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GUIDANCE, NAVIGATION AND CONTROL L.E. LARSON, JR., MANAGEMENT DIRECTOR APOLLO GUIDANCE AND NAVIGATION PROGRAM Approved: 6 Date: 16Nov67 Approved: \_ DAVID G. HOAG, DIRECTOR APOLLO GUIDANCE AND NAVIGATION PROGRAM Date: 17 nov 67 Approved: R. RAGAN, DEPUTY DIRECTOR RAL PH INSTRUMENTATION LABORATORY



E-1142 (Rev. 53)

# SYSTEM STATUS REPORT

October 1967



COPY # \_\_\_\_\_

# 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 with the Instrumentation Laboratory of the Massachusetts Institute of Technology in Cambridge, Massachusetts.

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.

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E-1142 (Rev. 53)

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 October 1967

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# ACCURACY

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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.

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# 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
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- 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 confirmentiation and the second second

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

- An increase of 0.6 lbs for the CMC is due to the measured weight of 2.0 lbs for each of six flight ropes. They were previously estimated at 1.9 lbs each.
- The following weight changes are estimated as a result of design changes to decrease flammability hazards.

CM Harness	+2.50
GNIC Panel	?
Optics Shroud	?
Eyepiece Stowage Unit	?
IMU	-0.54
Hoses	-0.20
Eyepieces	?
PSA	+0.25
PEA	+0.01

DSKY SCA ? +0.02 30

DATE: October 1967

											_
	Design Load <sub>*</sub> Weight	18.0#	, ** 	0.001		} 120.0	4. 5	100.0	15.0	5.0	4.0
	Status 10/67	16.9 (M)	54.6 (M)	(M) 7 (M) 10. 7 (M)	61.2 (M) 1.4 (M)	65.4 (M) 26.1 (M)	3.1 (M)	90.8 (M)	12,7 (M)	2.6 (M)	1.8 (M)
LBS AT 1G)	Change	0.0	0.0		0.0	0.0	0.0	0.0	0°.0	0.0	0.0
DULE G&N (	Status 6/67	16.9 (M)	54.6 (M)	10.7 (M)	61.2 (M) 1.4 (M)	65.4 (M) 26.1 (M)	3.1 (M)	90.8 (M)	12,7 (M)	2.6 (M)	1.8 (M)

HT STATUS OF BLOCK I 100 SERIES

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	TABLE 1. CURRENT WEI COMMAND MO	DIG
	Command Module G&N Equipment	
13	LOWER EQUIPMENT BAY CDU Assy CDU Assy CDU Assy Optical Subsystem SXT and gearing SXT and gearing SCT and gearing SCT and gearing Optical Base and gearing NVB and Resilient Mounts Bellows Assy IMU Coolant Hoses (Three) Bellows Assy IMU Coolant Hoses (Three) Power Servo Assy Coolant Hoses (Three) Coolant Hoses (Three) Coolant Hoses (Three) Power Servo Assy Control Electronice Assy Control Electronics Assy Control Electronics Assy Control Electronics Assy	

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G 407-66	11T in Letter A	omitted by N	IRN 3677, sub	" This design load weight taken from dated 9 May 1966.
ly. d the	ellows Assemb -44-65-55 date recognition of	gnt or the B tter EG-151 not include	ed in NASA letignment does	The Total Control Weight is specified to the total tot
65, submitte	gned 3 June 19	1256-416 si	ICD MH01-0	* Design Load Weights are taken fron by MIT in letter AG 478-65.
1 3 7	206.4	of the	IMU portions	Bare Guidance Systems - IMU, AGC, CDU's and IMU Support electronics
) pound total	thàn the 430. (	unds more	th is 13.8 po	The reported total weight for this mon control weight †
	443.8	0,0	443.8	TOTAL
1.0	0.3 (M)	0.0	0.3 (M)	Horizontal Hand Holds (Two)
5	2 1 (M)	0.0	2.1 (M)	Optics Cover
				LOOSE STORED ITEMS
26.0	25.3 (M)	0.0	25.3 (M)	DSKY
				MAIN PANEL AREA
26.0	24.5 (M)	0.0	24.5 (M)	DSKY
8.0	4.8 (M)	0.0	4.8 (M)	Signal Conditioner Assy
5.0	2.9 (M)	0.0	2.9 (M)	IMU Control Panel
15.0	10.9 (M)	0.0	10.9 (M)	G&N Indicator Control Panel
Weight	Status 10/67	Change	Status 6/67	Command Module G&N Equipment

407-66		
AG		
Letter		
in		
MIT		
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OULE	GN&C (LBS /	AT 1G)	Design
	Change	status 10/67	Load * Weight
M)	0.0	36.5 (M)	50.0
(1	0.0	55,7 (M)	
(1)	0.0	17.4 (M)	
(V	0.0	10.7 (M)	150.0
(I)	0.0	42.5 (M)	
(T)	0.0	1.2 (M)	
(F	0.0	49.4 (M)	58.0
(I)	0.0	9.0 (M)	12.0
(F	0.0	24,0 (M)	40.0
<b>(</b> )	+0.6	70.1 (M)	80.0
(IJ	0.0	3.1 (M)	4.5
(L)	0.0	I4.0 (M)	15.0
Ŕ	0.0	11.5 (M)	17.0
(J	0.0	17.5 (M)	25.0
(j	0,0	5.8 (M) <sup>**</sup>	8.0

NT WEIGHT STATUS OF BLOCK II ND MODULE GN&C (LBS AT 1G)

