APOLLO

GUIDANCE, NAVIGATION AND CONTROL

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E-1142 (Rev. 43)

SYSTEM STATUS REPORT

April 1966

MIT INSTRUMENTATION LABORATORY
CAMBRIDGE 39, MASSACHUSETTS

COPY # 4

ACKNOWLEDGEMENT

This report was prepared under DSR Project 55-238, sponsored by the Manned Spacecraft Center of the National Aeronautics and Space Administration through Contract NAS 9-4065.

The publication of this report does not constitute approval by the National Aeronautics and Space Administration of the findings or the conclusions contained therein. It is published only for the exchange and stimulation of ideas.

E-1142

(Rev. 43)

SYSTEM STATUS REPORT

ABSTRACT

The System Status Report is distributed on the 15th of each month. The areas of activity reported on in this month's revision include, but are not limited to, the following for the Block I 100 Series and Block II Command Modules and Lunar Excursion Module equipment: configuration weight, weight trend information, centers of gravity, moments of inertia, electrical power requirements, and computer programming status.

by Apollo Staff

April 15, 1966

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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 slight variations from system to system.

INTRODUCTION

The areas of activity reported on in this month's revision include, in general, the following for the Block I 100 Series and Block II Command Modules and Lunar Excursion Module equipment:

Section 1 - Configuration Weight
Reported Weight Changes
Weight Trend Information

Section 2 - Centers of Gravity
Moments of Inertia

Section 3 - Glossary and System Definition

Section 4 - Computer Programming Status

Section 5 - Electrical Power Requirements

Additional material, not suited to this format, will be presented from time to time as an appendix when it is particularly significant.

SECTION 1

WEIGHTS

Weights are reported to the nearest tenth of a pound on a component level. Each component weight is identified as estimated, calculated, or measured in order of increasing accuracy. These terms are defined as follows: estimated weights (E) are based on rough calculations; calculated weights (C) are based on detailed calculations made from final production drawings that will be used to build flyable equipment; measured weights (M) are actual weights of equipment built to the production drawings.

Tables 1, 2, and 3, respectively, present the weight of all CM Block I 100 Series, CM Block II, and LEM Guidance and Navigation equipment based upon the most current information. These tables offer a comparison of present component weight values with those listed in last month's revision of the System Status Report. The weights tabulated for Block II CM and LEM configuration represent operational flight hardware.

Also included are the respective control and design load weights as assigned by NASA. The Control Weight is the maximum allowable total weight of the Apollo Guidance and Navigation equipment for which MIT/IL is responsible. Design Load Weights are restricted to individual components and should be considered as "not to exceed" weights. These values represent a maximum within which design variations may cause changes without need for renegotiation.

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

When applicable, the tables will be followed by a discussion of reported weight changes and weight trend information. Each weight increase or decrease is accompanied with an explanation for the change and the effectivity by system number. Weight trend information describes future component changes presently being studied with an emphasis on weight reduction proposals.

North American Aviation and Grumman Aircraft Engineering Corporation will provide and be responsible for weights of cold plates that are not integral with guidance and control equipment.

TABLE 1. CURRENT WEIGHT STATUS OF BLOCK I 100 SERIES COMMAND MODULE G&N (LBS AT 1G)

Command Module G&N Equipment	Status 3/66	Change	Status 4/66	Design Load Weight*
LOWER EQUIPMENT BAY				
CDU Assy	16.9 (M)	0.0	16.9 (M)	16.0
Optical Subsystem				
SXT and gearing SCT and gearing Optical Base and gearing	47.6 (M)	0.0	47.6 (M)	
NVB and Resilient Mounts	25.7 (M)	0.0	25.7 (M)	155.0**
Bellows Assy	12.7 (M)	0.0	12.7 (M)	
IMU	61.2 (M)	0.0	61.2 (M)	
Coolant Hoses (Two)	0.9 (M)	0.0	0.9 (M)	
Power Servo Assy	65.4 (M)	0.0	65.4 (M)	120.0
G&N Interconnection Assy	26.1 (M)	0.0	26.1 (M)	
Optical Shroud	3.1 (M)	0.0	3.1 (M)	4.5
G&N to S/C Interface Assy AGC (with 6 rope modules)	87.0 (E)	+3.8	90.8 (M)	100.0
Optical Eyepiece Storage Assy Condition Annunciators SXT Normal Relief Eyepiece SCT Normal Relief Eyepiece SCT Long Relief Eyepiece	12.1 (E)	+1.0	13.1 (E)	---
D&C Electronics Assy	2.6 (M)	0.0	2.6 (M)	5.0
Control Electronics Assy	1.8 (M)	0.0	1.8 (M)	4.0

TABLE 1. CURRENT WEIGHT STATUS OF BLOCK I 100 SERIES COMMAND MODULE G&N (LBS AT 1G) (CONT)

Command Module G&N Equipment	Status 3/66	Change	Status 4/66	Design Load Weight*
G&N Indicator Control Panel	10.9 (M)	0.0	10.9 (M)	15.0
IMU Control Panel	2.9 (M)	0.0	2.9 (M)	5.0
Signal Conditioner Assy	4.8 (M)	0.0	4.8 (M)	8.0
DSKY	23.0 (M)	+1.5	24.5 (M)	26.0
MAIN PANEL AREA				
DSKY	25.2 (E)	+0.1	25.3 (M)	26.0
LOOSE STORED ITEMS				
Optics Cover	2.1 (M)	0.0	2.1 (M)	2.5
Horizontal Hand Holds (Two)	0.3 (M)	0.0	0.3 (M)	1.0
TOTAL	432.3	+6.4	438.7	---
The reported total weight for this month is 8.7 pounds more than the 430.0 pound total control weight †				
Bare Guidance Systems - IMU, AGC, IMU portions of the CDU's and IMU Support electronics			206.4	---

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

**This design load weight includes only 1/2 the weight of the Bellows Assembly.

† The Total Control Weight is specified in NASA letter EG-151-44-65-55 dated 10 February 1965. This weight assignment does not include recognition of the Optical Eyepiece Storage Assembly.

Reported Block I - 100 Series Weight Changes

AGC (with 6 Rope Modules) G&N to S/C Interface Assembly	(+3.8 lbs)
DSKY (Lower Equipment Bay)	(+1.5 lbs)
DSKY (Main Panel Area)	(+0.1 lbs)

In response to MIT's request for Block I - 100 Series AGC assembly weights, Raytheon Company submitted the following data obtained from the SP-1 computer ADP:

7.8 lbs	Six Rope Modules at 1.3 lbs each
5.0 lbs	Computer associated harness
78.0 lbs	Apollo Guidance Computer
90.8 lbs	Total
24.5 lbs	DSKY - Lower Equipment Bay
24.2 lbs	DSKY - Main Panel Area
1.1 lbs	Night Watchman Module
25.3 lbs	Total

It should be noted that wide variations often exist in the measured weights contained in the Acceptance Data Packages (ADPs). In view of these variations, MIT/IL is reporting the most pessimistic weight for the 100 Series computer.

