APOLLO

GUIDANCE AND NAVIGATION

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APOLLO GUIDANCE AND NAVIGATION PROGRAM

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(rev. 58)

SYSTEM STATUS REPORT

AUGUST 1968

MIT INSTRUMENTATION LABORATORY
CAMBRIDGE 39, MASSACHUSETTS

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E-1142

(Rev. 58)

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 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.

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 II Command Modules and Lunar Module equipment:

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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.

All Tables, Graphs and Schematics are dated as of their last revision.

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 1.1 and 1.2, respectively, present the weights of all CM Block II, and LM Guidance and Navigation operational flight hardware based upon the most current information. These tables offer a comparison of present component weight values with those listed in the last revision of the System Status Report.

Also included are the respective control and design load weights as assigned by NASA. The Control Weight is the maximum allowable total weight of the Apollo Guidance and Navigation equipment for which MIT/IL is responsible. Design Load Weights are restricted to individual components and should be considered as "not to exceed" weights. These values represent a maximum within which design variations may cause changes without need for renegotiation.

The row labeled "Bare Guidance System" is inserted to provide for comparisons with similarly specified systems.

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 by an explanation for the change.

North American Rockwell and Grumman Aircraft Engineering Corporation will provide and be responsible for weights of cold plates that are not integral with guidance and control equipment.

Reported Weight Changes

Block II CM: None
LM: None

TABLE 1.1 CURRENT WEIGHT STATUS OF BLOCK II COMMAND MODULE GN&C (LBS AT 1G.

Command Module GN&C Equipment	Status 2/68	Change	Status 4/68	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)	
Bellow Assy	10.7 (M)	0.0	10.7 (M)	
IMU	40.9 (M)	0.0	40.9 (M)	
Coolant Hoses (2)	1.0 (M)	0.0	1.0 (M)	
Power Servo Assy	49.4 (M)	0.0	49.4 (M)	58.0
PIPA Electronics Assy	8.5 (M)	0.0	8.5 (M)	12.0
G&N Interconnect Harness Group	25.5 (M)	0.0	25.5 (M)	40.0
AGC (with six rope modules & mag. trays)	70.1 (M)	0.0	70.1 (M)	80.0
Optical Shroud	3.3 (M)	0.0	3.3 (M)	4.5
Optical Eyepiece Storage Assy SXT Normal Relief Eyepiece SCT Normal Relief Eyepiece SCT Long Relief Eyepiece	13.6 (M)	0.0	13.6 (M)	15.0
G&N Indicator Control Panel	14.7 (M)	0.0	14.7 (M)	17.0
DSKY	17.8 (M)	0.0	17.8 (M)	25.0
Signal Conditioner Assy (Operational Flights)	5.8 (M)	0.0	5.8 (M)**	8.0

DATE: 1 April 1968

TABLE 1.1 CURRENT WEIGHT STATUS OF BLOCK II COMMAND MODULE GN& C (LBS AT 1G) (CONT'D)

Command Module GN&C Equipment	Status 2/68	Change	Status 4/68	Design Load Weight*
MAIN PANEL AREA DSKY	17.8 (M)	0.0	17.8 (M)	25.0
LOOSE STORED ITEMS Horizontal Hand Holds (2)	0.3 (M)	0.0	0.3 (M)	1.0
TOTAL	389.0	0.0	389.0	----
The reported total weight for this month is 11.0 pounds less than the 400.0 pound total control weight †				
Bare Guidance Systems - IMU, AGC, IMU portions of the CDUs and IMU support electronics.			172.8	----

*Design Load Weights are taken from ICD MH01-01356-416 signed 16 July 1965 at Meeting #22A.

**The weight of a qualification flight signal conditioner assy is 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 did not include the Optical Eyepiece Storage Assembly.

DATE: 1 April 1968

TABLE 1.2 CURRENT WEIGHT STATUS OF LM PGNCS (LBS AT 1G)

LM PGNCS Equipment	Status 2/68	Change	Status 4/68	Design Load Weight*
IMU	41.0 (M)	0.0	41.0 (M)	80.0
AOT (including eyepiece and bellows)	24.4 (E)	0.0	24.4 (E)	
NVB	5.2 (M)	0.0	5.2 (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	14.4 (M)	0.0	14.4 (M)	
HARNESS "A"	15.6 (M)	0.0	15.6 (M)	22.0
LGC (with six rope modules & mag. trays)	70.6 (E)	0.0	70.6 (M)	65.0
DSKY	17.8 (M)	0.0	17.8 (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	17.7 (M)	0.0	17.7 (M)	28.2
SCA (Operational Flights)	5.5 (M)	0.0	5.5 (M)	
TOTAL	255.8	0.0	255.8	----
The reported total weight for this month exceeds the 245.0 pounds total control weight by 10.8 lbs.†				
Bare Guidance Systems - IMU, LGC, IMU portions of the CDUs and IMU support electronics.			167.9	

*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.

DATE: 1 April 1968

SECTION 2

GLOSSARY AND SYSTEM DEFINITION

The description of what constitutes the MIT Guidance and Navigation equipment in 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 in Table 3.1. This table 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 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.

TABLE 3.1 G&N MISSION RELIABILITY ANALYSIS

FAILURE RATES EXPRESS IN "FAILURES PER 10^6 HOURS"

MISSION		IMU Assembly		IMU Electronics (PSA)		Optics Assembly		Optics Electronics (PSA)		IMU CDU		Optics CDU		AGC		DSKY		D&C		Mission Reliability
		ON	STBY	ON	STBY	ON	OFF	ON	OFF	ON	STBY	ON	OFF	ON	STBY	ON	OFF	ON	OFF	
MISSION C (AS205/101) MANNED	OPER HRS	129	134	129	134	21	-	21	-	129	-	129	-	158	105	158	-	129	-	0.894
	λ	129	10.2	110	6.3	94	-	77	-	155	-	91	-	235	60.5	2.3	-	2.3	-	
CM DES REF	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	0.9840
	λ	129	10.2	110	6.3	94	-	77	-	155	-	91	-	235	60.5	2.3	-	2.3	-	
LM DES REF	OPER HRS	3.25	66.3	3.25	66.3	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	0.9969
	λ	129	1.6	110	-	38	-	1.33	-	155	-	112	-	235	-	110	-	1.2	-	

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 diagrams 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.

