APOLLO

GUIDANCE AND NAVIGATION

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SYSTEMS STATUS
REPORT

September 15, 1963

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INSTRUMENTATION LABORATORY
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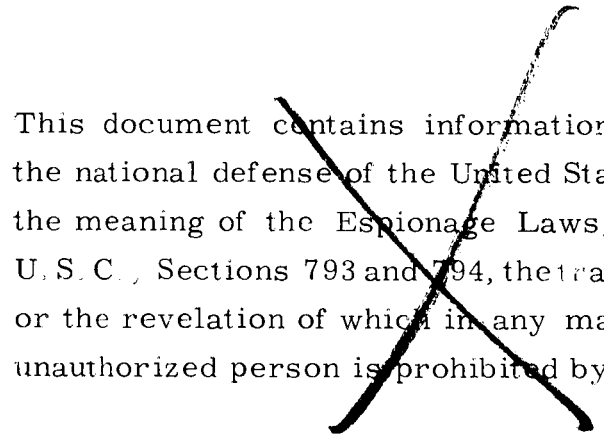

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ABSTRACT

The System Status report is distributed monthly on the 15th. This month's revision (E-1142, Rev. 12) contains weight and balance data and power requirement information for the guidance and navigation equipment in the Lunar Excursion and Command Modules. In addition, the first monthly report on the status of Command Module computer programs has been included.

Section 1

INTRODUCTION

1-1 INTRODUCTION

The following information is included in this month's report: (1) weights, centers of gravity, and moments of inertia of G&N equipment in the Command Module and weights of G&N equipment in the Lunar Excursion Module, (2) power requirements of G&N equipment in the Command and Lunar Excursion Modules, and (3) status of Command Module computer programs.

All weights in this report, including those for both the command module and LEM, are based upon the current "block I" design releases. Purely weight-saving design changes have been held, in general, for the "block II" release scheduled for early 1964.

1-2 ACCURACY

The accuracy of numerical values reported in this revision should not be considered to be within the tolerance implied by the significant figures quoted. Numerical values will approach the established tolerance as design and development phases approach completion.

Section 2

COMMAND MODULE DATA

2-1 WEIGHTS

Table 2-I presents all weight items, grouped according to their specific location within the Command Module. Subsystem weights are reported to the component level and to the nearest tenth of a pound.

Given component weights are identified as estimated, calculated, and measured in the order of increasing accuracy. These terms are defined by North American Aviation as follows:

Estimated weights (E) are rough calculations. Calculated weights (C) are weights based on detailed calculations made from final production drawings that will be used to build flyable equipment. Measured weights (M) are the actual weights of equipment built to the production drawings.

Since all weight values now reported may be classified as only estimated weights MIT herein affixes a prime to the (E) symbol, i.e., (E') to denote, for various reasons, values which MIT feels to be more accurate than estimated values, yet which cannot be defined as either calculated or measured weights.

North American Aviation will provide and be responsible for coldplate weights which are not integral with guidance and navigation equipment.

2-1.1 WEIGHT STATUS REPORTING. Table 2-I also offers a comparison of present component weight values with those listed in System Status Report, E-1142 (Rev. 11), August 15, 1963. All weight changes are explained (see 2-2).

2-1.2 SPEC. WEIGHT. The "Spec. Weight" column in table 2-I contains "proposed MSC" weights, that is, goals set forth by MSC in a memo to MIT dated December 5, 1962.

2-1.3 DESIGN LOAD WEIGHT. The "Design Load Weight" column contains assigned worst estimate design weights to G&N subassemblies attached to the spacecraft structure. These values are included in this report as the result of an S & ID request, at NASA Coordination Meeting No. 8, that one total weight figure for supported G&N load be assigned for structural design use. MIT herein assigns a total G&N design load weight, in table 2-I, which does not include items termed "loose stored items." The breakdown of this total weight into the individual items of column "d" is typical only.

