APOLLO

GUIDANCE AND NAVIGATION

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E-1142
(Rev. 51)

SYSTEM STATUS REPORT

June 1967

MIT 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.

E-1142

(Rev. 51)

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

June, 1967

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ACCURACY

The accuracy of numerical values reported in this revision should not be considered to be within the tolerances implied by the significant figures quoted. The reported values, although based upon the most current information, are subject to slight variations from system to system.

INTRODUCTION

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

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)	155.0**
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)	120.0
G&N Interconnection Assy	26.1 (M)	0.0	26.1 (M)	
Optical Shroud	3.1 (M)	0.0	3.1 (M)	4.5
G&N to S/C Interface Assy AGC (with 6 rope modules)	90.8 (M)	0.0	90.8 (M)	100.0
Optical Eyepiece Storage Assy Condition Annunciators SXT Normal Relief Eyepiece SCT Normal Relief Eyepiece SCT Long Relief Eyepiece	12,7 (M)	0.0	12.7 (M)	15.0
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

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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
TOTAL	443.8	0.0	443.8	---
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.

DATE: June 1967

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 SXT and gearing SCT and gearing Optical Base and gearing APTPS and Dust Covers	55.7 (M)	0.0	55.7 (M)	150.0
NVB and Mounts	17.4 (M)	0.0	17.4 (M)	
Bellows Assy	10.7 (M)	0.0	10.7 (M)	
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 (M)	0.0	49.4 (M)	58.0
PIPA Electronics Assy	9.0 (M)	0.0	9.0 (M)	12.0
G&N Interconnect Harness Group	24.0 (M)	0.0	24.0 (M)	40.0
AGC (with six(6) rope modules + mag. trays)	69.5 (E)	0.0	69.5 (E)	80.0
Optical Shroud	3.1 (M)	0.0	3.1 (M)	4.5
Optical Eyepiece Storage Assy SXT Normal Relief Eyepiece SCT Normal Relief Eyepiece SCT Long Relief Eyepiece	14.0 (M)	0.0	14.0 (M)	15.0
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

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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.

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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)	
HARNESS "B" Supported by the NVB	0.6 (E)	0.0	0.6 (E)	
HARNESS "B" Supported by the PTA	0.8 (E)	0.0	0.8 (E)	21.0
HARNESS "B" Supported by the structure	3.1 (E)	0.0	3.1 (E)	
PTA	14.3 (M)	0.0	14.3 (M)	
HARNESS "A"	14.6 (M)	0.0	14.6 (M)	22.0
LGC (with six(6) rope modules + mag trays)	69.5 (M)	0.0	69.5 (M)	65.0
DSKY	17.5 (M)	0.0	17.5 (M)	20.0
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)	
TOTAL	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 6000000 - amended by NASA Letter EG 26-233-66-565 dated 18 August 1966.

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SECTION 2

GLOSSARY AND SYSTEM DEFINITION

The description at 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 10^6 HOURS"

MISSION		IMU Assembly ON/STBY	IMU Electronics (PSA) ON/STBY	Optics Assembly ON/OFF	Optics Electronics (PSA) ON/OFF	IMU CDU ON/STBY	Optics CDU ON/OFF	AGC ON/STBY	DSKY ON/OFF	D&C ON/OFF	Mission Reliability
AGE 122 FLIGHT 501 UNMANNED	OPER HRS	8.63 -	8.63 -	- -	- -	8.63 -	- -	8.63 -	8.63 -	8.63 -	.9931
	λ	195 -	224 -	- -	- -	111 -	- -	257 -	12 -	6 -	
AGE 123 FLIGHT 502 UNMANNED	OPER HRS	8.3 -	8.3 -	- -	- -	8.3 -	- -	8.3 -	8.3 -	8.3 -	.9933
	λ	195 -	224 -	- -	- -	111 -	- -	257 -	12 -	6 -	
AGE 603 FLIGHT 204* UNMANNED LM	OPER HRS	9.6 -	9.6 -	- -	- -	9.6 -	- -	9.6 -	9.6 -	- -	.9938
	λ	129 -	110 -	- -	- -	155 -	- -	235 -	12 -	- -	
C/M	OPER HRS	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
DES. REF.	λ	129 10.2	110 6.3	94 -	77 -	155 -	91 -	235 60.5	2.3 -	2.3 -	
LM	OPER HRS	3.25 66.3	3.25 66.3	3.25 -	3.25 -	3.25 -	3.25 -	3.25 -	3.25 -	3.25 -	.9969
DES. REF.	λ	129 1.6	110 -	38 -	1.33 -	155 -	112 -	235 -	110 -	1.2 -	

*206 REDESIGNATED 204/LM1

JUNE 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.

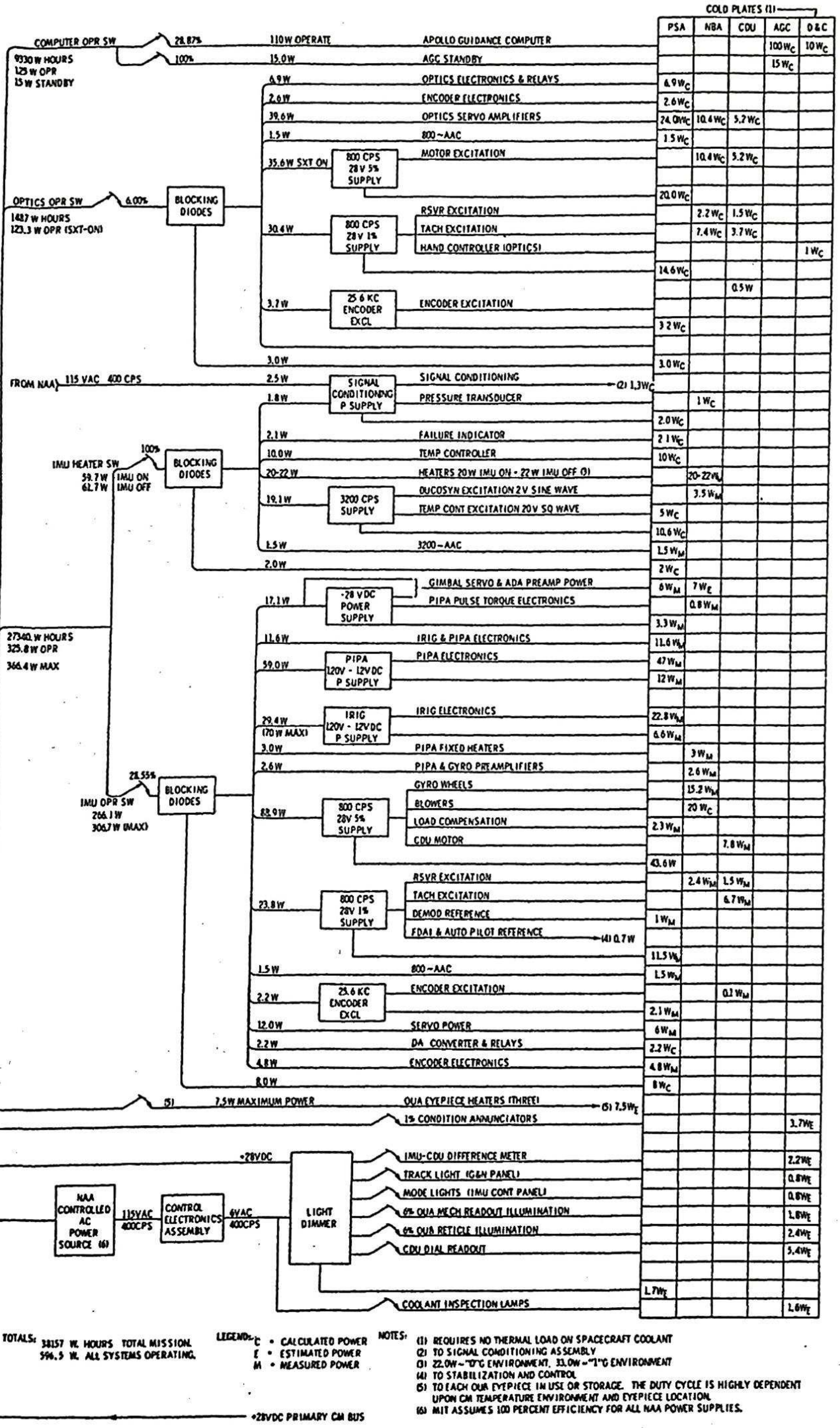
Interface Control Documents serve as the guidelines for reporting power figures.

