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APOLLO

GUIDANCE, NAVIGATION AND CONTROL

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SYSTEM STATUS REPORT

February 1966

MIT INSTRUMENTATION LABORATORY

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E-1142

(Rev. 41)

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, computer programming status, and reliability estimates.

by Apollo Staff

February 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 - Reliability Estimates

Section 5 - Computer Programming Status

Section 6 - 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.

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.

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.

After each table is an explanation of all weight changes reported this month with each component weight increment or decrement. A discussion of future component weight changes, presently being studied, will also be reported.

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

Command Module G&N Equipment	Weight Reduction Proposal	Status 1/66	Change	Status 2/66	Design Load Weight*
LOWER EQUIPMENT BAY					
CDU Assy		14.1 (M)	+2.8	16.9 (M)	16.0
Optical Subsystem					
SXT					
SCT		47.6 (M)	0.0	47.6 (M)	
Optical Base and Gearing					
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		87.0 (E)	0.0	87.0 (E)	100.0
AGC					
Optical Eyepiece Storage Assy		5.0 (E)	0.0	5.0 (E)	--
Condition Annunciator Assy		2.0 (E)	0.0	2.0 (E)	2.0
SXT Normal Eye-Relief Eyepiece		1.5 (M)	0.0	1.5 (M)	
SCT Normal Eye-Relief Eyepiece		2.8 (M)	0.0	2.8 (M)	7.2
SCT Long Eye-Relief Eyepiece		0.8 (M)	0.0	0.8 (M)	
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	Weight Reduction Proposal	Status 1/66	Change	Status 2/66	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		3.9 (C)	0.0	3.9 (C)	8.0
DSKY		23.0 (M)	0.0	23.0 (M)	26.0
MAIN PANEL AREA					
DSKY		25.2 (E)	0.0	25.2 (E)	26.0
LOOSE STORED ITEMS					
Optics Cover		2.1 (M)	0.0	2.1 (M)	2.5
Horizontal Hand Holds (Two)		1.0 (E)	-0.7	0.3 (M)	1.0
TOTAL	---	429.3	+2.1	431.4	--
The reported total weight for this month is 1.4 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				202.6	---

*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.

Block I 100 Series Reported Weight Changes

CDU Assembly (+2.8 lb)

Due to problems encountered in qualification testing of the assembly at AC Electronics/Milwaukee, a joint decision by NASA, MIT/IL, and AC Electronics resulted in a redesign of the CDU Frame Assembly to enclose the CDUs in a moisture-proof container. A more definitive weight breakdown follows:

	Old	New	Change
Panel	3.5 oz	15.25 oz	11.75 oz
Frame	1 lb 13.25 oz	3 lb 13.63 oz	2 lb 0.38 oz

The net change is +2 lb 12.13 oz or +2.8 lb. This change affects system 12 and all 100 Series systems.

Horizontal Handholds (Two) (-0.7 lb)

The decrease is due to the weighing of flight hardware at MIT/IL.

Block II Weight Trend Information

An increase in the CDU assembly weight is expected next month. The increase reflects a refinement of the module estimates based upon the measurement of potted prototypes. Tray estimates were also updated because stiffening members were added to the trays to reduce deflections when the unit is pressurized.

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

Command Module GN&C Equipment	Weight Reduction Proposal	Status 1/66	Change	Status 2/66	Design Load Weight*
LOWER EQUIPMENT BAY					
CDU Assy		36.2 (E)	0.0	36.2 (E)¢	50.0
Optical Subsystem SXT SCT Optical Base & Gearing		47.6 (M)	0.0	47.6 (M)	150.0
NVB & Mounts		14.9 (E)	0.0	14.9 (E)	
Bellows Assy		12.7 (E)	0.0	12.7 (E)	
IMU		42.2 (M)	0.0	42.2 (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 Assy		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 EyepieceStorage Assy		5.0 (E)	0.0	5.0 (E)	--
SXT Normal Eye-Relief Eyepiece		1.5 (M)	0.0	1.5 (M)	7.0
SCT Normal Eye-Relief Eyepiece		2.8 (M)	0.0	2.8 (M)	
SCT Long Eye-Relief Eyepiece		0.8 (M)	0.0	0.8 (M)	2.0
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	Weight Reduction Proposal	Status 1/66	Change	Status 2/66	Design Load Weight*
MAIN PANEL AREA					
DSKY		17.5 (E)	0.0	17.5 (E)	25.0
LOOSE STORED ITEMS					
Horizontal Hand Holds (Two)		1.0 (E)	-0.7	0.7 (M)	1.0
TOTAL	---	376.9	-0.7	376 2	---
The reported total weight for this month is 23.8 pounds less than the 400.0 pound total control weight†					
Bare Guidance Systems - IMU, AGC, IMU portions of the CDUs and IMU support electronics				167.8	---

