

APOLLO

GUIDANCE AND NAVIGATION

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APOLLO GUIDANCE AND NAVIGATION PROGRAM

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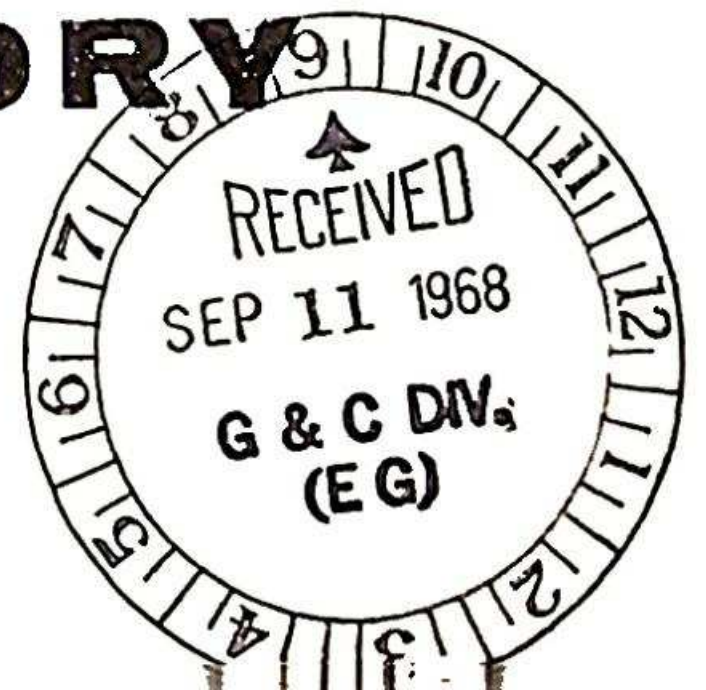
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E-1142
(rev. 57)

SYSTEM STATUS REPORT

JUNE 1968

MIT INSTRUMENTATION LABORATORY
CAMBRIDGE 39, MASSACHUSETTS



ACKNOWLEDGEMENT

This report was prepared under DSR Project 55-23870, 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.

All requests for information should be addressed to the editor of the document, Richard Harlow, at the Instrumentation Laboratory.

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E-1142
(Rev. 57)
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:

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

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

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)	58.0
Power Servo Assy	49.4 (M)	0.0	49.4 (M)	12.0
PIPA Electronics Assy	8.5 (M)	0.0	8.5 (M)	40.0
G&N Interconnect Harness Group	25.5 (M)	0.0	25.5 (M)	80.0
AGC (with six rope modules & mag. trays)	70.1 (M)	0.0	70.1 (M)	4.5
Optical Shroud	3.3 (M)	0.0	3.3 (M)	15.0
Optical Eyepiece Storage Assy SXT Normal Relief Eyepiece SCT Normal Relief Eyepiece SCT Long Relief Eyepiece	13.6 (M)	0.0	13.6 (M)	17.0
G&N Indicator Control Panel	14.7 (M)	0.0	14.7 (M)	25.0
DSKY	17.8 (M)	0.0	17.8 (M)	8.0
Signal Conditioner Assy (Operational Flights)	5.8 (M)	0.0	5.8 (M)**	

DATE: 1 February 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 does not include recognition of the Optical Eyepiece Storage Assembly.

DATE: 1 February 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)	
HARNES "B" Supported by the NVB	0.6 (E)	0.0	0.6 (E)	} 21.0
HARNES "B" Supported by the PTA	0.8 (E)	0.0	0.8 (E)	
HARNES "B" Supported by the structure	3.1 (E)	0.0	3.1 (E)	
PTA	14.4 (M)	0.0	14.4 (M)	} 22.0
HARNES "A"	15.6 (M)	0.0	15.6 (M)	
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)	
SCA (Operational Flights)	5.5 (M)	0.0	5.5 (M)	28.2
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 February 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 EXPRESSED IN "FAILURES PER 106 HOURS")

MISSION	IMU Assembly		IMU Electronics (PSA)		Optics Assembly		Optics Electronics (PSA)		IMU CDU		Optics CDU		AGC		DSKY		D&C		Mission Reliability
	ON	STBY	ON	STBY	ON	OFF	ON	OFF	ON	STBY	ON	OFF	ON	STBY	ON	OFF	ON	OFF	
AGE 123 FLIGHT 502 UNMANNED	8.3	-	8.3	-	-	-	-	-	8.3	-	-	-	8.3	-	8.3	-	8.3	-	.9933
	λ		λ																
C/M FLIGHT 503 MANNED	31.3	208	31.3	208	14.2	225	14.2	225	208	31.3	208	31.3	208	31.3	208	31.3	208	31.3	.9626
	λ		λ																
L/M FLIGHT 503 MANNED	8.4	120	8.4	-	8.4	-	8.4	-	8.4	-	8.4	-	8.4	-	8.4	-	8.4	-	.9923
	λ		λ																
C/M FLIGHT 205	76	190	76	190	20	-	20	-	76	-	20	-	9.5	170	9.5	-	76	-	.9315
	λ		λ																
C/M DES. REF.	13.8	55.6	13.8	55.6	9.1	60.3	9.1	60.3	13.8	55.6	13.8	55.6	13.8	55.6	13.8	55.6	13.8	55.6	.9840
	λ		λ																
LM DES. REF.	3.25	66.3	3.25	66.3	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	3.25	-	.9969
	λ		λ																

DATE: 1 February 1968

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.

