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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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GUIDANCE AND NAVIGATION

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E-1142 (REV. 6)

(UNCLASSIFIED TITLE)
WEIGHT AND BALANCE

REPORT (U)

March 15, 1963

MIT INSTRUMENTATION LABORATORY
CAMBRIDGE 39, MASSACHUSETTS

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GUIDANCE AND NAVIGATION:

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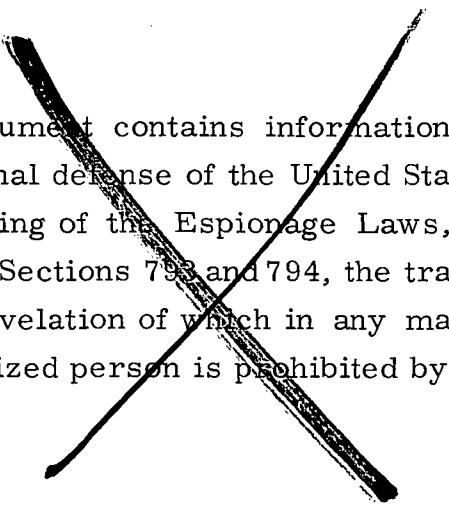
(NASA-



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ABSTRACT

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Report E-1142 (Rev. 6) presents weight, center of gravity, and moment of inertia values for all components of the guidance and navigation equipment.

Power requirements of the guidance and navigation equipment upon the Primary +28 VDC Power Supply have also been included.

Only data pertaining to the command and service modules is, at present, included in this report.

Also included in this month's report, at the specific request of NASA, is an estimate of weights which might result from a weight reduction program.

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

Introduction

E-1142 (Rev. 6) is submitted in compliance with the documentation requirement of weight, center of gravity, and moment of inertia data for Apollo guidance and navigation equipment. At present, however, E-1142 pertains to only the command and service module.

Power requirements, for Apollo guidance and navigation equipment, have been included to aid in the determination of spacecraft primary power.

Weights

All weight items are grouped according to their specific location within the spacecraft modules. 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.

Weight Status Reporting

Table 1 offers a comparison of present weight values with those listed in the previous Weight and Balance Report, E-1142 (Rev. 5), February 15, 1963. All weight changes are explained.

The "Spec. Weight" column contains "proposed MSC" weights, that is, goals set forth by MSC in a memo to MIT/IL dated December 5, 1962.

Centers of Gravity

The centers of gravity of each weight component or packaged assembly are determined with respect to the basic X, Y, Z axes of the command module which are shown in figure 1. Center of gravity values are given to the nearest tenth of an inch and are shown in table 2.

Moments of Inertia

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

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. Numerical values will approach the established tolerances as design and development phases approach completion.

Power Requirements

The electrical load of the guidance and navigation equipment, on the Primary + 28 VDC Power Supply, is shown in figure 2.

Explanation of Weight Listings, Table 1

During this reporting period there has been high activity in design releases leading to better weight estimates but unfortunately showing unanticipated weight growth. At the specific request of NASA this month's report includes estimates of weights which might result from a weight reduction program.

The new format of Table 1 for this month is as follows:

column (a) - Specification weight proposed by MSC in December, 1962 in an informal memo.

column (b-c) - The change from spec weight to last reported weight (by request of S&ID).

column (b) - Reported weight last report.

column (c-b) - Change from last reported weight to this report.

column (c) - Weight report this month.

columns (d), (e), (f), (g) - Estimates of results of possible weight reduction program listed in order of decreasing desirability. Many reductions listed are emphatically not recommended due to the resulting losses in system performance or reliability not to mention schedule and cost impact. Totals at bottom are based upon the particular pattern of reduction in the column. Various other combinations would be possible, of course.

column (h) - Estimates of worst possible weights which should be assumed in supporting structure design. These values should be listed in mechanical interface documents and ICDs, and were transmitted to S&ID on 13 March by letter AG 155-63.

The following short descriptions are of weight changes by rows with letters identifying the column in which the weight change occurs.

CDU & Frame Assembly

(c-b) Increase due to identification of frame assembly which was not included in earlier weight reports. This frame was identified in the mechanical interface with secondary structure on ICD 01-00004 negotiated in February with S&ID.

(g) Reduction resulting from non-interchangeable design of optics and IMU CDUs. Affects mission success by removing in-flight repair or backup capability.

