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GUIDANCE AND NAVIGATION

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E-1142 (REV. 13)

(UNCLASSIFIED TITLE)

SYSTEMS STATUS
REPORT

October 15, 1963

[redacted] **INSTRUMENTATION LABORATORY**

CAMBRIDGE 39, MASSACHUSETTS

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ABSTRACT

The System Status report is distributed monthly on the 15th. This month's revision (E-1142, Rev. 13) 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 status of the Command Module computer programs is 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) the status of Command Module computer programs.

Weights in this report for the Command Module 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. The Lunar Excursion Module weights are based on the best estimate of those expected for the LEM design release which will also occur early in 1964.

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

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. 12), September 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

BLOCK I

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

Item	Spec. Wt 12/63 (a)	(b-a)	Status 9/63 (b)	(c-b)	Status 10/63 (c)	Design Load Wt. 10/63 (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	+ 4.6	12.6	0.0	12.6(E)	
G&N Interconnection Assy	30.0	+17.2	47.2	-4.0	35.2(E)	42.8
G&N to S/C Interface Assy					8.0(E)	
D&C Nav Station						
IMU Control Panel			4.4	-1.9	2.5(E')	6.8
D&C Electronics LH			5.6	0.0	5.6(E')	7.7
Control Electronics	30.3	- 3.6	1.0	+ 0.7	1.7(E')	
Optical Shroud			3.8	0.0	3.8(E')	4.2
G&N Ind Cont Panel			11.9	- 0.2	11.7(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	-1.5	25.0(E)	
PSA	25.0	+31.7	56.7	+2.7	59.4(E)	65.0
Coolant Hoses	0.0	+ 1.0	1.0	0.0	1.0(E)	

(cont)

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

Item	Spec. Wt. 12/62 (a)	(b-a)	Status 9/63 (b)	(c-b)	Status 10/63 (c)	Design Load Wt. 10/63 (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	20.0	+11.5	17.0	+-0.3	17.3(E)	
PSA Loose Spares			11.5	+ 5.2	16.7(E)	
CDU Spare Gearbox			3.0	0.0	3.0(E)	
Computer Self-Check Plug	--	+ 1.0	1.0	-1.0	0.0	
Horizon Photometer	--	+ 4.0	4.0	0.0	4.0(E)	
Spare Lamps (3)	--	+ 0.2	0.2	-0.2	0.0	
Spare Relay & Diode Module	--	+ 0.3	0.3	0.0	0.3(E)	
TOTAL	325.3	+143.9	469.2	+ 0.1	469.3	
TOTAL (Exclusive of "Loose Stored Items")			427.7	- 4.2	423.5	484.1

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.

2-2 REPORTED WEIGHT CHANGES

The weight changes since last month's report, E-1142 (Rev. 12), September 15, 1963, shown in table 2-I are explained below.

2-2.1 G&N INTERCONNECTION ASSY AND G&N TO S/C INTERFACE ASSY. The weight decreased owing to the elimination of several cables coming from the S & ID Wire Channel to the computer. These assemblies, previously called the Interconnect Wiring Harness, allow for a better definition of the harness assembly (see Glossary). Note that the PSA End Connector Assembly (JBX) is now reported as part of the weight of the G&N Interconnection Assy.

2-2.2 IMU CONTROL PANEL. The weight decreased as a result of the weighing of the total IMU Control Panel.

2-2.3 CONTROL ELECTRONICS. The weight increased due to the addition of a new Relay and Diode Module. The gimbal lock light on the M&DV Panel will be lighted via this relay rather than through the switching arrangement on the G&N Panel.

2-2.4 G&N IND CONT. PANEL. The weight decrease is a result of the weighing of a greater number of parts.

2-2.5 AGC SPARE TRAY. The weight decrease is a result of a more comprehensive weight estimate (see Appendix C). Present AGC sparing philosophy calls for a spare logic tray within the computer plus sparing of all other unique AGC modules as loose spares.

2-2.6 PSA. The weight increase is the result of a more comprehensive weight estimate (see Appendix A).

2-2.7 AGC LOOSE SPARES. The weight increase reflects the identification of all unique modules that are to be spared (see section 2-2.5).

2-2.8 PSA LOOSE SPARES. The 5.2-pound increase is a result of the identification of all unique PSA modules that are to be stored as

loose spares (see Appendix A).

2-2.9 COMPUTER SELF-CHECK PLUG. This is no longer required as an in-flight item.

2-2.10 THREE SPARE LAMPS. These are no longer required as in-flight spares items.

2-3 CENTERS OF GRAVITY

Table 2-II presents the centers of gravity of each weight component or packaged assembly, 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 of 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 as defined by S&ID for power profile computation (Ref: S&ID letter 63MA 7332).

The total energy consumption has decreased from 84.4 kwh, as reported in last month's report, E-1142 (Rev. 12), September 15, 1963, to 63.4 kwh. This decrease is mainly due to the placing of the computer in standby mode for approximately 53.5 percent of the mission time.

