

APOLLO

GUIDANCE, NAVIGATION AND CONTROL

Approved: *[Signature]* Date: 9/7/66
for DAVID G. HOAG, DIRECTOR
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: *[Signature]* Date: 10 Aug 66
for RALPH R. RAGAN, DEPUTY DIRECTOR
INSTRUMENTATION LABORATORY

E-1142
(Rev. 46)

SYSTEM STATUS REPORT

July 15, 1966



CAMBRIDGE 39, MASSACHUSETTS

INSTRUMENTATION LABORATORY

COPY # 1

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. 46)

SYSTEM STATUS REPORT

ABSTRACT

The System Status Report is distributed monthly. 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, reliability failure rates, electrical power requirements, and computer programming status.

by Apollo Staff
July 15, 1966

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
Accuracy	7
Introduction	9
1. Weights	11
Reported Weight Changes: Block I CM G&N	13
Reported Weight Changes: Block II CM G&N	17
Weight Trend Information: CMC	20
Weight Trend Information: LGC	21
2. Centers of Gravity and Moments of Inertia	23
3. Glossary and System Definition	27
Command Module Block I, Series 100	28
Command Module Block II	33
Lunar Excursion Module	39
4. Reliability Analysis and Assessment	43
5. Electrical Power and Energy	47
6. Guidance Computer Programming	51

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 - Failure Rates
- Section 5 - Electrical Power Requirements
- Section 6 - Computer Programming Status

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.

Reported Weight Changes

Block I (100 Series) CM G&N

I. Optical Eyepiece Storage Assembly -0.4 lb.

A. The AC Electronics Acceptance Data Package for System 121 reported a measured weight of 6.63 lbs in contrast to the MIT/IL estimate of 7 lbs for the Eyepiece Storage Unit (ESU) including Condition Annunciators.

<u>Hardware</u>	<u>Old Weight</u>	<u>New Weight</u>	<u>Net Change</u>
ESU including Condition Annunciators	7.0 lb	6.63 lb	-0.37 lb

B. The Kollsman Instrument Corporation Acceptance Data Package No. 91-1, Block I (50 Series) Quick Disconnect Eyepieces consigned to OUA AGE12 reported the following weights:

<u>Hardware</u>	<u>Old Weight</u>	<u>New Weight</u>	<u>Net Change</u>
1. SXT Mirror Housing Assy including heater and insulation	1 lb 2 oz	1 lb 2 oz	
2. SXT Eyepiece Assy	<u>11 oz</u> 1 lb 13 oz	<u>11 oz</u> 1 lb 13 oz	
3. SCT Prism Housing Assy	1 lb 2 oz	1 lb 1 oz	-1 oz
4. SCT Eyepiece Assy in- cluding heater insulation and adjustable focus	<u>1 lb 14 oz</u> 3 lb	<u>1 lb 13 oz</u> 2 lb 14 oz	<u>-1 oz</u> -2 oz
5. SCT LER Eyepiece Assy including heater and insulation	1 lb 5 oz	1 lb 7 oz	<u>+2 oz</u> 0

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

Command Module G&N Equipment	Status 6/66	Change	Status 7/66	Design Load * Weight
LOWER EQUIPMENT BAY				
CDU Assy	16.9 (M)	0.0	16.9 (M)	18.0 #
Optical Subsystem				} 155.0 **
SXT and gearing	47.6 (M)	+6.0	53.6 (E)	
SCT and gearing	25.7 (M)	0.0	25.7 (M)	
Optical Base and gearing	12.7 (M)	0.0	12.7 (M)	
NVB and Resilient Mounts	61.2 (M)	0.0	61.2 (M)	
Bellows Assy	0.9 (M)	0.0	0.9 (M)	
IMU	65.4 (M)	0.0	65.4 (M)	} 120.0
Coolant Hoses (Two)	26.1 (M)	0.0	26.1 (M)	
Power Servo Assy	3.1 (M)	0.0	3.1 (M)	4.5
G&N Interconnection Assy	90.8 (M)	0.0	90.8 (M)	100.0
Optical Shroud				
G&N to S/C Interface Assy				} ---
AGC (with 6 rope modules)	13.1 (E)	-0.4	12.7 (M)	
Optical Eyepiece Storage Assy				
Condition Annunciators				} 5.0
SXT Normal Relief Eyepiece	2.6 (M)	0.0	2.6 (M)	
SCT Normal Relief Eyepiece	1.8 (M)	0.0	1.8 (M)	
SCT Long Relief Eyepiece				} 4.0
D&C Electronics Assy				
Control Electronics Assy				

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

Command Module G&N Equipment	Status 6/66	Change	Status 7/66	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	24.5 (M)	0.0	24.5 (M)	26.0
MAIN PANEL AREA				
DSKY	25.3 (M)	0.0	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	438.7	+5.6	444.3	---
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.

This design load weight taken from IRN 3677, submitted by MIT in Letter AG 407-66 dated 9 May 1966.

Acceptance Data Package No. 91-3 reported weights for the Block I Quick Disconnect Eyepiece consigned to Space OUA that substantiated the validity of the above weights.

II. The Optical Subsystem weight estimate has been increased six (6) pounds to fifty-three and six-tenths (53.6) pounds due to the addition of ablative material to the Sextant and Telescope heads caused by the removal of the astro-sextant door.

Reported Weight Changes

Block II CM GN&C

I. Optical Eyepiece Storage Assembly

The Kollsman Instrument Corporation Acceptance Data Package No. 91-2 Block II Quick Disconnect Eyepieces consigned to Qualification testing reported the following measured weights:

<u>Hardware</u>	<u>Old weight</u>	<u>New Weight</u>	<u>Net Change</u>
1. SXT Mirror Housing Assy in- cluding heater and insulation	1 lb 2 oz	1 lb 2 oz	
2. SXT Eyepiece Assy	<u>11oz</u>	<u>11oz</u>	
	1 lb 13 oz	1 lb 13 oz	
3. SCT Prism Housing Assy	1 lb 2 oz	1 lb 2 oz	
4. SCT Eyepiece Assy in- cluding heater insulation and adjustable focus	<u>1 lb 14 oz</u>	<u>1 lb 13 oz</u>	<u>-1 oz</u>
	3 lb	2 lb 15 oz	-1 oz
5. SCT LER Eyepiece Assy in- cluding heater and insulation	1 lb 5oz	1 lb 7 oz	<u>+2 oz</u>
			+1 oz

II. The Optical Subsystem weight estimate has been increased six (6) pounds to fifty-three and six-tenths (53.6) pounds due to the addition of ablative material to the Sextant and Telescope heads caused by the removal of the astro-sextant door.