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 1983 HOUR (8.27 DAY) LUNAR MISSION
DESIGN REFERENCE MISSION

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



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

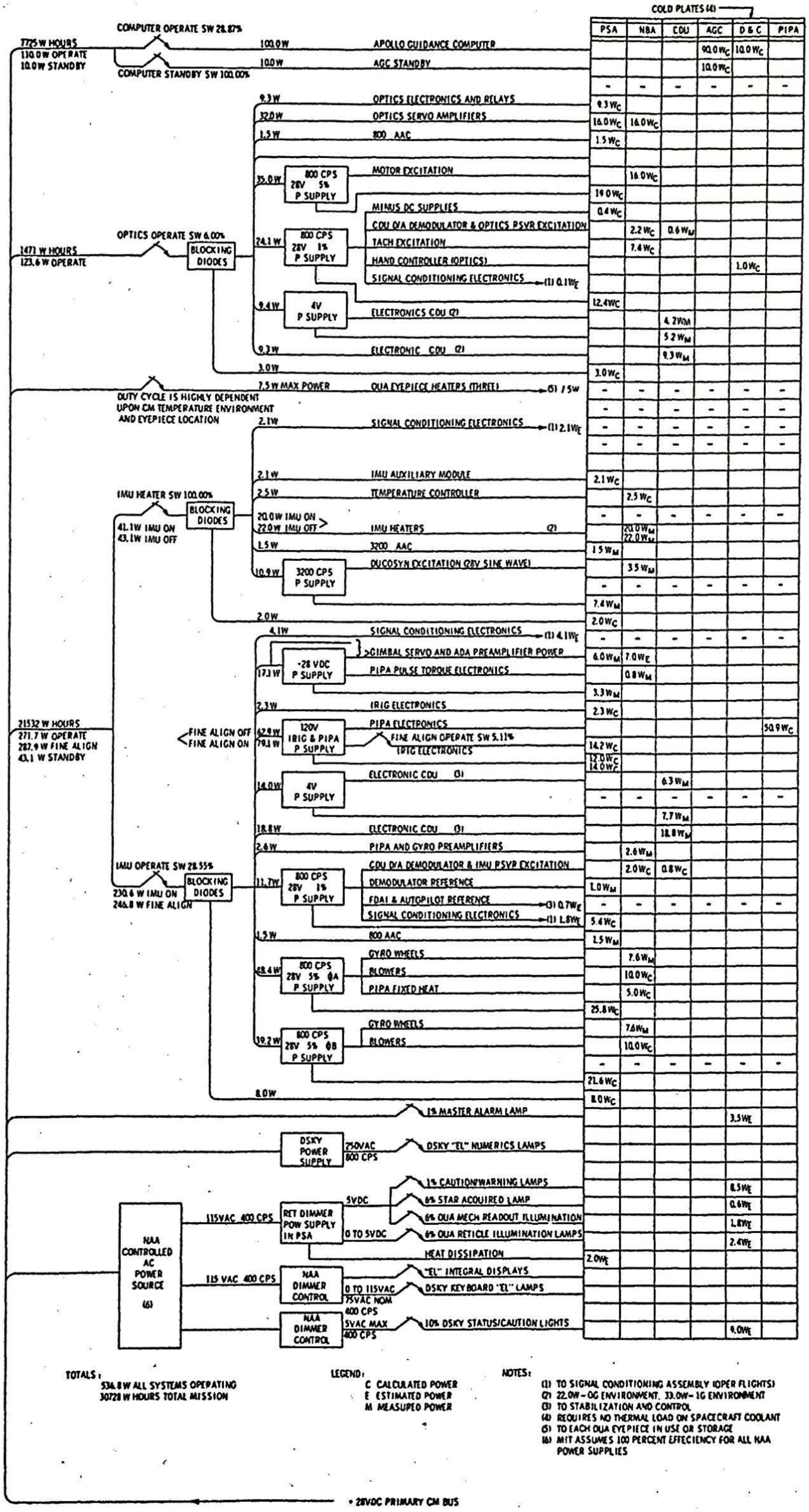
LEGEND: C • CALCULATED POWER
E • ESTIMATED POWER
M • MEASURED POWER

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

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

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

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



TOTALS:
534.8 W ALL SYSTEMS OPERATING
30728 W HOURS TOTAL MISSION

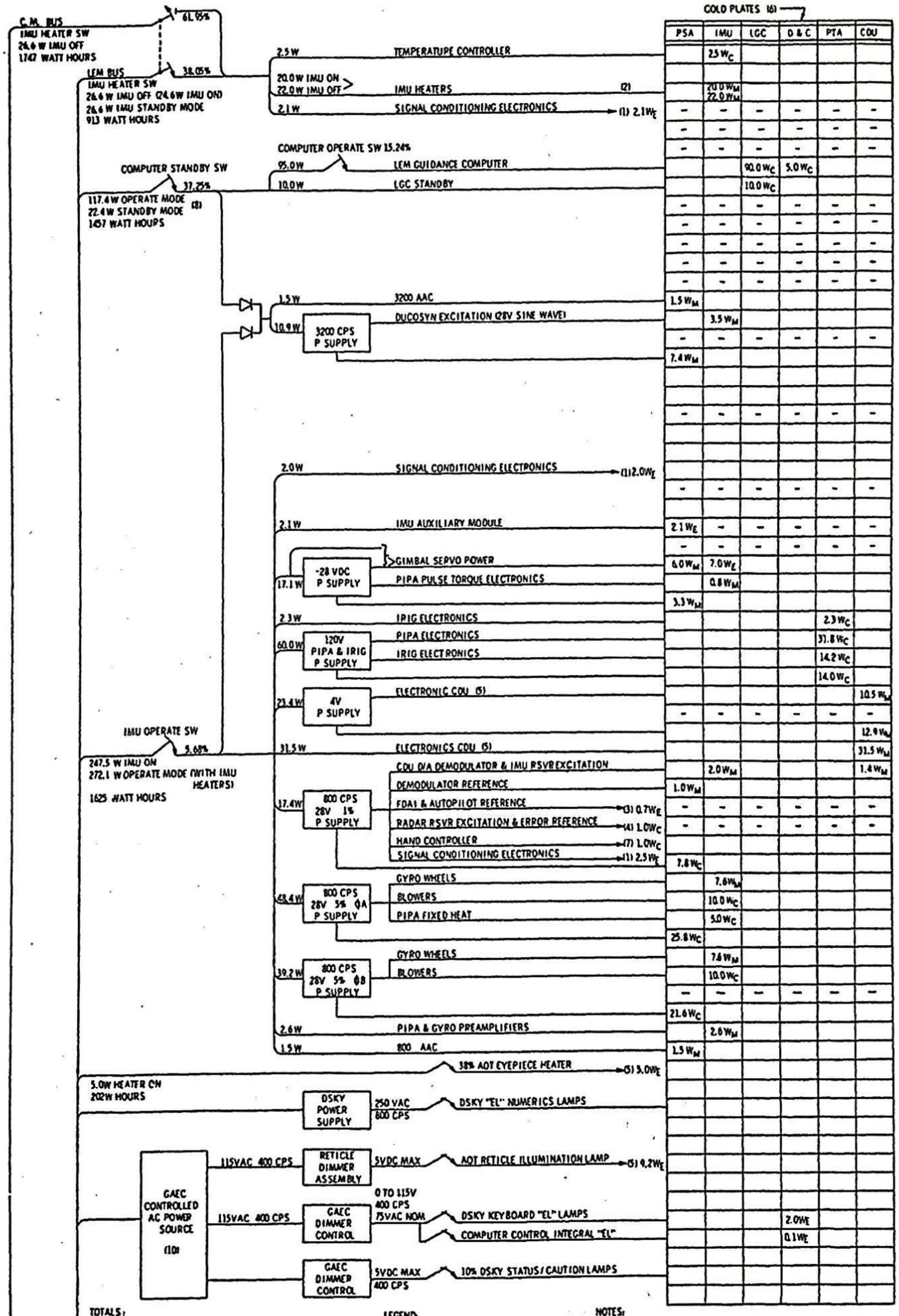
LEGEND:
C CALCULATED POWER
E ESTIMATED POWER
M MEASURED POWER

NOTES:
(1) TO SIGNAL CONDITIONING ASSEMBLY (OPER FLIGHTS)
(2) 22.0W - 0G ENVIRONMENT, 33.0W - 1G ENVIRONMENT
(3) TO STABILIZATION AND CONTROL
(4) REQUIRES NO THERMAL LOAD ON SPACECRAFT COOLANT
(5) TO EACH DUA EYEPIECE IN USE OR STORAGE
(6) MIT ASSUMES 100 PERCENT EFFECIENCY FOR ALL NAA POWER SUPPLIES

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



COLD PLATES (6)

PSA	IMU	LGC	D & C	PTA	COU
	2.5 W_C				
	20.0 W_M 22.0 W_M				
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
		90.0 W_C	5.0 W_C		
		10.0 W_C			
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
1.5 W_M					
	3.5 W_M				
–	–	–	–	–	–
7.4 W_M					
–	–	–	–	–	–
–	–	–	–	–	–
2.1 W_E	–	–	–	–	–
–	–	–	–	–	–
6.0 W_M	7.0 W_E				
	0.8 W_M				
3.3 W_M					
				2.3 W_C	
				31.8 W_C	
				14.2 W_C	
				14.0 W_C	
					10.5 W_M
–	–	–	–	–	–
					12.9 W_M
					31.5 W_M
	2.0 W_M				1.4 W_M
1.0 W_M					
–	–	–	–	–	–
–	–	–	–	–	–
7.8 W_C					
	7.6 W_M				
	10.0 W_C				
	5.0 W_C				
25.8 W_C					
	7.6 W_M				
	10.0 W_C				
–	–	–	–	–	–
21.6 W_C					
	2.6 W_M				
1.5 W_M					
			2.0 W_E		
			0.1 W_E		

NOTES:
(1) TO SIGNAL CONDITIONING ASSEMBLY (OPER FLIGHTS)
(2) 22.0 W ~ 0G ENVIRONMENT, 33.0 W ~ 1G ENVIRONMENT
(3) TO STABILIZATION AND CONTROL
(4) TO RADAR
(5) TO AOT (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-1 603	LM-2 605	LM-3 606	CSM-20 502	CSM98 2TV-1 202	CSM-101 204	CSM-102 205	CSM-103 206	CSM-17	122
INSTALLATION	X	X	X		(X)	(X)	(X)	X		X	
SUBSYSTEM CHECKOUT S/C	X	X			(X)	(X)				X	
INTEGRATED TEST S/C	X									X	
COMPLETE TESTING AT KSC											

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

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TABLE II

LM G&N SYSTEM CONFIGURATION

S/C	LTA-8		LM-1		LM-2	
COMPONENT NOMENCLATURE	System 602		System 603		System 605	
	Part No.	S/N	Part No.	S/N	Part No.	S/N
AGC	2003100-041	14	2003200-021	22	2003993-011	24
DSKY	2003985-051	13	2003994-011	38	2003994-011	43
IMU	2018699-021	2	2018601-051	13	2018601-071	6
ECDU	2010744-021	9	2007222-131	25	2007222-081	10
AOT	6011000-012	8	6011000-021	9	6011000-041	11

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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. LM 1, G&N System 603

   A. Replaced DSKY 2003950-011, S/N 28 with DSKY 2003944-011, S/N 38. DSKY was removed because it possibly contained contaminated relays.

