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APOLLO

GUIDANCE AND NAVIGATION

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E-1142 (REV. 10)

(Unclassified Title)

WEIGHT AND BALANCE REPORT

July 15, 1963

MIT INSTRUMENTATION LABORATORY

CAMBRIDGE 39, MASSACHUSETTS

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ACKNOWLEDGMENT

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ABSTRACT

Report E-1142 (Rev. 10) presents weight, center of gravity, and moment of inertia values for all components of the Command Module guidance and navigation equipment. Design load weights for Command Module components are specified.

Power requirements of the Command Module G & N equipment upon Primary +28 VDC Power Supply are also included.

In addition, this report presents weight estimates of the Lunar excursion Module G & N equipment.

E-1142 is prepared monthly and distributed on the 15th of each month.

Section 1

INTRODUCTION

1-1 INTRODUCTION

E-1142 (Rev. 10) is submitted in compliance with the documentation requirement of weight, center of gravity, and moment of inertia data for Apollo guidance and navigation equipment.

Section 2 presents the above information for the Command Module. In addition, power requirements of the Command Module G&N equipment, upon the Primary ±28 VDC, are included.

Section 3, at present, includes only estimated LEM weights.

1-2 WEIGHT STATUS REPORTING

Weight changes since the last report, E-1142 (Rev. 9), June 15, 1963, are shown and fully explained.

1-3 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 tolerances as design and development phases approach completion.

Section 2

COMMAND MODULE DATA

2-1 WEIGHTS

Table 2-1 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 calculated, measured, or estimated. These terms are defined by North American Aviation as follows:

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.

Estimated weights (E) are rough calculations.

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 2-1 offers a comparison of present component weight values with those listed in the previous Weight and Balance Report, E-1142 (Rev. 9), June 15, 1963. All weight changes are explained (see 2-2).

2-1.2 SPEC. WEIGHT. The "Spec. Weight" column in table 2-1 contains "proposed MSC" weights, that is, goals set forth by MSC in a memo to MIT/IL 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 #8, that one total weight figure for supported G&N load be assigned for structural design use. MIT/IL herein assigns a total G&N design load weight, in table 2-1, which does not include items termed "loose stored items".

Table 2-1. Current Weight Status of Command Module (lbs)

Item	Spec. Wt. 12/62 (a)	(b-a)	Status 6/63 (b)	(c-b)	Status 7/63 (c)	Design Load Wt. /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	1.5	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	+ 5.9	13.9	-1.3	12.6(E)	
Interconnect Wiring Harness	22.0	+ 3.0	25.0	+ 10.0	35.0(E)	27.2
D & C Nav Station						
IMU Control Panel	30.3	- 4.3	4.4	0.0	4.4(E)	6.8
D&C Electronics Module			5.6	0.0	5.6(E)	7.7
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	+ 28.0	93.0	-23.0	70.0(E)	126.4
Spare Tray			15.0	+ 10.0	25.0(E)	
PSA	25.0	+ 32.2	54.7	0.0	54.7(E)	65.0
Stored Spares			2.5	0.0	2.5(E)	

Table 2-1. Current Weight Status of Command Module (lbs) (con't.)

Item	Spec. Wt. 12/62 (a)	(b-a)	Status 6/63 (b)	(c-b)	Status 7/63 (c)	Design Load Wt. /63 (d)
JBX	8.0	+ 4.2	12.2	0.0	12.2(E)	15.6
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	20.0	+ 18.0	26.0	0.0	26.0(E)	
PSA Loose Spares			9.0	0.0	9.0(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	325.0	+152.0	477.0	- 4.3	472.7	
TOTAL (Exclusive of "Loose Stored Items")					424.7	484.1

CM

2-2 EXPLANATION OF REPORTED WEIGHT CHANGES

Component weight changes shown in column (c-b) of table 2-1 are explained below.

2-2.1 BELLOWS ASSY. The bellows and bellows seals, previously estimated, were weighed.

2-2.2 INTERCONNECT WIRING HARNESS. The weight increase is based upon AGC cabling previously reported in the AGC weight.

2-2.3 AGC. The substantial weight reduction is based upon the adoption of the LEM computer configuration in the Command Module. Major reasons for the change were: (a) Better packaging arrangement, (b) Substantial weight reduction, (c) Improved volumetric efficiency, and (d) Improved thermal interface.

2-2.4 SPARE TRAY. Increased volume of the spares area in the new computer configuration (see 2-2.3) has led to a re-evaluation of the spares to be stored.