SXT Normal Relief Eyepiece	(-0.3 lb)
SCT Normal Relief Eyepiece	(-0.2 lb)
SCT Long Relief Eyepiece	(+0.5 lb)

NASA letter, EG 44-85-66, directed MIT/IL to prepare for CCB approval the necessary documentation to implement the focusable SCT normal relief eyepiece change. The effectivity for this change is:

Block I Series 50	G&N 12,20, and a spare
Block I Series 100	G&N 110, and subsequent

The weights of the optical eyepieces have also been modified to include the eyepiece heaters and insulation.

SXT Normal Relief Eyepiece -	Mirror Housing	1 lb	
	Normal Relief Eyepiece		11 oz
	Heater & Insulation		2 oz
	TOTAL	1 lb	13 oz
SCT Normal Relief Eyepiece -	Prism Housing	1 lb	2 oz
	Normal Relief Eyepiece	1 lb	8.5 oz
	Modify eyepiece for focus capability		3 oz
	Heater & Insulation		2.5 oz
	TOTAL	3 lb	
SCT Long Relief Eyepiece -	Long Relief Eyepiece	1 lb	2.5 oz
	Heater & Insulation		2.5 oz
	TOTAL	1 lb	5 oz

Block I - 100 Series Weight Trend Information

MIT/IL realizes its responsibility to undertake weight reduction design studies if the total reported status weight exceeds the Control Weight. However, the control weight assignment, as specified in NASA letter EG-151-44-65-55 dated 10 February 1965, does not include recognition of the Optical Eyepiece Storage Assembly. Also, two added requirements have been imposed on MIT/IL: (1) each eyepiece must have a heater, and (2) the normal relief eyepiece for the SCT must have focus abilities. For these reasons MIT/IL does not feel that the control weight has truly been exceeded. It is suggested that NASA reassign the control weight to include these modifications.

Reported Block II Weight Changes

SXT Normal Relief Eyepiece	(+0.3 lb)
SCT Normal Relief Eyepiece	(+0.2 lb)
SCT Long Relief Eyepiece	(+0.5 lb)

NASA letter, EG 44-85-66, directed MIT/IL to prepare for CCB approval the necessary documentation to implement the focusable SCT normal relief eyepiece change. The effectivity for this change is: G&N System 201 and subsequent. The weights of the optical eyepieces have been modified to include the eyepiece heaters and insulation.

SXT Normal Relief Eyepiece -	Mirror Housing	1 lb	
	Normal Relief Eyepiece		11 oz
	Heater & Insulation		2 oz
	TOTAL	1 lb	13 oz
SCT Normal Relief Eyepiece -	Prism Housing	1 lb	2 oz
	Normal Relief Eyepiece	1 lb	8.5 oz
	Modify eyepiece for focus Capability		3 oz
	Heater & Insulation		2.5 oz
	TOTAL	3 lbs	
SCT Long Relief Eyepiece -	Long Relief Eyepiece	1 lb	2.5 oz
	Heater & Insulation		2.5 oz
	TOTAL	1 lb	5 oz

TABLE 2. CURRENT WEIGHT STATUS OF BLOCK II COMMAND MODULE GN&C (LBS AT 1G)

Command Module GN&C Equipment	Status 3/66	Change	Status 4/66	Design Load Weight*
LOWER EQUIPMENT BAY				
CDU Assy	36.2 (E)	0.0	36.2 (E)	50.0
Optical Subsystem SXT and gearing SCT and gearing Optical Base and gearing	47.6 (M)	0.0	47.6 (M)	150.0
NVB and Mounts	14.9 (E)	0.0	14.9 (E)	
Bellows Assy	12.7 (E)	0.0	12.7 (E)	
IMU	42.5 (M)	0.0	42.5 (M)	
Coolant Hoses (Two)	0.9 (E)	0.0	0.9 (E)	
Power Servo Assy	49.4 (E)	0.0	49.4 (E)	58.0
PIPA Electronics Assy	9.0 (E)	0.0	9.0 (E)	12.0
G&N Interconnect Harness Group	30.0 (E)	0.0	30.0 (E)	40.0
AGC	65.0 (E)	0.0	65.0 (E)	80.0
Optical Shroud	3.1 (M)	0.0	3.1 (M)	4.5
Optical Eyepiece Storage Assy SXT Normal Relief Eyepiece SCT Normal Relief Eyepiece SCT Long Relief Eyepiece	10.1 (E)	+1.0	11.1 (E)	15.0
G&N Indicator Control Panel	12.1 (E)	0.0	12.1 (E)	17.0
DSKY	17.5 (E)	0.0	17.5 (E)	25.0
Signal Conditioner Assy (Operational Flights)	8.0 (E)	0.0	8.0 (E)**	8.0

TABLE 2. CURRENT WEIGHT STATUS OF BLOCK II COMMAND MODULE GN&C (LBS AT 1G) (CONT)

Command Module GN&C Equipment	Status 3/66	Change	Status 4/66	Design Load Weight*
MAIN PANEL AREA				
DSKY	17.5 (E)	0.0	17.5 (E)	25.0
LOOSE STORED ITEMS				
Horizontal Hand Holds (Two)	0.3 (M)	0.0	0.3 (M)	1.0
SXT Long Relief Eyepiece	0.0 (M)	+0.4	0.4 (E)	
TOTAL	376.8	+1.4	378.2	---
The reported total weight for this month is 21.8 pounds less than the 400.0 pound total control weight †				
Bare Guidance Systems - IMU, AGC, IMU portions of the CDUs and IMU support electronics			168.1	---

*Design Load Weights are taken from ICD MH01-01356-416 signed 16 July 1965 at Meeting #22A.

**The weight of a qualification flight signal conditioner assy is 9.6 (E) pounds.

† The Total Control Weight is specified in NASA letter EG-151-44-65-55 dated 10 February 1965. This weight assignment does not include recognition of the Optical Eyepiece Storage Assembly.

SXT Long Eye-Relief Eyepiece (+0.4 lb)

Recent simulations by crew personnel have indicated that a SXT long relief eyepiece is required for Block II. NASA letter, EG 44-85-66, directed MIT/IL to proceed with the design of the SXT long relief eyepiece (LRE) for CCB release effective 201.

MIT/IL recommends that the SXT LRE not be stored in the eyepiece storage unit because of cost and schedule impact, but that it be stored in a bag with other loose stored miscellaneous items. In the event that the SXT LRE becomes installed in place of the SXT Normal Relief on the SXT eyepiece, then the replaced piece should be stored in the bag with miscellaneous items.

