

# APOLLO

## GUIDANCE AND NAVIGATION

Approved: L. E. Larson Jr. Date: 30 Aug. 1967  
L. E. LARSON JR., MANAGEMENT DIRECTOR  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: David G. Hoag Date: 30 Aug 67  
DAVID G. HOAG, DIRECTOR  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: Ralph R. Ragan Date: 31 Aug 67  
RALPH R. RAGAN, DEPUTY DIRECTOR  
INSTRUMENTATION LABORATORY

E-1142  
(Rev. 52)

### SYSTEM STATUS REPORT

August 1967



# INSTRUMENTATION LABORATORY

CAMBRIDGE 39, MASSACHUSETTS

## ACKNOWLEDGEMENT

This report was prepared under DSR Project 55-23850, 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. 52)

## SYSTEM STATUS REPORT

### ABSTRACT

The System Status Report is normally distributed bimonthly. The areas of activity reported on in this month's revision include, but are not limited to, the following for the Block 1 100 Series and Block II Command Modules and Lunar Excursion Module equipment: configuration weight, weight trend information, reliability failure rates, electrical power requirements, computer programming status, and G&N Status.

by Apollo Staff  
August 1967

## TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
1	Configuration Weights	11
2	Glossary and System Definition	19
3	Reliability - Failure Rates	21
4	Electrical Power Requirements	23
5	Guidance and Navigation Systems Status	27
6	G&N System Test	33
7	G&N Computer Status	41
8	Guidance Computer Programming	45
9	List of "E" and "R" Notes Published During Reporting Period	61

## 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 Module equipment:

- Section 1 - Configuration Weights
- Section 2 - Glossary and System Definition
- Section 3 - Reliability - Failure Rates
- Section 4 - Electrical Power Requirements
- Section 5 - Guidance and Navigation Systems Status
- Section 6 - G&N System Test
- Section 7 - G&N Computer Status
- Section 8 - Guidance Computer Programming
- Section 9 - List of "E" and "R" Notes Published During Reporting Period

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

SECTION 1  
CONFIGURATION 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 LM 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 LM 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 and  
Weight Trend Information

Block II

1. A decrease of 2.2 lbs for the operational signal conditioner is due to the measured weights of the SCA.
2. A decrease of 1.0 lbs for the F. Q. signal conditioner is due to measured weights of the F. Q. SCA.



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

Command Module G&N Equipment	Status 4/67	Change	Status 6/67	Design Load Weight *
LOWER EQUIPMENT BAY				
CDU Assy	16.9 (M)	0.0	16.9 (M)	18.0 #
Optical Subsystem				}
SXT and gearing SCT and gearing Optical Base and gearing	54.6 (M)	+0.0	54.6 (M)	
NVB and Resilient Mounts	25.7 (M)	0.0	25.7 (M)	}
Bellows Assy	10.7 (M)	0.0	10.7 (M)	
IMU	61.2 (M)	0.0	61.2 (M)	}
Coolant Hoses (Three)	1.4 (M)	0.0	1.4 (M)	
Power Servo Assy	65.4 (M)	0.0	65.4 (M)	}
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	90.8 (M)	0.0	90.8 (M)	100.0
AGC (with 6 rope modules)				
Optical Eyepiece Storage Assy				}
Condition Annunciators	12.7 (M)	0.0	12.7 (M)	
SXT Normal Relief Eyepiece				
SCT Normal Relief Eyepiece				
SCT Long Relief Eyepiece				
D&C Electronics Assy	2.6 (M)	0.0	2.6 (M)	5.0
Control Electronics Assy	1.8 (M)	0.0	1.8 (M)	4.0

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

Command Module G&N Equipment	Status 4/67	Change	Status 6/67	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
<b>TOTAL</b>	<b>443.8</b>	<b>0.0</b>	<b>443.8</b>	<b>---</b>
The reported total weight for this month is 13.8 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.

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

Command Module GN&C Equipment	Status 4/67	Change	Status 6/67	Design Load Weight *
LOWER EQUIPMENT BAY				
CDU Assy	36.5 (M)	0.0	36.5 (M)	50.0
Optical Subsystem				} 150.0
SXT and gearing	55.7 (M)	0.0	55.7 (M)	
SCT and gearing	17.4 (M)	0.0	17.4 (M)	
Optical Base and gearing APPS and Dust Covers NVB and Mounts	10.7 (M)	0.0	10.7 (M)	
Bellows Assy	42.5 (M)	0.0	42.5 (M)	
IMU	1.2 (M)	0.0	1.2 (M)	
Coolant Hoses (Two)	49.4 (M)	0.0	49.4 (M)	58.0
Power Servo Assy	9.0 (M)	0.0	9.0 (M)	12.0
PIPA Electronics Assy	24.0 (M)	0.0	24.0 (M)	40.0
G&N Interconnect Harness Group	69.5 (E)	0.0	69.5 (E)	80.0
AGC (with six(6) rope modules + mag. trays)	3.1 (M)	0.0	3.1 (M)	4.5
Optical Shroud				
Optical Eyepiece Storage Assy				} 15.0
SXT Normal Relief Eyepiece	14.0 (M)	0.0	14.0 (M)	
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 (M)	0.0	17.5 (M)	25.0
Signal Conditioner Assy (Operational Flights)	8.0 (E)	-2.2	5.8 (M)**	8.0

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

Command Module GN&C Equipment	Status 4/67	Change	Status 6/67	Design Load * Weight
MAIN PANEL AREA				
DSKY	17.5 (M)	0.0	17.5 (M)	25.0
LOOSE STORED ITEMS				
Horizontal Hand Holds (Two)	0.3 (M)	0.0	0.3 (M)	1.0
TOTAL	387.8	-2.2	385.6	---
The reported total weight for this month is 14.4 pounds less than the 400.0 pound total control weight †				
Bare Guidance Systems - IMU, AGC, IMU portions of the CDUs and IMU support electronics				
			172.2	---

\* 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 8.6(M) 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.

DATE: June 1967

Reported Weight Changes and  
Weight Trend Information

LM

1. A decrease of 1.7 lbs for the operational signal conditioner assembly is due to the measured weight on the SCA.
2. A decrease of 1.4 lbs for the Flight Qual Signal conditioner assembly is due to the measured weight of the F.Q. SCA.

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

LM PGNCS Equipment	Status 4/67	Change	Status 6/67	Design Load Weight*
IMU	42.4 (M)	0.0	42.4 (M)	} 80.0
AOT (including eyepiece and bellows)	23.1 (M)	0.0	23.1 (M)	
NVB	5.1 (M)	0.0	5.1 (M)	
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)	
HARNES "B" Supported by the structure	3.1 (E)	0.0	3.1 (E)	
PTA	14.3 (M)	0.0	<del>14.3 (M)</del>	
HARNES "A"	14.6 (M)	0.0	14.6 (M)	
LGC (with six(6) rope modules + mag trays)	69.5 (M)	0.0	69.5 (M)	
DSKY	17.5 (M)	0.0	17.5 (M)	
AOT Control Unit (CCRD)	1.6 (M)	0.0	1.6 (M)	2.0
CDU	37.5 (M)	0.0	37.5 (M)	37.0
PSA	17.5 (M)	0.0	17.5 (M)	} 28.2
SCA (Operational Flights)	7.2 (E)**	-1.7	5.5 (M)	
<b>TOTAL</b>	254.8	-1.7	253.1	---
The reported total weight for this month exceeds the 245.0 pounds total control weight by 8.1 lbs. †				
Bare Guidance Systems - IMU, LGC, IMU portions of the CDUs and IMU support electronics			167.3	

\* 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 7.8 (M) pounds.

† The Total Control Weight is specified in Contract Technical Specification PS 600000 - amended by NASA Letter EG 26-233-66-565 dated 18 August 1966.

## SECTION 2

### GLOSSARY AND SYSTEM DEFINITION

The description of what constitutes the MIT Guidance and Navigation equipment in Block I (100 series), Block II Command Modules and Lunar Modules has been defined in previous System Status reports. This Section will be updated when any significant changes are made in the systems.

## SECTION 3

### RELIABILITY FAILURE RATES

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, estimations of mission success probabilities may be calculated. Continual updating is accomplished and will be reported monthly in this report.