   B. Replaced ECDU 2007222-131, S/N 12 with ECDU 2007222-131, S/N 25. ECDU was replaced because of intermittent failure, would not go to middle gimbal angle commanded.

2. LM 2, G&N System 605

   A. Replaced DSKY 2003950-011, S/N 19 with DSKY 2003994-011, S/N 43. DSKY was replaced due to relay problem noted above and "No Attitude Light" was burned out.

   B. Replaced IMU 2018601-051, S/N 21 with IMU 2018601-071, S/N 6. IMU 2018601-051, S/N 21 was previously reported as having been removed due to short in 800 ~ 5%.

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							2003200-041	19
DSKY (Main)							2003994-011	35
DSKY (Nav.)							2003950-011	40
IMU							2018601-081	14
CDU							2007222-091	16
OPTICS							2001100-034	16

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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. CM-102, G&N System 205

   A. Replaced AGC 2003200-031, S/N 19 with AGC 2003200-041, S/N 19. Replaced test connector cover to connect all inputs to ground to eliminate noise problem.

   B. DSKY (Navigation) Replaced 2003994-011, S/N 32 with DSKY (Navigation) 2003950-011, S/N 32. Replaced unit sent to KSC Simulation Laboratory.

   C. DSKY (Navigation) Replaced 2003950-011, S/N 32 with DSKY (Navigation) 2003950-011, S/N 40. S/N 40 transferred from S/C 101.

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

TABLE IV

G&N SYSTEM CONFIGURATION AT KSC

S/C	17	
COMPONENT NOMENCLATURE	System 122	
	Part. No.	S/N
AGC	1003700-051	14
DSKY (Main)	1003563-051	2
DSKY (Navigation)	1003706-051	10
IMU	1001500-091	11
CDU	1021304-031	4
OPTICS	2011000-024	7

DATE: June 1967

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

SECTION 6

G&N SYSTEM TEST

A. System Test Laboratory

1. G&N 5

System has been operating in the Space Navigator Facility approximately 8.3 hours during April and May.

2. G&N 104

a. Ran tests and prepared summary on IMU Performance Testing.

b. Experimented with auto system test procedures for utilizing both fixed and erasable memory to automatically run all positions of a test.

c. Ran 501 Simflight and experimented with various SPS1 updates corresponding to different SIVBSEP times.

d. Incorporated routines in IRIG Coefficient test to measure "ADOA" terms (Reference: STG Memo No. 1016).

e. Field Support

(1) S/C 017 at KSC

(a) K-Start tape verification including Simflight.

(b) Ran downlist for normal version of 501 Simflight.

(c) Experimented with optics positioning during Simflight to provide optimum exposure to reentry environment.

(d) Removed pin "59" from NAVDSKY (+28 VDC to luminescent power supply) and verified that there is no conflict with program moding or Simflight operation.

(2) S/C 020 at NAA

(a) Night-Watchman investigations included:

1) Resolved that TM-FAIL bit is not set by a system test associated with Sunrise 69 program.

2) Verified that normal restart generated by random CMC fail will not cause Night-Watchman to be de-activated.

(b) Investigated misuse of clear button with Sunrise 69 ropes. Confirmed conditions reported to NAA.

3. G&N 200

a. Program Tests

(1) Continued checkout of SUNDISK program assembly. Presently working with Revision #169. Performing a continuous checkout of JDC's in order to update and reflect procedure change due to SUNDISK program change.

(2) Programs P22, P51, P52, R51 and R52 of SUNDISK #161 were exercised. It was possible to take star sightings and compute a reference matrix.

b. Special Test

(1) Performed a power interrupt test. Interrupt was for a period of 25 ms. This caused multiple computer restarts.

(2) Verified that removal of capacitor in Sextant Trunnion MDA output eliminated single phase drive of trunnion motor.

(3) Performed checkout of Basic End to End Polarity Test. (Reference: STG Memo No. 1012).

(4) Performed special tests on the AGC to verify that erasable memory is not lost because of "Restarts" or power interruptions (Reference: STG Memo No. 1013).

(5) Procedure to eliminate problem involved in the IMU Performance Test (JDC 12217) was proved and written up. (STG Memo No. 984).

(6) Signal Conditioner input signals were checked and verified.

(7) Signal interface for Simflight test was checked out and verified.

(8) A thermal test to determine if redundant system cooling is required was performed. Data analysis is in process.

(9) Started checkout of Sundisk programs. Problem in IMU performance and test program was discovered and is being investigated. Also a problem was found in the program for Semi-Auto Mode Test (JDC 12216E). Problem was corrected by insertion of patch into program.

c. Failures

(1) Azimuth gyro failed. Scale factor increased by a factor of two (2). After gyro was replaced, failure was verified at Gyro test as wheel not reaching synchronous speed.

(2) Computer logic module A2 failed causing continuous "Restart".

d. Modifications

(1) AGC was updated to incorporate the "Proceed" button modification.

(2) Accomplished mechanized optics anti-creep circuit fix. Proposed fix appears to be very effective in eliminating hop on low-speed optics drive.

4. G&N 600

a. Three K-start tapes were checked out on the system.

b. Special test runs were made to measure rate of temperature rise with coolant shut down from stabilized normal coolant flow conditions.

c. Exercised programs in Sundance. Concentration was mainly on Radar routines including search patterns and System Test routine.

d. Performed Simflight procedure checkout with Sunburst (AS-206).

e. Performed a continuous 37 hour test of gyrocompassing in a near mission 206 launch orientation. The recorded OGA placed at a 16X null, showed a $\pm 0.2^{o}$ accuracy.

f. CRS S/N 2 was updated to a full complement of 36 K memory for use with Sundance and Sundisk. The CRS has to be time shared by the CM and LM test stations.

B. Test Programming

1. Mission 206

Gyrocompassing verified by long digital simulation (2 hours real time). Effects of hardware errors as reported earlier were substantiated by a 37 hour laboratory run (item 4e above).

2. Mission 278

Gyrocompassing program verified on digital simulator. Runs were acceptable with and without launch vehicle sway.

3. Mission 504

a. Command module coding of system tests and prelaunch reduced to one bank.

b. LM programs are coded and are awaiting availability of a master assembly for digital simulation.

c. Provided support to Systems Engineering Group for GSOP preparation.

C. Field Operations

1. KSC Site

CSM-17 (Mission 501) G&N 122

Spacecraft Transport (MSOB to VAB) target date is 12 June 1967. OCP-K-0005, S/C Pre-electrical Mate, will be repeated; targeted for 17 June 1967. The delay is due to scheduled S/C work completion and booster reinspection schedules; OCP's K-0006 and 0021 are in review and approval cycles. Countdown demonstration OCP-K-0033 and countdown OCP-K-0007 are in development.

2. GAEC Site

a. LTA-8 (Thermo-Vacuum) G&N 602

FEAT testing has been completed. "A" and "B" Harnesses have been pulled for replacement.

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

Completed retest of OCP-37025, Individual Systems Test. Retests of OCP-37030, Individual Systems Test, has been completed.

c. LM-2 (Mission AS-208) G&N 605

Completed OCP-61014, Flight Control Checkout. Vehicle shutdown for modification cycle until 30 June 1967.

d. LM-3 (Mission AS-503) G&N 606

System awaiting installation; AOT is installed.

e. LM-4 (Mission AS-504) G&N 607

G&N Laboratory testing delayed.

3. MSC Site

a. Completed preparations for Block II System to be used for CSM Simulations.

b. Supported Flight Control Division in running Sim Flights on System 109.

4. NAA Site

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

All Phase III equipment has been removed from the S/C.

b. CSM-98 (2 TV-1 Thermo Vacuum) G&N 202

All Phase II equipment has been removed from the S/C.

c. CSM-101 (Mission AS-207) G&N 204

All Phase II and Phase III equipment has been removed from the S/C. Phase II equipment will go to AC Electronics for modification.

d. CSM-102 (Mission AS-503) G&N 205

The System is installed and awaiting the start of OCP 6504, Individual Systems Test. 102 is to be recycled to manufacturing for modification and redesignated S/C 105.

e. CSM-103 (Mission AS-504) G&N 206

Awaiting receipt of Phase III hardware.

f. CSM-104 (Mission AS-505) G&N 207

Awaiting receipt of Phase III hardware.

