicates the power requirements and operating time of each G&N activity and 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.

Table 3.3 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

Table 3.4 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

Section 4

LUNAR EXCURSION MODULE DATA

4.1 Introduction

Since the increased total weight in this report exceeds the control weight assigned by MSC letter EG-151-44-65-55, MIT is preparing weight reduction proposals as required by the provisions of this letter.

The current estimate 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

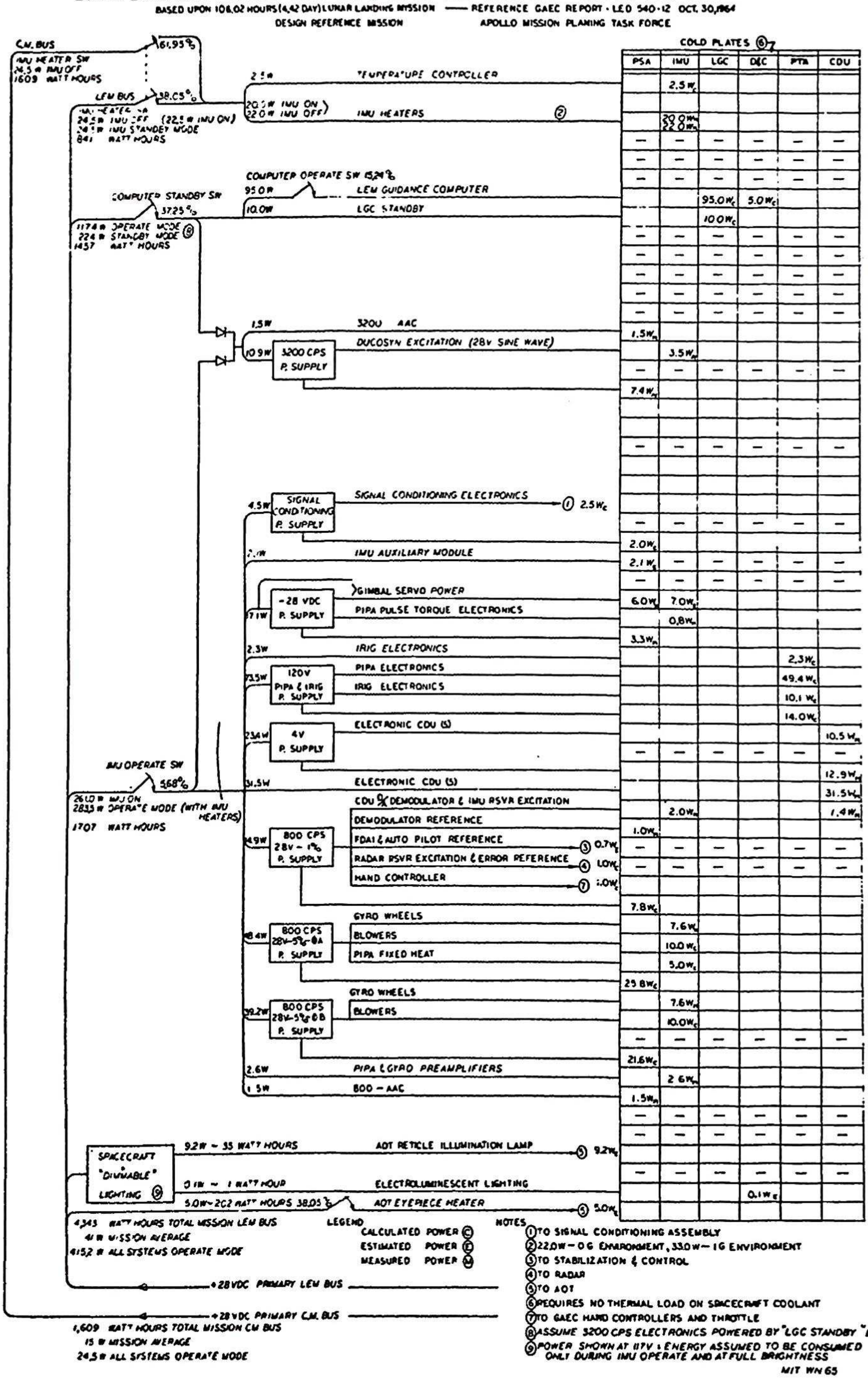
The operating times and associated mission success probabilities in Table 4.1 are based upon the Apollo Mission Planning Task Force (AMPTF) time line listed in GAEC Report No. LED-540-12, dated 30 October 1964, which uses the interval of LEM operation from earth launch to LEM lunar touchdown.