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

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						
G&N Interconnection Assy	35.2						
G&N to S/C Signal Assy	8.0						
D&C/NAV Station							
IMU Cont Panel	2.5	74.0	- 15.4	30.9			
D&C Electronics LH	5.6	49.5	- 9.6	39.6	40	40	40
Control Electronics Assy	1.7	60.5	10.7	37.2			
Optical Shroud	3.8	66.8	0.0	28.9	280	60	300
G&N Ind. Control Panel	11.7	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	25.0	38.2	- 7.7	45.3	1290	1360	140
PSA	59.4	45.0	- 1.1	41.5	3630	1340	2410
Coolant Hoses	1.0						

(cont)

Table 2-II Command Module center of gravity and moment of inertia data (cont)

Item	Weight (lbs)	Centers of Gravity (inches)			Moments of Inertia ($lb\text{-}in^2$)		
		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	17.3						
PSA Loose Spares	16.7	319.4 cu. in.					
CDU Spare Gearbox	3.0	(approximately 6.0 x 1-13/16 x 5.5 inches)					
Horizon Photometer	4.0	(6 x 6 x 3 inches)					
Spare Relay & Diode Mod	0.3	(3 x 3 x 2 inches)					

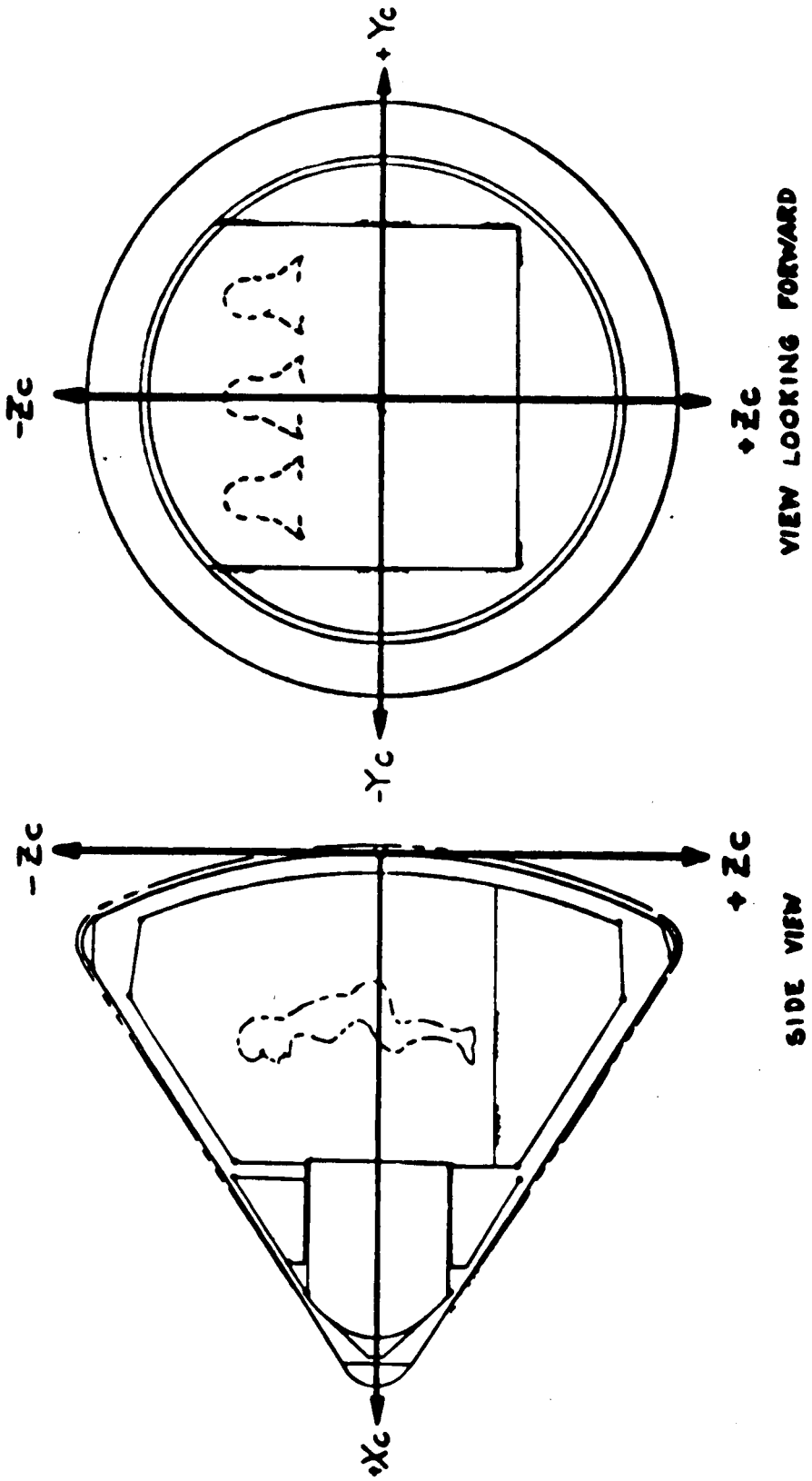

Figure 2-1. X, Y, Z axes of Command Module

COMMAND MODULE

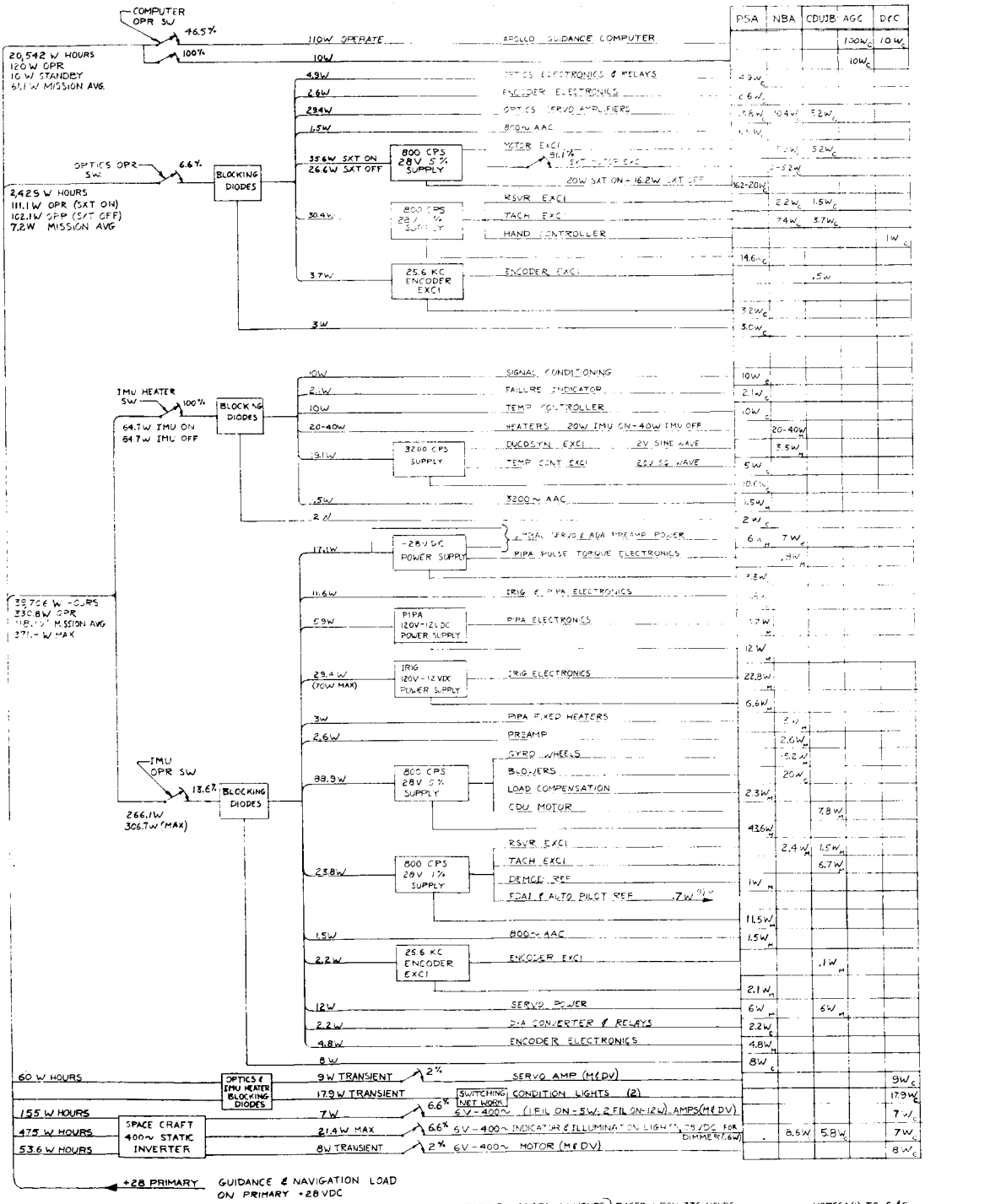

Figure 2-2. Electrical load on primary +28 VDC power supply

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	OBA				
A	IMU on with no Optics (1, 4)	74.5	0	22.1	233.5	0	110	440.1	10.7	450.8
B	IMU Alignment (1, 2, 4, 6)	74.5	39	44	233.5	63.6	110	564.6	42.7	607.3
C	Low-Orbit Tracking (1, 3, 4, 6)	74.5	33.8	44	233.5	59.8	110	555.6	42.7	598.3
D	Standby (No measurements) (1, 5)	43.5	0	0	41.2	0	110	194.7	10	204.7
E	Midcourse Measurements (1, 2, 5, 6)	43.5	39	21.9	41.2	63.6	110	319.2	42	361.2
F	IMU Standby and AGC Standby (5, 7)	43.5	0	0	41.2	0	10	94.7	0	94.7
G	IMU Operate & AGC Standby (4, 7)	74.5	0	22.1	233.5	0	10	340.1	0.7	340.8