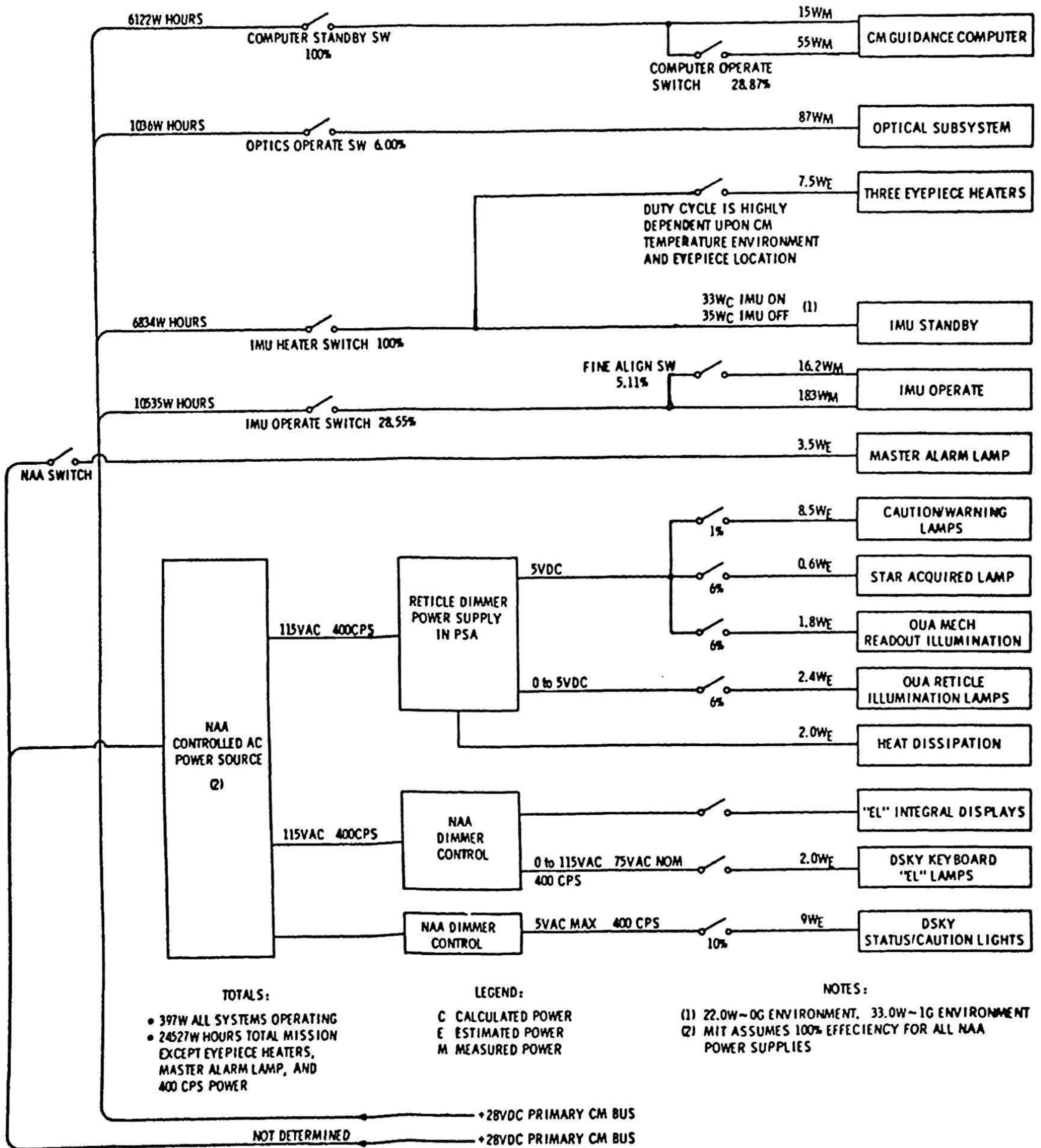
CM Block II	MH01-01327-216 "G&N Electrical Input Power" signed 15 July 1965
LM	LIS-390-10002 "PGNCS Prime Power Requirements and Characteristics" signed 30 July 1965.

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

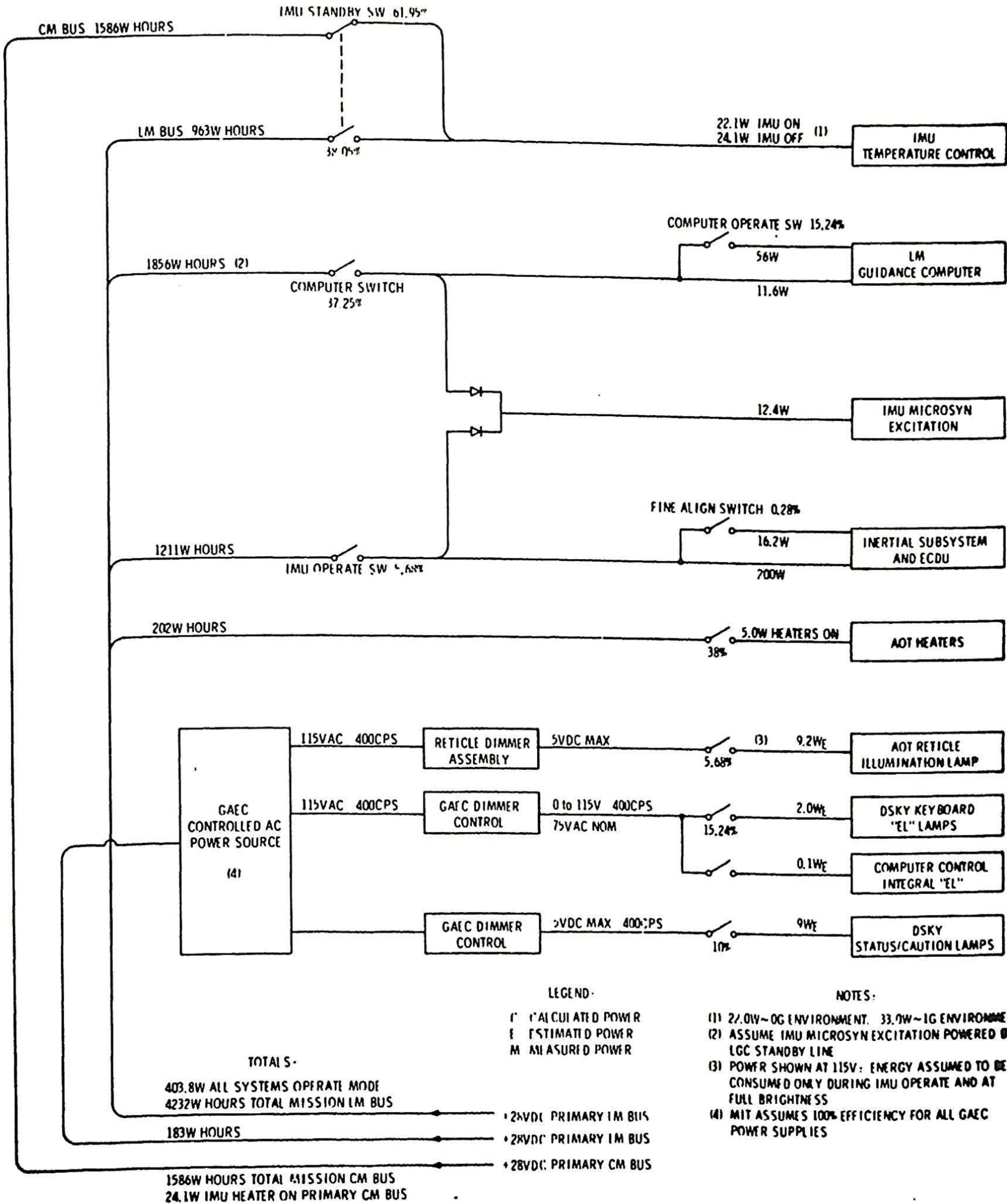


LUNAR MODULE GUIDANCE & NAVIGATION LOAD ON PRIMARY +28 VDC

BASED UPON 106.02 HOURS (4.47 DAY) LUNAR LANDING MISSION
DESIGN REFERENCE MISSION

STATUS OCTOBER 1967

REFERENCE GAEC REPORT - LED 540-12, 30 OCTOBER 1964
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-2 and subsequent LM Vehicles at GAEC.