D. System Engineering

1. Analysis and Testing

a. Data Sheets which define expected flight parameter for quick comparison with actual flight data to support the analysis of AS-501 are being prepared. STG Memo No. 986 was published suggesting an improvement in the data processing for AS-501 based on the experience of AS-202.

b. The Hybrid Program to simulate the AOT display on a CRT is complete, the program has not been run with the full LM simulation.

c. A program (Rope Searcher, STG Memo No. 1015) which checks for any reference to a channel with a particular instruction was prepared and used on the digital simulation. This program is particularly useful in performance of the discrete test.

d. STG Memo No. 1014 giving the system cause and results of all alarms was prepared and distributed. This was done as a first step in preparing the alarm test.

e. A test to verify the AOTNB program was run in the Laboratory and reported in System Test Group Memo No. 1006.

f. The work on planning the hardware software tests in the lab has continued. These tests plans will be formulated in the same manner as the Level III and IV plans for the hybrid and digital simulations, so that STG plans can be incorporated.

g. The polarity of one RCS DAP function was tested in the Lab (STG Memo No. 1012). Work is continuing to assist the mission programmers by developing polarity test procedures for MIT use.

h. Support was provided to the Mission Operation Group by performing portion of the optics program tests, reviewing AS-504 optics procedures, and preparing a flow chart and description of the IMU Performance Tests.

i. Support was provided to MSC for AOT testing at Kitt's Peak, Arizona. This testing indicated problems due to reflected incident light and solutions were suggested.

2. Spacecraft Operation Support

a. A spacecraft polarity test which is logically complete was proposed for KSC use. STG Memo No. 1005 will be published describing this. The test was modified to be run in the System Test Lab and the procedure verified (STG Memo No. 1012).

b. The gyro scale factor test was sucessfully assembled in E-Memory. A PIPA orthogonality test was designed and will be assembled in June. The SETCOARS program which puts the system in coarse align for MGA greater than 90^{o} is being changed so that gyro torquing can not be commanded in coarse align. Other possible effects of this change are being investigated.

c. Graphs of G/N 122 (AS-501) gyrocompassing and relative fine align performance were plotted for those supporting the Flight Readiness review.

d. A letter (AG: 171-66) outlining the recommended optics position during AS-501 was published.

3. KSC Checkout Support

a. Sold-off to NASA K-Start Tape F04C 017-K 00072-00 G&N SCS End to End Ramp Test (closed loop). Reference: STG Memo No. 1002.

b. CSM RCS DAP testing per STG Memo No. 1005, Basic End to End Polarity (BEEP), was conducted in the System Test Laboratory using SUNDISK program assembly.

c. STG Memo No. 1012 was written verifying CSM RCS DAP Programming and operation.

4. E-Memory Programming

Work has continued on the program to provide an E-Memory program for the IRIG scale factor test. A verification plan for the associated K-START tapes was developed and coordinated with AC.

5. Support of Mission Programming Group

Support was given to the mission programming for changes in the FRESH START and RESTART routines and for certain of the extended verbs. The work on extended verbs will continue and additional support will be given to define a polarity test for the DAP.

E. Special Test Equipment

1. An investigation is underway to determine whether an IRIG temperature measurement should be built into the PSAAM as a convenient test to measure whether wheel gaussing has occured.

2. The Digistore Pack was completed.

3. An additional source of downlink strobe pulses is being provided for the System Test Laboratory.

4. Assistance is being provided to the Digital DevelopmentGroup in the manufacture of additional CRS's. Steps have been taken to insure that STG has the capability to maintain the CRS, CTS etc. through the initiation of computer courses.

5. Documentation for Hybrid II is being completed.

6. A new cable is being built for Hybrid I computer interface.

7. A new cable is being built for the System Test Laboratory to allow a CRS to be used with either the Block II or LM stations from a central location.

SECTION 7

G&N COMPUTER STATUS

A. Analysis Facility

1. Design Analysis

Very little design analysis was performed during the reporting period due to AGC C200 being shipped to the manufacture for rework and AGC C1M being used as spare parts for other systems. However, some studies were performed with AGC C1M concerning "Power Turn ON" transients in the AGC Master Clock output, which did not require a fully operational computer. Problems have been encountered at GAEC when the AGC is powered up; the Abort Guidance Computer loses its memory. Photographs show that transients sometimes occur in the AGC clock output for approximately .5 to 1.0 ms. before reaching a steady output. This phenomenon was attributed to the slow build up of the AGC oscillator, and the characteristics of the counter when inputs of marginal amplitude are applied. (Reference: MIT/IL Letter No. AG-167-67).

2. Miscellaneous AGC Related Activities

a. Channel 77 Alarm Box

A breadboard Alarm box was fabricated by STG personnel and a preliminary functional checkout was performed. Further analysis of timing and noise margins, etc. will be performed.

b. Additional memories were fabricated and checked out for the existing core rope simulators to bring the capability of all Block II CRS's up to 36K, the amount required to check out new programs.

c. Fabrication of New Monitors

Mechanical work on S/N 5 is approximately 90% complete; all hardware has been mounted to the front panels. A wire wrapping "jig", so that the logic plates can be machine wrapped.will be prepared.

B. Programming

1. Keyboard and Display

An effort was undertaken in conjunction with 23B to modify the Keyboard and Display Program so that it could be moved to Superbanks. Extensive checkout was done on the all digital simulation.

2. Self-Check

a. Testing was done on the improvements to the way Fresh Start and Restart Programs handle the E-memory restoration situation for Self-Check.

b. Testing was done of BANKSUM Programs in conjunction with a bank full of program (and no TC SELF).

c. Self-Check was moved to a Superbank and checked out in operation there.

d. Meetings were attended with Raytheon regarding the new diagnostic capabilities of the revisions to the NU SPEAK ropes.

C. EMI Qualification Test Results

A preliminary review of the electromagnetic interference qualification test results was made. The information available was primarily that contained on Figure 1. These figures contain the out of specification conditions as they existed May 4, 1967.

The information (the conducted power line interference) on Fig. 1 is felt to be the most important. In analyzing this information three logical criteria were used.

1. That the same frequencies should be present in the 28 volt line as on the 0 volt line.

2. That the 28 volt line readings should be higher than the 0 volt line because of the high 0 volt to chassis capacitance.

3. That interference frequencies should correspond to data obtained at MIT on System 202.

On the 28 VDC line the 154K noise looks reasonable (based on data available) and AC Electronics has traced it to the AGC. The 167K and 180K hz signals have been reported by AC Electronics as being present in the pk but not in the carrier modes. This implies it is pulsed cw and should be compared to the broadband limits and therefore are not out of specification.

The 18-24 Mhz noise has been traced by AC Electronics to the gyro pulse torquing relay.

The 1.65 Mhz has been traced to the DSKY lights all going on and off (V35-36).

On the 0 volt line the 140, 180, and 400 cps readings do not show up on the 28V lines and vary from day to day frequency wise. Since (based on data available) these are 10 amp levels and not seen at MIT it is felt that they are peculiar to the test station.

MIT has suggested that the G&N be run on batteries to see if these signals would disappear.

The 154 Khz and 167 Khz are the same as those above.

The 308 Khz signal was not repeatable and disappeared while the 358 Khz signal was present when the system was off.

Summarizing Fig. 1, it looks like there are three out of specification frequencies 154K, 18-24M, and 1.65 Mhz. On Fig. 2, all the TVC pitch high line signals are really in specification. The 50 db signal would result in a 315 μa signal across a load of 20.1K or a 6.3 volt noise signal. The ICD requires noise less than 50 mv. The 50 db level was traced by AC Electronics to an operator error and really is 22db. This level signal is around 250 mv and would violate the ICD but MIT suspects that it is pickup in the GSE. The 3.9 Mhz signal was traced by AC Electronics to a counter in the GSE.

The signal conditioner out of specification condition has also been traced by AC Electronics to an operator error. This would have been interpreted as a 4 amp signal into a 1 meg load which is obviously incorrect.

The noise on the 115V 400 cps line is suspect too. Earlier data from AC Electronics had indicated more out of specification readings than these and this was traced to the LSN being in backwards. This implies that the source was noisier than the load. An examination indicated that this is quite possible since the relays opening in the DSKY could cause an inductive kick in the supply transformer coupling over into the 60-70 volt line. The data reading taken probably is this type of noise. From examining the ICD's GAEC will supply DC to the display lights and NAA doesn't appear to have any inductive components in the loop.

In summary it is felt that none of the out of specification conditions on Fig. 1 actually exist. The radiated data has not been closely analyzed. A feeling for this type of information has to be developed. It is suggested that comparable data from other spacecraft systems would be helpful.

It is felt that all this interference could be eliminated (theoretically) by wrapping the harnesses with more shielding. MIT suggested to AC Electronics that they wrap the cables with aluminum foil to see if all the readings would go down and in an attempt to ascertain whether the cables or connectors were radiating. This wasn't done.

A meeting is scheduled to be held where the test will be analyzed more completely.