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

Command Module GN&C Equipment	Status 6/66	Change	Status 7/66	Design Load * Weight
LOWER EQUIPMENT BAY				
CDU Assy	36.2 (E)	0.0	36.2 (E)	50.0
Optical Subsystem				150.0
SXT and gearing	47.6 (M)	+6.0	53.6 (E)	
SCT and gearing				
Optical Base and gearing				
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)	1.2 (M)	0.0	1.2 (M)	
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)	-6.0	24.0 (M)	40.0
AGC (with six(6) rope modules + mag. trays)	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				15.0
SXT Normal Relief Eyepiece	11.1 (E)	0.0	11.1 (E)	
SCT Normal Relief Eyepiece				
SCT Long Relief Eyepiece				
G&N Indicator Control Panel	11.5 (M)	0.0	11.5 (M)	17.0
DSKY	17.5 (E)	0.0	17.5 (M)	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 IG) (CONT)

Command Module GN&C Equipment	Status 6/66	Change	Status 7/66	Design Load Weight*
MAIN PANEL AREA				
DSKY	17.5 (E)	0.0	17.5 (M)	25.0
LOOSE STORED ITEMS				
Horizontal Hand Holds (Two)	0.3 (M)	0.0	0.3 (M)	1.0
SXT Long Relief Eyepiece	0.4 (E)	0.0	0.4 (E)	---
TOTAL	377.9	+0.0	377.9	---
The reported total weight for this month is 22.1 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.

Weight Trend Information

- I. MIT/IL is studying the effect of providing integral means for covering the Optical Subsystem to protect the internal mechanism and glass surfaces from radiation, solar flare and foreign matter.

- II. Preliminary information from the computer sub-contractor concerning the weight of the CMC indicates an increase of several pounds is expected for this subsystem. This will be covered more fully in following reports.

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

LEM PGNCS Equipment	Status 6/66	Change	Status 7/66	Design Load * Weight
IMU	42.4 (M)	0.0	42.4 (M)	80.0
AOT (including eyepiece and bellows)	23.1 (E)	0.0	23.1 (E)	
NVB	4.0 (E)	0.0	4.0 (E)	21.0
HARNES "B" Supported by the NVB	0.6 (E)	0.0	0.6 (E)	
HARNES "B" Supported by the PTA	0.8 (E)	0.0	0.8 (E)	22.0
HARNES "B" Supported by the structure	3.1 (E)	0.0	3.1 (E)	
PTA	14.3 (M)	0.0	14.3 (M)	65.0
HARNES "A"	14.6 (E)	0.0	14.6 (E)	
LGC (with six(6) rope modules + mag trays)	65.0 (E)	0.0	65.0 (E)	20.0
DSKY	17.5 (E)	0.0	17.5 (M)	
AOT Control Unit (CCRD)	1.6 (M)	0.0	1.6 (M)	37.0
CDU	37.0 (M)	0.0	37.0 (M)	
PSA	17.6 (E)	0.0	17.6 (E)	28.2
SCA (Operational Flights)	7.2 (E)**	0.0	7.2 (E)	
TOTAL	248.8	0.0	248.8	---
The reported total weight for this month exceeds the 240.0 pounds total control weight by 8.8 lbs.†				
Bare Guidance Systems - IMU, LGC, IMU portions of the CDUs and IMU support electronics			158.8	

* Design Load Weights are taken from ICD LIS-490-10001 as signed by Mr. R.A. Gardner (NASA/ MSC) on 29 March 1966.

** 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.

Weight Trend Information

I. Preliminary information from the computer subcontractor concerning the weight of the LGC indicate an increase of several pounds is expected for this sybssystem. This will be discussed more fully in following reports.

II. Preliminary information from AC Electronics concerning the NavBase indicates an increase of a fraction of a pound is expected. This also will be discussed more fully in future reports.

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.

MIT Letter AG 261-66 dated 23 March 1966, proposed that NAA provide storage for the SXT Long Relief Eyepiece in the Block II Command Module.

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

TABLE 5. LUNAR EXCURSION MODULE PGNC MASS PROPERTY DATA

LEM GN&C EQUIPMENT	Center of Gravity - Inches			Moment of Inertia - Slug-ft ²			
	\bar{x}	\bar{y}	\bar{z}	I_x	I_y	I_z	\pm Error
IMU	307.0	0	49.9	22.90	886.76	863.97	1%
Navigation Base	309.0	0	54.4	2.57	3.39	0.86	1%
AOT							
AOT Control Unit (CCRD)							
PTA							
Harness "B"							
DSKY	254.0	0	58.6	12.98	256.47	243.50	1%
LGC	266.0	0	-22.9	8.24	1034.57	1027.81	1%
CDU	252.2	0	-22.8	4.69	553.63	549.28	2%
PSA (not integral unit)	240.0	0	-22.8	3.04	308.63	305.88	5%
Signal Conditioner Assy							
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.

COMMAND MODULE BLOCK I, Series 100

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.

The SXT and SCT weights reported above include estimates of covers with ablative material.

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.

COMMAND MODULE BLOCK II

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) two hose connectors, and (3) 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 Mastr 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.

The SXT and SCT weights reported above include estimates of covers with ablative material.

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.

SXT Long Relief Eyepiece

A SXT eyepiece to provide eye relief of at least 1.6 inches for closed visor operation. Used in place of SXT normal eyepiece. The present MIT proposal suggests that this eyepiece be stored in a bay with other loose stored items.

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.

LUNAR EXCURSION MODULE

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 reticle. 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.

AOT Control Unit (Computer Control and Reticle Dimmer)

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.

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)

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

RELIABILITY ANALYSIS AND ASSESSMENT

The current status of reliability analysis is reported in summary form as a chart.