Optical Subsystem

SXT

(f) Engineering redesign and more expensive machining.

SCT

(f) Engineering redesign and more expensive machining.

OPT Base & Gearing

(f) Engineering redesign and more expensive machining.

Optical Eyepieces

Incomplete design and corresponding lack of accurate weight estimate. Consideration of weight reduction possibilities premature.

IMU

The IMU has 88% of its reported weight measured. No significant weight reductions seem possible that would preserve the IMU operation margins deemed necessary to justify the existence of the IMU. The IMU takes its design from the Polaris missile where weights reductions have been accomplished. Weight of coolant lines beyond the quick disconnects have not been included. MIT will negotiate with S&ID to determine weight reporting on these flexible lines.

Navigation Base and Shock Mounts

(e) Reduction in thickness of shock mounts corresponding to reduction in landing shock specification. Specification is now unofficial: 100 g's.

(g) Serious reduction in (1) alignment performance requirement and (2) highly qualified ability to hold together in current shock requirement.

Bellows Assembly

(c-b) Change to convoluted bellows instead of welded.

(d) Change seals to beryllium. Cost increase of about $6000 would appear worth the weight saved.

(g) Reduction from dual to single convoluted bellows. Very risky in terms of maintaining adequate seal.

Cabling

(c-b) Cable weight was reduced after weighing mockup cable identified after mechanical interface negotiations with S&ID in February. Weight

Cabling (Continued)

reductions cannot be anticipated at this time.

D&C Nav Station

IMU Control Panel

(d) Modification of support hardware

(e) Reduction in skin of honeycomb panel

(f) Removal of attitude error meter - operational significance not fully evaluated.

(g) Removal of total IMU control panel hardware to G&N Ind Cont Panel

Left Hand Turret

(d) Reduction by new identification of equipment.

(f) Removal of attitude error meter electronics.

Optical Shroud

(d) Skin thickness reduction.

(e) Replace shroud by dust cover. Extreme damage danger to optical alignment without protection.

G&N Ind. Cont. Panel

(c-b) Better identification of equipment.

(d) Elimination and reduction of miscellaneous hardware and skin thickness reduction.

(g) Additions due to moving IMU control panel hardware to this area.

D&C/AGC LEB & Main Panel

The 15 pounds estimated on each of these displays is an optimistic minimum estimate. No weight reductions can be anticipated until design is further along.

Map and Data Viewer, M&DV

(c-b) Reduction in weight and addition of film in viewer resulted in a net change of zero. No weight reductions of any significance can be anticipated. Removal of M&DV and substituting printed pages for required data would probably result in weight penalty.

AGC

No Spare Storage

(c-b) Increase resulting from: Design release possible from ICD negotiations (ICD 01-0002). Support for spare tray. AGC cable to front panel for spacecraft electrical interface. Spare logic in four trays. Addition of power supply.

(e) Optimistic reduction resulting from possible favorable thermal and structure strength loads allowing removal of metal in frames.

(f) Removal of 5th tray group to modified "H" frame structure leaving four sliding trays.

(g) Reduction to a mechanical configuration of four non-sliding trays. Not including coldplate.

Spares Tray & Stored Spares

(d) Removal of the spares tray completely.

PSA

(c-b) Increase resulted from: Electronic circuit design releases which identified larger modules than anticipated. Addition of electronics for pulse torquing and backup electronics required an extra tray. Addition of temperature controller electronics. Actual packaging releases of first two trays showed a higher density than original estimate. Addition of toe cap for tray holddown. Estimate does not include power diodes in interface with 28 V power now in negotiation.

(d) Optimistic reduction resulting from possible favorable thermal and structural loads allowing removal of metal in frames.

(e) Removal of tray 9 and capability for storing spares.

(g) Reduction in electronics identified in G&N allowing removal of one tray.

Stored Spares

(c) Item added to recognize room in PSA for spares storage.

(e) Removal of stored PSA spares corresponding to removal in frame to hold spares.

Signal Conditioning Tray

(c) New item identified in PSA to condition signals for telemetry and in-flight test equipment. Conditioning previously was performed in right hand turret.

(g) Removal of signal conditioning and interface with telemetry and in-flight test. Operational significance not evaluated.

PSA
Junction Box

(c-b) Added weight due to better estimates and recognition of increased width in PSA resulting from shift in walls desired by S&ID. This allows more PSA capacity .... up to 10 trays.