Table 2-I. Current weight status of Command Module (lbs)

Item	Spec. Wt. 12/62 (a)	(b-a)	Status 8/63 (b)	(c-b)	Status 9/63 (c)	Design Load Wt. 9/63 (d)
LOWER EQUIPMENT BAY						
CDU & Frame Assy	6.0	+ 10.5	16.5	0.0	16.5(E)	17.2
Optical Subsystem						
SXT	12.0	0.0	12.0	0.0	12.0(E)	
SCT	9.0	0.0	9.0	0.0	9.0(E)	
Optical Base & Gearing	14.0	+ 7.0	21.0	0.0	21.0(E)	
Optical Eyepieces						
SXT	2.0	+ 1.8	1.6	0.0	1.5(E')	154.2
SCT			2.3	0.0	2.3(E')	
IMU	40.0	+ 19.0	59.0	0.0	59.0(E')	
NVB & Shock Mounts	16.0	+ 11.2	27.2	0.0	27.2(E)	
Bellows Assy	8.0	+ 4.6	12.6	0.0	12.6(E)	
Interconnect Wiring Harness	22.0	+ 13.0	35.0	0.0	35.0(E)	27.2
D & C Nav Station						
IMU Control Panel	30.3	- 3.6	4.4	0.0	4.4(E')	6.8
D & C Electronics LH			6.6	0.0	5.6(E')	7.7
D & C Electronics RH					1.0(E)	
Optical Shroud			3.8	0.0	3.8(E')	4.2
G & N Ind Cont Panel			11.9	0.0	11.9(E')	13.2
D & C/AGC	15.0	0.0	15.0	0.0	15.0(E)	19.4
M & DV (including 1 film)	5.0	+ 3.5	8.5	0.0	8.5(E)	10.0
AGC (no spares)	80.0	+ 16.5	70.0	0.0	70.0(E)	126.4
Spare Tray			26.5	0.0	26.5(E)	
PSA	25.0	+ 31.7	56.7	0.0	56.7(E)	65.0
JBX	8.0	+ 4.2	12.2	0.0	12.2(E)	15.6
Coolant Hoses	0.0	+ 1.0	1.0	0.0	1.0(E)	

(con't)

Table 2-I. Current weight status of Command Module (lbs) (con't.)

Item	Spec. Wt. 12/62 (a)	(b-a)	Status 8/63 (a)	(c-b)	Status 9/63 (c)	Design Load Wt. 9/63 (d)
MAIN PANEL AREA						
D & C/AGC	5.0	+ 10.0	15.0	0.0	15.0(E)	17.2
D & C/NAV	8.0	- 8.0	--	--	--	
LOOSE STORED ITEMS						
Eye Relief Eyepieces	--	+ 1.5	1.5	0.0	1.5(E)	
Film Cartridges (4)	--	+ 3.0	3.0	0.0	3.0(E)	
AGC Loose Spares			17.0	0.0	17.0(E)	
PSA Loose Spares	20.0	+ 11.5	11.5	0.0	11.5(E)	
CDU Spare Gearbox			3.0	0.0	3.0(E)	
Computer Self-Check Plug	--	+ 1.0	1.0	0.0	1.0(E)	
Horizon Photometer	--	+ 4.0	4.0	0.0	4.0(E)	
Spare Lamps (3)	--	+ 0.2	0.2	0.0	0.2(E)	
Spare Relay & Diode Module	--	+ 0.3	0.3	0.0	0.3(E)	
TOTAL	325.3	+143.9	469.2	0.0	469.2	
TOTAL (Exclusive of "Loose Stored Items")			427.7	0.0	427.7	484.1

2-2 REPORTED WEIGHT CHANGES

No weight changes were reported for this month. The PSA and AGC have reached a stage of development that enables a much better weight calculation than was possible before. These data, which will include a large proportion of actual weighted items, should be available in the next report.

2-3 CENTERS OF GRAVITY

Table 2-II presents the centers of gravity of each weight component or packaged assembly, which are determined with respect to the basic X, Y, Z axes of the Command Module shown in figure 2-1. Center of gravity values are given to the nearest tenth of an inch.

2-4 MOMENTS OF INERTIA

Table 2-II also presents the moments of inertia of each weight component or packaged assembly, determined about each of the component axes which (1) run through the center of gravity of the component and (2) are parallel to the basic X, Y, Z axes of the Command Module.