G&N MISSION RELIABILITY ANALYSIS

FAILURE RATES EXPRESS IN "FAILURES PER 10<sup>6</sup> 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 122 FLIGHT 501 UNMANNED	8.63	-	8.63	-	-	-	-	-	8.63	-	-	-	8.63	-	8.63	-	8.63	-	.9931
	195	-	224	-	-	-	-	-	111	-	-	-	257	-	12	-	6	-	
AGE 123 FLIGHT 502 UNMANNED	8.3	-	8.3	-	-	-	-	-	8.3	-	-	-	8.3	-	8.3	-	8.3	-	.9933
	195	-	224	-	-	-	-	-	111	-	-	-	257	-	12	-	6	-	
C/M FLIGHT 503 MANNED	31.3	208	14.2	225	14.2	225	14.2	225	31.3	208	31.3	208	31.3	208	31.3	208	31.3	208	.9626
	129	10.2	110	6.3	94	-	77	-	155	-	91	-	235	60.5	2.3	-	2.3	-	
L/M FLIGHT 503 MANNED	8.4	120	8.4	-	8.4	-	8.4	-	8.4	-	8.4	-	8.4	-	8.4	-	8.4	-	.9923
	129	1.6	110	-	38	-	1.33	-	155	-	112	-	235	-	110	-	1.2	-	
AGE 603 FLIGHT 204* UNMANNED LM	9.6	-	9.0	-	-	-	-	-	9.6	-	-	-	9.6	-	9.6	-	-	-	.9938
	129	-	110	-	-	-	-	-	155	-	-	-	235	-	12	-	-	-	
C/M DES. REF.	13.8	55.6	13.8	55.6	9.1	60.3	9.1	60.3	13.8	55.6	13.8	55.6	13.8	55.6	13.8	55.6	13.8	55.6	.9840
	129	10.2	110	6.3	94	-	77	-	155	-	91	-	235	60.5	2.3	-	2.3	-	
LM DES. REF.	3.25	60.3	3.25	66.3	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	.9969
	129	1.6	110	-	38	-	1.33	-	155	-	112	-	235	-	110	-	1.2	-	

\* 20% RFD DESIGNATED 204 LM;

AUGUST 1967

## SECTION 4

### ELECTRICAL POWER REQUIREMENTS

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.

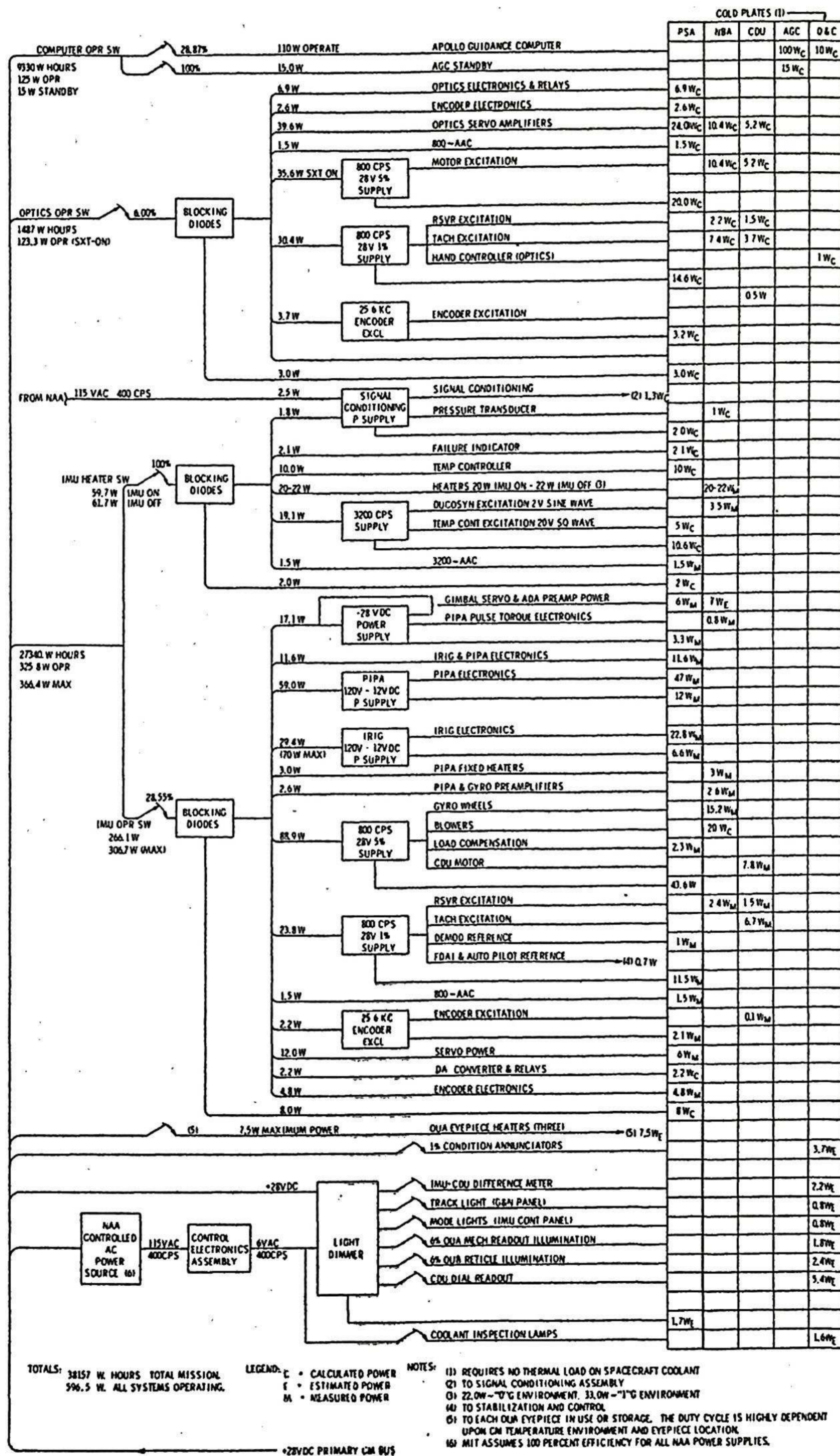
Interface Control Documents serve as the guidelines for reporting power figures.