MIT/IL does not deem it necessary to provide a heater or thermal blankets for the SXT LRE. The weight change is recorded as follows:

SXT Long Relief Eyepiece	6 oz
One polaroid filter	1 oz
Total	7 oz ≈ 0.43 lbs

TABLE 3. CURRENT WEIGHT STATUS OF LEM PGNCS (LBS AT 1G)

LEM PGNCS Equipment	Status 3/66	Change	Status 4/66	Design Load Weight*
IMU	42.4 (M)	0.0	42.4 (M)	43
Navigation Base	4.0 (E)	0.0	4.0 (E)	8
AOT	23.1 (E)	0.0	23.1 (E)	25
Button Box	2.0 (E)	0.0	2.0 (E)	2
PTA	14.8 (E)	-0.5	14.3 (E)	17
Harness "B"	4.5 (E)	0.0	4.5 (E)	8
DSKY	17.5 (E)	0.0	17.5 (E)	20
LGC	65.0 (E)	0.0	65.0 (E)	65
CDU	37.3 (E)	0.0	37.3 (E)	37
PSA (Independent) (Operation Flights)	24.6 (E)	+1.8	19.2 (E)	28.2
Signal Conditioner Assy (Operation Flights)			7.2 (E)**	
Harness "A"	14.6 (E)	0.0	14.6 (E)	22
Lens Cleaning Kit	0.3 (E)	-0.3	0.0 (M)	--
TOTAL	250.1	+1.0	251.1	---
The reported total weight for this month exceeds the 240.0 pounds total control weight by 11.1 lbs. †				
Bare Guidance Systems - IMU, LGC, IMU portions of the CDUs and IMU support electronics			160.6	

*Design Load Weights are taken from ICD LIS-490-10001 as modified by NASA letter EG-43-422-65-766 dated 27 October 1965.

**The weight of a qualification flight signal conditioner assy is 9.2 (E) pounds.

† The Total Control Weight is specified in NASA letter EG-151-44-65-55 dated 10 February 1965.

Reported LEM Weight Changes

MIT/IL apparently misinterpreted the contents of Contract Change Authorization 4065-0018. MIT/IL was not directed to implement the changes necessary to eliminate a separate LEM operational signal conditioner. The CCA intended to authorize MIT/IL to complete the design of an integrated LEM PSA and operational signal conditioner. This design was not be be released. Thus, the substantial weight savings reported last month for the integrated PSA/SCA is retracted.

Independent operational SCA	7.65 lbs
Independent PSA	20.6 lbs

Signal Conditioner Assy (Operational Flights) (-0.5 lb)

This decrease is due to the deletion of the PIPA power supply module. The functions of this module have been delegated to some of the remaining modules. This reduction was shown for the qualification flight SCA in last month's report.

Power Servo Assembly (Independent) (-1.4 lbs)

An anticipated weight savings is reported for the PSA due to the potting of voids in the header encapsulant. The effectivity for this change is PGNCS System 603. The computation follows:

Total volume of voids in encapsulant	-	36.8 c.i.
Density of potting material	-	0.038 lb/c.i.

Thus the weight savings is 1.4 lbs.

PTA (-0.5 lbs)

An anticipated weight savings of 0.5 lbs is reported this month for the PTA. This savings is due to the potting of voids in the header encapsulant. The effectivity for this change is PGNCS System 603. The computation follows:

Total volume of voids in encapsulant - 13.75 c.i.
Density of potting material - 0.038 lb/c.i.

Thus the weight savings is 0.523 lb.

Lens Cleaning Kit (-0.3 lbs)

NASA letter, EG 43-157-66-215, directed MIT/IL to delete the Lens Cleaning Kit from the LEM configuration. The kit will now be provided by NASA/MSC as part of the GFE crew provisions and will be stored in the existing food storage locker. For the LEM requirements, four wet wipes and one dry wipe will be adequate. These are the materials MIT recently evaluated and approved for use with the CSM optics.

SECTION 2

CENTERS OF GRAVITY AND MOMENTS OF INERTIA

The centers of gravity and moments of inertia are summarized in tabular form. This data has been prepared for MIT/IL designed equipment with respect to the reference axes of the Block II Command Module and the Lunar Excursion Module. MIT assumes that all hardware is in the proper configuration for Thrusting Modes; therefore, the eyepieces (3) will be located in the Optical Eyepiece Storage Assembly. North American Aviation will provide storage for the astronaut's Horizontal Handholds (2). Since this storage information is not available at MIT/IL, it is suggested that NAA supply the centers of gravity and moments of inertia for these items. The present MIT proposal is that NAA provide storage for the SXT Long Relief Eyepiece in Block II.

Each assembly has a percentage reflecting the error in the values recorded incurred in the calculation methods employed. Analytical values will be verified by experiment (Tri-Filar Pendulum Moment of Inertia Test) when flight hardware is available.

TABLE 4. COMMAND MODULE BLOCK II GN&C MASS PROPERTY DATA

Command Module G&N Equipment	Center of Gravity - Inches				Moment of Inertia - Slug-ft^2			
	$\bar{x}$	$\bar{y}$	$\bar{z}$	±Error	I_x	I_y	I_z	±Error
CDU Assy	39.0	15.6	42.3	5%	17.85	28.78	15.34	2%
Optical Subsystem SXT & gearing SCT & gearing Optical Base & gearing	69.7	0	33.6	10%	11.77	61.99	50.25	2%
NVB & Mounts Bellows Assy	65.5	0	39.8	10%	10.02	35.56	26.15	5%
IMU Coolant Hoses (two)	55.8	0	40.9	10%	15.41	43.96	28.67	5%
Power Servo Assy	44.2	0	44.4	5%	22.77	44.04	22.09	1%
PIPA Electronics Assy	64.2	-14.0	37.6	5%	3.12	10.70	8.39	2%
G&N Interconnect Harness Assy AGC Optical Shroud	38.0	-4.0	46.2	5%	32.11	52.93	21.49	1%
Optical Eyepiece Storage Assy SXT Normal Relief Eyepiece SCT Normal Relief Eyepiece SCT Long Relief Eyepiece								
G&N Indicator Control Panel	54.5	0	36.5	5%	3.61	11.27	7.91	4%
DSKY (L.E.B.)	61.5	17.1	36.5	5%	6.14	19.31	15.39	1%
Signal Conditioner Assy	72.5	15.1	31.6	5%	2.12	10.79	9.46	2%
DSKY (Main Panel)	68.0	-13.9	-20.5	5%	2.32	19.06	18.21	2%
Horizontal Handholds (Two) SXT Long Relief Eyepiece		See text on the preceeding page.						
TOTAL								

TABLE 5. LUNAR EXCURSION MODULE PGNCS MASS PROPERTY DATA

LEM GN&C EQUIPMENT	Center of Gravity - Inches				Moment of Inertia - Slug-ft^2			
	$\bar{x}$	$\bar{y}$	$\bar{z}$	±Error	I_x	I_y	I_z	±Error
IMU	307.0	0	49.9	5%	22.90	886.76	863.97	1%
Navigation Base	30.9	0	54.4	5%	2.57	3.39	0.86	1%
AOT Button Box PTA Harness "B"								
DSKY	254.0	0	58.6	10%	12.98	256.47	243.50	1%
LGC	266.0	0	-22.9	5%	8.24	1034.57	1027.81	1%
CDU	252.2	0	-22.8	10%	4.69	553.63	549.28	2%
PSA (not integral unit) Signal Conditioner Assy	240.0	0	-22.8	5%	3.04	308.63	305.88	5%
Harness "A"								
TOTAL								

SECTION 3

GLOSSARY AND SYSTEM DEFINITION

A description of what constitutes MIT supplied hardware for the guidance and navigation equipment in Block I (100 Series) and Block II Command Modules and Lunar Excursion Module is contained in this section.

Apollo Guidance Computer (AGC)

A single complete flight computer containing all logic, memory associated power supplies, and all interface circuits except those identified with the CDU's. Does not contain the associated displays and controls.