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
7.	AGC Standby	10	Watts

2-6 CURRENT STATUS OF COMMAND MODULE AGC PROGRAMS

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

A high and low word estimate is given with each program. Each status is defined as follows:

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

Table 2-IV. Current Memory Estimates and the Status 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, and 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
Reentry Control	Planning	1290	1024
Injection and De-Boost	Planning	1000	400
Totals		12240	8968

*This is a temporary status. Normally checkout on the AGC simulator would follow coding immediately, thus a statement that a program is coded would be of little interest. Accordingly, this category will be dropped when simulation commences.

LUNAR EXCURSION MODULE

Section 3

LUNAR EXCURSION MODULE DATA

3-1 POWER REQUIREMENTS FOR LEM

The current estimate of LEM G&N power and energy (see table 3-1) is based upon the fixed-telescope concept and the use of the Command Module IMU and computer.

The values shown in table 3-I are center value estimates and do not include any safety factor for bad estimating.

Transient power peaks, occuring at higher levels during turn-on and slowing operations, are considered to contain negligible energy. Data on these peaks will be included when they become available.

Table 3-I. LEM Power Requirements
(Based upon GAEC Profile, Ref: NASA Coord. Meeting L3A)

	Power (watts)	Time (hrs)	Energy (kwh)
IMU Standby	84.7	103.8	8.78
IMU Operate	348.0	26.4	9.19
AGC Standby	10.0	21.3	0.21
AGC Operate	115.0	26.4	3.04
Radar CDU	18.4	23.8	0.44
Optics	Negligible		
Display and Controls	12.2	3.0	0.04
Rendezvous Radar	*	2	*
Landing Radar	*	1	*
TOTALS	493.6 (peak)		21.70

* Totals do not include radar loads.

Note that the total energy drawn, 21.70 kwh, is considerably higher than for a "normal" mission since the estimate provides for full operate power for the 18 hours of "orbit contingency" mode. Without this contingency the G&N takes about 13 kwh using the GAEC profile.

Separate power turn-on switches are assumed for "IMU operate," "computer standby," "computer operate," and "radar CDU." The LEM G&N uses only the spacecraft +28 VDC power supply except for operation of condition lights. The condition lights operate from the spacecraft 400-cps power supply.

3-2 WEIGHTS FOR LEM

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

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 asterisks in column (a).

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

3-3 REPORTED LEM WEIGHT CHANGES

3-3.1 CDU's. The 5.3-pound weight decrease is a result of converting from six mechanical to five electrical CDU's. It appears that the extra mechanical CDU, the sixth CDU reported in last month's report as necessary to provide the landing engine thrust magnitude control with the analog carrier interface, will not be necessary with the five electronic CDU's.

3-3.2 NAVIGATION BASE. This item has been removed as a result of Meeting No. L3A (see Minutes of NASA Coordination Meeting No. L3A with MIT and GAEC). GAEC will provide the IMU and OAT mounting base as a portion of the vehicle secondary structure. The mounting base will provide four mounting pads for both the IMU and the OAT.

3-3.3 OTHER DISPLAYS AND CONTROLS. The weight increase is a result of added electronics required for the electronic CDU's.

3-3.4 AGC. The minor weight decrease is a result of further evaluation.

3-3.5 PSA. The 2.9 weight decrease is the result of a more comprehensive weight evaluation of the PSA (see Appendix B).

3-3.6 COLD PLATE. As a result of response to action item L63A-0056 (Ref. MIT Memo APM 735), MIT responsibility for the cold plate was not required.

Table 3-II. Estimated Weights of LEM G&N Components (lbs at 1 g)

Item	Target Wt 8/63 (a)	(b-a)	Status 9/63 (b)	(c-b)	Status 10/63 (c)	Design Load Wt. (d)
CDU's	*		19.0	-5.3	13.7(E)	**
Telescope and all Eyepieces	12	+12.5	24.5	0.0	24.5(E)	
Navigation Base	4	- 1.0	3.0	-3.0	0.0	
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	+ 1.0	59.0	0.0	59.0(E)	
AGC/PSA Interconnection Assy	15	- 5.0	10.0	0.0	10.0(E)	
AGC Display and Controls	*		15.0	0.0	15.0(E)	
Other Display and Controls	*		15.0	+0.9	15.9(E)	
Book of Procedures, etc.	2	0	2.0	0.0	2.0(E)	
AGC	60	0	60.0	-0.4	59.6(E)	
PSA	35	+ 2.5	37.5	-2.9	34.6(E)	
Cold Plate	5	0	5.0	-5.0	0.0	
TOTAL	191 plus * items not yet given		257.0	-15.7	241.3	
Bare Guidance System (IMU, PSA, and computer): ** No design load weight has been assigned			156.5	-3.3	153.2	

Section 4

GLOSSARY*

AGC: APOLLO Guidance Computer--complete computer except display and keyboard. Includes all structural mounting details, one logic and one memory tray, the AGC end connector assembly, and a beryllium toe plate.