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

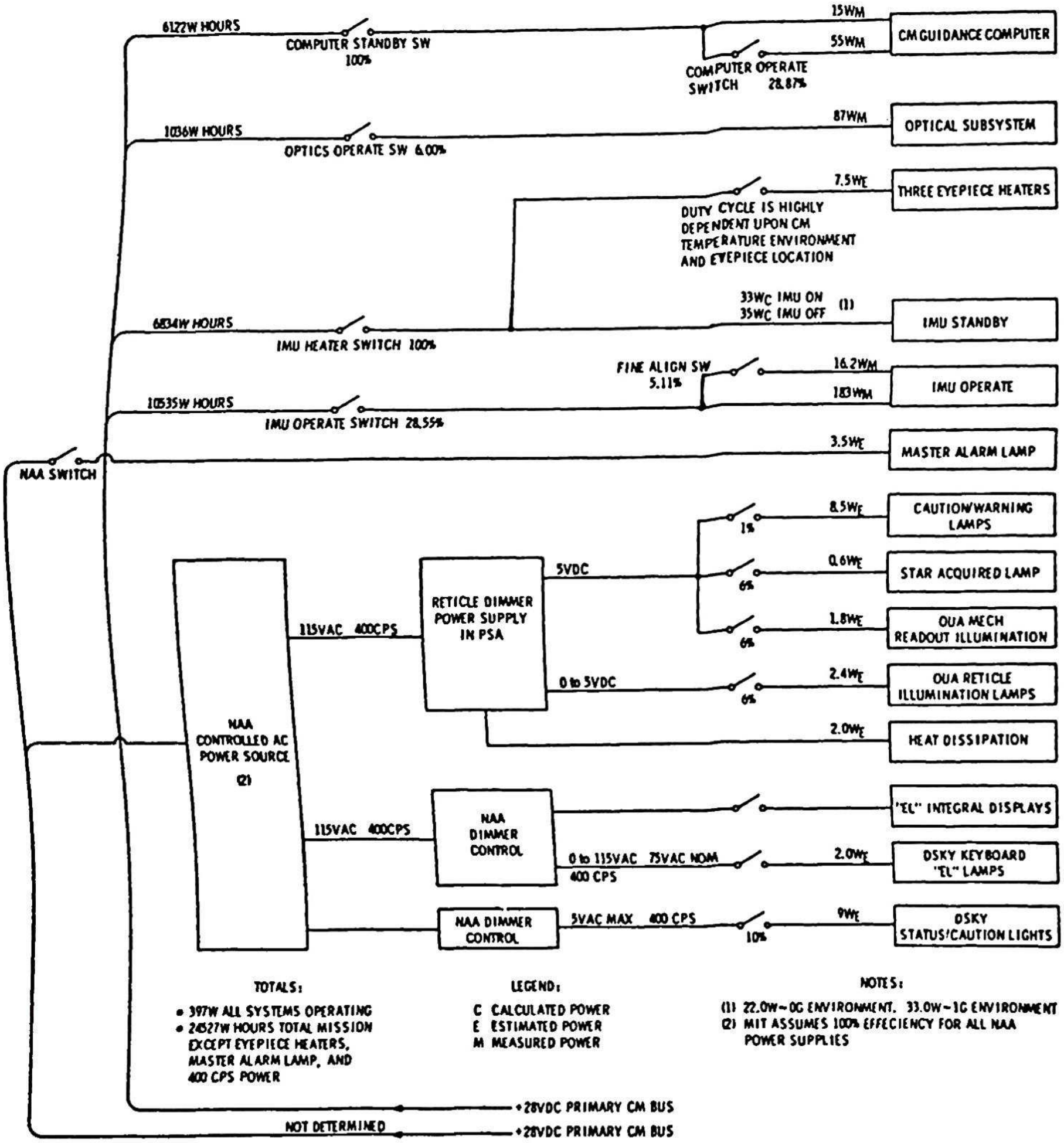
CM Block II	MH01-01327-216 "G&N Electrical Input Power" signed 15 July 1965
LM	LIS-390-10002 "PGNCS Prime Power Requirements and Characteristics" signed 30 July 1965.

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

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

STATUS OCTOBER 1967

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



TOTALS:

- 397W ALL SYSTEMS OPERATING
- 24527W HOURS TOTAL MISSION EXCEPT EYEPIECE HEATERS, MASTER ALARM LAMP, AND 400 CPS POWER

LEGEND:

C CALCULATED POWER
E ESTIMATED POWER
M MEASURED POWER

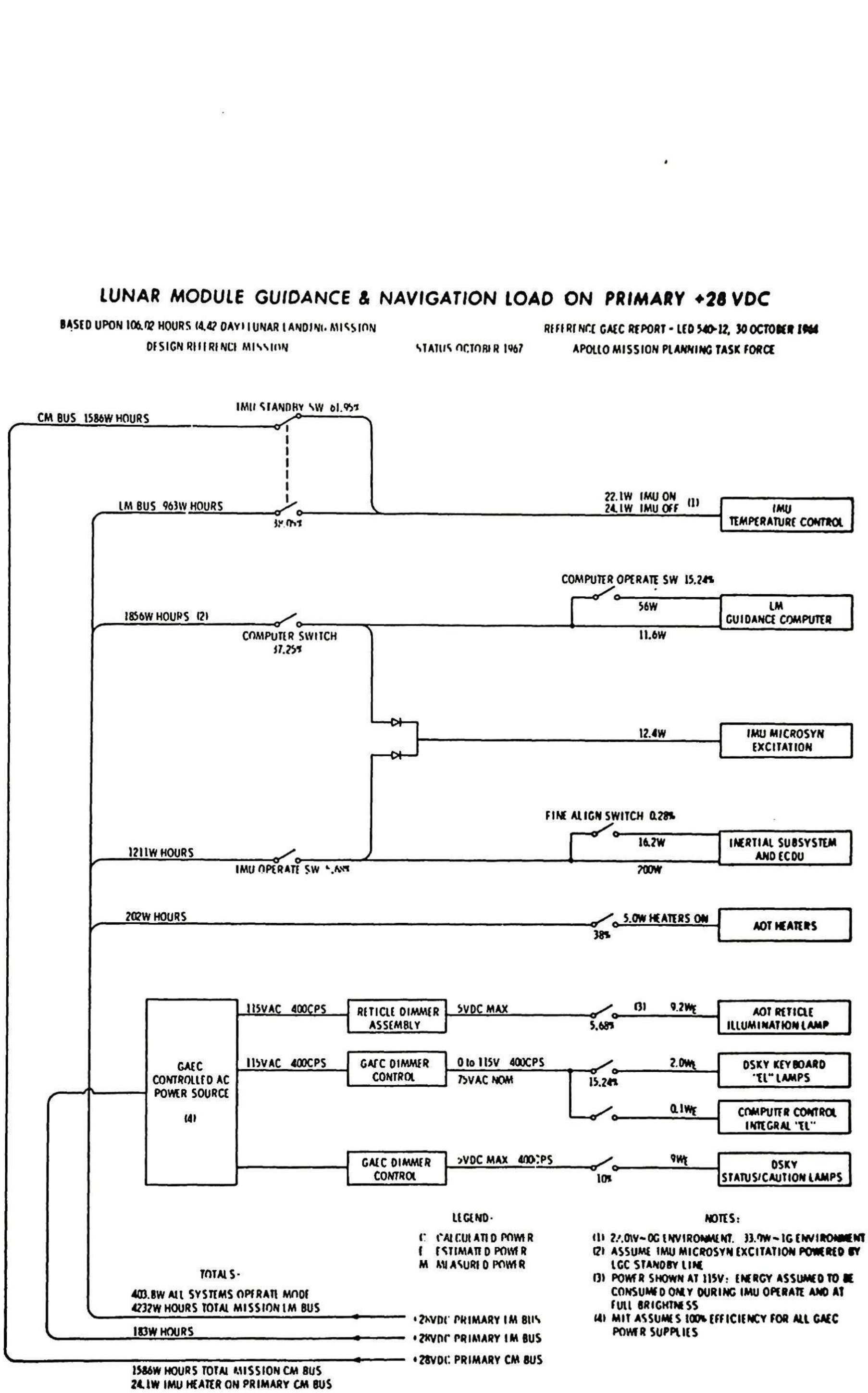
NOTES:

(1) 22.0W~0G ENVIRONMENT. 33.0W~1G ENVIRONMENT
(2) MIT ASSUMES 100% EFFECIENCY FOR ALL NAA POWER SUPPLIES

LUNAR MODULE GUIDANCE & NAVIGATION LOAD ON PRIMARY +28 VDC

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

REFERENCE GAEC REPORT - LED 540-12, 30 OCTOBER 1964
STATUS OCTOBER 1967
APOLLO MISSION PLANNING TASK FORCE



SECTION 5

GUIDANCE AND NAVIGATION SYSTEMS STATUS

The status of delivered G&N Systems is shown in tabular form. Table 5.1 shows the status of G&N Systems progressing from installation to final test at KSC.