The AGC consists of one case containing factory replaceable electronic modules. The weight estimate includes a cover for moisture-proofing and the G&N to S/C Interface Assembly which is located in the adjacent area. The weight of the necessary cold plate is not included.

Bellows Assembly

Consists of two flexible metal bellows forming a pressure seal between CM and optical subsystem for penetration of hull.

Coupling Data Unit (CDU) Assembly

The CDU provides the necessary signal interface among the IMU gimbal angles, optics gimbal angles, angle registers in the AGC, and the spacecraft autopilot attitude error signals.

The assembly contains five interchangeable gear boxes each with necessary motor tachometer, resolver synchros, and encoder. The CDU does not include associated electronics. (This electronics is located in the Block I PSA.) A frame assembly encloses the CDUs in a moisture-proof container and mounts them to the spacecraft structure.

Cold Plates

Cold plates for the IMU are built into the IMU. Necessary cold plates for electronics are part of the equipment supplied by the spacecraft manufacturer (NAA).

Control Electronics Assembly

Consists of one power transformer, one relay and diode module and a bracket end connector mounted behind G&N indicator control panel to support display and control functions. Includes moisture-proofing.

Coolant Hoses

Consists of: (1) three steel-flex coolant hoses between IMU and spacecraft, (2) line transition piece, (3) bracket assembly screws and clamp, and (4) entrapped coolant. (The line transition piece makes two of the hoses a single unit.)

DSKY (D&C/AGC)

Number displays and keyboard control associated with the operation of the AGC. Two functionally identical and parallel operating units: one in lower equipment bay and one on main panel between left and center couches. The main panel DSKY has a piece of fail-safe alarm detection equipment called a "nightwatchman".

D&C Electronics Assembly

Consists of a chassis, a relay and diode module, a demod. elect. module, a saturable reactor, a time delay module, a connector, and wiring and is mounted behind the G&N Indicator Control Panel. Used to support display and control functions. Connectors will be moisture-proofed.

G&N Indicator Control Panel

Consists primarily of controls and displays for the operation of the optics, IMU temperature control, panel brightness control, and attitude impulse control. It includes display and control elements, panel, panel wiring, supporting hardware, and moisture-proofing.

G&N Interconnection Assembly

Consists of an interconnect wiring harness, which electrically ties together the assemblies that constitute a completely integrated system. The weight of the PSA End Connector is included with this item. This term does not include weights of harness support brackets, which are an NAA responsibility.

G&N to S/C Interface Assembly

This assembly provides the electrical interface between the spacecraft wiring channel, the computer connector, and the PSA end connector assembly. There are no active electronics in the assy. The weight of this item is included with the Block I computer.

Horizontal Handholds (Two)

These handholds are part of the body tethering system for use during navigation sightings. Two handholds are mounted on the G&N Indicator Control Panel and will be removed when not in use. The weight reported includes the mounting screws.

Inertial Measurement Unit (IMU)

The IMU consists of three gyros and three accelerometers mounted on the innermost gimbal of a three degree-of-freedom gimbal structure. The size 14 IMU (14-inch case diameter) gimbal assembly including all parts inside hermetic case, entrapped coolant, and heat exchanger insulation are included in the weight.

IMU Control Panel

Consists of panel, wiring, attitude error meter, CDU transfer switch, manual alignment switch, CDU mode control switches, connector, supporting hardware, and associated moisture-proofing.

NVB and Resilient Mounts

Rigid beryllium structure supporting the IMU and the optical subsystem with its associated hardware. The NVB is attached to the spacecraft using flexible resilient mounts to prevent spacecraft strains from distorting the NVB and the alignment between the IMU and optics. These mounts also provide shock and vibration attenuation.

Optical Eyepiece Storage Assy (ESU)

A polyurethane filled structure will provide storage for three optical eyepieces: SXT normal relief, SCT normal relief, and SCT long relief eyepieces. The condition annunciator assembly is part of the compartment structure. The weight also includes a protective cover or door. The assembly is located in the area vacated by the M&DV.

Condition Annunciator Assy; This unit visually displays the status of G&N System. This function was previously part of the Map and Data Viewer.

Normal Relief Eyepieces: Removable SXT eyepiece and SCT eyepiece.

Long Relief Eyepiece: A SCT eyepiece to provide eye relief of at least 1.6 inches for closed visor operation. Used in place of normal eyepiece of SCT.

Optical Subsystem

The subsystem consists of a sextant, scanning telescope, and an optical base, each with associated hardware. An equipment definition follows:

Sextant (SXT): A two line-of-sight, narrow field-of-view, two degree-of-freedom sextant with its attached gearing.

Scanning Telescope (SCT): A single line-of-sight, wide field-of-view, two degree-of-freedom articulation optical instrument with its attached gearing.

Optical Base: A base for the SXT and SCT with its associated gearing.

Optical Shroud & Cover Assembly

Consists of the optical shroud and protective cover.

Power Servo Assembly (PSA)

The PSA includes most of the support electronics: power supplies; IMU, Optics, and CDU servos; IMU temperature control; accelerometer pulse torquing and gyro pulse torquing. Replaceable modules are placed in each of the 10 trays. Moisture protection is provided for each tray individually by a gasket and a connector cover with mounting screws. A beryllium front toe plate is included in the PSA weight.

The PSA end connector is the electrical interface between the 10 PSA trays, the G&N Interconnection Assy, and the G&N to S/C Interface Assy. The end connector weight is reported in the G&N Interconnection Assembly value.

Signal Conditioner Assembly

This assembly buffers and conditions signals for transmission to telemetry.

Apollo Guidance Computer (AGC)

A single complete flight computer containing all logic, memory associated power supplies, and all interface circuits except those identified with the CDU's. Does not contain the associated displays and controls.

Consists of one case containing factory replaceable electronic modules. Includes cover for moisture-proofing, but does not include the necessary cold plate.

Many Block I modules have been redesigned and repackaged in a separate case. Memory capacity increased over Block I.

Bellows Assembly

Consists of two elastomeric, semi-toroidal, strain isolation, pressure vessel penetration seals between the CM hull and the optical subsystem.

Coupling Data Unit Assembly (CDU)

The coupling data unit provides central data conversion between the G&N analog subsystems (inertial and optics sextant), and in addition certain spacecraft analog control and display functions. The CDU is an all-electronic device that employs analog computational techniques in conjunction with digital counters and control logic to perform both analog to digital (A/D) and digital analog (D/A) conversion.

Moding of various Guidance and Control system functions that operate in conjunction with the CDU signals is accomplished by the computer through the CDU control and synchronizing logic.

The weight includes all the support electronics, the 4 V power supply, and the header mounted adjacent to the AGC.

Cold Plates

Cold plates for the IMU are built into the IMU. Necessary cold plates for electronics are part of the equipment supplied by the spacecraft manufacturer. (NAA).

Coolant Hoses

Consists of: (1) two steel-flex coolant hoses, between IMU and spacecraft and (2) entrapped coolant. (Bracket assembly, screws and clamps will be supplied by NAA)

DSKY (D&C/AGC)

Number displays and keyboard control associated with the operation of the AGC. Two functionally identical and parallel operating units: one in lower equipment bay and one on main panel between left and center couches.