AGC SPARES: Consists of a complete spare logic tray to be stored in the computer spares area and one spare module for each module not already spared, i.e., a spare for each unique module to be stored as a loose spare.

BELLOWS ASSEMBLY: Connection between Command Module and Optical Subsystem consisting of SXT and SCT bellows plus bellows seals.

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 AND FRAME ASSEMBLY: Coupling Display Units and Frame Assembly--In Command Module (Block I), interchangeable gear boxes and frame assembly used as a data interface among the optics, IMU, AGC, and spacecraft autopilot. In LEM five electronic CDU's including mounting frame, screws, interwiring and connectors.

D & C/AGC: Display and Control, Computer--consists of letter and number readout, keyboard, control panel, relays, and support structure. One is located in lower equipment bay and one is located in main panel.

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.

* 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.

G&N IND. CONT. PANEL: G&N Indicator Control Panel--consists of the necessary switches, indicators, and controls for navigation that are not reported elsewhere. Includes optics hand controller, altitude impulse control, panel wiring, panel, and supporting hardware.

IMU CONTROL PANEL: Consists of panel, wiring, attitude error meter, CDU transfer switch, manual alignment switch, CDU mode control switches, connector, and supporting hardware.

CONTROL ELECTRONICS ASSY: Control Electronics Assembly--consists of one power transformer, one relay and diode module, and a bracket and connector.

D&C ELECTRONICS LH: D&C Electronics, Left Hand--consists of a chassis, a relay and diode module, a Demod. Elect. module, a saturable reactor, a time delay module, a connector, and wiring.

OPTICAL SHROUD & COVER ASSY: Optical Shroud and Cover Assembly--consists of the Optical Shroud and protective cover.

LONG EYE RELIEF EYEPIECES: Consists of a SXT and a SCT eyepiece to provide eye relief of at least 1.6 inches for closed-visor operation.

FILM CARTRIDGES: Consists of film cartridges, including film, for Map and Data Viewer.

G&N INTERCONNECTION ASSY: Guidance and Navigation Interconnection Assembly--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 the G&N to S/C Interface Assembly weight or the weights of harness support brackets which are a NAA responsibility.

G&N TO S/C INTERFACE ASSY: Interconnect cabling from S&ID wire channel, through computer, to PSA End Connector Assembly.

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, which includes inertial components, data transducers, support structure, cooling, and entrapped coolant.

PSA END CONNECTOR ASSY: PSA End Connector Assembly--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. In the LEM, the NVB and shock mounts are replaced by mounting pads provided by GAEC.

OPTICAL EYEPIECES: Optical eyepieces for SXT and SCT.

OPTICAL SUBSYSTEM: Consists of SXT, SCT, Optical Base and gearing, panel base, and associated hardware.

> OPTICAL BASE AND GEARING: Base for SCT and SXT with associated gearing and internal cooling.
>
> SCT: Scanning Telescope--a single-line-of-sight, wide-field, two-degree-of-freedom telescope and its attached gearing.
>
> SXT: Sextant--a two-line-of-sight, narrow-field, two-degree-of-freedom sextant and its attached gearing.

PSA: Power Servo Assembly--In Command Module, consists of ten trays containing IMU, SCT, and SXT servos, power supplies, CDU electronics, IMU backup mode electronics, signal conditioning electronics, miscellaneous electronics, tray frames, and toe cap. In LEM, consists of six trays containing various electronic modules plus tray frames and toe cap.

PSA LOOSE SPARES: Consists of separate sparing for all unique PSA modules in the Command Module. These items are to be stored as loose spares.

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APPENDIX A

Command Module - PSA Weight Estimate, Block I

A significant number of measured PSA weight values are now available for the Weight and Balance Report. Although all the measured values were for unpotted modules, the risk of large error in correcting for potting is insignificant. Therefore, the corrected values are considered as measured values rather than estimated ones.

NOTE: Weight of tray frame assemblies includes buffer resistors in Trays 1, 2, 5, 6, 7, 10 and the shorting plug at the portable temperature controller connector in Tray 7.

Spare weight estimate assumes that one spare module will exist for each different module type.