*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.

¢ See the section entitled Block II Weight Trend Information.

Block II Reported Weight Changes

Horizontal Handholds (Two) (-0.7 lb)

The decrease is due to the weighing of flight hardware at MIT/IL.

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

LEM PGNCS Equipment	Weight Reduction Proposal	Status 1/66	Change	Status 2/66	Design Load Weight*
IMU		42.1 (M)	0.0	42.1 (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)	0.0	14.8 (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		20.6 (E)	0.0	20.6 (E)	21
Signal Conditioner Assy (Operational Flights)		7.7 (E)	0.0	7.7 (E)**	7.2
Harness "A"		14.6 (E)	0.0	14.6 (E)	22
Lens Cleaning Kit		0.3 (E)	0.0	0.3 (E)	0.5
TOTAL	---	253.5	0.0	253.5	---
The reported total weight for this month exceeds the 240.0 pounds total control weight by 13.5 lbs.†					
Bare Guidance Systems - IMU, LGC, IMU portions of the CDUs and IMU support electronics				162.0	

*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 9.7 (E) pounds.

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

¢ See the section entitled "LEM Weight Trend Information".

LEM Weight Trend Information

An increase in the CDU assembly weight is expected next month. The increase reflects a refinement of the module estimates based upon the measurement of potted prototypes. Tray estimates were also updated because stiffening members were added to the trays to reduce deflections when the unit is pressurized.

Weight reduction proposals were reported in the January System Status Report E-1142 Revision 40.

SECTION 2

CENTERS OF GRAVITY AND MOMENTS OF INERTIA

This information will be summarized in the near future in tabular form. Each assembly will have a number reflecting the degree of confidence in the values recorded. Analytical values which have been computed 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			
	$\bar{x}$	$\bar{y}$	$\bar{z}$	Confidence	I_x	I_y	I_z	Confidence
CDU Assy								
Optical Subsystem SXT SCT Optical Base & Gearing								
NVB & Mounts								
Bellows Assy								
IMU								
Coolant Hoses (two)								
Power Servo Assy								
PIPA Electronics Assy								
G&N Interconnect Harness Assy								
AGC								
Optical Shroud								
Optical Eyepiece Storage Assy SXT Eyepiece SCT Eyepiece SCT Long Eye Relief Eyepiece								
G&N Indicator Control Panel								
DSKY (L. E. B.)								
Signal Conditioner Assy								
DSKY (Main Panel)								
Horizontal Handholds (Two)								
TOTAL								

TABLE 5. LUNAR EXCURSION MODULE PGNCS MASS PROPERTY DATA

LEM GN&C EQUIPMENT	Center of Gravity - Inches				Moment of Inertia - Slug-ft^2			
	$\overline{x}$	$\overline{y}$	$\overline{z}$	Confidence	I_x	I_y	I_z	Confidence
IMU								
Navigation Base								
AOT								
Button Box								
PTA								
Harness "B"								
DSKY								
LGC								
CDU								
PSA								
Signal Conditioner Assy								
Harness "A"								
Lens Cleaning Kit								
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.

Condition Annunciator Assembly

Visually displays G&N system status. This function was previously part of the Map & Data Viewer. The current proposal includes this in the optics eyepiece storage unit.

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.

Five interchangeable gear boxes each with necessary motor tachometer resolver synchros, and encoder with mounting frame work. Does not include associated electronics which are located in the PSA.

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. 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 Hand Holds (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 - Long Eye-Relief

Consists of an 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 Eyepiece - Normal Eye-Relief

Removable SXT eyepiece and SCT eyepiece.