(e) Reduction due to removal of plug wire and structure due to corresponding removal of one tray in PSA.

(g) Reduction due to removal of plug, wire and structure due to corresponding removal of second tray in PSA.

D&C/Nav Main Panel

(c-b) Items previously anticipated for G&N main panel have been removed. MIT is supplying S&ID with relay closures to operate main panel status and condition lights. All G&N main panel items are incorporated in the D&C/AGC on main panel.

Eye Relief Eyepiece

(c) Item added as a result of MSC request of 1 February 1963 to provide eye relief of at least 1.6 inches for closed visor operation.

(e) Recuction in weight of eye relief eyepieces with corresponding reduction in magnification and/or field of view restricting severely performance of sighting functions.

(g) Elimination of eye relief eyepieces preventing any possibility of navigation measurements or IMU alignment sightings in depressurized cabin.

Film Cartridges

(c) New item identified: storage of four additional film cartridges to operate in M&DV and increase data storage capacity. No significant weight reductions can be anticipated, especially since other weight reductions may put burden on M&DV to display more backup mode procedures. Each cartridge handles 1800 frames of high resolution data.

Loose Stored Items

(c-b) Increase in spares due to a better estimate of module weight. Figure includes sparing every unique module with no use of modules from LEM. Spares required to meet reliability allocation.

AGC Loose Spares

(d) Increase due to removal of stored spares and renaming them loose.

(e) Removal of memory from spares.

(f) Reduction of AGC spares. Reliability is adversely affected unless support from LEM computer sticks.

(g) No AGC spares. Serious reliability effect.

PSA Loose Spares

(e) Increase due to removal of stored spares from PSA and renaming them loose.

(f) Reduction in PSA spares to include only partial spare capability. Reliability is affected unless LEM modules can be used.

PSA Loose Spares (Continued)

(g) No PSA spares. Serious reliability effect.

CDU Spare Gearbox

(d) Removal of CDU Spare Gearbox would decrease operational flexibility and reliability.

Computer Self-Check Plug

(c) Additional item to provide capability of connecting computer outputs back onto inputs for checkout and diagnosis of failure.

(g) Removal of self-check plug recognizing corresponding removal of computer spares.

Horizon Photometer

(c) Weight reported for first time. Interchanges with sextant eyepiece to provide capability for use of earth's illuminated limb as navigation reference. May be very important for earth orbital operations under possible conditions of cloud cover hiding landmarks. Design not firm enough to anticipate weight reduction.

(g) Removal of horizon photometer; advisable only if actual earth orbital navigation using landmarks provides an experience with cloud cover consistent with high probability of consistent on-board navigation.

Radar Transponder

(c-b) Reduction in estimated weight. No further weight reductions can be anticipated at this time.

Rendezvous Radar

(c) Item added to recognize LEM rendezvous backup mode. Impact on G&N in command module weight report is anticipated to be trivial but does not recognize power switching or interface cabling between service and commond modules.

(f) Removal of rendezvous radar. Corresponding reduction in LEM rendezvous probability not evaluated.