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 198.5 HOUR (8.27 DAY) LUNAR MISSION  
DESIGN REFERENCE MISSION

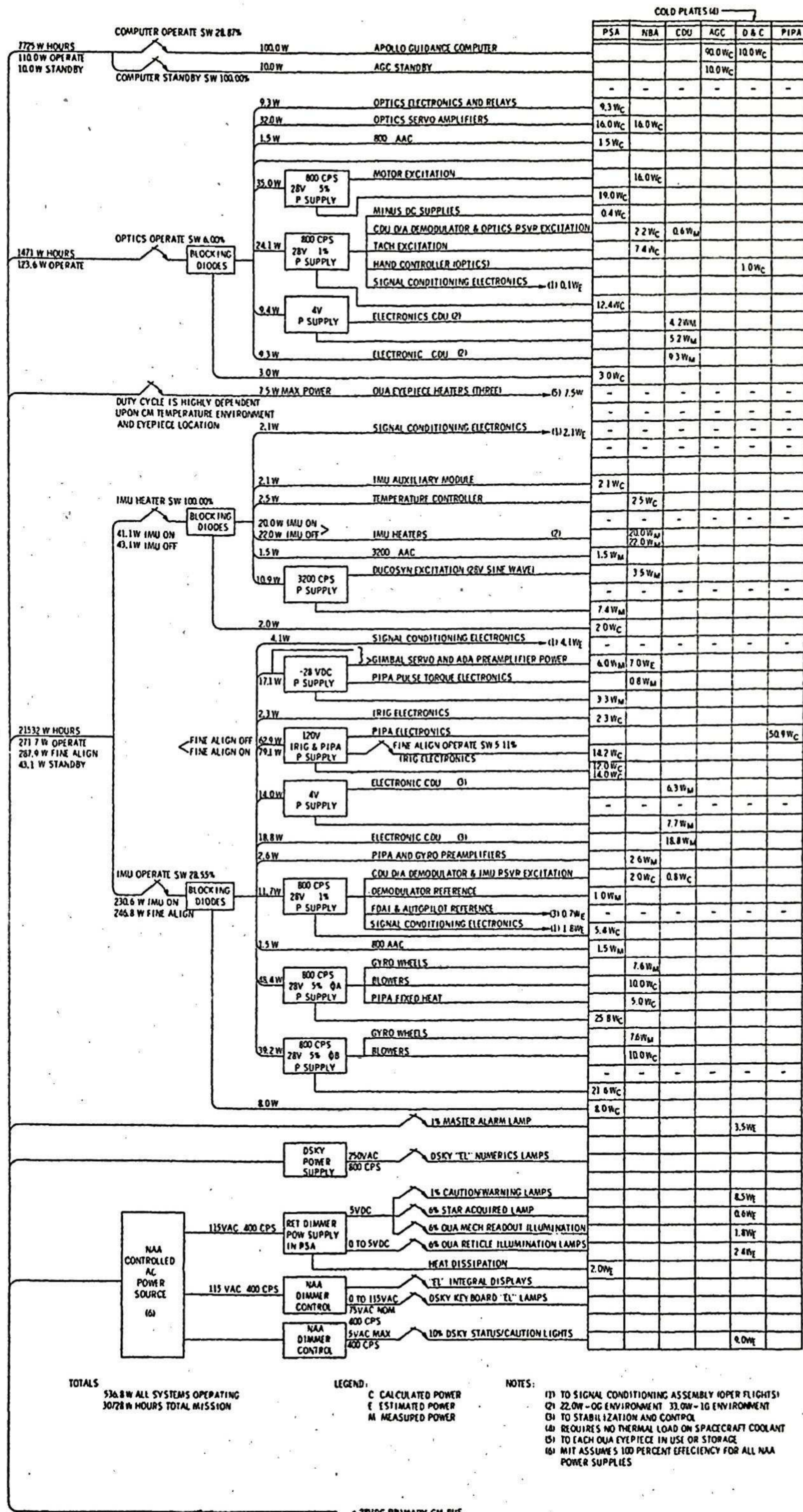
REFERENCE GAEC REPORT - LED 540-12, 30 OCTOBER 1964  
APOLLO MISSION PLANNING TASK FORCE



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

BASED UPON 198.5 HOUR (27 DAY) LUNAR ORBIT MISSION  
DESIGN REFERENCE MISSION

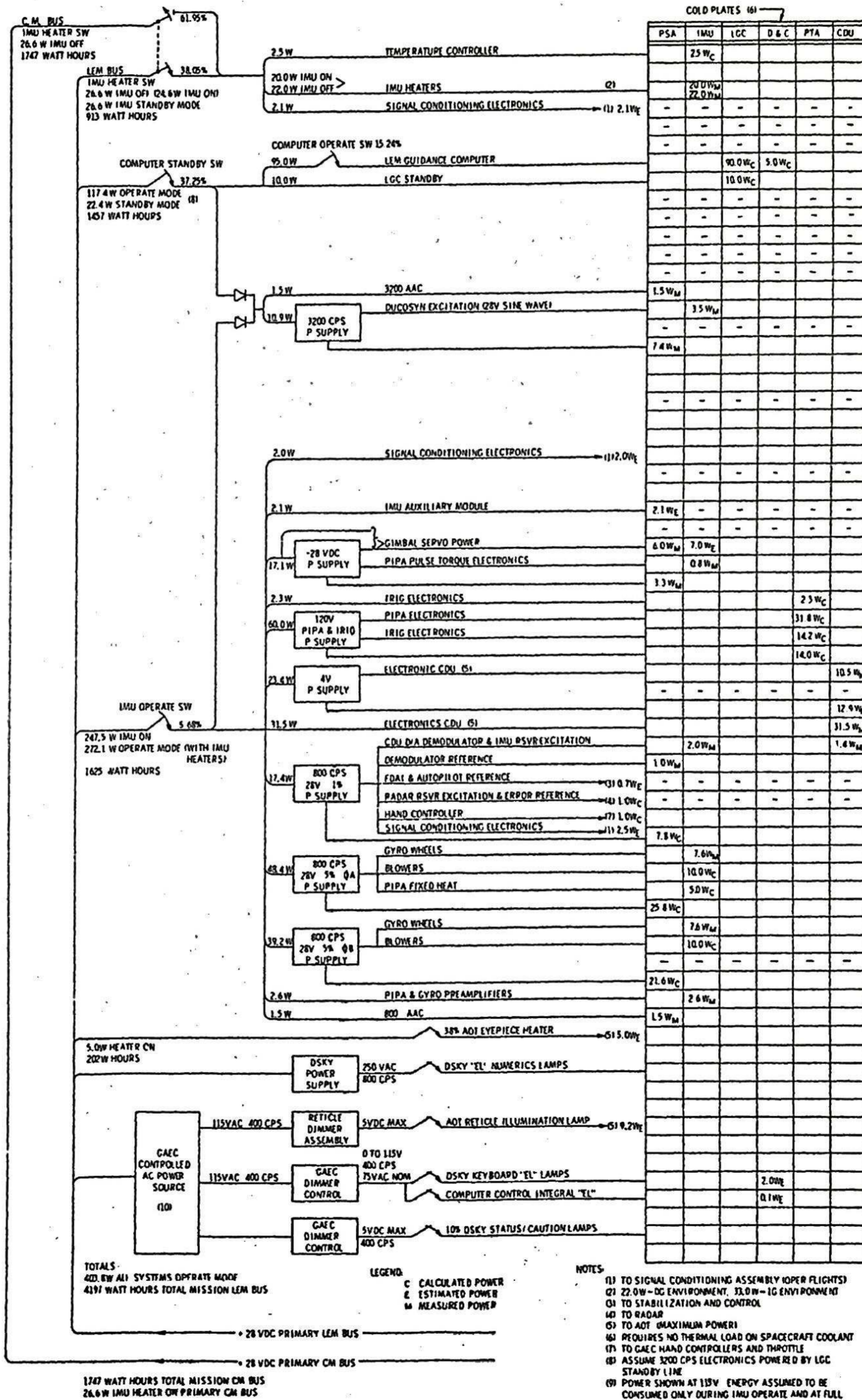
REFERENCE GAEC REPORT - LEO 540-12, 30 OCTOBER 1964  
APOLLO MISSION PLANNING TASK FORCE



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

BASED UPON 106.02 HOURS (4.42 DAY) LUNAR LANDING MISSION  
DESIGN REFERENCE MISSION

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



TOTALS:  
403.8W ALL SYSTEMS OPERATE MODE  
4197 WATT HOURS TOTAL MISSION LEM BUS

1747 WATT HOURS TOTAL MISSION CM BUS  
26.6W IMU HEATER ON PRIMARY CM BUS

LEGEND:  
C CALCULATED POWER  
E ESTIMATED POWER  
M MEASURED POWER

NOTES:  
(1) TO SIGNAL CONDITIONING ASSEMBLY (OPER FLIGHTS)  
(2) 22.0W - DC ENVIRONMENT, 33.0W - IG ENVIRONMENT  
(3) TO STABILIZATION AND CONTROL  
(4) TO RADAR  
(5) TO ADT (MAXIMUM POWER)  
(6) REQUIRES NO THERMAL LOAD ON SPACECRAFT COOLANT  
(7) TO GAEC HAND CONTROLLERS AND THROTTLE  
(8) ASSUME 3200 CPS ELECTRONICS POWERED BY LGC STANDBY LINE  
(9) POWER SHOWN AT 115V. ENERGY ASSUMED TO BE CONSUMED ONLY DURING IMU OPERATE AND AT FULL BRIGHTNESS  
(10) MIT ASSUMES 100 PERCENT EFFICIENCY FOR ALL GAEC POWER SUPPLIES

## SECTION 5

### GUIDANCE AND NAVIGATION SYSTEMS STATUS

The status of delivered G&N Systems are shown in tabular form. Table I shows the status of G&N Systems progressing from installation to final test at KSC.

Table II shows the configuration for major units comprising the G&N Systems assigned to LTA-8 and subsequent LM Vehicles at GAEC.

Table III shows the configuration for major units comprising the G&N Systems assigned to CSM-20 and subsequent Command Modules at NAA.