Mechanically and electrically similar to Block I but smaller configuration because of smaller relays. The Block II displays and keyboard controls will be sealed by encasing the unit in a container and using pressurized O-rings.

G&N Indicator Control Panel

Consists of controls and displays for optics, condition lamps, telemetry, and Master Alarm. Also contains attitude impulse switch and hand controller. Has integral illuminated computer instructions. The condition lamps replace the Block I Condition Annunciator Assembly.

G&N Interconnect Harness Group

This assembly consists of eight cables that electrically tie together the hardware that makes up the GN & C system and also provides the electrical interface with the spacecraft. The cables are defined as follows:

HARNESS A	AGC-CDU to Left Hand Bracket and S/C
HARNESS B	PSA to Optics (SXT) and Optics Resolver
HARNESS C	PSA to Upper and Lower IMU &PIPA
HARNESS D	PSA to Left Hand Bracket (AGC-CDU)
HARNESS E	PSA to G&N Panel
HARNESS F	PSA to Optics (SCT)
HARNESS G	PSA to Signal Conditioner and S/C Right Hand Bracket
HARNESS H	PSA to DSKY, Left Hand Bracket and Right Hand Bracket (Power)

The estimated weights include the group shielding, potting compound, connectors, wire, cable clamps, and clamp brackets.

Horizon Photometer - Star Tracker (Experimental Basis Only)

An earth horizon brightness photometer and automatic star tracker used for navigation measurements against the earth's illuminated limb. The sensors are incorporated into the head of the SXT, the weight of which includes this function. The PSA includes all support electronics for the horizon photometer.

Horizontal Handholds (Two)

These handholds are part of the body tethering system for use during navigation sightings. Two handholds are mounted on the G&N Indicator Control Panel and will be removed when not in use. The reported weight includes the mounting screws.

Inertial Measurement Unit (IMU)

The IMU consists of three gyros and three accelerometers mounted on innermost gimbal of a three degree-of-freedom gimbal structure. The size 12.5 IMU (12.5-inch case diameter) gimbal assembly including all parts inside the hermetic case, entrapped coolant, and heat exchanger insulation are included in the weight.

NVB & Mounts

A polyurethane filled aluminum skinned structure functionally similar to Block I but lighter and will provide for mounting the size 12.5 IMU. The Block II NVB is attached to the spacecraft by use of strain isolation hardmounts and will have a transition piece as a result of the re-orientation of the NVB so that the IMU axes will be parallel to the Command Module axes.

Optical Eyepiece Storage Assembly (ESU)

A polyurethane filled structure will provide storage for three optical eyepieces: SXT normal relief, SCT normal relief, and a SCT long relief eyepiece. The weight also includes a protective cover or door. This assembly is located in the area vacated by the M&DV. There is no provision for a condition annunciator as part of the compartment structure.

Normal Relief Eyepieces: Removable SXT eyepiece and a SCT eyepiece.

Long Relief Eyepieces: A SCT eyepiece to provide eye relief of at least 1.6 inches for closed visor operation. Used in place of SCT normal eyepiece.

Optical Subsystem

The subsystem consists of a sextant, scanning telescope, and an optical base each with associated hardware. An equipment definition follows:

Sextant (SXT): A two line-of-sight, narrow field-of-view, two degree-of-freedom sextant with its attached gearing. The horizon photometer and automatic star tracker sensors are incorporated into the SXT head. (See the experimental Horizon Photometer - Star Tracker)

Scanning Telescope (SCT): A single line-of-sight, wide field-of-view, two degree-of-freedom articulation optical instrument with its attached gearing.

Optical Base: A base for the SXT and SCT with its associated gearing.

Optical Shroud & Cover Assembly

Contains an optical shroud. The optics cover is to be used also as a work table during the flight. NAA has design responsibility for the "optics cover - work table".

PIPA Electronics Assembly (PEA)

Consists of electronics which directly support the function of the PIPA loop, including the calibration modules, containing selected components, assigned to each IMU. This sealed assembly is located in the Block I CDU location.

Power Servo Assembly (PSA)

The PSA consists of a single-plane matrix header with a cold plate mounted on top and the modules plugging in from beneath. A cover is required to protect the modules from moisture. The assembly is similar in function to the Block I PSA; however, many of the modules have been redesigned and repackaged.

The support electronics for the PIPA loop has been transferred to the PIPA Electronics Assembly. The CDU servos are deleted because the Block II CDU is an electronic package. The PSA includes electronics used to support the display and control functions previously identified with the Block I Control Electronics Assy and D&C Electronics Assy. The operational modules of the Horizon Photometer-Star Tracker have been replaced by equivalent dummy modules.

Signal Conditioner Assembly (SCA)

This assembly buffers and conditions signals for transmission to telemetry. These modules are located in the same volume occupied by the Block I lower equipment bay DSKY.

Apollo Guidance Computer (LGC)

A single complete flight computer containing all logic, memory associated power supplies, and all interface circuits except those identified with the CDUs. Does not contain the associated displays and controls.

Consists of one case containing factory replaceable electronic modules. Includes cover for moisture-proofing, but does not include the necessary cold plate.

Except for computer programs, the LGC is identical to the CM Block II AGC.

Alignment Optical Telescope (AOT)

The AOT is a three-position periscope with a single degree-of-freedom, manually read recticle. The weight estimate includes a normal eye-relief eyepiece and a bellows assy between the AOT and the LEM hull. The bellows assy is an elastomeric, semi-toroidal, strain isolation, pressure vessel penetration seal. The AOT reticle is used for alignment of the IMU.

Cold Plates

Cold plates for the IMU are built into the IMU. Necessary cold plates for electronics are part of the equipment supplied by the spacecraft manufacturer. (GAEC)

Computer Control and Reticle Dimmer Assy (Button Box)

Located on GAEC Supplied Hardware protecting the AOT. Contains illuminated push button controls mark "x", mark "y", and "reject" mark. Also has an AOT reticle dimmer.

Coolant Hoses

The coolant hoses for the LEM IMU will be supplied by the spacecraft manufacturer. (GAEC)

Coupling Data Unit (CDU)

The coupling data unit provides central data conversion between the computer and G&N analog subsystems (inertial and radar), and in addition certain spacecraft analog control and display functions. The CDU is an all-electronic device that employs analog computational techniques in conjunction with digital counters and control logic to perform both analog to digital (A/D) and digital to analog (D/A) conversion.

Moding of various Guidance and Control system functions that operate in conjunction with the CDU signals is accomplished by the computer through the CDU control and synchronizing logic.

The LEM CDU uses modules identical to those used in the CM Block II but mounted on a different header. The weight includes all the support electronics, the 4V power supply, and the header mounted adjacent to the AGC.

DSKY

Number Displays and Keyboard controls associated with the operation of the LGC. The DSKY will be sealed by encasing the unit in a container and using pressurized O-rings. Identical to the Block II DSKY except only a single unit is required.

Harness "A"

Harness "A" provides electrical interconnection in the CDU, AGC, and PSA areas. The estimated weights include the connectors, wire, insulation, shielding, and cable clamps.