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, 2.1.1, and 2.1.2.

LUNAR EXCURSION MODULE GUIDANCE & NAVIGATION LOAD ON +28VDC PRIMARY

BASED UPON 108.02 HOURS (4.42 DAY) LUNAR LANDING MISSION — REFERENCE GAEC REPORT · LED 540-12 OCT. 30, 1964
DESIGN REFERENCE MISSION — APOLLO MISSION PLANING TASK FORCE



COLD PLATES (6)

PSA	IMU	LGC	DSC	PTA	CDU
	2.5 Wc				
	39.0 Wc 22.0 Wc				
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
		95.0 Wc	5.0 Wc		
		10.0 Wc			
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
1.5 Wm					
	3.5 Wm				
—	—	—	—	—	—
7.4 Wm					
—	—	—	—	—	—
—	—	—	—	—	—
2.0 Wc					
2.1 Wc	—	—	—	—	—
—	—	—	—	—	—
6.0 Wc	7.0 Wc				
	0.8 Wc				
3.3 Wm					
				2.3 Wc	
				49.4 Wc	
				10.1 Wc	
				14.0 Wc	
					10.5 Wm
—	—	—	—	—	—
					12.9 Wm
					31.5 Wm
	2.0 Wm				1.4 Wm
1.0 Wm					
—	—	—	—	—	—
—	—	—	—	—	—
7.8 Wc					
	7.6 Wc				
	10.0 Wc				
	5.0 Wc				
25.8 Wc					
	7.6 Wm				
	10.0 Wc				
—	—	—	—	—	—
21.6 Wc					
	2.6 Wm				
1.5 Wm					
—	—	—	—	—	—
—	—	—	—	—	—
			0.1 Wc		

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	13	3.25	0	0	42	0.99996
Total					4932	0.995

Table 4.2 Estimated Weights of LEM PGNCS (lbs at 1g)

Item	Control Weight (a)	(b-a)	Status 8/65 (b)	(c-b)	Status 9/65 (c)	Design Load Wt. 9/65* (d)
1) IMU			41.3(M)	0.0	41.3(M)	43
2) Nav Base			4.0(E)	0.0	4.0(E)	8
3) AOT			23.1(E)	0.0	23.1(E)	25
4) Button Box			2.0(E)	0.0	2.0(E)	3
5) PTA			14.8(E)	0.0	14.8(E)	17
6) Harness "B"			4.5(E)	0.0	4.5(E)	8
7) DSKY			17.5(E)	0.0	17.5(E)	20
8) LGC			70.0(E)	0.0	70.0(E)	75
9) CDU			36.8(E)	0.0	36.8(E)	42
10) PSA			20.1(E)	0.0	20.1(E)	32
11) Signal Conditioner Assy			7.2(E)	0.0	7.2(E)	
12) Harness "A"			19.0(E)	0.0	19.0 (E)	22
13) Lens Cleaning Kit			0.0(M)	+0.3	0.3(E)	0.5
Total	240.0**	+20.3	260.3	+0.3	260.6	

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

**Total Control Weight specified in Letter EG-151-44-65 (February 10, 1965) from Mr. R.W. Young, ASPO, to Mr. M. Trageser, MIT/IL. See section 2.1.2.

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4.4 Reported LEM Weight Changes

4.4.1 Lens Cleaning Kit (+0.3 lb)

The kit is not specially defined but it will contain one or more appropriate cloths for cleaning the accessible surface of the optics lens.

4.5 Power Requirements

The estimate for LEM power and energy consumption shown in Fig. 4.1 is based upon the 8.27-day lunar orbit 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 power consuming equipment.

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 Interconnector 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. Harness "B" connects the IMU and PTA areas. The estimated weight includes connectors, distribution box, wire, insulation, shielding, and cable clamps.

G&N Interconnection Harness Assembly

CM Block I
Not required.

CM Block II
Consists of nine 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 Eyepieces

CM Block I

Consists of a SXT and a SCT eyepiece to provide eye relief

of at least 1.6 inches for closed visor operation. Used in place of normal eyepieces of SXT and 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 the 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 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 and Block II

Consists of the optical shroud and protective cover.

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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