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b/67     10/67     Weight <sup>3</sup> tAIN PANEL AREA     I7.5 (M)     0.0     17.5 (M)     25.0       SKY     OCSE STORED ITEMS     0.3 (M)     0.0     17.5 (M)     25.0       ONSE STORED ITEMS     0.3 (M)     0.0     0.3 (M)     25.0       OCSE STORED ITEMS     0.3 (M)     0.0     0.3 (M)     1.0       OCSE STORED ITEMS     0.3 (M)     0.0     0.3 (M)     1.0       OPTAL     385.6     +0.6     386.2        The reported total weight for this month is 13.8 pounds less than the 400.0 pound total ontrol weight t        Tare Guidance Systems - IMU, AGC, IMU portions of the     172.8        Tare Guidance Systems - IMU, support electronics         * 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 weight of a qualification flight signal conditioner assy is 8.6(M). pounds.        * The veight of a qualification flight signal conditioner assy is 8.6(M). pounds.        * The veight of a specified in NASA letter EC-151-44-65-55 dated of the OFICE Differed	d Module GN&C Equipment	ATUS OF BLC IN&C (LBS AT Change	CCK II C 1G) (CONT Status	) Design Load
KY17.5 (M)0.017.5 (M)25.0DSE STORED ITEMSDSE STORED ITEMS0.3 (M)1.023.0DSE STORED ITEMS0.3 (M)0.00.3 (M)1.0TAL0.00.3 (M)0.00.3 (M)1.0FAL385.6+0.6386.2TAL385.610.00.0 nud totaltrol weight for this month is 13.8 pounds less than the 400.0 pound totaltrol weight †Us and IMU support electronicsUs and IMU support electronicsUs and IMU support electronicsthe weight of a qualification flight signal conditioner assy is 8.6(M). pounds.he weight of a qualification flight signal conditioner assy is 8.6(M). pounds.he Total Control Weight as specified in NASA letter EC-151-44-65-55 dated0 February 1965. This weight assignment does not include recognition of the ptical Eyepiece Storage Assembly.DATE: October	NEL AREA		10/67	Weight*
DOSE STORED ITEMS0.3 (M)0.00.3 (M)1.0DTAL0.3 (M)0.3 (M)1.01.0DTAL385.6+0.6386.2DTAL385.613.890000586.2DTAL385.613.8900005120.0900004te reported total weight for this month is 13.8900005172.8ntrol weight †172.8172.8DUS and IMU support electronics0.00.1356-416signed 16 July 1965 atDesign Load Weights are taken from ICD MH01-01356-416172.8Design Load Weights are taken from ICD MH01-01356-416signed 16 July 1965 atThe weight of a qualification flight signal conditioner assy is 8.6(M). pounds.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 dated10 February 1065. This weight assignment does not include recognition of the Optical Eyepiece Storage Assembly.DATE: October	17.5 (M)	0.0	17.5 (M)	25.0
orizontal Hand Holds (Two)0.3 (M)1.0OTAL0.3 (M)0.3 (M)1.0OTAL385.6+0.6386.2ne reported total weight for this month is 13.8 pounds less than the 400.0 pound totalntrol weight †385.6172.8DUs and IMU support electronics172.8bus and IMU support electronics172.634"Design Load Weights are taken from ICD MH01-01356-416 signed 16 July 1965 at"The weight of a qualification flight signal conditioner assy is 8.6(M). poundsThe Veight of a qualification flight signal conditioner assy is 8.6(M). pounds.The Total Control Weight assignment does not include recognition of the Optical Eyepiece Storage Assembly.Data for a f	TORED ITEMS			
OTAL385.6 $+0.6$ $386.2$ $$ he reported total weight for this month is 13.8 pounds less than the 400.0 pound totalnontrol weight $+$ are Guidance Systems - IMU, AGC, IMU portions of the $172.8$ $$ DUS and IMU support electronicsbesign Load Weights are taken from ICD MH01-01356-416 signed 16 July 1965 at*** </td <td>al Hand Holds (Two) 0.3 (M)</td> <td>0.0</td> <td>0.3 (M)</td> <td>1.0</td>	al Hand Holds (Two) 0.3 (M)	0.0	0.3 (M)	1.0
he reported total weight for this month is 13.8 pounds less than the 400.0 pound total ontrol weight † are Guidance Systems - IMU, AGC, IMU portions of the 172.8 DUs and IMU support electronics 172.8 DUs and IMU support electronics 172.8 heeting #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.	385.6	+0.6	86.2	1
are Guidance Systems - IMU, AGC, IMU portions of the172.8:DUs and IMU support electronics*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: October	rted total weight for this month is 13.8 pour reight †	mds less than	the 400.0 po	und total
<ul> <li>*Design Load Weights are taken from ICD MH01-01356-416 signed 16 July 1965 at Meeting #22A.</li> <li>* The weight of a qualification flight signal conditioner assy is 8. 6(M). pounds.</li> <li>* 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.</li> </ul>	dance Systems - IMU, AGC, IMU portions c d IMU support electronics	of the 17	72.8	2 2 1
<ul> <li>*The weight of a qualification flight signal conditioner assy is 8.6(M). pounds.</li> <li>• 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.</li> <li>Date Detical Eyepiece Storage Assembly.</li> </ul>	g #22A.	1356-416 signe	ed 16 July 19	65 at
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: October	sight of a qualification flight signal condition	ner assy is 8.6	3(M). pounds.	
DATE; October	otal Control Weight is specified in NASA lett ruary 1965. This weight assignment does n l Eyepiece Storage Assembly.	ter EG-151-44 not include rec	4-65-55 dated cognition of t	d he
			DA'	TE: October

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# Reported Weight Changes and Weight Trend Information

LM

- An increase of 0.6 lb for the LGC is due to the measured weight of 2 lbs for each of six flight ropes. They were previously estimated at 1.9 lbs each.
- 2. An increase of 0.5 lb for the LGC is estimated for the weight of two spacers which will be placed between the LGC and the GAEC cold rails.
- 3. The following weight changes are estimated as a result of design changes to decrease flammability hazards.