Harness "B"

Harness "B" provides the electrical interconnection in the IMU and PTA areas. The estimated weights include the connectors, distribution box, wire, insulation, shielding, and cable clamps.

Inertial Measurement Unit (IMU)

The IMU consists of three gyros and three accelerometers mounted on the innermost gimbal of a three-degree-of-freedom gimbal structure. The size 12.5 LEM IMU is physically identical to the Block II. The weight value includes the gimbal assembly (and all parts inside the hermetic case), entrapped coolant, and the heat exchanger insulation.

Lens Cleaning Kit

Not specifically defined but appropriate cloths for cleaning the accessible surfaces of the optics lens.

NVB and Mounts

A toroidal aluminum ring with: (1) four tubular aluminum posts to provide for IMU mounting, (2) four tubular aluminum posts for AOT mounting, and (3) three aluminum inserts to provide strain isolation ball mounting to the GAEC structure.

Power Servo Assembly (PSA)

The PSA consists of a single-plane matrix header mounted on a cold plate with the modules plugging in from the top. A cover is required to protect the modules from moisture. The assembly consists of electronics modules similar to those identified in the Block II PSA; however, many of the modules have been redesigned and repackaged.

Support electronics for the PIPA and IRIG loops are not included. See "Pulse Torque Assembly". Support electronics for the optical subsystem is not identified.

Pulse Torque Assembly (PTA)

This assembly consists of electronics contained in the PIPA and IRIG loops, including the pulse torque power supply and PIPA and IRIG calibration modules. The PIPA calibration modules, containing selected components, are assigned to each IMU. This sealed assembly is located adjacent to the IMU in LEM.

Signal Conditioner Assembly (SCA)

This assembly buffers and conditions signals for transmission to telemetry. This assembly is located "piggyback" on top of the LEM PSA.

SECTION 4

GUIDANCE COMPUTER PROGRAMMING

Guidance computer programs fall into three categories: service, test and mission programs.

1. Service Programs: The service programs may be regarded as the "tools" used to accomplish the mission objectives. These programs are necessary for the general operation of the computer and they are completely insensitive to mission planning.

2. Test Programs: The test programs are used to test the AGC, the G&N System, and other programs.

3. Mission Programs: The mission programs are those AGC programs which directly accomplish the guidance and navigation functions. Certain parts of these are highly sensitive to mission plans, vehicle configuration, ground based activities, etc. Although some portions of these programs are quite general, a complete specification is not possible until the release of the Guidance System Operation Plan for each particular mission.

The memory also contains all mission and vehicle dependent data that is written directly into the memory of AGC. The very limited erasable section is intended primarily for storage of computational variables. Those mission parameters that do not change during flight are consigned to the fixed section of the memory.

Table 6. Memory Allocation for Block I Series 100 Command Module Computer

AGC Program	FLIGHT 202 Fixed Memory	FLIGHT 204 Fixed Memory
Interrupt Transfer Routines	39	
Fixed-Fixed Interpreter Section	941	
Bank 03 Interpreter Section	822	
Executive	339	
Waitlist	221	
Restart Control	116	
202 Restart Tables and Routines	464	
Fresh Start and Restart	312	
Down-Telemetry Program	230	
T 4 Rupt Output Control Program	805	
Mode Switching and Mark Routines	587	
IMU Compensation Package	215	
IRIG Pulse-Torquing Routines	288	
Extended Verbs for Moding	695	
AGC-Self Check	984	
Inter-bank Communication	74	
Alarm and Display Procedures	59	
Orbital Integration Program	840	
Midcourse Navigation Game	808	
Latitude-Longitude Subroutines	279	
Midcourse Initialization	159	
Orbital Integration for 202	170	
Measurement Incorporation	168	
B Vector Routine	535	
Prelaunch Alignment Program	900	
Inflight Alignment Program	235	
RTB OP Codes	348	
IMU Performance Tests 1	1009	
IMU Performance Tests 2	1017	
Inflight Alignment Subroutines	410	
Keyrupt, Uprupt, Fresh Start	98	
Pinball Game Buttons and Lights (DSKY)	2259	
202 Mission Control Program	2015	
Powered Flight Subroutines	1867	
Dummy 202 Initialization	32	
Re-Entry Control	1349	
Average G Integrator	153	
Verification Assistance Programs	99	
Sum Check End of Record Marks	24	
TOTAL FIXED MEMORY WORDS	21,965	

Table 7. Program Status for Block II Command Module Computer

The programming of SUNDIAL has begun by carrying over many of the applicable sections from AURORA. Some of these sections have been exercised on the digital simulator at M.I.T. and on a GN&C system at A.C. Electronics, Inc. in Milwaukee. Program status may be summarized as follows:

Fresh Start and Restart	(4,2,1)
Interpreter	(3)
Executive	(4)
Waitlist	(4)
Restart Control	(2)
T4RUPT Program	(4,2,1)
IMU Mode Switching	(4)
Optics Routines	(1)
Extended Verbs	(4,1)
Keyboard & Display	(4)
Alarm & Abort	(4)
Downlink	(2)
Self-check	(4)
Prelaunch Alignment	(2,1)
CSM & Saturn Integrated Tests	(3)
G&N System Tests	(3,2,1)
CSM Digital Autopilot	(2,1)

Numeric designations have the following meanings:

1) Planned
2) Programmed
3) "Bench" Tested on Digital Simulator
4) Test run on GN&C System

Multiple numbers mean that different sections of the program are at different stages.

Table 8. Program Status for Lunar Excursion Module Computer

LGC Program AURORA is midway to completion, with some sections already run on the PGNCS. Program status may be summarized as follows:

Fresh Start and Restart	(4)
Interpreter	(3)
Executive	(4)
Waitlist	(4)
Restart Control	(2)
T4RUPT Program	(4,2,1)
IMU Mode Switching	(4)
AOT Routines	(3)
Radar Routines	(2)
Extended Verbs	(4,1)
Keyboard & Display	(4)
Alarm & Abort	(4)
Meter Routines	(2)
Downlink	(3)
LGC Self Check	(4)
Prelaunch Alignment	(2)
LEM Flight Control System Test	(3)
G&N System Tests	(3)
Digital Autopilot	(3,2,1)

Numeric designations have the following meanings:

1) Planned
2) Programmed
3) Bench Tested on Digital Simulator
4) Test Run on PGNCS

Multiple numbers mean that different sections of the program are at different stages.

Preliminary estimates of the memory capacity for the LEM AURORA program will be reported when the values become established.

SECTION 5

ELECTRICAL POWER AND ENERGY

Electrical power and energy reporting is based upon the inflight spacecraft sequence of events for the Design Reference Mission as developed by the Apollo Mission Planning Task Force (AMPTF). (Reference GAEC Report Volume III - LED-540-12, dated 30 October 1964.)

The accompanying tables present the magnitude and distribution of power dissipated on a subsystem level. It is assumed that power is drawn from the spacecrafts' primary +28VDC supply and a 400 cps - 115 VAC single phase inverter.

Intermittent power peaks can exist, particularly during operation of displays and controls at random times. The energy content in these peaks is considered negligible.

All values (except those mentioned above) are actual expected levels of power. No margin factor has been applied to protect against possible differences between actual loads which will be experienced and the calculated levels quoted. Thus, these values should not be taken as "not to exceed" extremes.