Optical Eyepiece Storage Assy

A polyurethane filled structure will provide storage for three optical eyepieces: SXT normal eye-relief, SCT normal eye-relief, and SCT long eye-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.

Optical Subsystem

Consists of SXT, SCT, Optical Base, and associated hardware defined as follows:

SXT:	Sextant: A two-line-of-sight, narrow-field, two-degree-of-freedom sextant and its attached gearing.
SCT:	Scanning Telescope: A single-line-of-sight, wide-field-of-view, two-degree-of-freedom articulation optical instrument and its attached gearing.
Optical Base:	Base for SXT and SCT with 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 to S/C Interface Assy value.

Signal Conditioner Assembly

Conditions signals for 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 Assembly

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 (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 Eyepieces - Long Eye-Relief

Consists of an 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 Eyepieces - Normal Eye-Relief

Removable SXT eyepiece and SCT eyepiece.

Optical Eyepiece Storage Assembly

A storage unit for eyepieces is provided similar to the Block I (100 Series) unit. There is no provision for the Condition Annunciator Assembly as part of the compartment structure.

Optical Subsystem

Consists of SXT, SCT, Optical Base, and associated hardware defined as follows:

SXT:	Sextant: A two-line-of-sight, narrow-field, two-degree-of-freedom sextant and its attached gearing. The horizon photometer and automatic star tracker sensors are incorporated into the SXT head. (See Horizon Photometer Electronics.)
SCT:	Scanning Telescope: A single-line-of-sight, wide-field-of-view, two-degree-of-freedom articulation optical instrument and its attached gearing.
Optical Base:	Base for SXT and SCT with 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

Conditions signals for telemetry. These modules are located in the same volume now 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, distribution box, 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. The

LEM PSA does not include electronics for the PIPA and IRIG loops. See "Pulse Torque Assembly". Optics and dummy photometry modules are not included in this package.

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

Conditions signals for telemetry. This assembly is identical to Block I and is located on top of the LEM PSA.

SECTION 4

RELIABILITY

The current status of reliability is reported in summary form as charts.

The following charts contain tabulatons of the failure rates associated with each major configuration of G&N systems. These have been derived from the parts counts of each assembly using generic type part failure rates, modified only by the stress applied to each part and its singular application in the system. From these data, estimations of probabilities of mission success have been derived. Continual updating is accomplished and will be reported monthly in this report.

The numerical reliability objectives for the G&C system are provided by NASA/MSC-ASPO TWX PR 2-64-314 of 5 August 1964. It should be noted that these values are associated with an outdated configuration having a redundant computer. The latter was deleted by NASA direction as part of the interface realignment. The Lunar Orbit Rendezvous numerical reliability mission success objectives are as follows:

Command Module	0.985
Lunar Excursion Module	0.994

TABLE 6. RELIABILITY ESTIMATES FOR CSM G&N SYSTEM 17 BASED ON APOLLO UNMANNED MISSION - FLIGHT 202†
(Probability of Success of G&N System 17 from Earth Launch Until CM Splashdown)

G&N Subsystems	Operate Failure Rate Per 10^6 hrs	Operate Time (hours)	Failures per 10^6 Missions	Success Probability
IMU	185	1.4	259	.99974
IMU Electronics	224	1.4	314	.99968
CDU (IMU)	111	1.4	155	.99984
Optics	---	0	0	---
Optics Electronics	---	0	0	---
CDU (Optics)	---	0	0	---
AGC	257	1.4	360	.99964
DSKY (2)	12	1.4	17	.99998*
D&C	6	1.4	8	.99999
TOTAL			1113	.9988

† Based upon NASA approved MIT Report R-477, "G&N System Operations Plan Apollo Mission 202"

*Success requires that only one of redundant pair of DSKY's not fail.

TABLE 7. RELIABILITY ESTIMATES FOR CSM GN&C BASED ON AMPTF DESIGN REFERENCE MISSION†
(Probability of success of CSM PGNCS from earth launch until LEM powered descent.)
(Elapsed time of approximately 69 hours.)