2-5 COMMAND MODULE POWER REQUIREMENTS

The power requirements of the Command Module G & N equipment on the primary +28 VDC Power Supply are shown in figure 2-2, which presents the magnitude and location of dissipated power values on a subassembly level. This chart assumes a 14-day lunar orbit mission.

Table 2-III shows the magnitude and location of power dissipation for various mode operation combinations.

2-6 CURRENT STATUS OF COMMAND MODULE AGC PROGRAMS

Table 2-IV lists current memory estimates and the status of Command Module AGC programs. LEM AGC programs are not reported at this time.

A high and low word estimate is given with each program. The following statuses are defined:

Table 2-II. Command Module center of gravity and moment of inertia data

Item	Weight (lbs)	Centers of Gravity (inches)			Moments of Inertia ($lb\text{-}in^2$)		
		X	Y	Z	Ixx	Iyy	Izz
LOWER EQUIPMENT BAY							
CDU & Frame Assy	16.5	63.5	- 14.4	35.8	50	470	470
Optical Subsystem							
SXT	12.0	70.5	- 3.5	34.7			
SCT	9.0	70.5	5.5	34.7			
Opt. Base & Gearing	21.0	67.9	0.0	30.7			
Optical Eyepieces							
SXT	1.5	65.1	- 3.5	26.2	5	10	5
SCT	2.3	65.1	4.5	26.2	10	10	10
IMU	59.0	56.6	0.0	41.7	1330	1330	1330
NVB & Shock Mounts	27.2	64.3	- 0.1	41.3	3270	4050	5210
Bellows Assy	12.6						
Interconnect Wiring Harness	35.0	56.9	0.0	42.5	9410	5130	11500
D & C/NAV Station							
IMU Cont Panel	4.4	74.0	- 15.4	30.9	20	40	30
D & C Electronics LH	5.6	49.5	- 9.6	39.6	40	40	15
D & C Electronics RH	1.0	60.5	10.7	37.2			
Optical Shroud	3.8	66.8	0.0	28.9	280	60	300
G & N Ind. Control Pnl	11.9	54.1	0.1	33.9	560	150	720
D & C/AGC	15.0						
M & DV (includes 1 film)	8.5	73.5	- 4.5	31.0			
AGC (no spares)	70.0	37.8	1.3	46.1	4980	3990	1770
Spare Tray	26.5	38.2	- 7.7	45.3	1290	1360	140
PSA	56.7	45.0	- 1.1	41.5	3630	1340	2410
Junction Box	12.2	45.2	0.0	53.1	550	50	540
Coolant Hoses	1.0						

(con't)

Table 2-II. Command Module center of gravity and moment of inertia data (con't)

Item	Weight (lbs)	Centers of Gravity (inches)			Moments of Inertia ($lb-in^2$)		
		X	Y	Z	Ixx	Iyy	Izz
MAIN PANEL AREA							
D & C/AGC	15.0						
LOOSE STORED ITEMS							
Eye Relief Eyepieces (2)	1.5	(SCT - 4-5/8" x 2-1/2" dia; SXT - 3" x 2-1/4" dia.)					
Film Cartridges (4)	3.0	(Each cartridge - 1-1/2 x 3 x 6 inches)					
AGC Loose Spares	17.0						
PSA Loose Spares	11.5						
CDU Spare Gearbox	3.0	(approximately 6.0 x 1-13/16 x 5.5 inches)					
Computer Self-Check Plugs	1.0	(3 x 1 x 1 inches)					
Horizon Photometer	4.0	(6 x 6 x 3 inches)					
Spare Lamps (3)	0.2						
Spare Relay & Diode Module	0.3	(3 x 3 x 2 inches)					

CM

Table 2-III. Nominal power dissipation (watts) vs G & N activity

	G&N ACTIVITY	NBA		CDUJB	PSA		AGC	THERMAL LOAD ON S/C COOLANT	D&C And S&C	ELECTRICAL LOAD
		IMU	OBA		IMU	OPTICS				
A	IMU ON WITH NO OPTICS (1, 4)	74.5	0	22.1	233.5	0	120	450.1	.7	450.8
B	IMU ALIGNMENT (1, 2, 4, 6)	74.5	39	44	233.5	63.6	120	574.6	32.7	607.3
C	LOW ORBIT TRACKING (1, 3, 4, 6)	74.5	33.8	44	233.5	59.8	120	565.6	32.7	598.3
D	STANDBY (NO MEASUREMENTS) (1, 5)	43.5	0	0	41.2	0	120	204.7	0	204.7
E	MIDCOURSE MEASUREMENTS (1, 2, 5, 6)	43.5	39	21.9	41.2	63.6	120	329.2	32	361.2