Harnesses	+1.40
CCRD	+0.05
IMU	-0.54
AOT	+0.20
PTA	+0.01



PGNCS (LBS AT 1G) LM WEIGHT STATUS OF

LM PGNCS Equipment	Status 6/67	Change	Status 10/67	Design Load Weight
IMU	42.4 (M)	0.0	42.4 (M)	
AOT (including eyepiece and bellows)	23.1 (M)	0.0	23.1 (M)	80.0
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)	
HARNESS 'B' Supported by the structu	re 3.1 (E)	0.0	3.1 (E)	> 21.0
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	69.5 (M)	+1,.1	70.6 (E)	65.0
DSKY trays)	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)	5.5 (M)	0.0	5.5 (M)	
TOTAL	253.1	+1.1	254.2	1
The reported total weight for this monthey 9.2 lbs.t	n exceeds the	245.0 poun	ds total control	weight
Bare Guidance Systems - IMU, LGC, I CDUs and IMU support electronics	MU portions o	f the	167.9	
* Design Load Weights are taken from IC (NASA/ MSC) on 29 March 1966.	CD LIS-490-1	0001 as sig	ned by Mr. R.	A. Gardner
** The weight of a qualification flight sigr	nal conditione	r assy is 7.	8 (M) pounds.	
The Total Control Weight is specified	in Contract T	echnical Sp	ecification	

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PS 6000000 - amended by NASA Letter EG 26-233-66-565 dated 18 August 1966.

DATE: October 1967

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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.

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# SECTION 3

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# 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 106 HOURS"

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Mission Reliability			1800		5500	6666.		. 9626		. 9923				- 9840		
с,	/	OFF			•	•	308	•			,		55.6	•	•	٠
D	NO	$\backslash$	8.63	ę	8.3	ę	31.3	2.3	8.4	1.2			13.8	2.3	3.25	1.2
КY		OFF			•		208		•	•	•	•	55.6	•	•	
DS	NO	$\searrow$	8.63	12	8.3	12	31, 3	2.3	8.4	110	9.6	12	13.8	2.3	3.25	10
U,	$\langle$	STBY	ŧ		•	•	208	60, 5	,	•		٠	55.6	60.5	•	
AC	NO	$\backslash$	8.63	257	8.3	257	31.3	235	8.4	235	9.6	235	13.8	235	3.25	235
S D	$\langle$	OFF					208			•	•		55.6		•	
opti CC	NO			•		•	31.3	16	8.4	112			13.8	16	3.25	112
	1	STBY					208	•	,	•			55.6		•	
CDI	NO		8.63	ш	8.3	Ξ	31.3	155	8.4	155	9.6	155	13.8	155	3.25	155
s nics		DFF			1		522	•	•	•		•	60.3	•		
Optic Electro (PS/	NO	$\overline{\ }$					14.2	2	8.4	1.33		•	9.1	"	3.25	1.33
cs nbly		OFF	•	•		,	225	•		•	•	3.	60.3		•	•
Opti Assen	NO		•	٠			14. 2	64	8.4	38			9.1	94	3.25	8
U onics A)	$\overline{\ }$	TBΥ	•				208	6.3		•	•		55.6	6.3	643	•
Electro (PS	NO	S	8.63	224	8.3	224	31.3	110	8.4	110	9.6	110	13.8	110	3.25	110
u bly		TBY			•		208	10.2	120	1.6		•	55.6	10.2	66.3	1.6
IM Asser	NO	Ľ	8.63	195	8.3	195	31.3	621	8.4	129	9.6	129	13.8	129	3.25	21
			OPER HRS	×	OPER HRS	x	OPER HRS	~	OPER HRS	ĸ	OPER HRS	~	OPER HRS	x	OPER HRS	*
		MISSION	AGE 122	UNMANNED	AGE 123	UNMANNED	CIM	MANNED	UM G 1CUT SM	MANNED	AGE 603	UNMANNED UM	C/M	DES. REF.	Ł	DES. REF.

AUGUST 1967

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# **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 power drawn through the spacecraft circuit breakers. It is assumed that power is drawn from the spacecraft's 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 at 28.0 VDC. They are based on measured values on G & N systems 207 and 208

for the Block II Command Module and G & N systems 608, 600, and LM learner for the LM. No margin factor has been applied to protect against possible differences between G & N systems and spacecrafts. 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
LM	LIS-390-10002 "PGNCS Prime Power Requirements and Characteristics" signed 30 July 1965

				COLD	PLATES	1)	
	110W OPERAT	APOLLO GUIDANCE COMPUTER	PSA	NBA	COU	AGC	DL
9330W HOURS	15.0W	AGC STANDRY				100 WC	10 W
125 W OPR	6 0 W		_			15 WC	-
IS W STANDBY	(24W		- 49Wc				-
	2011		2.6WC				
	39.6₩	OPTICS SERVO AMPLITIERS	24.0Wc	10.4 WC	5.2WC		
	1.5 W		-15WC				
	35.6W SXT ON 284 59	MOTOR EXCITATION		10.4WC	SZWC		
	SUPPL	Y					
OPTICS OPR SW A00% BLOCK			-20.0WC				
1487 W HOURS DIOD	ES	RSVR EXCITATION		2.2WC	1.5 WC		
123 3 W OPR ISXT-ONI	30.4W 28V 15	TACH EXCITATION		74Wc	3.7 WC		
	SUPPLY	HAND CONTROLLER IOPTICS	_				1₩,
1			14.0 %				
					0.5W		
	3.7W ENCODE	R ENCODER EXCITATION	_				
	DXCL		- 3.2 Wc				
1							
l	3.0W		3.0Wc			-+	
115 VAC 400 CPS	2.5W SIGNA	SIGNAL CONDITIONING	1110				
	1.8W CONDITION	ANG PRESSURE TRANSDUCER		IWe			
	L P SUPPL		2.0%	1C			
	2.1W	FAILURE INDICATOR	214				
1007	100W	TEMP CONTROLLER	100				
IMU HEATER SW BLOCK	1NG	HEATERS 20W IMU ON + 22W IMU OFF GI					
61.7W IMU OFF		DUCOSYN EXCITATION 2V SINE WAVE		co cen			
	19,1 W 3200 CPS	TEMP CONT EXCITATION 20V SQ WAVE		37mM		·	
			- 3WC		-		
	1.5W	3200 - AAC	INONC		-		
1 1	2.0.0		LSWM		-		
		GIMBAL SERVO & ADA PREAMP POWER	2WC		_		
	17 I.W -28 VOC		6WM	TWE			_
1	POWER		-	08WM			
740 10 10 10 10 10			- 3.3WM				
2.8W OPR			12.61				
66.4 W MAX	59.0W 120V - 12VD		47 WM				
	P SUPPLY	<u>ي</u>	12 WM				
	29.4W IRIG	IRIGEUCIKONICS	-22.8WM				
1	TOW MAXI P SUPPLY	·	- 46WM				
1	3.0W	PIPA FIXED HEATERS	_	31.			