Table 5.2 shows the configuration for major units comprising the G&N Systems assigned to LM-4 and subsequent LM Vehicles at GAEC.

Table 5.3 shows the configuration for major units comprising the G&N Systems assigned to CM-103 and subsequent Command Modules at NAR.

Table 5.4 shows the configuration for major units comprising the G&N Systems at KSC.

TABLE 5.1 DELIVERED G&N SYSTEM STATUS

OPERATION	LOCATION			
	GAEC		NAR	KSC
	LM-4 System 606 LM-5 System 609		CM-103 System 206 CM-104 System 209 CM-106 System 206	CM-101 System 204 LM-3 System 605
INSTALLATION	X	X	X X X	X X
SUBSYSTEM CHECKOUT S/C	X	X	X X	X X
INTEGRATED TEST S/C			X	X X
COMPLETE TESTING AT KSC				

DATE: 1 August 1968

1. LM-2, G&N System 608; completed all G&N testing at S/C contractor and vehicle was shipped to MSC during the week of 16 June.

2. LM-3, G&N System 605; shipped from GAEC to KSC 14 June 1968.

TABLE 5.2 LM G&N SYSTEM CONFIGURATION

S/C	LM-4		LM-5			
COMPONENT NOMENCLATURE	System 606		System 609			
	Part Number	S/N	Part Number	S/N	Part Number	S/N
LGC	2003993-031	31	2003993-031	42		
DSKY	2003994-021	65	2003994-021	54		
IMU	2018601-221	21	2018601-191	11		
ECDU	2007222-221	18	2007222-241	31		
AOT	6011000-081	16	6011000-081	15		

DATE: 1 August 1968

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

1. LM - 2 G&N System 608

   Completed all G&N testing at S/C contractor. Vehicle shipped to MSC during the week of 16 June 1968.

2. LM - 3 G&N System 605

   Completed all G&N Testing at S/C contractor. Vehicle shipped to KSC 14 June 1968.

TABLE 5.3 CM G&N SYSTEM CONFIGURATION AT NAR

S/C	CM-103		CM-104	
COMPONENT NOMENCLATURE	System 203		System 209	
	Part Number	S/N	Part Number	S/N
AGC	2003993-031	33	2003003-031	37
DSKY (Main)	2003994-021	58	2003994-021	59
DSKY (Navigation)	2003994-021	48	2003994-021	42
IMU	2018601-201	23	2018601-201	22
CDU	2007222-231	35	2007222-231	34
OPTICS	2011000-071	19	2011000-071	27

DATE: 1 August 1968

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

CM-104 (G&N System 209)

Replaced DSKY (Main) Part Number 2003994-021, S/N 53 with 2003994-021, S/N 59. Change caused by bent pins.

TABLE 5.4 G&N SYSTEM CONFIGURATION AT KSC

S/C	LM-3		101	
COMPONENT NOMENCLATURE	System 605		System 204	
	Part Number	S/N	Part Number	S/N
AGC	2003993-031	32	2003993-031	27
DSKY (Main)	2003994-021	51	2003994-031	50
DSKY (Navigation)			2003994-031	64
IMU	2018601-211	15	2018601-201	8
CDU	2007222-221	24	2007222-191	15
OPTICS	6011000-074	18	6011000-071	24

DATE: 1 August 1968

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

1. LM-3, G&N System 605

   A. Optics part number changed from 6011000-072, S/N 18 to 6011000-074, S/N 18 due to sun shade modification and addition of protective shield to wire harness.

   B. Replaced IMU part number 2018601-221, S/N 27 with 2018601-211, S/N 15 due to PIPA Fail indication that could not be verified.

2. CM-101, G&N System 204

   DSKY Main and DSKY Navigation part numbers changed from 2003994-021 to 2003994-031 due to addition of new EL and IL safety glass covers.

SECTION 6

G&N SYSTEM TEST

SYSTEM TEST LABORATORY

A. G&N 5

No operating hours.

B. G&N 104

No operating hours.

C. G&N 200

1. Program Tests

a. Reverified TVC polarity testing with new DAP filter coefficients on SUNDISK 282.

b. Continued checkout of COLOSSUS Program, presently on Revision 224. Level III testing completed 7/21/68.

c. Analyzed the following program anomalies.

1) Inability to point optics for optical verification of gyrocompass. Resolution: Erasable conflict between optical verification and gyrocompass. Eliminated by relocating gyrocompass restart storage registers.

2) DSKY monitor program stops for 163 seconds after driving a gimbal into gimbal lock by gyro torquing. Resolution: Error in gyro torquing routine corrected.

3) Prelaunch alignment optical verification could not be terminated while the program was expecting marks, program would proceed without marks. Resolution: Program changed to improve operating procedure.

d. Continued checkout of TVC polarity testing for K-START tape development.

e. Continued flight simulation test checkout and development on COLOSSUS.

f. Verified operation of erasable segments for COLOSSUS. Self test and IMU performance segments verified. Scale factor test waiting for tape.

2. Hardware Tests

a. Performed noise testing on CDU with RFI filter in loop between IMU and CDU. Found that filter appears to be effective in reducing noise susceptibility.

b. Schedules have prevented further checkout of special PIPA test routine for determination of air bubbles. (Ref. Progress Report 1 February 1968).

3. Failures

a. DSKY S/N 14 had verb button fail. Replaced with DSKY S/N 18.

b. Digital Mode module S/N P003 replaced with S/N 007. This corrected Optics Trunnion runaway problem..

c. X-gyro failed. Replaced S/IVA114 with S/IV7B146.

4. Modification

a. D&C panel S/N 2 replaced with updated D&C panel - no S/N.

D. <u>G&N 600</u>

1. Program Tests

a. The month of July was devoted mainly to System Test Group Level V verification of SUNDANCE. Nine anomalies were reported since DANCE 292. The verification tests have been completed except for a few odds and ends.

b. Verified MARVIN, T self-test segment.

c. Continued SUNDANCE testing through "A" release (Rev. 302).

d. Verified STG K-START tapes K-00081 through K-00086 for LM-3 DANCE 302. Tested ACED generated K-START tapes K-10530, K-10531 and K-10538. Found several procedural deficiencies as well as DANCE program change effects. Informed KSC for impact on OCP's.

e. Continued Simflight development runs.

f. Verified for MSC that their uplink problems were hardware and not software or K-START program problems.

2. Hardware Tests

a. Confirmed that the pulse torque power supply capacitor could have caused the LM-3 PIPA failure.

3. Failures

a. Three DSKY buttons failed on different occasions - the 01, 02, and VERB. The spring leaf fractured in each. The buttons were replaced.

b. A troublesome OG CDU MSA module was retired from the system. Soft solder joints in the prototype module has caused problems on several occasions.

c. The UPLINK lines were verified to support UPLINK susceptibility study. Found a short in the ITC as well as incorrect shield terminations.