Table 5.3 shows the configuration for major units comprising the G&N Systems assigned to CM-98 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-2 System 608 LM-3 System 605 LM-4 System 606	CM-98 2TV-1 System 202 CM-103 System 206 CM-104 System 209	CM-020 System 123 CM-101 System 204
INSTALLATION	X X X	X X X	X X
SUBSYSTEM CHECKOUT S/C	X X X	X X	X X
INTEGRATED TEST S/C	X X	X	X X
COMPLETE TESTING AT KSC			X

DATE: 1 June 1968

1. Apollo 6 successfully launched with CSM-20, G & N System 123, Mission AS-502 on 4 April 1968.
2. CM-98, 2 TV-1, with G & N System 202, shipped to MSC during the week of 21 April 1968.
3. CM-101, G & N System 204, shipped from NAR to KSC week of 26 May 1968.
4. LM-2, G & N System 608, completed all G & N testing at S/C Contractor; vehicle remains in bonded storage.

TABLE 5.2 LM G&N SYSTEM CONFIGURATIONS

S/C COMPONENT NOMENCLATURE	LM-2		LM-3		LM-4	
	System 608 Part Number	S/N	System 605 Part Number	S/N	System 606 Part Number	S/N
LGC	2003993-031	28	2003993-031	32	2003993-031	31
DSKY	2003994-011	46	2003994-021	51	2003994-021	65
IMU	2018601-191	26	2018601-221	27	2007222-221	21
ECDU	2007222-221	10	2007222-221	24	2007222-221	18
AOT	6011000-071	17	6011000-072	18	6011000-081	16

DATE: 1 June 1968

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

LM-2, G & N System 608:

Completed all G & N testing at S/C Contractor; Vehicle remains in bonded storage.

TABLE 5.3 CM G&N SYSTEM CONFIGURATION AT NAR

S/C	CM-98		CM-101		CM-103		CM-104	
	System 202		System 204		System 208		System 209	
	Part Number	S/N	Part Number	S/N	Part Number	S/N	Part Number	S/N
AGC	2003100-061	9	2003993-031	27	2003993-031	33	2003003-031	37
DSKY (Main)	2003950-031	28	2003994-021	50	2003994-021	58	2003994-021	53
DSKY (Navigation)	2003950-011	30	2003994-021	64	2003994-021	48	2003994-021	42
IMU	2018699-031	5	2018601-201	8	2018601-201	23	2018601-201	22
CDU	2010744-051	13	2007222-191	15	2007222-231	35	2007222-231	34
OPTICS	2011000-062	23	2011000-071	24	2011000-071	19	2011000-071	27

DATE: 1 June 1968

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

CM-98 (G&N System 202)

CM-98, 2 TV-1 with G&N System 202 shipped to MSC.

CM-101 (G&N System 204)

CM-101, with G&N System 204, shipped to KSC.

TABLE 5.4 G&N SYSTEM CONFIGURATION AT KSC

S/C	020		101	
COMPONENT NOMENCLATURE	System 123		System 204	
	Part Number	S/N	Part Number	S/N
AGC	1003700 - 071	13	2003993 - 031	27
DSKY (Main)	1003563 - 051	9	2003994 - 021	50
DSKY (Navigation)	1003706 - 051	7	2003994 - 021	64
IMU	1001500 - 111	4	2018601 - 201	8
CDU	1021304 - 031	6	2007222 - 191	15
OPTICS	2011000 - 023	9	2011000 - 071	24

1 June 1968

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

G&N System 123 successfully launched with CM-020 on 4 April 1968.

SECTION 6

G&N SYSTEM TEST

SYSTEM TEST LABORATORY

A. G&N 5

No operating hours.

B. G&N 104

1. Program Tests

Supported post-flight analysis of S/C-20 at NAR by generating a routine to transmit the contents of any AGC erasable location via downlink telemetry at a 20 millisecond rate.

Validated the Block I portable AGC monitor for use in S/C testing by exercising all capabilities of this unit prior to its use on S/C-20.

2. Hardware Tests

Investigated "Y" accelerometer (S/N 2AP-51) bias shifts of up to 13 cm/sec. Traced problem area to IMU. Decided to remove this unit from the Y loop by physically swapping the X and Y units and their respective pre-amplifier and calibration modules. This was done to allow more accurate IRIG drift measurements to be made.

New configuration - X PIP S/N 2AP-51
Y PIP S/N 2AP-64

Conducted a series of special IRIG performance tests designed to investigate varying NBD measurements associated with Block I IRIGs. The data compiled thus far indicates there is an initial transient period during which NBD terms varied as much as six meru from average, depending on flotation temperature. Following this "settling" period data varied two to three meru.

C. G&N 200

1. Program Tests

Completed RCS and TVC polarity testing and verification of K-START Tapes for SUNDISK 282.

TVC Pitch and Yaw Ramp Tests as performed on SUNDISK disclosed problem with DAP response. This problem has been corrected with a program change.

Completed checkout of Flight Simulation Test procedures on SUNDISK 282.

Continued checkout of COLOSSUS Program, now on revision 212.

The following problems found in COLOSSUS Program (revision 196) have been corrected:

Found problem with routine to do IMU Performance Test on COLOSSUS. Unable to run Vertical Drift Test.

Found problem with Gyro Compass routine in COLOSSUS 196. Znb azimuth is not properly interpreted by program.

Found problem with OPER. ERR. LIGHT turn-on routine in COLOSSUS 196. This was fixed by inverting two words in extended Verb 41 and 42 routine.

Following are problems which were found in the noted COLOSSUS revisions:

- a. Optics mark routine of PO3 in COLOSSUS 196.
- b. Optics angle computation of PO3 in COLOSSUS 202.
- c. Azimuth change routine of PO2 in COLOSSUS 202.

2. Hardware Tests

Completed CDU noise testing. Full report issued in APM Memo No. 1887.

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

Schedules have prevented further investigation of shaft overshoot and trunnion CDU problem (Ref. Progress Report, 1 February 1968).

Major part of month was spent in determining time constant of gyro drift term (NBD). A full report will be published at a future time.

3. Failures

DSKY S/N 14 repaired and returned to system.

Trunnion DAC failed. This failure found while performing TVC pitch and yaw ramp test. Bit #3 output transistor failed. This was noted through normal use and checkout.

4. Modification

All MSA and Quad. Reg. modules in CDU have been modified per ECP-515 and ECP-609 and returned to system.

D. G&N 600

1. Program Tests

Continued checkout of SUNDANCE Program, Provision 282 through 290 (FACI release). Received and loaded the 'B' release, Revision 1 of Program DANCE 292 by NASA 202110-011 on 26 April 1968.

The 'B' release is being used for final verification of erasable programs for K-START tape generation (STG Memo No. 1152).

Erasable memory segments E/IMUPER and E/IRIGSF were tested extensively. A suspension problem was uncovered as well as an unstable ADIA term. These were verified on a unit level test.

All three gyros were calibrated at unit level for comparison with the system test program results, (Table 6-1).

TABLE 6-1
SYSTEM TEST PROGRAM RESULTS

GYRO	X		Y		Z	
	G&N*	Unit	G&N*	Unit	G&N*	Unit
NBD	- 6.65	- 2.9	-3.06	+1.4	- 0.95	+1.4
ADSRA (meru/g)	-32.7	-27	+5.50	+6.9	- 2.36	+0.2
ADIA (meru/g)	- 2.68	+ 1.66) - 2.8)	-6.31	-6.0	+15.48	+2.2
ADOA (meru/g)	+ 3.54		-3.23		+ 1.43	
SF + (ppm)	+864	+552	-121	-517	+1289	+1000
SF - (ppm)	+651	+569	- 69	-258	- 598	- 150

*Average of 3 tests

The data agreement is considered good. Investigation of causes for variations in performance data continues.