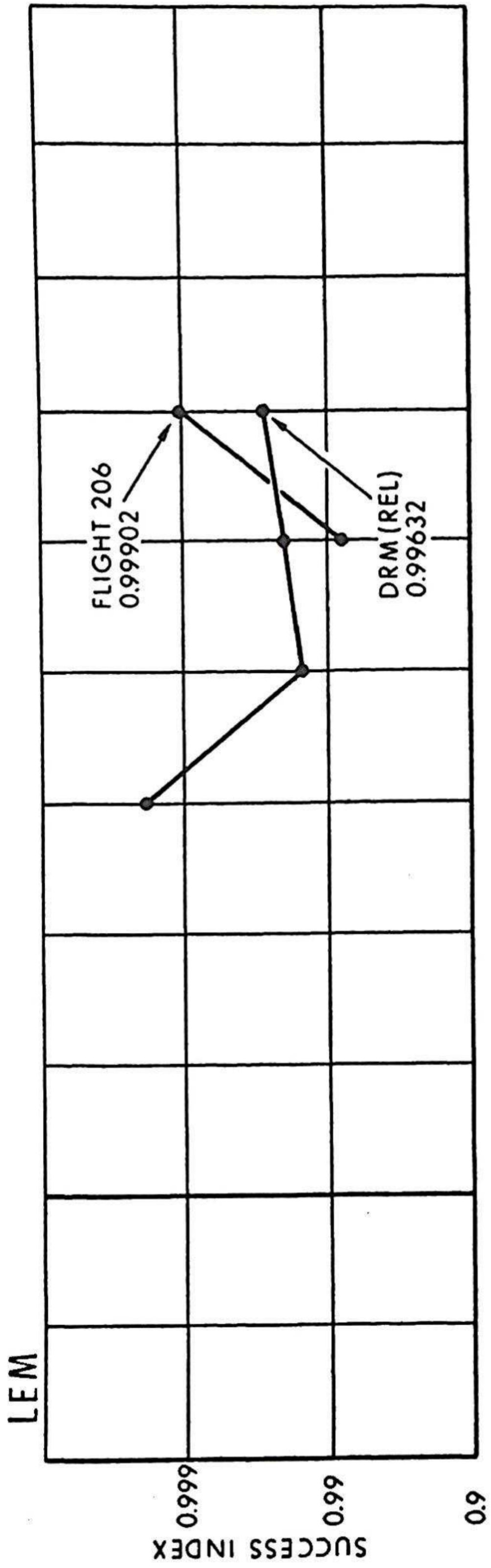
This chart contains tabulations of the failure rates associated with each major configuration of G&N systems. These have been derived from the parts count of each assembly using generic type part failure rates, modified only by the stress applied to each part and its singular application in the system. From these data, estimates of mission success probabilities have been calculated. Continual updating is accomplished and will be reported monthly in this report.

Reliability assessment for G&N Systems is presented graphically. These calculations are made in accordance with the MSC program for Success Index and are based on actual operating experience gained on G&N Systems in the field.

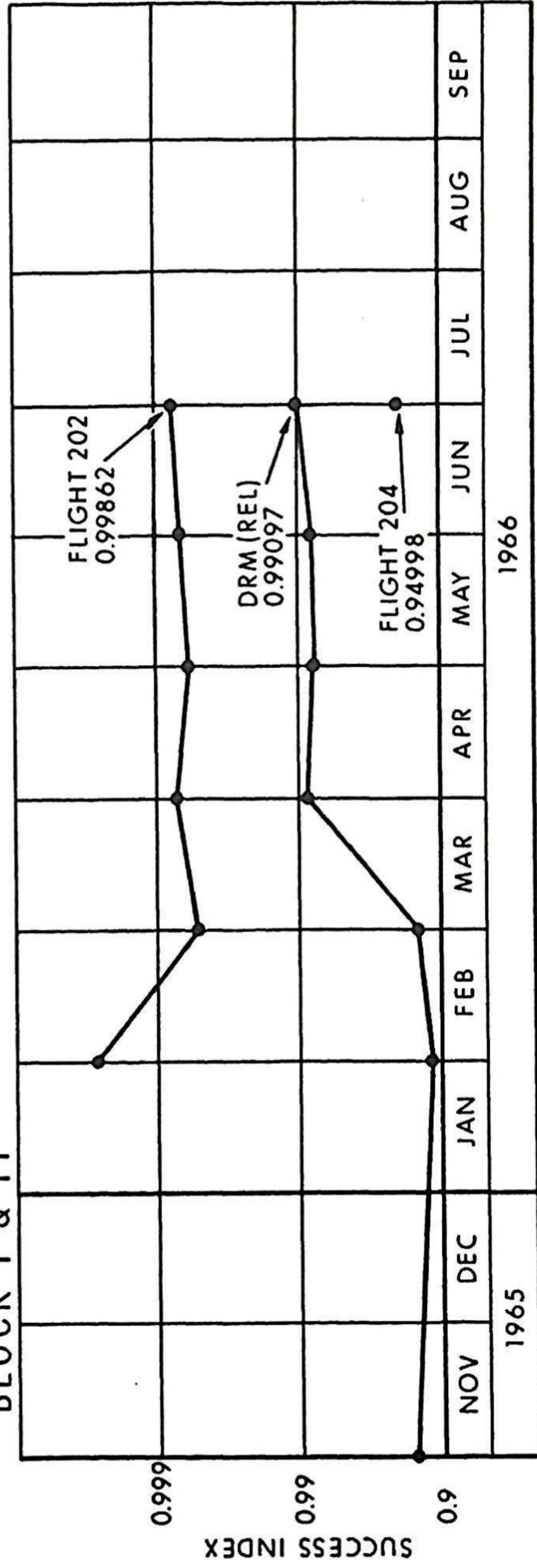
G&N MISSION RELIABILITY ANALYSIS
FAILURE RATES EXPRESSED IN "FAILURES PER 10⁶ HOURS"