1. AGC 120 WATTS
2. OPTICS, SXT ON 111.1 WATTS
3. OPTICS, SXT OFF 102.1 WATTS
4. IMU OPERATE 330.8 WATTS
5. IMU STANDBY 84.7 WATTS
6. DISPLAY AND CONTROL 45.4 WATTS

2-6 CURRENT STATUS OF COMMAND MODULE AGC PROGRAMS (con't)

1) Planning stage.
2) Programming stage.
2a) Program coded.*
3) Check out on AGC simulation.
4) Check out on G & N simulation.
5) Check out on AGC.

Table 2-IV. Current Memory Estimates and Statuses of Command Module AGC Programs

Program	Status	Memory Estimate (words)	
		High	Low
List Processing Interpreter	Coded	1600	1600
AGC Executive	Coded	250	250
AGC Waitlister	Coded	150	150
AGC System Exerciser, Checkout, & Error Handler	Planning	1000	400
G&N System Exerciser & Checkout	Planning	1000	750
Display, Keyboard, and Telemetry	Programming	1500	1024
Input/Output Control	Programming	850	350
Midcourse and Orbital Navigation	Programming	2000	1500
Midcourse and Orbital Guidance	Planning	500	500
Pre-launch Platform Alignment	Planning	120	120
In-Flight Platform Alignment	Programming	980	900
Re-entry Control	Planning	1290	1024
Injection and De-boost	Planning	1000	400
Totals		12240	8968

* This is a temporary status. Normally check-out on the AGC simulator would immediately follow coding and the statement that a program is coded would not be of much interest. Accordingly, this category will be dropped when simulation commences.