Continued Simflight development on 3 half-day/week basis.

Completed checkout of K-START Tapes for DANCE 292 on 24 May. Tapes included F07L003-K00067, 68, 78, and 81 through 85.

Demonstrated AGS Alignment stability over 14 hours of gyro-compassing with multiple ASA-CDU zeroes.

Verified the LM-3 RCS/TVC DAP Polarity Test responses. Verified the ACA manual attitude maneuver - minimum impulse and T/TCA translation polarity tests.

Commenced Level V SUNDANCE STG Verification Tests with the P52 and Extended Verbs procedures.

2. Hardware Tests

An erasable patch to the E/IRIGSF segment has been developed to corroborate IRIG suspension failures. The gimbals are coarse aligned in a direction such that the float is forced to a particular side. Repeated tests with changes in the torquing direction will cause large scale-factor variations for bad suspension.

3. Failures

The suspension of Gyro #106 was verified as weak due to a fractured solder connection.

Gyro #7A21 was removed due to an unstable ADIA term. An 84 meru/g instability was measured on unit tests.

The OG CDU MSA & QUAD Ref. module had to be repaired twice - once for bad welds and the other for a broken solder connection. The module is a prototype.

FIELD OPERATIONS

A. GAEC

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

Vehicle to remain in bonded storage.

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

Completed Phase III CARR on 16 May 1968. Descent stage to be shipped 10 June 1968. Ascent stage shipment scheduled for 15 June.

3. LM-4 (Mission AS 504) G&N System 606

OCP 61014, Flight Control Checkout, now in progress.
Completed OCP 61015, Pre-FEAT testing.

4. LM-5 (Mission AS 505) G&N System 609

Installation scheduled for 15 May has now slipped to early in June 1968.

B. KSC

S/C-101, OCP 6504 is in preliminary form. ACE accuracies being RSS'd to G&N System performance tolerances and have been sent to MSC and Downey.

LM-3 TCP's 0010 and 4502 and TCOP in review. Reviewing preliminary revision to LM-3 TSCD. KL-10012, G&N installation, has been approved.

LM-4 TCRD and TSCD is awaited to enable completion of LM-4 TCOP. LM-4, TCP-6004, hard copy is now available.

S/C-101, OCP-6023, G&N Integrated Test, is undergoing its final review.

S/C-101 TCP-K-0005 is in preliminary review. S/C-103 TCOP is in work.

C. MSC

LTA-8 testing is delayed again. Participating in post-flight data analysis, Mission 502. Assisting with hardware and software problems concerned with verification of K-START Tapes at MSC.

LTA-8 Vacuum Chamber Testing is in progress with astronauts operating system. Unmanned runs on 2 TV-1 are holding.

D. NAR

1. CM-101 (Mission AS 205) G&N System 204

Completed OCP-131, Integrated Test.

Completed Phase III CARR on 9 May 1968. Vehicle was shipped on 29 May 1968.

E. ACED, Milwaukee

Arrangements have been made for ACED personnel to spend a week at MIT/IL working in the gyro wheel area. MIT personnel will then go to ACED to observe their gyro wheel assembly techniques. Review of ACED flow documentation continuing. Final Assembly routine not yet reviewed.

Final Assembly documentation review has been completed. This was the final outstanding documentation item.

Visited Boston with AC personnel to discuss wheel build procedures.

SYSTEM ENGINEERING

A. Spacecraft Test Support

An extended self test for use at marginal voltages was developed and checked out (STG Memo No. 1153). This tests the operation of 32 computer instructions.

The investigation of anomalies in the IMU Performance Test data continued. One error in the K-START Tape was corrected; however, complete conclusions are not available.

The IRIG SF test was changed so that it is initialized with the gyro in alternating stops for each position. The results are still under investigation. The checkout of the AGS Align Test was continued. A preliminary listing was supplied to KSC.

No progress was made this month on the special diagnostic tests for PIPA and IRIG problems.

More work was performed in cooperation with AC on the checkout of K-START Tapes on the digital simulation.

The problem of optic gear failures during zeroing was studied and a letter (AG: 145-68) issued.

The CDU transient problem was reviewed again at a meeting with NASA. At their request letters were prepared incorporating the same 50ms fix in LM as that in CM programs, and discussing the impact on SUNDISK Missions.

The self test programs DSKY Test, INOUT, and MARVIN, T were updated to SUNDANCE 292 and are being checked out.

The K-START Tape for the IRIG Scale Factor Test (DANCE 292) was prepared, checked out and delivered to MSC. Also, the K-START Tape for AGSALIGN Test (DANCE 292) was checked out and delivered to MSC.

The Performance Test for DANCE 292 was modified by interchanging two sets of positions. The investigation of vertical gyro drift measurement accuracy is continuing. The COLOSSUS Program is being modified to be compatible with the E-Memory Performance Test.

No K-START Tapes were received from AC for simulation on the Digital Simulation. The AC generated RRCDU Test was reviewed and comments were supplied to AC.

The IRIG Scale Factor Test was modified to give 24 steps so as to be useful as a test for a soft suspension. This is included in the tape sent to MSC.

B. Program Testing

Level III testing of SUNDANCE was officially completed with the FACI. In preparation for that, all anomaly reports from the STG Laboratory were reviewed with the Mission Program Group. Some routines were updated.

Preparation for the Level V tests has begun and a schedule is available. A few preliminary runs have been made.

Level V testing of SUNDANCE, Revision 292, was begun. Two extended verb tests and 20% of the alarm tests have been run. Detailed plans for the remainder of the tests were prepared. Assistance was provided in the preparation of a downlink processing program to print selected downlink data.

The COLOSSUS Level III tests have also been started. A schedule (STG Memo No. 1169) was prepared and distributed.

KSC CHECKOUT

A. Preliminary TVC and RCS DAP Polarity Test K-START Tapes were sent to NAR/Downey.

B. Final TVC and RCS DAP Polarity Test K-START Tapes (F08-C101-K00079-00) were sent to KSC and MSC. Due to card deck assembly and program design problems, Revision 01 of the Tapes is forthcoming.

C. STG Memo No. 1148 was written specifying the MIT/IL K-START Tape schedule per the latest known KSC OCP/TCP "run" dates.

D. K-START card deck for the IMU Performance Test was updated per SUNDANCE Program Assembly, Revision 292.

E. Met with AC Electronics to review the LM Process Specification for Post-Installation Testing at KSC.

F. STG Memos No. 1148, Rev. A, 1162, Rev. A, and 1166 were written to coordinate LM-3 and S/C-101 K-START Tape design and delivery to MSC and KSC.