Table IV shows the configuration for major units comprising the G&N Systems at KSC.

TABLE 1

OPERATIONS	LOCATION									
	GAEC			NAA				KSC		
	LTA-8 602	LM-2 608	LM-3 606	CSM-20 502	CSM-98 2TV-1 202	CSM-101 204	CSM-102 205	CSM-103 206	CSM-17 122	LM-1 603
INSTALLATION	X			X	(X)	(X)	X		X	X
SUBSYSTEM CHECKOUT S/C	X			X	(X)		X		X	X
INTEGRATED TEST S/C	X								X	X
COMPLETE TESTING AT KSC										

(X) Indicates System previously installed and tested but removed from the Spacecraft at this reporting.

DATE: August 1967

TABLE II

LM G&N SYSTEM CONFIGURATION

S/C	LTA-8	
COMPONENT NOMENCLATURE	System 602	
	Part No.	S/N
LGC	2003100-041	14
DSKY	2003985-051	13
IMU	2018699-021	2
ECDU	2007222-041	5
AOT	6011000-012	8

DATE: August 1967

NOTE: Listing will be revised if major units are changed.  
Explanatory notes will describe reason for changes.

The following changes affect the previous listing:

1. LTA-8, G&N System 602  
Replaced ECDU 2010744-021, S/N 9, with 2007222-041, S/N 5.  
ECDU would not go to commanded middle gimbal angle.
2. LM-1, G&N System 603  
Vehicle shipped to KSC.
3. LM-2, G&N System 608  
G&N System 605 removed from vehicle, will be replaced by  
G&N System 608.



TABLE III

CSM G&N SYSTEM CONFIGURATION AT NAA

S/C COMPONENT NOMEN- CLATURE	CSM-20 System 123		CSM-98 System 202		CSM-101 System 204		CSM-102 System 205	
	Part No.	S/N	Part No.	S/N	Part No.	S/N	Part No.	S/N
AGC	1003700-071	7					2003200-041	19
DSKY (Main)	1003563-051	9					2003994-011	35
DSKY (Nav.)	1003706-051	7					2003994-011	40
IMU	1001500-111	8					2018601-081	14
CDU	1021304-031	-					2007222-091	16
OPTICS	2011000-023	9					2001100-034	16

DATE: August 1967

NOTE: Listing will be revised if major units are changed. Explanatory notes will describe reason for change.

The following changes affect the previous listing:

1. Blank spaces in Table above indicate Systems removed from Spacecraft. Upon reinstallation, configuration will be updated.

TABLE IV

## G&amp;N SYSTEM CONFIGURATION AT KSC

S/C	17		LM-1	
COMPONENT NOMENCLATURE	System 122		System 603	
	Part No.	S/N	Part No.	S/N
AGC	1003700-051	14	2003993-011	30
DSKY (Main)	1003563-051	2	2003994-011	37
DSKY (Navigation)	1003706-051	10	-----	--
IMU	1001500-111	4	2018601-111	6
CDU	1021304-031	4	2007222-131	25
OPTICS	2011000-024	7	6011000-021	9

DATE: August 1967

NOTES: Listing will be revised if major units are changed. Explanatory notes will describe reason for change.

The following changes affect the previous listing:

1. CM-17, G&N System 122
  - A. Replaced capacitors in PIP Preamps; Part Number 1010317-001. IMU 1001500-091, S/N 11 becomes 1001500-111, S/N 13.
  - B. Replaced IMU 1001500-111, S/N 13 with IMU 1001500-111, S/N 4. Replacement caused by erratic Z Gyro.
2. LM-1, G&N System 603
  - A. Replaced Computer 2003200-021, S/N 22 with 2003993-011, S/N 30. Computer replacement caused by RESTART's traced to Clear Rope Driver.
  - B. Replaced DSKY 2003994-011, S/N 38 with 2003994-011, S/N 37. DSKY replaced to meet CARR commitment of additional Vibration Tests.
  - C. Replaced IMU 2018601-051, S/N 13 with 2018601-111, S/N 6. IMU problem was with Y Gyro NBD term.

SECTION 6  
G&N SYSTEM TEST

A. System Test Laboratory

1. G&N 5

System has been operating in the Space Navigator Facility for approximately 16.7 hours during June and July.

2. G&N 104

a. Program Tests

- (1) Ran 501 Simflight to evaluate program for updating R&V vectors.
- (2) Ran tests to evaluate erasable programs for measurement of IRIG ADOA terms.
- (3) Retested the 501 compensation program during pre-launch and free-fall. Verified correct polarity and scaling for various compensation terms.

b. Hardware Tests

- (1) Conducted a special low level torquing test on a ternery current switch trying to induce it to fail by (1) increasing module temperature to 70 degrees C., and (2) unbalancing switching transients. Were unsuccessful in trying to duplicate condition reported at KSC on IMU 11.
- (2) Ran monthly IMU performance tests.
- (3) Evaluated prototype regulated Pulse Torque Power Supply. Observed excessive cross-coupling between loops.

c. Failures

The IG CDU S/N 10 failed in system. Cause was traced to excessive wear in the motor gear train. The unit was repaired and re-installed in the system.

3. G&N 200

a. Program Tests

- (1) Continued checkout of JDC's against revisions of SUNDISK.
- (2) Found problem with V55. (Data loaded into DSKY was not causing the clock to be incremented). Corrected and incorporated into revision #188 of Sundisk.
- (3) Found problem with OCDU fail. (Tracker light was being turned on for failure but not extinguished when failure was removed). Program was corrected and incorporated in revision #188 of Sundisk.

- (4) Found problem with P52. (Major mode check interpreted as being in P54). Program was corrected and incorporated in revision #188 of Sundisk.
- (5) Verified operation of P01, P02, P03 and P05 in revision #188 of Sundisk.
- (6) Started checkout of P20 in revision #188 of Sundisk.
- (7) Attempted to use P06 to switch CMC to Standby. Found that after program turned on standby enable bit, it did a TC to SLAP1 which turned the bit back off. So Standby button was inoperative.
- (8) There exists a problem with the optics drive program in that the optics can be driven into both the shaft and trunnion stops without generating an alarm. This is an undesirable condition.
- (9) The major portion of July was spent in verifying SUNDISK #209 programs required for mission 205-CSM. This program verification was completed and a formal and comprehensive report will be generated.
- (10) Verified problem with Gyro Compass program in Sundial E. In this version of the program, Gyro compassing is not continued during optical verification, therefore, if a long time is spent in the optical verification routine, a step input of platform level error at the end of the optical verification causes the gyrocompass to drive the azimuth off. This problem occurs because only earth rate compensation is applied to the gyros during optical verification. This problem does not exist in SUNDISK.

b. Failures

- (1) System sustained a failure in the CDU. The inner gimbal loop would go into oscillations and generate a CDU failure. The inner loop modules were removed from the CDU for investigation.
- (2) The optics Resolved mode is inoperative. It is believed that a relay failure has occurred, but the problem has not yet been duly investigated.

4. G&N 600

a. Program Tests

- (1) Exercised 206 Simflight to confirm erasable load, proof listing and observed several operational features.
- (2) Processed 4 AC K-START tapes.

b. Special Tests

- (1) Determined the accuracy of measuring a 3 minute error in the PGNCS to be within 5.8% (STG Memo No. 1024).
- (2) Continued Landing Radar data processing from the new series of White Sands flights.
- (3) Investigated the CDU coarse align error problem encountered at GAEC. The problem could only be generated during the first coarse aligning of the gimbals after turn on and appears to be associated with the 90° sine switches. This was proven by maintaining charges across capacitors. To prove the converse of the CDU coarse align problem the capacitors on the suspect switches were drained by adding 100k resistors to ground. Repeated runs showed continued malfunctions.

c. Hardware Tests

- (1) Conducted EMI investigations of action items from June EMI Data Review Meeting. Results of testing showed
  - (a) setting of gyro torque enable to relay eliminates EMI interference levels noted in testing,
  - (b) ±50 transients on the +28V lines show no noise effect on the +120V pulse torque power supply lines (gyro torque relay set) or on PIPA performance tests,

- (c) conducted interference tests on the DC DAC signal (Forward Velocity) showed noise less than 1 db from 14 kc to 25 mc when measured at GAEC interface. Confirmed noise levels of 25 db when measured at the PSA-TPA, thus proving the noise source to be in the GSE,
- (d) CDU susceptability was proven to be above 100V open circuit transients between 0V and ground. 50 volt transients were measured between CDU 0V and case.