TRAY	MODULE	NO. OF MODULES	TOTAL VOLUME (cu. in.)	TOTAL WEIGHT (lbs.)	SPARES VOLUME (cu. in.)	SPARES WEIGHT(lb
1	Gimbal Servo Amp.	3	31.89	1.749 m	10.63	.583 m
	Gimbal Coarse Align	3	14.76	.753 m	4.92	.251 m
	-28VDC Power Supply	1	12.55	.708 m	12.55	.708 m
	3200 cps 1% Amp.	1	6.24	.281 m	6.24	.281 m
	3200 cps AAC Filter	1	6.24	.287 m	6.24	.287 m
	Temp. Cont. Power Supply	1	5.90	.379 m	5.90	.379 m
	Module Totals:	10	77.58	4.157	46.48	2.489
	Tray Frame Assembly:			1.85 c	No Frame Spare	
	TRAY 1 TOTAL			6.01 LB		2.49 LB.

TRAY	MODULE	NO. OF MODULES	TOTAL VOLUME (cu. in.)	TOTAL WEIGHT (lbs.)	SPARES VOLUME (cu. in.)	SPARES WEIGHT (lbs.)
2	800 cps 1% Amp.	1	9.23	.704 m	9.23	.704 m
	800 cps 5% Amp.	1	12.55	1.005 m	12.55	1.005 m
	800 cps AAC Filter	1	6.56	.306 m	6.56	.306 m
	Pulse Torq. Power Supply	1	18.50	1.200 c	18.50	1.200 c
	IMU-CDU Load Comp.	1	6.81	.307 c	6.81	.307 c
	25.6 KC Power Supply	2	13.12	.722 c	6.56	.361 c
	Failure Indicator	1	10.21	.498 m	Not	Spared
	Module Totals:	8	76.98	4.742	60.21	3.883
	Tray Frame Assembly:			2.19 c	No Frame Spare	
	TRAY 2 TOTAL			6.93 LB.		3.88 LB.
3	AC Diff. Amp.	2	11.80	.712 m	5.90	.356 m
	Interrogator	2	15.80	.918 m	7.90	.459 m
	Binary Current Switch	2	15.10	.800 m	7.55	.400 m
	DC Diff. Amp.	3	13.71	.777 m	4.57	.259
	PIPA Calibration	2	10.48	.604 m	5.24	.302 n
	Pulse Torq. Gyro Calibr.	1	6.24	.359 c	6.24	.359 c
	Module Totals:	12	73.13	4.170	37.40	2.135
	Tray Frame Assembly:			1.78 e	No Frame Spare	
	TRAY 3 TOTAL			5.95 LB.		2.14 LB.

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TRAY	MODULE	NO. OF MODULES	TOTAL VOLUME (cu. in.)	TOTAL WEIGHT (lbs.)	SPARES VOLUME (cu. in.)	SPARES WEIGHT (lb
4	AC Diff. Amp.	1	5.90	.356 m	Previously Spared	
	Interrogator	1	7.90	.459 m	Previously Spared	
	Ternary Current Switch	3	22.65	1.089 m	7.55	.363 m
	DC Diff. Amp.	3	13.71	.777 m	Previously Spared	
	PIPA Calibration	1	5.24	.302 m	Previously Spared	
	Pulse Torq. Gyro Calibr.	2	12.48	.717 c	Previously Spared	
	Binary Current Switch	1	7.55	.400 m	Previously Spared	
	Module Totals:	12	75.43	4.100	7.55	.363
	Tray Frame Assembly:			2.02 c	No Frame Spare	
	TRAY 4 TOTAL			6.12 LBs		.36 LB
5	Back-Up Mode	1	10.88	.571 c	Not	Spared
	Forward-Backward Ctr.	1	10.55	.422 c	10.55	.422 c
	D to A Converter	3	13.71	.615 m	57	.205 m
	Encoder	3	29.70	1.560 c	9.90	.520 c
	Lamps, B-U Mode	1	3.57	.143 c	Not	Spared
	CDU Zeroing & Lock Rel.	1	2.64	.106 c	2.64	.106 c
	Module Totals:	10	71.05	3.417	27.66	1.253
	Tray Frame Assembly:			1.78 e	No Frame Spare	
	TRAY 5 TOTAL			5.20 LB		1.25 LB.

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TRAY	MODULE	NO. OF MODULES	TOTAL VOLUME (cu. in.)	TOTAL WEIGHT (lbs.)	SPARES VOLUME(cu. in.)	SPARES WEIGHT(lbs.
6	Motor Drive Amp. & Sel.	3	27.69	1.455 c	9.23	.485 c
	800 cps 1% Amp.	1	9.23	.704 m	Previously Spared	
	800 cps 5% Amp.	1	12.55	1.005 m	Previously Spared	
	800 cps AAC Filter	1	6.56	.306 m	Previously Spared	
	CDU Resolver Loads	1	10.55	.422 c	10.55	.422 c
	CDU Zeroi[illegible] Transf. Rel.	1	6.56	.263 c	6.56	.263 c
	Module Totals:	8	73.14	4.155	26.34	1.170
	Tray Frame Assembly:			2.02 e	No Frame Spare	
	TRAY 6 TOTAL			6.18 LB.		1.17 LB.
7	IMU Temp. Controller	1	12.61	.742 m	12.61	.742 m
	Encoder	2	19.80	1.041 c	Previously Spared	
	Pulse Torq. Power Supply	1	18.51	1.200 c	Previously Spared	
	CDU Fixed Resol. Transf.	1	4.92	.197 c	4.92	.197 c
	IMU Temp. Indicator	1	16.51	.972 c	16.51	.972 c
	Module Totals:	6	72.35	4.152	34.04	1.911
	Tray Frame Assembly:			1.91 e	No Frame Spare	
	TRAY 7 TOTAL			6.06 LB.		1.91 LB.