G. The LM-3 IMU Performance Test design was finalized and verified in the G&N Systems Laboratory.

H. All formal preliminary listings of MIT/IL K-START Tapes for LM-3 and S/C-101 were sent to KSC to support OCP design.

I. Final listings of LM-3 (DANCE 292) IRIG S/F and IMU Performance Tests were sent to AC Electronics to support the Process Spec (ND1002349) design.

J. All final LM-3 (DANCE 292) MIT/IL K-START Tapes and listings were sent to MSC and KSC.

K. The procedure for the Manual RGC and THC tests and minimum impulse test were verified in the G&N System Lab.

L. The S/C-101 TVC/RCS DAP Polarity Test K-START Tapes and listings were sent to MSC and KSC.

M. The latest process specs for LM and CM (ND1002349 and ND1002348) have been released as Revision "F". Additional changes are in process for ND1002349. In the future, separate (new) process specs will be released for G&N Systems using COLOSSUS and LUMINARY Program Assemblies.

TEST EQUIPMENT

A. The GDB and hardware changes must still be released and the demodulators designed. It is feasible that the test equipment (with the exception of the demodulators) will be ready on 1 June as originally planned.

B. DAC Monitor: The DAC Monitor circuits have been fabricated and checked out. The documentation for this package has been completed.

C. Portable Wheel Power Monitor: Work is nearing completion of the initial design phase of this project. A report should be available by the end of this month.

D. Miscellaneous Mainline Activities: Review of contractor design changes, drawings and interface control documents is continuing on an as-required basis. Maintenance of the Apollo test stations at MIT/IL is continuing on both a scheduled and as-required basis.

E. Documentation: A documentation center has been established. Documentation on previous projects has been reviewed and updated when required. Improved standards have been established for existing projects.

F. Project Trace/Block II Coroner: CCA51: STL System. The Coroner Front Panel Design has been DRB'd and is in drafting for artwork. Most parts are on order. Major exceptions include the y logic and power supplies. They should be on order this month. It is expected that circuit design will be completed this month and that computer-aided design of the system and interface will begin in July.

CCA51: Rev. 1: Documentation. A cost estimate and product plan is being generated.

MISCELLANEOUS REPORTS AND INVESTIGATIONS

- A. Prelaunch operations at KSC for Apollo 6 were supported.
- B. Reviewed Section 1 of GSOP with NASA/MSC (M. Kayton). The GSOP will be modified to conform to NASA requirements.
- C. Supported FACI for SUNDANCE 292. Program test results for System Test Laboratory tests were reviewed.
- D. Attended S/C-101 CARR Meeting.
- E. Prepared activity summary and reports on test results for the Quarterly Status Review held 14 May 1968.
- F. Section I of the GSOP for LUMINARY, COLOSSUS, and SUNDANCE was updated to NASA requirements and submitted to Publications on 15 May 1968.

SECTION 7
G&N COMPUTER STATUS

DESIGN ANALYSIS & SUPPORT

A. Analysis Facility Activities

1. Design analysis of the change in V-Fail from 22.3 ± 0.3 to 20.0 ± 0.3 . The results of the analysis and tests were summarized and forwarded to MSC in MIT letter AG 133-68. The design review of the documentation required for the design change is complete.

B. Field Support

1. Activity relating to the support of flight 502 included a review of Block I V-Fail circuitry and specification in order to determine the lowest safe operating voltage. Also following the flight there has been an investigation of the uplink susceptibility to external noise. This investigation reconfirmed that the computers receive an adequate test during sale to insure that they meet the ICD requirements with substantial margins (that is, the computer must reject noise pulses of at least 0.7 volts) and that the ICD specifications were clearly stated. The conclusions to date are that there is excessive noise being generated in the spacecraft. This noise is probably of the same order of magnitude as normal signals. Because of the similarity between the Block I and Block II computers there is no hope of improvement unless the source of spacecraft noise is eliminated.

C. Miscellaneous AGC Related Activity

1. A complete review of the procedures, documentation, and testing related to the release and manufacture of rope modules has been accomplished. This activity was triggered by a proposed change in what MIT releases to production, which in turn was triggered by the change over to a 360 computer at MIT. See MIT letter AG 143-68 and its addendum AG 206-68 for details. Several documentation and procedural changes have been proposed and need to be completed in time for the next program release which is scheduled for July 1st.

2. Alternate methods of expanding the IL panel displays were investigated. One MSC proposal is to provide, by software changes, the capability of flashing or steady illumination of the program alarm thus expanding the capability of multiple usage of the lights now available. The program changes necessary to provide a flashing mode were investigated and a program logic flow diagram was developed.

3. The restart monitor modules were completed and drawings are ready for release.

4. A braid memory containing SUNDISK program was built and delivered to MSC. The braid adapter which had been built previously was checked out and delivered with the braid.

5. Status of CRS S/N 5

All memories have now been updated to final configuration.

6. Status of CRS S/N 6

All checkout complete but still waiting on the memory units.

7. Block II AGC Status at MIT

- | | |
|-------------|--|
| a. AGC-600M | Operating in hybrid simulation facility. |
| b. AGC-200 | Operating in C/N system in STG Lab. |
| c. AGC-200M | Presently in DD Group Lab. Module A7 is questionable. |
| d. AGC-C1M | In DD Group Lab. Erasable memory, 2 interface modules, and 3 bit sticks are bad or questionable. |
| e. AGC-PC2 | Operating in hybrid simulation facility. |
| f. AGC-C200 | Operating in LM system in STG Lab. |

8. Block II DSKY Status at MIT

Several bad keys have been repaired. The springs were replaced using parts obtained from Raytheon. Since these are of the old design which is known to be defective, a fairly high level of failures and repair is expected to continue.

- | | |
|-------------|---|
| a. AGC-600M | Sent to Raytheon for repair. |
| b. AGC-200M | Sent to Raytheon for repair. |
| c. AGC-200M | Approximately 6 bad keys. (Being repaired at MIT) |
| d. AGC-C1M | Used as test unit for IL DSKY components. |
| e. AGC-PC2 | Some burned-out status lamps. |
| f. AGC-C200 | Several bad keys. (Being repaired at MIT.) |

II. COMPONENT PROBLEMS

A. Contamination in Flatpacks

This problem continues to be the most serious problem in the computer. Analysis of the data available is continuing but as yet nothing further is

being proposed to bring the problem under control. The computers are being vibrated in the more sensitive Y-axis vibration and all flatpacks are being subjected to X-Ray analysis.

B. Tape - Wound Cores

The temperature sensitivity of the cores used in ropes is a continuing problem; however, due to a temperature test introduced at a repairable level of assembly, the cores are being screened out. The cause of the problem is still under investigation.

C. Multilayer Board Failures

This problem seems to be under control. Tighter inspection has been introduced in the FPS processing. Also the boards that are being rejected are being returned to the vendor for reprocessing. An ND is being prepared by Raytheon to specify the reprocessing procedure.

D. Relays

The recent failures of Potter Brumfield relays during IDM testing were induced by the test equipment. This was another case of using high voltage with no current-limiting resistors during insulation resistance-type tests. However, some significant information was obtained relating to the construction of the relays; that is, the contact space can be as low as 1 to 2 mils in the PB relays where the Filtor relays were around 6 mils.