- (2) Made several runs in fine align, pulse torquing across 45 degrees on each gimbal. Recorded transients in the coarse and fine errors as well as erroneous counts of  $\pm \Delta\theta g$  pulses. The transients were present after turn-on and disappeared with repeated use of the IMU.

d. Failures

- (1) A blower in the IMU was replaced for bad bearings at 2,325 hours.
- (2) Replaced the OG Quadrant Select Module in CDU. It was shown to have faulty operation during EMI testing.

B. Test Programming

1. 205 C/M SUNDISK

- a. IMU Performance Tests were further digitally verified by comparing a trace of AGC computations with a trace of the MAC Development Program with the same inputs. The Development Program is used to test the response of the statistical filter to various inputs.
- b. Test decks being prepared for final digital verification of all system tests in 205.
- c. Automatic optics positioning was included during prelaunch gyrocompass verification.
- d. Variable launch azimuth (by Astronaut) capability added to prelaunch gyrocompass.
- e. Crew checklists for P01, P02, P03 updated to reflect Block II and changes above.

2. 504 C/M COLOSSUS

- a. IMU Performance Tests programming and procedures were completed. Digital simulations were successful.
- b. Automatic optics positioning was included during prelaunch gyrocompass verification.
- c. Variable launch azimuth (by Astronaut) capability added to prelaunch gyrocompass.
- d. Crew checklists for P01, P02, P03 updated to reflect Block II and changes above.
- e. A total of 1170 words is required for the Performance Tests and gyro compass.

3. 504 L/M SUNDANCE

- a. IMU Performance Tests programming and procedures were completed. Digital simulations were successful. Approximately 680 LGC words are used.
- b. Lunar surface system tests programming completed. Digital verification was successful. Crew checklists and Guidance System Operation Plan (GSOP) were written for this program. Approximately 182 LGC words are required.

C. Field Operations

1. GAEC

- a. LTA-8 (Thermo-Vacuum) G&N 602
  - (1) Completed CARR on 29 June 1967.
  - (2) Due to removal of panels, and other fire-proofing modifications, GAEC will be re-running the FEAT again on this vehicle. FEAT re-run schedule for 10 August 1967.

- b. LM-2 (Mission AS 208) G&N 608

Vehicle shut down for modification cycle. Completed laboratory checkout of G&N System.

2. KSC

- a. CM-17 (Mission AS 501) G&N 122

Completed OCP K-0005, Pre-electrical Mate, currently running OCP-K-0006, Overall Test (Plugs In).

Review of OCP'S K-0028, K-0033 and K-0043A has been completed.

- b. LM-1 (Mission AS 206) G&N 603

Computer locked up with restarts. Problem appeared to be in clear rope driver circuit, modules B-5 and B-6. Raytheon is currently verifying this diagnosis. Computer S/N 22 (C-2) replaced with S/N 30 (C-11) Started OCP K-0011, Combined System Test.

3. MSC

- a. LM-CM optics reflected flight simulator is being constructed by MSC. The AOT is suspected of being unacceptable at this time for lunar observations or navigations sightings. Assisting MSC in investigation to determine what sextant restrictions will occur.

- b. Running 206 Simflight Program in NASA Laboratory. Started Simflight simulation of 501, but discontinued because PAC is being moved.

4. NAA

- a. CM-20 (Mission AS 502) G&N 123

Completed Individual System Test, OCP 6504.

b. CM-98 (2 TV-1 Thermo Vacuum) G&N 202  
System awaiting installation.

c. CM-101 (Mission AS 207) G&N 204  
G&N System shipped to ACED for modification.

d. CM-102 (Mission AS 503) G&N 205  
Completed OCP 6504, Individual Systems Test. Retest required to investigate  
1/2 degree shift in azimuth during gyrocompassing.

102 is to be recycled to manufacturing for modification and redesignated  
S/C 105.

Completed OCP 126, Combined System Test.

e. CM-103 (Mission AS 504) G&N 206  
All G&N equipment has been removed from the Spacecraft.

f. CM-104 (Mission AS 505) G&N 207  
All G&N equipment has been removed from the Spacecraft.

D. System Engineering

1. Analysis and Tests

a. Tests of various programs in the Mission 205 SUNDISK ropes were developed  
and many were performed in the Systems Test Lab. The results are tabulated  
below:

<u>Program Type</u>	<u>No. of Test</u>	<u>Tested &amp; Informal Report Available</u>	<u>Program shown to be good</u>
IMU Operational	5	5	5
Optics Operational	8	8	7
System Operations Extended Verbs	9	9	7
Systems Test Programs	9	9	8
IMU Compensation	4	1	1
RCS & TVC Polarity	2*	0	0
Alarm Test	2*	0	0
Back up IMU Align and realign	2*	0	0

\*These tests are being developed, and if successful will be used  
in the formal sell-off.

b. The current work on the hybrid simulation has been completed with the  
publication of Hybrid Memo No. 24 describing the simulation of the AOT. The  
binary deck has been turned over to the hybrid simulation group.

c. The data sheets which define expected flight parameters for quick comparison with actual flight data for AS 501 are being reproduced for preliminary distribution for comment.

d. Work has begun to define radar tests based on the experience with optics test. A review of GRUMMAN and other radar tests has begun as an aid in determining what additional tests can profitably be performed by this group.

e. A TVC polarity test for use in the laboratory is also being developed.

f. Work on the alarms has continued, and a survey of what alarms are tested in which test phase was initiated so that the exact requirements for test in the STG Laboratory can be determined. A memo (STG 1018) describing the proper operation of the tracker light was published.

g. Inputs to the overall verification plan were provided for the following programs:

P20

P22

P51

P52

IMU Operations (including extended verbs)

System Tests

RCS Polarity

Spacecraft Integrated Test

## 2. Spacecraft Operations Support

a. K-Start tape for the gyro-scale factor test is being manufactured. This tape is compatible with Sundial and will be updated for 504.

b. A program change to turn off displays of uplink words by the DSKY during K-Start tape loading was verified. The purpose of this change is to save operations of the DSKY relays. Any verb 36 Enter will terminate the updating of displays until a DSKY key is pressed which then causes displays to be updated.

c. An E-Memory Program to torque the Block I IRIG's with an arbitrarily specifiable number of pulses per burst and time between bursts was developed.

d. Plans for checkout of the LM radar were reviewed with GAEC and a memo (STG #1033) issued answering several questions. More work defining radar tests and required programs is in progress.



E. KSC Checkout Support

- a. SUNDISK program assembly checkout and verification.
- b. Defined new Earth Rate compensation terms for MIT/KSC (R. O'Donnell) to be used with K-Start tape FO4C017-K00014, (G&N SCS Interface Test) during FRT on launch pad 39A.  
(F04 C017-K00014 was originally designed for VAB testing, Azimuth =  $348^{\circ}$ ; LC 39A Azimuth =  $270^{\circ}$ .)
- c. Investigating possible interface signal interference problem during Block II CSM parallel testing of SCS and G&N systems at KSC.
- d. SPS thrusting polarity test verification (P30 & P40).
- e. Block II CSM Process Specification (for KSC) verification using SUNDISK program assembly.

F. Special Test Equipment

1. Work on G&N Inertial Subsystem Test Station proceeding.
2. 16 PM PIPA Test Console work is continuing.

## SECTION 7

### G&N COMPUTER STATUS

#### A. Analysis Facility

##### 1. Design Analysis

a. AGC C200 was received from the manufacture unchecked. Voltage, frequency, temperature margins were checked. These checks showed that the temperature sensitivity had been cured. The four (4) volt margin has also improved, but this may be due to a different A2 (timing) module.

b. A four volt noise test was run (injection of square waves onto the 4 volt power supply lines) by AC Electronics. Failure points were almost identical to the DC failure levels.

c. An erasable memory preservative test was run to determine if the erasable memory is altered during power turn on/turn off. The program used "sum checks" approximately 5/8ths of the memory, then starts option 4 of AGC Self Check (erascheck), after completing one iteration of erascheck another program is started which accesses every erasable memory location. It is during this time that power is interrupted. Channel 77 is interrogated prior to power interruption to see if a parity failure has occurred. Approximately 10,000 cycles were preformed with no failures occurring.