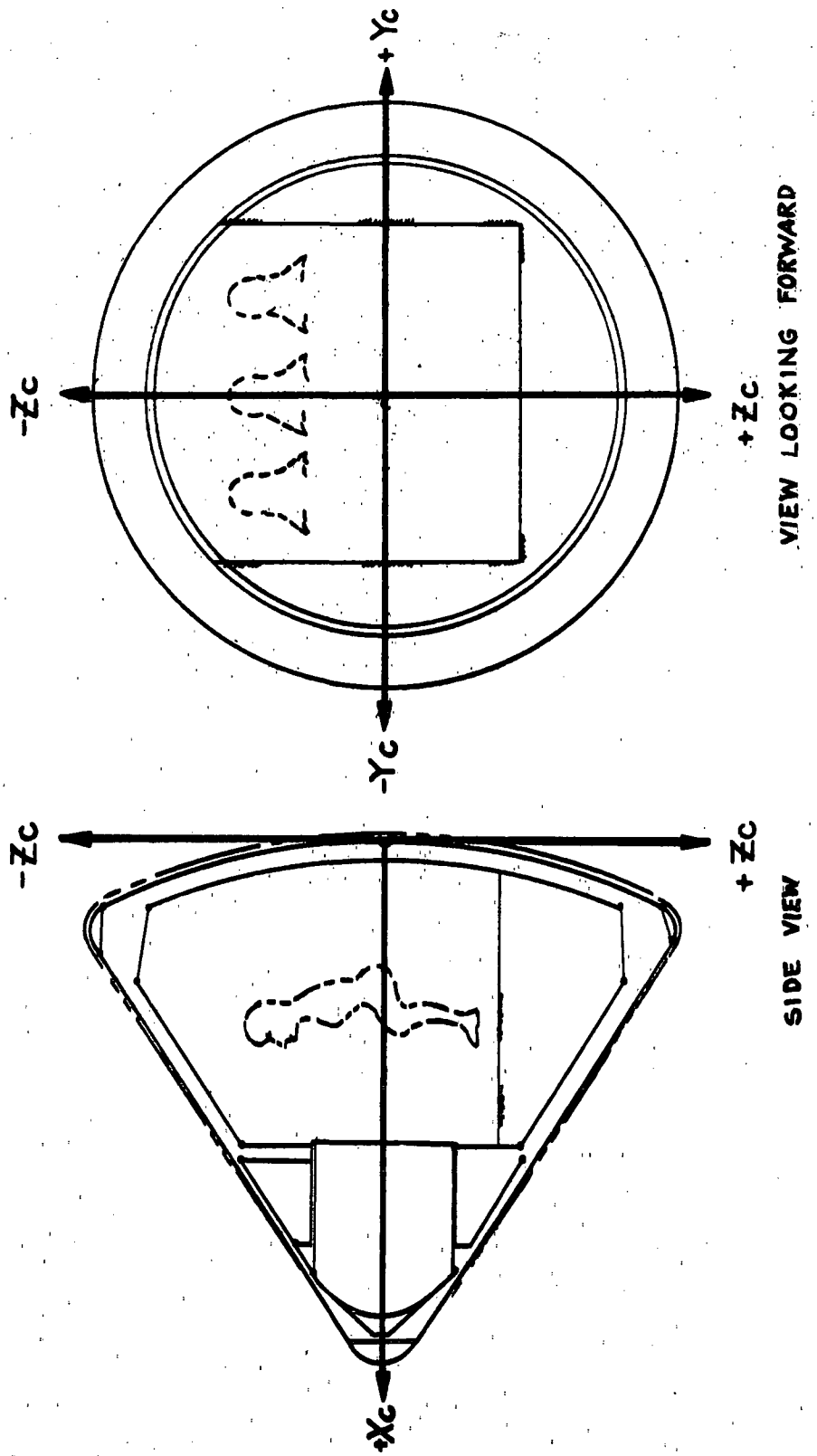

Figure 1. -X, Y, Z axes of Command Module

Table 1. Current Weight Status and Results of Possible Weight Reduction Program (lbs.)

Item	Current Weight Status - 3/63					Results of Possible Weight Reduction Program (see text)				Struct. Design Wt.
	Spec 12/62 (a)	(b-a)	Status 2/63 (b)	(c-b)	Status 3/63 (c)	(d)	(e)	(f)	(g)	(h)
COMMAND MODULE										
Lower Equipment Bay										
CDU & Frame Assembly	6.0	+9.0	15.0	+1.5	16.5(E)	16.5	16.5	16.5	15.4	18.0
Optical Subsystem										
SXT	12.0	+5.0	40.0	0.0	12.0(E)	12.0	12.0	11.0	11.0	175.0
SCT	9.0			0.0	9.0(E)	9.0	9.0	8.3	8.3	
Opt. Base & Gearing	14.0			0.0	19.0(E)	19.0	19.0	15.0	15.0	
Optical Eyepieces										
SXT	2.0	+3.0	5.0	0.0	1.0(E)	1.0	1.0	1.0	1.0	
SCT					4.0(E)	4.0	4.0	4.0	4.0	
IMU	50.0	+8.3	58.3	-0.1	58.2(E)	58.2	58.2	58.2	58.2	
NVB & Shock Mounts	16.0	+8.0	24.0	0.0	24.0(E)	24.0	23.0	23.0	19.0	
Bellows Assembly	8.0	+7.0	15.0	-4.0	11.0(E)	8.0	8.0	8.0	6.7	
Cabling	22.0	+18.0	40.0	-15.0	25.0(E)	25.0	25.0	25.0	25.0	30.0
D&C Nav. Station										
IMU Control Panel	30.0	+1.5	31.5	0.0	6.3(E)	6.0	5.8	4.0	0.0	7.5
Left Hand Turret				0.0	7.0(E)	3.2	3.2	2.3	2.3	8.5
Optical Shroud				0.0	4.0(E)	3.8	1.9	1.9	1.9	4.5
G&N Ind. Cont. Panel				-4.0	10.2(E)	9.4	9.4	9.4	12.2	17.0
D&C/AGC/LEB	15.0	0.0	15.0	0.0	15.0(E)	15.0	15.0	15.0	15.0	25.0