E. DSKY Lights

The problems of light intensity and aging have been masked as a result of the more recent problem of glass breakage in LTA-8 testing. Since both EK and IL glass covers have been broken, there is concern about the design and considerable effort is being expended in order to determine the cause of breakage. It is certain that some changes will be required to provide a solution to the breakage problem.

III. AGC PROBLEMS

1. Some computers do not always come out of standby when the Proc. key is depressed. This condition is the result of transients in the power supply which result from switching the power on. These transients cause the computer logic to switch back to standby before the operation of coming out of standby has been completed. This condition has a very low probability of occurrence and therefore can be corrected by a second depression of the key. However,

there is some concern that the same transient will disturb the electronic time counter. If that happens, the time within the computer would have to be updated from ground. All computers are tested at sale to verify that the time counter operates through the process of switching into and out of standby without loss of time.

2. Several oscillators have exhibited a shift in frequency during and after vibration. This condition has been under study for some time but the cause of the shift is not known. The magnitude of the shift is not large enough to cause any mission problem but the cause of the shift needs to be determined.

SECTION 8

APOLLO GUIDANCE COMPUTER PROGRAMMING SUMMARY

SOLARIUM - UNMANNED CSM

(Apollo 6 mission with Command Service Module 20 and AS-502 on 4, April 1968.)

This was the second mission using the Saturn 5 launch vehicle. The unmanned command and service module injected into earth orbit with Saturn was under the control of the MIT Block 1 GN&C System in a flight plan very similar to the AS-501 Apollo 4 mission.

During Saturn boost two engines of the second stage cut off resulting in a longer burn of the remaining three engines and caused a longer-than-planned earth orbit insertion burn of the SIVB third stage. The Saturn guidance was able to achieve orbit, although the orbit was quite elliptical.

After two coasting earth orbits a second burn of the SIVB was planned to rehearse the injection of the Apollo to the moon. The near-earth escape velocity would then have been reduced with a retrograde burn of the Apollo Service Module engine under G&N steering so that an apogee of only 12,000 nautical miles would result. Unfortunately, the SIVB could not be started for the lunar trajectory injection simulation burn. Consequently, the G&N, which was already prepared to steer the CSM to the 12,000 n. mile apogee trajectory, was commanded by the ground to do so. This required a very long burn of 445 seconds of the service propulsion engine leaving too little fuel for the planned second CSM burn on the return from apogee to drive the Command Module back into the earth's atmosphere as an entry test at lunar return velocity. Without this push back to earth to 36,500 feet per second the resulting unexpected 32,776 feet per second was too low

for the entry guidance of the G&N to control the range out to the planned recovery area. The command module had to be recovered about 50 miles short of the original target.

During the flight there was considerable noise on the uplink channel from the telemetry receiver to the G&N flight computer. The computer, by the redundant code, was able to reject this noise successfully, although this problem made it difficult for the ground to send up data.

The G&N system operated through the flight without a flaw. The performance of the inertial guidance and navigation system was excellent. The system was turned on two days before launch and aligned by all inertial gyro compass action without any optical alignment check; the alignment remained under all inertial control throughout the mission.

The guidance of the long CSM burn was targeted for an apogee of 12,000 n. miles. The ground tracking confirmed the resulting apogee as 12,020 n. miles.

The on-board computer and the ground tracking determinations of the orbital elements compared as follows:

	G&N on Board	Ground Tracking
Apogee	12,027	12,020 n. miles
Perigee	17.4	18 n. miles
Eccentricity	0.6346	0.6343
Inclination	32.56	32.57 degrees

The on-board state vector was so accurate that no ground update was necessary prior to entry although it was sent in compliance with the flight plans.

The G&N all-inertial navigation was such that the indicated location in the G&N computer was within two miles of the landing point in the Pacific reported by the recovery force.

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

The following activities were performed during the reporting period:

Fifteen (15) additional verification runs requested by NASA/MSC were run, utilizing MIT's digital and hybrid facility.

Twenty-one (21) Mission Verification Tests for Mission "C" were defined and started.

Review of the Apollo Operations Handbook, Mission Rules, Flight Plans and Onboard Data is underway at MIT.

The G&N Functional Description (E-2150) was published.

Revision to Section 3, Digital Autopilot and Section 5, Guidance Equations, of the Guidance System Operations Plan were published.

Continued support has been given by MIT to the Apollo Mission Simulator Group and the MPAD Group at NASA/MSC.

Six (6) additional anomalies were written against the SUNDISK Program, bringing to a total of 19 the anomalies written to date.

Initial planning and discussion meetings have been held with NASA/MSC regarding MIT/IL mission support. Additional work and definitions of efforts are to be established in the near future.

The "How and Why" type of astronaut training is scheduled for 17 June 1968.

C. SUNDANCE - MANNED LM (EARTH ORBITAL)

Level 4 testing of the SUNDANCE Program was completed on 12 April 1968 and a FACI meeting held on 17 April 1968.

After FACI NASA/MSC authorized release of the SUNDANCE Program Revision 292 for manufacturing of ropes to be used for spacecraft testing at KSC.

Since then, FACI level 5 testing has been underway, with the completion scheduled for 13 July 1968. Mission D Verification is scheduled to start 1 August 1968 with completion 15 Sept. 1968.

Twenty-eight (28) anomalies have been written since the FACI.

The SUNDANCE DAP Performance Testing is scheduled to be completed in late June.

D. COLOSSUS - MANNED CSM (LUNAR CAPABILITY)

The COLOSSUS Program development was in the final stages of level 3 testing and the initial phases of level 4 during the reporting period. Completion of level 4 is now scheduled for mid July.

Revision to Section 3, Digital Autopilot, Section 4, Operational Modes and Section 5, Guidance Equations of the Guidance System Operations Plan were published.

E. LUMINARY - MANNED LM (LUNAR CAPABILITY)

The LUMINARY Program development was in the middle of level 3 testing during the reporting period. Level 3 is scheduled for completion in late June and level 4 completion in early October.

Revision to Section 2, Data Links and Section 4, Operational Modes of the Guidance System Operational Plan were published.

F. GENERAL

A second IBM 360 model 75 was brought on the air in mid May. The addition of a second digital computer facility will somewhat relieve the computer turnaround time of jobs submitted to the facility, which has heretofore plagued software development.