2-3 CENTERS OF GRAVITY

Table 2-2 presents the centers of gravity of each weight component or packaged, 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 2-2 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 POWER CHART

The power requirements of the Command Module G & N equipment, upon the primary ± 28 VDC, are shown in figure 2-2. This chart assumes a new 14 day lunar orbit mission (previous reports assumed a 200 hour mission) in which the calculations were made with the IMU on during the lunar orbit period. More reasonably, the IMU would be off during this period. This would reduce the energy requirement by about 45 KWH.

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Table 2-2. 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			
SCT	2.3	65.1	4.5	26.2			
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	5150	11500
D & C/NAV Station							
IMU Cont Panel	4.4	74.0	- 15.4	30.9	20	40	30
D & C Electronics Module	5.6	49.5	- 9.6	39.6			
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	4840	3870	1670
Spare Tray	25.0	38.2	- 7.7	45.3			

Table 2-2. Command Module Center of Gravity and Moment of Inertia Data (con't.)

Item	Weight (lbs)	Centers of Gravity (inches)			Moments of Inertia ($lb\text{-}in^2$)		
		X	Y	Z	Ixx	Iyy	Izz
LOWER EQUIPMENT BAY (cont'd)							
PSA	54.7	45.0	- 1.1	41.5			
Stored Spares	2.5						
Junction Box	12.2	45.2	0.0	53.1	450	70	430
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	26.0						
PSA Loose Spares	9.0						
CDU Spare Gearbox	3.0	(approximately 6.0 x 1 13/16 x 5.5 inches)					
Computer Self-Check Plugs (4?)	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)					