MISSION	IMU Assembly		IMU Electronics (PSA)		Optics Assembly		Optics Electronics (PSA)		IMU CDU		Optics CDU		AGC		DSKY		D&C		Mission Reliability
	ON	STBY	ON	STBY	ON	OFF	ON	OFF	ON	STBY	ON	OFF	ON	STBY	ON	OFF	ON	OFF	
AGE #17 202 UNMANNED	Opr Hrs λ	1.57 -	1.57 -	224 -	- -	- -	- -	- -	1.57 -	1.57 -	- -	- -	1.57 -	257 -	1.57 -	12 -	1.57 -	6 -	.9988
AGE #12 FLIGHT 204 MANNED	Opr Hrs λ	49 185 10.2	266 224 6.3 94	266 224 6.3 94	13 84	302 -	13 84	302 -	49 111	266 -	13 68	302 -	50 257 66.8	265 3.2	50 26	265 -	49 -	266 -	.9580
AGE 601 206 UNMANNED LEM	Opr Hrs λ	9.6 129	9.6 110	- -	- -	- -	- -	- -	9.6 155	9.6 -	- -	- -	9.6 235	9.6 12	9.6 -	9.6 -	- -	- -	.9938
C/M	Opr Hrs λ	13.8 129 10.2	55.6 110 6.3 94	9.1 110 6.3 94	60.3 77	9.1 77	60.3 -	60.3 -	13.8 155	55.6 -	13.8 91	55.6 -	13.8 235 60.5	55.6 2.3	13.8 22	55.6 -	13.8 -	55.6 -	.9840
LEM	Opr Hrs λ	3.25 129 1.6	66.3 110	3.25 38	3.25 -	3.25 -	3.25 -	3.25 -	3.25 155	66.3 -	3.25 112	66.3 -	3.25 235	66.3 -	3.25 110	66.3 -	3.25 -	66.3 -	.9969

SUCCESS INDEX GROWTH



BLOCK I & II



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.

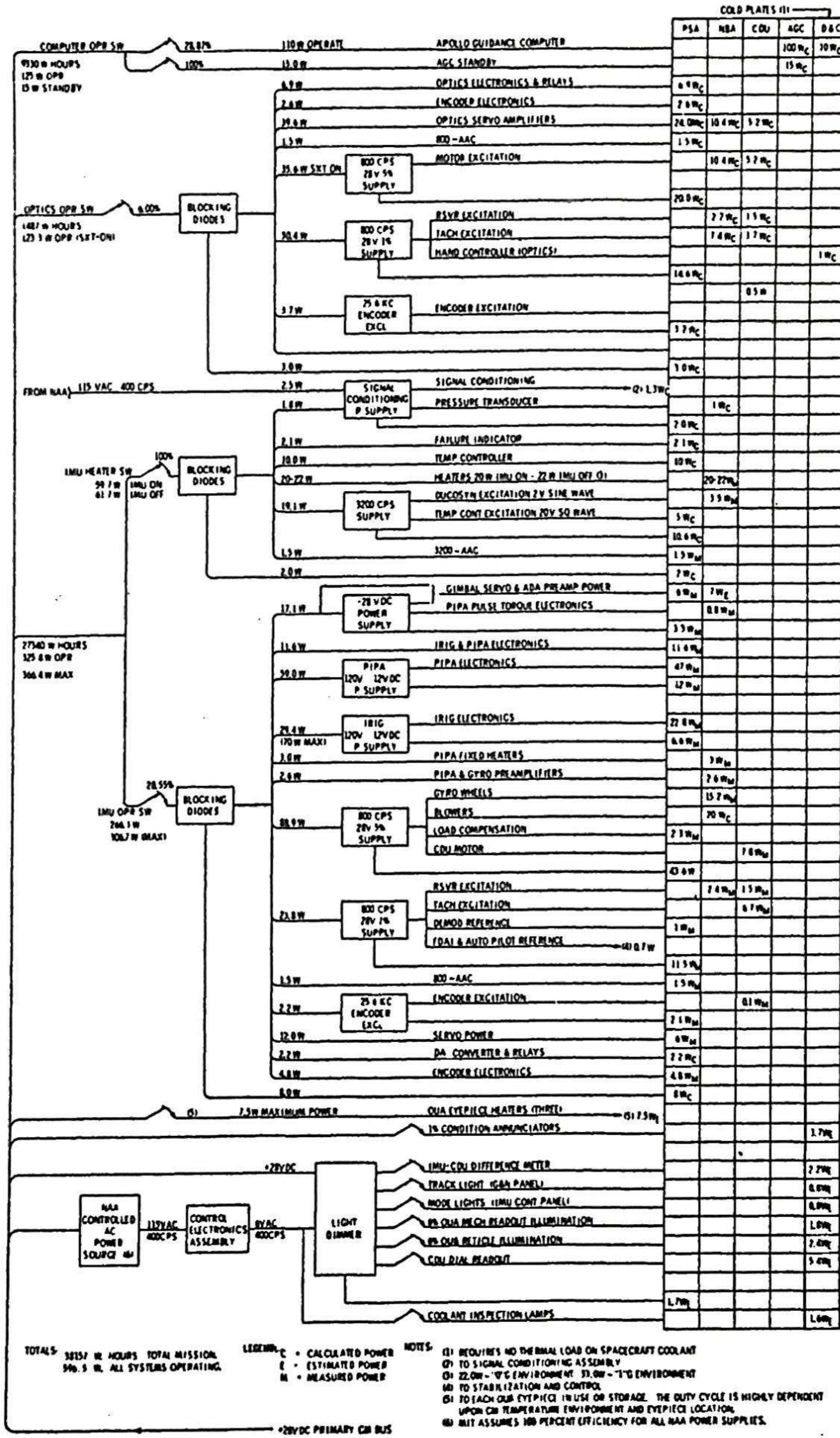
Interface Control Documents serve as the guidelines for reporting power figures.

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 196.5 HOUR (8.77 DAY) LUNAR MISSION
DESIGN REFERENCE MISSION

REFERENCE GAC REPORT LEO 540-12 30 OCTOBER 1964
APOLLO MISSION PLANNING TASK FORCE



TOTALS: 38157 W HOURS TOTAL MISSION
596.5 W ALL SYSTEMS OPERATING.