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

BASED UPON 1965 HOUR (8.27 DAY) LUNAR MISSION DESIGN REFERENCE MISSION

.

REFERENCE GAEC REPORT - LED 540-12, 30 OCTOBER 1954 APOLLO MISSION PLANNING TASK FORCE



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



# LUNAR MODULE GUIDANCE & NAVIGATION LOAD ON PRIMARY +28 VDC

STATUS OCTOBER 1967

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

BASED UPON 106.02 HOURS (4.42 DAY) LUNAR LANDING MISSION

DESIGN REFERENCE MISSION



# 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.

![](_page_21_Picture_6.jpeg)

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

![](_page_22_Figure_1.jpeg)

DATE: October 1967

# TABLE II

# LM G&N SYSTEM CONFIGURATION

s/c	LM-2					
COMPONENT	System 608					
NOMENCLATURE	Part No.	S/N				
LGC	2003993-021	26				
DSKY	2003994-011	46				
IMU	2018601-111	18				
ECDU	2007222-221	10				
AOT	6011000-071	17				

DATE: October 1967

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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. LTA-8 G&N System 602

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LTA-8 Vehicle shipped to MSC.

2. LM-2 G&N System 608

ECDU 2007222-131, S/N 26, was installed to permit testing to proceed until an updated ECDU 2007222-221, S/N 10 became available.

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# TABLE III

# CSM G&N SYSTEM CONFIGURATION AT NAA

s/c	CSM-20		CSM-98		CSM-101			
COMPONENT	System 12	23	System 2	02	System 204			
NOMEN- CLATURE	Part No.	S/N	Part No.	S/N	Part No.	S/N		
AGC	1003700-071	13						
DSKY (Main)	1003563-051	9		87				
DSKY (Nav.)	1003706-051	7						
IMU	1001500-111	8						
CDU	1021304-031	-						
OPTICS	2011000-023	9						

DATE: October 1967

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

The following changes affect the previous listing:

- Blank spaces in Table above indicate Systems removed from Spacecraft. 1. Upon reinstallation, configuration will be updated.
- Completed testing of CM-102, G&N System 205. 2.
- CM-20, System 123 3.

Replaced AGC 1003700-071, S/N 7, with AGC 1003700-071, S/N 13, because of parity fail problem.

# TABLE IV

# **G&N SYSTEM CONFIGURATION AT KSC**

s/c	17		LM-1			
COMPONENT NOMENCLATURE	System 1	22	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	11	2018601-111	6		
CDU ·	1021304-031	4	2007222-131	25		
OPTICS	1021368-051	7	6011000-021	9		

DATE: October 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 Optics, 2011000-024, S/N 7, with 1021368-051, S/N 7. Added thermal protection.
  - B. Replaced IMU, 1001500-111, S/N 4, with 1001500-111, S/N 11. "Y" PIPA bias out of specification.

# **SECTION 6**

# **G&N SYSTEM TEST**

- System Test Laboratory Α.
- G&N 5 1.

The AGC and OUA were operated for approximately 25.6 hours during August and September.

- G&N 104 2.
  - **Program Tests** a.

(1) Investigated occurrence of parity fail during PIPA SF test observed at NAA with Sunrise 69 Program Assembly. It only occurs when test is run in conjunction with the nightwatchman routine (tape K00028), and during zero encode routine after position 1 of the PIPA test is finished. Conditions were duplicated in STG Lab and problem was traced to an erasable conflict with a subroutine called BLIVOT.

(2) Investigated and resolved the lift-off discrete problem associated with Mission 501.

(3) Verified K-START Tape for Flight Readiness Test, S/C-017, Number F040017-K00067-00.

Hardware Tests b.

> (1) Conducted special low voltage transient test for NAA to determine effect on G&N performance when prime power is lowered to 19 VDC for 1 sec. Concluded that the above conditions result in loss of control of the G&N System. (Gimbal runaway). (See STG Memo No. 1047)

(2) Evaluated a sequential PIPA pulse rate measurement test for use in troubleshooting at KSC. With slight modification to the PIPA SF test, it allows several pulse rate measurements to be made with the platform inertial.

(3) Continued investigation of cross-coupling between Y and Z PIPA torques.

(4) Conducted voltage transient test reducing prime power to 22.5 VDC for approximately 600 msec. simulating battery switchover. Observed no change in 3200 2 VAC supply and approximately 5% change in Phase A of wheel supply voltage.

# c. Modifications

Since the nightwatchman module is sensitive to input noise when the G&N fail light is on, it was suggested that the module be retrofitted by inserting a capacitor between + 13 VDC and the signal output to reduce the level of input noise (10 to 20 megacycles; 1 V - 2 V). After experimentation it was decided that a value of .01  $\mu$ f was the best compromise from the standpoint of filtering the 24 user nightwatchman pulses.

# 3. G&N 200

a. Program Tests

(1) Problem with gyrocompass program in Sundisk was found to be due to the "Proceed" program. Generation of a proceed command at the right time would cause the gyrocompass program to malfunction. This has been corrected.

(2) There is presently a problem with Optical Verification portion of gyrocompass. This is being investigated.

(3) G&N Fine Align test does not work. This problem is related to the Optical Verification problem above.

(4) New Gyro compass JDC for SUNDIAL Program was checked out and verified.

(5) Considerable time was spent on verification of Flight Simulation routines. Programs P01, P02, P11, P20, P21, P22, P23, P27, P30, P34, P35, P40, P41, P47, P51, P52, P54, P61, P62, P63, P64, P67, P74, and P75 were performed satisfactorily. V49 was checked out.