(Continued)

Item	Current Weight Status - 3/63					Results of Possible Weight Reduction Program (see text)				Struct. Design Wt.
	Spec 12/62 (a)	(b-a)	Status 2/63 (b)	(c-b)	Status 3/63 (c)	(d)	(e)	(f)	(g)	(h)
COMMAND MODULE Lower Equipment Bay (Continued)										
M&DV (incl. 1 film)	5.0	+3.5	8.5	0.0	8.5(E)	8.5	8.5	8.5	8.5	12.0
AGC (no spares)	80.0	-22.0	58.0	+35.0	93.0(E)	93.0	88.0	78.0	70.0	150.0
Spares Tray	---	---	---	---	4.0(E)	0.0	0.0	0.0	0.0	
Stored Spares	*	*	*	*	11.0(E)	0.0	0.0	0.0	0.0	
PSA (except as noted below)	25.0	+4.0	29.0	+20.7	49.7(E)	47.0	45.3	45.3	40.0	75.00
Stored Spares	*		*	*	2.5(E)	2.5	0.0	0.0	0.0	
Signal Conditioning Tray	---		---	---	5.0(E)	5.0	5.0	5.0	0.0	
Junction Box	8.0	+3.0	11.0	+1.2	12.2(E)	12.2	11.9	11.9	11.6	20.0
Main Panel Area										
D&C/NAV	8.0	+2.0	10.0	-10.0	0.0(E)	0.0	0.0	0.0	0.0	
D&C/AGC	5.0	+10.0	15.0	0.0	15.0(E)	15.0	15.0	15.0	15.0	20.0
Loose Stored Items										
Eye Relief Eyepieces	---	---	---	---	3.0(E)	3.0	2.5	2.5	0.0	
Film Cartridges (4)	---	---	---	---	3.0(E)	3.0	3.0	3.0	3.0	
AGC Loose Spares	20.0*	+20.0	40.0*	+11.5*	26.0(E)	37.0	28.0	14.0	0.0	
PSA Loose Spares					9.0(E)	9.0	11.7	3.4	0.0	
CDU Spare Gearbox					3.0(E)	0.0	0.0	0.0	0.0	

(Continued)

Item	Current Weight Status - 3/63 Spec 12/62 (a)	(b-a)	Status 2/63 (b)	(c-b)	Status 3/63 (c)	Results of Possible Weight Reduction Program (see text) (d)	(e)	(f)	(g)	Struct. Design Wt. (h)
COMMAND MODULE(cont) Loose Stored Items (cont)										
Computer Self Check Plug	---	---	---	---	1.0(E)	1.0	1.0	1.0	0.0	
Horizon Photometer	---	---	---	---	4.0(E)	4.0	4.0	4.0	0.0	
SERVICE MODULE										
Radar (Transponder)	15.0	0.0	15.0	-5.0	10.0(E)	10.0	10.0	10.0	10.0	
(Rendezvous Radar)	---	---	---	---	30.0(E)	30.0	30.0	0.0	0.0	
TOTALS										
Weight Increase of Items previously reported.				+32.1						
Weight of Items not previously reported				+50.0						
Lower Equipment Bay					408.4(E)					
Main Panel					15.0(E)					
Loose Stored Items					49.0(E)					
COMMAND MODULE	335.0	+80.3	415.3		472.4(E)	454.3	434.9	394.2	343.1	
SERVICE MODULE	15.0	0.0	15.0		40.0(E)	40.0	40.0	10.0	10.0	
TOTAL	350.0	+80.3	430.3	+82.1	512.4(E)	494.3	474.9	404.2	353.1	

* Stored and loose spares reported in columns (a), (b-a), (b), (c-b) are combined into the loose spares row.