FIELD OPERATIONS

A. GAEC

1. LM-2 (Mission AS-208) G&N System 608 shipped to MSC.

2. LM-3 (Mission AS-503) G&N System 605 shipped to KSC.

3. LM-4 (Mission AS-504) G&N System 606.
OCP 61015 pre-flight testing has been completed.

4. LM-5 (Mission AS-505) G&N System 609
OCP-62000, LM Combined Subsystems Test has been completed.

5. LM-6 (Mission AS-506) G&N System 607
S/C installation is in progress.

6. LM-7 (Mission AS-507) G&N System 610
Completed laboratory testing.

B. KSC

1. S/C 101 (Mission AS-205) G&N System 204
TCP-K-0070, Abbreviated Combined System Test has been completed. TCP-K-0034, Altitude Chamber Test has been completed.

2. LM-3 (Mission AS-503) G&N System 605
Completed combined systems test, TCP-K-0011.

C. MSC

1. Completed thermal vacuum runs on 2TV-1.

2. LTA-8 presently being reconfigured, having completed thermal vacuum runs.

3. Supporting flight controllers and flight control support group at Apollo Data Priority Meetings.

4. Spent one week training in programming area at MIT/IL. Started simulated flights, S/C-101 in order to prepare flight controllers. Sent temperature data on 2TV-1, LTA-8 secondary cooling loop tests to the Thermal Group at MIT/IL.

D. NAR

1. CM-103 (Mission AS-503) G&N System 208

Completed CARR, Phase III on 25 July 1968. Completed OCP-126, combined systems test.

2. CM-104 (Mission AS-504) G&N System 209

Completed CARR, Phase II on 16 July 1968. System is installed in S/C awaiting start of test cycle.

3. CM-106 (Mission AS-505) G&N System 206

Completed Phase III installation.

4. CM-107 (Mission AS-506) G&N System 210

Phase II and III installations in progress.

5. CM-108 (Mission AS-507) G&N System 211

System awaiting S/C installation, has completed all G&N laboratory testing.

SYSTEM ENGINEERING

A. Spacecraft Support

1. The Sum-Erasable program, BCSUM, has been revised to include the following additional features:

a. Accumulate and display the total sum of the contents of any number of groups of consecutive erasable memory locations.

b. Blank the DSKY in the event the start and stop addresses are entered in reverse order.

c. The blanking feature may be used to blank the DSKY after a correct sum has been verified.

2. The final version of the DSKY test and computer instruction test (MARVIN, T) were transmitted to AC on 5 June by AG-237-68.

3. The revised BCSUM has been assembled in each of the above segments. Each assembled BCSUM data table includes data for summing its parent segment.

4. The assembled programs have been simulated "directly" via a new feature recently completed by the digital simulator group. That is, the programs were not loaded via special request cards, but simulated as though they were part of the parent assembly, SUNDANCE or COLOSSUS. The programs were first summed and then executed. The sum for each segment is available to the System Test Lab.

5. K-START card decks of the Computer Functional Tests, G/N Operational Tests, LM Semi-Automatic Moding Tests, and Jet Sequencing Tests were received from ACED with the following incompatibilities to the MIT Conversion Program:

a. Keypunching, necessary for making the decks acceptable for conversion to astronaut cards, has been performed.

b. The G/N Operational Tests have been simulated to completion.

c. The LM Semi-Automatic Moding Tests have a hang-up. The digital simulator will not simulate.

d. The Computer Functional Tests simulation ran to completion after a VERIFY card was replaced by a WAIT card. However, the contents of monitored locations did not change. Diagnostics will be performed via a rollback.

e. The Jet Sequencing Tests comprise three sets of programs.

1) One set overflowed the astronaut input data file. It will somehow be divided into parts.

2) The other two sets encountered display verification conflicts which have been remedied. However, the simulation of each has been restarted in an attempt to reduce computer execution time.

6. An optical method was developed for determining the orientation of the LM Navigation Base with respect to the CSM Navigation Base when the two vehicles are docked and mounted in the altitude chamber at the MSO Building, KSC. STG Memorandum #1182 was prepared on this method and was forwarded to G. Silver.

The investigation of the accuracy of the vertical drift test was continued. The following data was obtained.

Procedure used:

a. Put in a varying (exponential) drift for the east gyro.

b. Then measure the vertical drift.

c. Ran with no exponential drift.

d. Then measured the vertical drift.

Results:

Input East Gyro Drift (meru)	Tau (Time Const) (sec)	Actual Drift (meru)	Meas Drift (meru)
1	900	-5	-7.32
3	900	-5	-16.17
10	900	-5	-40.77
0	0	-5	-4.67

7. AC Electronics Erasable Program K-START tapes

All ten K-START programs have been simulated to completion. STG Memo No. 1208 describes problems in the semi-automatic mode test. A summary of problems and solutions for each program simulation is being written. Simulation results have been forwarded to AC Electronics. All ten K-START card decks were listed, major format errors were marked, and the listing returned to AC. AG Letter 354-68 reported the results to NASA and STG Memo No. 1205 describes requirements for AC submittals of K-START tapes.

8. Erasable Computer Self-Test Program for SUNDANCE

The computer instruction and DSKY tests were reassembled in segment CINDYSUE, Revision 302, to include AC Electronics requests. The segment was thoroughly tested with the digital simulator and it was forwarded to AC Electronics for K-START manufacture. STG Memo No. 1192 and 1205 were issued describing this test and operating procedures.

9. Erasable Computer Self-Test Program for COLOSSUS

The Computer Instruction and DSKY tests were reassembled in segment CINDYC to avoid erasable conflict with shifted erasable assignment for fixed programs. A thorough test of CINDYC 222 proved successful. CINDYC 224, assembled with COLOSSUS 224, was tested successfully (reference: STG Digital Simulation Report STP-4).

10. IMU AGS Align Test

The K-START tape with LINAGS 35 was successfully made into astronaut cards and simulated with SUNDANCE 302. It was also successfully run in the STG lab, and a K-START tape was manufactured. STG Memo No. 1206 was written describing this program.

11. IRIG SF Test

The K-START tape for this test with DANCE 302 was generated and checked on the lab system, and the segment was run on the digital simulator. The COLOSSUS version was also simulated.

12. IMU Performance Test

The performance test for DANCE 302 and for COLOSSUS were simulated.

13. Miscellaneous

An automatic K-START tape generating program from segments is being developed.

B. Program Tests

1. DANCE Level 5

All the tests are complete with the following exceptions:

a. ALM Tests 1 and 2 - now in typing.

b. RP10 - radar downlink. Processing of data completed by hand and document being prepared.

c. IP2 - anomalies remain in the processed downlink data.

A meeting was held with GAEC and NASA to discuss our alarm testing.

2. COLOSSUS Level III

All tests complete with the following exceptions

a. ALARMS test being performed.

b. STP3, 4 being documented.

Test of P53 and P54 were added and are being documented. A presentation was prepared for the COLOSSUS FACI.

3. COLOSSUS Level V

A new test plan was drafted and is being circulated.

4. LUMINARY Level III

A schedule for these tests was published. They will begin on August 5.

C. System Programming

The IMU gyro torquing and optics drive routines in COLOSSUS were fixed. The optical verification program was fixed so that it can be terminated and cannot proceed without any marks being made.

These program changes resulted from analysis of problems discovered during laboratory testing of COLOSSUS.

D. Auxiliary Memory Project

A version of the LINEAGS segment was created to operate in E-Memory. E-Bank declarations are problem with the assembler, (High F. BANK declarations have been accommodated through assembler modifications).