(6) Program verification on SUNDISK #260 was started. V40, V41, V42, V55, V91, V92, V93, S/C Installation Alignment Test, CDU Operation Test, and Error Counter Test were performed and verified.

b. Failures

(1) The Y-Gyro S/N 103 failed. Wheel would not run. Replaced with S/N 100 A. Unit tests on the failed IRIG showed 50 volts was needed to start the wheel running.

(2) The problem with the Optics - Resolved Mode was traced to a failed relay module. This module was replaced.

(3) IMU Blower S/N 3 was replaced with S/N 10M. S/N 3 had a worn shaft.

- 4. G&N 600
  - a. Program Tests

(1) Developed and checked out an end-to-end Polarity Test for LM-1 descent engine Gimbal Trim System (STG Memo No. 1042).

(2) Identified the cause of an IDR in LM-1 OCP K0011. A program change in SETCOAR turns off the C/A bit so that the iterative procedure used in SAMODCHK for GASTA readings are ineffective in SUNBURST.

(3) A restart problem in BURST 116 has been solved as a Job conflict due to an interrupt occurring in DUMMYJOB. The conflict is resolved by SMARTJOB in the rework on Module B3.

- b. Hardware Tests
  - (1) EMI report issued (STG Memo No. 1044).
  - (2) LR/LGC processed data was obtained for 3, 9, and the standard 5 samples to evaluate the effect of averaging of the velocity samples.

(3) Measured currents on the LM system in support of power consumption estimates.

(4) Investigated CDU fine switching transients. Three methods were mechanized to aid in the understanding of the problem:

(a) Software patch to record CDU angle differences in erasable. Recorded angles between specified limits every 10 msec.

(b) LGC hardware modification that puts CDUZ pulses on uplink lines. Software patch to record every  $\pm$  pulse in erasable.

(c) CDU modification to monitor and shift the phase reference of PI between 51.2 KPPS and 800 CPS.

The status of the investigation is presented in STG Memo No. 1048. Testing has shown that the limiting diodes have no effect on the fine switching transients. The phase relationship of PI pulses has no pronounced effect on the turn on transients. Modifications to the CDU are presently being bench tested and will be tried on the system when modules are available.

(5) CDU Transient Tests: The phasing of the PI pulse  $\overline{w}$ rt 800 CPS shows no effect on switching characteristics. A voltage divider fix was ineffective due to transistor overvoltage and leakage. Modules was 15 V transistors have been installed and are presently undergoing tests.

(6) IRIG Preamplifier Tests: Added inductance of 22 microhenries in the error common line shows the 250 kc oscillation. The associated gain reduction of the preamp was 75%. A wiring modification to use signal common for the preamp power return appears effective. EMI tests are to be run to verify acceptability.

(7) Ascent Battery Switchover Tests: Descent to ascent battery switchover simulations were run on the G&N System with an actual ascent battery. Ten switchover pulse conditions were run and data is being analyzed.

- B. Field Operations
- 1. GAEC
  - LTA-8 (Thermo-Vacuum) G&N 602
     FEAT re-run and completed, vehicle was shipped 17 September 1967.
  - b. LM-2 (Mission AS-208) G&N 608 System re-installation completed and OCP 37030 Individual System Test completed.
  - c. LM-3 (Mission AS-503) G&N 605 Installation of System has begun.
- 2. KSC
  - a. CM 17 (Mission AS-501) G&N 122

Vehicle moved to pad on 26 August 1967, OCP K-0033, Countdown Demonstration, is in progress.

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

Completed OCP K-0002, Mission Simulation (Plugs Out). The Vehicle has been demated and returned to the work stand. Testing will be discontinued for approximately three weeks.

3. MSC

a. Working on Flight Test Requirements in support of Post-Flight Data Reduction.

b. Investigated various software problems for the Simulation Group.

c. Preparing for LTA-8 Thermo-Vacuum Test. Supported Flight Control Division.

4. NAA

- a. CM-20 (Mission AS-502) G&N 123 Holding OCP 126 due to North American S/C problem. Combined System Test will not begin before October 1967.
- b. CM-98 (2 TV-1 Thermal Vacuum G&N 202 System completed laboratory testing, awaiting installation.
- c. CM-101 (Mission AS-207) G&N 204 G&N Laboratory testing is complete. Returned PSA to ACED for repair of badly bent connector pins.

## Edward Air Force Base 5.

Rewiring of X-15-1 is proceeding on schedule. Sandia format for radar data will go into effect in mid-September. Earliest possible date for the next flight is 13 November 1967. This will be a captive flight.

- System Engineering c.
- Analysis and Test 1.

Work on the tests of the SUNDISK Programs in the STG Lab continued. All a. the required tests have been shown to be ready for the formal testing after configuration control. The running of these tests after configuration control has begun, and is to be completed and documented by the A release of SUNDISK. Digital Simulator Tests of some system test programs are also being performed. The study of LM Radar Program testing continued.

Considerable effort was expended to help fix the problems in the SUNDISK b. programs found to date by this testing.

Work is also continuing on polarity testing both for MIT checkout of programs c. in the STG Lab and in support of KSC testing. Similar tests are expected to fulfill both requirements.

A study of the CDU transient problem was undertaken. Considerable data was d. collected and a memo (STG No. 1055) was prepared describing the results of the CDU problem investigation.

A memo was prepared showing the requirements for Radar Programs and cone. cluding that almost no memory can be saved by eliminating ground test programs.

Investigation of Mission Critical Relay problem (APM No. 1779) approxif. mately 50% completed. STG Memo No. 1050 based upon partial findings was distributed.

A study of the possibility of changing the interpreter so that interpretive g. instructions can be used from Eraseable Memory was undertaken.

Spacecraft Test Support 2.

> The feasability of installing optical targets in the SLA for performing the a. fine align test was studied. The plans for the fine align test and AOT functional accuracy test at GAEC were reviewed and information was given to GAEC, AC, and NASA so that the documentation could be made consistant and correct.