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	240
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	183
Pinball Program and Noun Tables	2920
Displays, Priolarm	700
Program Select (V37, P00, R00)	353
Self Check	314
Extended Verbs	717
RTBOP Codes	200
SXTMARK	311
IMU Mode Switching	572
IMU Compensation	250
LGC Startup	32
LGC Power Down (P06)	48
IMU Status Check	17
Systems Test (P07)	630
Interpretive Constants	35
Flagup, Flagdown	63

GENTRAN	15
DAP Data Load (R03)	48
End Bank Markers	78
TOTAL UTILITY AND SERVICE PROGRAMS	12,735
II. Autopilot and Maneuver Programs	
Entry DAP	801
BOOST	65
RCS	1833
TVC	1688
TWINGIMB S40.6	68
TVNG	30
KALCMANU	715
Attitude Maneuver (R60)	85
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	5725
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	1141
TOTAL POWERED GUIDANCE	2247
VII. Alignment Routines	
Coarse Align (R50)	80
Fine Align (R51)	116
Auto Optics (R52)	135
Sighting Mark (R53)	47
Star Data Test (R54)	41
Gyro Torquing (R55)	27
Pick-A-Pair	127
Star Catalog	223
Alternate LOS Sighting Mark (R56)	118
Optics Calibration (R57)	53
TOTAL ALIGNMENT ROUTINES	967
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	170
R32 - Target Delta V	100
R33 - CMC/LGC Clock Synchronization	26
TOTAL MISCELLANEOUS PROGRAMS AND ROUTINES	1383

IX. Mission Control Programs

P01 - Prelaunch or Service Initialization	42
P02 - Prelaunch or Service Gyrocompassing	328
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	} 648
P35, P75 TPM Prethrust	
P37 - Return to Earth	1304
P38, P78 SOR Prethrust	} 231
P39, P79 SOM Prethrust	
P40 - SPS Thrusting	} 781
P41 - RCS Thrusting	
P47 - Thrust Monitor	52
P51, P53 IMU Orientation Determination & Backup	256
P52, P54 IMU Realign and Backup	380
P61 - Maneuver to CM/SM Sep Attitude	278
P62 - CM/SM Sep and Pre-Entry Maneuver	92
P63 - Entry Initialization	16
P64 - Post 0.05G	6
P65 - Upcontrol	27
P66 - Ballistic	4
P67 - Final Phase	36
P77 - LM TPI Search	1
TOTAL MISSION CONTROL PROGRAMS	6604
GRAND TOTAL	35827
REMAINING FIXED MEMORY	1037

TABLE 8.2

LUMINARY LGC PROGRAM

FIXED MEMORY ALLOCATION CHART (ESTIMATED)

I. Utility and Service Programs	
Interpreter, Single Precision Subroutines	2201
Fixed-Fixed Constant Pool	2200
Executive	337
Waitlist, Longcall	240
Interrupt Lead Ins	58
Interbank Communication	88
T4rupt (R10, R25)	632
Keyrupt-Urupt	68
Downlink Program and 5 Lists	425
Fresh Start and Restart	429
Alarm and Abort	77
Delayjob	30
Restart Routine and Tables	325
Phase Table Maintenance	165
Pinball Program and Noun Tables	2957
Displays, Priolarm	700
Program Select Check (V37, P00, R00)	310
Self Check	314
Extended Verbs	550
RTB OP Codes	200
Radar Rupts	190
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	63
GENTRAN	15
DAP Data Load (R03)	150
Radar Subroutines	784
End Bank Markers	72
TOTAL UTILITY AND SERVICE PROGRAMS	13448
II. Autopilot and Maneuver Programs	
Digital Autopilot	3250
KALCMANU	670
Find CDU W	414
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	4753
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	} 649
Constant Delta Altitude	
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	650
(R21, R22, R23, R24, R29, LPS20.1, LPS20.2 LRS22.1, LRS22.2, LRS24.1, CALXY)	
TOTAL NAVIGATION ROUTINES	1626
VI. Powered Guidance Routines	
Servicer (R12)	1071
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)	750
Throttle Logic	125
Ascent Guidance	550
TRIMGIMB (S41.1, S40.6)	54
TOTAL POWERED GUIDANCE ROUTINES	2959
VII. Alignment Routines	
Coarse Align (R50)	61
Fine Align (R51)	103
Auto Optics (R52)	65
Star Data Test (R54)	41
Gyro Torquing (R55)	27
Pick-A-Pair (R56)	132
Lunar Surface Sighting Routine	215
Star Catalog	223
TOTAL ALIGNMENT ROUTINES	867
VIII. Miscellaneous Programs and Routines	
R47 - AGS Initialization	130
R36 - Rendezvous Out of Plane Display	93
P27 - Update Program	306
P30 - External Delta V Prethrust	101
P31 - General Lambert Maneuver	100
R04 - RR/LR Self Test	} 145
R77 - LR Spurious Return Test	
R05 - S Band Antenna Display	132

R29 - Rendezvous Radar Flight Designate	285
R30 - Orbit Parameter Display	278
R31 - Rendezvous Parameter Display	170
R32 - Target Delta V	100
R33 - CMC/LGC Clock Synchronization	26
R10 - Landing Analog Display Monitor	454
R11 - Abort Discretes Monitor	25
R13 - Auto Modes Monitor	35
TOTAL MISCELLANEOUS PROGRAMS AND ROUTINES	2380