LEGEND: C - CALCULATED POWER
E - ESTIMATED POWER
M - MEASURED POWER

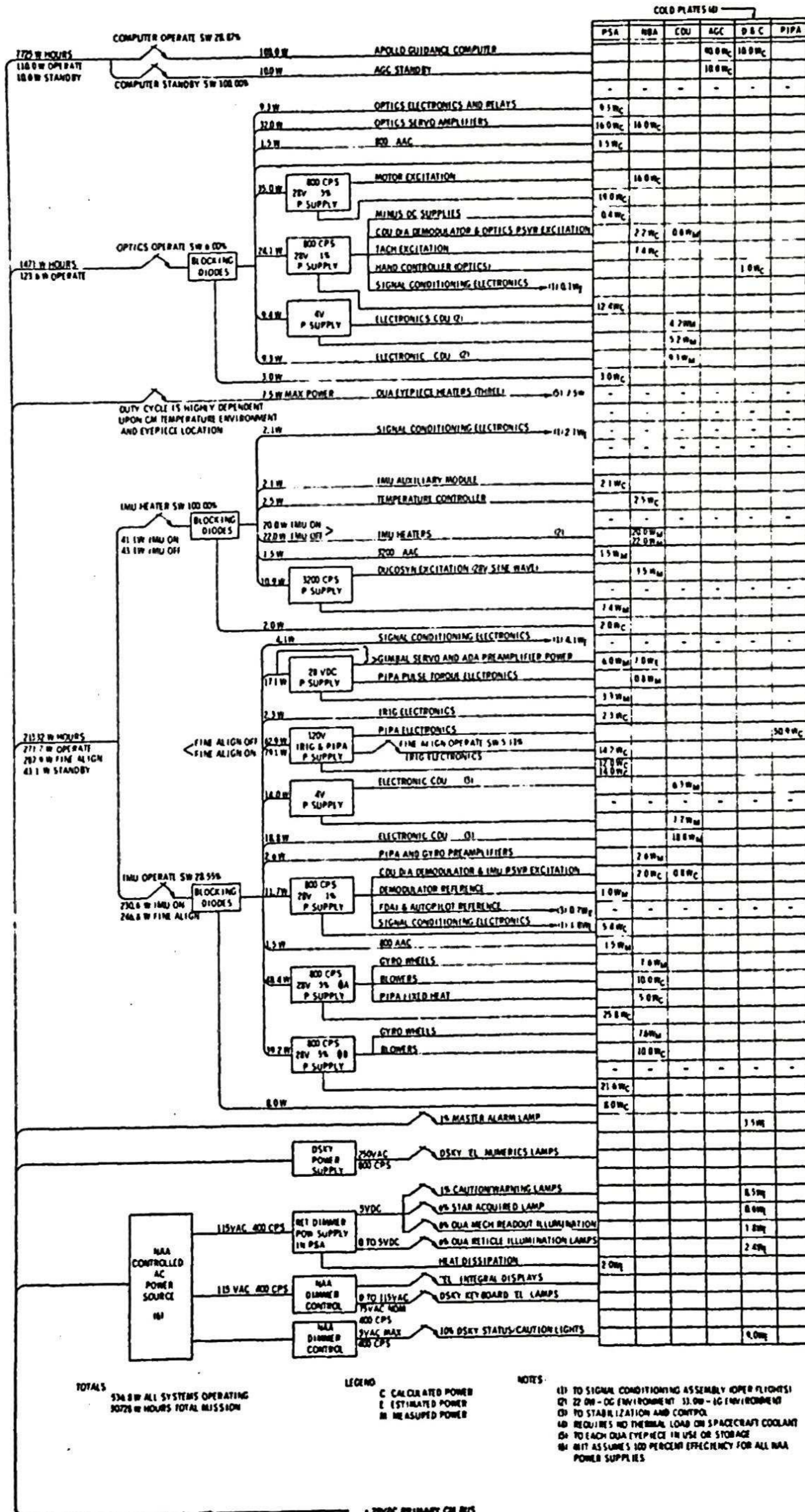
NOTES: (1) REQUIRES NO THERMAL LOAD ON SPACECRAFT COOLANT
(2) TO SIGNAL CONDITIONING ASSEMBLY
(3) 22.0W - 0°C ENVIRONMENT 33.0W - 1°C ENVIRONMENT
(4) TO STABILIZATION AND CONTROL
(5) TO EACH CON EYEPIECE IN USE OR STORAGE. THE DUTY CYCLE IS HIGHLY DEPENDENT UPON CON TEMPERATURE ENVIRONMENT AND EYEPIECE LOCATION
(6) MIT ASSUMES 100 PERCENT EFFICIENCY FOR ALL NAA POWER SUPPLIES.