MIT/IL has the responsibility to write Erasable Programs for the IMU b. Performance Test and IRIG Scale Factor Test. The programming effort for both tests is complete. Digital simulations have been made. The procedures to be incorporated into the OCP's at KSC to exercise the programs have been written

but not verified with a G&N System. No K-START Tapes for Mission 504 erasable programs have been made yet. K-START Tapes for the IMU Performance and IRIG Scale Factor Test will be made after each test program has been verified with a G&N System with Mission 504 Programs in the computer.

c. Support to the preparation of DAP Polarity Tests has continued.

d. An investigation of the failure of Mission critical relays was continued. The effort on those in the Saturn IVB is summarized in STG Memo No. 1059. Further testing (by Raytheon) is needed to define the problem for the radar relays.

e. Work continued to define the radar test requirements at KSC and a meeting of all parties was held at MSC.

3. KSC Checkout

a. The following K-START Tapes were manufactured, verified in the G&N Laboratory, sold-off (DD 250), and shipped to KSC and MSC:

F04C017 - K00067, Launch Load, 501 F04C017 - K00068, Mission Load, 501 F04C017 - K00073, FRT Simulation Flight, 501

b. Simulation Flight Test verification was continued using the SUNDISK Program Assembly.

c. Investigating Y Accelerometer performance measurement problem during Block II CSM and LM S/C testing.

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D. Test Equipment

1. Advanced CG&N

a. The following drawers have been completed: DVM Scan and Multiple Control.

b. The following drawers are in fabrication and are estimated at an average of 70% complete: Counter Control, Multiplex, Mode Control and Buffer Reg.

c. The following are in design: Temp. Monitor Drawer, Remote Control and Interface Cabling.

d. The overall task is expected to be completed by the end of October.

2. 16 PM PIPA Console - Houston

The schedule has slipped two weeks due to vendor deliveries and vacations. These problems have been overcome. It is not expected that this slippage will cause a delivery delay.

E. Mission Test Programming

1. Supporting verification checkout of CMC Sundisk assembly. Major area of incorrectly programmed proceed button action was corrected. All system test and gyrocompass programs now are laboratory verified.

# 2. SUNBURST (LM-1) 116

Probable cause of restarts at KSC during gyrocompass was traced to the programming error in the executive. This discrepancy was corrected in SUNBURST 120.

3. SUNDISK (CMC-)

<sup>•</sup> Formal verification of gyrocompass and system tests begun. Digital verification of gyrocompass (P01.1, P01.2) completed. Operational test modified to take care of possible ICDU transients.

4. COLOSSUS (CMC - )

An investigation indicates a further 180 word saving is possible if the STORE instruction is modified. SGA Group investigating consequences.

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5. SUNDANCE (LMC - )
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Same comment as COLOSSUS. Lunar Surface System Test deleted as instructed.

![](_page_32_Picture_8.jpeg)

# SECTION 7

# **G&N COMPUTER STATUS**

A. Analysis Facility

# 1. Design Analysis

Further checks into the use of a capacitor to reduce the noise susceptibility of the Block I Night Watchman Module were performed (Reference D. D. Memo No. 379). No other analysis was performed during this period due to investigation of field problems and checkout of Monitor S/N 5.

2. Field Support

After many days of searching and hours of testing in the STG Laboratory the problem of the restart which occurred in LM-1 (SUNBURST 116) was finally reproduced and traced to the interaction between DUMMY JOB and the EXECUTIVE. Analysis Facility personnel assisted in tracking down this problem.

- 3. Miscellaneous AGC Related Activities
  - a. Fabrication of New Monitor Checkout of the first new monitor (S/N 5) is

about complete. Scheduled delivery to the STG Lab is 2 October 1967. Several problems have been encountered with the memory units for the new monitors; of the ten units received only four were operational. The vendor has been contacted.

b. Restart Monitor - Preliminary drawings for the Restart Monitor (Channel 77 Alarm Box) were reviewed. The first unit is completely assembled.

c. Routine Maintenance - Routine Maintenance of AGC's and support equipment in use in the STG Lab and Hybrid Simulation Facility was performed.

# B. Component Problems

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a. The diode (1006399) and the PNP transistor (1006310) appear to have new problems. At the present time there is only one supplier of the diode. Five of those lots failed to pass the FPS because of forward voltage problem. A large number of the diodes have failed in a number of memory modules. These two problems may or may not be related even though the failure modes appear to be similar. In the memory modules, the hard potting which is leaking down the leads and onto the diode may be the sole cause of the memory module failures. The hard potting stressof the diode package, is causing the diodes to open. At screen and burn-in, the diodes fail because of open between stud and chip.

b. The PNP transistor 1006310 has developed a new failure mode in the last two lots. At the present time there is only on supplier of this transistor. The failure mode is a drop in low current  $H_{fe}$ . This problem is particularly troublesome since it may not be a screenable failure. The vendor conducts 100% FPS screening before the units reach Raytheon. Raytheon has seen the failure mode at 1st, 2nd and 3rd electrical tests. The vendor has looked at some of the transistors which had been left on the shelf and has also seen the problem on the shelf units. The next question to be answered is do the Vendor transistors already in modules also exhibit this problem?

c. MIT/IL is conducting an in-house test on the effectiveness of X-Ray as a screen for loose particles in the package as well as continuing the study on the life test of 1006323 transistor. Test results:

DSKY circuit -  $8.7 \times 10^{6}$  HZ No failures. Rope driver -  $5.8 \times 10^{6}$  HZ

# C. AGC Problems

# 1. AGC-C2

The failure of C-2 in LM-1 when the flight ropes were installed has been completely analyzed and shown to be the result of a defective clear rope driver transistor as predicted. The failure analysis at Raytheon, of the part, was not adequate therefore it is not possible to confirm the cause of the failure. It has been assumed that the failure was induced when the old rope jumpers were used in the computer last fall during field testing. These rope jumpers have now been replaced by ones with load resistors. All computers in the field have been retested to check for this type of failure. The Factory test procedures are being revised to insure an adequate test at sell-off. 2. Block II AGC Erasable Memory Module Failures References

a. D.D. Memo No. 382 dated 22 August 1967 - Erasable Memory Preservation.

b. AG 376-67 dated 27 September 1967 - Evaluation of E-Memory Potting Materials.