EMI BLOCK II QUALIFICATIONS TEST RESULTS

	Freq.	Measure db	Spec Limit	Type	Instr.	Mode
I. Conducted Interference						
1. 28 VDC High	154K	84	80	Narrow Band	Stab Network	Coarse Align
	167K	82	80	NB	SN	CA
	180K	81	80	NB	SN	Gyro Compass
	18-24M	113	100	BB	SN	GC
	1.65M	105	103	BB	Current Probe	DSKY Switch
2. 0 VDC	140	148	132	NB	CP	Coars Align
	180	145	132	NB	CP	CA
	400	139	132	NB	CP	CA
	154K	84	80	NB	SN	CA
	167K	82	80	NB	SN	CA
	308K	121	120	BB	SN	CA
	358K	124	120	BB	SN	CA
3. TVC Pitch High Line	3.5M	50	40	NB	CP	GC
	3.9M	52	40	NB	CP	GC
	5.1M	54	40	NB	CP	GC
	9.0M	48	40	NB	CP	GC
4. Signal Conditioner Torque Motor O. G. I.	32	132	115	NB	CP	Coarse Align
5. 115V 400 cps	8.9-10.3M	115	110	BB	SN	DSKY Switch MD Chng.
II. Radiated Interference						
	1.018M	64/58*	60	NB		Gyro Compass
	2.9M	64/58	60	NB		GC
	5.07M	61/-	60	NB		GC
	19.6M	63/59	60	NB		GC
	27.6M	89/89	80	BB		GC
	30M	98/104	80	BB		GC
	30.7M	100/105	80	BB		GC
	39M	89/85	80	BB		GC
	3.02M	61/60	60	NB		Coarse Align
	11.1M	61/62	60	NB		CA
	19.5M	63/62	60	NB		CA
	21.8M	63/59	60	NB		CA
	25M	64/61	60	NB		CA
	27.5M	88/83	80	BB		CA
	28.5M	89/-	80	BB		OPT SW Sys. Mod.

*64/58 - 64 is first measurement, 58 is repeated measurement.

Fig. 1

SECTION 8

GUIDANCE COMPUTER PROGRAMMING

Apollo Guidance Computer Programming Summary
for the Month of April and May

Mission AS-501

Continued analysis of the released and manufactured program for Mission AS-501 has been preformed. From this analysis ground procedure have been revised and program limitations defined.

Mission AS-206

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.

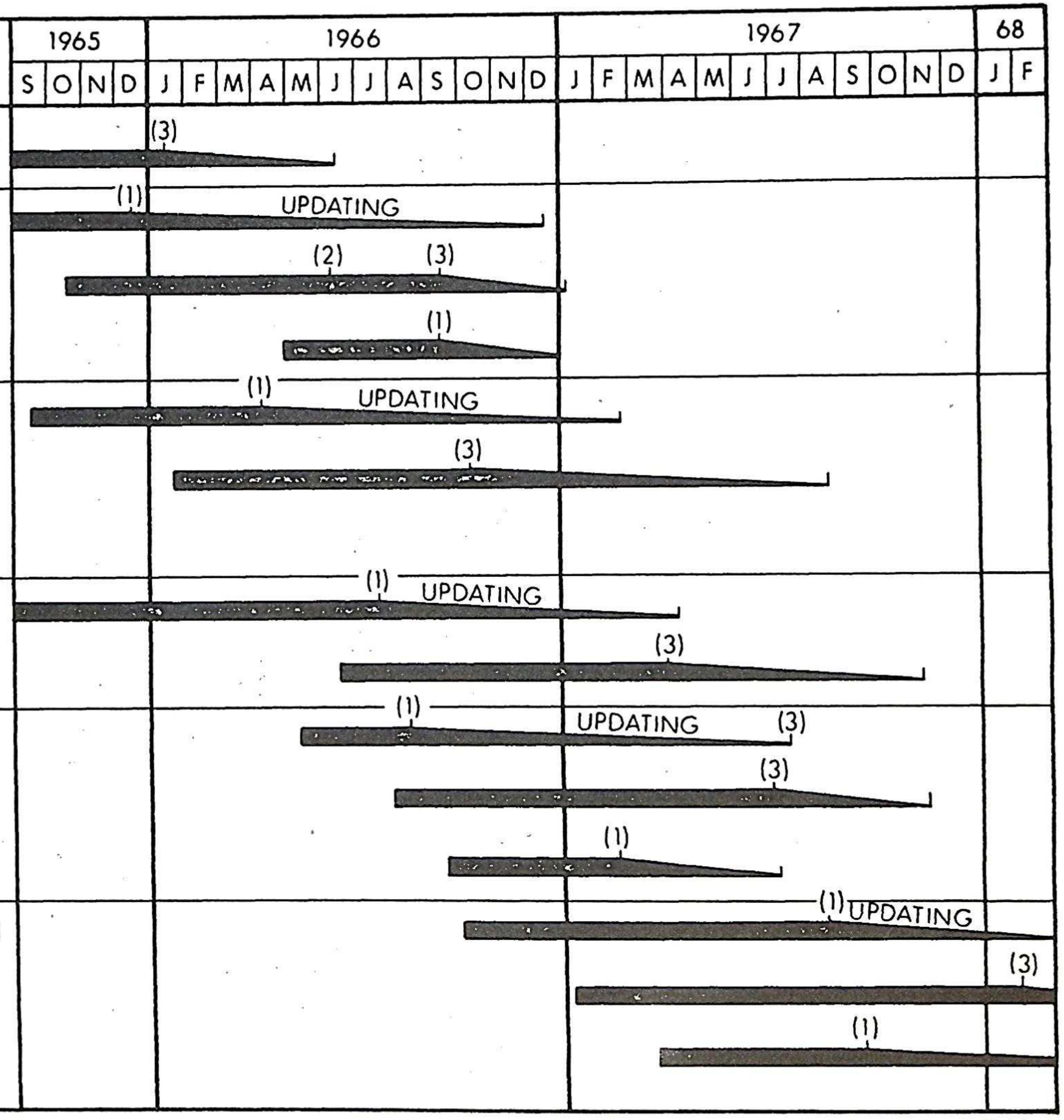
Mission AS-205

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 July but rope manufacturing will not start until late - October.

Mission AS-504

The Guidance Software Operations Plan (GSOP) for Mission AS-504 is under preparation with complete preliminary copies scheduled for mid-July and final publications scheduled for mid-August. Selected portions of Sections 4 and 5 of the GSOP were submitted to NASA/MSC for comments. Work is underway on the program formulation and equation testing for the computer program. The "A" release of the program for rope manufacturing is expected by early February 1968.

MISSION	ITEM
202	COMPUTER PROGRAM DEVELOPMENT
204	GUIDANCE SYSTEM OPERATIONS PLAN
	COMPUTER PROGRAM DEVELOPMENT
	OPERATIONS HANDBOOK
501/502	GUIDANCE SYSTEM OPERATIONS PLAN
	COMPUTER PROGRAM DEVELOPMENT
206	GUIDANCE SYSTEM OPERATIONS PLAN
	COMPUTER PROGRAM DEVELOPMENT
205	GUIDANCE SYSTEM OPERATIONS PLAN
	COMPUTER PROGRAM DEVELOPMENT
	OPERATIONS HANDBOOK
504	GUIDANCE SYSTEM OPERATIONS PLAN
	COMPUTER PROGRAM DEVELOPMENT
	OPERATIONS HANDBOOK



(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

FIXED MEMORY ALLOCATION CHART

CMC

	AS-205 SUNDISK (actual)	AS-504 COLOSSUS (estimated)
I. Control Programs		
A. DSKY		
Pinball	2793	3000
Extended Verbs	471	793
Keyrupt and Uprupt	80	80
Display and Priolarm	670	700
Down Telemetry List & Program	600	600
Program Select Check	200	210
B. Interpreter and Executive		
Interpreter	2271	2271
Waitlist	233	233
Delayjob	43	43
Executive	328	328
Restart Tables & Routines	294	374
Fresh Start and Restart	298	423
Phase Change and New Phase	158	160
T4 Rupt	753	753
Alarm and Abort	63	63
Self Check	986	966
Interrupt Lead In	52	52
RTB OP Codes	211	200
End Bank Marks	108	36
Interbank Communication	88	88
C. Other		
Digital Auto-Pilot	3215	3124
Saturn and CM Tests	550	----
Transformations	600	600
Gyro Torquing (R-55)	42	44
SVDWN	30	30
TOTAL - DSKY and Interpreter and Executive and Other	15137	15171

	AS-205 SUNDISK (actual)	AS-504 COLOSSUS (estimated)
II. CMC Routines		
A. Basic Routines		
Conic Subroutines	845	1300
Orbital Integration	1122	1204
Latitude, Longitude & Altitude	216	200
Lunar and Solar Ephemeris	----	80
LOCSAM	127	----
Lunar Rotation	----	200
Initial Velocity	188	188
Rendezvous Parameters	----	100
Maneuver Specification	205	199
Maneuver Calculation	829	560
Attitude Drive	1069	735
Mid Gimbal Display	33	40
B. Targetting		
TPI	275	290
PERIAPO	34	34
Midcourse Maneuver (S35.1)	55	54
Return to Earth (Near Earth)	----	1000
LOPC	----	150
TPI Search	----	200
Landing Time Prediction	----	200
C. Navigation		
Cislunar Midcourse	----	300
Rendezvous	380	440
Lunar Orbit	555	555
Measurement Incorporation	408	422
Preferred Tracking Attitude	303	350
Sight Mark (R-53)	39	40
SXT Mark	296	350
D. Entry		
Entry Calculations	1284	1300
Preentry Computations (S61.2)	128	140
Gimbal Angles for Separation (S61.3)	32	35
IMU Entry Status (S61.1)	81	80
Trim Gimbal Angles (S62.3)	29	35
DAP Entry	799	773
Apogee, Perigee and T_{FF}	326	334