CSM PGNCS Subsystem	Operate Failure Rate Per 10^6 hrs	Operate Time (hrs)	Standby Failure Rate Per 10^6 hrs	Standby Time (hrs)	Failures Per 10^6 Missions	Success Probability
IMU	129	13.8	10.2	55.6	2347	0.99766
IMU Electronics	110	13.8	6.3	55.6	1868	0.99813
CDU (IMU)	155	13.8	0	55.6	2139	0.99861
Optics	94	9.1	0	59.1	855	0.99914
Optics Electronics	77	9.1	0	59.1	701	0.99929
CDU (Optics)	91	9.1	0	59.1	828	0.99917
AGC	235	13.8	60.5	55.6	6607	0.9931
DSKY (2)	2.3 Equiv.	13.8	0	55.6	2	0.99999*
D&C	22	13.8	0	55.6	304	0.99969
TOTAL					15,652	0.9844

†Based upon the latest Apollo Mission Planning Task Force - Design Reference Mission - (GAEC Report LED-540-12, Vol. III dated 30 October 1964) as modified by NASA letter EG 131-5-65-374.

*Success requires that only one of redundant pair of DSKYs not fail.

TABLE 8. RELIABILITY ESTIMATE FOR LEM G&N BASED ON AMPTF DESIGN REFERENCE MISSION †
(Probability of success for LEM PGNCS from earth launch until LEM touchdown.)

LEM PGNCS Subsystem	Operate Failure Rate Per 10^6 hrs	Operate Time (hrs)	Standby Failure Rate Per 10^6 hrs	Standby Time (hrs)	Failures Per 10^6 Missions	Success Probability
IMU	129	3.25	1.6	66.2	525	0.9995
IMU Electronics	110	3.25	0	0	357	0.9997
CDU (IMU)	155	3.25	0	0	504	0.9995
AOT	38	3.25	0	0	124	0.99988
AOT Electronics	1.33	3.25	0	0	4	0.99999
CDU (Rendezvous Radar)	112	3.25	0	0	364	0.9997
LGC	235	3.25	0	0	764	0.9992
DSKY	110	3.25	0	0	358	0.9996
D&C	7	3.25	0	0	23	0.99998
TOTAL					3008	0.9970

† Based upon the latest Apollo Mission Planning Task Force - Design Reference Mission - (GAEC Report LED-540-12, Volume III, dated 30 October 1964) as modified by NASA letter EG-131-5-65-374.

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SECTION 5

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.

FLIGHT 202

The guidance routines for the various mission phases are incorporated within the 202 mission control program section of program CORONA as specified in the NASA approved Guidance System Operation Plan presented in MIT Report R-477, "Guidance and Navigation System Operations Plan Apollo Mission 202". See Table 9.

FLIGHT 204

The preliminary version of MIT/IL Report R-507 "Guidance and Navigation Systems Operations Plan, AS-204" as modified by NASA letter EG 22-65-858 dated 23 November 1965, constitutes a NASA/MSC - approved document. Computer programming has started for the various 204 mission control sections incorporated in Program CORONA. Preliminary estimates of the fixed-memory allocation for Flight 204 are in the process of being calculated and will be reported when the values become established.

BLOCK II & LEM

The AURORA Guidance Computer Program represents the basic Block II guidance computer and contains programs similar to the CORONA assembly for the Block I CSM PGNS. The LGC Program, AURORA, is midway to completion. Estimates of the fixed-memory capacity will be recorded as the values become established.

TABLE 9. MEMORY ALLOCATION FOR 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 10. 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 or 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 6

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.