Table 2. Center of Gravity and Moment of Inertia Data

Item	Weight (lbs)	Center of Gravity (inches)			Moment of Inertia ($lb\text{-}in^2$)		
		X	Y	Z	I_{xx}	I_{yy}	I_{zz}
COMMAND MODULE							
Lower Equip. Bay							
CDU & Assembly	16.5(E)	63.5	-14.4	35.8	44	470	470
Optical Subsystem	40.0(E)	69.0	1.7	32.3	---	---	---
SXT	12.0(E)	---	---	---	---	---	---
SCT	9.0(E)	---	---	---	---	---	---
Opt Base & Gearing	19.0(E)	---	---	---	---	---	---
Optical Eyepieces	5.0(E)	---	---	---	---	---	---
SXT	1.0(E)	65.1	-3.5	26.2	---	---	---
SCT	4.0(E)	65.1	4.5	26.2	---	---	---
IMU	58.2(E)	56.6	0.0	41.7	---	---	---
NVB & Shock Mounts	24.0(E)	60.6	0.0	44.0	---	---	---
Bellows Assembly	11.0(E)	71.5	-0.3	36.3	---	---	---
	138.2(E)	62.3	0.0	38.6	6,492	10,664	9,274
Cabling	25.0(E)						
D&C/NAV Station	31.7(E)	61.8	-2.8	33.3	---	---	---
IMU Cont Panel	6.3(E)	73.0	-15.1	31.7	---	---	---
Left Hand Turret	3.2(E)	61.6	0.0	36.0	---	---	---
Optical Shroud	4.0(E)	66.8	0.0	28.9	---	---	---
G&N Ind Cont Panel	10.2(E)	55.1	0.5	34.2	---	---	---
D&C/AGC/LEB	15.0(E)						
M&DV (includes 1 film)	8.5(E)						
AGC (no spares)	93.0(E)						
Spares Tray	4.0(E)						
Stored Spares	11.0(E)						
PSA	49.7(E)						
Stored Spares	2.5(E)						
Signal Conditioning Tray	5.0(E)						
Junction Box	12.2(E)						

(Continued)

Item	Weight (lbs)	Center of Gravity (inches)			Moment of Inertia ($lb\text{-}in^2$)		
		X	Y	Z	I_{xx}	I_{yy}	I_{zz}
COMMAND MODULE							
Main Panel Area							
D&C/AGC	15.0(E)						
Loose Stored Items							
Eye Relief Eyepieces	3.0(E)						
Film Cartridges (4)	3.0(E)						
AGC Loose Spares	26.0(E)						
PSA Loose Spares	9.0(E)						
CDU Spare Gearbox	3.0(E)						
Computer Self Check Plug	1.0(E)						
Horizon Photometer	4.0(E)						
SERVICE MODULE							
Radar (Transponder)	1.0(E)						
(Rendezvous Radar)	4.0(E)						

NOTE: Due to the complete re-evaluation of the weight situation, a complete breakdown of component centers of gravity and moments of inertia is not included in this report but will be included in subsequent reports.