 Night Watchman Noise References

a. D.D. Memo No. 379 - Night Watchman Noise Problems II.

4. LGC Tray Bowing

References

a. AG 323-67 dated 25 August 1967 - LM LGC Out of Specification at LGC/LM Cold Rail Interface.

- b. AGC 349-67 LGC/LM Cold Rail Spacers
- 5. ICD Problems
  - a. LM Hand Controller

ICDs have been changed to reflect lower GAEC source impedance. Results in a decrease in input quantization.

b. Clock Sync Transient

MIT/IL submitted change - when AGC goes from standby to operate - clock sync amplitude goes out of spec. GAEC reports the transient will cause loss of telemetry sync for 1 second. NASA has to resolve the problem perhaps through

a procedure change.

c. PGNS Caution Display

Program caution enables PGNS caution and activates spacecraft master alarm system. Fix is to remove PGNS caution from S/C master alarm and caution system.

d. Ranging Unit

NASA has proposed putting a ranging unit into CM so that the CM can measure range and can rendezvous with LM.

ICD's (preliminary) completed but not signed off. AGC input is that harness has to change to add new wires and the program has to be provided.

e. DSKY Flammability Fix

There is no problem but ICD's have to be modified to insure no future problem.

# D. Design Changes

Block II LM DSKY "Standby" Key engraving (ref.: MIT/IL Letter AG 346-67, dated 14 September 1967). The engraving on the DSKY standby key has been changed from "STBY" to "PRO" (Proceed).

# E. Redesign Activity

# Block II DSKY

The DSKY redesign is 75% completed. The new design will reduce the number of relays from 132 to five. The five remaining relays can only be eliminated with a change of the interface ICD. The five remaining relays can either be the half crystal can size used in Block II DSKYs or the full crystal can size which will yield a more reliable relay. In the new design, a new alarm panel as well as a new digital indicator panel will be used. The use of a new alarm panel enabled MIT/IL to get rid of relays as well as to reduce alarm panel power. In the old DSKY the alarm panel was run by 2.5 amps of 5 volt warning power. In the new design the alarm panel will be run from the same power supply which runs the digital indicator panel. It is anticipated that the total power dissipation of the new DSKY will be no more than the old version.

**SECTION 8** 

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22

# GUIDANCE COMPUTER PROGRAMMING

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OCTOBER 1967 OF THE SPACECRAFT COMPUTER PROGRAM RELEASED FOR FLIGHT ROPE MANUFACTURE ON OF THE SPACECRAFT COMPUTER PROGRAM

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ITEM	PROGRAM DEVELOPMEN	SYSTEM OPERATIONS P	ROGRAM DEVELOPMEN	NS HANDBOOK	SYSTEM OPERATIONS P	PROGRAM DEVELOPMEN	SYSTEM OPERATIONS P	ROGRAM DEVELOPMEN	SYSTEM OPERATIONS P	PROGRAM DEVELOPMEN	SYSTEM OPERATIONS P	ROGRAM DEVELOPMEN	(2) "B RELEASE = PRELIM
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 (3) "A RELEASE" = FLIGHT VERSION OF THE SPACECRAFT CC

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Apollo Guidance Computer Programming Summary

for the Months of August & September

# Mission AS-501 (Solarium) Unmanned CSM

Continued analysis of the released and manufactured program for Mission AS-501 has been preformed. From this analysis, ground procedures have been revised and program limitation defined. In addition mission support has been provided to NASA/ MSC and Cape Kennedy.

# Mission AS-204 (Sunburst) Unmanned LM

Continued analysis and testing of the released and manufactured program for Mission 204. Module 3 was modified and released for re-manufacturing on 26 September 1967. From the analysis and testing, ground procedures have been revised and program limitation defined.

# Mission AS-205 (Sundisk) Manned CSM

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. FACI was held on 4 October 1967. Completion of level V testing and program release is scheduled for 15 November 1967.

Mission AS-504 (Sundance) Manned LM Earth Orbital

During the reporting period the Guidance System Operations Plan (GSOP) underwent review and updating by NASA and MIT. In addition a special team of NASA and MIT personnel were assigned to change the Rendezvous Procedures in the GSOP. Coding and testing has been underway with scheduled FACI of the program scheduled for 8 March 1968.

# COLOSSUS CMC PROGRAM (AS-504)

# FIXED MEMORY ALLOCATION CHART (ESTIMATED)

I.

Utility and Service Programs	
Interpreter, Single Precision Subroutines, Fixed-Fixed Constant Pool	2262
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	500
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	310
Extended Verbs	550
RTBOPCodes	200
SXTMARK	353
IMU Mode Switching	580
IMU Compensation	250
LGC Startup (P05)	57
LGC Power Down (P06)	63
IMU Status Check	30
Systems Test (P07)	650
Interpretive Constants	29
Flagup, Flagdown	31
DAP Data Load (R03)	29
End Bank Markers	36
TOTAL UTILITY AND SERVICE PROGRAMS	12679

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	Entry DAP	850
	CSM DAP Inertia Calo	3421
	Stroke Test	79
	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
ш.	Basic Math Routines	
	Inflight Alignment Routines	287
	Powered Flight Subroutines	156
	CSM Geometry	210
	Time of Free Fall	300
	Conic Subroutines	1050
	Orbital Integration	1400
	PERIAPO	100
	Lattitude, Longitude, Altitude	170
	Initial Velocity	175
	Lunar and Solar Ephemeris	75
	Planetary Inertial Orientation	280
	TOTAL BASIC MATH ROUTINES	4203
īv.	Targeting Routines	
	Transfer Phase Initiation Search	320
	Return to Earth	1200
	TOTAL TARGETING ROUTINES	1520
v.	Navigation Routines	
	Measurement Incorporation	350
	Preferred Tracking Attitude (R61)	310
	Lunar Orbit Navigation	750
	Lunar Landmark Selection (R35)	190
	Rendezvous Tracking Sighting Mark & Backup (R21, R23)	90
	Rendezvous Tracking Data Processing & Backup (R22, R24)	400
	Landmark Table	150
	Cislunar Navigation	220
	TOTAL NAVIGATION ROUTINES	3570
		2510