The wiring of the Auxiliary Memory hardware is such that the BBANK register bit assignments are not compatible with those of the AGC. If the hardware is changed to agree with the AGC, the Raytheon demonstration program will not operate without modifications. Since the demonstration program is, in part, required to be used in loading and manipulating segments data between the ACM, ATM and CRS, some changes must be made to the system to allow switching these bit assignments back and forth between the two configurations. This is to be done during August by Raytheon resident personnel. A demonstration test of the Auxiliary Memory in the STG Lab is still planned to take place on the 1st or the 2nd of August.

E. Experiment M-439

1. A meeting was held between NASA and MIT/IL during June for the purpose of reviewing the Procurement Specification on the Tracker/Photometer to be used in the M-439 experiment. The change recommendations made by MIT/IL and accepted by NASA were incorporated into the Procurement Specification and forwarded to Kollsman.

2. Created version of COLOSSUS for use as the test vehicle for the M-439 experiment. Also created and assembled a special version of P23 for this purpose. Developed a special subroutine to calculate the Pseudo Star Vector. This is to be incorporated into this version and tested. Still prediciting 31 August date for completion, barring any further work on Auxiliary Memory during August.

KSC CHECKOUT

A. Verified CSM process spec, ND-1002348, Rev. F, with COLOSSUS, Rev. 222, for Level III verification testing in G&N lab.

B. F07L003-K00081-03 IMU Performance Test - SUNDANCE 302, was manufactured and verified, and is ready for sell-off and shipment to KSC.

D. STG Memo No. 1146, Revision C, 1204 and 1210 were written to define the MIT/IL K-START tape delivery schedules for S/C 101, S/C 103, LM-3 and LM-4.

E. The following AC Electronics! designed K-START tapes were verified using SUNDANCE, Rev. 292.

a. LGC Self Test
b. LM G&N Operational
c. LM Semi-Automatic Mode

F. Verified the S/C 101 TVC/RCS DAP Polarity Test K-START Tape, F08C101-K00079-03, which contains the third-order DAP filter gain values. The tape will be shipped to MSC and KSC shortly.

G. LM process spec ND-1002349, Rev. F, test requirements (software) were verified in the G&N lab as part of the SUNDANCE Level V Verification (SPS).

H. STG Memo No. 1148, Revision B - MIT/IL K-START tape schedule for S/C 101, S/C 103, and LM-3.

I. The following K-START tapes for S/C 101 were verified, sold-off and shipped to MSC and KSC: (SUNDISK 282).

a. F08C101-K00067-00, Launch Erasable Load
b. F08C101-K00068-00, Mission Erasable Load
c. F08C101-K00078-00, Flight Rope Controlled Mission Profile

J. F08C101-K00079-02, TVC/RCS DAP Polarity Test, Design and verification is in progress.

K. The following K-START tapes for LM-3 were verified, sold off and shipped to MSC and KSC (SUNDANCE 292):

a. F07L003-K00067-03, Launch Erasable Load
b. F07L003-K00068-03, Mission Erasable Load
c. F07L003-K00078-03, Flight Rope Controlled Mission Profile
d. F07L003-K00083-01, IRIG Scale Factor Test

L. F07L003-K00086-00, RCS/TVC DAP contingency polarity test design and verification is in progress.

M. F07L003-K00082-02, AGS Initialization (for AGS state vector transfer test) has been manufactured and delivered and will be shipped to MSC and KSC the first week of July (the changes for this tape were received June 28 by phone).

TEST EQUIPMENT

A. Project Trace/Block II Coroner

1. The overall project is proceeding satisfactorily. It appears we will be on schedule and in budget.

2. DRB of the logic design has been initiated. This has resulted in some minor design changes and the possibility of adding a semi automatic self check feature.

3. The logic for the interpretive trace section of the 360 program and most of the basic trace section has been worked out.

4. Spec writing has been initiated.

5. There do not appear to be any significant parts problems.

6. Work on the computer aided design is progressing satisfactorily.

B. Outstanding ECP's

1. Hybrid Trace

2. Portable Gyro Certification UNIT (PGCU). No action has been taken by NASA on either of these ECP's.

C. Uplink-Downlink Timer

Fabrication of the Uplink-Downlink Timer should begin this month.

D. Miscellaneous

1. Review of contractor drawings is continuing on as required basis.

2. Maintenance of GSE stations is continuing.

3. Our in-house documentation is being strengthened.

4. Additional marriage kit changes have been installed on P-9.

MISSION TEST PROGRAMMING

A. Level III testing of COLOSSUS gyrocompass program completed (P01.1-P01.5).

B. Optical verification of gyrocompass (COLOSSUS) still undergoing modification to permit termination in the middle of the program and to prevent proceeds without having entered marks.

C. A NASA document pertaining to a simplified error model for the Apollo G&N was critically reviewed.

MISCELLANEOUS

A. Prepared and presented system test portion of overall review of G&N checkout activity by C. Kraft, MSC

B. Prepared and submitted outline for G&N system section of the Apollo G&N Final Report.

C. Reviewed and modified where necessary the G&N section of Volume 1 of Spacecraft Operational Data Book (SNA-8-D-027).

D. Prepared and presented lecture on Inertial Subsystem to the crews of D and E missions.

E. Worked with Data Analysis group in an effort to get the Laboratory Data Processing System on the air.

F. Attended S/C 103 CARR meeting in Downey, California on 25 July 1968.

G. Final review of COLOSSUS and LUMINARY Prelaunch (Section 1) GSOP.

H. Prepared TDRR to PS 201500 and PS 601500 to eliminate any chance of misinterpretation of the Voltage Field Alarm Test specifications. Reviewed ACED submitted TDRRS.

SECTION 7

G&N COMPUTER STATUS

DESIGN ANALYSIS & SUPPORT

A. Analysis Facility Activities

1. Investigation of the noisy B2 SUNDANCE rope module at Raytheon revealed the cause of the problem to be dynamically mismatched diodes in the strand select lines. Further testing is being performed at Raytheon to determine how to detect this situation in rope modules presently fabricated and to ensure that new modules will not utilize mismatched pairs.

B. Field Support

1. Uplink Problem at MSC

Uplink K$\overline{\text{K}}$K failures were experienced quite frequently in a command module mockup at MSC (AGC-601 operating with SUNDISK 282 supplied by a PAC). The cause of the problem was traced to noise generated by the PAC. Extraneous pulses sent by the PAC to the AGC during the execution of the UPRUPT routine (which checks the validity of the Uplink transmission) caused the program to fail.

C. Miscellaneous AGC Related Activity

1. An investigation of the uplink noise problem was made and from this several fixes were proposed. This activity was reported in AG 351-68.

2. The configuration of the new IL Status and Caution Panel with 4 extra caution lights was specified. The relay word required to address and turn on the light was determined.

3. As a result of the EL and IL glass breakage in LTA-8 testing, a new fire-fix cover was designed using safety glass. The same cover assembly was used without the gaskets that provided the seal and the glass was replaced with safety glass.

4. The new documentation for software release and processing at Raytheon has been released. There need to be some minor changes in the way tester tapes are checked. These changes are defined in AG 383-68

5. The restart monitor drawings have been released. Three of the six modules were delivered to ACE. The balance of the contractual requirement for six modules is ready to be delivered but must be waivered before NASA/RASPO will accept them.

6. Status of CRS S/N 6

Still waiting for memory units. Presently supporting auxiliary memory testing in Digital Development Group Lab.

7. Block II AGC & DSKY Status at MIT

Status of all other hardware is unchanged since the last report.