+28VDC PRIMARY CON BUS

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

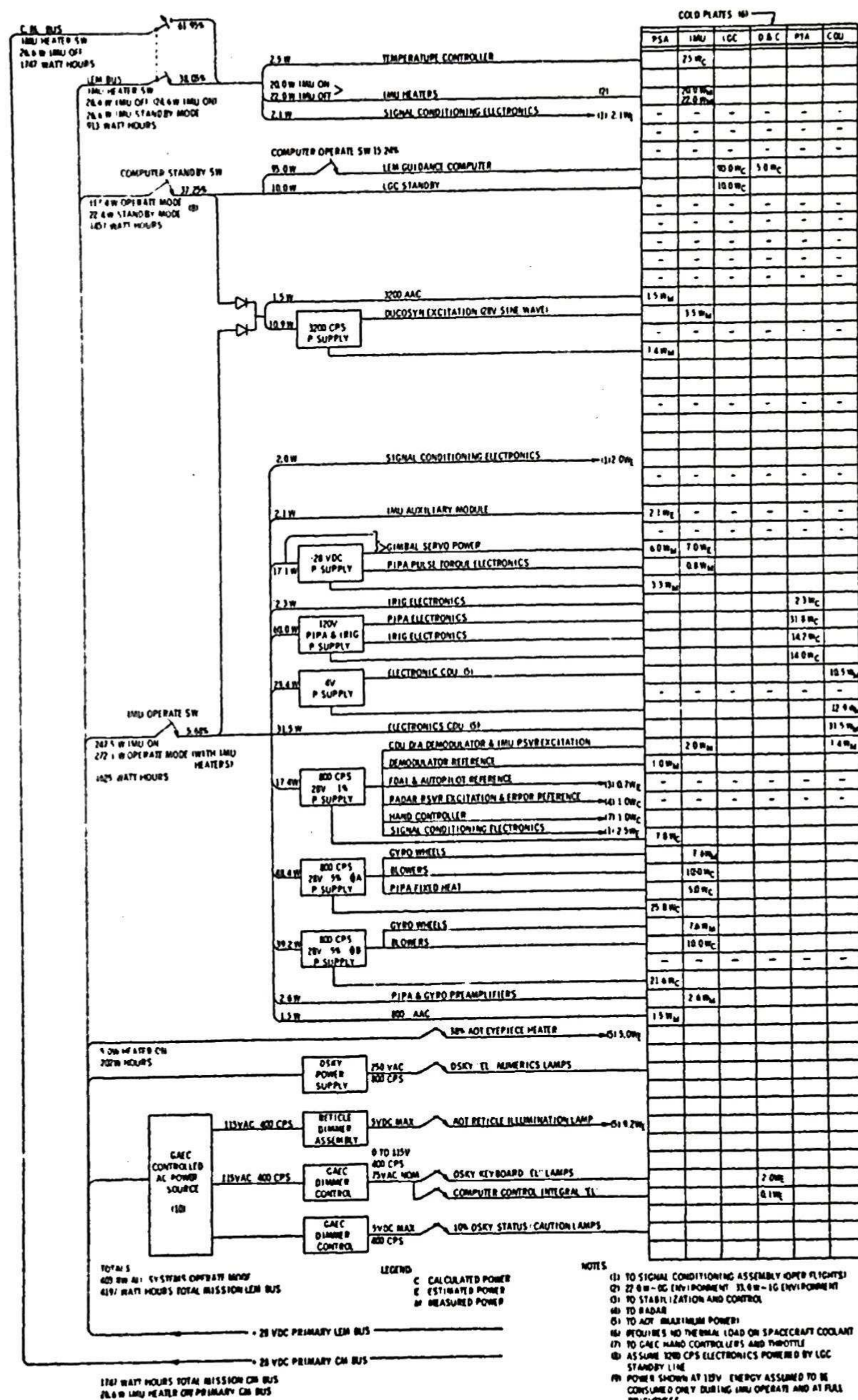
BASED UPON 198.5 HOUR 16.27 DAY LUNAR ORBIT MISSION
DESIGN REFERENCE MISSION

REFERENCE GAC REPORT LEO 540-12 30 OCTOBER 1964
APOLLO MISSION PLANNING TASK FORCE



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

BASED UPON 106.07 HOURS 14.42 DAY LUNAR LANDING MISSION REFERENCE GAEC REPORT - LEO 540-12, 30 OCTOBER 1964
DESIGN REFERENCE MISSION APOLLO MISSION PLANNING TASK FORCE



SECTION 6

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.

FIXED MEMORY ALLOCATION FOR BLOCK I CMC
CORONA FLIGHT AS-202

Interrupt Transfer Routines	39
Fixed-Fixed Interpreter Section	941
Bank 03 Interpreter Section	822
Executive	339
Waitlist	221
Restart Control	116
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	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
Mission Control Program	2015
Powered Flight Subroutines	1867
Dummy 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

FIXED MEMORY ALLOCATION FOR BLOCK I CMC
CORONA FLIGHT AS-501 AND AS-502

Executive	336
Waitlist	219
Restart Control	114
Fresh Start Restart	302
Keyrupt	97
Mission Control	183
Interrupt Transfer Routine	38
Down Telemetry	228
T4 Rupt	301
Mode Switching and Mark	593
AGC Self Check	988
Alarm and Display	57
Pinball	2263
501 Mission Control	1964
Prelaunch Alignment	896
Fixed-Fixed Interpreter	941
Interbank Communication	73
Inflight Alignment Program	234
Inflight Alignment Subroutines	408
Time of Free Fall Calculations	272
Bank 03 Interpreter	821
Orbital Integration for 501	1002
IRIG Pulse Torquing Routine	286
RTB OP Codes	342
Re-Entry	1360
Average G Integrator	184
Extended Verbs	706
Powered Flight Subroutine	1839
IMU Compensation Package	98
IMU Performance Tests 1	1008
IMU Performance Tests 2	1016
Restart Tables and Routines	471
Verification Assistance Program	98
Dummy 202 Initialization	30
Sum Check End of Record Marks	48
TOTAL FIXED MEMORY WORDS	19,816

FIXED MEMORY ALLOCATION FOR BLOCK I CMC
SUNSPOT FLIGHT AS-204 AND AS-205

Interrupt Transfer Routines	38
Fixed-Fixed Constant Pool	54
Fixed-Fixed Interpreter Section	1024
Bank 03 Interpreter Section	821
Star Catalog	184
Executive	493
Waitlist	63
Restart Control	236
Restart Tables and Routines	366
Fresh Start and Restart	321
Down Telemetry Program	548
T4 Rupt Output Control Programs	797
Mode Switching and Mark Routines	595
IMU Compensation Package	215
IRIG Pulse Torquing Routines	286
Extended Verbs for Moding	664
AGC Self Check	802
Inter-bank Communication	73
Alarm and Display Procedures	61
Orbital Integration Program	819
Midcourse Navigation Game	941
Latitude-Longitude Subroutines	433
Target Routine	369
Verb 64	18
Deorbit Target Subroutines	272
Measurement Incorporation	188
B Vector Routine	229
Program 22 Start	12
Program 23	39
Prelaunch Alignment Program	823
RTB OP Codes	394
IMU Performance Tests 1	1000
IMU Performance Tests 2	1008
Inflight Alignment Subroutines	328
204 Alignment Routines	892
Star Selection Routine	254
Keyrupt, Uprupt, Fresh Start	91
Pinball Game Buttons and Lights	2547
204 Service Routines	153
Coordinate Transforms and Geometry	254
Attitude Maneuver Routine	1174
204 Mission Control Program	2874
Automatic Optics Positioning Routine	245
Re-Entry Control	1112
Sum Check End of Record Marks	48
TOTAL FIXED MEMORY WORDS	 24, 156