##### 2. Miscellaneous AGC Related Activities

###### a. Channel 77 Alarm Box

The breadboard Channel 77 Alarm box was checked out with C200 for voltage and timing margins. Results looked good.

###### b. Fabrication of New Monitors

The logic plates are at the vendors for wirewrapping. The first set of memories has been received and checked out. All other fabrication is complete for the first system.

c. Routine Maintenance

Routine maintenance and updating of AGC's and support equipment in use in the STG Laboratory and Hybrid Simulation Facility was performed. All AGC's now have a pseudo STANDBY capability, which software wise is identical to flight computers.

3. Components

a. Waivers

Waivers have been reviewed by MIT/IL; in particular, the waivers for particles in the 1006321 nor gate flat pack and the particles and contact resistance for 2005001 and 2005003 relay. In the cases of the 1006321 nor gate, a team from MIT viewed about 2000 x-ray photographs before rejecting the waiver and returning it with instruction that further x-ray screening for the lot was required. This was accomplished and the waiver was resubmitted and signed. Many meetings were held to review the conflicting data obtained from the Apollo DSKY relays. Vibration which was initially introduced to detect particle failures in the relays seem to be an even greater aggravant to a contact resistance problem. Particles, after the vibration screen, are found not to be a problem even though the screen is not perfect. The next problem was contact resistance. This was solved by writing a specification which stated that whenever any relays of a lot exhibited opens, the lot was resubmitted to an additional vibration cycle. For some lots this was repeated as many as 16 times to get 26 supposedly good relays. The question still remains as to what the failure mechanism is and what the repeated vibration is actually doing to the relays. Even though the high voltage of the Electroluminescent panel and the high currents of the Alarm panel would not be affected by the contact resistance problem, contact resistance is still a very real problem in many critical applications such as the SIVB injection and the SIVB cutoff. MIT's position is that the best way to solve the relay problem is to get rid of the relays. The waivers that have been signed indicate that everything possible has been done to test the relays; not that the relays are reliable.

b. Flight Processing Specifications (FPS)

- (1) A new FPS has been written by Raytheon and submitted to MIT for review. The FPS incorporates all the tests that Raytheon has been doing by the waiver route. It can not be considered adequate to guarantee the reliability required by the Apollo Program.
- (2) A new nor gate FPS revision, incorporating 100% x-ray testing, has been written by MIT and submitted to Raytheon. This new FPS also tightens the visual requirements for particles. This is in compliance with a request from NASA/MSC to rewrite the FPS.

c. Erasable Memory

Failures have occurred in the erasable memory modules of computers in the field. In all cases the modules which failed were in computers which received extensive vibration during sell off. If during sell off the computer fails due to an intermittent contact in some module, the computer vibration is continued till the faulty module is found and replaced.

Testing was conducted to see if vibration could cause the erasable memory module to fail. By the end of a week of vibration, six (6) failures (wire breakage) were detected in one module.

d. Pin-light Numeric Display

The single digit Pin-light Numeric Displays have been subjected to vibration and shock testing at MIT/IL.

e. Transistors 1006323

A life test using four different constructions of the 1006323 transistors is being conducted at MIT/IL. This test is similar to the test runs at NASA/MSC and Raytheon/Sudbury. The test results do not agree. This can partially be due to the fact that the tests were all conducted slightly different. MIT has to date, after  $6 \times 10^6$  cycles at 300 milliamps, detected no failures, while NASA and Raytheon have both experienced extensive failures.

In order to further understand the failure mechanism, the transistors are being examined by a thermal plotter.

SECTION 8

GUIDANCE COMPUTER PROGRAMMING

MISSION	ITEM	1965												1966												1967												68												
		S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A		S	O	N	D								
202	COMPUTER PROGRAM DEVELOPMENT	(3)												UPDATING																																				
204	GUIDANCE SYSTEM OPERATIONS PLAN	(1)												UPDATING																																				
	COMPUTER PROGRAM DEVELOPMENT													(2)												(3)																								
	OPERATIONS HANDBOOK													(1)																																				
501/502	GUIDANCE SYSTEM OPERATIONS PLAN													UPDATING																																				
	COMPUTER PROGRAM DEVELOPMENT													(3)																																				
206	GUIDANCE SYSTEM OPERATIONS PLAN													(1)												UPDATING																								
	COMPUTER PROGRAM DEVELOPMENT																									(3)																								
205	GUIDANCE SYSTEM OPERATIONS PLAN																									UPDATING																								
	COMPUTER PROGRAM DEVELOPMENT																									(3)																								
	OPERATIONS HANDBOOK																									(1)																								
504	GUIDANCE SYSTEM OPERATIONS PLAN																									(1)												UPDATING												
	COMPUTER PROGRAM DEVELOPMENT																																					(1)												
	OPERATIONS HANDBOOK																																					(1)												

(1) NASA APPROVAL (2) "B RELEASE" = PRELIMINARY VERSION OF THE SPACECRAFT COMPUTER PROGRAM  
(3) "A RELEASE" = FLIGHT VERSION OF THE SPACECRAFT COMPUTER PROGRAM RELEASED FOR FLIGHT ROPE MANUFACTURE

AUGUST 1967

Apollo Guidance Computer Programming Summary  
for the Month of June and July

Mission AS-501 (Solarium)

Continued analysis of the released and manufactured program for Mission AS-501 has been performed. From this analysis ground procedure have been revised and program limitations defined. Generation of erasable load coefficients and verification of the erasable load have continued.

Mission AS-206 (Sunburst)

Continued analysis and testing of the released and manufactured program for Mission AS-206 has been performed. From this analysis and testing ground procedures have been revised and program limitations defined.

Mission AS-205 (Sundisk)

During the reporting period the computer program for Mission AS-205 continued to be tested to the Level III and IV portion of the Verification Plan. It is anticipated that the AS-205 program will be ready for "A" Release in late September. Program Configuration Control is scheduled for late August.

Mission AS-504 (Colossus/Sundance)

During the reporting period the Guidance System Operations Plan (GSOP) for Mission 504 was under preparation with preliminary copies of Section 5 "Guidance Equations" delivered in June and preliminary copies of Section 4 "Operations Mode" delivered in late July. a GSOP review meeting with NASA/MSC is scheduled for mid-August. Following the review a joint MIT/NASA meeting is scheduled to define the program content considering Computer Storage, Schedule and Mission Requirements.

COLOSSUS CMC PROGRAM (AS-504)

FIXED MEMORY ALLOCATION CHART (ESTIMATED)

I. Utility and Service Programs	
Interpreter, Single Precision Subroutines, Fixed-Fixed Constant Pool	2227
Executive	328
Waitlist, Longcall	240
Interrupt Lead Ins	52
Interbank Communication	88
T4RUPT	800
SXT Angle Monitor	75
Keyrupt-Uprupt	70
Downlink Program and 5 Lists	600
Fresh Start and Restart	420
Alarm and Abort	63
Delayjob	30
Restart Routine and Tables	400
Phase Table Maintenance	183
Pinball Program and Noun Tables	3000
Displays, Priolarm	700
Program Select (V37, P00, R00)	300
Self Check	990
Extended Verbs	550
RTBOPCodes	200
SXTMARK	350
IMU Mode Switching	580
IMU Compensation	250
LGC Startup (P05)	57
LGC Power Down (P06)	63
IMU Status Check	30
Systems Test (P07)	410
Interpretive Constants	29
Flagup, Flagdown	31
DAP Data Load (R03)	29
End Bank Markers	36
TOTAL UTILITY AND SERVICE PROGRAMS	13181