		AS-205 SUNDISK (actual)		AS-504 COLOSSUS (estimated)	
E.	Powered Guidance				
	Cross Product Steering (S40.8)	124		125	
	Vg Calculation (S40.9)	77		100	
	Time of Burn Calculation (S40.13)	66		77	
	Servicer	401		500	
	Desired Thrust Direction (S40.1)	149		270	
	Wings Level (S40.2, 3)	173		173	
	NEWSC	17		17	
F.	IMU and Optics				
	IMU Compensation	258		258	
	IMU Status Check (R02)	17		17	
	Coarse Align Cal 53A	64		64	
	Fine Align (R51)	78		75	
	Auto-Optics Positioning (R52)	317		317	
	Target Determination(SR52.1)	88		88	
	Compute Gimbal Angles (Present)(S52.2)	35		35	
	Compute Gimbal Angles (Desired)(S53.1)	9		9	
	Pick-A-Pair	131		135	
	Star Data Test (R54)	53		53	
	IMU Mode Switching	531		531	
	Star Catalog	260		263	
	Landmark Catalog	----		150	
G.	Boost				
	Boost Routine	83		100	
	Saturn Takeover	47		100	
TOTAL - CMC Routines			12636		15345
III.	CMC Programs				
	P-01-P03 Prelaunch Align Calib.	865		1048	
	P-05 GNCS Startup	57		57	
	P-06 CMC Power Down	61		61	
	P-07 System Test	2489		----	
	P-11 EOI Monitor	133		150	
	P-15 TLI	----		250	
	P-17 TPI Search	----		50	
	P-20 Rendezvous Navigation	67		100	
	P-21 Ground Track Det.	35		50	
	P-22 Lunar Orbit Navigation	270		270	

	AS-205 SUNDISK (actual)	AS-504 COLOSSUS (estimated)
P-23 Cislunar Midcourse Navigation	74	75
P-25 Predicted Lunar Landing	----	50
P-27 CMC Update	233	250
P-30 External Delta V	229	245
P-31 General Lambert	----	120
P-32 Lunar Orbit Insertion (LOI)	----	120
P-33 Lunar Orbit Plane Change (LOPC)	----	120
P-34 Transfer Phase Initiation (TPI)	262	265
P-35 Transfer Phase Midcourse (TPM)	84	100
P-37 Return to Earth (Near Earth)	----	100
P-40 SPS	560	560
P-41 RCS	154	155
P-47 Thrust Monitor	124	125
P-51 IMU Orientation Determination	130	140
P-52 IMU Realign	164	164
P-53 IMU Realign Backup	----	100
P-61 Maneuver to CM/SM Sep. Att.	41	50
P-62 CM/SM SEP. and Preentry Maneu.	46	120
P-63 Entry Initialization	10	20
P-64 Post 0.05G	7	20
P-65 Up Control	----	20
P-66 Ballistic	----	20
P-67 Entry Final Phase	40	35
P-70 Safe Perilune Targetting	----	120
P-74 LM TPI Targetting	11	25
P-75 LM TPM Targetting	10	25
P-77 LM TPI Search	----	25
R-03 Load DAP Data	32	40
R-05 S-Band Pointing	----	50
R-23 Rendezvous Tracking Data Process (Dock Ret)	----	150
R-30 Orbital Parameter Display	110	110
R-31 Rendezvous Parameter Display	68	68
R-32 Target Delta V	89	94
R-33 CMC/LGC Clock Sync.	----	24
TOTAL - CMC Programs	6455	5741
GRAND TOTAL	34228	36257
Remaining Fixed Memory	2636	607

	AS-504 SUNDANCE (estimated)
I. Control Programs	
A. DSKY	
Pinball	3000
Extended Verbs	900
Keyrupt and Uprupt	80
Display and Priolarm	700
Down Telemetry List & Program	600
Program Select Check	200
B. Interpreter and Executive	
Interpreter	2118
Waitlist	220
Executive	335
Restart Table and Routines	374
Fresh Start and Restart	307
Phase Change and New Change	160
T4 Rupt	848
Alarm and Abort	70
Self Check	966
Interbank Communications	88
Interrupt Lead In	52
RTB OP Codes	209
End of Bank Marks	36
C. Other	
Digital Auto-Pilot	3694
Transformations	879
Gyro Torquing (R55)	44
TOTAL - DSKY and Interpreter and Executive and other	15880
II. LGC Routines	
A. Basic Routines	
Conic Subroutines	1300
Orbital Integration	1200
Latitude, Longitude, & Altitude	200
Lunar and Solar Ephemeris	80
Lunar Rotation	20
Initial Velocity	188

		AS-504 SUNDANCE (estimated)
	Rendezvous Parameters	100
	Maneuver Specification	215
	Maneuver Calculation	560
	Attitude Drive	175
	Mid Gimbal Display	68
	Radar Subroutines	600
	Radar Rupts	176
B.	Targetting	
	Predicted Landing Time	200
	DOI	150
	Predicted Launch Time (CFP)	400
	Predicted Launch Time (TPI)	100
	CSI	540
	CDH	390
	TPI	290
	Midcourse Maneuver (S35.1)	54
	TPI Search	200
C.	Navigation	
	Rendezvous	520
	RR Lunar Surface	100
	Measurement Incorp	420
	Preferred Tracking Attitude (R-61)	60
	AOT Mark	350
	Radar Test	60
	RR Search Designation Read.	560
D.	Powered Guidance	
	Cross Product Steering (S40.8)	190
	VG Calc (S40.9)	77
	Servicer	600
	Desired Thrust Direction (S40.1)	238
	Time of Burn Calc (S40.13)	100
E.	IMU and Optics	
	IMU Compensation	258
	IMU Status Check (R02)	17
	Coarse Align Cal 53A	64
	Fine Align (R-51)	75

	AS-504 SUNDANCE (Estimated)	
Auto-Optics (R-52)	42	
Pick-A-Pair	135	
Star Data Test (R-54)	52	
IMU Mode Switch	531	
Anytime Align	100	
Star Catalog	225	
TOTAL - LGC Routines		12160
III. LGC Programs		
P-00 LGC Idling	50	
P-02 AGS Initialization	100	
P-04 Lunar Surface Checkout	250	
P-05 LGC Startup	57	
P-06 LGC Power Down	60	
P-07 System Tests	724	
P-10 Predicted Launch Time (CFP)	100	
P-11 Predicted Launch Time (TPI)	100	
P-12 Powered Ascent Guidance	700	
P-17 TPI Search	49	
P-20 Rendezvous Navigation	160	
P-21 Ground Track Determination	50	
P-22 RR Lunar Surface Navigation	50	
P-25 Preferred Tracking Attitude	50	
P-27 LGC Update	250	
P-30 External ΔV	150	
P-32 CSI	145	
P-33 CDH	146	
P-34 TPI	255	
P-35 TPM	100	
P-40 DPS	750	
P-41 RCS	250	
P-42 APS	25	
P-47 Thrust Monitor	120	
P-50 Docked IMU Align	25	
P-51 IMU Orientation Determination	120	
P-52 IMU Realign	160	
P-53 Backup IMU Orientation Determination	25	
P-54 Backup IMU Realign	25	

			AS-504 SUNDANCE (estimated)
P-55 IMU Surface Align (Normal)			319
P-56 IMU Surface Align (Backup)			50
P-57 Anytime Launch Align			50
P-60 Predicted Lunar Landing			50
P-61 DOI			100
P-63 Braking Phase			
P-64 Approach Phase			
P-65 Landing Phase (Automatic)			1516
P-66 Landing Phase (Rate of Descent)			
P-67 Landing Phase (Manual)			
P-70 DPS Abort			100
P-71 APS Abort			
P-72 CSM CSI Targetting			30
P-73 CSM CDH Targetting			35
P-74 CSM TPI Targetting			25
P-75 CSM TPM Targetting			25
P-76 TEI Backup			120
R-03 Load DAP Data			140
R-04 RR Self Check			75
R-05 S-Band Pointing			90
R-30 Orbit Parameter Display			110
R-31 Rendezvous Parameter Display			35
R-32 Target ΔV			100
R-33 CMC/LGC Clock Sync			24
TOTAL - LGC Programs			8040
GRAND TOTAL			36080
Remaining Fixed Memory			784