COMPONENT PROBLEMS

A. Contamination in Logic Flatpacks

The seriousness of this problem is now recognized by all concerned. An analysis of all computer failures was summarized in AG 363-68. Since the introduction of the new Y-axis vibration there has been an average of two failures per computer. The X-ray screen has been added to the flatpack F.P.S.

B. Rope Diode Problem

Several rope failures have occurred recently similar to the failure in LM 3 with SUNDANCE B2 module. After considerable investigation the cause of the failure was determined to be the result of dynamic mismatch in the diodes. A special test must be run to match the turn-on times of the diode pairs to within 3 ns.

SECTION 8

APOLLO GUIDANCE COMPUTER PROGRAMMING SUMMARY

SUNDISK - MANNED CSM (EARTH ORBITAL) MISSION "C"

The following activities were performed during the reporting period.

The Constants Verification in the SUNDISK Program is to be completed in early August. The results of the review will be published in an MIT memo.

The Postflight Data Processor Program has been checked out on the IBM 360 in preparation for Mission "C".

Planning and discussion meetings have been held with NASA/MSC regarding mission support by MIT.

The Flight Readiness Review (FRR) for Mission "C" is presently scheduled for August.

Stress testing of the Level 3 and 4 type tests were completed during the reporting period.

Mission verification of the SUNDISK Program for Mission "C" is scheduled for completion in early August.

Three additional anomalies were written against the SUNDISK Program, bringing a total of 22 anomalies written to date.

SUNDANCE - MANNED LM (EARTH ORBITAL)

Level 5 testing of the SUNDANCE Program was conducted during the reporting period. Revision 302 of the SUNDANCE Program was released to rope manufacturing on 3 July 1968.

A total of 106 anomalies have been written since the FACI.

The SUNDANCE DAP performance testing is scheduled to be completed in September 1968.

Revisions to Section 2 (Data Links), Section 3 (Digital Autopilot), Section 4 (Operational Modes) and Section 5 (Guidance Equations) of the GSOP were published.

"Hows and Whys" type training was conducted during the reporting period.

COLOSSUS - MANNED CSM (LUNAR CAPABILITY)

The COLOSSUS Program development was in the final stages of Level 4 testing during the reporting period.

Meetings have been held with NASA/MSC to discuss the procedure to be adopted for conducting the COLOSSUS FACI to be held in early August. The present plans are to form individual working groups of NASA and MIT personnel to examine the COLOSSUS Program status and test results. Each group chairman will then report the group's findings and recommendations at the formal FACI.

To provide a current set of documents for the FACI review, revisions to all sections of the GSOP are planned prior to the meeting.

LUMINARY - MANNED LM (LUNAR CAPABILITY)

The Luminary Program was in the final stages of Level 3 testing and the initial phase of Level 4 testing during the reporting period.

The G&N Functional Description, Volume II, was published in mid July, as well as Section I, Prelaunch, of the GSOP.

COLOSSUS II AND LUMINARY II

During the reporting period, the preliminary requirements for the next flight programs to be developed at MIT/IL were established by MIT/IL and NASA/MSC. Development schedules for these programs are presently being established.

TABLE 8.1

COLOSSUS CMC PROGRAM

FIXED MEMORY ALLOCATION CHART (ESTIMATED)

I.	Utility and Service Programs	
	Interpreter, Single Precision Subroutines, Fixed-Fixed Constant Pool	2225
	Executive	340
	Waitlist, Longcall	245
	Interrupt Lead Ins	58
	Interbank Communication	88
	T4RUPT	794
	SXT Angle Monitor	50
	Keyrupt-Uprupt	68
	Downlink Program and 5 Lists	425
	Fresh Start and Restart	420
	Alarm and Abort	77
	Delayjob	30
	Restart Routine and Tables	434
	Phase Table Maintenance	179
	Pinball Program and Noun Tables	2920
	Displays, Priolarm	700
	Program Select (V37, P00, R00)	357
	Self Check	314
	Extended Verbs	741
	RTBOP Codes	200
	SXTMARK	313
	IMU Mode Switching	572
	IMU Compensation	250
	LGC Startup	32
	LGC Power Down (P06)	47
	IMU Status Check	17
	Systems Test (P07)	630
	Interpretive Constants	35
	Flagup, Flagdown	59

GENTRAN	15
DAP Data Load (R03)	50
End Bank Markers	79
TOTAL UTILITY AND SERVICE PROGRAMS	12,764

II. Autopilot and Maneuver Programs

Entry DAP	802
BOOST	65
RCS	1833
TVC	1695
TWINGIMB S40.6	69
TVNG	30
KALCMANU	715
Attitude Maneuver (R60)	86
Crew Defined Maneuver (R62)	11
Vecpoint	130
Rendezvous Final Attitude (R63)	40
Middle Gimbal Display	64
CM Body Attitude	195
TOTAL AUTOPILOT AND MANEUVER PROGRAMS	5735

III. Basic Math Routines

Inflight Alignment Routines	225
Powered Flight Subroutines	187
CSM Geometry	254
Time of Free Fall	268
Conic Subroutines	1094
Orbital Integration	1500
PERIAPO	78
Lattitude, Longitude, Altitude	159
Initial Velocity	195
Lunar and Solar Ephemeris	75
Planetary Inertial Orientation	204
TOTAL BASIC MATH ROUTINES	4239

IV. Targeting Routines

Transfer Phase Initiation Search	322
Central Angles Subroutine	46
TOTAL TARGETING ROUTINES	368

V. Navigation Routines	
Measurement Incorporation	333
Preferred Tracking Attitude (R61)	280
Lunar Landmark Selection (R35)	223
Rendezvous Tracking Sighting Mark & Backup (R21, R23)	75
Rendezvous Tracking Data Processing & Backup (R22, R24)	498
Landmark Table	150
TOTAL NAVIGATION ROUTINES	1559
VI. Powered Guidance Routines	
Servicer	450
Desired Thrust Direction (S40.1, S40.2, 3)	300
Cross Product Steering (S40.8)	140
VG Calculation (S40.9)	115
Time of Burn Calculation (S40.13)	81
Initial VG (S41.1)	20
Entry Guidance	1151
TOTAL POWERED GUIDANCE	2257
VII. Alignment Routines	
Coarse Align (R50)	80
Fine Align (R51)	116
Auto Optics (R52)	140
Sighting Mark (R53)	51
Star Data Test (R54)	43
Gyro Torquing (R55)	27
Pick-A-Pair	127
Star Catalog	223
Alternate LOS Sighting Mark (R56)	130
Optics Calibration (R57)	53
TOTAL ALIGNMENT ROUTINES	990
VIII. Miscellaneous Programs and Routines	
P27 - Update Program	306
R36 - Rendezvous Out of Plane Display	93
P30 - P31 EXT DELTA V & General Lambert Maneuver	325
R05 - S Band Antenna Display	85
R30 - Orbit Parameter Display	278
R31 - R34 Rendezvous Parameter Display Routine 1 & 2	177
R33 - CMC/LGC Clock Synchronization	26
TOTAL MISCELLANEOUS PROGRAMS AND ROUTINES	1290