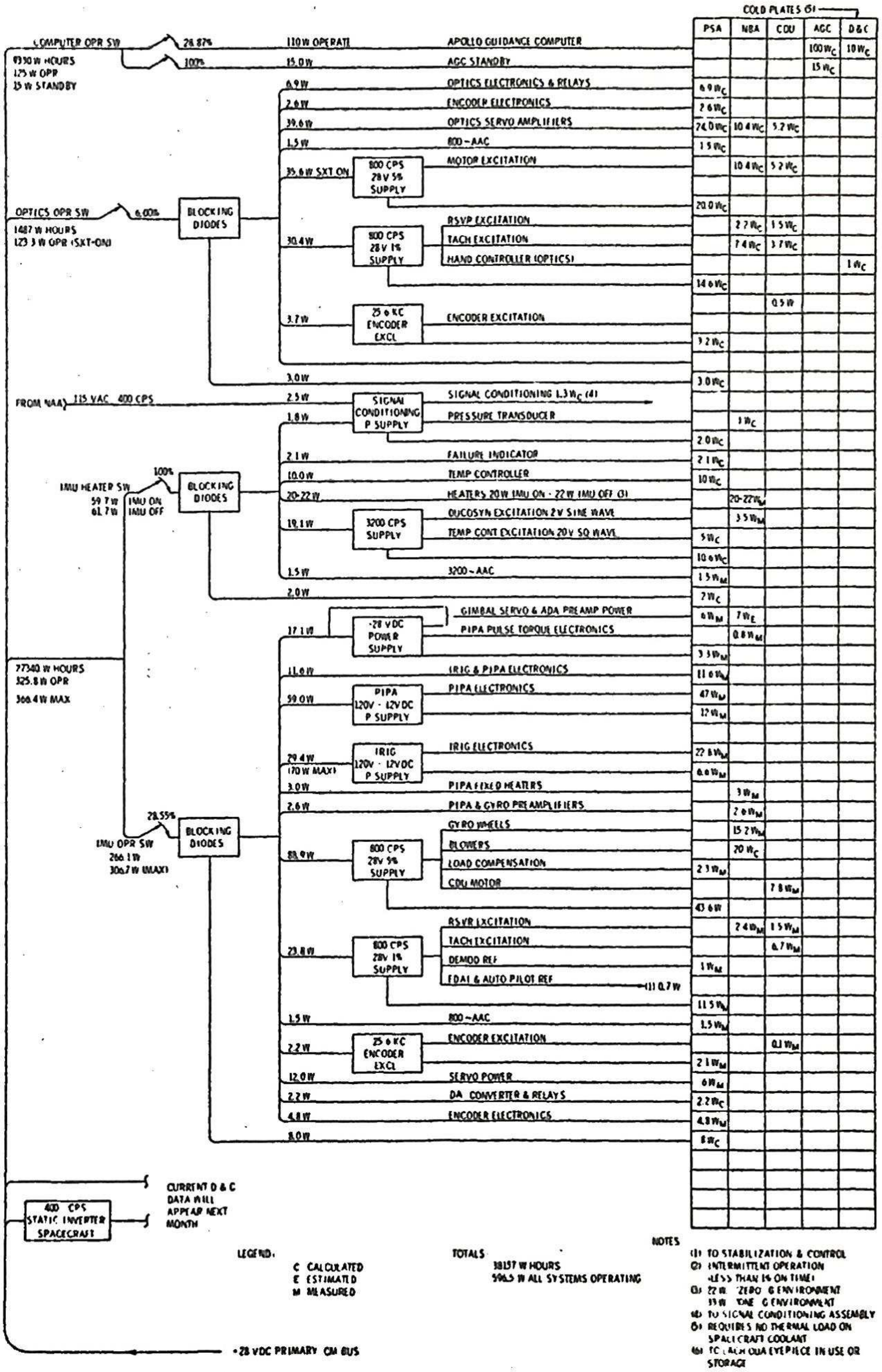
Interface Control Documents serve as the guidelines for reporting power figures.

CM Block I 100 Series	MH01-01227-216 "G & N Electrical Input Power" signed 11 June 1965
CM Block II	MH01-01327-216 "G & N Electrical Input Power" signed 15 July 1965
LEM	LIS-390-10002 "PGNCS Prime Power Requirements and Characteristics" signed 30 July 1965

BLOCK I - 100 SERIES GUIDANCE AND NAVIGATION LOAD ON PRIMARY +28 VDC COMMAND MODULE

BASED UPON 1985 HOUR (82.7 DAY) LUNAR MISSION
DESIGN REFERENCE MISSION

REFERENCE GAEC REPORT - LED 540-12, 30 OCTOBER 1964
APOLLO MISSION PLANNING TASK FORCE



LEGEND:
C CALCULATED
E ESTIMATED
M MEASURED

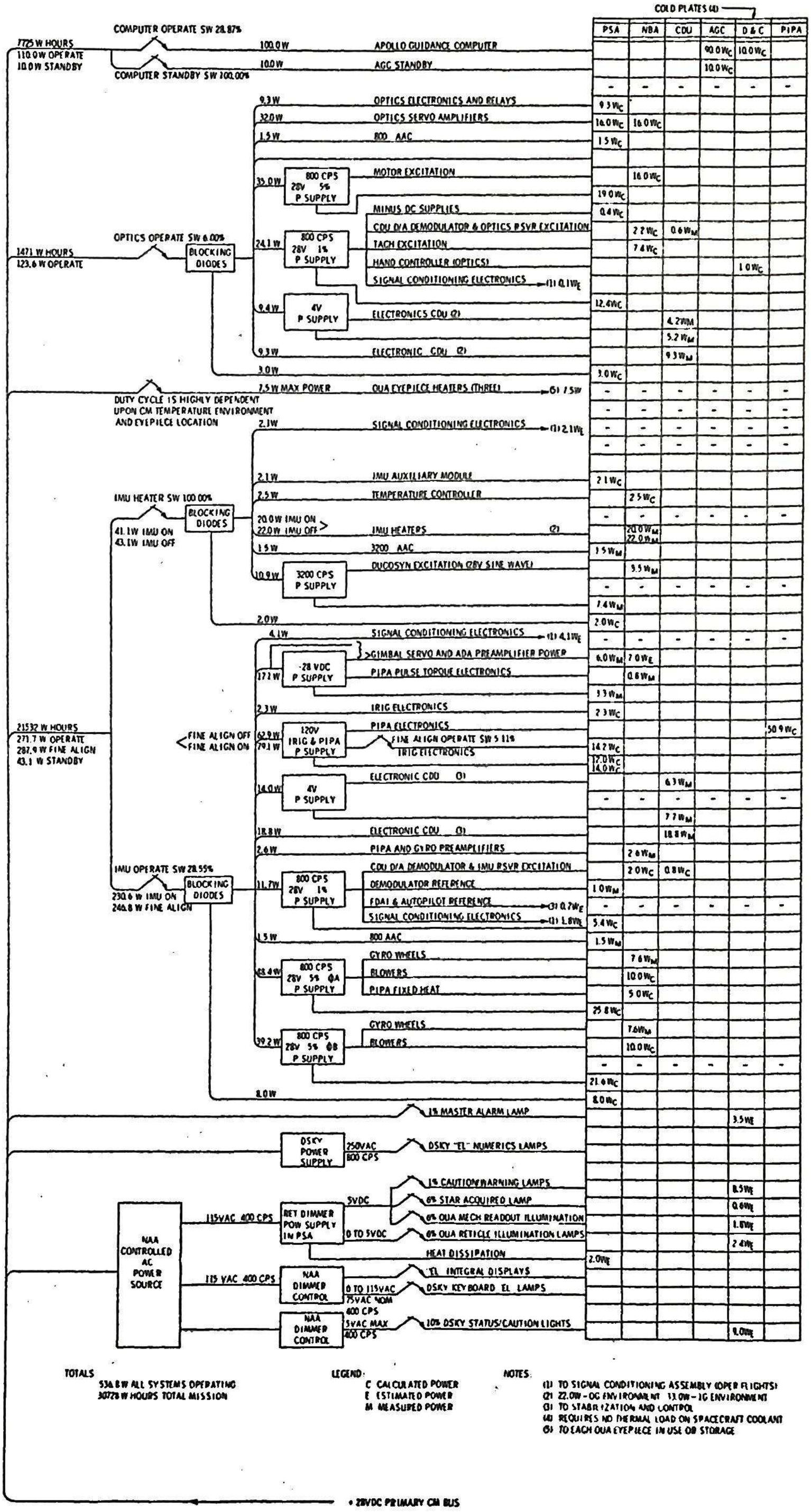
TOTALS
18157 W HOURS
5963 W ALL SYSTEMS OPERATING