CMC PROGRAM UTILIZATION AS-504

MAY, 1967

MISSION PHASES \ CMC CONTROL PROGRAMS -AS-504	P01 Prelaunch Initialization	P02 Gyro Compassing	P03 Optics Verification of Az.	P05 CMCS Startup	P06 CMCS Power Down	P11 EOI Monitor	P15 Translunar Injection (TLI)	P17 TPI Search	P20 Rendezvous Navigation	P21 Ground Track Determination	P22 Orbital Navigation	P23 Cislunar Midcourse Navigation	P25 Predicted Lunar Landing	P27 CMC Update	P30 External ΔV	P31 General Lambert Maneuver	P32 Lunar Orbit Insertion (LOI)	P33 Lunar Orbit Plane Change	P34 Transfer Phase Initiation (TPI)	P35 Transfer Phase Midcourse	P37 Return to Earth	P40 SPS Thrust Maneuver	P41 RCS Thrust Maneuver	P47 Thrust Monitor	P51 IMU Orientation Determination	P52 IMU Realign	P53 Back Up IMU Orient. Det.	P61 Entry Maneuver to CM/SM Seperation	P62 Entry CM/SM Seperation and Pre-entry	P63 Entry Initialization	P64 Entry Post ΔV DSG	P65 Entry Up-Control	P66 Entry Ballistic	P67 Entry Final Phase	P70 Safe Perilune	P74 CM TPI Targeting	P75 LM TPMI Targeting	P77 CM TPI Search	R09 Load GAP Data	R05 Sextant Sighting	R23 Rend Trk Data Process (Dock. Ref)	R30 Orbit Parameter Display	R31 Rendezvous Parameter Display	R22 Target ΔV	R33 CMC/GSE Clock Sync
1. Earth Prelaunch	✓	✓	✓	✓	✓									✓																														
2. Earth Orbit Injection (EOI)						✓																																						
3. Earth Orbit Phase							✓							✓												✓	✓													✓				
4. Translunar Injection (TLI)							✓							✓										✓																✓				
5. Translunar Phase				✓	✓							✓S		✓C	✓C	✓G						✓	✓	✓	✓	✓	✓											✓	✓				
6. Lunar Orbit Insertion (LOI) Prethrust & Maneuver														✓			✓					✓				✓	✓											✓	✓				
7. Lunar Orbit Phase Prior to DOI									✓	✓S	✓		✓	✓G																							✓	✓		✓	✓		
8. Descent Orbit Injection & Descent Coast Phase									✓																												✓	✓			✓		
9. Powered Lunar Landing									✓																												✓	✓					
10. Lunar Surface Phase to 3 orbits Before LM Launch				✓	✓					✓S	✓S			✓G											✓	✓	✓										✓	✓		✓			
11. Lunar Prelaunch Phase (Final 3 orbits before LM Ascent)				✓						✓S	✓S			✓G			✓S			✓				✓	✓	✓										✓	✓		✓			
12. LM Powered Ascent									✓																												✓	✓					
13. Rendezvous Phase (LM Active)									✓	✓S				✓G											✓	✓										✓	✓	✓	✓	✓	✓	✓	✓
14. Lunar Orbit Pre TEI										✓S	✓S			✓G											✓	✓										✓	✓		✓			
15. Transearth Injection (TEI) Prethrust & Maneuver														✓G		✓G					✓S	✓			✓	✓										✓	✓					
16. Transearth Phase				✓	✓							✓S		✓G	✓G	✓G					✓S	✓	✓		✓	✓	✓										✓	✓		✓			
17. Entry Phase																												✓	✓	✓	✓	✓	✓	✓			✓	✓					
18. LM Rescue (CSM Active)								✓S	✓	✓S				✓G	✓G	✓G		✓	✓			✓	✓				✓	✓									✓	✓		✓		✓	
19. Abort From Earth Orbit Prethrust & Maneuver														✓G	✓G	✓G					✓S	✓	✓				✓	✓									✓	✓					
20. Abort from TL, LO, or TE Phase Prethrust & Maneuver														✓G	✓G	✓G					✓S	✓					✓	✓							✓S		✓	✓					

KEY: ✓ = Program Required
S = Program required for self-contained capability only.
G = Program required for ground navigation target capability only.

CMC PROGRAM / ROUTINE RELATIONSHIPS & SIZES

MAY, 1967

CMC Control Programs (sizes: SUNDISK AS-258 / COLOSSUS AS-504)

Program	Name	SUNDISK AS-258	COLOSSUS AS-504
P01	Prelaunch Initialization	← 865 →	← 1098 →
P02	Gyrocompassing		
P03	Optical Verification of Azimuth		
P05	CMCS Startup	57	57
P06	CMCS Power Down	61	62
P07	System Test	2484	—
P11	EOI Monitor	133	150
P15	Translunar Injection (TLI)	—	250
P17	TPI Search	—	50
P20	Rendezvous Navigation	67	100
P21	Ground Track Determination	35	50
P22	Orbital Navigation	272	270
P23	Cis-Lunar Midcourse Nav.	74	15
P25	Predicted Lunar Landing	—	50
P27	CMC Update	233	250
P30	External ΔV	229	240
P31	General Lambert Maneuver	—	120
P32	Lunar Orbit Insertion (LOI)	—	120
P33	Lunar Orbit Plane Change	—	120
P34	Transfer Phase Initiation (TPI)	262	240
P35	Transfer Phase Midcourse	84	100
P37	Return to Earth Target	—	130
P40	SPS Thrust Maneuver	560	560
P41	RCS Thrust Maneuver	174	130
P47	Thrust Monitor	128	125
P51	IMU Orientation Determination	182	140
P52	IMU Realign	144	144
P53	Back Up IMU Orient. Det.	·	100
P61	Entry Maneuver to CM/SM Sep.	47	50
P62	Entry CM/SM Sep. and Pre-Entry	46	120
P63	Entry Initialization	10	20
P64	Entry Post 0.05 G	7	20
P65	Entry Up-Control	··	20
P66	Entry Ballistic	··	20
P67	Entry Final Phase	40	35
P78	Safe Perigee	··	120
P74	LM TPI Targeting	18	25
P75	LM TPM Targeting	10	25
P77	LM TPI Search	—	25
R03	DAP Data Loads	32	40
R05	S-Band Pointing	—	30
R27	Rend. Int. Data Process. (Clock Rd.)	~	150
R30	Orbit Parameter Display	110	150
R31	Rend. Parameter Display	88	48
R32	Target ΔV	89	94
R33	CMC/LGC Clock Sync.	·	24
TOTAL		4,435	5,741

CMC Routines

CMC Routine	AS-258	AS-504	Used by CMC Control Programs (✓)
BASIC ROUTINES			
Conic Subroutines	843	1,300	P15, P17, P20, P21, P22, P23, P25, P30, P31, P32, P33, P34, P35, P37, P40, P41, P52, P61, P78, P74, P75, P77, R30, R31, R32
Orbital Integration	1,128	2,758	P17, P20, P21, P22, P23, P25, P30, P31, P32, P33, P34, P35, P37, P40, P41, P61, P78, P74, P75, P77, R32
Lat., Long., Alt.	214	200	P21, P22, P23, P37, P67
Lunar & Solar Eph.	·	40	P23, P37, P52, P78
LOCSAM	127		
Lunar Rotation	—	200	P21, P22, P23, P25, P33
Lat, Vel	105	105	P15, P31, P34, P35, P40, P41, P74, P75
Rendezvous Parameters	—	100	P34, P35, P74, P75, R31
Maneuver Spec. (R10, R12)	205	199	P20
Maneuver Calculation	129	340	P15, P20, P40, P41, P61
Attitude Drive	1,060	735	P20, P40, P41, P61
Rel. Gimbal Display	33	40	P15, P30, P31, P32, P33, P34, P35, P37, P78
TARGETING			
TPI	275	290	P34, P74
Perigee	34	34	
Midcourse Maneuver (S35.1)	15	14	P35, P75
Return to Earth (Near Earth)	—	1,600	P37, P78
LOPC	—	150	P33
TPI Search	—	250	P17, P77
Landing Time Pred.	—	250	P25
NAVIGATION			
Cislunar Midcourse	—	300	P23
Rendezvous (R21, R22)	180	440	P20
Lunar Orbit	395	555	P22
Meas. Incorp.	428	422	P20, P22, P23
Preferred Track Att. (R61)	328	350	P20, P22
Sighting Mark (R53)	39	40	P22, P23, P51, P52
SXT Mark	246	250	P20, P22, P23, P51, P52
ENTRY			
Entry Calculations	1,254	1,300	P64, P65, P66, P67
Preentry Computations (S61.2)	128	140	P63
Gimbal Angles for Sep. (S61.3)	32	35	P61
IMU Entry Status (S61.1)	81	80	P61, P62
Trim Gimbal Angles (S62.3)	29	35	P62, P63
DAP Entry (S62.1, S62.2)	199	173	
Apogee, Perigee, T_{FF}	326	534	P40, P41, R30
POWERED GUIDANCE			
Cross Product Steering (S40.8)	120	125	P15, P40
Vg Calc. (S40.9)	77	100	P15, P40, P41
Time of Burn Calc. (S40.13)	66	77	P30, P31, P32, P33, P34, P35, P37
Servicer	403	500	P15, P40, P41, P47, P61, P62, P63, P64, P65, P66, P67
Desired Thrust Direction (S40.1)	149	270	P15, P40, P41
Wings Level (S40.2, .3)	123	123	
AEWSC	17	17	
IMU & OPTICS			
IMU Comp.	258	258	P01, P02, P15, P40, P41, P51, P52, P53, P61, P62, P63, P64, P65, P66, P67
IMU Status Check (R02)	17	17	P20, P22, P40, P41, P51, P52, P53
Coarse Align (CA, 53A)	64	64	P51, P52, P53
Fine Align (R51)	75	75	P51, P52, P53
Auto Optics Positioning (R52)	317	317	P20, P22, P52
Auto Optics Positioning (S52.1)	38	38	
Compute Gimbal Angles (Prepared S52.11)	37	35	
Compute Gimbal Angles (General S33.1)	9	9	
Pick-A-Pair	131	135	P52, P53
Star Data Test (R54)	53	55	P51, P52, P53
IMU Mode Switching	331	331	P20, P22, P51, P52, P53
Star Catalog	250	252	P22, P23, P51, P52, P53
Landmark Catalog	—	150	P22, P23
BOOST			
Boost Routine	81	100	P11
Saturn Takeover	47	100	P11, P15
TOTAL	12,436	15,345	

	AS-258	AS-504
DSKY		
Pinball	2793	3000
Extended Verbs	471	793
Keyrupt & Uprupt	80	80
Display Programs	675	750
Down Telemetry List & Program	600	600
Program Select Check	200	250
INTER & EXEC		
Interpreter	2271	2271
Waitlist	233	233
Delayjob	43	43
Executive	329	329
Restart Tables & Routines	294	378
Fresh Start & Restart	278	425
Phase Change & Newphase	158	160
T 4 Rupt	753	755
Alarm & Abort	43	63
Self Check	986	966
Interrupt Lead Ins	52	52
BBT OP Codes	211	200
End Bank Marks	108	36
Interbank Communication	89	68
OTHER		
DAPS	3215	3126
Saturn & CM Tests	550	—
Transformations	600	600
SVDWN	30	30
GYRO Torquing	47	44
TOTAL	15137	15171
GRAND TOTAL	14729	16257
PAD REMAINING	2626	607