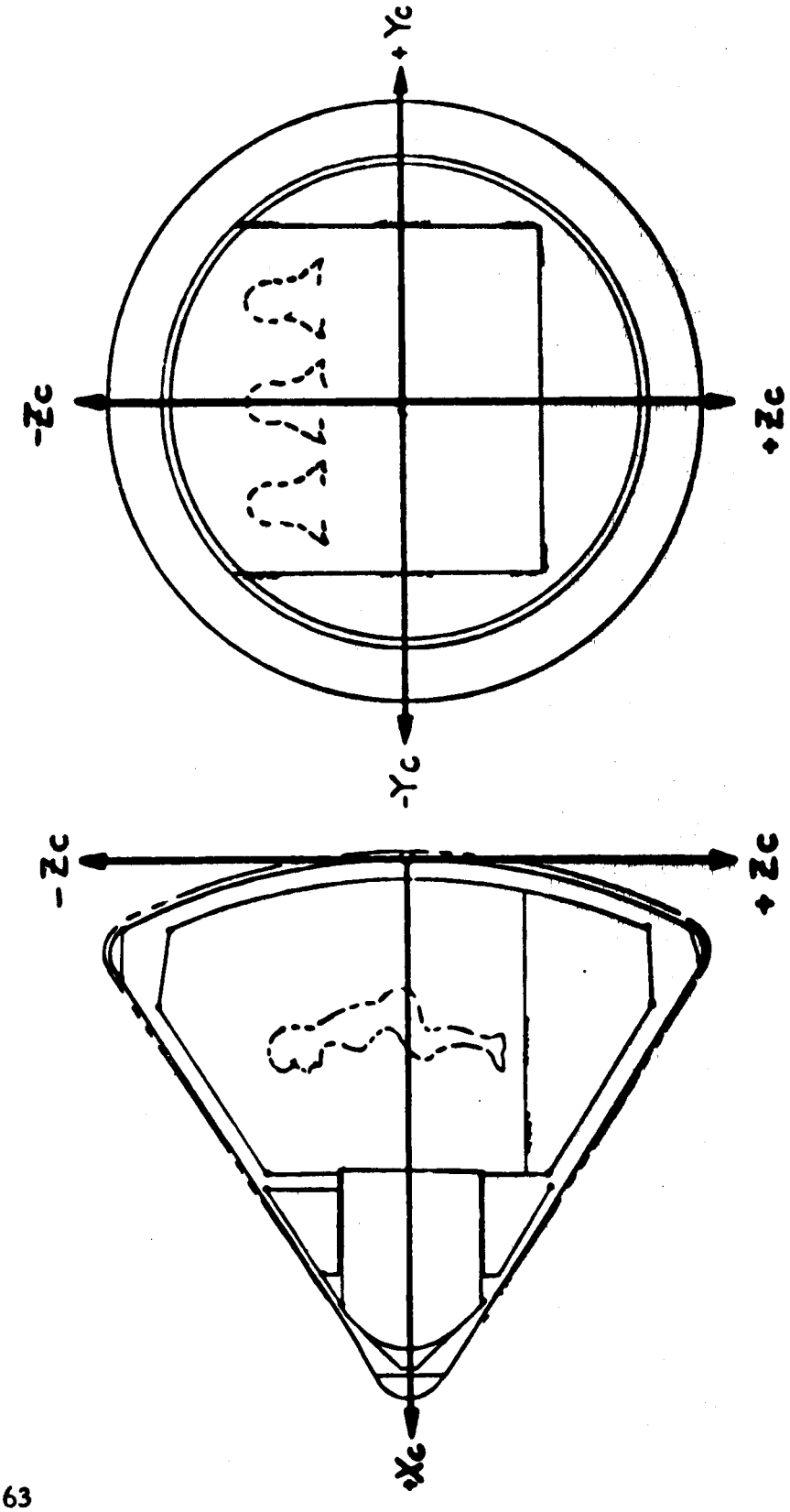

Figure 2-1. X, Y, Z axes of Command Module

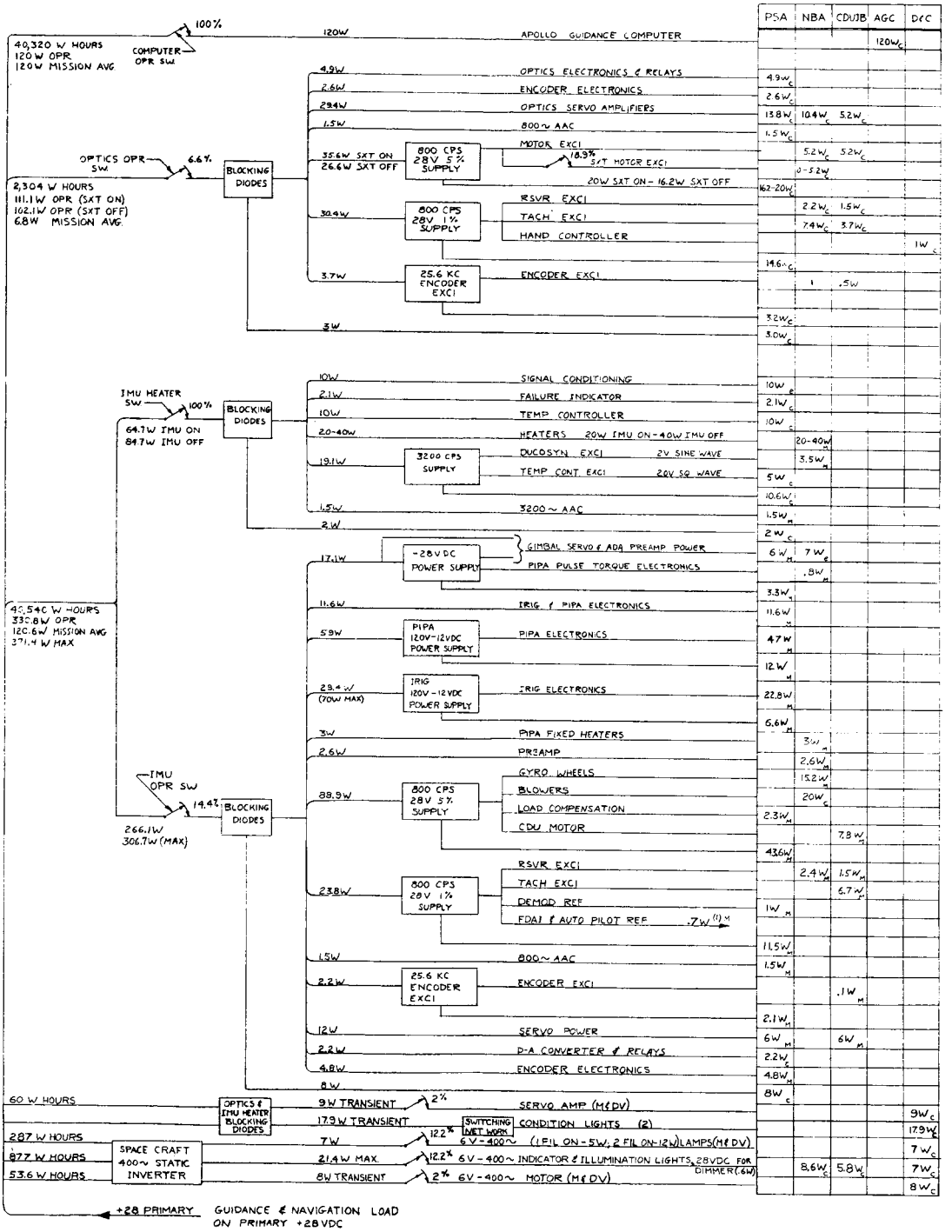

Figure 2-2. Electrical load on Primary + 28 VDC

LEM

Section 3

LUNAR EXCURSION MODULE DATA

3-1 POWER REQUIREMENTS FOR LEM

The current estimate of LEM G&N power and energy (see table 3-I) is based upon the fixed-telescope concept and the use of the Command Module IMU and computer.

Earlier estimates used a shorter IMU standby power time than is indicated in table 3-I. The values shown in table 3-I are normal average power and energy estimates and do not include any factor for bad estimating.

Table 3-I. LEM Power Requirements

	Power (watts)	Time (hrs)	Energy (kwh)
IMU Standby	70	100	7.0
IMU Operate	330	6.2	2.05
AGC	100	30	3.0
Optics	Negligible		
Display and Controls	18	3	0.05
Radar Interface CDU's	26	2	0.05
Randezvous Radar	*	2	*
Landing Radar	*	1	*
* Totals do not include radar loads	474 (peak) watts *		12.15 (total) KWH *

The data include checkout time as required. The computer is turned on and time zeroed at the start of LEM operations and runs at full power for 24 hours on the moon's surface. Separate power turn-on switches are assumed for IMU operate, computer, and radar CDU's. The LEM G&N uses spacecraft + 28 VDC supply only. Other voltages are generated internally.

3-2 WEIGHTS FOR LEM