FIXED MEMORY ALLOCATION FOR BLOCK II CMC

SUNDIAL FLIGHT AS-278

Pinball, including Lunar Mission Requirements	2500
Interrupt Lead-in	50
Inter-bank Communication	50
Interpreter	2000
S. P. Subroutines	80
Executive	400
Waitlist	170
Phase Tables	300
Fresh Start and Restart	400
T4 Rupt	130
IMU Mode Switching	500
OSS Mode Switching	260
Extended Verbs	500
Keyrupt and Urupt	80
Alarm, Abort, and Down T/M	210
Self Check	824
Inflight IMU Alignment Routines	500
RTB, Op Codes	480
TVC DAP	1900
RCS DAP	2000
Calc T_{ff}	300
Earth Rotation	25
Determine LEM Initialization Data	300
Orbit Integration (conic and Encke)	800
Midcourse Navigation Game	1190
LAT/LONG Routines	390
Navigation Measurement Incorporation	110
B Vector Routines	210
Star Catalogue	336
Servicer	500
IMU Compensation	200
Attitude Maneuver Routine	250
Store Co-variance Matrices, diagonal	90
Star Selection Routine	260
Rendezvous Navigation and Intercept Trajectory	500
Computation of Special Orbit Parameters for Display	500
Four Downlink Lists	340
Verb 37 Table	100
Pre-Launch (includes IMU Performance Tests)	1200
Start Up and Power Down	50
CMC Update	130
Boost Monitor	200
Saturn Take-over for EOI	2000
SXT Rendezvous Tracking	100
Preferred Attitude	500
Landmark Tracking	100
Star-Landmark Measurements	300
IMU Alignment	750
Pre-Thrust Orbit Change	200

SUNDIAL FLIGHT AS-278 (Continued)

Pre-Thrust, Direct Intercept	150
Pre-Thrust, MCC	150
Pre-Thrust, Term Rendezvous	150
SPS Thrust Programs	375
RCS Thrust Programs	375
Common Thrust Programs	500
External Delta V	400
Entry	2500
LET Abort	20
First Abort Burn	25
Pad	5400

TOTAL FIXED MEMORY WORDS	34,610
--------------------------	--------

FIXED MEMORY ALLOCATION FOR BLOCK II CMC

SUNDIAL FLIGHT AS-503 AND AS-504

Pinball, including Lunar Mission Requirements	2500
Interrupt Lead-in	50
Inter-bank Communication	50
Interpreter	2000
S. P. Subroutines	80
Executive	400
Waitlist	170
Phase Tables	300
Fresh Start and Restart	400
T 4 Rupt	130
IMU Mode Switching	500
OSS Mode Switching	260
Extended Verbs	500
Keyrupt and Uprupt	80
Alarm, Abort, and Down T/M	210
Self Check	976
Inflight IMU Align Routines	500
RTB, Op Codes	480
IMU Performances tests	200
TVC DAP	1900
RCS DAP	2000
Calc T_{ff}	300
Earth Rotation	25
Determine LEM Initialization Dates	300
Determine LEM Azimuth Alignment (backup)	50
Lunar Inertial Orientation	100
Lunar Ephemeris	200
Orbit Integration (Conic and Encke) including lunar Triaxiality	1000
Midcourse Navigation Game	1190
LAT/LONG Routines	390
Navigation Measurement Incorporation	110
B Vector Routines	210
Star Catalogue	336
Lunar Landmarks	168
Servicer	500
IMU Compensation	200
Attitude Maneuver Routine	250
Store 5 Co-variance Matrices, diagonal	90
Star Selection Routine	260
Rendezvous Navigation and Intercept Trajectory	500
Computation of Special Orbit Parameters for Display	500
Four Downlink Lists	340
Verb 37 Table	100
Pre-Launch	1000
Start Up and Power Down	50
CMC Update	130
Boost Monitor	300
Translunar Injection using cross product steering	300

SUNDIAL FLIGHT AS-503 AND AS-504 (Continued)

SXT Rendezvous Tracking	100
Preferred Attitude	500
Landmark Tracking	100
Star-Landmark Measurements	300
IMU Alignment	750
Pre-Thrust, Sphere of Influence	200
Pre-Thrust Orbit Change	200
Pre-Thrust, Return to earth	3900
Pre-Thrust, Direct Intercept	150
Pre-Thrust, MCC	150
Pre-Thrust, Term Rendezvous	150
SPS Thrust Programs	500
RCS Thrust Programs	500
Common Thrust Programs	500
External Delta-V	400
Entry	2500
LET Abort	20
First Abort Burn	25
TOTAL FIXED MEMORY WORDS	33,530

FIXED MEMORY ALLOCATION FOR BLOCK II LGC
AURORA FLIGHT AS-206

Pinball plus lunar mission requirements	2500
Interrupt Lead-in	50
Inter-bank Communication	50
Interpreter	2000
S. P. Subroutines	80
Executive	400
Waitlist	170
Phase Tables	300
Fresh Start and Restart	400
T4 Rupt	130
IMU Mode Switching	500
AOT Mark (NO LORS)	300
Extended Verbs	500
Keyrupt and Urupt	80
Alarm, Abort, and Down T/M	210
Self Check	824
RTB, Op Codes	480
Radar Lead-in Routines	750
LEM DAP	3000
LORS Interface	1750
 Mission Programming Estimated	 8000
 TOTAL FIXED MEMORY WORDS	 22,474 ESTIMATED

FIXED MEMORY ALLOCATION FOR BLOCK II LGC
AURORA FLIGHT AS-278

Pinball plus lunar mission requirements	2500
Interrupt Lead-in	50
Inter-bank Communication	50
Interpreter	2000
S. P. Subroutines	80
Executive	400
Waitlist	170
Phase Tables	300
Fresh Start and Restart	400
T4 Rupt	130
IMU Mode Switching	500
AOT Mark	300
Extended Verbs	500
Keyrupt and Uprupt	80
Alarm, Abort, and Down T/M	210
Self Check	824
RTB, Op Codes	480
IMU Performance Tests	2500
Radar Lead-in Routines	750
LEM DAP	3000
Inflight IMU Align Routines	500
Orbit Integration (Conic and Encke) and Triaxiality	950
Star Catalog	336
Servicer	500
IMU Compensation	200
Attitude Maneuver Routine	250
Store 3 Co-Variance Matrices	54
Star Selection Routine	260
LGC Clock Synchronization	50
LGC Initialization	100
Search Pattern	50
DPS Gimbal Test and Positioning	50
Five Down-Link Lists	430
CFP Targeting and Timing	2000
Rendezvous Navigation and Intercept Trajectory	3000
Verb 37 Table	100
Start Up and Power Down	50
LGC Update	130
RRDR Rendezvous Tracking	100
Preferred Attitude	500
Inflight IMU Alignment Modes	400
Pre-Thrust, External Delta V	400
Pre-Thrust, CSI	150
Pre-Thrust, CDH	150