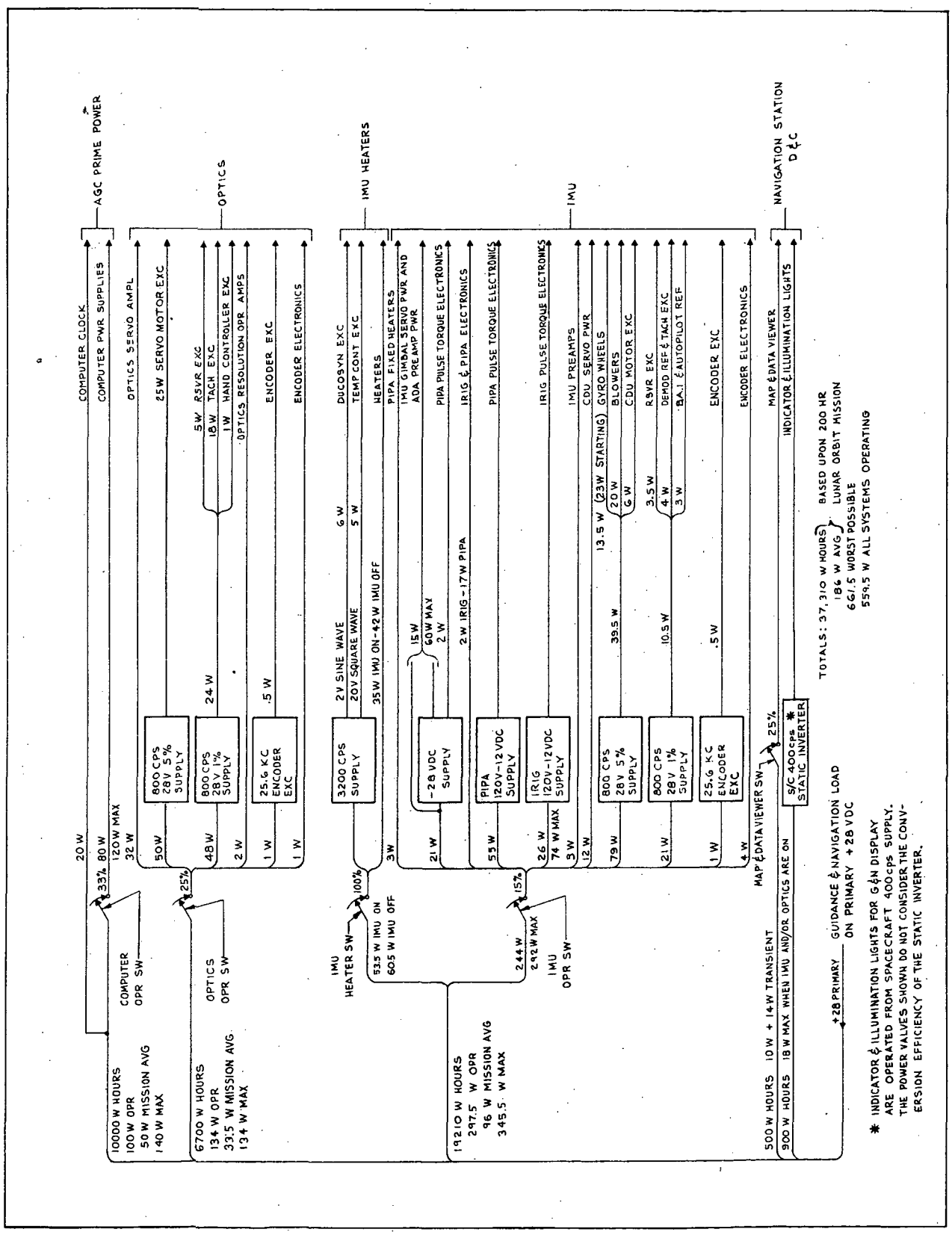

Figure 2. Electrical Load on Primary + 28 VDC

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.
CABLING:	Cabling: intrasubassembly cabling in lower equipment bay. (Interequipment cabling from lower equipment bay to other assemblies is assumed a spacecraft responsibility.)
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.
COMPUTER SELF-CHECK PLUG:	Computer Self-Check Plug: an additional item to provide capability of connecting computer outputs back onto inputs for checkout and diagnosis of failure.
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, Left Hand Turret, 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

G&N IND CONT PANEL: (cont'd)	elsewhere. Includes optics hand controller, altitude impulse control, panel wiring, and supporting hardware.
IMU CONT PANEL:	IMU Control Panel: meters, switches, panel wiring and supporting hardware.
LEFT HAND TURRET:	Left Hand Turret: contains electronic modules.
OPTICAL SHROUD:	Optical Shroud: includes protective cover.
EYE RELIEF EYEPIECES:	Eye Relief Eyepieces: eyepieces 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 sexant 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 spacecraft.
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 AND 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-freedom telescope and its drive mechanism.
SXT:	Sextant: two line-of-sight, narrow field, two-degree-of-freedom sextant, including drive mechanism and internal cooling.
PSA:	Power Servo Assembly: IMU, SCT, and SXT servos, power supplies, CDU electronics, IMU backup mode electronics, and miscellaneous electronics.
SIGNAL CONDITIONING TRAY:	Signal Conditioning Tray: tray in PSA to condition signals for telemetry and in-flight test equipment.
RADAR (TRANSPONDER AND RENDEZVOUS RADAR):	Radar (Transponder and Rendezvous Radar): electromagnetic ranging equipment, located in service module, for lunar orbit rendezvous.

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