Lunar Excursion Module weights are presented in table 3-II. The data, in general, conform to the information contained in paragraphs 2-1 and 2-1.1.

Table 3-II. Estimated weights of LEM G&N components weights are in pounds at 1 g

Item	Target Wt 8/63 (a)	(b-a)	Status 8/63 (b)	(c-b)	Status 9/63 (c)	Design Load Wt. (d)
CDU's	*	-	16.0	+3.0	19.0(E)	**
Telescope and all Eyepieces	12	0	12.0	+12.5	24.5(E)	
Navigation Base	4	0	4.0	-1.0	3.0(E)	
Eye Register for Reticule	*	-	2.0	0.0	2.0(E)	
Two-Digit Readout for Reticule	*	-	5.0	0.0	5.0(E)	
IMU	58	0	58.0	+1.0	59.0(E)	
Interconnect Harness Assy	15	0	15.0	-5.0	10.0(E)	
AGC Display and Controls	*	-	15.0	0.0	15.0(E)	
Other Display and Controls	*	-	20.0	-5.0	15.0(E)	
Book of Procedures, etc.	2	0	2.0	0.0	2.0(E)	
AGC, JBX	60	0	60.0	0.0	60.0(E)	
PSA	35	0	35.0	+2.5	37.5(E)	
Cold Plate	5	0	5.0	0.0	5.0(E)	
TOTAL	191 plus * items not yet given		249.0	+8.0	257.0	
"Bare Guidance System" (IMU electronics and computer):			143.0		156.5	

** No design load weight has been assigned

Column (a), "Target Weight" was taken from "GAEC LMD 490-39 Enclosure 1" submitted to MIT at a weights review meeting on 10 September 1963. GAEC reported that G&N weights associated with D&C will be reported by them as part of the total spacecraft D&C. Therefore, target weights were not given by GAEC to supply the five items denoted by the asterisk in column (a).