[redacted]

TRAY	MODULE	NO. OF MODULES	TOTAL VOLUME (cu. in.)	TOTAL WEIGHT (lbs.)	SPARES VOLUME (cu. in.)	SPARES WEIGHT (lbs)
8	Motor Drive Amp.	2	11.2	.504 c	5.6	.252 c
	2 Speed Switch	1	5.6	.243 c	5.6	.243 c
	Cosecant Generator	1	5.6	.257 c	5.6	.257 c
	Motor Drive Preamp.	1	6.2	.248 c	6.2	.248 c
	Resolver Drive Amp.	1	5.6	.224 c	5.6	.224 c
	Relay	1	8.0	.470 c	8.0	.470 c
	Buffer Circuit	1	7.8	.312 c	Not	Spared
	Zero Optics	1	4.0	.160 c	4.0	.160 c
	D to A Converter	2	9.1	.410 m	Previously Spared	
	Module Totals:	11	63.2	2.828	40.6	1.854
	Tray Frame Assembly:			1.85 c	No Frame Spare	
	TRAY 8 TOTAL			4.68 LB.		1.85 LB.
9	Motor Drive Amp.	4	22.4	1.010 c	Previously Spared	
	2 Speed Switch	1	5.6	.243 c	Previously Spared	
	Motor Drive Preamp.	1	6.2	.248 c	6.20	.248 c
	Isolation Transformer	1	6.6	.297 c	6.60	.297 c
	Relay	1	8.0	.470 c	Previously Spared	
	Buffer Circuit	1	7.8	.312 c	Not	Spared
	Resistor & Capacitor	1	9.5	.380 c	9.5	.380
	Module Totals:	10	66.1	2.960	22.30	.925
	Tray Frame Assembly:			1.85 c	No Frame Spare	
	TRAY 9 TOTAL			4.81 LB.		.93 LB.

[redacted]

TRAY	MODULE	NO. OF MODULES	TOTAL VOLUME (cu. in.)	TOTAL WEIGHT (lbs.)	SPARES VOLUME(cu. in.)	SPARES WEIGHT(lbs.)
10	800 cps 5% Amp.	1	12.55	1.005 m	Previously Spared	
	800 cps Comp., Optics	1	7.32	.329 c	7.32	.329
	G & N Subsystem Filter	3	21.00	1.156 c	7.0	.385
	Module Totals:	5	40.87	2.490	14.32	.714
	Tray Frame Assembly:			1.77 c	No Frame Spare	
	TRAY 10 TOTAL			4.26 LB.		.71 LB.

COMMAND MODULE WEIGHT & VOLUME SUMMARY

TOTAL NUMBER OF MODULES: 92

TOTAL MODULE VOLUME:

TRAYS & MODULES ..... 56.20 LB.

TOE CAP ..... 3.24 m

TOTAL PSA WEIGHT : 59.44 LB.

TOTAL PSA

10/1/63 BLOCK I ESTIMATE -

CM PSA SPARES:

10/1/63 BLOCK I ESTIMATE -

Number of Modules Spared 45

Total Volume of Module Spares ..... 316.9 cu. in.

Total Weight of Module Spares ..... 16.69 LB.

LUNAR EXCURSION MODULE

Appendix B

PSA WEIGHT ESTIMATE FOR LUNAR EXCURSION MODULE

The recently measured weights of PSA modules for "Block I" Command Module Systems permit the following refinement of LEM Module estimates. These measured values ("m") are repeated below for those modules that are not expected to change significantly for LEM.

Also, the effect on the PSA of the replacement of the existing electro-mechanical CDU by an electronic CDU is reflected in this weight estimate.

The assignment of modules to trays should be considered as arbitrary at this time, particularly for Trays 5 and up. The assignment was made to estimate the number of LEM trays required for active PSA electronics.

The reliability factor for mission success is met without requiring spare PSA modules. Table B-I shows number, weight, and volume for PSA modules.