AURORA FLIGHT AS-278 (Continued)

Pre-Thrust Direct Intercept	150
Pre-Thrust, MCC	150
Pre-Thrust, Term Rendezvous	150
Common Thrust Programs	1500
APS Common Thrust Programs	125
RCS Common Thrust Programs	125
DPS Common Thrust Programs	125
Pad	5400
TOTAL FIXED MEMORY WORDS	33,659

FIXED MEMORY ALLOCATION FOR BLOCK II LGC
AURORA FLIGHT AS-503 AND AS-504

Pinball plus lunar mission requirements	2500
Interrupt Lead-in	50
Inter-bank Communication	50
Interpreter	2000
S. P. Subroutines	80
Executive	400
Waitlist	170
Phase Tables	300
Fresh Start and Restart	400
T4 Rupt	130
IMU Mode switching	500
AOT Mark (NO LORS)	300
Extended Verbs	500
Keyrupt and Uprupt	80
Alarm, Abort, and Down T/M	210
Self Check	824
RTB, Op Codes	480
Radar Lead-in Routines	750
LEM DAP	3000
LORS Interface	1750
Inflight IMU Align Routines	500
Lunar Inertial Orientation	100
Orbit Integration (Conic and Encke) and Triaxiality	950
Star Catalog	336
Servicer	500
IMU Compensation	200
Attitude Maneuver Routine, Calculate	250
Attitude Maneuver	250
Store 3 Co-Variance Matrices, Midcourse	54
Naviagation Game	54
Star Selection Routine	260
LGC Clock Synchronization	50
LGC Initialization	100
Search Pattern	50
DPS Gimbal Test and Positioning	50
Four Down-Link Lists	350
Direct Ascent Targetting and Timing	400
CFP Targetting and Timing	2000
Rendezvous Navigation and Intercept Trajectory	3000
Verb 37 Table	100
Landing Initialization and Targetting	300
Direct Ascent Targetting and Timing	100
CFP Ascent Targetting and Timing	100
Start Up and Power Down	50
LGC Update	130
Pre DO I	100
DO I	600
Pre-Powered Descent	450
Powered Landing	2500
Manual Landing	50

AURORA FLIGHT AS-503 AND AS-504 (Continued)

RRDR Rendezvous Tracking	100
Preferred Attitude	500
Eight IMU Alignment Modes	750
Pre-Thrust, External Delta V	400
Pre-Thrust, CFP Powered Ascent	200
Pre-Thrust, CSI	150
Pre-Thrust, CDH	150
Pre-Thrust, Direct Intercept	150
Pre-Thrust, MCC	150
Pre-Thrust, Term Rendezvous	150
Common Thrust Programs	1500
APS Common Thrust Programs	125
RCS Common Thrust Programs	125
DPS Common Thrust Programs	125
Landing Abort, CFP Profile, DPS	125
Landing Abort, CFP Profile, APS	125
TOTAL FIXED MEMORY WORDS	32,930

E-1142 (Rev. 46)

DISTRIBUTION LIST

Internal

M. Adams (MIT/GAEC)
R. Battin
P. Bowditch/F. Siraco
N. Cluett
J. Dahlen
J. DeLisle
E. Duggan
J.B. Feldman
S. Felix
J. Flanders (MIT/KSC)
Eldon Hall
T. Hemker (MIT/NAA)
E. Hickey
D. Hoag
F. Houston
L.B. Johnson
A. Koso
M. Kramer
L. Larson
J. Lawrence (MIT/GAEC)
T.J. Lawton

T. M. Lawton (MIT/MSC)
G. Mayo
John Miller
J. Nelson (2)
J. Nevins
J. Nugent
E. Olsson
R. Ragan
E. Schwarm
J. Sciegienny
N. Sears
W. Shotwell (MIT/AC)
W. Stameris
M. Trageser
P. Watson
R. Weatherbee
L. Wilk (2)
R. Woodbury
Apollo Library (5)
MIT/IL Library (8)

NAA RASPO: (1)

NASA Resident Apollo Spacecraft Program Office
North American Aviation, Inc.
Space and Information Systems Division
Downey, California 90241

ACSP RASPO: (1)

National Aeronautics and Space Administration
Resident Apollo Spacecraft Program Officer
Dept. 32-31
AC Electronics Division of General Motors
Milwaukee 1, Wisconsin
Attn; Mr. W. Swingle

Mr. H. Peterson (1)
Bureau of Naval Weapons
c/o Raytheon Company
Foundry Avenue
Waltham, Massachusetts

Mr. S. Schwartz (1)
Department of Defense
DCASD, Garden City
605 Stewart Avenue,
Garden City, L.I., N.Y.
Attn: Quality Assurance

D. F. Kohls (1)
AFPRO (CMRKKK)
AC Electronics Division of General Motors
Milwaukee 1, Wisconsin 53201

DISTRIBUTION LIST

External:

W. Rhine (NASA/MSC)	(2)
NASA/RASPO	(1)
T. Heuermann (GAEC/MIT)	(1)
AC Electronics	(10)
Kollsman	(10)
Raytheon	(10)
Major H. Wheeler (AFSC/MIT)	(1)
MSC:	(30 + 1R)
National Aeronautics and Space Administration Manned Spacecraft Center Apollo Document Distribution Office (PA2) Houston, Texas 77058	
KSC:	(1R)
NASA J. F. Kennedy Space Center Technical Document Control Office, HB-23 Cape Kennedy, Florida	
GAEC:	(3 + 1R)
Grumman Aircraft Engineering Corporation Data Operations and Services, Plant 25 Bethpage, Long Island, New York Attn: Mr. E. Stern	
NAA:	(18 + 1R)
North American Aviation, Inc. Space and Information Systems Division 12214 Lakewood Boulevard Downey, California Attn: Apollo Data Requirements AE99 Dept. 41-096-704 (Bldg 6)	