LGC PROGRAM UTILIZATION AS-504

MISSION PHASES \ LGC CONTROL PROGRAMS AS-504	P00 LGC Idling	P02 AGS Initialization	P04 PGNCS Checkout	P05 BCAGCS Startup	P06 BCAGCS Pgnr Down	P10 Predicted Launch Time (CTP)	P11 Predicted Launch Time (TPI)	P12 Powered Ascent	P17 TPI Search	P20 Rendezvous Navigation	P21 Ground Track Determination	P22 Lunar Surface Navigation	P25 Preferred Tracking Attitude	P27 LGC Update	P30 External ΔV	P31 General Lambert	P32 Co-Elliptic Seq. Initiation	P33 Constant Δ Attitude	P34 Transfer Phase Initiation	P35 Transfer Phase (Midcourse)	P40 DPS	P41 RCS	P42 APS	P47 Thrust Monitor	P50 Docked IMU Align	P51 IMU Orientation Determination	P52 IMU Realign	P53 Backup IMU Orient_Det.	P54 Backup IMU Realign	P55 IMU Surface Align. (Normal)	P56 IMU Surface Align. (Backup)	P57 Lunar Surface Align	P60 Predicted Lunar Landing	P61 Descent Orbit Injection	P63 Braking Phase	P64 Approach Phase	P65 Landing Phase (Auto)	P66 Landing Phase (ROD)	P67 Landing Phase (Manual)	P70 DPS Abort	P71 APS Abort	P72 CSM CSI Targeting	P73 CSM CDH Targeting	P74 CSM TPI Targeting	P75 CSM TPFA Targeting	P76 Transearth Inject. Backup	R03 DAP Data Loads	R04 RR/LR Self Test	R05 S-Band Pointing	R30 Orbital Parameter Display	R31 Rendezvous Parameter Display	R32 Target ΔV	R33 CMC/LGC Clock Sync	R62 Crew Defined Maneuver
1. Lunar Orbit (Pre DOI)	✓	✓			✓					✓	✓									✓				✓	✓	✓	✓	✓				✓										✓				✓	✓	
2. DOI and Descent Coast	✓										✓	✓	✓								✓																						✓					✓	
3. Powered Lunar Landing Maneuver		✓																								✓	✓	✓						✓	✓	✓	✓	✓										
4. Lunar Surface Phase	✓		✓		✓																										✓																
5. Lunar Prelaunch Phase		✓		✓		✓	✓																						✓	✓	✓																
6. Powered Ascent Phase								✓																																								
7. Rendezvous (LM Active-Self Contained)		✓							✓	✓	✓		✓			✓	✓	✓	✓	✓	✓	✓																					✓	✓	✓			✓		✓
8. Rendezvous (LM Active-External Calc)										✓			✓		✓				✓		✓	✓																					✓	✓	✓		✓		✓
9. Rendezvous (CSM Active-LGC Passive)													✓																														✓	✓	✓		✓	✓	✓
10. Rendezvous (CSM Active-LGC Calc)										✓	✓		✓																							✓	✓	✓	✓				✓	✓		✓
11. Trans Earth Injection (TEI) Backup				✓	✓										✓	✓					✓				✓	✓	✓	✓														✓		✓				✓
12. Descent Orbit Abort (PGNCS-Self Contain)*									✓							✓	✓	✓	✓	✓	✓	✓	✓																				✓			✓		✓
13. Descent Orbit Abort (PGNCS-Ext. Calc)*															✓						✓	✓	✓																				✓			✓		✓
14. Powered Landing Aborts*																																				✓	✓										✓		
15. AGS Aborts*																								✓																									
16. Aborts (from Translunar (Prethrust & Maneuver)				✓	✓										✓	✓					✓				✓																		✓		✓			✓	✓

*Refer to Items (7) - (10) for subsequent rendezvous.

LGC PROGRAM / ROUTINE RELATIONSHIPS & SIZES

MAY, 1967

LGC ROUTINES \ LGC CONTROL PROGRAMS	SUNDANCE AS-504	P00 LGC Idling	P01 AGS Initialization	P02 PGNCS Checkout	P04 PGNCS Startup	P05 PGNCS Power Down	P06 System Test	P10 Predicted Launch Time (CFP)	P11 Predicted Launch Time (TPI)	P12 Powered Ascent	P17 TPI Search	P20 Rendezvous Navigation	P21 Ground Track Determination	P22 Lunar Surface Navigation	P25 Preferred Tracking Attitude	P27 LGC Update	P29 External ΔV	P32 CSI (Coelliptic Seq. Initiation	P33 CDH (Constant-g Attitude	P34 Transfer Phase Initiation	P35 TPI (Terminal Phase Midcourse)	P40 DPS	P41 RCS	P42 APS	P47 Thrust Monitor	P50 Docked IMU Align	P51 IMU Orientation Determination	P52 IMU Realign	P53 Backup IMU Orient. Det.	P54 Backup IMU Realign	P55 IMU Surface Align (Normal)	P56 IMU Surface Align (Backup)	P57 Lunar Surface Align	P60 Predicted Lunar Landing	P61 Descent Orbit Insertion	P63 Braking Phase	P64 Approach Phase	P65 Landing Phase (Auto)	P66 Landing Phase (P66D)	P67 Landing Phase (Manual)	P70 DPS Abort	P71 APS Abort	P72 CSM CSI Targeting	P73 CSM CDH Targeting	P74 CSM TPI Targeting	P75 CSM TPM Targeting	P76 Transearth Inject Backup	R03 DAP Data Load	R04 R/LR Self Test	R05 S-Band Pointing	R30 Orbit Parameter Display	R31 Rendezvous Parameter Display	R32 Target ΔV	R33 GMT/LGC Clock Sync	TOTAL
CONTROL PROGRAMS		50	100	250	52	66	720	100	100	200	79	160	50	50	50	250	150	165	140	259	100	750	250	25	120	25	120	160	25	25	819	50	50	660	130	1514	120	30	35	25	29	620	140	75	90	110	35	100	74	8,988
BASIC ROUTINES																																																			
Conic Subroutines	L 300		✓					✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓				✓				✓	✓	✓												✓	✓	✓	✓			
Orbital Integration	L 200		✓					✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓											✓					
Lat., Long., Alt.	200												✓	✓																						✓														
Lunar & Solar Eph	80																											✓			✓																			
Lunar Rotation	200							✓	✓				✓	✓																	✓			✓	✓			✓												
Initial Velocity	188																	✓	✓	✓	✓																													
Rendezvous Parameters	180																	✓	✓	✓	✓																													
Maneuver Specif. (R60, R62)	215											✓																																						
Maneuver Calculation	560														✓							✓	✓	✓																										
ASL Orbre	128														✓							✓	✓	✓																										
MSK, Global Display	68																✓	✓	✓	✓	✓																												
Radar Subroutines	600											✓	✓																																				
Radar Routines	178																																																
TARGETING																																																		
PLBT (Prel. Land Time)	200																																			✓														
DOI	150																																			✓														
PLNT (CFP)	400							✓																																									
PLNT (TPI)	100								✓																																								
CSI	540							✓										✓																																
CDH	920							✓											✓																														
TPI	290							✓												✓																													
Midcourse Maneuver (S35.1)	54																				✓																													
TPI Search	200								✓		✓																																						
NAVIGATION																																																		
Rendezvous	520											✓	✓																																				
RR Lunar Surface	320												✓																																				
Mass, Incorp.	420											✓	✓																																				
Prel. Track ASL (R61)	60														✓																																		
AOT Mark	350																											✓				✓	✓																
Radar Test	60											✓	✓																																				
RR Search Des. Rend. (R21, R22, R23, R24)	348											✓	✓																																				
POWERED GUIDANCE																																																	
Cross Product Steering	199																																			✓													✓	
Vg Calc.	82																																			✓													✓	
Servicer	600									✓												✓	✓	✓		✓										✓		✓	✓	✓	✓	✓							✓	
Desired Thrust Dir.	278																																			✓													✓	
Time of Burn Calc.	100																✓	✓	✓	✓	✓															✓													✓	
IMU & OPTICS																																																	
IMU Compensation	258																											✓	✓			✓	✓																
IMU Status Check (R02)	17											✓	✓															✓	✓			✓	✓																
Coarse Align Cal. 53A	64																											✓	✓			✓	✓																
Fine Align (R51)	88																											✓	✓			✓	✓																
Auto Optics (R52)	42																											✓																					
Pick-A-Pair	135																											✓				✓																
Star Data Test (R54)	92																											✓	✓			✓	✓																
IMU Mode Switch	331																											✓	✓			✓	✓	✓															
Any Time Align	100																											✓				✓																
Star Catalog	225																											✓	✓			✓	✓	✓															
	12,160																																																

KEY	AS-504
Pinball	3850
Extended Verbs	900
Keyrupt & Uprupt	80
Display, Prograrm	700
Down Tele. List & Program	600
Program Select Check	200
INTERP & EXEC.	
Interpreter	2118.
Waitlist	220
Executive	335
Restart Table & Routines	374
Fresh Start & Restart	387
Phase Change & New Change	160
T4 Rupt	848
Alarm & Abort	80
Self Check	966
Interbank Communications	88
Interrupt Lead In	92
RBT Op Codes	209
End Bank Marks	36
OTHER	
DAPS	3694
Transformations	879
GYRO Torquing (R55)	44
Total	15820
GRAND TOTAL	36080
PAD REMAINING	784

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