II. Autopilot and Maneuver Programs Digital Autopilot	
Entry DAP	850
CSM DAP	3500
Inertia Calc	100
KALCMANU	710
Attitude Maneuver (R60)	60
Crew Defined Maneuver (R62)	16
Vecpoint	130
Rendezvous Final Attitude (R63)	30
Middle Gimbal Display	75
CM Body Attitude	200
TOTAL AUTOPILOT AND MANEUVER PROGRAMS	5671
III. Basic Math Routines	
Inflight Alignment Routines	287
Powered Flight Subroutines	156
CSM Geometry	210
Time of Free Fall	300
Conic Subroutines	1000
Orbital Integration	1400
PERIAPO	100
Latitude, Longitude, Altitude	170
Initial Velocity	175
Lunar and Solar Ephemeris	75
Planetary Inertial Orientation	280
TOTAL BASIC MATH ROUTINES	4153
IV. Targeting Routines	
Predicted Landing Time	230
Transfer Phase Initiation	300
Return to Earth	1200
TOTAL TARGETING ROUTINES	1730
V. Navigation Routines	
Measurement Incorporation	350
Preferred Tracking Attitude (R61)	310
Rendezvous Parameters	100
Lunar Orbit Navigation	750
Lunar Landmark Selection (R35)	340
Rendezvous Tracking Sighting Mark and Backup (R21, R23)	420
Rendezvous Tracking Data Processing and Backup (R22, R24)	330
TOTAL NAVIGATION ROUTINES	2600

## VI. Powered Guidance Routines

Servicer	500
Desired Thrust Direction (S40.1, S40.2, 3)	350
Cross Product Steering (S40.8)	140
VG Calculation (S40.9)	100
Time of Burn Calculation (S40.13)	80
Initial VG (S41.1)	20
Entry Guidance	1200
TOTAL POWERED GUIDANCE ROUTINES	2390

## VII. Alignment Routines

Coarse Align (R50)	75
Fine Align (R51)	90
Auto Optics (R52)	155
Sighting Mark (R53)	50
Star Data Test (R54)	65
Gyro Torquing (R55)	40
Pick-A-Pair	125
Star Catalog	223
Alternate LOS Sighting Mark (R56)	54
Optics Calibration (R57)	50
TOTAL ALIGNMENT ROUTINES	927

## VIII. Miscellaneous Programs and Routines

P27 - Update Program	320
P30 - External Delta V Prethrust	250
P31 - General Lambert Maneuver	120
R05 - S Band Antenna Display	85
R30 - Orbit Parameter Display	115
R31-R34 Rendezvous Parameter Display Routine 1 & 2	100
R32 - Target Delta V	100
R33 - CMC/LGC Clock Synchronization	24
TOTAL MISCELLANEOUS PROGRAMS AND ROUTINES	1114

## IX. Mission Control Programs

P01	Prelaunch or Service Initialization	25
P02	Prelaunch or Service Gyrocompassing	650
P03	Optical Verification of Gyrocompassing	130
P11	Earth Orbit Insertion Monitor	380
P15	Translunar Injection	250

P17	TPI Search	150
P20	Rendezvous Navigation	150
P21	Ground Track Determination	50
P22	Orbital Navigation	75
P23	Cislunar Midcourse Navigation	80
P25	Predicted Lunar Landing Time	100
P32	Lunar Orbit Insertion	200
P33	Lunar Orbit Plane Change	370
P34, P74	TPI Prethrust	450
P35, P75	TPM Prethrust	100
P37	Return to Earth	250
P38, P78	SOR Prethrust	100
P39, P79	SOM Prethrust	100
P40	SPS Thrusting	560
P41	RCS Thrusting	150
P47	Thrust Monitor	100
P51, P53	IMU Orientation Determination & Backup	265
P52, P54	IMU Realign and Backup	260
P61	Maneuver to CM/SM Sep Attitude	320
P62	CM/SM Sep and Pre-Entry Maneuver	90
P63	Entry Initialization	25
P64	Post 0.05G	20
P65	Upcontrol	20
P66	Ballistic	20
P67	Final Phase	40
P70	Safe Perilune	150
P77	LM TPI Search	25
TOTAL MISSION CONTROL PROGRAMS		5655
GRAND TOTAL		37421
REMAINING FIXED MEMORY		-557

SUNDANCE LGC PROGRAM (AS-504)

FIXED MEMORY ALLOCATION CHART (ESTIMATED)

I. Utility and Service Programs

Interpreter, Single Precision Subroutines, Fixed-Fixed Constant Pool	2227
Executive	328
Waitlist, Longcall	240
Interrupt Lead Ins	52
Interbank Communication	88
T4rupt (R10, R25)	850
Keyrupt-Uprupt	70
Downlink Program and 5 Lists	600
Fresh Start and Restart	420
Alarm and Abort	63
Delayjob	30
Restart Routine and Tables	350
Phase Table Maintenance	183
Pinball Program and Noun Tables	3000
Displays, Priolarm	700
Program Select Check (V37, P00, R00)	300
Self Check	990
Extended Verbs	600
RTB OP Codes	200
Radar Rupts	230
AOTMARK (R53, R59)	381
Backup Marking	50
IMU Mode Switching	580
IMU Compensation	270
LGC Startup (P05)	57
LGC Power Down (P06)	63
IMU Status Check	30
Lunar Surface Checkout	870
Interpretive Constants	29

Flagup, Flagdown	31
DAP Data Load (R03)	160
Radar Subroutines	710
End Bank Markers	36
TOTAL UTILITY AND SERVICE PROGRAMS	14788
II. Autopilot and Maneuver Programs	
Digital Autopilot	3700
KALCMANU	680
Attitude Maneuver (R60)	60
Crew Defined Maneuver (R62)	18
Vecpoint	130
Rendezvous Final Attitude (R63)	82
Middle Gimbal Display	75
TOTAL AUTOPILOT AND MANEUVER PROGRAMS	4745
III. Basic Math Routines	
Inflight Alignment Routines	250
Powered Flight Subroutines	156
LM Geometry	96
Time of Free Fall	300
Conic Subroutines	1000
Orbital Integration	1400
PERIAPO	100
Latitude, Longitude, Altitude	170
Initial Velocity	175
Lunar and Solar Ephemeris	75
Planetary Inertial Orientation	280
TOTAL BASIC MATH ROUTINES	4002
IV. Targeting Routines	
Predicted Landing Time	250
Predicted Launch Time	650
Coelliptic Sequence Initiation	440
Constant Delta Altitude	300
Transfer Phase Initiation	320
Descent Orbit Injection (S61.1, S61.2)	115
TOTAL TARGETING ROUTINES	2075

V. Navigation Routines	
Measurement Incorporation	350
Preferred Tracking Attitude (R61)	50
Rendezvous Navigation (LSR22.3, RADARANG)	450
Lunar Surface Navigation (LSR22.4)	100
RR Search, Designate and Read	650
(R21, R22, R23, R24, R29, LPS20.1, LPS20.2 LRS22.1, LRS22.2, LRS24.1, CALCXY)	
Rendezvous Parameters	100
TOTAL NAVIGATION ROUTINES	1700
VI. Powered Guidance Routines	
Servicer (R12)	850
Desired Thrust Direction (S40.1, S40.2, 3)	230
Cross Product Steering (S40.8)	75
VG Calculation (S40.9)	100
Time of Burn Calculation (S40.13)	105
Descent Guidance (R11, R13)	923
Ascent Guidance	700
TRIMGIMB (S41.1, S40.6)	65
TOTAL POWERED GUIDANCE ROUTINES	3048
VII. Alignment Routines	
Coarse Align (R50)	75
Fine Align (R51)	80
Auto Optics (R52)	55
Star Data Test (R54)	56
Gyro Torquing (R55)	40
Pick-A-Pair (R56)	142
Star Catalog	223
TOTAL ALIGNMENT ROUTINES	671

VIII. Miscellaneous Programs and Routines

P02 - AGS Initialization	100
P27 - Update Program	320
P30 - External Delta V Prethrust	150
P31 - General Lambert Maneuver	120
R04 - RR/LR Self Test	102
R05 - S Band Antenna Display	105
R30 - Orbit Parameter Display	120
R31 - Rendezvous Parameter Display	90
R32 - Target Delta V	100
R33 - CMC/LGC Clock Synchronization	24
TOTAL MISCELLANEOUS PROGRAMS AND ROUTINES	1231