The row labeled "Bare Guidance System" is inserted to provide for comparisons with similarly specified systems.

3-3 REPORTED WEIGHT CHANGES FOR LEM

3-3.1 CDU's. The increase of 3 pounds in the CDU weights reflects the addition of a sixth CDU to provide the landing engine thrust magnitude control with an analog carrier interface. Previously this interface was assumed to be the direct digital increment command from the AGC output.

3-3.2 TELESCOPE AND ALL EYEPIECES. The increase in alignment telescope weight is a consequence of the telescope installation being worked out with GAEC. The earlier figure assumed a 12-inch tube looking directly through the side of the spacecraft. Installation constraints for the spacecraft and radar provided by Grumman have led to the use of a 37-inch long periscope looking through the top of the spacecraft. The characteristics of this telescope have been changed from a fixed 70-degree field of view to a three-position 55-degree field of view having a fourth storage position. These changes were made for the following reasons:

a. To avoid possible optical line of sight interference with the radar dish if it gets stuck in an unfortunate position.

b. To prevent the large weight penalty associated with the long optical transfer of a wide field of view.

c. To enhance the possibility of finding two acceptable stars for three degrees of freedom IMU alignment. This depends upon preventing sunlight from striking the objective and assumes that the sunlit earth, moon, or spacecraft does not appear in the field of view.

d. To provide for protection of the objective elements against deposits arising from operation of the jets and engines and to prevent abrasion by lunar materials during the landing. The fourth storage position can provide this at almost no additional penalty. Otherwise some type of door protecting the glass might prove necessary and heavy.

The weight for the telescope provides for a separate 2 pound eyepiece for long eye relief emergency operation with spacesuit helmet faceplate down. This eyepiece would be designed for 1/2 power to save the severe penalty of large glass size. If a helmet transfer telescope were used, this weight could be eliminated. The normal eyepiece operates at unity power.

3-3.3 NAVIGATION BASE. The current installation concept considers the navigation base as four reference buttons in the spacecraft secondary structure opposite the mounting feet of the IMU on one side and opposite the optics attachment points on the other. It is expected that this positioning can be done for the 1-pound saving shown over earlier estimates.

3-3.4 IMU. The change of 1 pound in the IMU brings the IMU up to the weight quoted for the command module. This estimate includes a very high proportion of actual weighed items.

3-3.5 INTERCONNECT HARNESS ASSEMBLY. The Interconnect Harness Assembly weight linear densities have been estimated for the various interconnections of G&N hardware. Unlike the command module installation, the G&N in LEM will probably consist of widely separated elements. This means a high usage of spacecraft cable runs, and only a small amount of cable harness will be furnished by the manufacturer with the G&N. The new weight figure estimates this effect.

3-3.6 DISPLAYS AND CONTROLS. The displays and controls for the LEM will have neither the shroud nor the optics associated items included in the command module. This simplification results in the new estimate tabulated.

3-3.7 AGC, JBX. The previous estimates for the LEM AGC assumed a 12,000-word fixed memory and arrangement to provide partial sparing. The latest concept uses two trays identical with those in the command module, which provides twice the memory capacity, 24,000 words. The weight figure, unchanged from last report, includes the interconnections between all AGC and PSA trays and assumes, as indicated, that the coldplate is provided as part of the over-all G&N electronics.

3-3.8 PSA. The modules of the PSA for the LEM have been identified and all are identical with modules existing in the command module system. The new figure incorporates a 50 percent actual weight knowledge of LEM PSA modules.

3-4 GENERAL COMMENT. The common usage of LEM and CM G&N hardware will be based upon block II CM G&N design for those common parts in the LEM. Accordingly, any weight saving changes incorporated into CM block II design that have common usage with the LEM will reflect in a reduction of the LEM weight. The figures do not show this as yet since final MIT and NASA review of the block II proposals has not been completed.