Table B-I. PSA Weight Estimate

Tray	Module	No. of Modules	Total Vol. (cu. in.)	Total Wt. (lbs)
1	Gimbal Servo Amp.	3	31.89	1.749 m
	Gimbal Coarse Align.	3	14.76	0.753 m
	-28 VDC Power Supply	1	12.55	0.708 m
	3200 cps 1% Amp.	1	6.24	0.281 m
	3200 cps AAC Filter	1	6.24	0.287 m
	Temp. Cont. Power Supply	1	5.90	0.379 m
	Module Totals	10	77.58	4.157
	Tray Frame Assy			1.85 c
	TRAY 1 TOTAL			6.01

(cont)

Table B-I. PSA Weight Estimate (cont)

Tray	Module	No. of Modules	Total Vol. (cu. in.)	Total Wt. (lbs)
2	800 cps 1% Amp.	1	9.23	0.704 m
	800 cps 5% Amp.	1	12.55	1.005 m
	800 cps AAC Filter	1	6.56	0.306 m
	Pulse Torque Power Supply	1	18.50	1.200 c
	IMU-CDU Load Comp.	1	6.81	0.307 c
	4 volt Power Supply	1	6.56	0.361 c
	Failure Indicator	1	10.21	0.498 m
	Module Totals	7	70.42	4.381
	Tray Frame Assy			2.19 c
	TRAY 2 TOTAL			6.57
3	AC Diff. Amp.	2	11.80	0.712 m
	Interrogator	2	15.80	0.918 m
	Binary Current Switch	2	15.10	0.800 m
	DC Diff. Amp.	3	13.71	0.777 m
	PIPA Calibr.	2	10.48	0.604 m
	Pulse Torq. Gyro Calibr.	1	6.24	0.359 c
	Module Totals	12	73.13	4.170
	Tray Frame Assy			1.78 e
	TRAY 3 TOTAL			5.95
4	AC Diff. Amp.	1	5.90	0.356 m
	Interrogator	1	7.90	0.459 m
	Ternary Current Switch	3	22.65	1.089 m
	DC Diff. Amp.	3	13.71	0.777 m
	PIPA Calibr.	1	5.24	0.302 m
	Pulse Torq. Gyro Calibr.	2	12.48	0.717 c
	Binary Current Switch	1	7.55	0.400 m
	Module Totals	12	75.43	4.100
	Tray Frame Assy			2.02 c
	TRAY 4 TOTAL			6.12

(cont)

Table B-I. PSA Weight Estimate (cont)

Tray	Module	No. of Modules	Total Vol. (cu. in.)	Total Wt. (lbs)
5	Forward-Backward Ctr.	1	10.55	0.422 c
	CDU Zeroing & Lock Rel.	1	2.64	0.106 c
	Pulse Torq. Power Supply	1	18.51	1.200 c
	IMU Temp. Controller	1	12.61	0.742 m
	IMU Temp. Indicator	1	16.51	0.972 c
	CDU Resolver Loads	1	5.28	0.211 c
	CDU Zeroing Transf. Rel.	1	3.28	0.132 c
	Module Totals	8	69.38	3.785
	Tray Frame Assy			1.85 c
	TRAY 5 TOTAL			5.64
6	800 cps 5% Amp.	1	9.41	0.754 c
	G&N Subsystem Filter	2	14.00	0.771 c
	Module Totals	3	23.41	1.525
	Tray Frame Assy			1.75 c
	TRAY 6 TOTAL (PARTIAL)			3.28

Total Number of Modules	51
Total Module Volume	390 cu. in.
Weight, Trays and Modules	33.57 lbs.
Toe Cap (Beryllium)	.85
TOTAL LEM PSA WEIGHT ESTIMATE	34.42 lbs.

COMMAND MODULE

Appendix C

AGC WEIGHT ANALYSIS

Tables C-I and C-II show component weights for the Command Module AGC.

Table C-I. AGC Weight Analysis

	Weight (lbs)	Total (lbs)
LOGIC TRAY		25.0
Logic Tray Subassembly	10.5	
Logic Modules (36)	13.25	
Interface Modules (4)	1.25	
MEMORY TRAY		34.6
Memory Tray Subassembly	12.5	
Power Supply (3 + 1)	4.5	
Sense Amplifier (4)	1.25	
Eraseable Driver (2)	1.8	
Eraseable Memory	1.0	
Current Switch	0.9	
Driver Service	0.9	
Ropes (6)	7.25	
Rope Driver (2)	1.8	
Strand Gate	0.9	
Strand Select	0.9	
Oscillator	0.9	
End Connector Assembly		8.0
Toe Plate (Beryllium)		2.4
TOTAL		70.0

Table C-II. Unique AGC Modules

	Weight (lbs)	Total (lbs)
UNIQUE MEMORY TRAY MODULES		17.275
Sense Amplifiers (2)	0.625	
Ropes (6)	7.25	
Power Switch	1.2	
Power Control (1)	0.9	
Eraseable Memory (1)	1.0	
Eraseable Drive (1)	0.9	
Current Switch (1)	0.9	
Driver Service (1)	0.9	
Strand Select (1)	0.9	
Strand Gate (1)	0.9	
Rope Driver (1)	0.9	
Oscillator	0.9	
TOTAL UNIQUE AGC MODULES		17.3