IX. Mission Control Programs

P10-P11 Predicted Launch Time	200
P12 Ascent Guidance	200
P17 TPI Search	150
P20 Rendezvous Navigation	200
P21 Ground Track Determination	50
P22 Lunar Surface Navigation	20
P25 Preferred Tracking Attitude	70
P32-P72 CSI Prethrust	70
P33-P73 CDH Prethrust	100
P34-P74 TPI Prethrust	460
P35-P75 TPM Prethrust	95
P38-P78 SOR Prethrust	100
P39-P79 SOM Prethrust	100
P40 DPS Thrust	900
P41 RCS Thrust	150
P42 APS Thrust	30
P46 Separation Monitor	100
P47 Thrust Monitor	70
P50 Docked IMU Align	100
P51-P53 IMU Orientation Determination and Backup	210
P52-P54 IMU Realign and Backup	164
P57 Lunar Surface Align	400
P60 Predicted Lunar Landing Time	100
P61 DOI Maneuver	300

P63	Landing Braking	150
P64	Landing Approach	150
P65	Landing (AUTO)	100
P66	Landing (ROD)	100
P67	Landing (Manual)	100
P70	DPS Abort	100
P71	APS Abort	100
TOTAL MISSION CONTROL PROGRAMS		5139
GRAND TOTAL		37399
REMAINING FIXED MEMORY		-535



SUNDISK CMC PROGRAM (AS-205)

FIXED MEMORY ALLOCATION CHART (ACTUAL)

I. Control Programs

A. DSKY

Pinball	2876
Extended Verbs	470
Keyrupt and Uprupt	70
Display and Priolarm	695
Down Telemetry List & Program	628
Program Select Check (V37, P00, R00)	271

B. Interpreter and Executive

Interpreter	2256
Waitlist	240
Delayjob	30
Executive	328
Restart Tables & Routines	386
Fresh Start and Restart	394
Phase Change and New Phase	183
T4 Rupt	782
Alarm and Abort	63
Self Check	990
Interrupt Lead In	52
RTB OP Codes	158
End Bank Marks	36
Interbank Communication	88
Flagup, Flagdown	31

C. Other

Digital Auto-Pilot	3210
Saturn and CM Tests	542
Transformations	651
Gyro Torquing (R-55)	35

TOTAL - DSKY and Interpreter and Executive  
and Other

15465

## II. CMC Routines

A. Basic Routines	
Conic Subroutines	850
Orbital Integration	1085
Latitude, Longitude & Altitude	216
LOCSAM	127
Initial Velocity	189
Maneuver Specification (R60, R62)	200
Maneuver Calculation	923
Attitude Drive	149
Mid Gimbal Display	33
B. Targetting	
TPI	275
PERIAPO	34
Midcourse Maneuver (S35.1)	55
C. Navigation	
Rendezvous (R21, R22)	380
Lunar Orbit	777
Measurement Incorporation	406
Preferred Tracking Attitude (R61)	280
Sight Mark (R-53)	49
SXT Mark	296
D. Entry	
Entry Calculations	1354
Preentry Computations (S61.2)	141
Gimbal Angles for Separation (S61.3)	34
IMU Entry Status (S61.1)	88
Trim Gimbal Angles (S62.3)	23
DAP Entry	938
Apogee, Perigee and $T_{FF}$	272
E. Powered Guidance	
Cross Product Steering (S40.8)	135
Vg Calculation (S40.9)	96
Time of Burn Calculation (S40.13)	66
Servicer	433
Desired Thrust Direction (S40.1)	147
Wings Level (S40.2, 3)	188
NEWSC.	17

F. IMU and Optics	
IMU Compensation	246
IMU Status Check (R02)	26
Coarse Align Cal 53A	75
Fine Align (R51)	90
Auto-Optics Positioning (R52)	151
Target Determination (SR52.1)	97
Compute Gimbal Angles (Present)(S52.2)	44
Compute Gimbal Angles (Desired)(S53.1)	9
Pick-A-Pair	131
Star Data Test (R54)	60
IMU Mode Switching	573
Star Catalog	260
Alt LOS Sighting Mark (R56)	54
G. Boost	
Boost Routine (Part of P11)	----
Saturn Takeover	47
TOTAL - CMC Routines	12119

### III. CMC Programs

P-01-P03 Prelaunch Align Calib.	885
P05 CMC Startup	55
P-06 CMC Power Down	62
P-07 System Test	2492
P-11 EOI Monitor	372
P-20 Rendezvous Navigation	85
P-21 Ground Track Det.	35
P-22 Lunar Orbit Navigation	68
P-23 Cislunar Midcourse Navigation	71
P-27 CMC Update	311
P-30 External Delta V	235
P-34 Transfer Phase Initiation (TPI)	263
P-35 Transfer Phase Midcourse (TPM)	75
P-40 SPS	788
P-41 RCS	134
P-47 Thrust Monitor	73
P-51-P53 IMU Orientation Determination and Backup	155
P-52-P54 IMU Realign and Backup	106

P-61 Maneuver to CM/SM Sep. Att.	44
P-62 CM/SM SEP. and Preentry Maneuver	55
P-63 Entry Initialization	18
P-64 Post 0.05 G	6
P-67 Entry Final Phase	31
P-74 LM TPI Targeting	2
P-75 LM TPM Targeting	5
R-03 Load DAP Data	27
R-30 Orbital Parameter Display	114
R-31-R-34 Rendezvous Parameter Display No. 1 & 2	102
R-32 Target Delta V	94
TOTAL	6763
GRAND TOTAL	34347
Remaining Fixed Memory	2517

SECTION 9

"E" AND "R" NOTES PUBLISHED DURING THE REPORTING PERIOD

- E-1944 The Impact of the Flight Specification on Semiconductor Failure Rates, Jayne Partridge and L. David Hanley, Jr., June 1967, (U).
- E-2129 Keyboard and Display Program and Operation, Alan I. Green and Robert J. Filene, June 1967, (U).
- E-2141 Apollo Guidance, Navigation and Control System Gyro Reliability, John E. Miller and Julius Feldman, June 1967, (U).
- E-2146 The Digital Simulation for the Verification of Program Sunburst (Unmanned LM, AS-206), W.S. Widnall, F.K. Glick, J. Henize and L.W. Drane, July 1967, (C).

E-1142 (Rev. 52)  
DISTRIBUTION LIST

Internal

M. Adams (MIT/GAEC)	A. Laats
R. Battin	L. Larson
P. Bowditch/F. Siraco	J. Lawrence
J. Dahlen	T. M. Lawton (MIT/MSC)
J. DeLisle	G. Mayo
E. Duggan	John Miller
J. B. Feldman	J. Nevins
S. Felix	R. Ragan
G. Silver (MIT/KSC)	J. Sciegienny
Eldon Hall	N. Sears
T. Hemker (MIT/NAA)	W. Stameris
E. Hickey	R. Weatherbee
D. Hoag	R. Woodbury
F. Houston	Apollo Library (5)
L. B. Johnson	MIT/IL Library (8)
K. Greene	

E-1142 (Rev. 52)  
DISTRIBUTION LIST

External:

C. Frazier (NASA/MSC EG44)	(2)
NASA/RASPO	(1)
AC Electronics	(10)
Kollsman	(10)
Raytheon	(10)
Capt. Mark Jensen (AFSC/MIT)	(1)
T. Gibson (NASA/MSC FS55)	(2)

MSC: (30 + 1R)

National Aeronautics and Space Administration  
Manned Spacecraft Center  
Apollo Document Distribution Office (PA2)  
Houston, Texas 77058

KSC:

NASA J. F. Kennedy Space Center (1R)  
Technical Document Control Office, HB-23  
Cape Kennedy, Florida

GAEC:

Grumman Aircraft Engineering Corporation (3 + 1R)  
Data Operations and Services, Plant 25  
Bethpage, Long Island, New York  
Attn: Mr. E. Stern

NAA:

North American Aviation, Inc. (18 + 1R)  
Space and Information Systems Division  
12214 Lakewood Boulevard  
Downey, California  
Attn: Apollo Data Requirements, 096-340  
Bldg 3, CA 99

NAA RASPO:

NASA Resident Apollo Spacecraft Program Office (1)  
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 32-21  
AC Electronics Division of General Motors  
Milwaukee 1, Wisconsin  
Attn: Mr. W. Swingle .

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

(1)

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

(1)

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

(1)