II. Autopilot and Maneuver Programs Digital Autopilot

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VI. Po	wered 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. Ali	ignment 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

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# VIII. Miscellaneous Programs and Routines

P27 - Update Program	320
R36 - Rendezvous Out of Plane Display	120
P30 - External Delta V Prethmist	250
1 50 - External Delta V Flethiust	200
P31 - Ceneral Lambert Maneuver	120
r 51 - General Lambert Maneuver	140
RO5 - S Band Antenna Dignlay	85
100 - D Dalid Alitellia Dispiay	00
R30 - Orbit Parameter Display	115
1650 Ofbit I af afficier Display	
R31-R34 Rendezvous Parameter Display Routine 1 & 2	100
1101 1104 Hendezvous I alameter Display Houthe I a D	200
R32 - Target Delta V	100
1000 Target Derta V	
<b>B33 - CMC/LGC Clock Synchronization</b>	24
100 Chief Ede Clock Synchronization	
TOTAL MISCELLANEOUS PROGRAMS AND ROUTINES	1234

# IX. Mission Control Programs

P01	Prelaunch or Service Initialization	38
P02	Prelaunch or Service Gyrocompassing	397
P03	<b>Optical Verification of Gyrocompassing</b>	130
P11	Earth Orbit Insertion Monitor	380
P15	Translunar Injection	250

P17	TPI Search	150
P20	Rendezvous Navigation	160
P21	Ground Track Determination	50
P22	Orbital Navigation	100
P23	Cislunar Midcourse Navigation	100
P34, P74	TPI Prethrust	450
P35, P75	TPM Prethrust	100
P37	Return to Earth	250
P38, P78	SOR Prethrust	50
P39, P79	SOM Prethrust	50
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
P77	LM TPI Search	10

TOTAL MISSION CONTROL PROGRAMS	4535
MIT PAD	1100
GRAND TOTAL	36829

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REMAINING FIXED MEMORY	35
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# LUMINARY LGC PROGRAM

# FIXED MEMORY ALLOCATION CHART (ESTIMATED)

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# I. Utility and Service Programs

35

Interpreter, Single Precision Subroutines, Fixed-Fixed Constant Pool	2262
Executive	328
Waitlist, Longcall	240
Interrupt Lead Ins	52
Interbank Communication	88
T4rupt (R10, R25)	850
Keyrupt-Uprupt	70
Downlink Program and 5 Lists	500
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	310
Extended Verbs	600
RTB OP Codes	200
Radar Rupts	230
AOTMARK (R53)	381
Backup Marking	50
IMU Mode Switching	580
IMU Compensation	270
LGC Startup (P05)	57
LGC Power Down (P06)	63
IMU Status Check	30
System Test (P07)	675
Interpretive Constants	29

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	Flagup, Flagdown	31
	DAP Data Load (R03)	160
	Radar Subroutines	710
	End Bank Markers	36
	TOTAL UTILITY AND SERVICE PROGRAMS	13848
ц.	Autopilot and Maneuver Programs Digital Autopilot	3250
	KALCMANU	680
	Attitude Maneuver (R60)	60
	Crew Defined Maneuver (R62)	18
	Vecpoint	1 30
	Rendezvous Final Attitude (R63)	30
	Ball Angle Display	82
	Middle Gimbal Display	75
	TOTAL AUTOPILOT AND MANEUVER PROGRAMS	4325
III.	Basic Math Routines	
	Inflight Alignment Routines	250
	Powered Flight Subroutines	156
	LM Geometry	96
	Time of Free Fall	300
	Conic Subroutines	1050
	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	4052
IV.	Targeting Routines	
	* Predicted Launch Time	650
	Coelliptic Sequence Initiation	440
	Constant Delta Altitude	<b>300</b>
	TOTAL TARGETING ROUTINES	1390

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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)	
	TOTAL NAVIGATION ROUTINES	1600
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 75 Coarse Align (R50) 80 Fine Align (R51) 55 Auto Optics (R52) 56 Star Data Test (R54) 40 Gyro Torquing (R55) Pick-A-Pair (R56) 142 223 Star Catalog 671 TOTAL ALIGNMENT ROUTINES

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VIII. Miscellaneous Programs and Routines			
	R47 - A0	GS Initialization	100
	R36 - Re	endezvous Out of Plane Display	120
	P27 - Up	odate Program	320
	P30 - Ex	cternal Delta V Prethrust	150
	* P31 - Ge	eneral Lambert Maneuver	120
	<b>R</b> 04 - RI	R/LR Self Test	102
	* R05 - S	Band Antenna Display	105
	R30 - O1	rbit Parameter Display	120
	R31 - Re	endezvous Parameter Display	90
	* R32 - Ta	arget Delta V	100
	R33 - CI	MC/LGC Clock Synchronization	27
	TOTAL N	MISCELLANEOUS PROGRAMS AND ROUTINES	1354
IX.	Mission Co	ontrol Programs	
	* P10-P11	Predicted Launch Time	200
	* P12	Ascent Guidance	200
	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	50
*P39-P79	SOM Prethrust	50
P40	DPS Thrust	900
P41	RCS Thrust	150
P42	APS Thrust	30
* P46	Separation Monitor	50
P47	Thrust Monitor	70
P51	IMU Orientation Determination	210
P52	IMU Realign	154
* P57	Lunar Surface Align	500

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*	P63	Landing Braking	200
*	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 M	ISSION CONTROL PROGRAMS	4479
MIT PAD		1615	
GRAND TOTAL		36382	

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# REMAINING FIXED MEMORY

 Indicates program and routines that will be omitted from the Earth Orbital LM Program (Sundance).

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# SECTION 9

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- E-2159 <u>Computer-Controlled Steering of the Apollo Spacecraft, F.H. Martin</u> and R. H. Battin, August 1967 (U)
- E-2160 <u>Verification Results Summary for LGC Sunburst (LM-1 Mission)</u>, J.A. Sampson (AC), August 1967 (U)

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