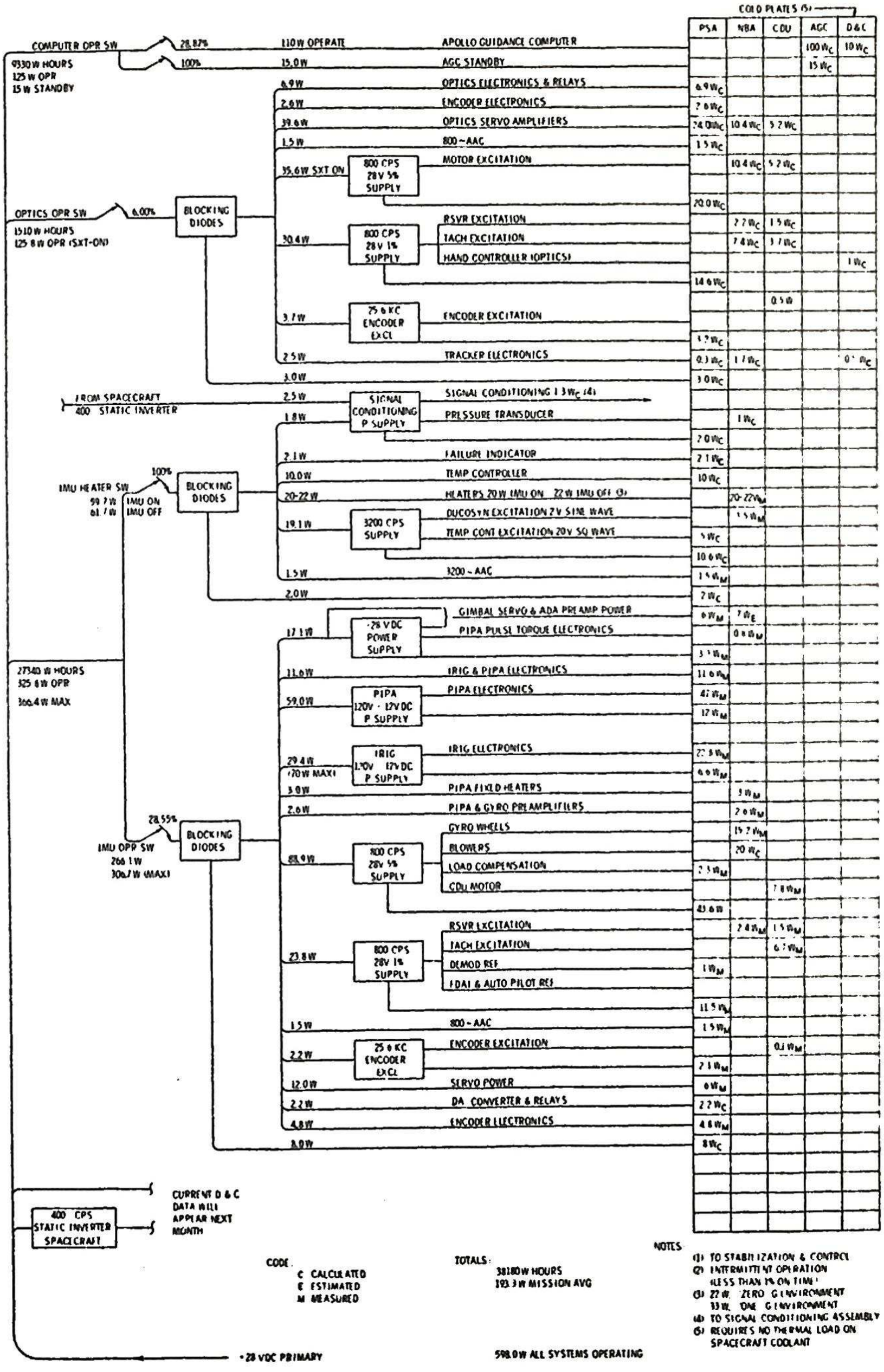
Interface Control Documents serve as the guidelines for reporting power figures.