IX. Mission Control Programs

P01 - Prelaunch or Service Initialization	42
P02 - Prelaunch or Service Gyrocompassing	329
P03 - Optical Verification of Gyrocompassing	178
P11 - Earth Orbit Insertion Monitor	411
P17 - TPI Search	80
P20 - Rendezvous Navigation	150
P21 - Ground Track Determination	66
P22 - Orbital Navigation	970
P23 - Cislunar Midcourse Navigation	567
P34, P74 TPI Prethrust P35, P75 TPM Prethrust	648
P37 - Return to Earth	1306
P38, P78 SOR Prethrust P39, P79 SOM Prethrust	231
P40 - SPS Thrusting P41 - RCS Thrusting	784
P47 - Thrust Monitor	58
P51, P53 IMU Orientation Determination & Backup	256
P52, P54 IMU Realign and Backup	380
P61 - Maneuver to CM/SM Sep Attitude	316
P62 - CM/SM Sep and Pre-Entry Maneuver	92
P63 - Entry Initialization	18
P64 - Post 0.05G	6
P65 - Upcontrol	27
P66 - Ballistic	4
P67 - Final Phase	36
P76 - Target Delta V	100
P77 - LM TPI Search	1
TOTAL MISSION CONTROL PROGRAMS	7056
GRAND TOTAL	36258
REMAINING FIXED MEMORY	606

TABLE 8.2

LUMINARY LGC PROGRAM

FIXED MEMORY ALLOCATION CHART (ESTIMATED)

I. Utility and Service Programs	
Interpreter, Single Precision Subroutines Fixed-Fixed Constant Pool	2202
Executive	337
Waitlist, Longcall	245
Interrupt Lead Ins	58
Interbank Communication	76
T4rupt (R10, R25)	632
Keyrupt-Uprupt	68
Downlink Program and 7 Lists	425
Fresh Start and Restart	429
Alarm and Abort	100
Delayjob	30
Restart Routine and Tables	325
Phase Table Maintenance	165
Pinball Program and Noun Tables	2964
Displays, Priolarm	700
Program Select Check (V37, P00, R00)	310
Self Check	314
Extended Verbs	675
RTB OP Codes	181
Radar Rupts	242
AOTMARK (R53)	430
Backup Marking (COAS)	20
IMU Mode Switching	572
IMU Compensation	282
LGC Startup	32
LGC Power Down (P06)	48
IMU Status Check	17
System Test (P07)	632
Interpretive Constants	35

Flagup, Flagdown	59
GENTRAN	15
DAP Data Load (R03)	150
Radar Subroutines	784
End Bank Markers	73
TOTAL UTILITY AND SERVICE PROGRAMS	13627

II. Autopilot and Maneuver Programs

Digital Autopilot	3250
KALCMANU	670
Find CDU W	441
Attitude Maneuver (R60)	98
Crew Defined Maneuver (R62)	11
Vecpoint	130
Rendezvous Final Attitude (R63)	67
Ball Angle Display	49
Middle Gimbal Display	64
TOTAL AUTOPILOT AND MANEUVER PROGRAMS	4780

III. Basic Math Routines

Inflight Alignment Routines	227
Powered Flight Subroutines	187
LM Geometry	99
Time of Free Fall	268
Conic Subroutines	1094
Orbital Integration	1504
PERIAPO	78
Latitude, Longitude, Altitude	159
Initial Velocity	195
Lunar and Solar Ephemeris	126
Planetary Inertial Orientation	206
TOTAL BASIC MATH ROUTINES	4143

IV. Targeting Routines

Coelliptic Sequence Initiation Constant Delta Altitude }	649
TOTAL TARGETING ROUTINES	649

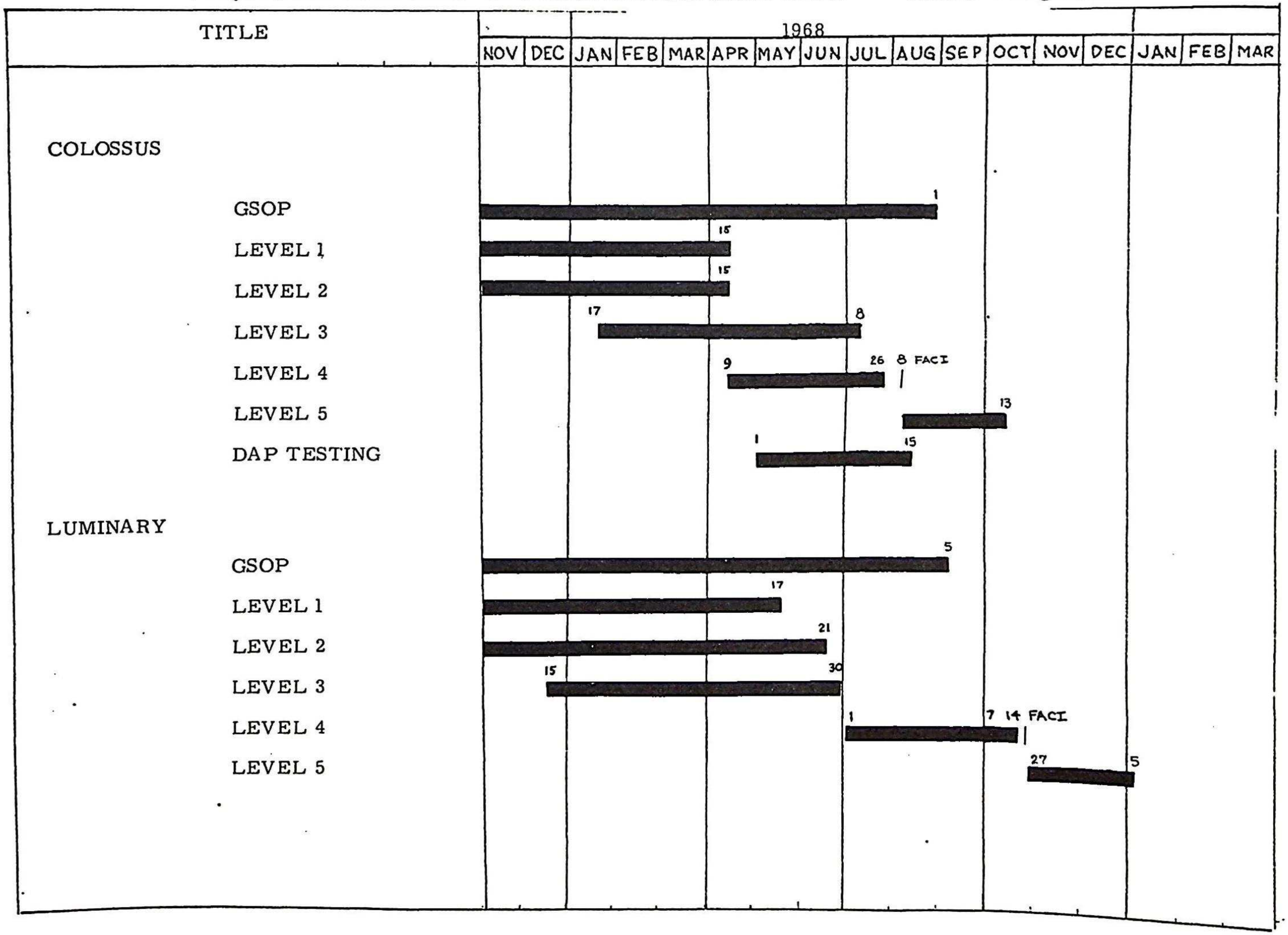
V. Navigation Routines	
Measurement Incorporation	333
Preferred Tracking Attitude (R61)	118
Rendezvous Navigation (LSR22.3, RADARANG)	525
Lunar Surface Navigation (LSR22.4)	
RR Search, Designate and Read (R21, R22, R23, R24, R29, LPS20.1, LPS20.2 LRS22.1, LRS22.2, LRS24.1, CALCXY)	650
TOTAL NAVIGATION ROUTINES	1626
VI. Powered Guidance Routines	
Servicer (R12)	1084
Desired Thrust Direction (S40.1, S40.2, 3)	121
Cross Product Steering (S40.8)	67
VG Calculation (S40.9)	103
Time of Burn Calculation (S40.13)	118
Descent Guidance (R11, R13)	700
Throttle Logic	129
Ascent Guidance	550
TRIMGIMB (S41.1, S40.6)	44
TOTAL POWERED GUIDANCE ROUTINES	2916
VII. Alignment Routines	
Coarse Align (R50)	61
Fine Align (R51)	134
Auto Optics (R52)	65
Star Data Test (R54)	41
Gyro Torquing (R55)	27
Pick-A-Pair (R56)	132
Lunar Surface Sighting Routine	221
Star Catalog	223
TOTAL ALIGNMENT ROUTINES	904
VIII. Miscellaneous Programs and Routines	
R47 - AGS Initialization	138
R36 - Rendezvous Out of Plane Display	93
P27 - Update Program	306
P30 - External Delta V Prethrust	80
P31 - General Lambert Maneuver	75
R04 - RR/LR Self Test R77 - LR Spurious Return Test	145
R05 - S Band Antenna Display	132