Section 4

GLOSSARY *

AGC:	Apollo Guidance Computer: complete computer, except display and keyboard. Includes: - all structural mounting details, support for spare trays, electrical interface plug, and AGC power supply. Interconnection matrix with the PSA and spacecraft is reported as part of interconnection wiring harness.
BELLOWS ASSEMBLY:	Bellows Assembly: connection between Command Module and Optical Subsystem consisting of SXT and SCT bellows plus bellows seals.
INTERCONNECT WIRING HARNESS:	Interconnect wiring harness which electrically ties together the assemblies which constitute a completely integrated system.
COOLANT HOSES:	Coolant Hoses: consists of (1) coolant hose between IMU and spacecraft, optics and spacecraft, and optics and IMU, (2) bracket assembly screws and clamps, and (3) entrapped coolant.
CDU & FRAME ASSEMBLY:	Coupling Display Units and frame assembly: all inter-changeable gear boxes and frame assembly used as a data interface among the optics, IMU, AGC, and spacecraft autopilot. (Radar and thrust magnitude in LEM)
D & C/AGC:	Display and Control, Computer: letter and number readout, keyboard, control panel, relays, and support structure.

* This applies specifically to command module, though it can provide a guide to the interpretation of LEM items. As unique LEM details become better identified, descriptions will be included.

D & C/NAV:	Display and Control, Navigation: consists of G&N Indicator Control Panel, IMU Control Panel, D&C Electronics, and Optical Shroud. The above includes meters, switches, lights, etc. except as reported elsewhere. The weight does not include the clock group which is supplied by NAA.
G&N Ind. Cont Panel:	G&N Indicator Control Panel: consists of the necessary switches, indicators, and controls for the navigation task not reported elsewhere. Includes optics hand controller, altitude impulse control, panel wiring, and supporting hardware.
IMU Cont Panel:	IMU Control Panel: meter, switches, panel wiring and supporting hardware.
Optical Shroud & Cover Assy:	Optical Shroud & Cover Assembly: optical shroud and protective cover.
D&C Electronics LH	D&C Electronics: consists of six electronic modules in one space envelope.
D&C Electronics RH	One step down power transformer for map and data viewer and indicator and illumination lights.
LONG EYE RELIEF EYEPIECES	Long Eye Relief Eyepieces: a SXT and a SCT eyepiece to provide eye relief of at least 1.6 inches for closed-visor operation.
FILM CARTRIDGES:	Film Cartridges: film cartridges, including film, for Map and Data Viewer.
HORIZON PHOTOMETER:	Horizon Photometer: an automatic, photometric, horizon detector device interchangeable with sextant eyepiece to provide capability for use of earth's illuminated limb as a navigation reference.

IMU:	Inertial Measurement Unit: gimbal assembly--inertial components, data transducers, support structure, cooling, and entrapped coolant.
JUNCTION BOX:	Junction Box: electrical interconnection center between subassemblies in lower equipment bay.
M&DV:	Map and Data Viewer: film viewer for display of maps, charts, procedures, etc. Weight includes one film cartridge with film.
NVB & SHOCK MOUNTS:	Navigation Base and Shock Mounts: rigid structure supporting the IMU and the Optical Subsystem with its associated hardware and supported by three shock mounts that attach the NVB to the spacecraft. Includes three snubbers and three bolts.
OPTICAL EYEPIECES:	Optical Eyepieces: optical eyepieces for SXT and SCT.
OPTICAL SUBSYSTEM:	Optical Subsystem: SXT, SCT, Optical Base and gearing, panel base, and associated hardware.
Optical Base & Gearing:	Optical Base and Gearing: base for SCT and SXT with associated gearing and internal cooling.
SCT:	Scanning Telescope: single line-of-sight, wide-field, two-degree-of-freedom telescope and its attached gearing.
SXT:	Sextant: two line-of-sight, narrow-field, two-degree-of-freedom sextant, including attached gearing.
PSA:	Power Servo Assembly: IMU, SCT, and SXT servos, power supplies, CDU electronics, IMU backup mode electronics, Signal Conditioning electronics, and miscellaneous electronics. Includes toe cap.

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