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 1983 HOUR (8.27 DAY) LUNAR MISSION
DESIGN REFERENCE MISSION

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



CODE:
C CALCULATED
E ESTIMATED
M MEASURED

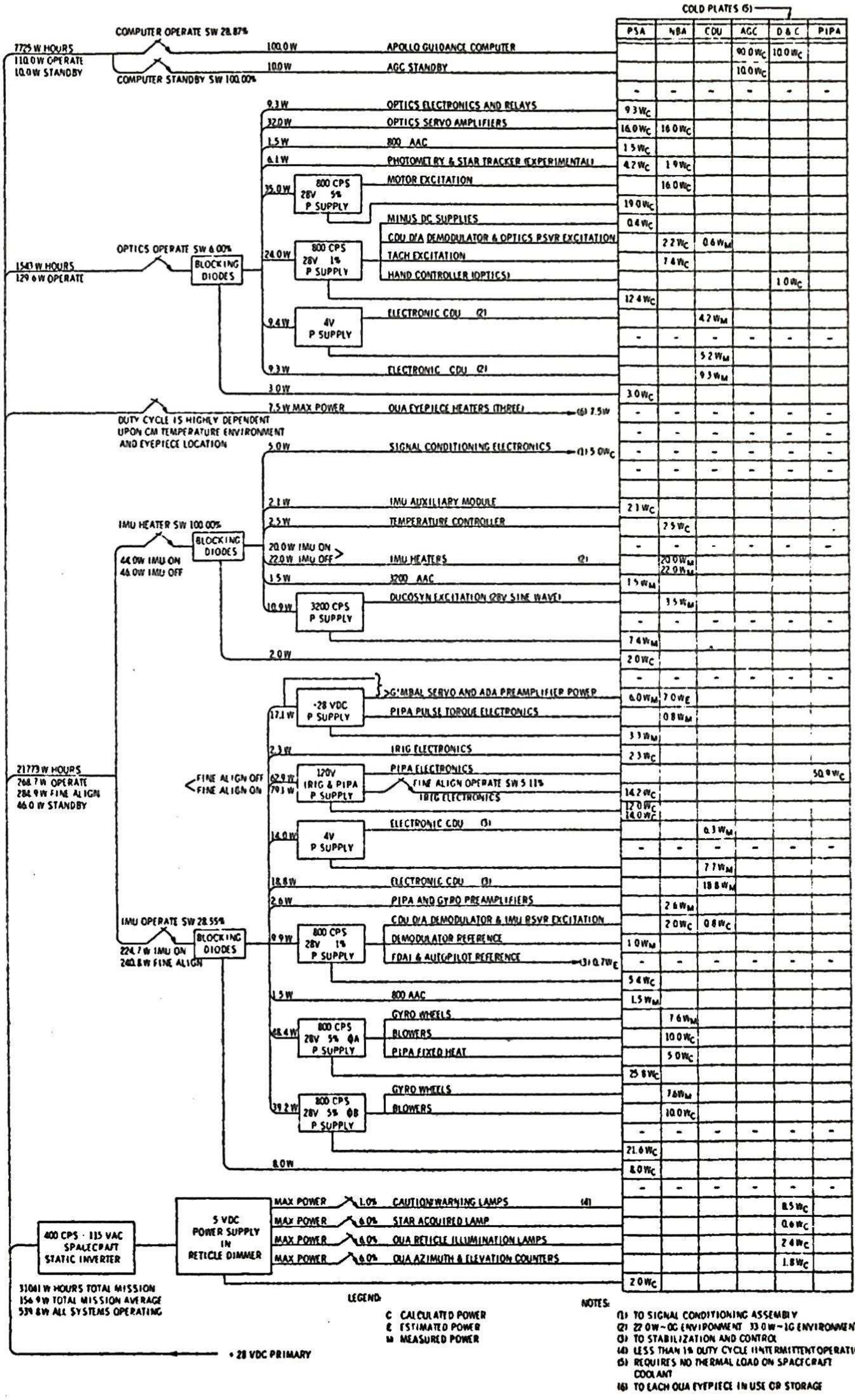
TOTALS:
3818 0 W HOURS
193.3 W MISSION AVG

NOTES:
(1) TO STABILIZATION & CONTROL
(2) INTERMITTENT OPERATION (LESS THAN 1% ON TIME)
(3) 22 W ZERO G ENVIRONMENT
13 W ONE G ENVIRONMENT
(4) TO SIGNAL CONDITIONING ASSEMBLY
(5) REQUIRES NO THERMAL LOAD ON SPACECRAFT COOLANT

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

BASED UPON 198.5 HOUR (8.27 DAY) LUNAR ORBIT MISSION
DESIGN REFERENCE MISSION

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



LEGEND:

C CALCULATED POWER
E ESTIMATED POWER
M MEASURED POWER

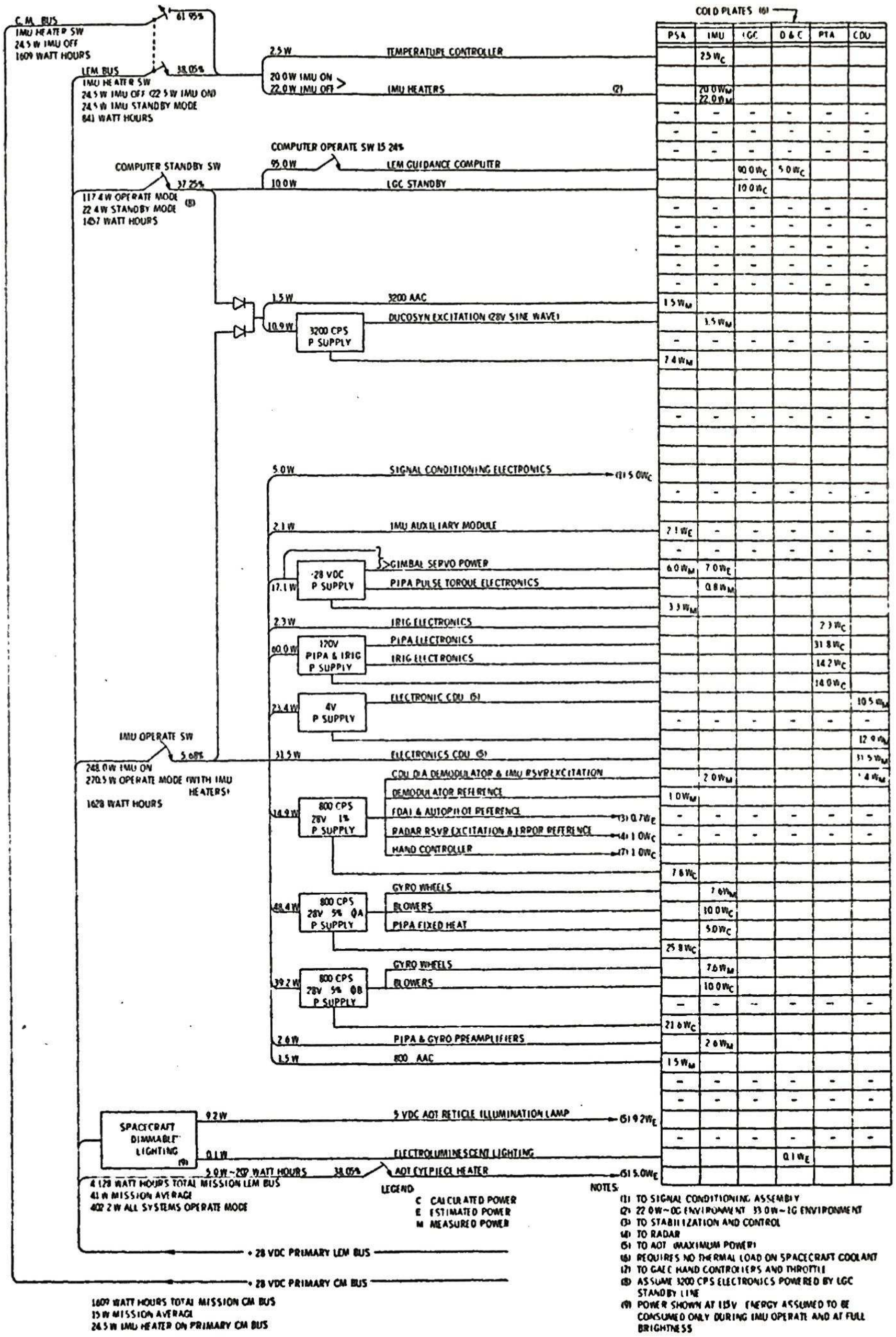
NOTES:

(1) TO SIGNAL CONDITIONING ASSEMBLY
(2) 22.0 W – 0G ENVIRONMENT 33.0 W – 1G ENVIRONMENT
(3) TO STABILIZATION AND CONTROL
(4) LESS THAN 1% DUTY CYCLE (INTERMITTENT OPERATION)
(5) REQUIRES NO THERMAL LOAD ON SPACECRAFT COOLANT
(6) TO EACH OUA EYEPIECE IN USE OR STORAGE

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

BASED UPON 106.02 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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