R29 - Rendezvous Radar Flight Designate	329
R30 - Orbit Parameter Display	278
R31 - Rendezvous Parameter Display	177
R33 - CMC/LGC Clock Synchronization	26
R10 - Landing Analog Display Monitor	454
R11 - Abort Discretes Monitor	45
R13 - Auto Modes Monitor	41
TOTAL MISCELLANEOUS PROGRAMS AND ROUTINES	2314

IX. Mission Control Programs

P12 - Ascent Guidance	168
P20 - Rendezvous Navigation	350
P21 - Ground Track Determination	66
P22 - Lunar Surface Navigation	20
P25 - Preferred Tracking Attitude	54
P32-P72 CSI Prethrust	93
P33-P73 CDH Prethrust	140
P34-P74 TPI Prethrust	642
P38-P78 SOR Prethrust P39-P79 SOM Prethrust	227
P40 - DPS Thrust	850
P41 - RCS Thrust	78
P42 - APS Thrust	20
P47 - Thrust Monitor	63
P51 - IMU Orientation Determination	263
P52 - IMU Realign	207
P57 - Lunar Surface Align	600
P63 - Landing Braking P64 - Landing Approach	174
P65 - Landing (AUTO) P66 - Landing (ROD) P67 - Landing (Manual)	45
P68 - Landing Conformation	--
P70 - DPS Abort	275
P71 - APS Abort	35
P76 - Target Delta V	100
TOTAL MISSION CONTROL PROGRAMS	4470
GRAND TOTAL	35434
REMAINING FIXED MEMORY	1434

MIT/IL MASTER APOLLO SOFTWARE DEVELOPMENT PLAN DATE: 1 August 1968



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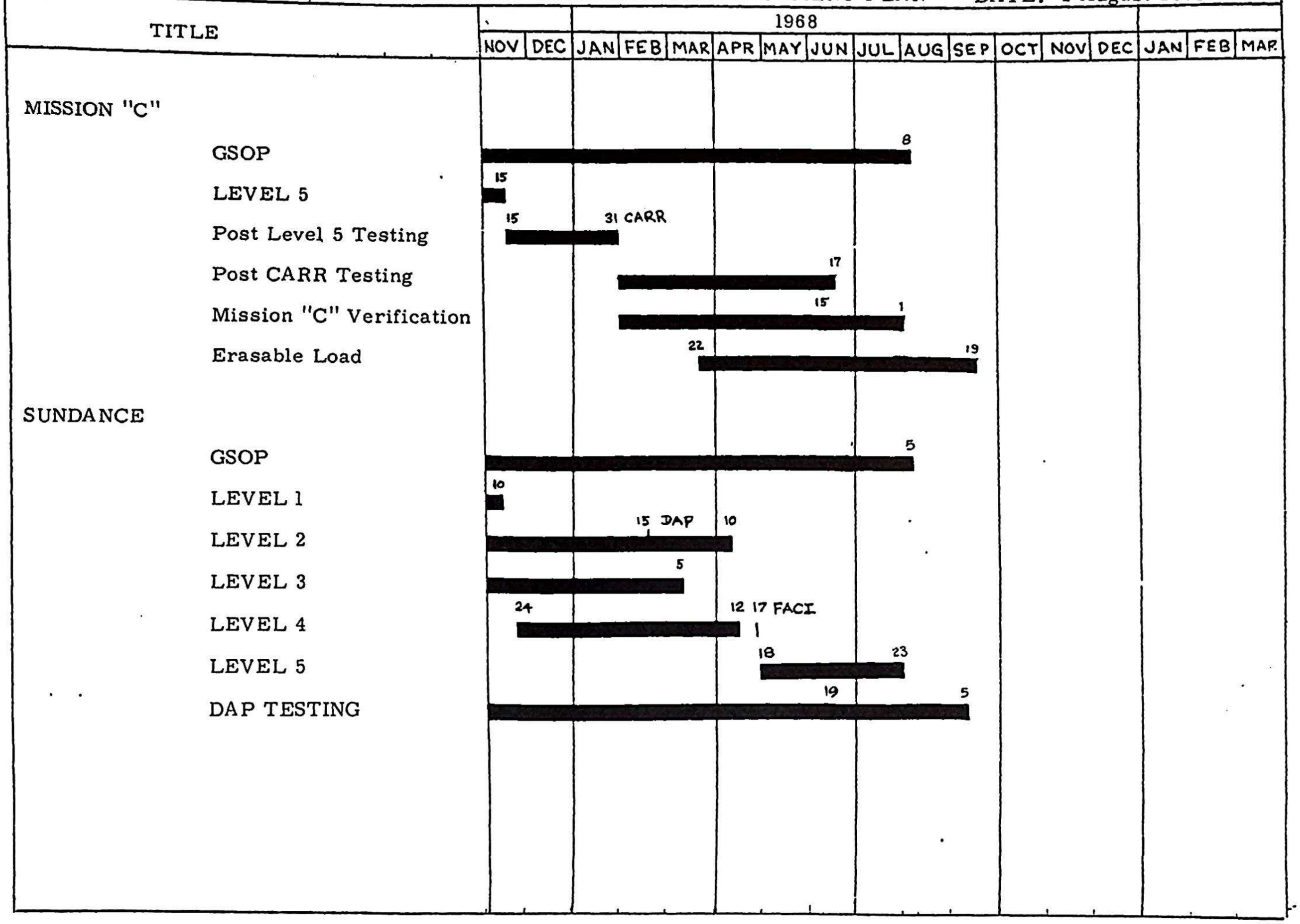

SECTION 9

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

R-557 GSOP, Program SUNDANCE, Section 4 Operational Modes, (Rev. 2), July 1968

R-557 GSOP, Program SUNDANCE, Section 6 Control Data, August 1968

R-577 GSOP, Program COLOSSUS, Section 1 Prelaunch, July 1968

R-529 Apollo Mission Simulations Utilizing Flight Software and Hardware, July 1968

R-618 A New Solution for Lambert's Problem, August 1968

E-2307 Recovery from Transients Failures of the Apollo Guidance Computer, August 1968

E-2308 A Non-Orthogonal Multi-Sensor Strapdown Inertial Reference Unit, August 1968

T-502 Fuel-Time Optimal Spacecraft Reorientation, May 1968

E-1142 (Rev. 57)

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