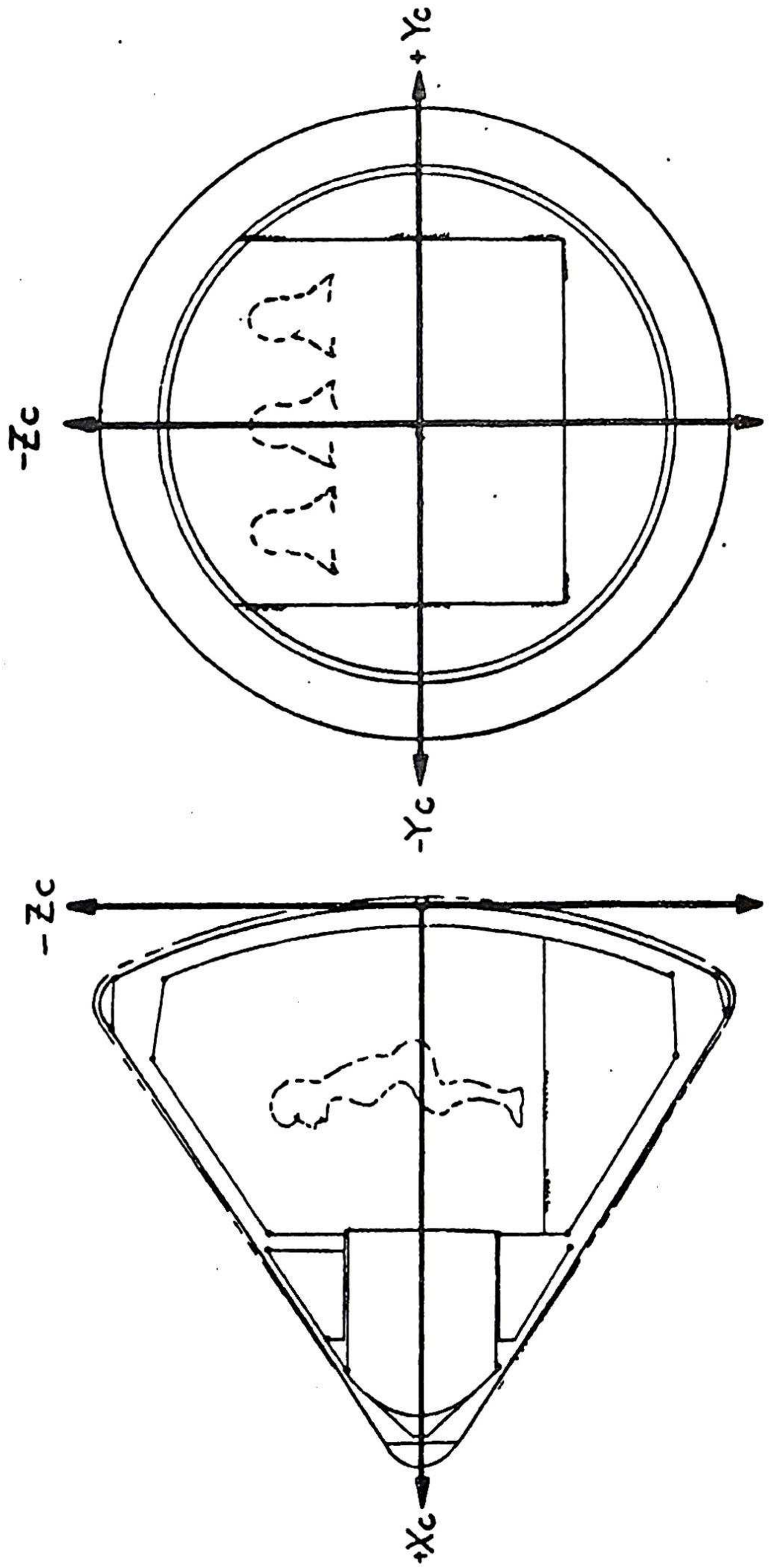

Figure 2-1. X, Y, Z Axes of Command Module

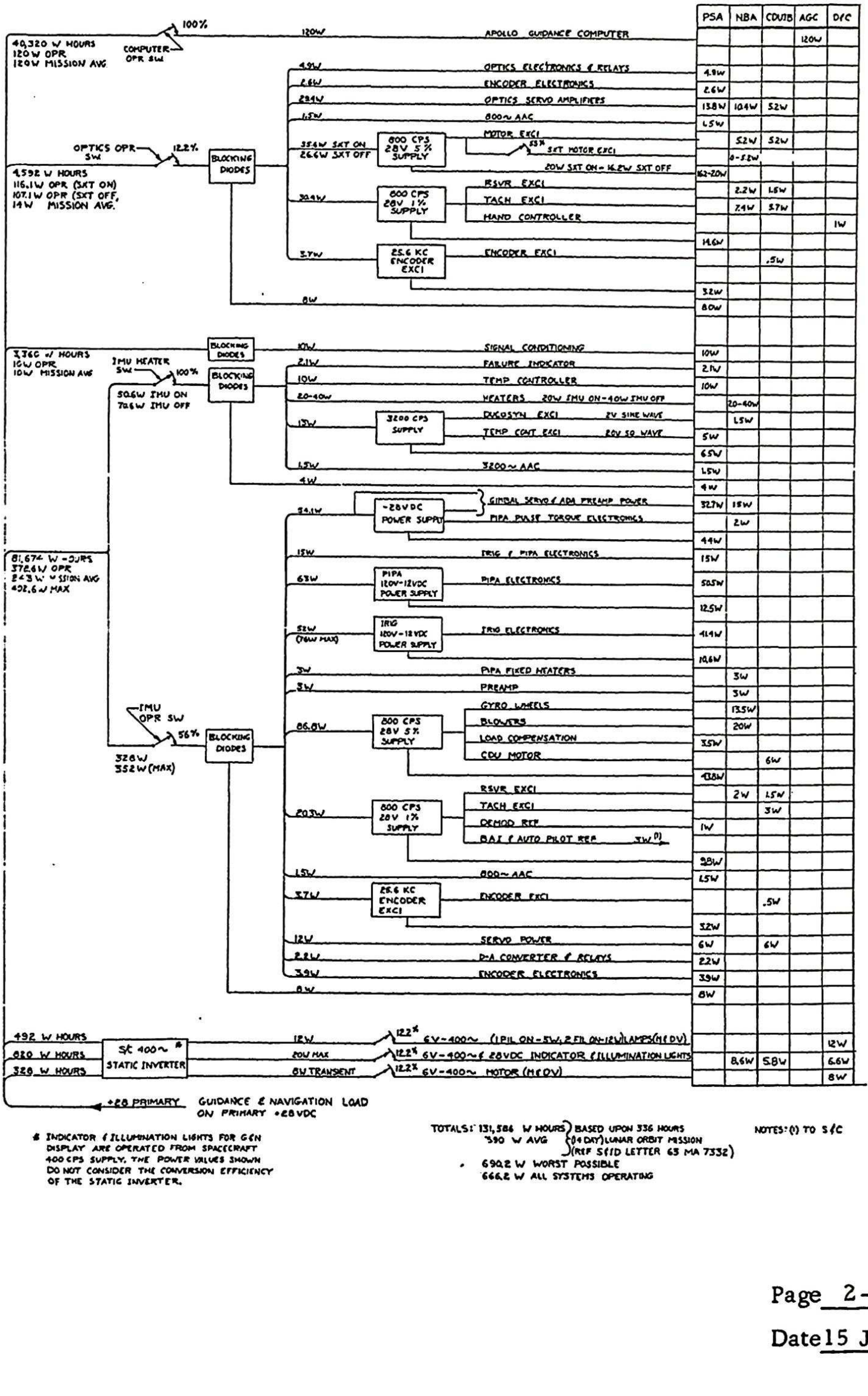

Figure 2-2. Electrical Load on Primary +28 VDC

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Date 15 July 1963

* INDICATOR & ILLUMINATION LIGHTS FOR G&N DISPLAY ARE OPERATED FROM SPACECRAFT 400 CPS SUPPLY. THE POWER VALUES SHOWN DO NOT CONSIDER THE CONVERSION EFFICIENCY OF THE STATIC INVERTER.