NOTES
(1) TO STABILIZATION & CONTROL
(2) INTERMITTENT OPERATION (LESS THAN 1% ON TIME)
(3) 22 W ZERO G ENVIRONMENT 33 W ONE G ENVIRONMENT
(4) TO SIGNAL CONDITIONING ASSEMBLY
(5) REQUIRES NO THERMAL LOAD ON SPACECRAFT COOLANT
(6) TO EACH OUA EYEPIECE IN USE OR STORAGE

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

BASED UPON 195.5 HOUR (8.27 DAY) LUNAR ORBIT MISSION
DESIGN REFERENCE MISSION

REFERENCE GAEC REPORT - LED 540-12 30 OCTOBER 1964
APOLLO MISSION PLANNING TASK FORCE



TOTALS
536 8 W ALL SYSTEMS OPERATING
30728 W HOURS TOTAL MISSION

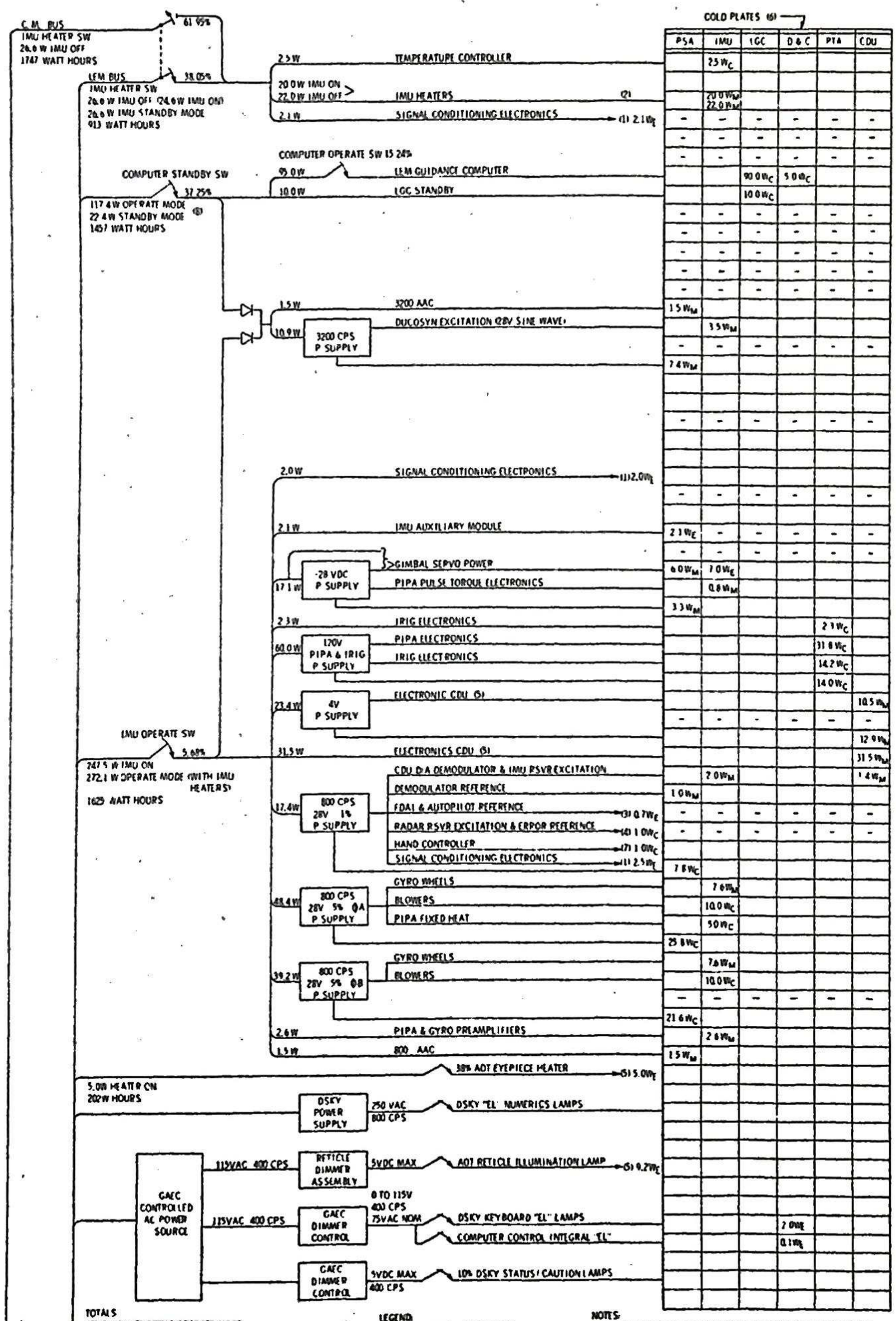
LEGEND:
C CALCULATED POWER
E ESTIMATED POWER
M MEASURED POWER

NOTES:
(1) TO SIGNAL CONDITIONING ASSEMBLY (OPER FLIGHTS)
(2) 22.0W - OG ENVIRONMENT 13.0W - 1G ENVIRONMENT
(3) TO STABILIZATION AND CONTROL
(4) REQUIRES NO THERMAL LOAD ON SPACECRAFT COOLANT
(5) TO EACH DUA EYEPIECE IN USE OR STORAGE

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

BASED UPON 100.02 HOURS (4.42 DAY) LUNAR LANDING MISSION DESIGN REFERENCE MISSION

REFERENCE GAEC REPORT - LED 540-12, 30 OCTOBER 1964 APOLLO MISSION PLANNING TASK FORCE



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