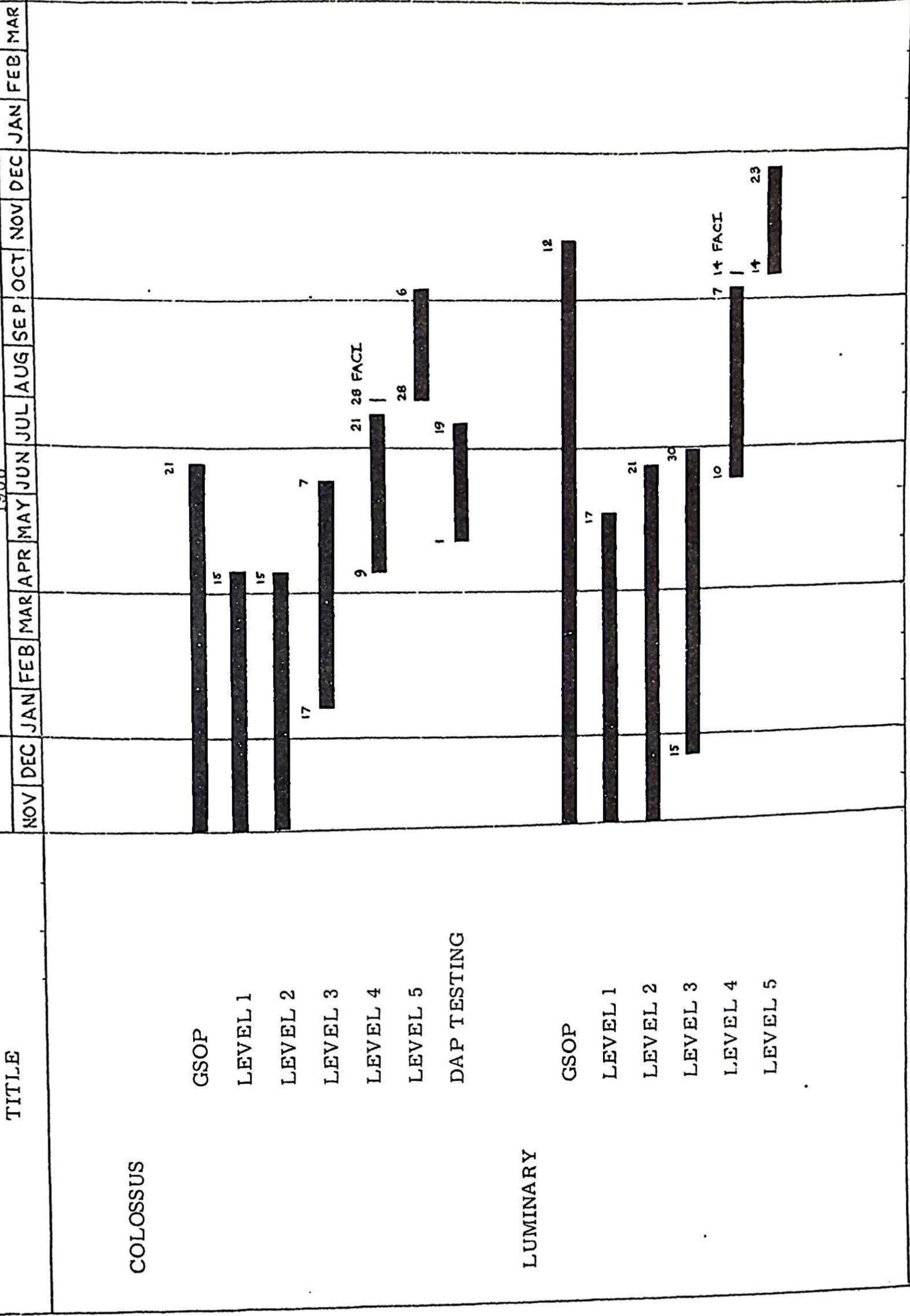
IX. Mission Control Programs

P12 - Ascent Guidance	163
P20 - Rendezvous Navigation	427
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	} 227
P39-P79 SOM Prethrust	
P40 - DPS Thrust	900
P41 - RCS Thrust	78
P42 - APS Thrust	20
P47 - Thrust Monitor	63
P51 - IMU Orientation Determination	263
P52 - IMU Realign	188
P57 - Lunar Surface Align	600
P63 - Landing Braking	} 174
P64 - Landing Approach	
P65 - Landing (AUTO)	} 60
P66 - Landing (ROD)	
P67 - Landing (Manual)	
P70 - DPS Abort	310
P71 - APS Abort	80
TOTAL MISSION CONTROL PROGRAMS	4568
GRAND TOTAL	35393
REMAINING FIXED MEMORY	1471

Date 5/31/68

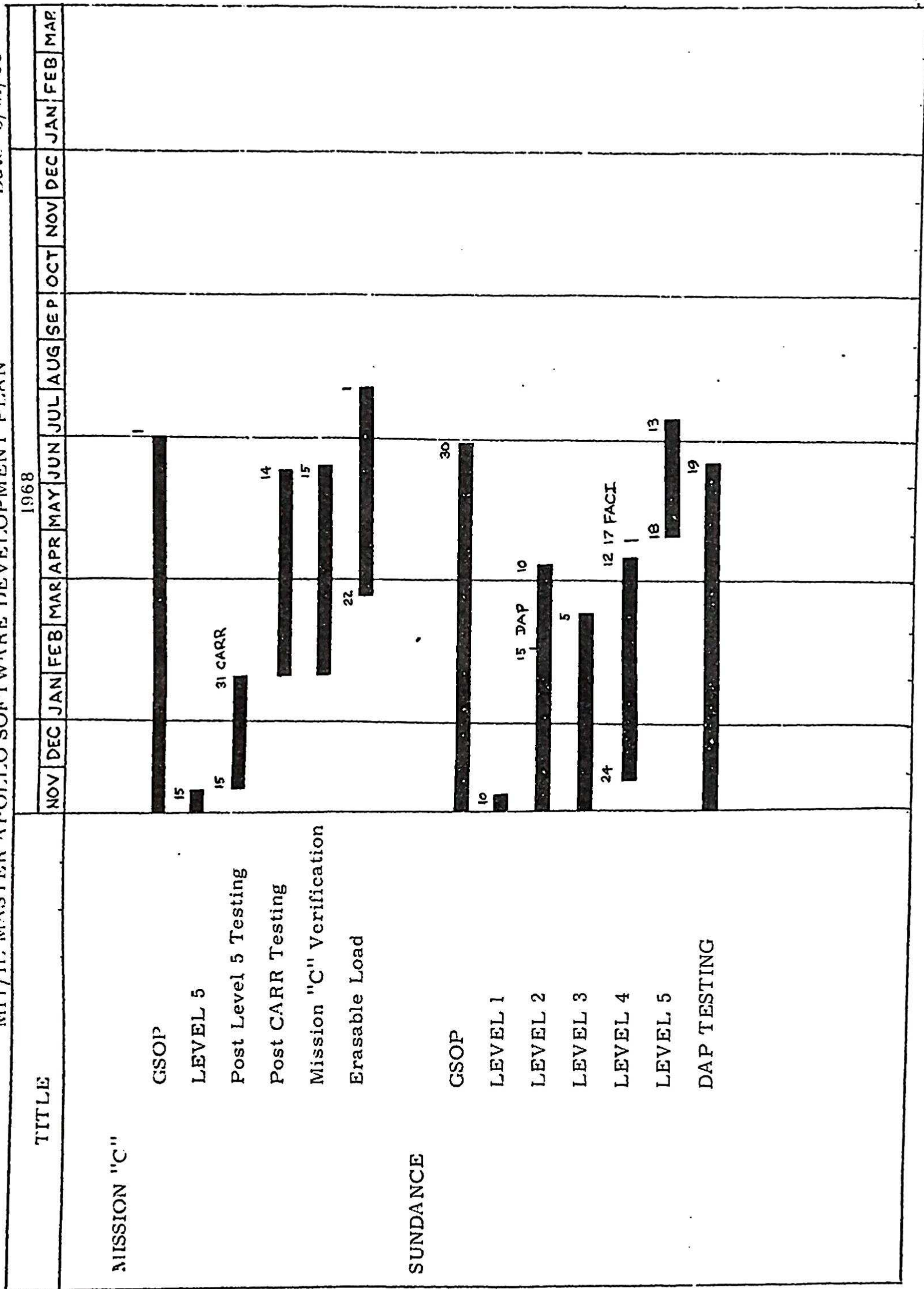
MIT/IL MASTER APOLLO SOFTWARE DEVELOPMENT PLAN

1968



Date 5/31/68

MIT/II, MASTER APOLLO SOFTWARE DEVELOPMENT PLAN



SECTION 9

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

- R-527 Guidance System Operations Plan LM-1 Using Burst 116 Program,
Rev. 2, July 1968 (U)
- R-547 Guidance System Operations Plan - SUNDISK, Section 3 CSM Digital
Autopilots, (Rev. 2), May 1968. (U)
- R-577 Guidance System Operations Plan - COLOSSUS, Vol. I, Section 4.4
GNCS Operations, June 1968; Vol. II, Section 4.4 PGNCS Operations,
June 1968; Section 4 GNCS Operational Mode, Rev. 2, May 1968;
Section 5 Guidance Equations, Rev. 1, May 1968. (U)
- E-2246 Computer-Aided Inertial Platform Realignment in Manned Space Flight,
May 1968 (U)
- T-493 A Study of Transformation Algorithms for Use in a Digital Computer
by R. McKern, January 1968. (U)

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