TOTALS: 131,586 W HOURS } BASED UPON 336 HOURS
390 W AVG } (14 DAY) LUNAR ORBIT MISSION
(REF SID LETTER 63 MA 7332)
690.2 W WORST POSSIBLE
666.2 W ALL SYSTEMS OPERATING

NOTES: (1) TO S/C

Section 3

LUNAR EXCURSION MODULE DATA

3-1 WEIGHTS

Table 3-1 presents LEM G&N weights and is similar to table 2-1 (see section 2). "Spec." and "Design Load" weights for the LEM are not available at this time.

The indicated weights are based upon a fixed telescope installation. A 32 pound weight saving in the LEM is estimated in using the fixed telescope installation instead of the articulating telescope. Useful references regarding this subject are:

1) Apollo Project Memo No. 594 11 June 1963
2) MIT Confidential letter AG 448-63 11 June 1963
3) MIT letter AG 451-63 11 June 1963

3-2 EXPLANATION OF REPORTED WEIGHT CHANGES

3-2.1 TWO DIGIT READOUT FOR RETICULE. This item should have been, but was not, included in the previous report, E-1142, Rev. 9.

Table 3-1. Estimated Weights of LEM G&N Components

Item	Spec. Wt. (a)	(b-a)	Status 6/63 (b)	(c-b)	Status 7/63 (c)	Design Load Wt. (d)
CDU's			16.0	0.0	16.0(E)	
Telescope and all Eyepieces			12.0	0.0	12.0(E)	
Navigation Base			4.0	0.0	4.0(E)	
Eye.Register for Reticule			2.0	0.0	2.0(E)	
Two Digit Readout for Reticule			----	+ 5.0	5.0(E)	
IMU			58.0	0.0	58.0(E)	
Interconnect Harness Assy			15.0	0.0	15.0(E)	
AGC Display and Controls			15.0	0.0	15.0(E)	
Other Display and Controls			20.0	0.0	20.0(E)	
Book of Procedures, etc.			2.0	0.0	2.0(E)	
AGC, 1 Spares Tray; JBX			60.0	0.0	60.0(E)	
PSA			35.0	0.0	35.0(E)	
Cold Plate			5.0	0.0	5.0(E)	
TOTAL			244.0	+ 5.0	249.0(E)	

Section 4

GLOSSARY

AGC:	Apollo Guidance Computer: complete computer, except display and keyboard. Includes: - all structural mounting rails, support for spare tray, AGC cable to front panel for spacecraft electrical interface, spare logic in four trays, and power supply.
BELLOWS ASSEMBLY:	Bellows Assembly: connection between Command Module and Optical Subsystem consisting of SXT and SCT bellows plus bellows seals.
CABLING:	Cabling: interconnect wiring harness which electrically ties together the assemblies which constitute a completely integrated system.
CDU & FRAME ASSEMBLY:	Coupling Display Units and frame assembly: five gear boxes and frame assembly, used as an angle data interface among the optics, IMU, AGC, and spacecraft autopilot.
D&C/AGC:	Display and Control, Computer: letter and number readout, keyboard, control, relays, and support structure.
D&C/NAV:	Display and Control, Navigation: consists of G&N Indicator Control Panel, IMU Control Panel, D&C Electronics Module, 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.
EYE RELIEF EYEPIECES:	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 interchangable 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, and internal cooling.
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 space-craft.
OPTICAL EYEPIECES:	Optical Eyepieces: optical eyepieces for SXT and SCT.
OPTICAL SUBSYSTEM:	Optical Subsystem: SXT, SCT, Optical Base and gearing, panel base, and asso-ciated hardware.
Optical Base & Gearing:	Optical Base and Gearing: base for SCT and SXT with associated gearing.
SCT:	Scanning Telescope: single line-of-sight, wide-field, two-degree-of free-dom telescope and its attached gearing.
SXT:	Sextant: two line-of-sight, narrow field, two-degree-of-freedom sextant, including attached gearing and internal cooling.
PSA:	Power Servo Assembly: IMU, SCT, and SXT servos, power supplies, CDU elec-tronics, IMU backup mode electronics, Signal Conditioning electronics, and mis-cellaneous electronics.

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